



# exploration

...the essence of the human spirit.

*Frank Borman*  
APOLLO ASTRONAUT



*Requirements Process Overview*  
*Michael F. Lembeck, Ph.D*  
*ESMD Requirements Division*



# The Vision for Space Exploration

The fundamental goal of this vision is to advance U.S. scientific, security and economic interest through a robust space exploration program

- ***Implement a sustained and affordable human and robotic program to explore the solar system and beyond***
- ***Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations***
- ***Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration***
- ***Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests***



# Exploration Strategy Outline

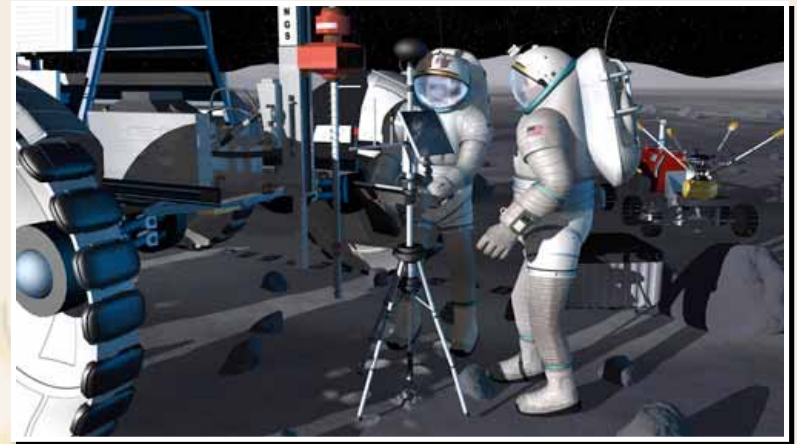
- **Re-establish competencies for crewed lunar and interplanetary flight spirals**
  - *Ultimate “System-of-Systems” architecture not known a priori*
  - *Stepping stone “spiral” approach*
    - *Spiral 1 – Crew transportation demonstration in LEO*
    - *Spiral 2 – Extended duration lunar missions*
    - *Spiral 3 – Long Duration lunar missions, testbed demos*
    - *Spiral 4 – Crewed Mars flyby*
    - *Spiral 5 – Humans on Mars*
  - *Lunar testbed incrementally validates systems and operations concepts*
- **Robotic precursors identify locations of interest and demonstrate technologies**
- **Extend capabilities and reduce dependence on logistics train**
  - *Enable affordable and sustainable exploration of Mars*
  - *Open new commercial opportunities for products and services*



# Preparing for Mars Exploration

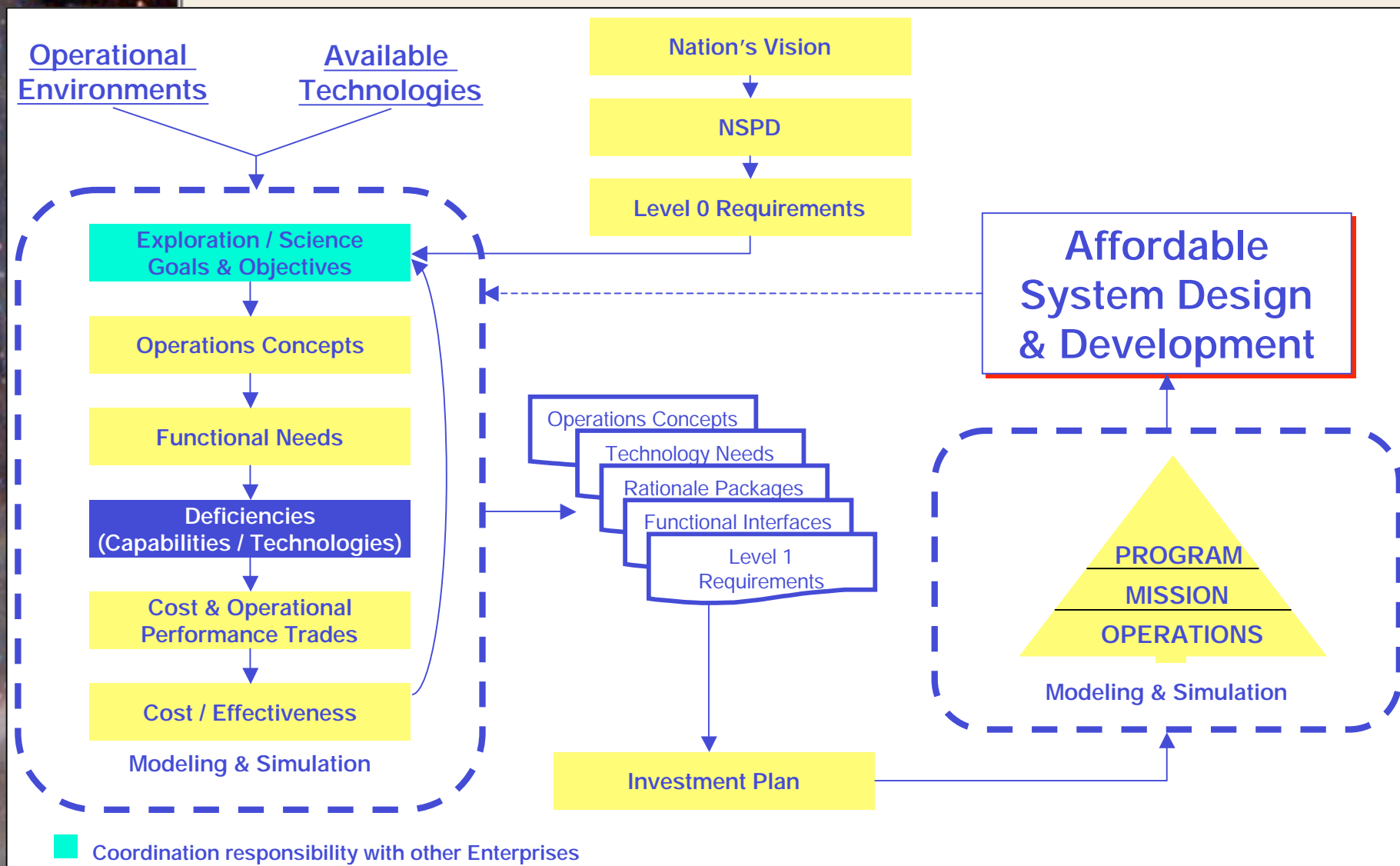
## *Our Moon as a test bed*

- Technology advancement reduces mission costs and supports expanded human exploration
- Systems testing and technology test beds to develop reliability in harsh environments
- Expand mission and science surface operations experience and techniques
- Human and machine collaboration: Machines serve as an extension of human explorers, together achieving more than either can do alone
- Breaking the bonds of dependence on Earth: (e.g., life science/closed loop life support tests)
- Power generation and propulsion development and testing
- Common investments in hardware systems for Moon, Mars and other space objectives



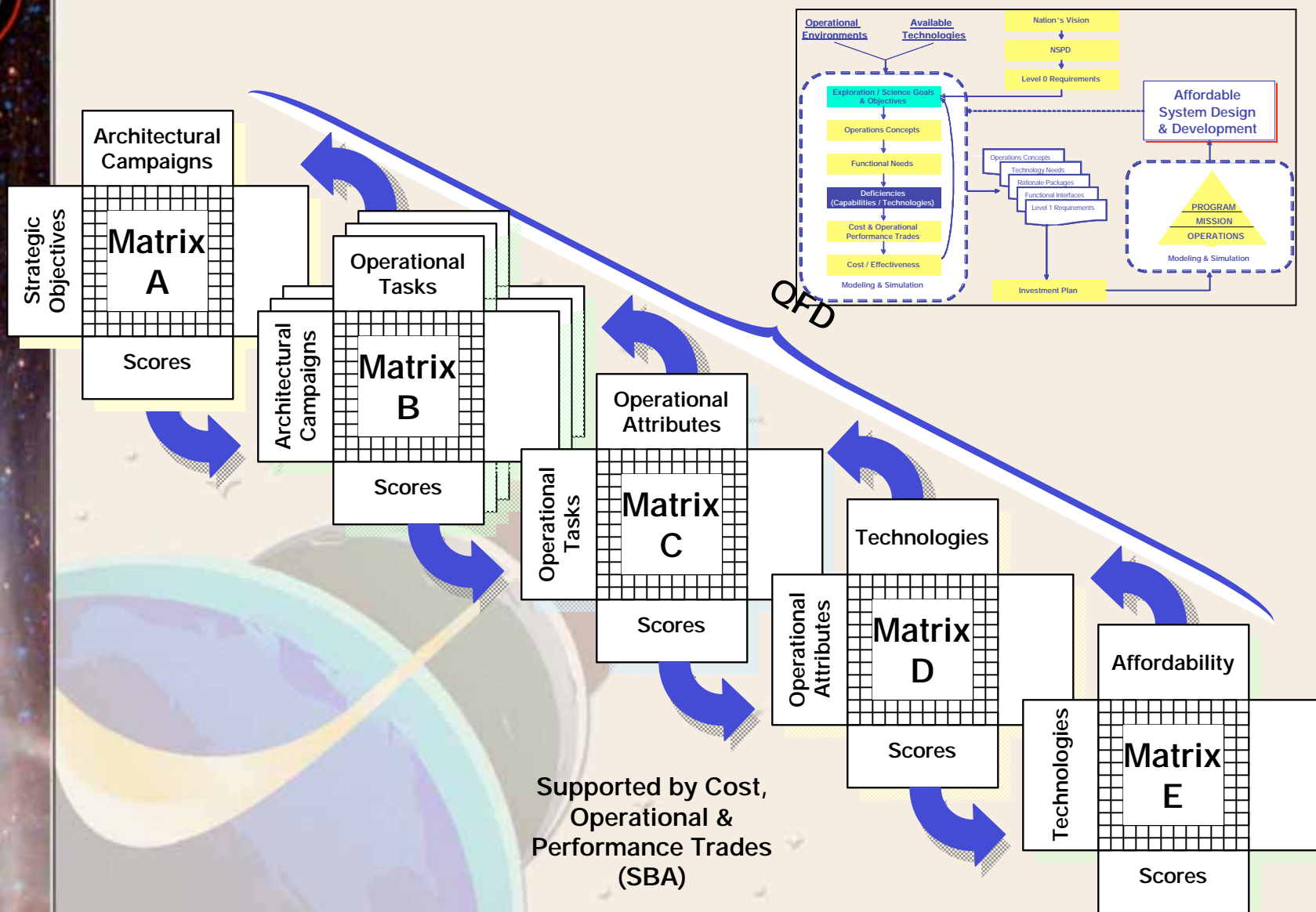


# Strategy-to-Task-to-Technology Process





# Quality Functional Deployment (QFD) Flowdown





# Requirements Development Flowdown

## Broad Trades

### Architectural Variants (Examples)

- Moon Short Stay
- Moon Long Stay
- Global Access
- Single Site
- Multiple Sites
- High-Earth Orbit
- Libration Points
- Mars Orbit
- Mars Short Stay
- Mars Long Stay

### Technology Infusion (Examples)

- Chemical
- Nuclear
- Fuel Cells
- Solar
- ECLSS Closure
- Open Loop
- Storables
- Cryogenics
- Thermal Protection
- Breakthroughs

### Operational Concepts (Examples)

- Pre-Deploy
- All-Up
- Lunar Orbit
- Libration Point
- Tandem
- Convoy
- Surface Stay
- Abort Options
- Staging Altitude
- Staging Strategy

Safety

Effectiveness

Extensibility

Affordability

## Focused Trades

### Architectural Variants (Examples)

- Launch Constraints
- Return Strategy
- Staging Altitude
- Plane Change
- Tandem / Convoy
- Surface Strategy

### Technologies & Sensitivities (Examples)

- Propellants
- Power
- Crew Size
- Surface stay
- Payload Down
- Payload Returned
- Launch Frequency
- Radiation Shielding

### Mission Capture (Examples)

- Lunar Short Stay
- Lunar Long Stay
- Polar / Equatorial
- Global Access
- Libration
- Mars Staging
- Mars Return

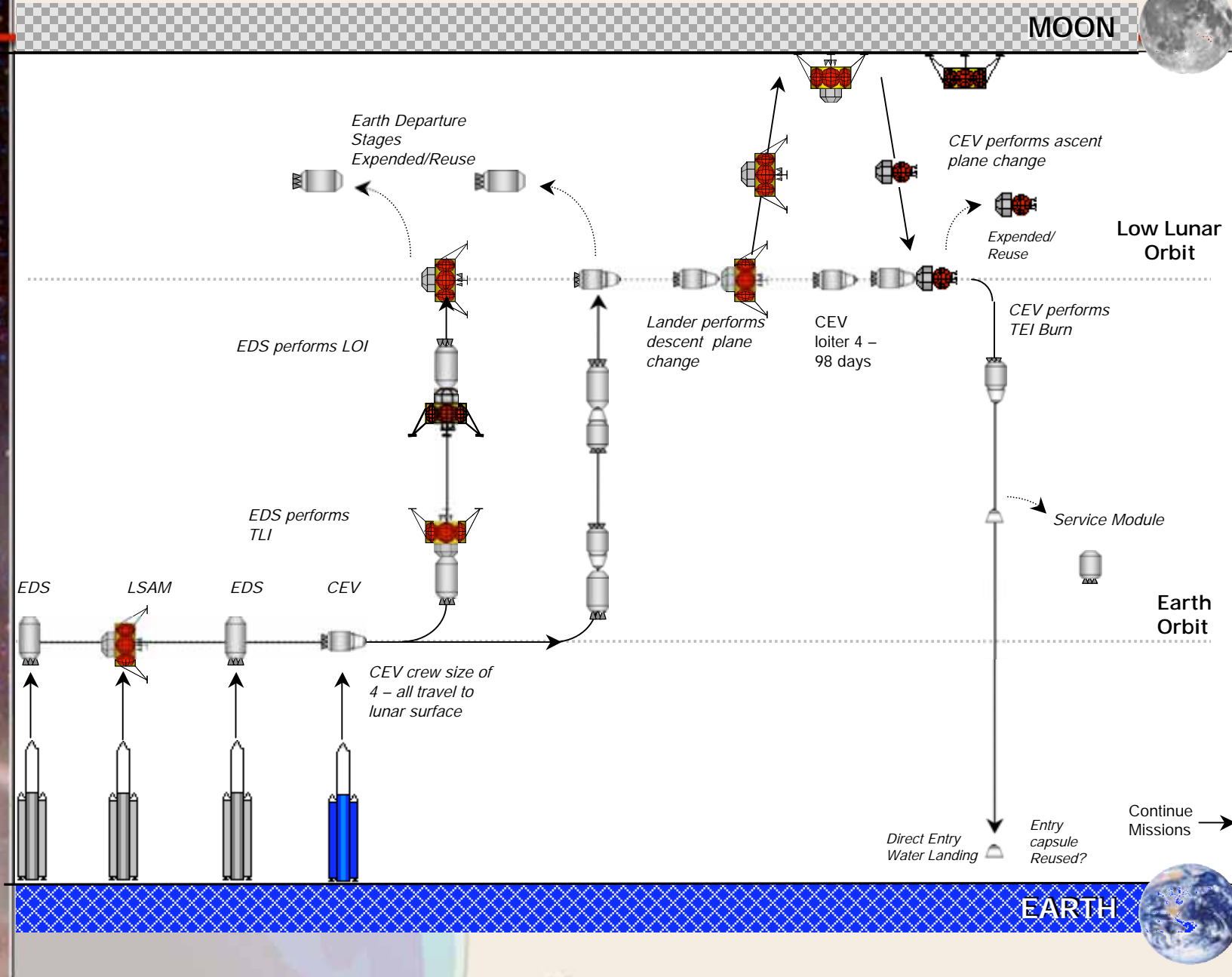
OAG/STT Decision Panel

Concept of Operations and Draft Requirements



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# POD- Lunar Trade Architecture

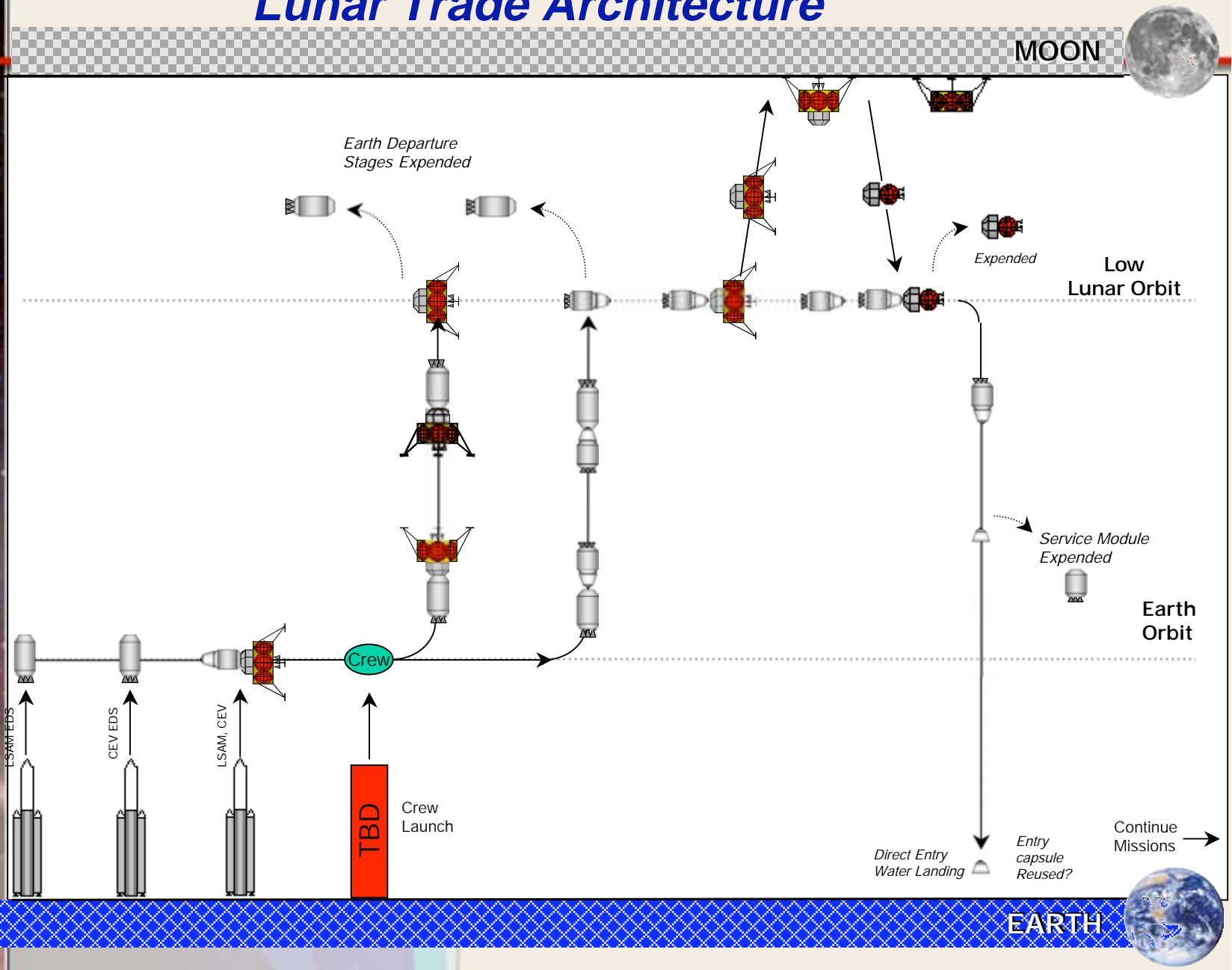






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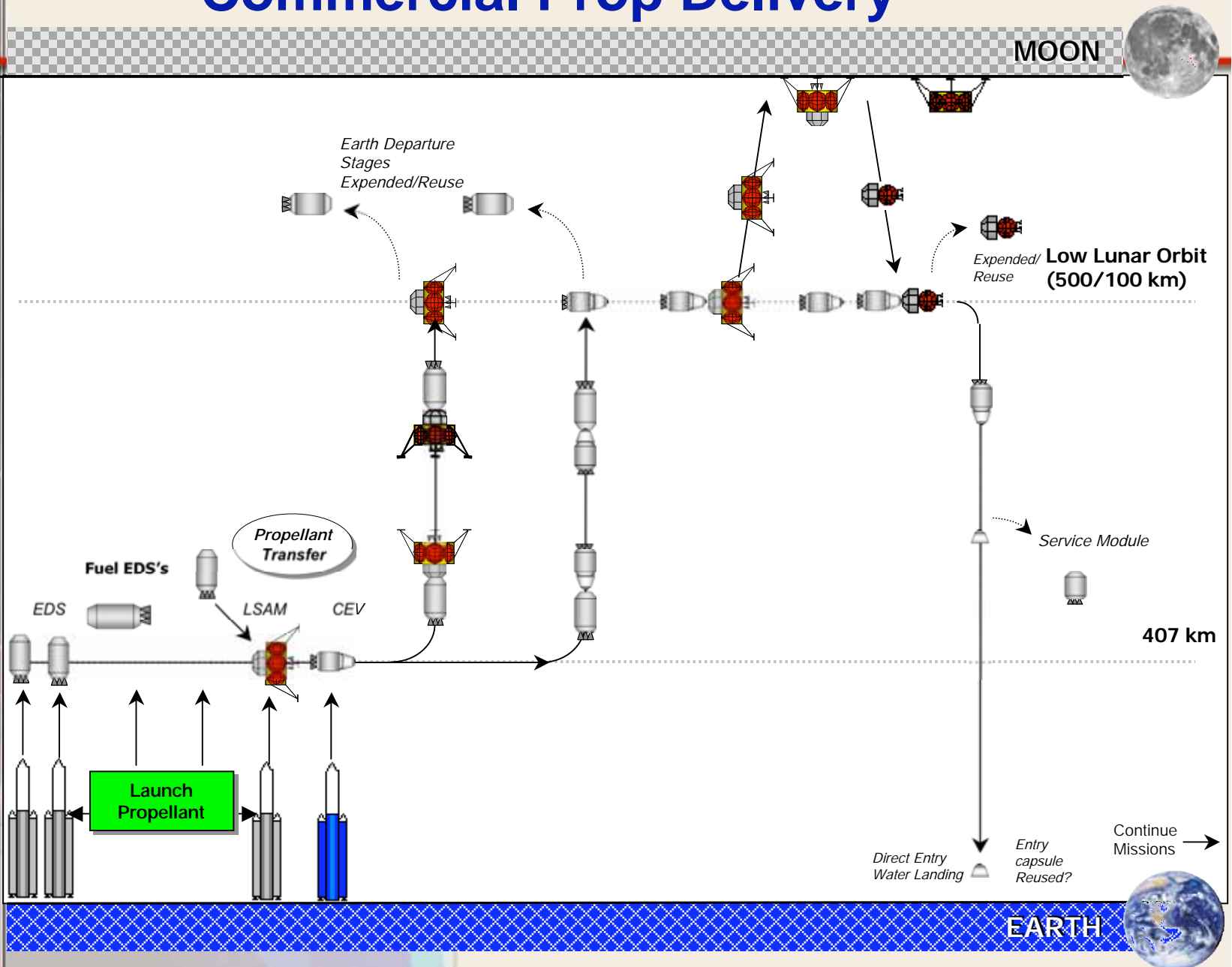
# Commercial Crew Delivery Lunar Trade Architecture



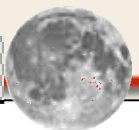


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# Commercial Prop Delivery



MOON



Low Lunar Orbit (500/100 km)

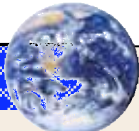
Service Module

407 km

Direct Entry  
Water Landing  
Entry capsule Reused?

Continue Missions

EARTH

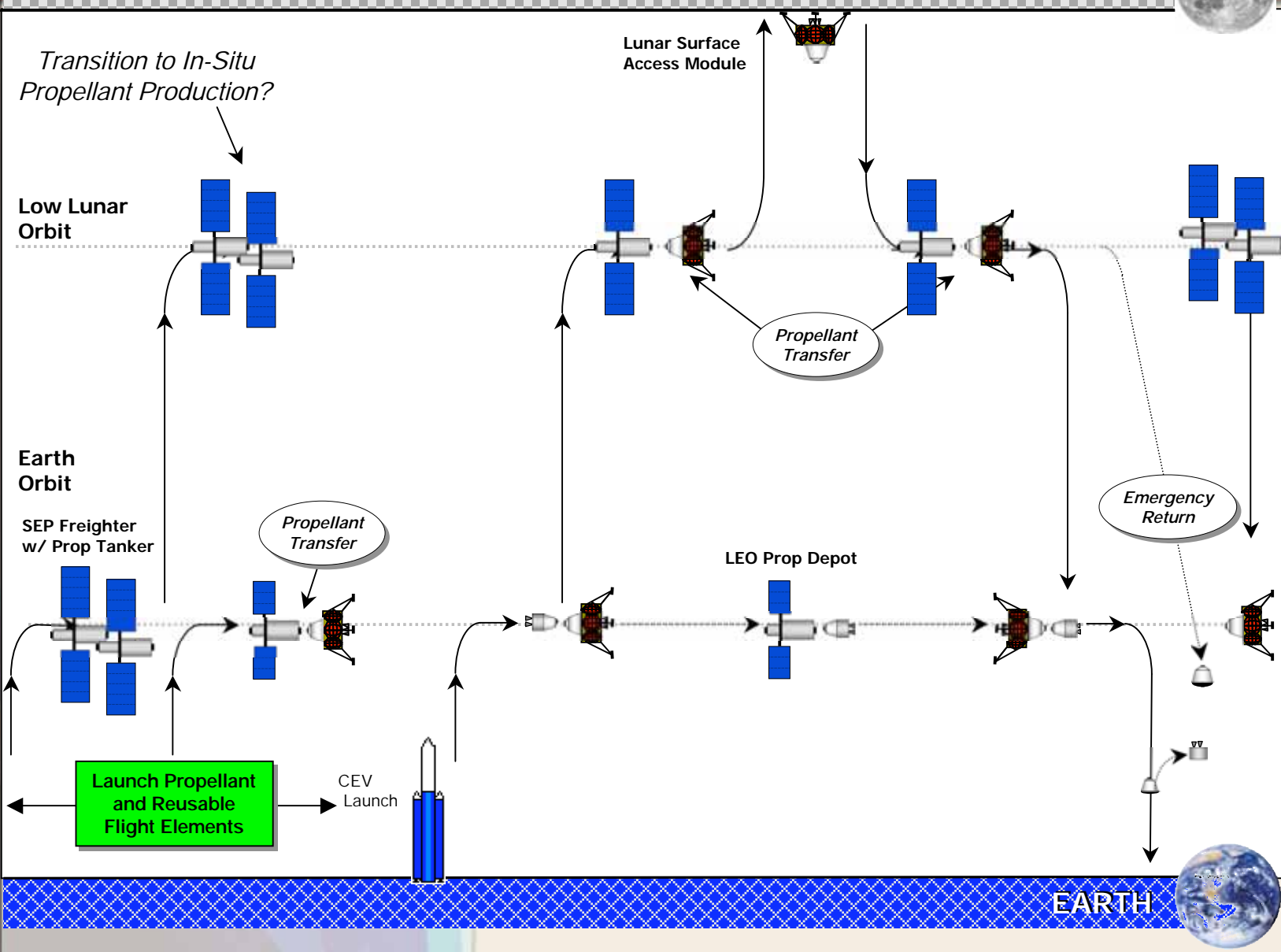




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# Modular Reusable Architecture

MOON

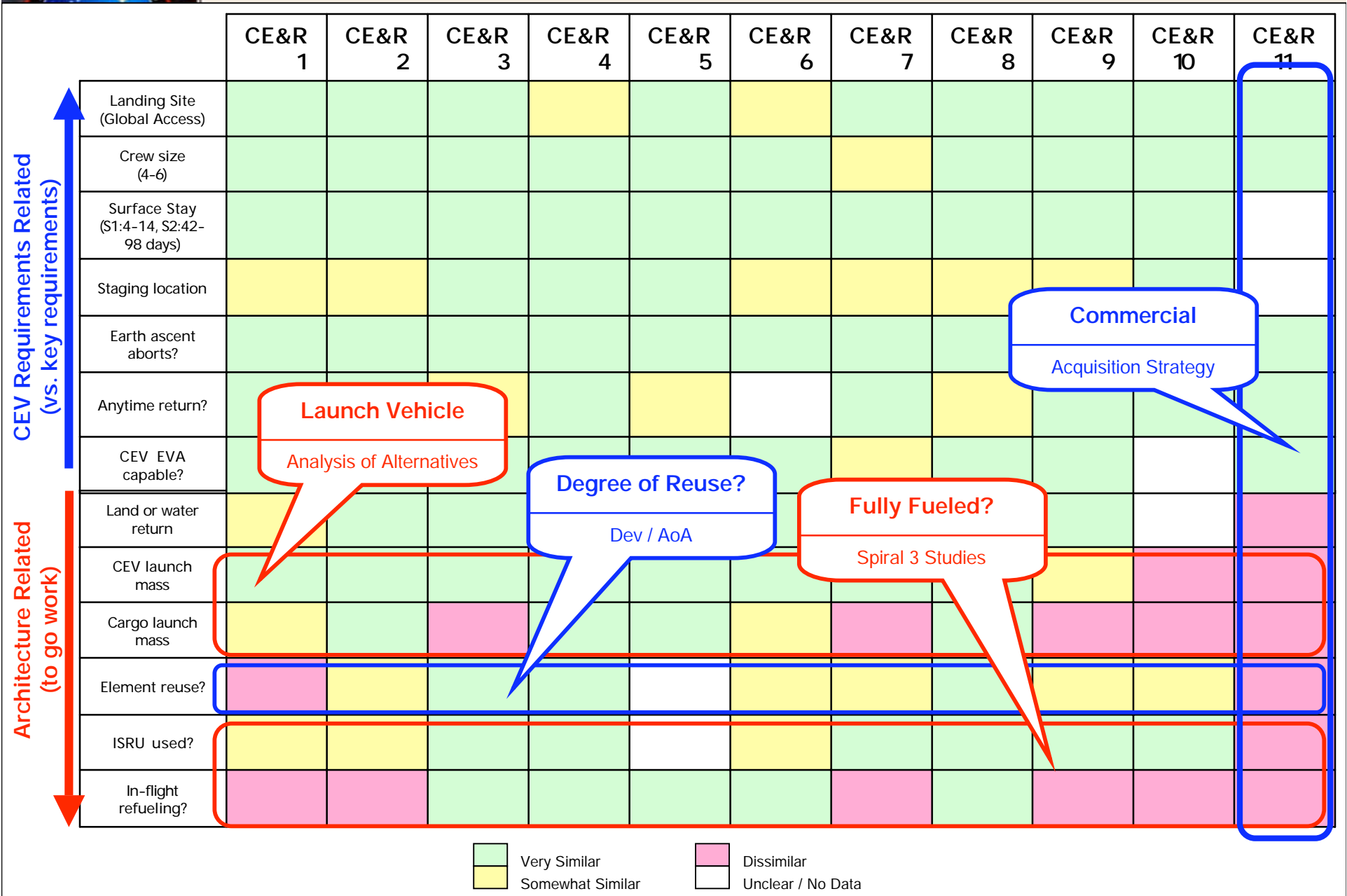


EARTH





# CE&R contractor mid-term summary





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APOLLO ASTRONAUT



*Crew Exploration Vehicle Overview*  
*CAPT Mike Hecker*  
*ESMD CEV Project Manager*