



“Exploring Together”

The ISECG Reference Architecture for Human Lunar Exploration

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- **Phased approach with the ability to incrementally assess Scientific and Mars Forward risk reduction needs and make adjustments as required**
- **Pervasive use of robotics and human-robotic interactions**
- **Extensive autonomous robotic operations on lunar surface between crew visits**
- **Leverages reusable and relocatable surface assets to maximize exploration opportunities while minimizing the need to deliver cargo to the moon.**
- **Science objectives are equal in priority to Mars Forward risk reduction objectives**
- **Flexibility to accommodate changes in technologies, international partner priorities and programmatic constraints**
- **Consideration of ISS Lessons Learned including the importance of dissimilar redundancy in critical systems**



Lunar Exploration Capabilities

GPOD

GLOBAL POINT OF DEPARTURE



SPR
Small Pressurized Rover

The SPR provides pressurized habitable volume, mounted on a mobility chassis. The SPR provides habitation, mobility and exploration functionality and mates to other elements by way of docking hatches.



Tri-ATHLETE

Tri-ATHLETes working in pairs, provide off loading of modular cargo pallets from the top of Altair Descent Modules (or equivalent), transport them across the lunar surface and replace them on the surface.



Centaur

The Centaur provides a cover capable of carrying a variety of payloads, including the anthropomorphic Robonaut system. Centaur and Robonaut may form a versatile Robotic Astronaut Assistant or Autonomous Robot capable of using EVA tools and interfaces.



RAPIER

The RAPIER provides an unpressurized cover for carrying support & plug-in payload, recoverable chassis used to carry up to six payloads.



TMV
Terrain Management Vehicle

The Terrain Management Vehicle provides support to the ISRU elements as well as providing basic functionality for rugged handling and may assist transportation on the lunar surface.



SELENE-X Class Rover

The SELENE-X Class Rover provides an unpressurized rover function which may off load cargo from a lander, perform site survey, visit geological locations to collect surface and subsurface samples, provide descent imagery, collect cap, fenders and first human lander and assist human crew.



CRADLE
Canadian Reconfigurable Adapter for Deployment of Large Elements

The CRADLE provides a reconfigurable payload handling function that supports the unloading of large payloads from a lander and deployment to a location on the lunar surface in support of communications, inspection, maintenance & docking and operations support.




LDH
Long Duration Habitat

The Long Duration Habitat provides a pressurized habitable volume. The LDH provides four hatches to operate in conjunction with the SPRs and provide all of the functions for four crew duration missions ranging from 60 to 70 days. This includes a hybrid suit lock at one end of the module. It integrates two suit ports for conventional EVA with air lock functions providing access to the pressurized environment for suit maintenance.



LLM
Logistics-to-Living Module 2 Segment

The Logistics-to-Living module provides a pressurized volume that may be filled with logistics for logistic delivery to the surface and storage while on the surface. The LLM may be reconfigured to provide resources and workstations for geological and physical sciences.



EVA System

The EVA System provides an EVA suit, PLSS and subsystems to enable crew members to perform extravehicular activities (EVA) during lunar missions. The suit uses two pressure garment cores – one for the Altair lander and lunar surface operations and the other for Orion Launch, Entry, Abort (LEA) operations.



PUP
Portable Utility Pallet

The Portable Utility Pallet (PUP) provides power generation, power storage and logistics support to supplement pressurized rover operations including SPR resupply and lander or other element keep-alive power.



ISRU
In-situ Resource Utilization Plant

The ISRU plant, provides technology demonstration or ECLSS closure, e.g. oxygen from one of two processes, 1) the Hydrogen (H2) Reduction Demonstration Plant element produces oxygen from lunar regolith, 2) Carbothermal Reduction process to produce oxygen from lunar regolith.



PCT
Portable Communication Terminal

The portable communication terminal (PCT) is a transportable space communications gateway connecting surface elements with each other, and with the Earth and/or orbiting relay communications assets, while stationary and during transport.



PSU
Power and Support Unit

The PSU provides launch structural support and surface transportation support structure for payloads, power generation, power storage and ECLSS closure. The PSU may interface with ATHLETE for off-loading and surface transport of pressure vessels, logistics payloads, rovers, PUPs and communications systems. The PSU interfaces with surface elements to provide power and ECLSS consumables.



Lunar Relay Satellite

The Lunar Relay provides communication, tracking, and data services for the lunar orbiting and surface (fixed and mobile) elements with coverage focused on the polar region but also periodic coverage of the rest of Moon.



JAXA Lander

A lander providing transportation of 600 kg of unpressurized cargo to the lunar surface.



ESA Lander

A lander providing transportation of 1000 kg of unpressurized cargo to the lunar surface.



Altair Descent Module

A lander providing transportation of 14 600 kg of mass to the lunar surface. This may include one or an Ascent Module or palletized cargo via the Structural Support Unit.



Ascent Module

The Ascent Module provides transportation for a crew of four to and from the lunar surface. The AM may be configured for a Bottle or Down-and-Out Mission.

Extended Stay - Relocation Exploration Mode



Crew Mission

Long range pressurized mobility with small dexterous SPR that meet with large ATHLETE/Power infrastructure for periodic servicing

Crew Mission

Second site

4 crew

Up to 28 days

Crew Mission

First site

3 crewed

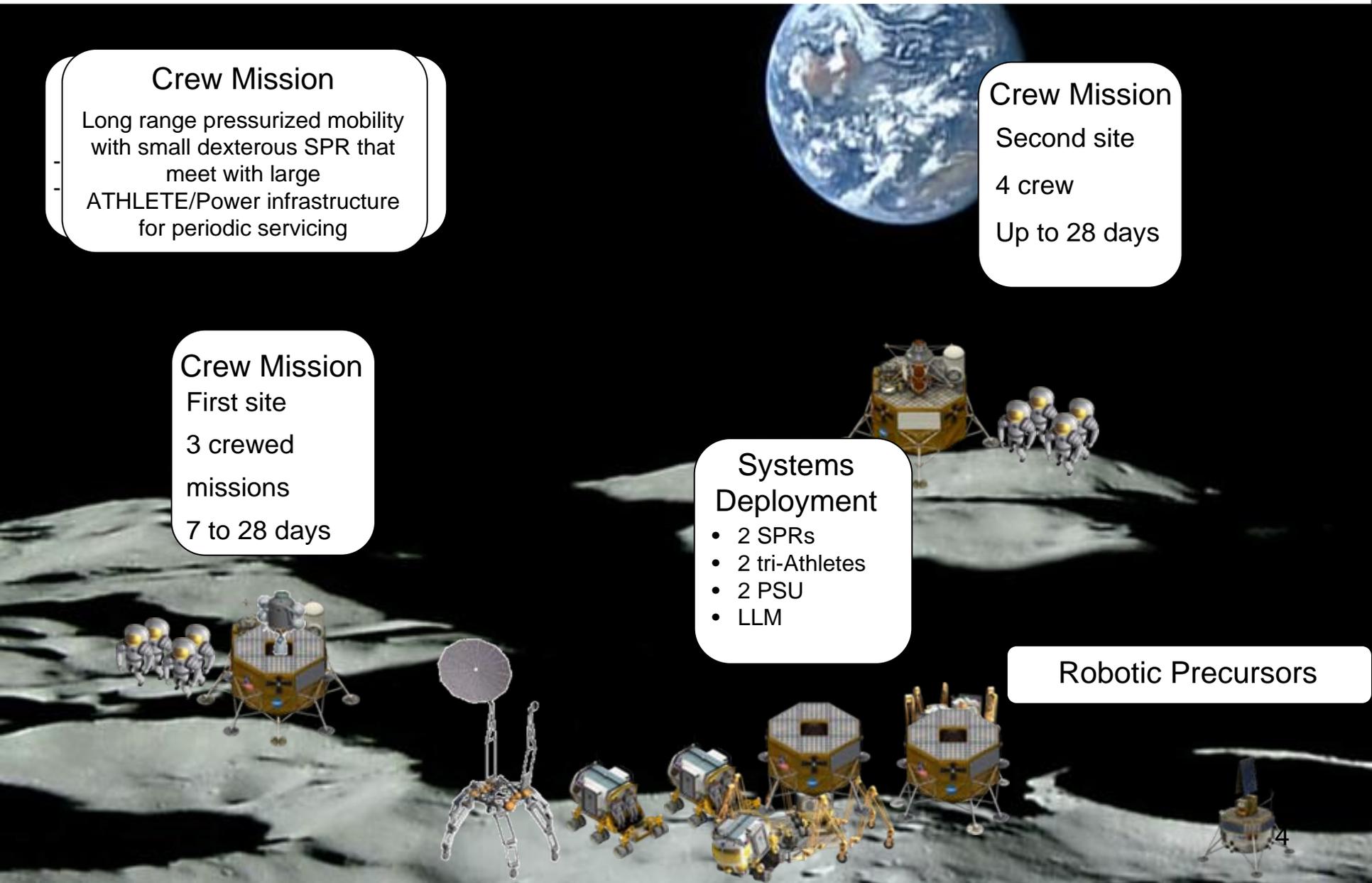
missions

7 to 28 days

Systems Deployment

- 2 SPRs
- 2 tri-Athletes
- 2 PSU
- LLM

Robotic Precursors

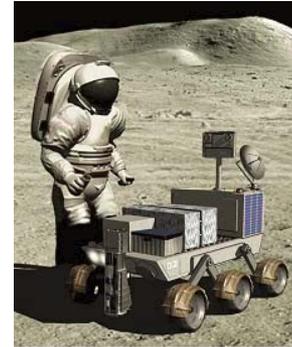


Lunar Campaign Phase Definitions



The architecture is organized into five distinct phases which can be implemented in any order:

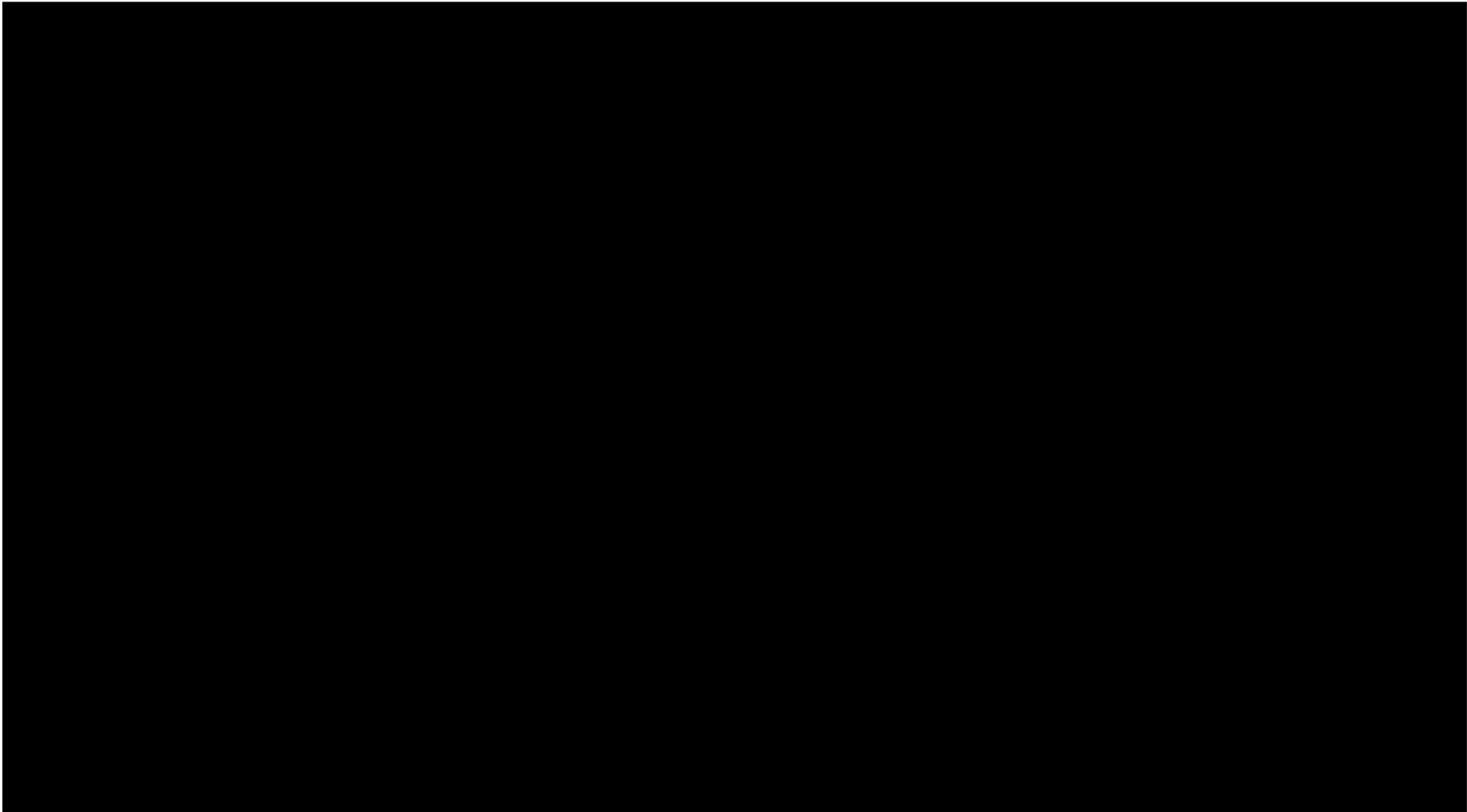
- **Early Robotic Phase** – Robotic missions to increase knowledge, and reduce risk
- **Polar Exploration / System Validation Phase** – Validation & verification of mobility and power infrastructure assets at the lunar pole
- **Polar Relocatability Phase** – Enable extended crew missions to “near polar locations” with mobile surface assets
- **Non-Polar Relocatability Phase** – Use of evolved assets to enable crew exploration, of at least 14 days, at non-polar locations
- **Long Duration Phase** – Enable extended crew expeditions of at least 60 days



Ability to add targeted Sortie missions to meet science objectives as required



GPOD Visualization



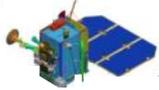
- Intent was to develop an integrated set of lunar precursor missions consistent with GPoD campaign needs while attempting to balance sustainability and affordability
 - Number and type of mission opportunities provided as top down guidance from IAWG (Montreal, March 2010)
 - Mission content, scheduling and location derived through bottoms up analysis from inputs provided by Function Teams, Science Community, Public Engagement representatives, IPs, etc.
- Current manifest represents a *preliminary scoping* of functions and tasks that provide substantial benefit if performed in the precursor phase
 - Product is *not* intended to be taken as a final detailed manifest of missions and payloads
 - Mission definition is extremely preliminary in nature (i.e. think “back of the envelope”) and needs to be verified through a more rigorous concept definition process
 - Should be used as a first step in a highly iterative process to derive requirements for actual mission content
- Key Lessons Learned
 - Significant opportunities exist for early international coordination on robotic pre-cursor mission
 - When planned in conjunction with a human exploration campaign, considerable value can be added to the robotic campaign and pre-cursor activities can provide significant risk deduction for eventual human missions.



GPoD Precursor Phase



Orbital Mission to Provide Earth Comm., Complete Detailed Mapping of all Landing Sites & LLO Testing



Very Early Precursor to Complete Critical Environmental Mapping, Site Survey, Test/Demo at Fixed Location & Public Engagement (50 kg class)



LLO

GPoD Site A (South Pole)

Early Precursor to Complete All Materials Testing & STEM - Must Survive Lunar Night (300 kg class)



GPoD Site A (South Pole)

Early Precursor for All Mobile Mapping, Resource Characterization, Site Survey, Test/Demo at South Pole & Public Engagement (300 kg class)



GPoD Site A (South Pole)

Small Mobile Precursor to Complete Site Survey at Near-Polar Relocation Site & Public Engagement (50 kg class)



GPoD Site D (e.g. Malapert)

Large Mobile Precursor to Complete Site Survey and Resource Characterization at Non-Polar Landing Site & Public Engagement - Must Survive Lunar Night (300 kg class)

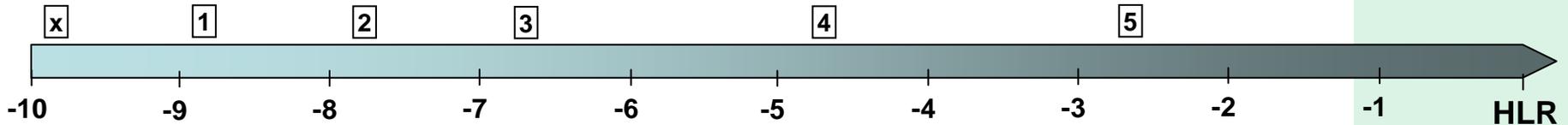


GPoD Site I (e.g. Aristarchus)

Small Cargo landers (part of Polar Exploration / System Validation phase deliver 3 servicing robots (800-1000 kg class)



GPoD Site A (South Pole)

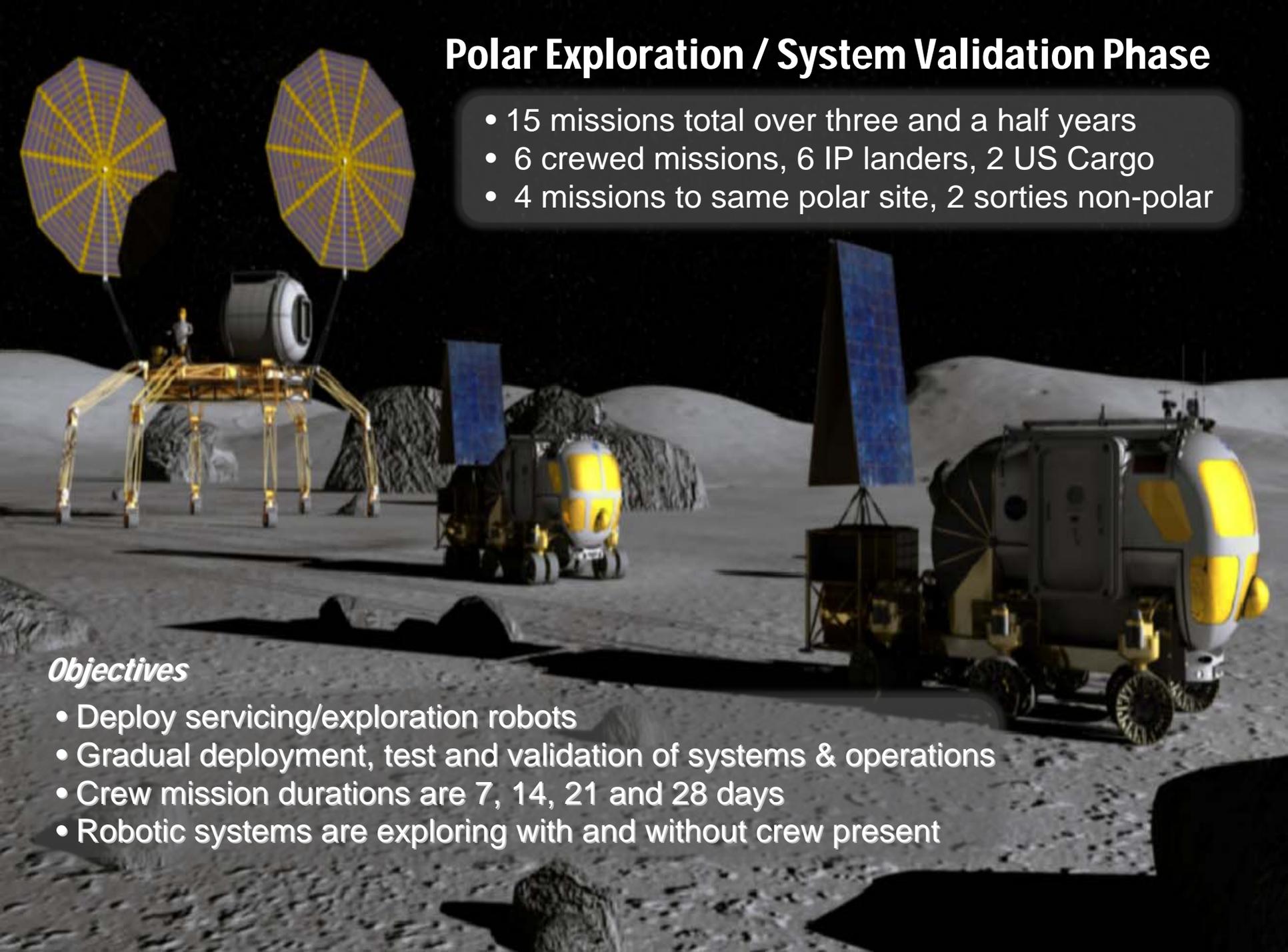


Polar Exploration / System Validation Phase

- 15 missions total over three and a half years
- 6 crewed missions, 6 IP landers, 2 US Cargo
- 4 missions to same polar site, 2 sorties non-polar

Objectives

- Deploy servicing/exploration robots
- Gradual deployment, test and validation of systems & operations
- Crew mission durations are 7, 14, 21 and 28 days
- Robotic systems are exploring with and without crew present



Polar Relocatability Phase

- 10 missions total over two and a half years
- 5 crewed missions, 5 IP landers, **Zero** US Cargo
- 3 extended missions to near-polar sites, 2 sorties non-polar

Objectives

- Months of robotic exploration at Malapert
- 28 days of crewed exploration at Malapert
- Critical science and spares delivered by IP landers
- Months of robotic exploration at and in between Schrödinger Basin and South Pole-Aitken Basin Interior
- 14 days of crewed exploration at Schrödinger Basin and South Pole-Aitken Basin Interior
- Any systems that survive through the last mission are driven back to the South polar site for future use

Non-Polar Relocatability Phase

- 13 missions total over two and a half years
- 5 crewed missions, 5 IP landers, **three** US Cargo
- 4 extended missions to non-polar, 1 sortie non-polar

Objectives

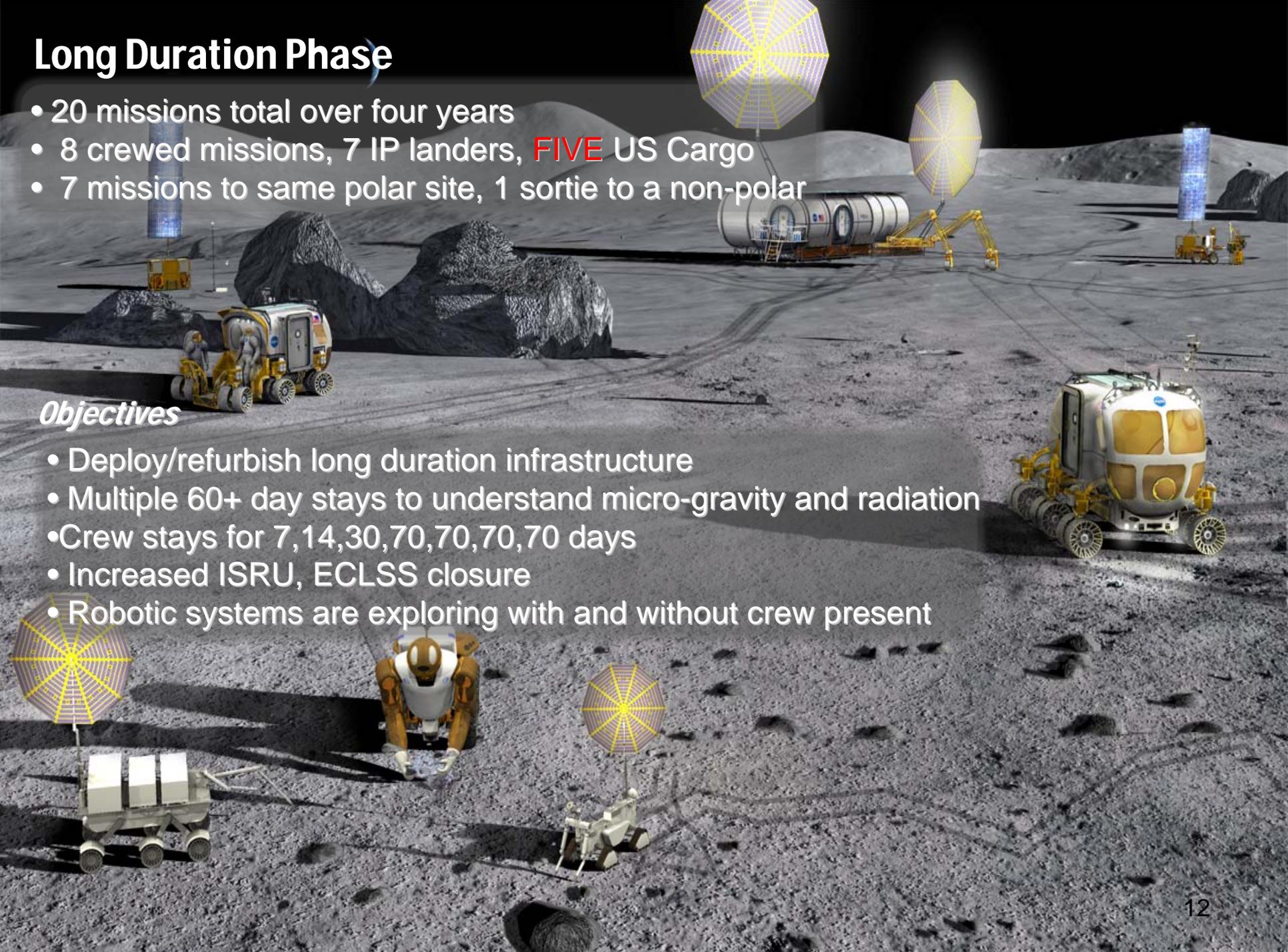
- New generation of exploration systems deployed and tested (second ATHLETE to carry large fuel cell stack assumed)
- Years of robotic exploration at Aristarchus region
- Crewed missions of 7, 14, 28, 28, & 28 days
- Critical science and spares delivered by IP landers
- Any systems that survive through the last mission are either deployed robotically to continue exploring or are used to support the option of an non-polar long duration phase

Long Duration Phase

- 20 missions total over four years
- 8 crewed missions, 7 IP landers, **FIVE** US Cargo
- 7 missions to same polar site, 1 sortie to a non-polar

Objectives

- Deploy/refurbish long duration infrastructure
- Multiple 60+ day stays to understand micro-gravity and radiation
- Crew stays for 7, 14, 30, 70, 70, 70, 70 days
- Increased ISRU, ECLSS closure
- Robotic systems are exploring with and without crew present



The Moon and NEOs as Destinations



DESERT RATS NEAR EARTH ASTEROID MISSION APPLICATIONS



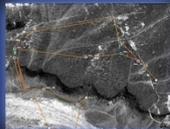
NIGHT OPERATIONS



EVA SUIT PORT



ATHLETE LEG



SITE EXPLORATION

PORTABLE COMM TOWER



COMMUNICATIONS & NAVIGATION CONCEPTS



INFLATABLE ATTIC (2011)



MISSION OPERATIONS



SCIENCE BACKROOM



PARTICIPATORY EXPLORATION

SYSTEM CONCEPT VALIDATION

HABITATION DEMONSTRATION UNIT



SPACE EXPLORATION VEHICLE (SEV)

OPERATIONS CONCEPT VALIDATION

Summary



- **The GPOD is a conceptual baseline description of a series of elements delivered to the lunar surface over time, and a concept of operations that uses them to meet the goals and objectives of the participating agencies.**
- **The proposed campaign establishes an architectural framework that enables significant scientific and exploration risk reduction through the use of a phased approach to exploration.**
- **The architecture provides a flexible method for lunar exploration which can accommodate changes in technologies, international partner priorities, and programmatic constraints as required.**
- **The GPOD maximizes the use of robotic and relocatable assets to reduce costs and enhance opportunities for scientific discovery.**

