SPACEHAB®

WE MEAN BUSINESS IN SPACE ™

Concept Evaluation and Refinement

of the

Lunar Exploration System of Systems

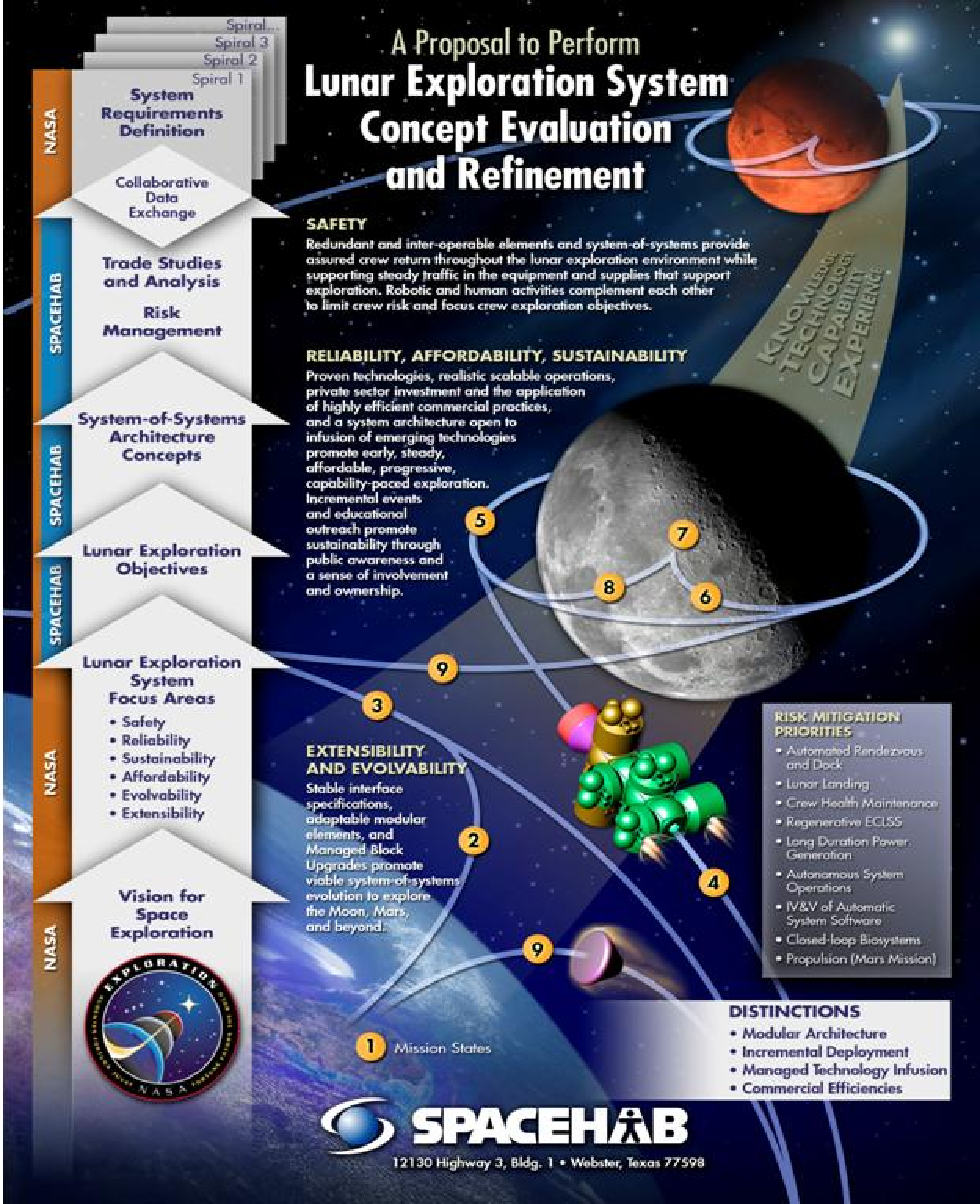
September 13, 2004

Proven Innovation for the Next Destination

SPACEHAB Twenty Years

- Supports ESMD Effort
- Promotes idea sharing
- Focuses on SE Vision
- Safety/ risk emphasis
  - Mission Design
  - Systems Design
  - Technology Infusion
- Mission model based
  - Facilitates trades
- Architecture
  - Modular
  - Incrementally Deployed
  - Managed Technology Infusion
  - Commercial Efficiencies

Proven Innovation for the Next Destination
SPACEHAB Twenty Years 20



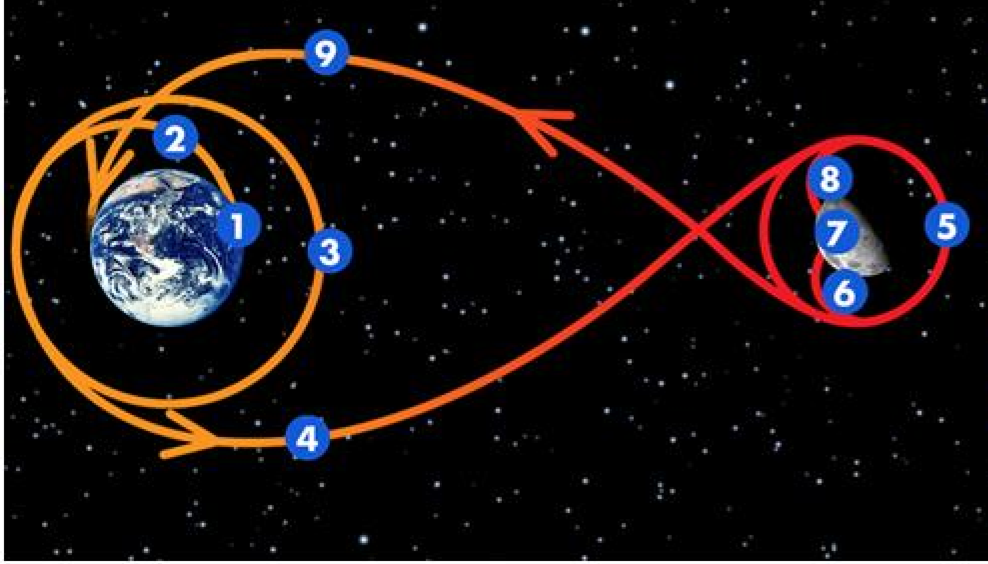
Recommended Objectives

1. Identify, assess and mature key enabling (building block) technologies, especially those that offer potential contributions to U.S. economic and security interests
2. Validate selected elements of the space exploration infrastructure
3. Prove concepts for safe, long duration habitation and operations in space
4. Validate scientific research equipment, methods and procedures through scientific investigations of the moon
5. Develop, deploy, and mature a safe integrated system of humans and robots
6. Establish and continually mature operations concepts and risk mitigation strategies supporting explorations of increasing complexity and distance from the Earth
7. Identify, assess and implement improved processes, including commercial procurement and the appropriate application of commercial practices and related services, which offer the potential to reduce the life cycle cost of exploration

Mission States

- Incremental mission states provide discrete spiral development thresholds
- Depots in LEO and LO enable vehicle staging, resource transfer, and crew transfer
- Vehicle configurations accommodate environmental conditions commensurate with mission states
- Operational thresholds and system-level redundancies provide contingency response, safe haven, and abort options
- Reasonable payload scale fits most economical launchers and limits per-event risks in critical mission states

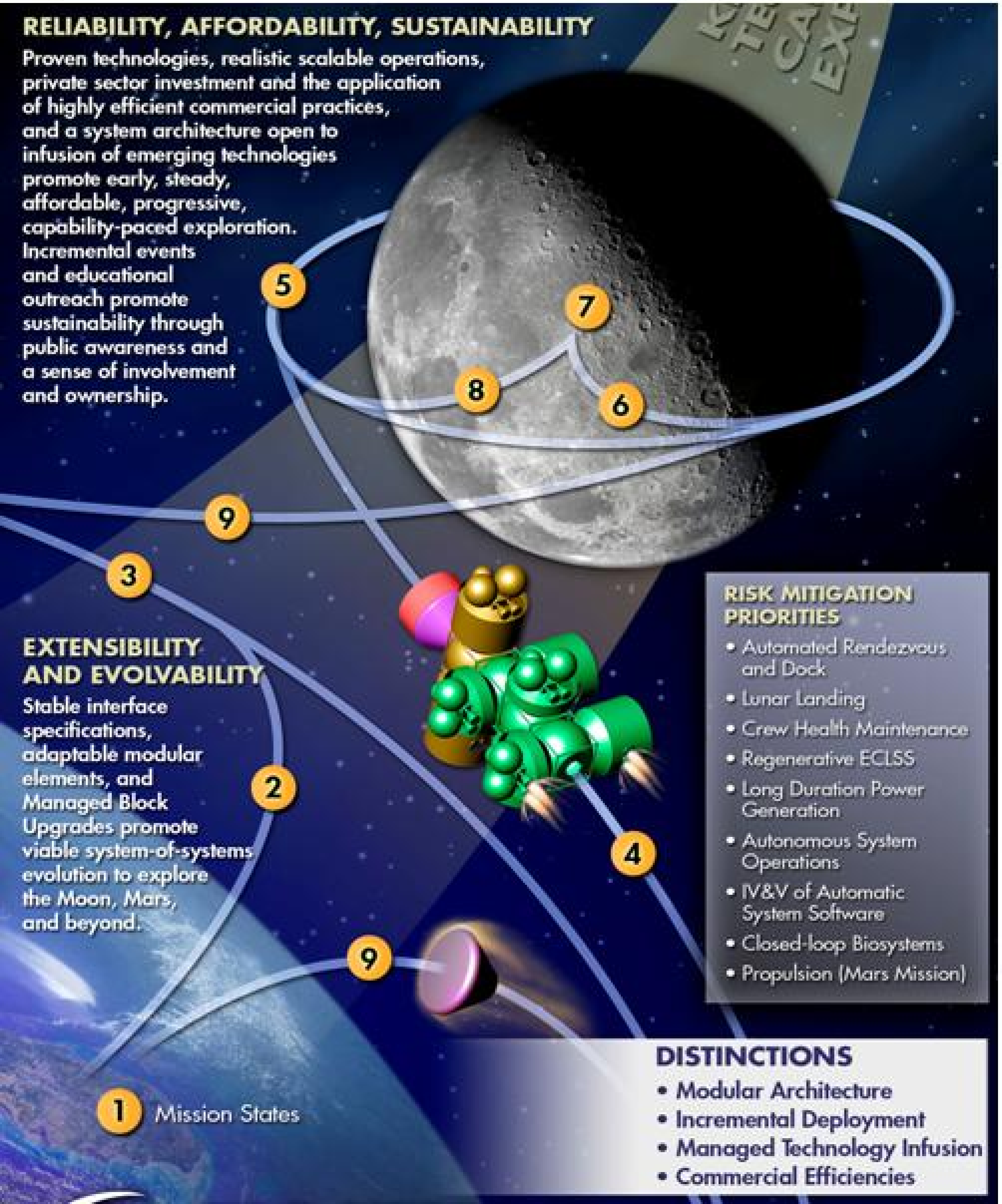
LES Mission States



Mission States	Events	Δ-V Required	Crew Mission	Cargo Mission
1	Ground Segment	Ø	✓	✓
2	Earth Ascent	7.78 km/s	✓	✓
3	LEO Operations	0.20 km/s	✓	✓
4	TLI	3.20 km/s	✓	✓
5	Lunar Orbit	1.00 km/s	✓	✓
6	Lunar Descent	2.07 km/s	✓	✓
7	Surface Ops	Ø	✓	✓
8	Lunar Ascent	1.90 km/s	✓	See Note
9	Direct Return	1.00 km/s	✓	See Note

NOTE: Autonomous LEV & CEV missions parallel crew missions to enable return of 700 kg of lunar samples to Earth.

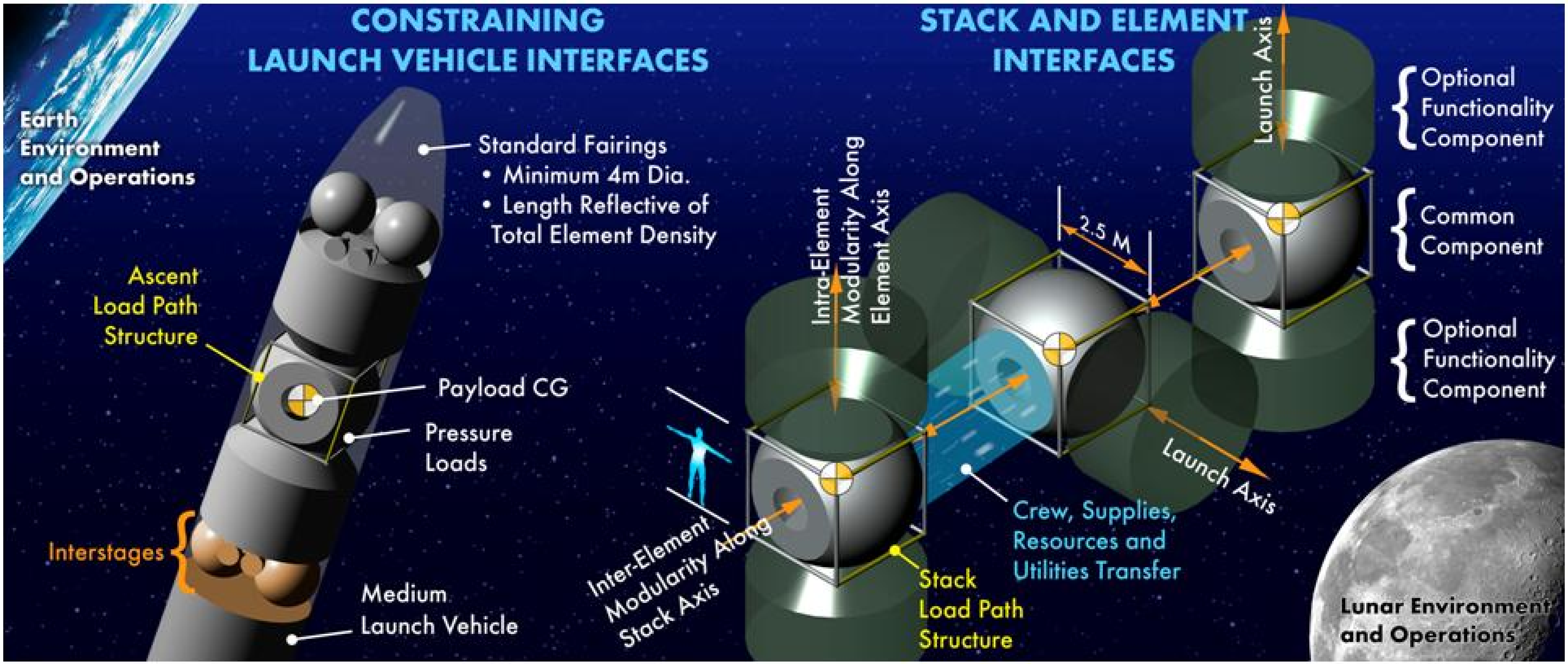
Generic Traffic Model



- Resources and payloads are entrained in LEO
- Crew and Cargo missions are separate during critical mission states
- Crew retains abort options throughout crew transport mission
- Standard Propulsion Elements are expended during TLI and LOI
- Payloads and Lunar Descent Stages are configured in Lunar Orbit
- Lunar surface payloads deploy from expendable descent stage using precursor robotic surface transportation system
- Lunar Excursion Vehicle carries crew from Lunar Orbit to surface using LDS, ascends using multi-mission lunar ascent stage (refueled in Lunar Orbit)
- Crew transfers to CEV and executes direct return

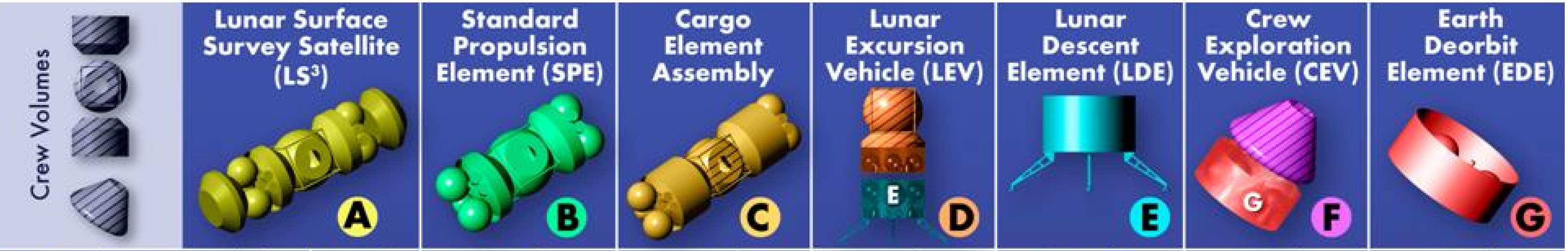
Safe, Evolvable, Extensible, Modular, Adaptable, Affordable

- **Ascent to LEO on economical commercial ELVs from optimal launch sites**
- **Individual and entrained vehicle assemblies are ARPO capable in LEO and LO**
- **Radial docking and thrusting promote modularity within and among discrete payloads**
- **Standardized multi-functional mating interface supports assembly and reassembly of elements**
- **Resource transfer capabilities and selective expendability economize on net resource requirements**
- **Common Vehicle Core and modular augmentation offer versatility and accommodate spiral development**



Vehicle variants illustrate versatility, extensibility, affordability

- **Highly integrated, efficient design for of most frequently used components, e.g. Common Vehicle Core**
- **Modular vehicle variants offer versatile logistics capacity, accessibility, and resource transfer opportunities**
- **Incremental deployment of increasingly capable vehicles through increasingly advanced mission states provides continual validation opportunities while increasing confidence in key mission enabling systems**



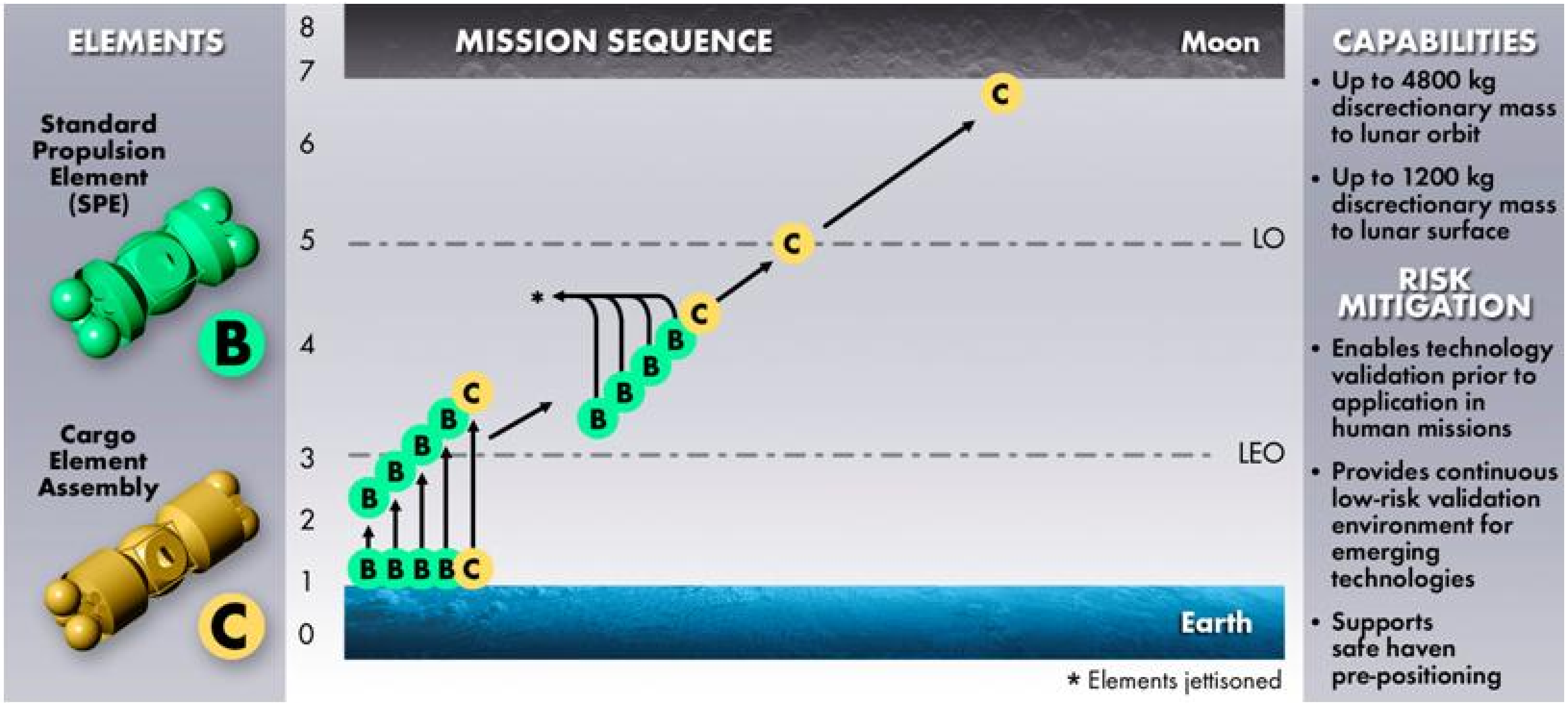
	Crew Volumes	Lunar Surface Survey Satellite (LS^3)	Standard Propulsion Element (SPE)	Cargo Element Assembly	Lunar Excursion Vehicle (LEV)	Lunar Descent Element (LDE)	Crew Exploration Vehicle (CEV)	Earth Deorbit Element (EDE)
		A	B	C	D	E	F	G
Properties	Dry/Empty Mass (kg)	3350 kg	1800 kg	3350 kg	720 kg	1200 kg	3383 kg	2292 kg
	Propellant Mass (max)	8950 kg	12364 kg	10500 kg	2300 kg	6000 kg	(1)	3325 kg
	Cargo Mass (max)	3100 kg	optional	1550 kg	1780 kg	➡ 4800 kg	(1)	3383 kg
	Pressurized Volume (m^3)	10.6 m^3	7 m^3	10.6 m^3	9.6 m^3	0	9 m^3	0
	Passive Mission States	1 - 4	0	1 - 4	1 - 5	1 - 5	6 - 8	1 - 9
	Active Mission States	5	1 - 5	5 - 7	6 - 8	6 - 7	1 - 5, 9	9
Major Subsystems	Propulsion	YES	YES	YES	YES	YES	NO	YES
	Attitude Control	YES	YES	YES	YES	YES	YES	NO
	ARPO	YES	YES	YES	YES	NO	YES	NO
	Docking	YES	YES	YES	YES	(2)	YES	NO
	ECLSS	NO	NO (3)	YES (3) (4)	YES	NO	YES	NO
	Comm	YES	YES	YES	YES	NO	YES	NO

(1) Included in dry/empty mass
(2) Mates with LEV returning to state 5
(3) Parasitic when mated to stack
(4) Optional depending on cargo item rule

Note: All elements embody power and thermal systems, 3 SPE + Cargo Element deliver 12000 kg to LO, 3 SPE + Cargo Element + LDE deliver 4800 kg to lunar surface

Typical Lunar Surface Payload Delivery Mission

- **Represents delivery of a payload with its own descent propulsion (other options to be investigated include larger payloads using separable, expendable Lunar Descent Stage elements**
- **Provide validation opportunities for extensible vehicle systems and components**
- **Delivered payloads include Common Vehicle Core and discretionary modular augmentations**
  - Crew accommodations hardware and supplies
  - Exploration-enabling tools, surface vehicles, logistical resources



CEV/Crew/Lunar Excursion Vehicle: Lunar landing and return

- **All resources and capabilities are pre-positioned prior to initiating CEV mission**
- **Recurring Lunar Excursion Vehicle missions require fresh Lunar Descent Stage and refueling of Lunar Ascent Stage in LO**
- **Unmanned missions using autonomous LEV and CEV (or derivatives) provide additional non-crew recoverable mass from the moon and Earth (requires payload transfer in LO via crew or robotic operations)**