NORTHROP GRUMMAN

Integrated Systems

CE&R Initial Concept Overview

13 September 2004
CE&R Initial Forum
Washington, D.C.

DEFINING THE FUTURE

Agenda

- Proposed Objectives
- Initial Lunar System-of-Systems Concept
- Driving Architecture Issues

Proposed Objectives

Recommended Level 0 Objectives

Science

1. Develop and Demonstrate Methods, Technologies, and Systems for Human Exploration of the Solar System
2. Determine the Extent of Exploitable Resources on the Moon; Assess and Demonstrate In Situ Resource Use
3. Develop Methods to Mitigate Impact of Long-Duration Human Exposure to the Space and Lunar Environments
4. Determine the Origin of the Moon and Impact History of the Inner Solar System

Econ

5. Stimulate the High-Tech Industry in the United States
6. Enable Commercial Lunar Activities by Developing and Transferring Lunar Knowledge and Capabilities to Private Sector

Security

7. Develop and Maintain Autonomous Proximity Operations, Docking, Support, and Assembly Capability
8. Develop and Maintain Space Asset Human Servicing Capability in Near-Earth Orbits
9. Improve and Sustain the Nation's Technical Workforce by Inspiring Students to Pursue Mathematics, Sciences, and Engineering

Proposed Objectives

Recommended Level 1 Spiral Objectives

Bold Blue – Meets a Specific Time-Based NASA Requirement

● – Major Contributor

○ – Contributor

		Recommended Level 0 Objectives								
		Security			Econ		Science			
		1	2	3	1	2	1	2	3	4
Spiral 1	**Robotically Collect Topography, Gravity, Radiation, and Mineralogy Data by 2008 to Support Site Selection**			○	○	○	○	●	●	●
	Demonstrate Crew Exploration Vehicle (CEV) Earth Entry, Descent, and Landing System (EDLS) by 2008			○	○		●			
	Robotically Collect and Return Lunar Surface Samples by 2010	○		○	○		○	●		●
	Robotically Qualify a Human-Rated CEV and Crew Launch Vehicle for Rendezvous, Docking, and EDLS by 2011	●		○	●	○	●			
	Demonstrate Crewed CEV Habitability, Egress/Ingress, EVA, and Crew Transfer by 2012	○	●	●	○	○	●			
	Robotically Demonstrate 180-Day CEV On-Orbit Endurance by 2013		○	○			○			
Spiral 2	Qualify Exploration Transfer Stage by 2015			○	●	●	●			
	Deploy Space Weather Monitor by 2016		●	○		○	●		●	
	Qualify End-to-End Crew Transportation System by 2017	●	●	●	●	●	●			
	Conduct a Crewed Day / Night Stay on the Lunar Surface by 2018			●	●	○	●			
Spiral 3	Demonstrate Surface Nuclear Power Operation by 2019			○	●	○	●			
	Demonstrate Base Surface Operations and Logistics by 2020			●	●	●	●		○	
	Prove 180-Day Crewed Endurance by 2021			○			●		○	
	Conduct Long Duration Traverse / Science Exploration by 2022			●	○	●	○	○		●
	Demonstrate Critical Mars Surface Functionality by 2022	○		●	●	●	●	○	○	
Spiral 4	Development and First Flight of 100t Class Launch Vehicle (2024)		○	●	●	●	●			
	Crewed LEO Demonstration of Mars Elements: Endurance and Latencies (2024 to 2026)	○	○	●	●	○	●			
	Crewed Demonstration of Mars Landing and Return Elements at the Moon (2026)	○		●	●	○	●			
	First Crewed Mars Flight (2027)			●	●		●			

Three Spiral Initial Concept Established

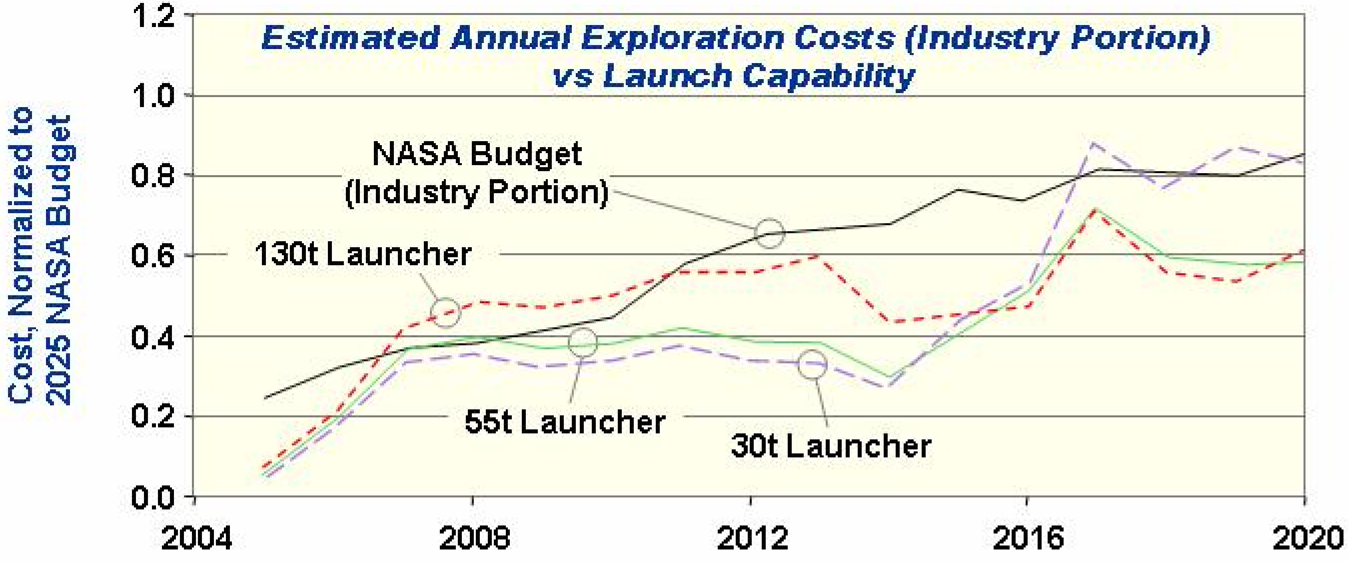
- Credible Baseline Established Based on Concept Studies and Initial Trades
- Primary FOMs considered: Cost Profile, Safety, Prob. of Mission Success
- Broad Trade Space Defined

Point-of-Departure Concept Features:

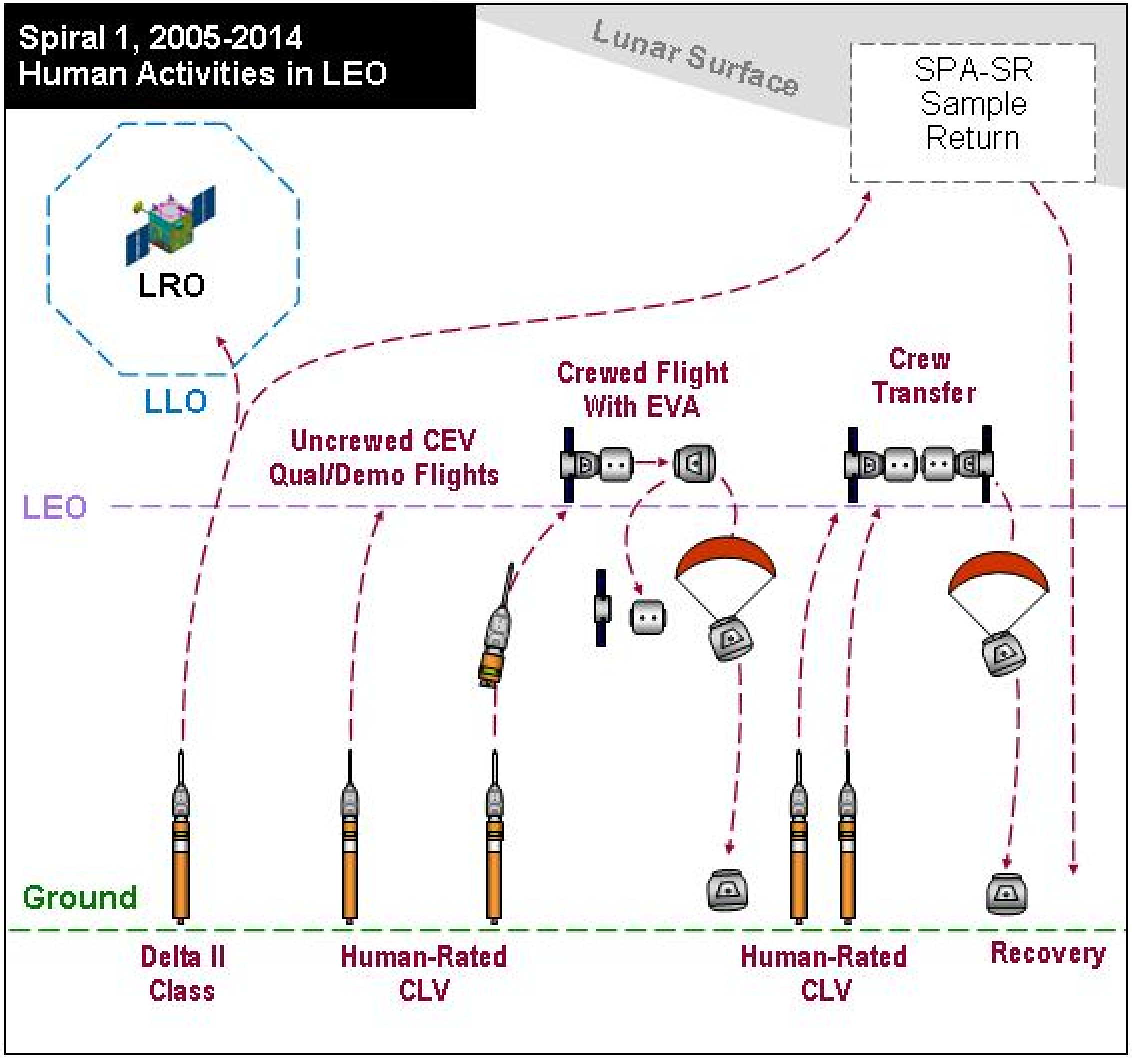
- *Explorers on the moon for entire month in 2018. Evolve to a sustained human capability by 2020.*
- *Safe human transport using Earth-Moon Lagrange point (EML1) rendezvous, for flexible lunar access and earth return*
- *Deliver unmanned cargo and surface systems using efficient direct trajectory.*
- *Elements launched, assembled in LEO into translunar vehicles like Mars missions in later spirals.*
- *Minimized number of unique elements.*
- *Flight elements sized to balance launcher development affordability, reliability.*
- *55t commercially procured Atlas or Delta derivative launchers for cargo.*
- *Lunar exploration features both fixed and mobile assets, potential Mars architectures*

Early Trades Show Affordability of Intermediate Launchers

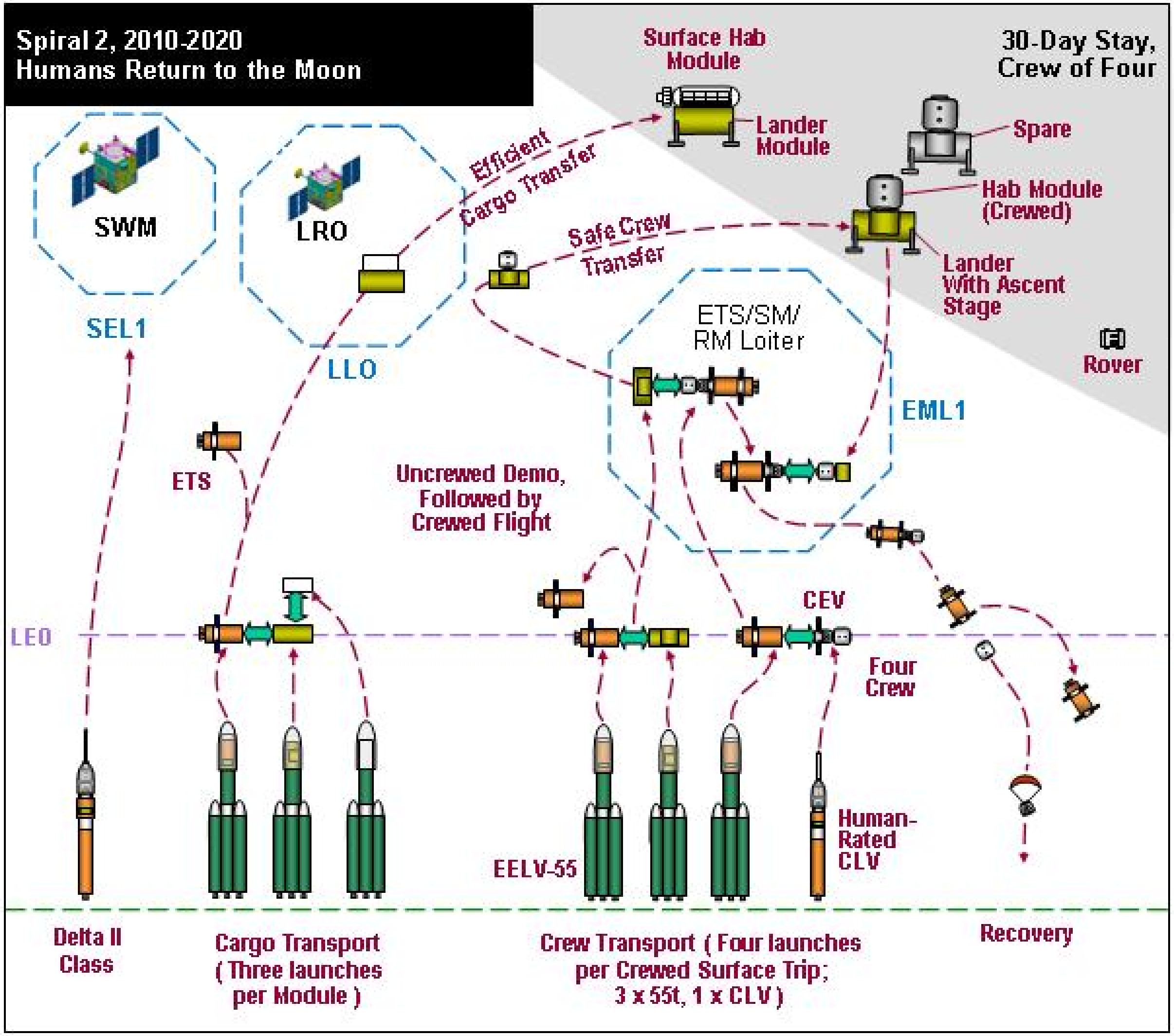
- 130t Launcher Unaffordable in Early Development, No Cost Benefit Over 55t Class
- Reliance on Existing LVs Unaffordable Post-2016 Due to Launch Rates
- 55t Class Cheaper Than Reliance on Current Vehicles



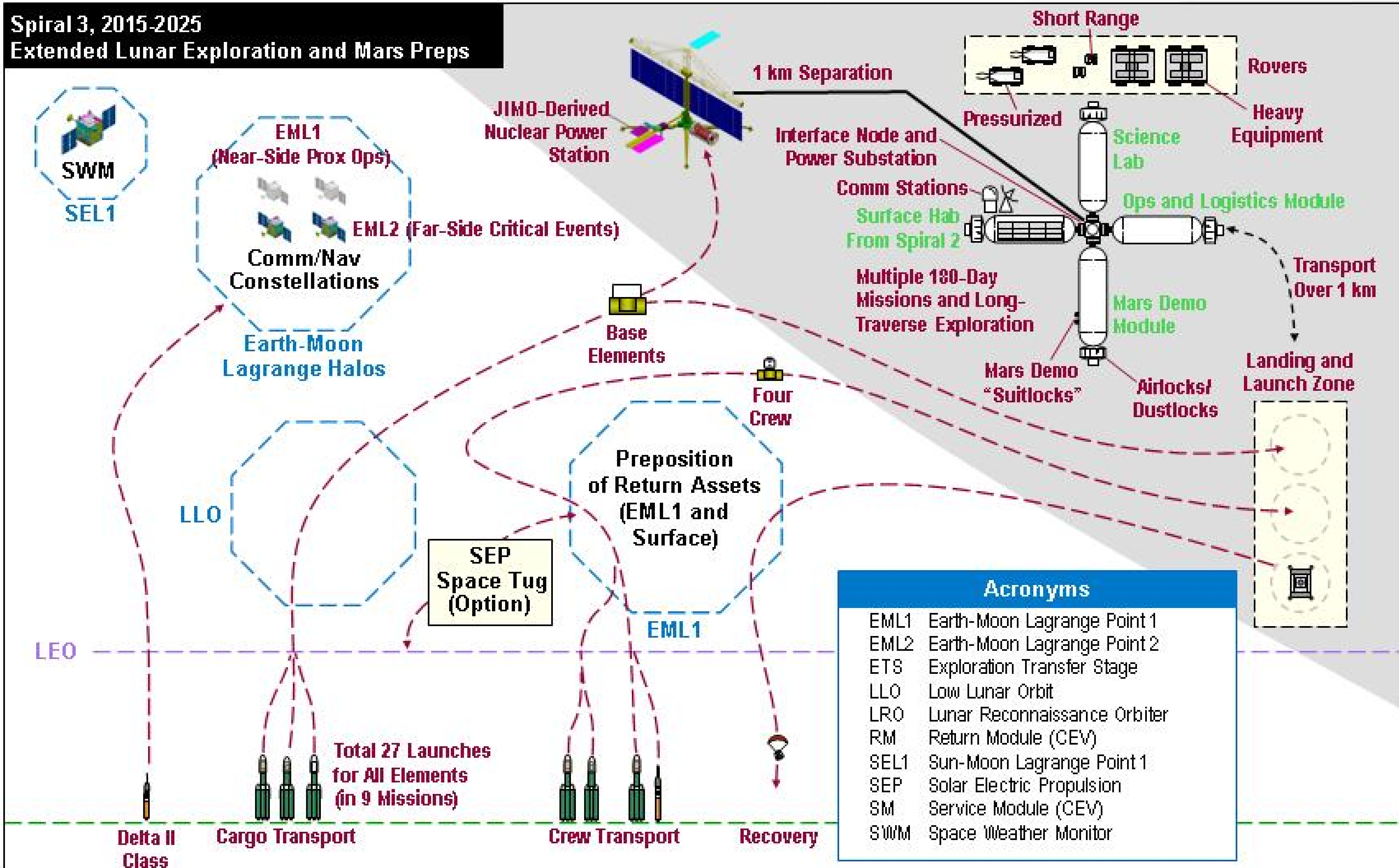
Spiral One


Spiral 1, 2005-2014
Human Activities in LEO
Lunar Surface
SPA-SR Sample Return
LRO
LLO
Crewed Flight With EVA
Crew Transfer
Uncrewed CEV Qual/Demo Flights
LEO
Ground
Delta II Class
Human-Rated CLV
Human-Rated CLV
Recovery

Spiral Two

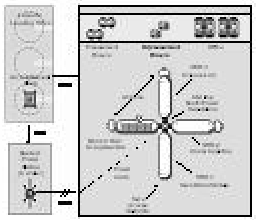

Spiral 2, 2010-2020
Humans Return to the Moon
Surface Hab Module
30-Day Stay, Crew of Four
Lander Module
Spare
Hab Module (Crewed)
Lander With Ascent Stage
Rover
Efficient Cargo Transfer
Safe Crew Transfer
SWM
LRO
SEL1
LLO
ETS/SM/ RM Loiter
EML1
ETS
Uncrewed Demo, Followed by Crewed Flight
CEV
LEO
Four Crew
EELV-55
Human-Rated CLV
Delta II Class
Cargo Transport (Three launches per Module)
Crew Transport (Four launches per Crewed Surface Trip; 3 x 55t, 1 x CLV)
Recovery

Spiral Three



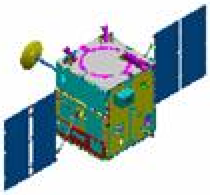
Constellation Systems – Initial Concept

Surface System (SS)



- Long-Term Habitat for a Crew of Four at the Base Location – 5m, 15t modules
- Supports Surface Science and Exploration
- Provides Crew Mobility
- Supports Infrastructure for Lunar Resource Utilization and Lunar Commerce
- Testbed for Future Mars Missions

Robotic Precursor System (RPS)



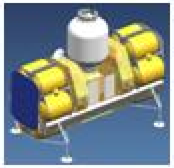
- Reduces Risks for Manned Missions
- Discovery or New Frontiers Class Incl./ Lunar Reconnaissance Orbiter (LRO) in 2008
- Sample Return Mission to the South Pole-Aitken Basin in 2010

Ground System (GS)

- Processes SoS System Elements for Flight
- C3I for CrTS, CaTS, and SS Elements
- Flight System and Crew Recovery Simulators
- Non-Toxic Propellants – all LH2/LOX
- Crew Recovery at Edwards AFB (Primary), White Sands (Secondary), Ocean (Contingency)
- Automated Mission Planning and Flight Operations with Integrated System Health Management

Crew Transport System (CrTS)

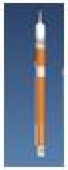
- Four Crew CEV
- Multifunctional Hab Module (HM)
- Long Duration Loiter



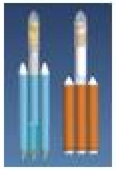
- Two-Stage Lunar Lander
- Carries CEV HM
- Autonomous Ops

- ETS-1
- Human Rated Upper Stage
- Higher T/W

- ETS-2 (Exploration Transfer Stage)
- EML1/Earth Transfer
- Long Duration Loiter



- Crew Launch Vehicle
- Uses ETS-1
- Atlas V Derived First Stage



- 55t non-crew launchers
- 5m P/L Fairings
- Commercially-Procured Standard Loads

Cargo Transport System (CaTS)

- Includes CrTS Common Elements, ETS-2, LM, and 55t Launch Capability
- Prepositions Lunar Base Modules
- ETS/LM/Cargo, Direct to the Moon for Efficiency
- JIMO-Derived Solar-Electric Tug Option in Spiral 3 – Affordability Trade

In-Space System (I-SS)

- Space-Based Space Weather Monitor (SWM) for Space-Weather Predictions and Status
- Far-Side Telecommunications Coverage Using Two-Ball EML2 Halo Constellation
- Optional Near-Side Constellation for Prox Ops

System of Systems Trades

Trade Area	Trade Options								Initial Concept Rationale
Spiral 2 Base Crew Size	1	2	3	4	5	6	8	10	Two Buddy Teams, Affordability
Spiral 3 Base Crew Size	1	2	3	4	5	6	8	10	Two Buddy Teams, Affordability
Spiral 2 Unresupplied Base Endur	5 days	15 days	30 days	60 days					Operations Over Entire Lunar Month
Spiral 3 Unresupplied Base Endur	30 days	90 days	180 days	600 days					Threshold for Sustainable Operations
Crew Near-Earth Assy Orbit	None – Direct	LEO	MEO						Improved PLOC, Easy Abort to Earth
Cargo Near-Earth Assy Orbit	None – Direct	LEO	MEO						Easier, More Rapid Launch of Spares
Crew Near-Lunar Assy Orbit	None	Polar	EML1	Equatorial	Cycler	Deep Space			Safe, Earth, and Lunar Access/Logistics
Cargo Near-Lunar Assy Orbit	None	Polar	EML1	Equatorial	Cycler	Deep Space			Mass/Cost, 10% Lower dV Than EML1
Lunar Base Deployment Plan	Robotically Preestablish Base	Use Crew to Establish Lunar Base							Crew Safety
Lunar Base Location	Equatorial Limb	Polar	Meridional	Far Side					Mare/Highlands Interface, Full Sky
Docking Port Type	Crew Specific	Common	Cargo Specific	Surface Specific					Flexibility, Evolvability / Extensibility
Avionics and Software Architecture	Modular Reconfigurable	Module Specific							Reliability, Mars Extensible

Lunar Base Scope

Staging

Proposed Initial Concept | Key Trade Options

Surface System Trades

Trade Area	Trade Options	Initial Concept Rationale
Base Setup Assy and Control	Robotic; Teleoperated Ground Controlled; Crew	Flexibility, Affordability
Habitat Construction	Rigid Deployable; Inflatable; Landed Modules; Translunar Tanks	Rigid Modules Proven on ISS
Habitat Radiation Shielding	Regolith "Insulation"; Prefabricated shield; Underground	Reduces Landed Mass of Modules
Extent of Hab Rad Shielding	Fully Shielded Habitat; Safe-Haven Shelter	Balanced Design Maximizes Safety/kg
Spiral 2 Base Power Source	RTG; Photovoltaic; Nuclear; From EML1; Fuel Cell	Affordable Initial Lunar Night Capability
Spiral 3 Base Power Source	RTG; Photovoltaic; Nuclear; From EML1; Fuel Cell (Backup)	Lunar Sustainability, Mars Extensibility
Base Power Storage	Fuel Cells; Batteries; Mechanical	More Robust, Less Complex
Ingress-Egress Methods	Air/Dust Locks; Depressurize Hab Module; Via Pressurized Rover	Reduces Risk, Inc Crew Safety
Landing Zone Separation	None (Land in Place); 1 km; 3+ km	Crew Safety and Base Sustainability vs Mobility
Base Element Offload/Transport	None (Land in Place); Self-Mobile; Dedicated Transporter	Safety and Requirements Simplicity
Crew Mobility Enablers	None; Short-Range Rovers (Unpress); Mobile Labs (Long Range)	Logistics Affordability, Science Quality
Mobility Control	Autonomous; Crew Operated; Base Operated; Ground Operated	Safety and Exploration Quality
Surface EVA Spacesuit	Orlan Derived; Shuttle Derived; New Robotic Enhanced; Exterior Only W Airlock I/F	Commonality, Cost

Proposed Initial Concept | Key Trade Options

Crew Transportation System Trades

CLV

Partitioning

Refueling

Trade Area	Trade Options					Initial Concept Rationale
Crew Launch Vehicle (CLV)	EELV-M	Atlas V CCB + ETS	EELV-H	Zenit S1 + ETS	SRM + ETS	Safety: Propulsion, Staging, and Abort
Crew Accom Partitioning	Separate RM and HM	Single Crew Space				Smaller, Lower-Cost RM, Multifunction HM
Service Module Partitioning	Integrate SM With RM	Maintain Separate Module	Integrate SM With HM			Flexibility, Evolvability /Extensibility
Docking Port Hardware	LIDS Derived	Existing (APAS/ Russian)	New			Flexibility, Mars Extensibility
ETS and Lander Propulsion Safety	Engine-Out Capability	Increased Engine Reliability				Redundancy for Crew Safety
CLV Launch Pad	Mod Atlas Pad	Mod Shuttle Pad	Mod Delta Pad	New		Optimized for Safety, Avoids Access Conflicts
Crew Trans Propellant Tanks	Composite	Metal				Lower Mass/System Cost, Insulation/MMOD Benefits
Crew Trans Lunar (ETS) Propulsion	LOX/LH_2	Nuclear-Electric	Solar-Electric	Nuclear-Thermal	Reusable/Refuel	Lowest Risk, Fast Transfer
Crew Lander Configuration	Staged	Reusable	Stacked	Underslung	Sky Crane	LV Limited, Crew Safety
Crew Lander Propulsion	LOX/LH_2	Storable	LOX/Ethanol	LOX/Methane	Gel	Lower Mass and System Cost

Proposed Initial Concept | Key Trade Options | Key Issues

Cargo Transporation System Trades

Trade Area	Trade Options	Initial Concept Rationale
Spiral 2 Noncrew LV System	EELV-H / EELV Derived / Shuttle Derived / New Heavy Lift / International / Hybrid	Affordable Development
Noncrew Launch Procurement	Commercial / NASA / Mission Specific / Mostly Fixed Size (55t)	Competition for Multiple Units, Lower Cost
Maximum LEO Launch Mass	30t / 40t / 55t / 70t / 90t / 130t	Balance of Affordability / Reliability
Cargo Load Size Standardization	Mission Specific / Crew Trans Driven Std / Surface Sys Driven Std	Commonality for Affordability / Reliability
Cargo Translunar Propulsion	LOX/LH_2 / Nuclear-Electric / Solar-Electric / Nuclear-Thermal / Reusable/Refuel	Commonality for Affordability / Reliability
Cargo Lander Design	Same as Crew Trans (No Ascent) / Cargo Optimized	Commonality for Affordability / Reliability

Non-Crew Spacelift

Refueling or High Isp Cargo Propulsion

Proposed Initial Concept: EELV-H, EELV Derived, Commercial, Mostly Fixed Size (55t), 55t, Crew Trans Driven Std, LOX/LH_2, Same as Crew Trans (No Ascent)

Key Trade Options: Shuttle Derived, New Heavy Lift, International, Hybrid, Mission Specific (procurement), 30t, 40t, 70t, 90t, 130t, Nuclear-Electric, Solar-Electric, Nuclear-Thermal, Reusable/Refuel, Cargo Optimized

Key Issues

Driving Architecture Issues

- Scope of Initial and Evolved Lunar Infrastructure
- CEV Crew Size / Crew Exchange Manifesting
- Staging Approach
- Viability of In-Situ Resource Utilization
- Non-Crewed Spacelift Payload Size vs. Number of Flight Elements
  - Larger: Fewer launches, Simpler in-space ops, Traditionally more reliable
  - Smaller: Higher flight rate > Requires reliable multi-element in-space operations and responsive spacelift
- Effectiveness of Refueling / Reusable Elements
  - Higher payoff for Lander and Transfer Stages
  - Propellant modules vs. Propulsion modules vs. Propellant transfer
  - Reuse of tankage – surface habitats, in-situ resource storage
- Effectiveness of High Isp Propulsion Transfer for Lunar Missions
- Engaging Broader Communities – Effect on Requirements