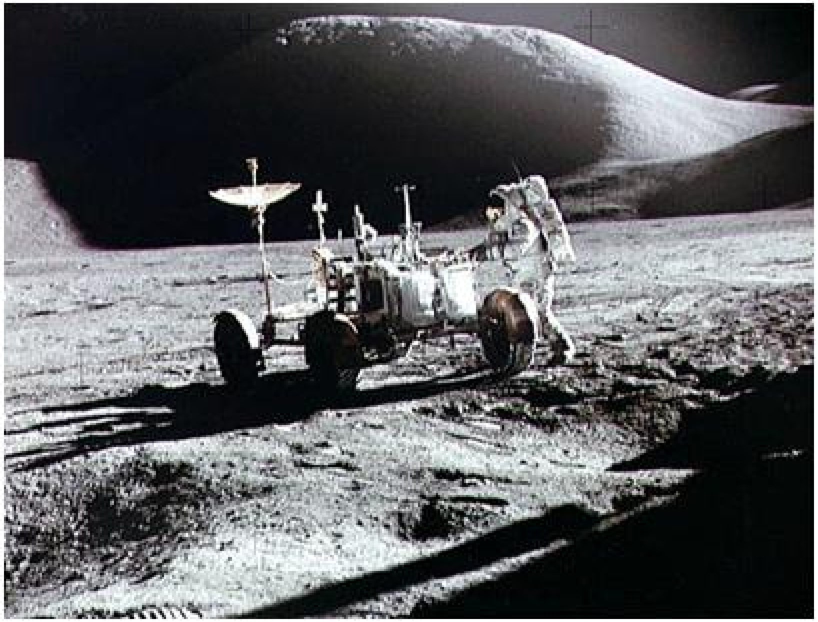
CA-1 Concept Sumary

Draper/MIT Team

September 13, 2004



Briefing Objectives

- Introduce Team
- Summarize SoS Concept
  - Objectives for HLE
  - Guiding design principals
  - Design considerations
  - Functional architecture
  - Physical architecture
- Describe Team Approach
  - Technical approach
  - Spiral development

Draper/MIT Team

- CEV Design Focused on Autonomy, GN&C, Reliable Avionics and Software
- Independent, non-profit laboratory
- Significant role on every NASA human spaceflight program since Apollo
- National center of excellence in GN&C, reliable avionics and autonomous systems
- National leader in technology transfer

- Innovative System-of-Systems Architecture Design and Analysis
- Educator of future generation of explorers
- National center for Technical and scientific innovation
- National center of excellence for Lean Enterprise models
- Incubator for technology commercialization

Payload Systems Inc.

Georgia Tech — Daniel Guggenheim School of Aerospace Engineering

Human Space Exploration Experience

Draper/MIT have supported every NASA Human Space flight since Apollo

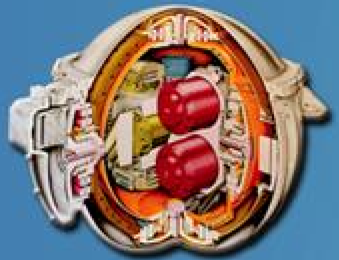
- GN&C Algorithms and Software • Highly Reliable, Fault-Tolerant Avionics • Autonomous Systems

Apollo

Space Shuttle

Space Station

X-38



As the MIT Instrumentation Laboratory, we designed the Apollo Guidance Computer which managed all GN&C functions for the Command Module & Lunar Lander

Shuttle Abort Flight Manager

Cockpit Avionics Upgrade

Draper played a key role in the Shuttle GN&C design, development and verification. Draper developed the Fault Tolerant Data Processing System and Backup Flight System.

Draper, MIT, and PSI have contributed NASA's Space Station design and operations. Draper's Timeliner language automates the control of experiments onboard the ISS.

Draper's Fault-Tolerant Parallel Processor is the core of NASA's X-38 avionics architecture.

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NASA'S

Space Exploration Initiative

Exploration Programs Office (ExPO) Lunar / Mars Mission Architecture Studies

Level II Navigation Lead for architecture concepts, systems, and requirements

Led the Navigation Technical Working Group (1990-1993)

- Conducted GN&C system analyses for Moon/ Mars missions

First Lunar Outpost (FLO) - 1993

- Mission Navigation Lead for manned return to Moon
- Designed autonomous lunar navigation architecture
- Conducted navigation performance analyses
- Lead for multi-disciplinary NASA team on Safe Lunar Landing
  - Developed methodology for cost effective safe landing

Lunar Scout – (1993)

- Lunar gravity mapping mission
- Provided orbit analyses and mission design

Artemis Common Lunar Lander – Precursor to FLO

- Low cost, general purpose Lunar Lander
- Lead for Descent and Landing navigation system
- Developed sensor requirements as a function of landing accuracy

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Objectives for Lunar Exploration

- Immediate Objectives
  - Develop resource knowledge throughout the Solar System
  - Accumulate operational experience for further exploration
  - Accumulate development experience and infrastructure
  - Fulfill the frontier spirit, develop pride and inspiration

- Scientific Objectives
  - Discover knowledge of the evolution of the solar system and the origin of the Moon
  - Locate resources on the Moon; determine the presence or absence of water
  - Use the Moon as a testbed for science investigations of other destinations

- Economic Objectives
  - Commercialize space products and services
  - Maintain U.S. space technology and manufacturing
  - Develop an industrial base with high export potential
  - Develop breakthrough technologies that also have commercial applications
  - Explore economically useful resources found on the Moon

- Security Objectives
  - Ensure that no country can claim sovereignty of the Moon
  - Develop technology that can also be used for security applications
  - Grow the manufacturing base that can also be used for defense purposes
  - Support the defense industrial base, including the domestic launch industry
  - Strengthen strategic international partnerships

Guiding Design Principals

- Design for sustainability
  - Sustainability: meeting today's goals in a way that also ensures that we can meet tomorrow's goals
  - The Exploration System of Systems must be designed with robustness to areas of policy, budgetary, and technical uncertainty

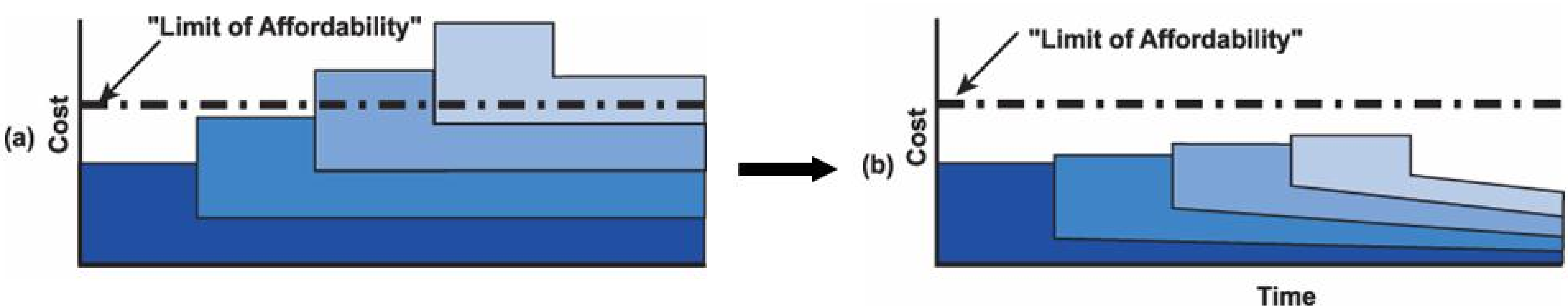
- Holistic view of entire SoS
  - SoS includes Hardware, Software and Human elements; process and organization
  - Focus on Value Delivery

- Highly modular and accretive design
  - Extensible System: Evolve gracefully, reconfigured easily, extended naturally
  - Accretion of assets: Reuse functionality and hardware; minimize disposal of hardware

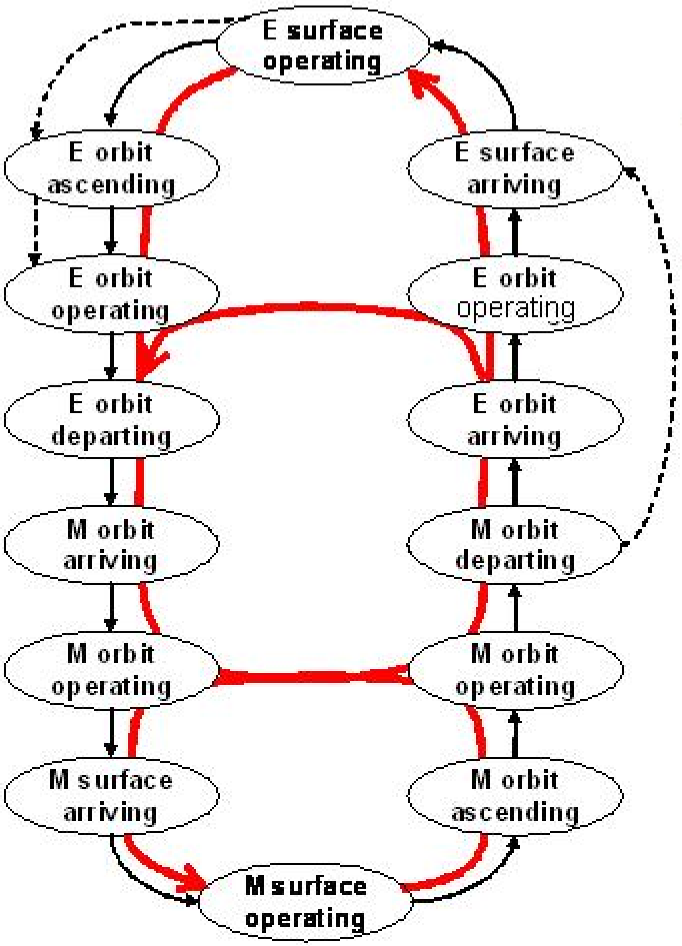
- Mars as a reference goal
  - Mars exploration is more stressful mission than Lunar exploration
  - Recommend Mars-Back approach: Optimize for Mars and test on the Moon
  - Conduct early trade on cost of commonality vs. life cycle cost to contrast Mars-back and Moon-forward approaches

Sustainability

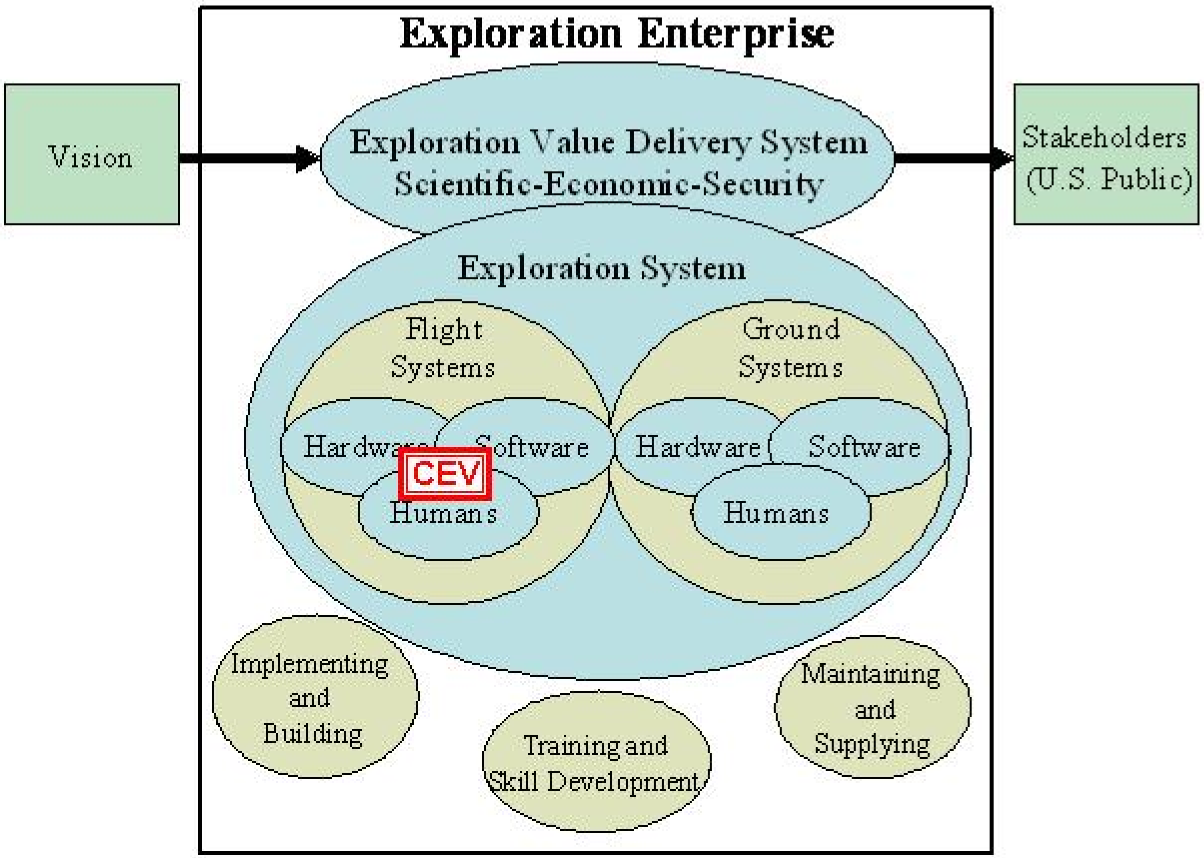
- Sustainability is the primary organizing principle of our architecture, and has 4 key factors:
  - Value of Exploration
    - Must be explicitly identified and delivered to the beneficiaries
    - The delivery must be clearly and continuously explained to them
  - Steady Cadence
    - Must have a steady cadence of successful and increasingly challenging missions
  - Risk
    - Risks must be broadly understood and explicitly minimized
    - Residual risks must be clearly communicated to all stakeholders
  - Affordability
    - System elements must be acquired and operated within the “go as you pay” profile
    - New designs must build upon old
    - Operations must incorporate organizational learning and diminish with time



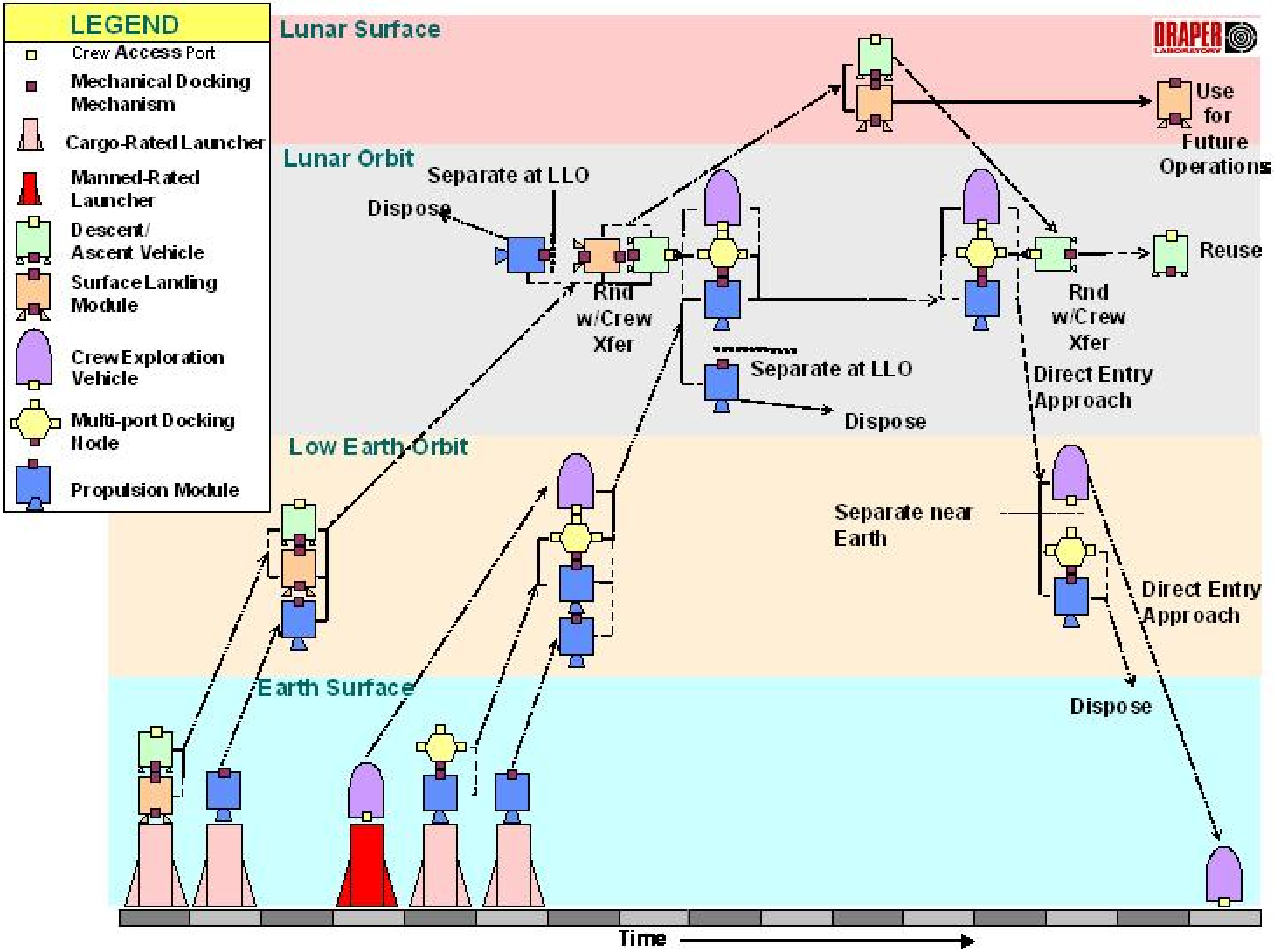
Functional Description of the HLE Enterprise



Initial HLE Concept



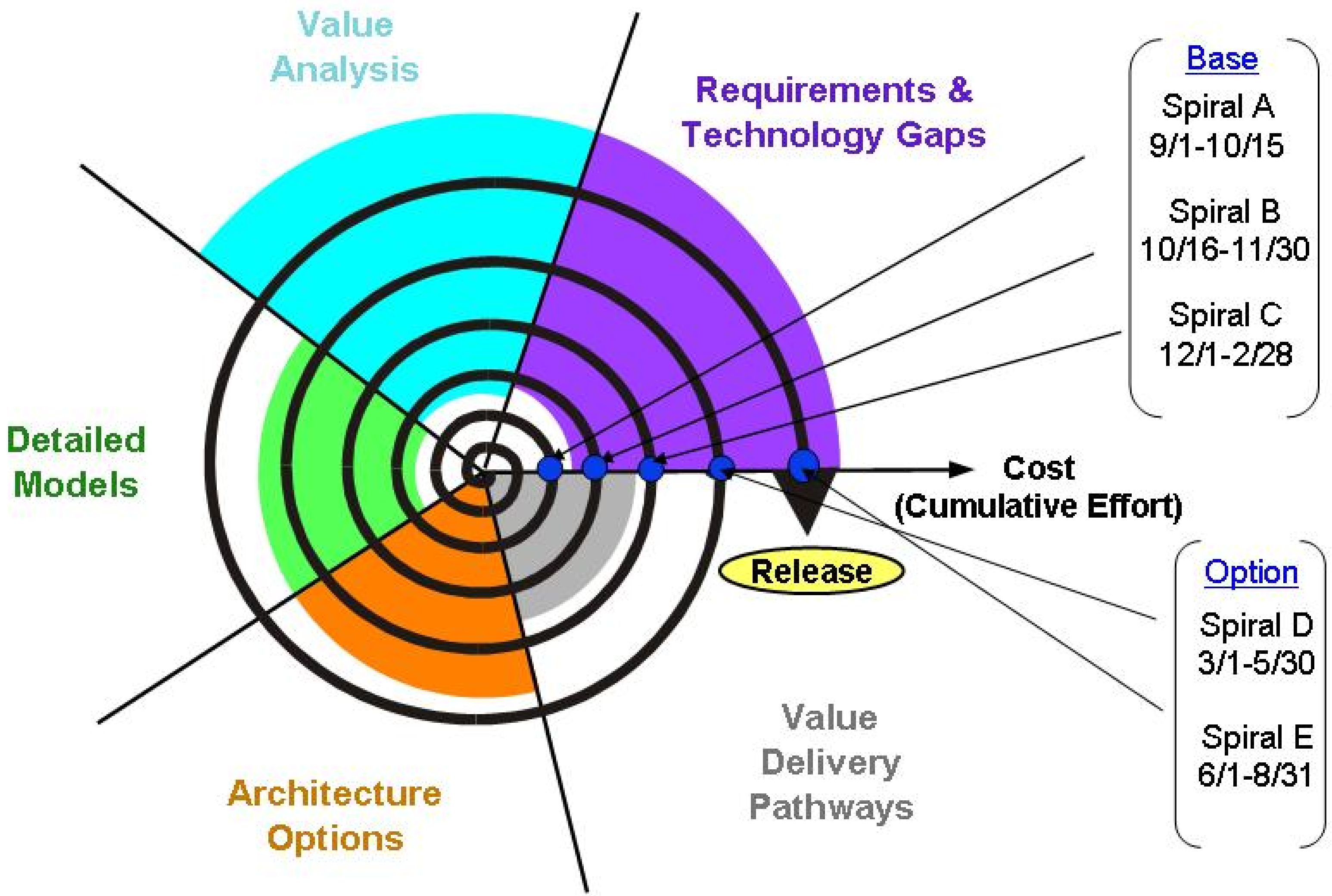
Physical View of HLE Concept



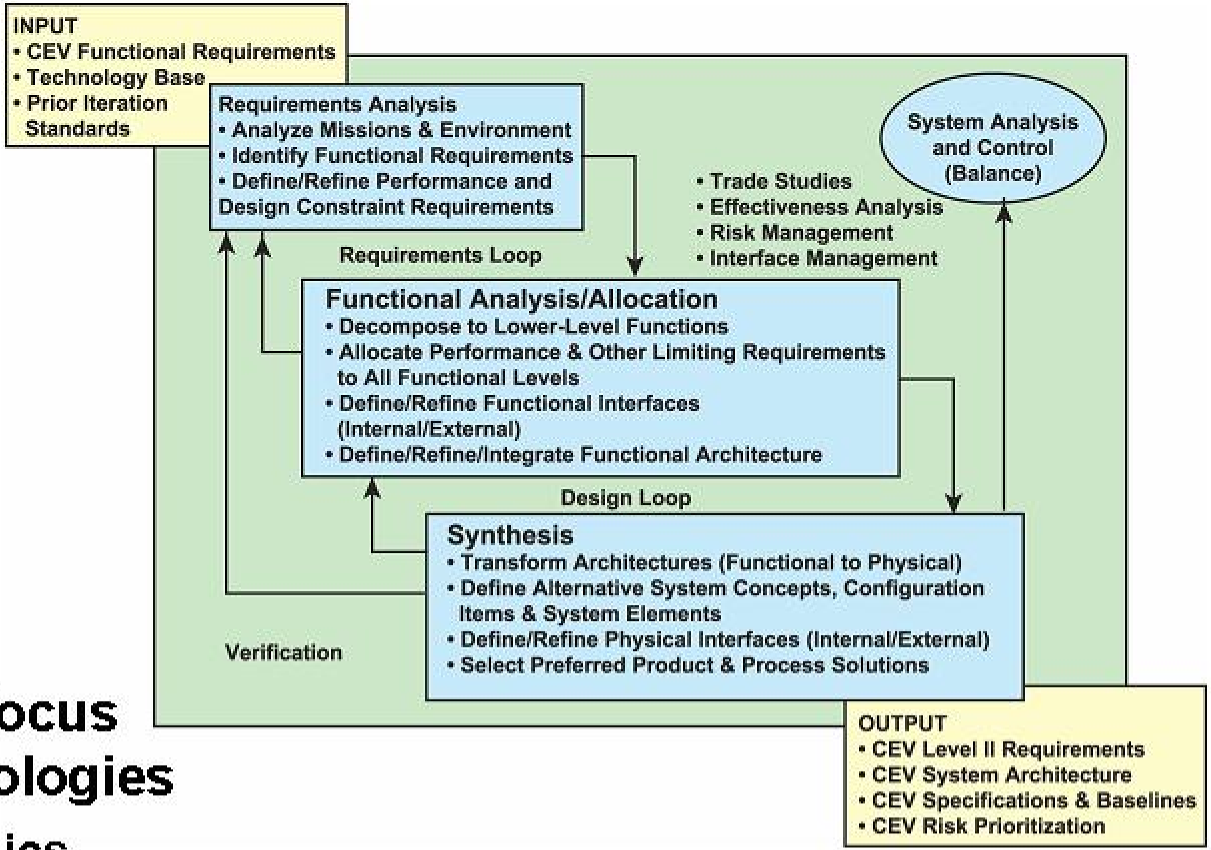
Technical Approach

- Integrated approach to Concept Area 1 and Concept Area 2
- Spiral Development
  - Define SoS Value Delivery Pathways
  - Enumerate Architectural Options
  - Identify Key Trades
  - Model Hardware, Information, and Human components in a way that relates the trades to the value delivery system
  - Evaluate Value Delivered by Architecture
    - Value, Safety, Reliability, Sustainability, Affordability, Extensibility
    - Use sensitivity analysis to guide the design
  - Define functional requirements for CEV and required technology maturation
- Open Team approach
  - All products available to all teams

Spiral Approach



CEV Technical Approach



- CEV refinement will focus on high payoff technologies
  - Highly reliable avionics
  - Robust GN&C
  - In-Space Assembly
  - Multi-level Autonomy
  - Reliable Software

Summary

- Architecture driven by Value Delivery
  - Sustainability is the primary organizing principle
- SoS includes:
  - Hardware, Software and Human elements
  - Flight and Ground Systems
  - Process and Organization
- Spiral development of architecture and CEV requirements
- Our unique team will provide modern approaches to the exploration enterprise architecture
  - System of Systems Analysis
  - Mission Operations and Autonomy
  - Integrated Safety Analysis
  - Lean Enterprise Architecture
  - Hazard and Safety Analysis
  - Policy Analysis