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

Operational Environments
- Exploration / Science Goals & Objectives
- Operations Concepts
- Functional Needs
- Deficiencies (Capabilities / Technologies)
- Cost & Operational Performance Trades
- Cost / Effectiveness

Available Technologies
- Modeling & Simulation

Nation’s Vision
- NSPD
- Level 0 Requirements

Affordable System Design & Development
- Investment Plan

Coordination responsibility with other Enterprises
Quality Functional Deployment (QFD) Flowdown

Supported by Cost, Operational & Performance Trades (SBA)

Architectural Campaigns

Operational Tasks

Operational Attributes

Technologies

Affordability
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

**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

**Safety**  
**Effectiveness**  
**Extensibility**  
**Affordability**

**OAG/STT Decision Panel**

**Concept of Operations and Draft Requirements**
Commercial Crew Delivery
Lunar Trade Architecture

Earth Departure Stages Expended

Low Lunar Orbit

Earth Orbit

Crew

TBD

Crew Launch

Service Module Expended

Direct Entry Water Landing

Entry capsule Reused?

Continue Missions

Earth Departure

Stages Expended

Commercial Crew Delivery

Lunar Trade Architecture

Earth

Orbit

Moontoon
Commercial Prop Delivery

Earth Departure Stages
Expended/Reuse

Low Lunar Orbit
(500/100 km)

Launch Propellant

Fuel EDS's

Service Module

Direct Entry
Water Landing

Entry capsule Reused?

Continue Missions

MOON

407 km
# CE&R contractor mid-term summary

## Launch Vehicle

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### Degree of Reuse?

- Dev / AoA

### Fully Fueled?

- Spiral 3 Studies

### Commercial Acquisition Strategy

- Very Similar
- Somewhat Similar
- Dissimilar
- Unclear / No Data
...the essence of the human spirit.

Frank Borman
Apollo Astronaut

Crew Exploration Vehicle Overview
CAPT Mike Hecker
ESMD CEV Project Manager