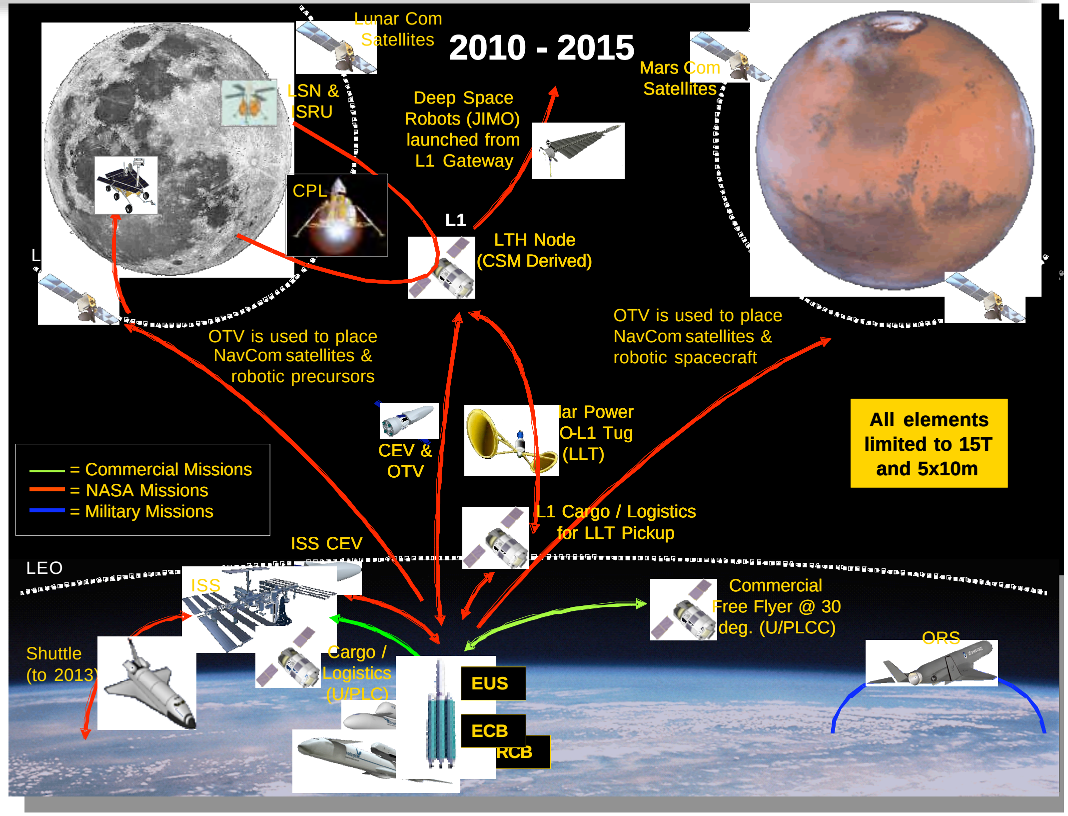
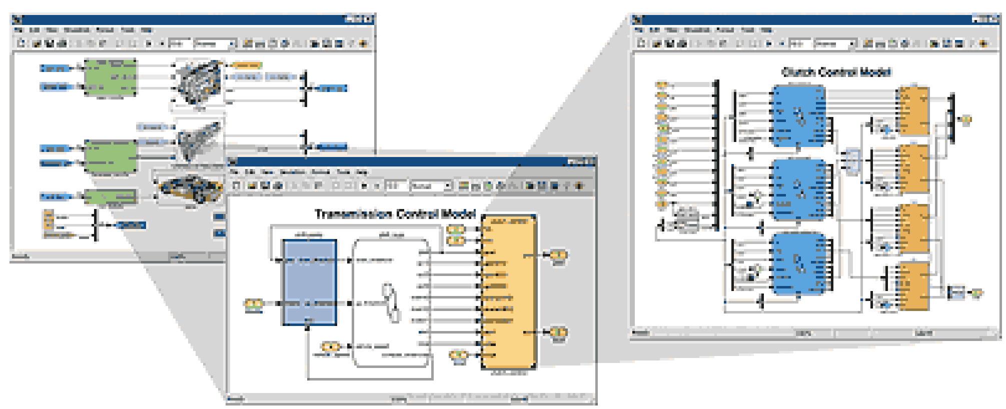
Andrews Highlights

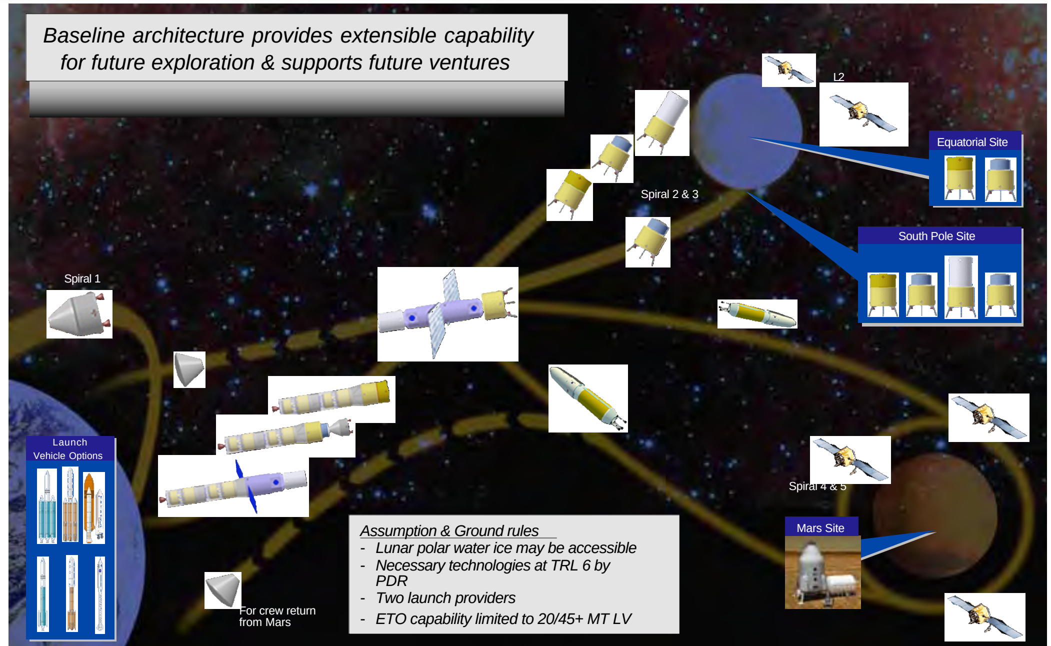
- **Reference concepts derived from stakeholder objectives, historical data, and timing / sequence constraints.**
- **7 Design Reference Cases**
- **Key Aspects of DRC1**
  - Global access
  - Launch anytime
  - Landing location determined from robotics
  - Nominal crew of 4
  - Surface excursions of 10 days
  - Lunar base grows for 1-year tours of duty (up to 8 crew)
  - Commercial opportunity potential after 2020

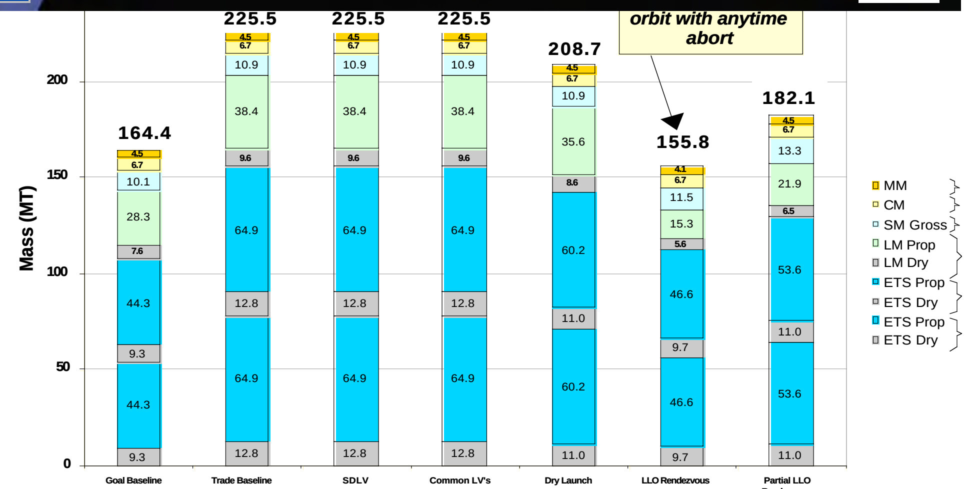




Boeing Highlights

- **Architecture driven from the Vision, lunar exploration objectives, lunar resource utilization, and national security**
- **Numerous architecture / design trades**
- **Architecture Summary**
  - Earth-Moon L1 Rendezvous
  - LEO aggregation of elements
  - Reusable lunar module
  - Single stage LM
  - Anytime returns; L1 gateway
  - Trip time extended by L1 operations
  - 14 days - continuous/long duration lunar stays



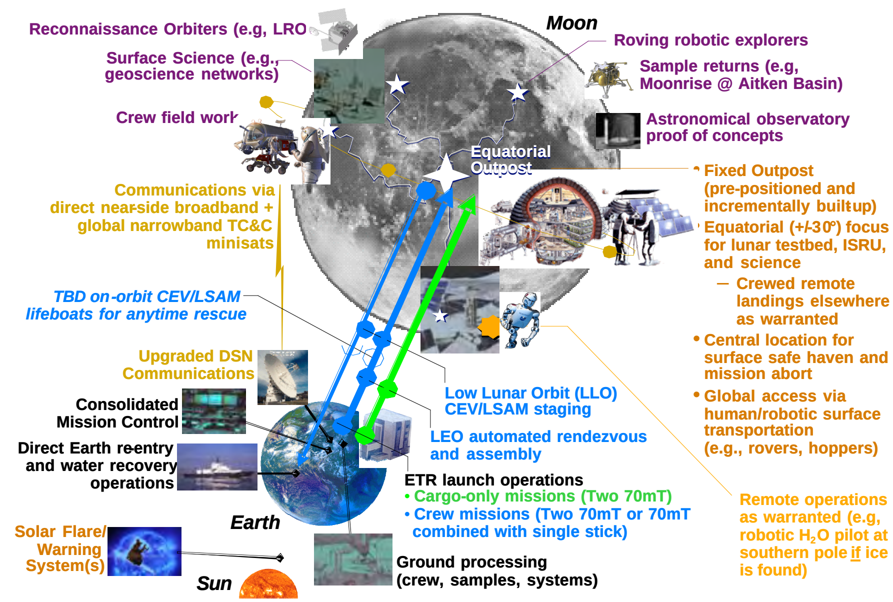


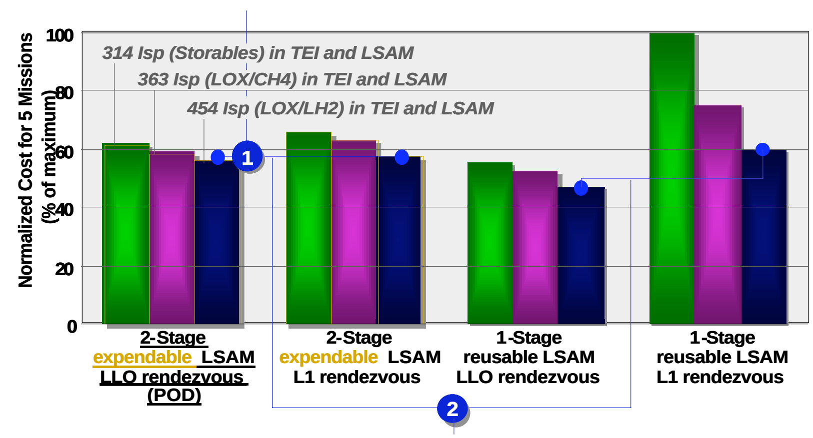
Trade Results show masses needed in LEO for various cases

Lockheed Martin Highlights

- **Guiding Principals**
  - Simultaneously address all Vision Objectives
  - Start with Mars and work backwards
  - Answer fundamental questions to determine post-2025 future of exploration on Moon, Mars, Beyond
- **Numerous trades being conducted**
- **Exploration Approach**
  - Mars robotic precursors (orbiters and landers) already leading the way
    - Pursuing water/life clues
    - Providing global access to H20 ice at poles/near poles
    - Soon to be performing combined science, ISRU, engineering testbed missions
    - Improving rover duration and speed
  - Human missions likely to use fixed, near-equatorial site for surface stays of 30-630 days
    - Near the most desirable sites
    - Low altitude to minimize entry/descent/landing difficulty
    - Enables incremental build-up
    - Most energy/mass efficient location
    - More favorable thermal environment (20°C to -140°C)
    - Safest approach
    - Best solar fluence

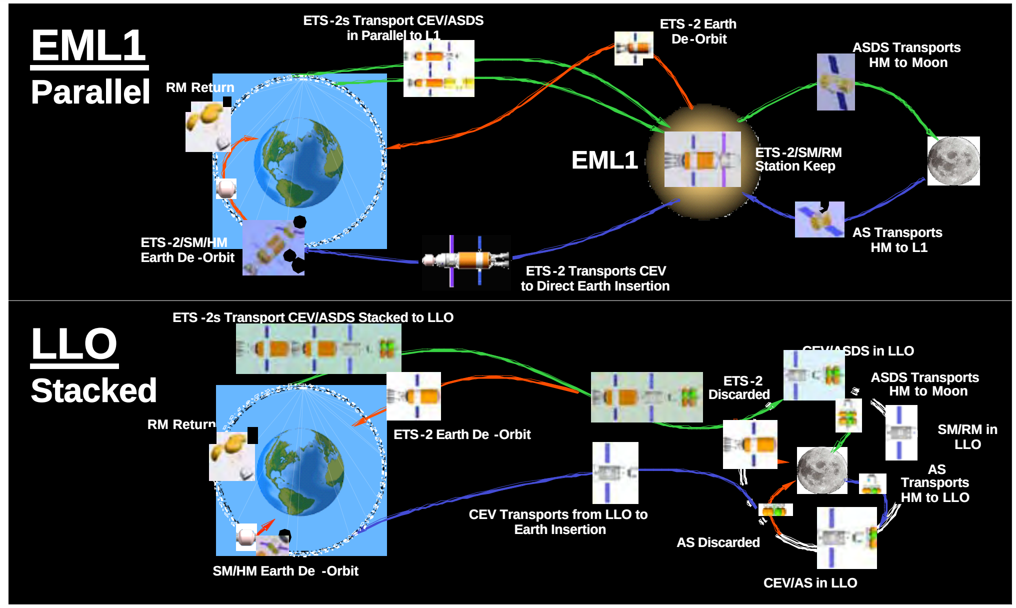
POD Lunar Architecture Features (2018-2023)

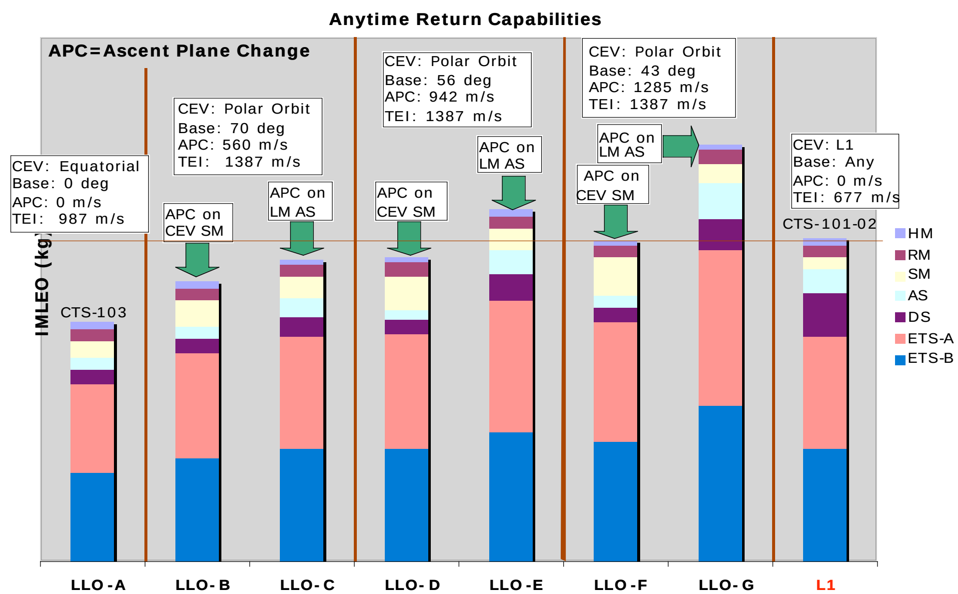




Northrop Grumman Highlights

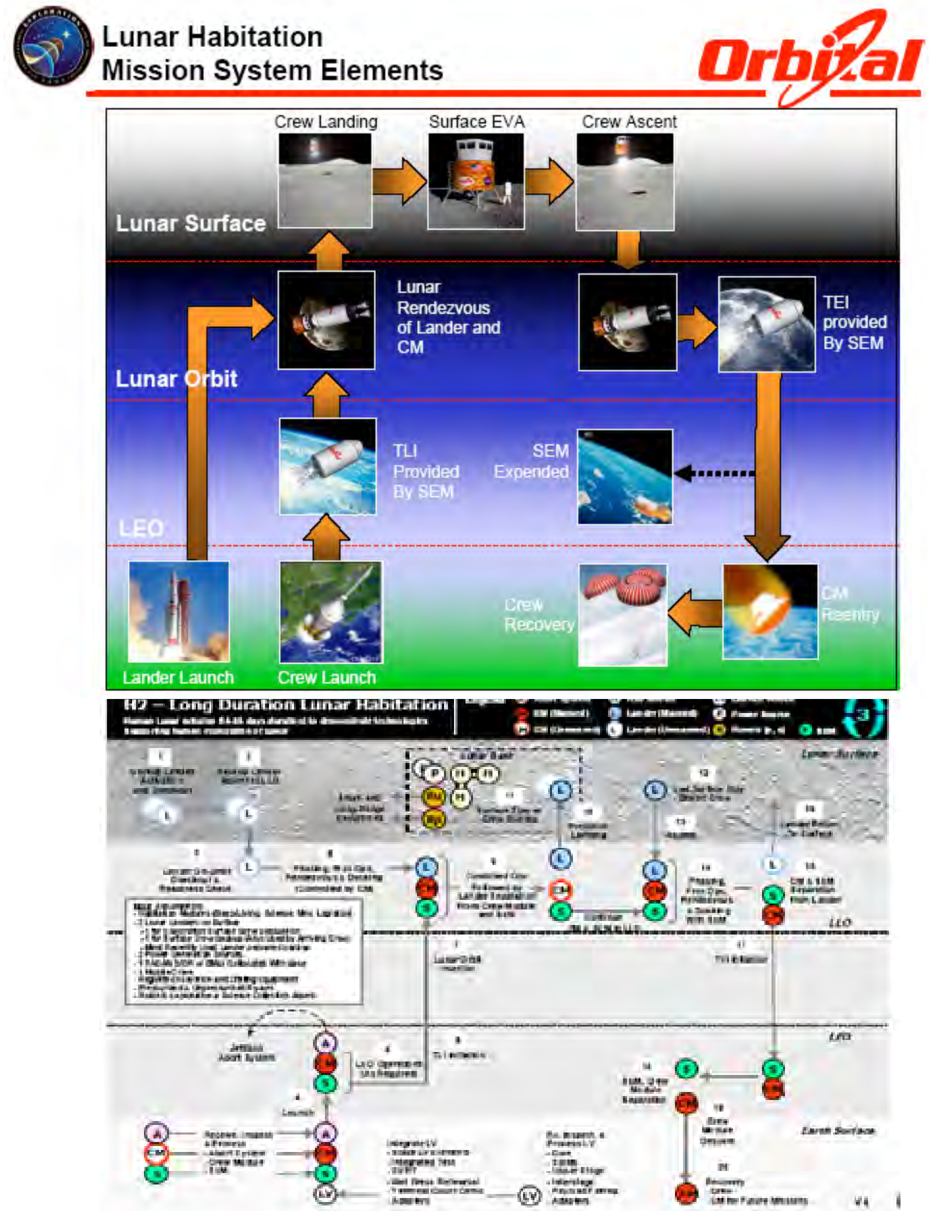
- **Guiding Principles**
  - Simultaneously address each of the Vision Objectives
  - Start with Mars and work backwards
  - Answer the fundamental questions to determine the post-2025 future of exploration on Moon, Mars, and Beyond
- **Numerous trades being conducted**
- **Exploration Approach**
  - Polar landing site
  - 180 days surface duration
  - Safe-haven abort; Implicit Rescue with Responsiveness
  - 0-4 crew members
- **Mars preparation has two components**
  - Technology demonstration and test
  - Operational experience: "Lessons Learned"





Orbital Sciences Highlights

- **Vision Mapped to Objectives, Missions, Functions, and Requirements**
- **Numerous trades being conducted**
- **Example Habitation Alternatives**
  - Multiple Outpost Capability Anywhere on Lunar Surface?
  - Lunar Logistics Base: Establish Single Lunar Base and Provide for Distributed Exploration Capability?
  - Lunar Orbiter: Provide 90 Day Capable Lunar Orbiter With Surface Excursion Capability Anywhere on Lunar Surface?
- **Observations**
  - Coupling of Lunar Base Selection and Lunar Abort/Safe Haven Capability
  - It's Primarily a Transportation and Logistics Problem
  - Lunar/Mars Operations Need to Be Compatible and Traceable
  - Need a Budget Strategy at Spiral Transitions to Ensure Sustainability



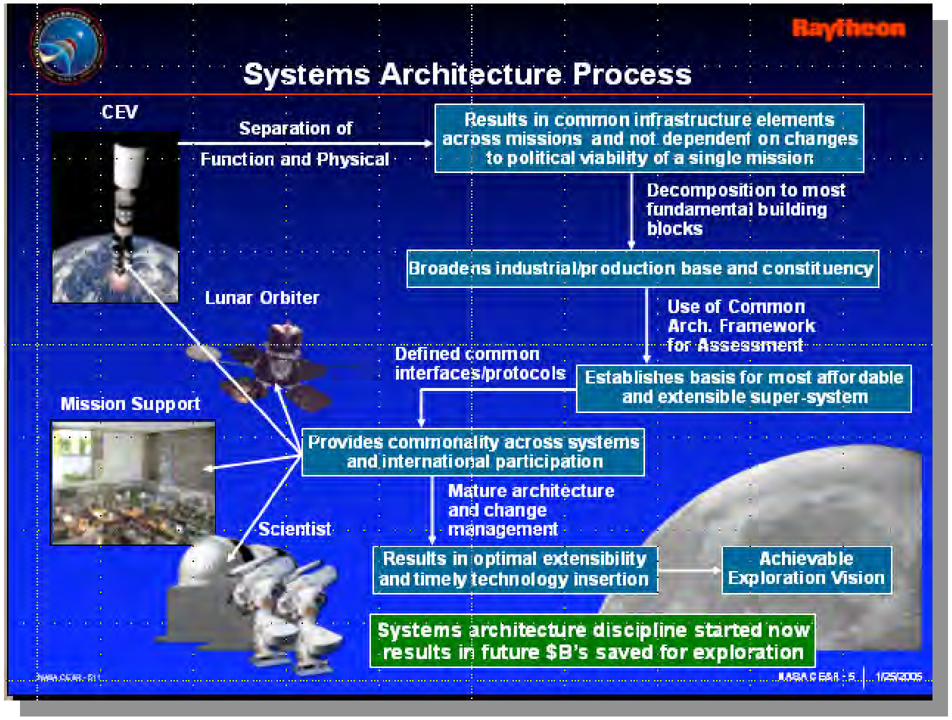
Raytheon Highlights

- **Vision for Space Exploration drives exploration strategy**
  - Common infrastructure elements across missions
  - Not dependent on changes to political viability of a single mission

- **Numerous trades being conducted**
  - Mission architecture related
  - System sensitivities
  - Technologies

- **Applicability of Lunar Operations to Mars Exploration Identified**

- **Key Architectural Construct**
  - Initial basing at South Pole
  - Low-Lunar Orbit staging for cargo
  - L1 staging for crew
  - Lunar regolith used for crew protection from lunar environment
  - Launch vehicle strategy being traded
  - 3 crew members provide the operational and safety margins desirable at minimum cost
  - Critical technologies identified



SAIC Highlights

♦ Study Status

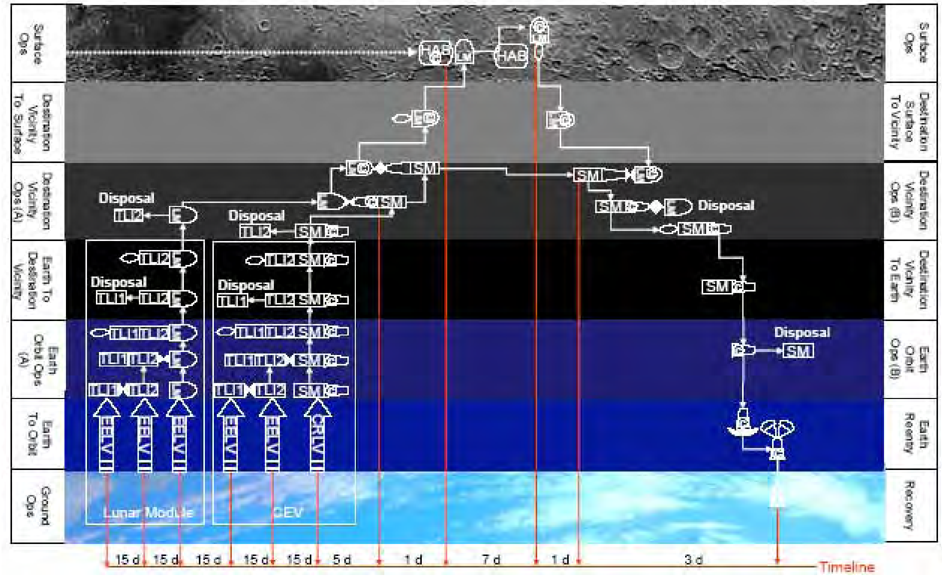
- Preliminary analysis of Initial Concept for Technical Solution (ICTS) 20-mission campaign is complete
- Conservative assumptions have been made throughout this preliminary analysis
- Results indicate that the baseline campaign is both feasible and achievable
- Additional trade studies are underway

♦ Campaign Studies Conducted

- Mass Flow
- Loss of Mission / Loss of Crew
- Risk Mitigation Measure
- Launch Manifest Trades

♦ Figures of Merit Assessments

- Safety & Mission Success: LOM & LOC risks have been identified and initial values generated
- Effectiveness: Being explored
- Extensibility: Campaign is based around developing long-duration mission capability without resupply (in preparation for Mars surface missions) and selected subsystems
- Affordability: Under development

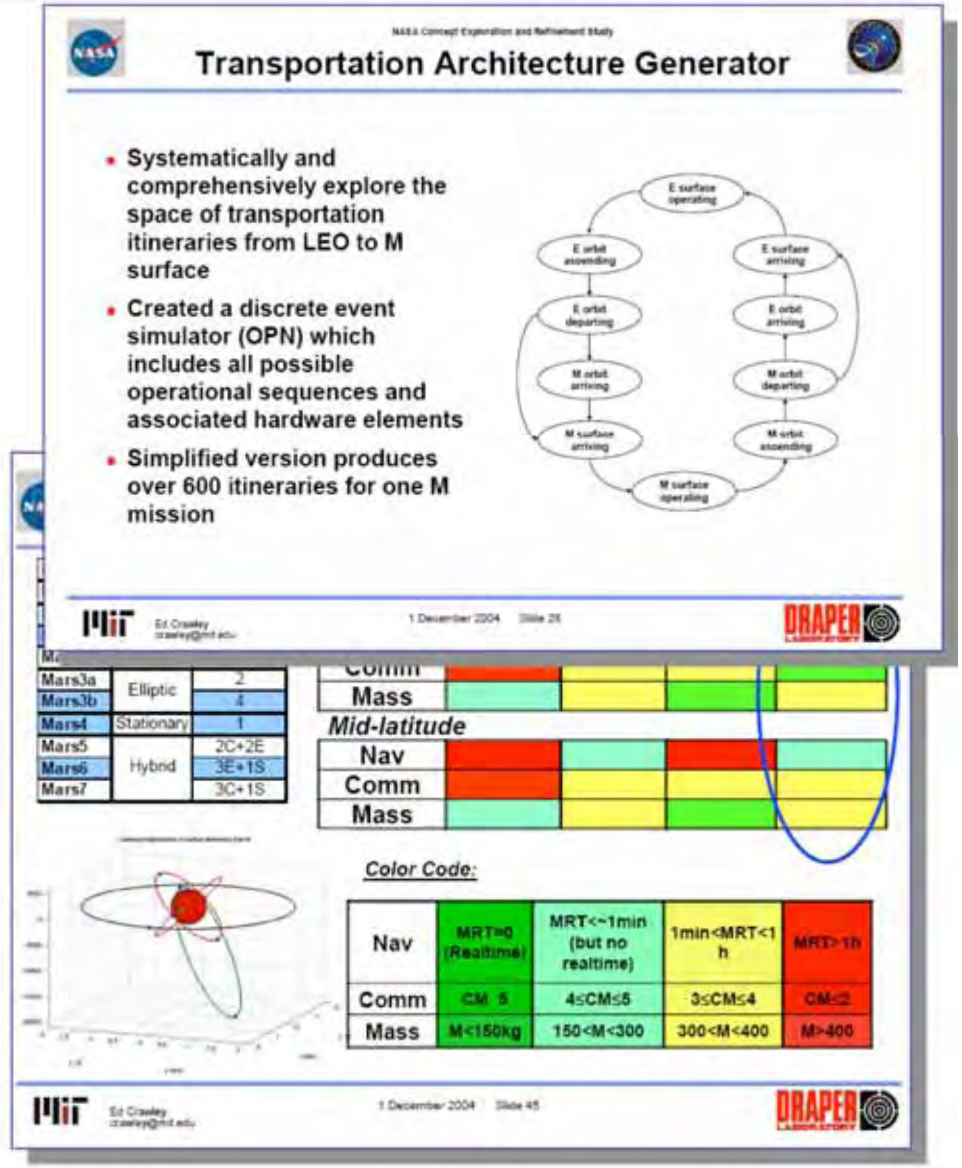


System		Fiscal Year: 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	System Description
Earth-To-Orbit	EELV				1	2	4	5	6		7				9	10	11	12	13	15	16			Delta or Atlas EELV
	Crew Rated Launch Vehicle								6			8			9	10	11	12	13	15	16	17,19	20	Clean Sheet or Evolved Man Rated LV
	Heavy Lift Launch Vehicle																			14,15	16	17-19	20	Clean Sheet or Evolved w/ 50+ MT lift cap.
In-Space Transportation	Descent /Ascent Modules							5			7						11	12	13	15	16	17,19	20	Evolving functions – single nonstart eng.to multi
	Advanced Chemical				1	2	4	5	6		7				9	10	11	12	13	15	16	17,19	20	Low boil-off cryo or adv. storable prop. engines
	High Isp Propulsion																			14		18	20	SEP, NEP propulsion for slow p/d delivery
Earth Return	Earth Direct Entry						4	5	6		7	8			9	10	11	12	13	15	16	17,19	20	Adv. TPS for direct atm. re-entry from LEO/LLO
	Earth Capture - Aero-assist																		13	14			20	Aerobraking or aerocapture in LEO -exper return
Crewed Spacecraft	CEV - Escape System					3	4		6			8			9	10	11	12	13	15	16	17,19	20	Launch escape system for crew safety
	CEV - Capsule					3	4		6			8			9	10	11	12	13	14	16	17,19	20	Capsule for launch, re-entry and crew support
In-Space Operations	Remote Docking				1																			Human manipulated docking done remotely
	AR&D					3			6		7	8			9	10	11	12	13	14	16	17,19	20	Autonomous rendezvous and docking
Habitats & Life Support	Modular Surface Habitat - IOC										7					10	11							Habitat for short stay missions
	Connected/Enlarged Modular Surface Habitat														9			12	13	15	16	17,19	20	Linked modular surface habs for extended stay missions
	ECLSS														9	10	11	12	13	15	16	17,19	20	Open-loop life support evolving to Mars-compat.
In-Space & Surface Power	Solar Electric				1		4	5	6		7	8			9	10	11	12	13	15	16	17,19		Photovoltaic power production
	Fuel Cells				1	3	4		6		7	8			9	10	11	12	13	15	16	17,19	20	H2/O2 fed power production and storage
	Nuclear																	12	13	15	16	17,19	20	Surface nuclear power for sustained lunar bases
Surface Operations	ISRU															10	11	12	13	15	16	17,19	20	O2 generation evolving to mult. Purpose suits
	Surface Navigation															10	11	12	13	15	16	17,19	20	Beacons or inertial ref. systems for surface nav.
	Surface Mobility																11	12	13	15	16	17,19	20	Non-pressurized evolving to pressurized
	EVA Suits - Evolved Lunar Suit														9	10	11	12	13	15	16			Evolved suits - tailored for lunar environment
	EVA Suits - Evolved Mars Suit																			15	16	17,19	20	Evolved suits - tailored for Martian environment
		Spiral 1											Spiral 2					Spiral 3						

Legend: Common system within the lunar mission set (yellow) · Evolvable system (later lunar mission and/or Mars) (green) · Common system extensible to Mars (blue)

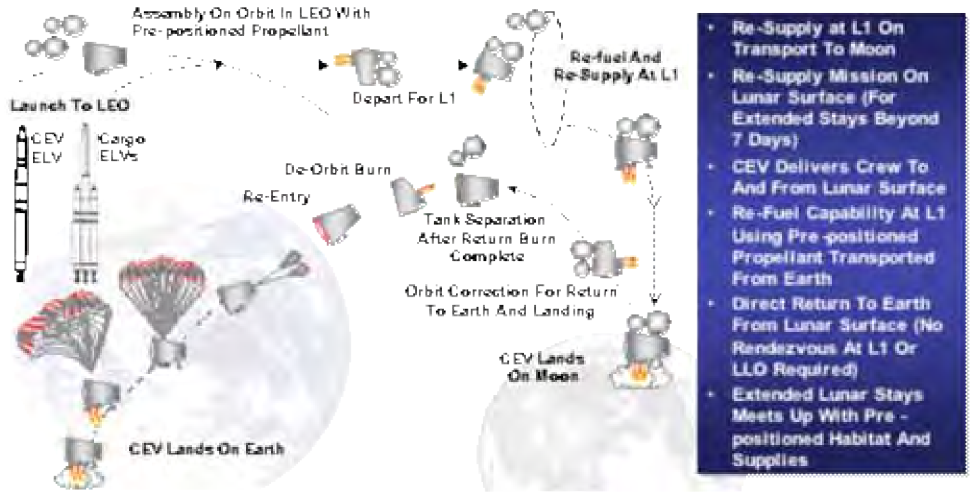
Draper / MIT Highlights

- **Stakeholder Value Analysis Approach:**
  - Stakeholders identified (14)
  - Stakeholder needs defined (~90)
  - Exploration objectives (24)
  - Technical architecture proximate measures (~18)
  - Indicator metrics (~40)
- **Mars Back Emphasis**
- **QFD Tool utilized to screen options**
  - For over 600 itineraries, and fixed technology/operational decisions, optimization determines best mix of technologies
- **Numerous architecture, system, and technology trades being conducted.**
- **Key Findings to Date**
  - A sustainable exploration program must focus on delivering value throughout its lifetime to all stakeholders
  - A Mars-back focus should be maintained throughout the architecture and mission development process

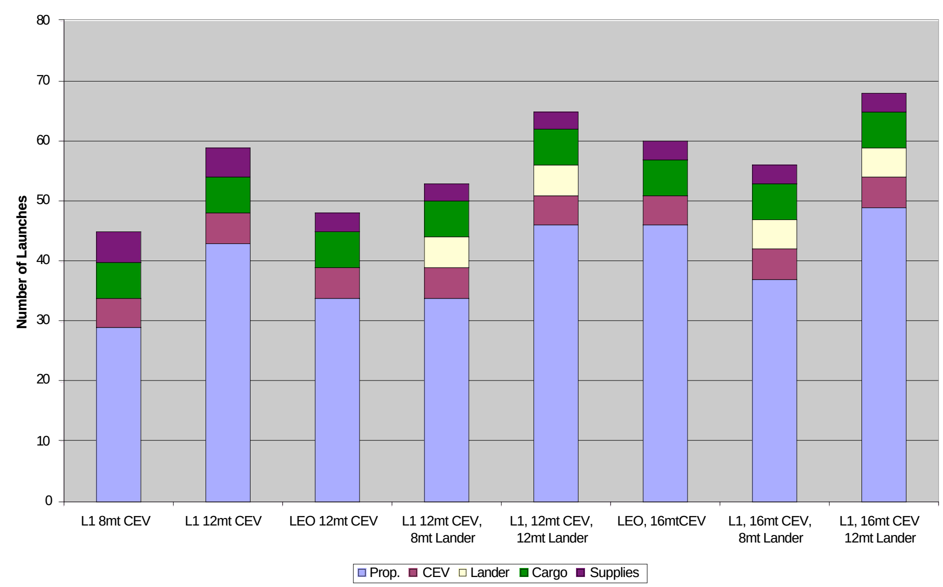


Schafer Highlights

- **Architecture Overview**
  - Emphasizes Gateway Architecture
  - Architecture Fosters In Situ Resource Utilization (ISRU)
  - L1 Refueling and resupply
  - Direct return from lunar surface
  - Off Earth Robotic Assembly, Set-up, and Operation For All Infrastructure
  - Robotic Reconnaissance Missions Select Near Lunar Equator And South Pole Locations For Probable Extended Presence And Continued Exploration
  - Assume One Crewed Mission Per Year Over 5-year Campaign In Spiral-2



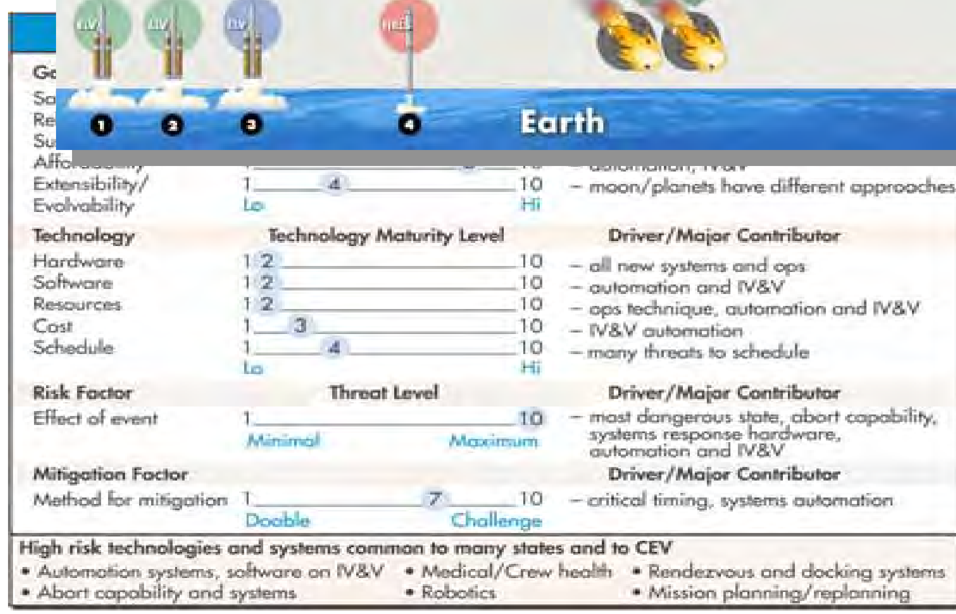
- **Drivers and Sensitivities**
  - CEV Mass Strongly Influences Propellant Required
  - Radiation Shielding Of CEV Is Severe Penalty
  - Launch Of Propellant Mass To LEO Dominates All Architectures
  - CONUS Landing Stresses CEV For Direct Return
  - LV Capabilities And Lift Mass To LEO
  - CEV Crew Size
  - Reliability Of Storage And Transfer Of Cryo Propellant In Space
  - ISRU Propellant Or LunOX Production Effectiveness For Future Spiral-3 Missions
  - Abort Scenarios For Crew Safety Determine Size And Mass Of L1 Infrastructure



SpaceHab Highlights

- **Architecture Overview**
  - Maximize system modularity to the greatest extent possible
  - Each element will have the capability to operate alone or in conjunction with other elements
  - All non-crewed elements are launched on commercial Expendable Launch Vehicles (ELVs) with a lift capability of at least 15 metric tons.
  - The Crew Exploration Vehicle (CEV) is launched on a human rated launch system.
  - The CEV is sized to accommodate four crewmembers.
  - Reuse of systems

- **Key Technologies Identified to Date**
  - Automated Rendezvous, Proximity Operations and Docking (ARPOD)
  - Liquid Cryo Propellant Management
  - Extended-duration power generation (Nuclear Power)
  - Interplanetary communications relay
  - Regenerative ECLSS
  - Radiation Shielding

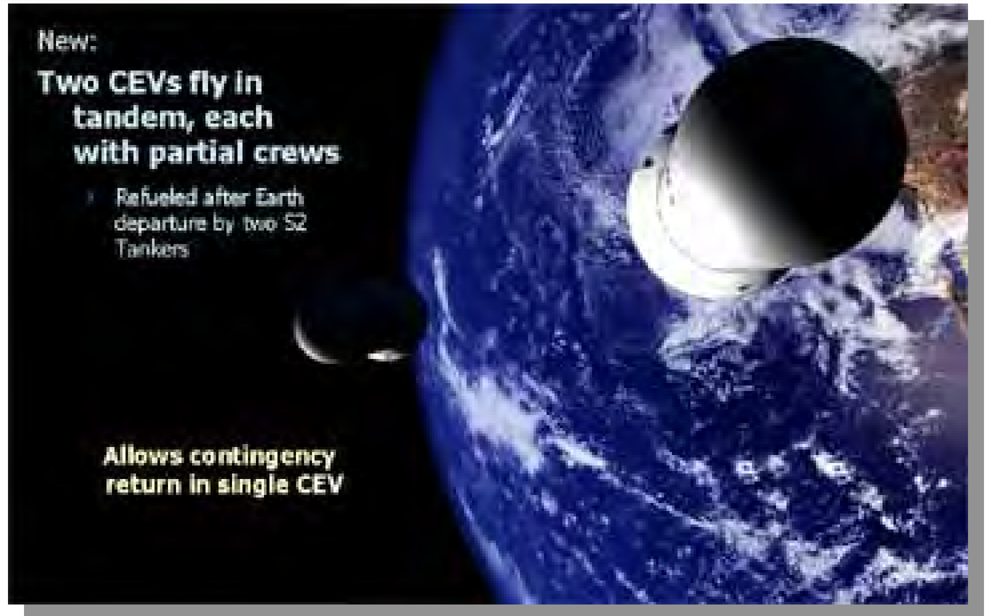


Extensibility/ Evolvability	1 — 4 — 10 (Lo – Hi)	– moon/planets have different approaches
Technology	**Technology Maturity Level**	**Driver/Major Contributor**
Hardware	1 2 — 10	– all new systems and ops
Software	1 2 — 10	– automation and IV&V
Resources	1 2 — 10	– ops technique, automation and IV&V
Cost	1 — 3 — 10	– IV&V automation
Schedule	1 — 4 — 10 (Lo – Hi)	– many threats to schedule
Risk Factor	**Threat Level**	**Driver/Major Contributor**
Effect of event	1 — 10 (Minimal – Maximum)	– most dangerous state, abort capability, systems response hardware, automation and IV&V
Mitigation Factor		**Driver/Major Contributor**
Method for mitigation	1 — 7 — 10 (Doable – Challenge)	– critical timing, systems automation

High risk technologies and systems common to many states and to CEV
- Automation systems, software on IV&V
- Abort capability and systems
- Medical/Crew health
- Robotics
- Rendezvous and docking systems
- Mission planning/replanning

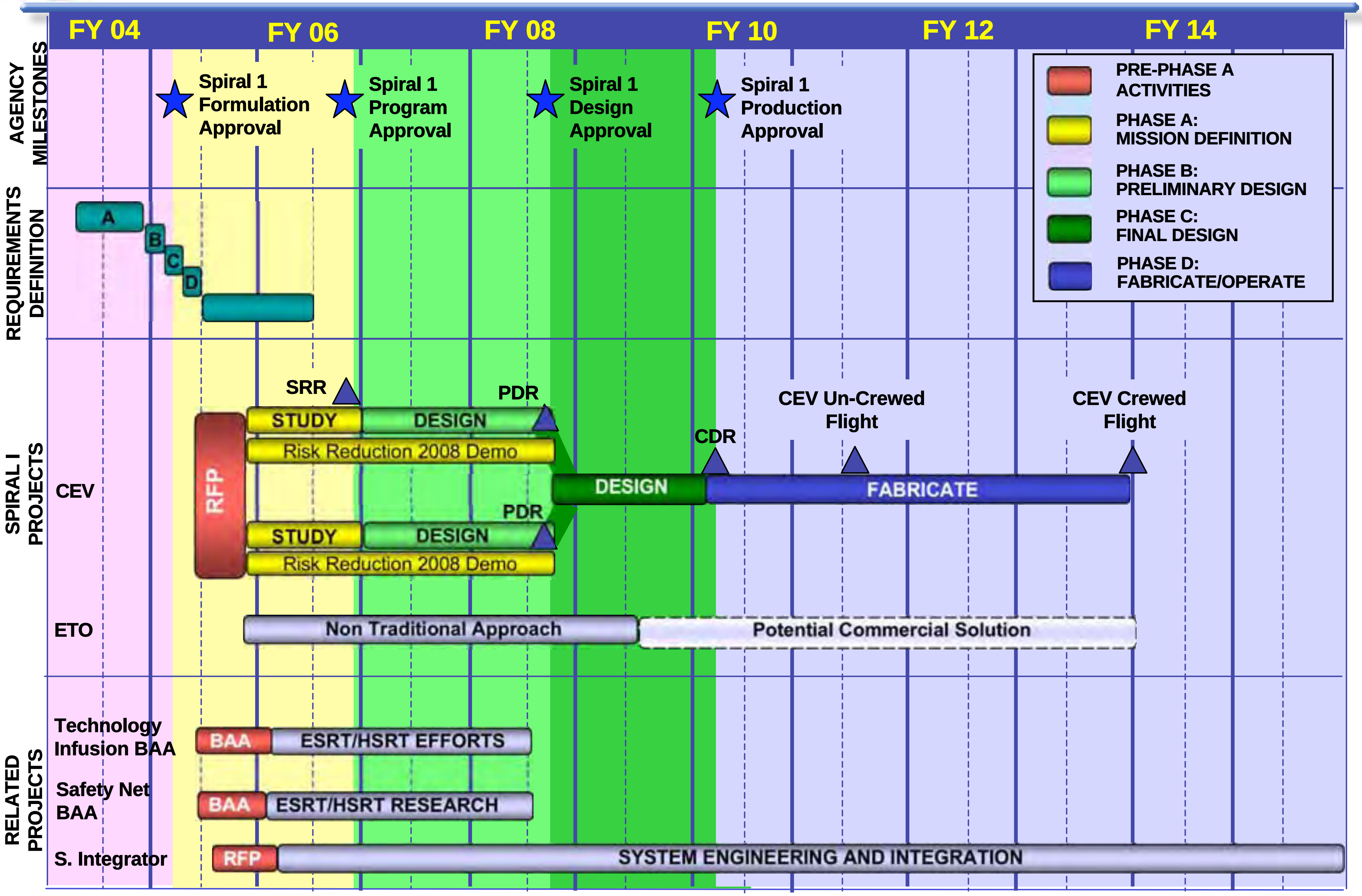
t-Space Highlights

- **An Engine for Free Enterprise**
  - Pay-for-results rather than pay-for-analysis
  - Businesses can grow from earnings
  - NASA-commercial partnerships will build a more resilient system
  - With NASA as an enabling partner, firms can transform space into a net generator of tax revenues instead of an endless consumer of them
- **An Open Frontier**
  - Government leadership rather than government ownership
  - Flotilla expeditions, not single vehicles
  - Smaller, simpler vehicles
  - For the first 20-40 expeditions, it will be cheaper to use more propellant than to create new optimized vehicles (lunar lander)
  - Simplicity equals reliability
  - Enable commercial passenger markets
- **Mission Definition**
  - Land at south pole quickly
  - Each expedition builds in-space infrastructure
  - Public must see understandable value



S1 | S2 | Launch Elements

CEV Project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PHASE B: PRELIMINARY DESIGN
PHASE C: FINAL DESIGN
PHASE D: FABRICATE/OPERATE
REQUIREMENTS DEFINITION
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B
C
D
SPIRAL I PROJECTS
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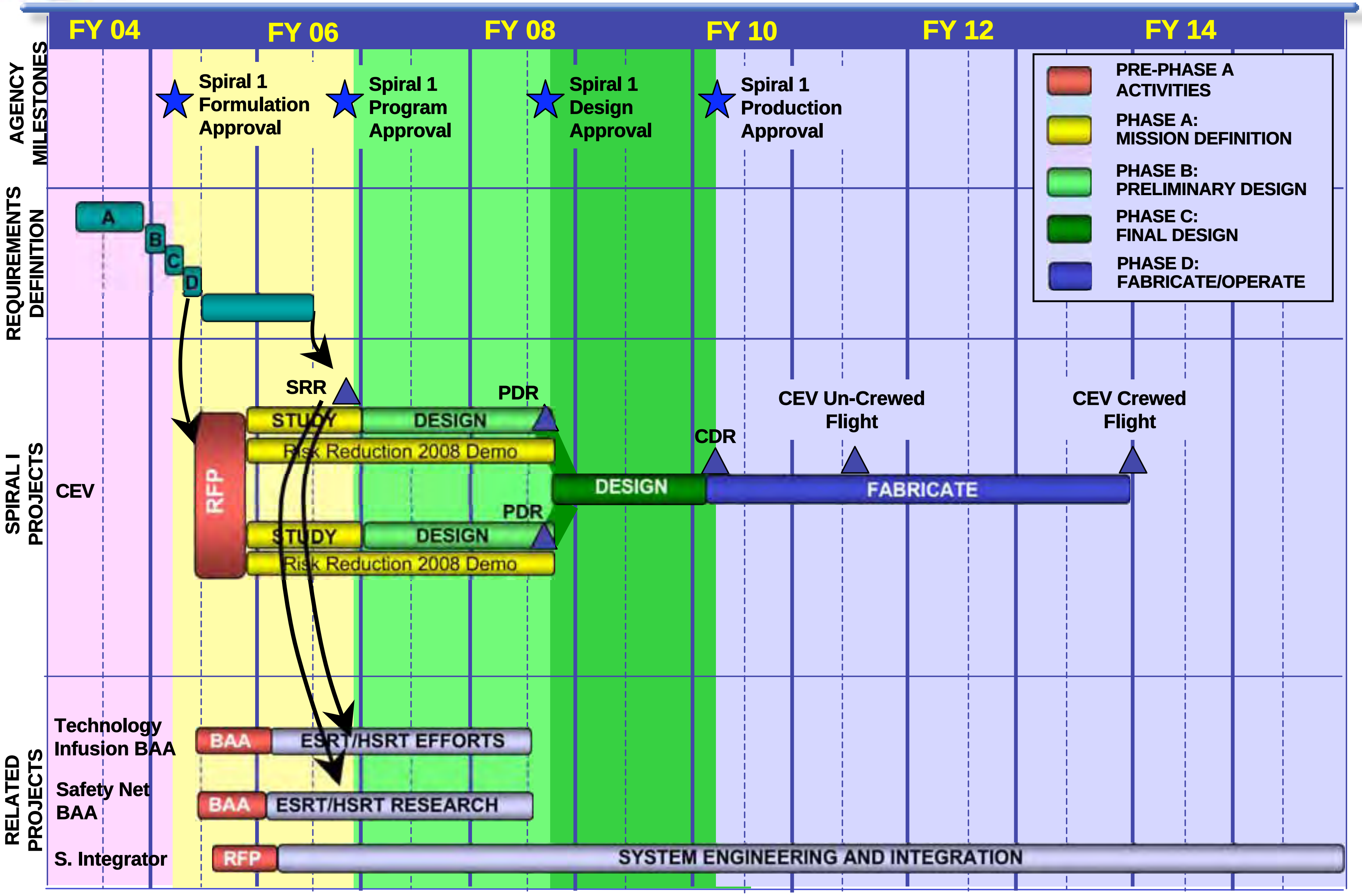
SRR
PDR
RFP
STUDY
DESIGN
Risk Reduction 2008 Demo
PDR
STUDY
DESIGN
Risk Reduction 2008 Demo
DESIGN
CDR
FABRICATE
CEV Un-Crewed Flight
CEV Crewed Flight
ETO
Non Traditional Approach
Potential Commercial Solution
RELATED PROJECTS
Technology Infusion BAA
BAA
ESRT/HSRT EFFORTS
Safety Net BAA
BAA
ESRT/HSRT RESEARCH
S. Integrator
RFP
SYSTEM ENGINEERING AND INTEGRATION

CEV Project



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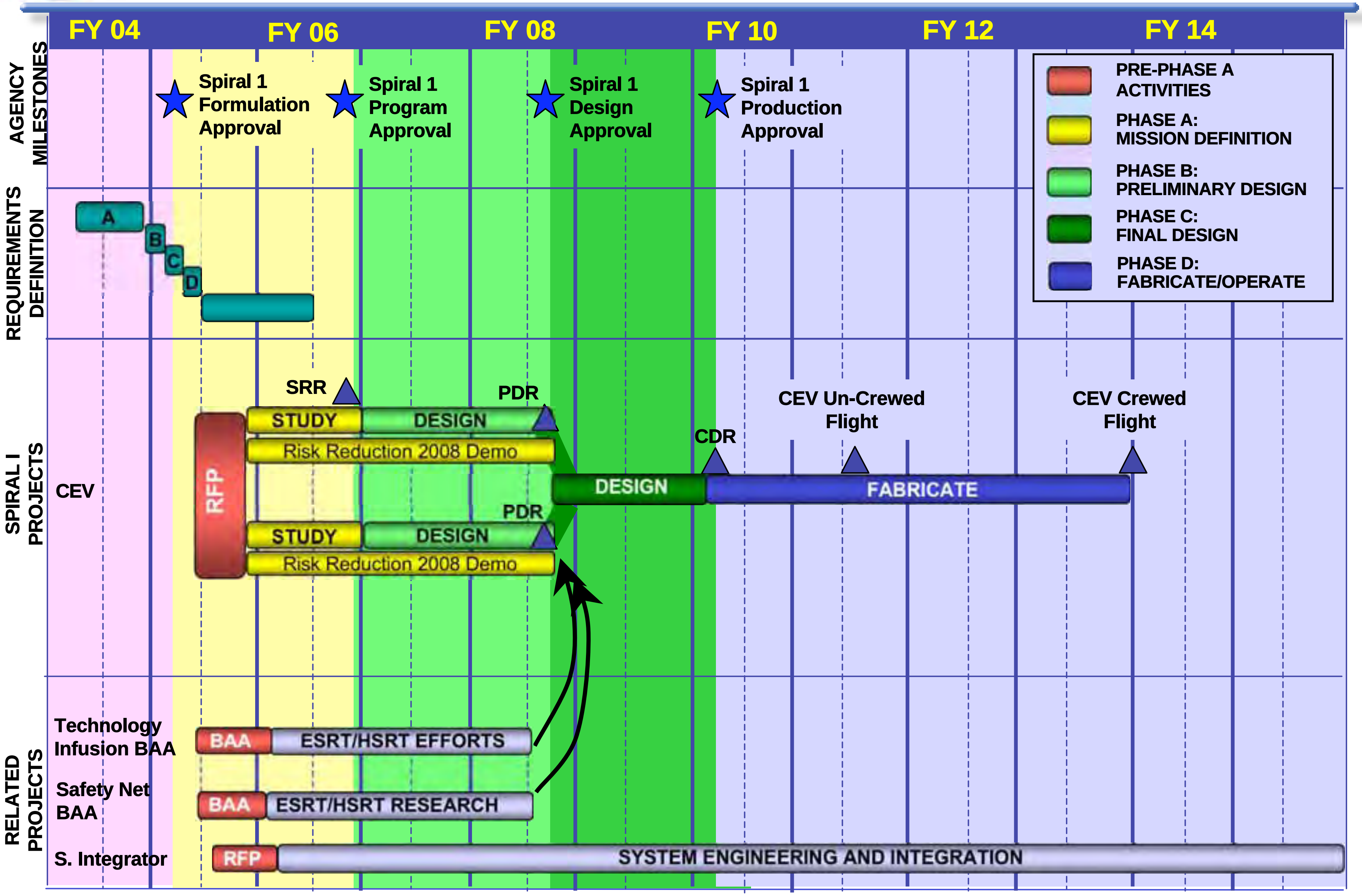

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