“Exploring Together”

The ISECG Reference Architecture
for
Human Lunar Exploration

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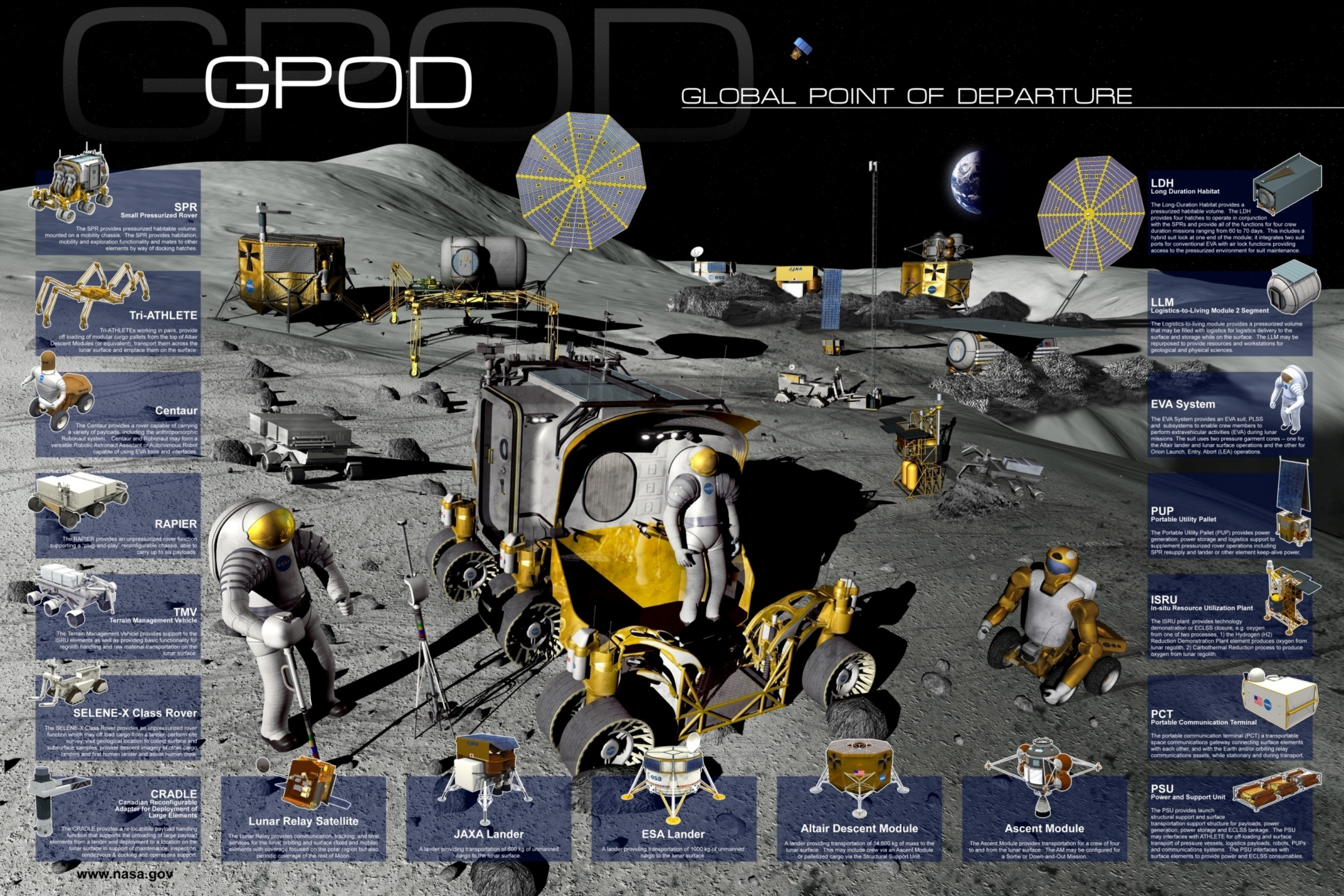
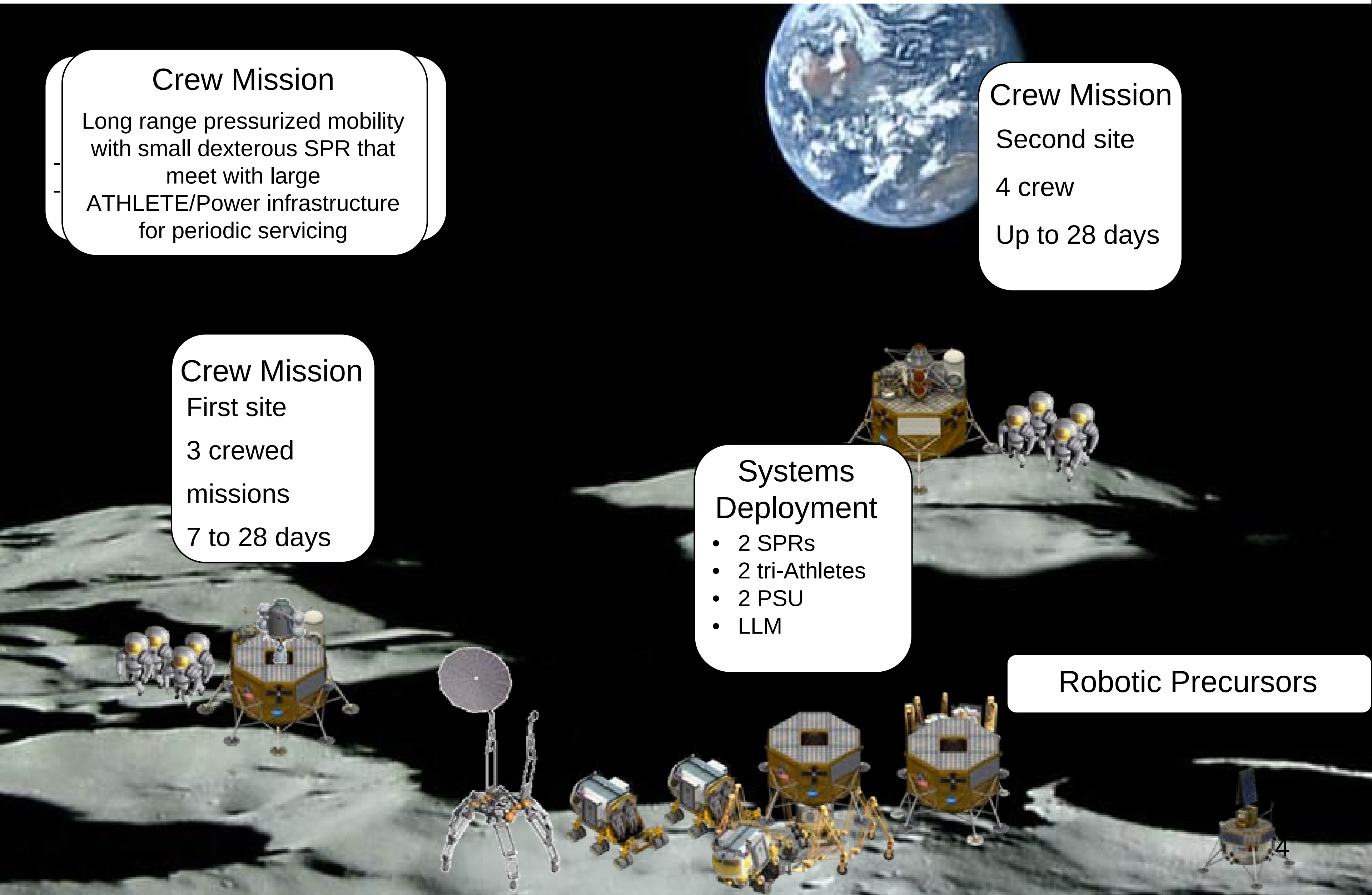
Philosophy of the GPoD – Sustainability!

- 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



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:

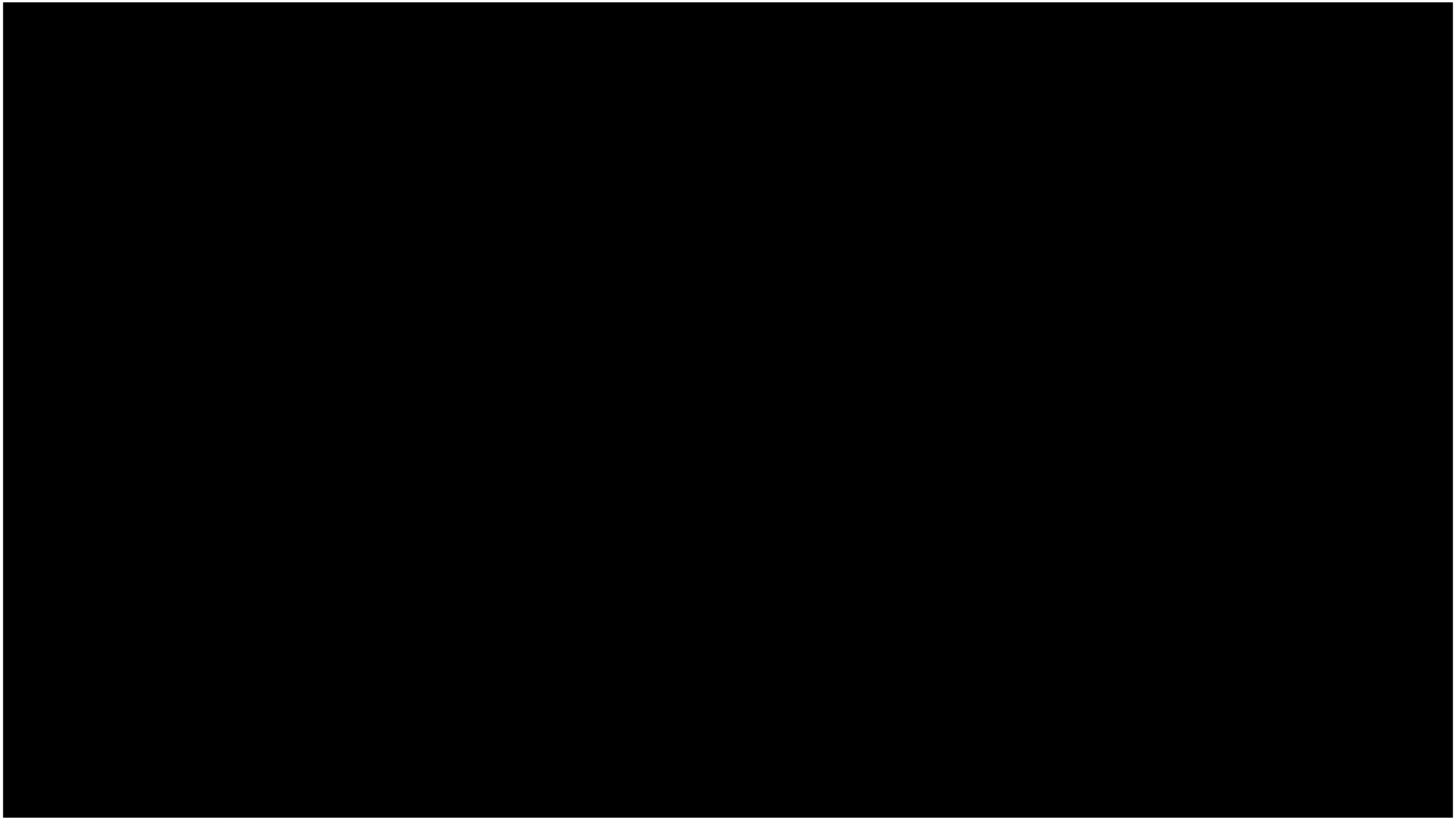
- **Early Robotic Phase** – Robotic missions to increase knowledge, and reduce risk
- **Polar Exploration / System Validation Phase** – Validation & verification of mobility and power infrastructure assets at the lunar pole
- **Polar Relocatability Phase** – Enable extended crew missions to “near polar 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

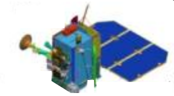


Robotic Precursor Phase

- 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



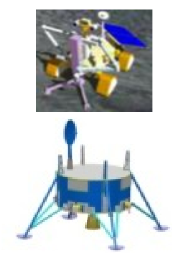
Very Early Precursor to Complete Critical Environmental Mapping, Site Survey, Test/Demo at Fixed Location & Public Engagement (50 kg class)

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

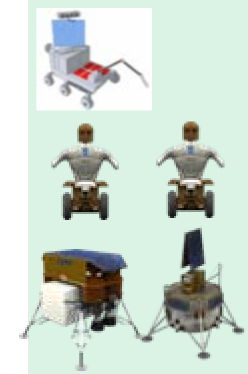
Early Precursor for All Mobile Mapping, Resource Characterization, Site Survey, Test/Demo at South Pole & Public Engagement (300 kg class)

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

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



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

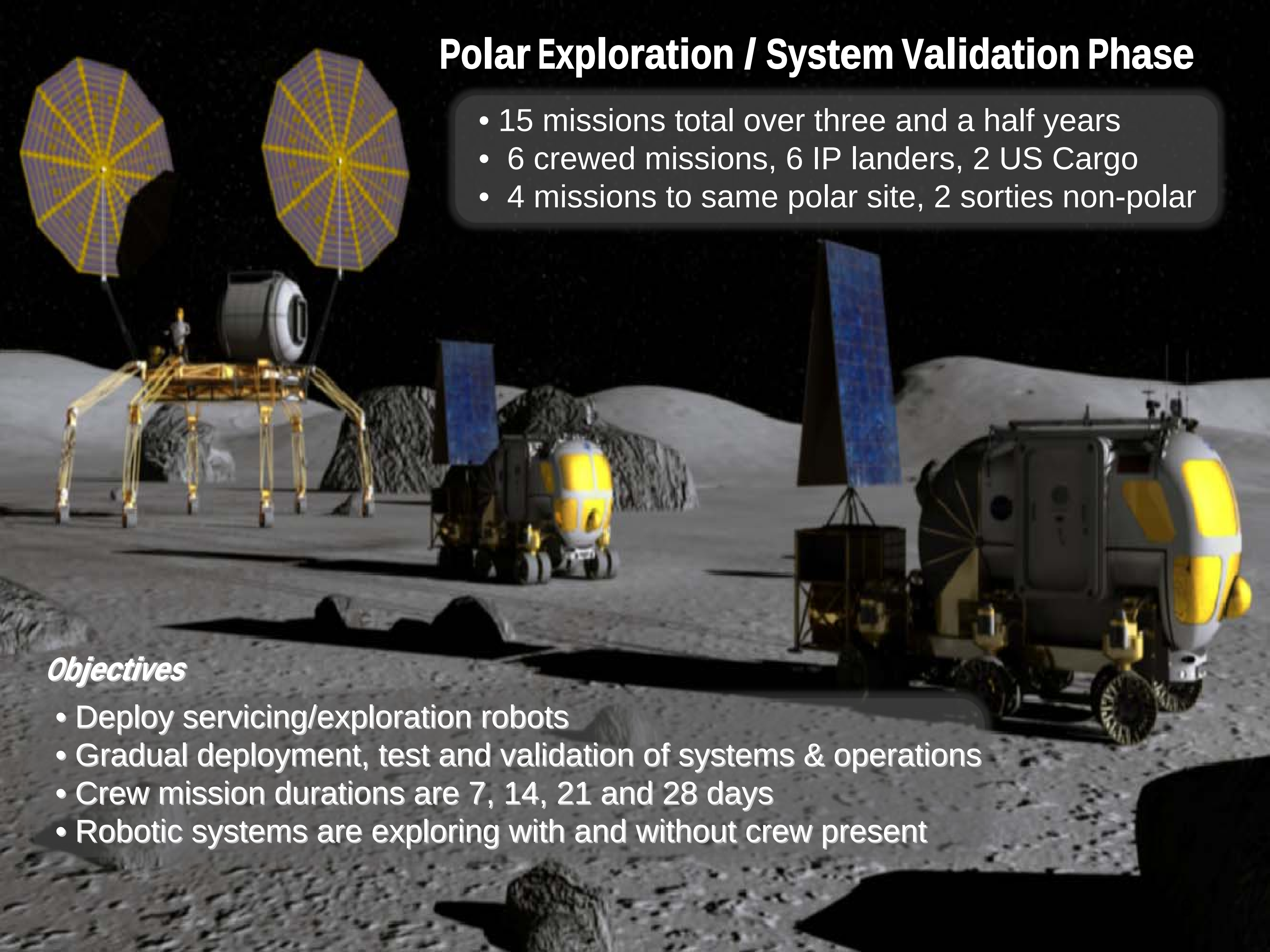


LLO	GPoD Site A (South Pole)	GPoD Site A (South Pole)	GPoD Site A (South Pole)	GPoD Site D (e.g. Malapert)	GPoD Site I (e.g. Aristarchus)	GPoD Site A (South Pole)
x	1	2	3	4	5	

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 HLR

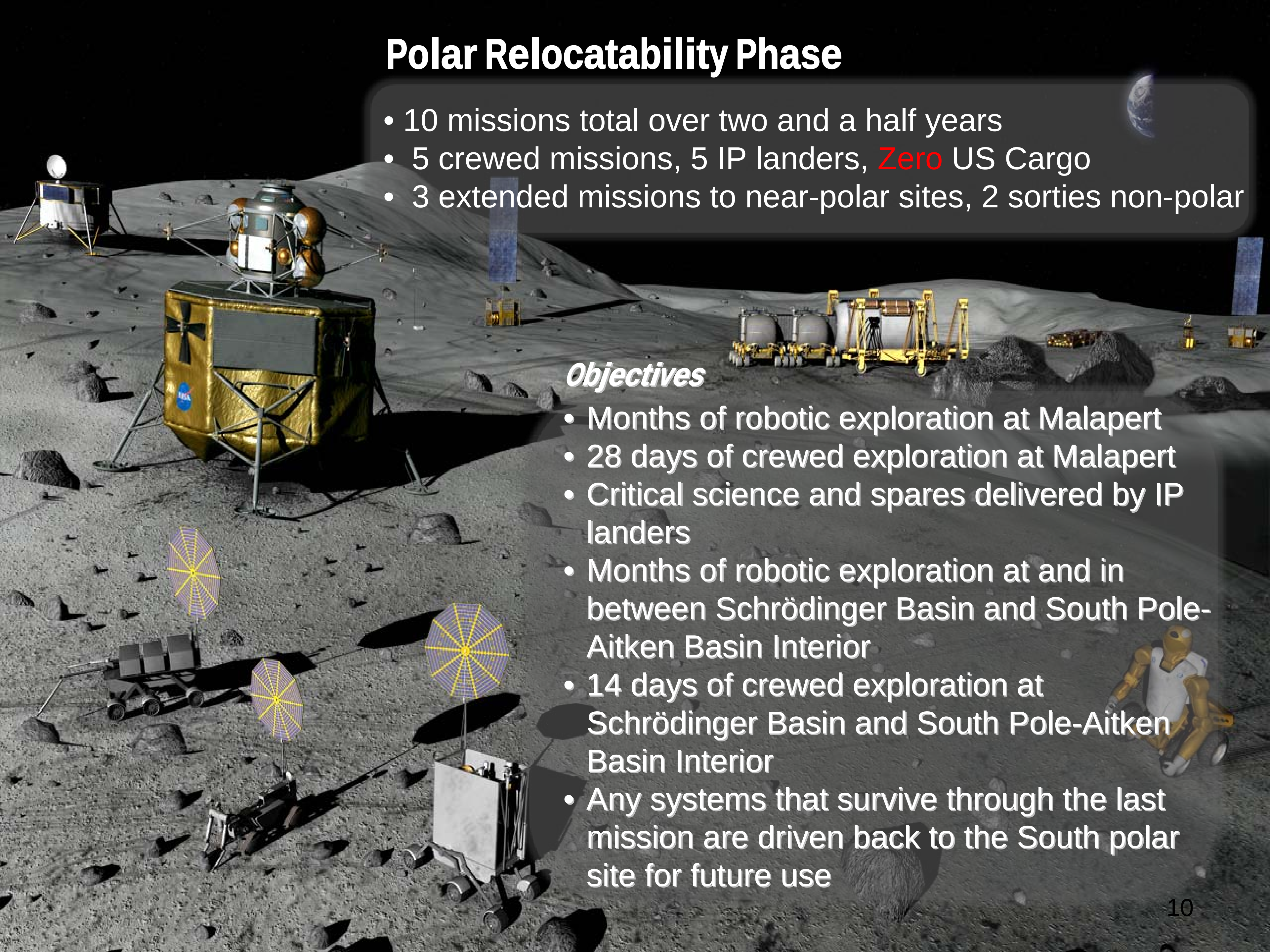
Polar Exploration / System Validation Phase

- 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



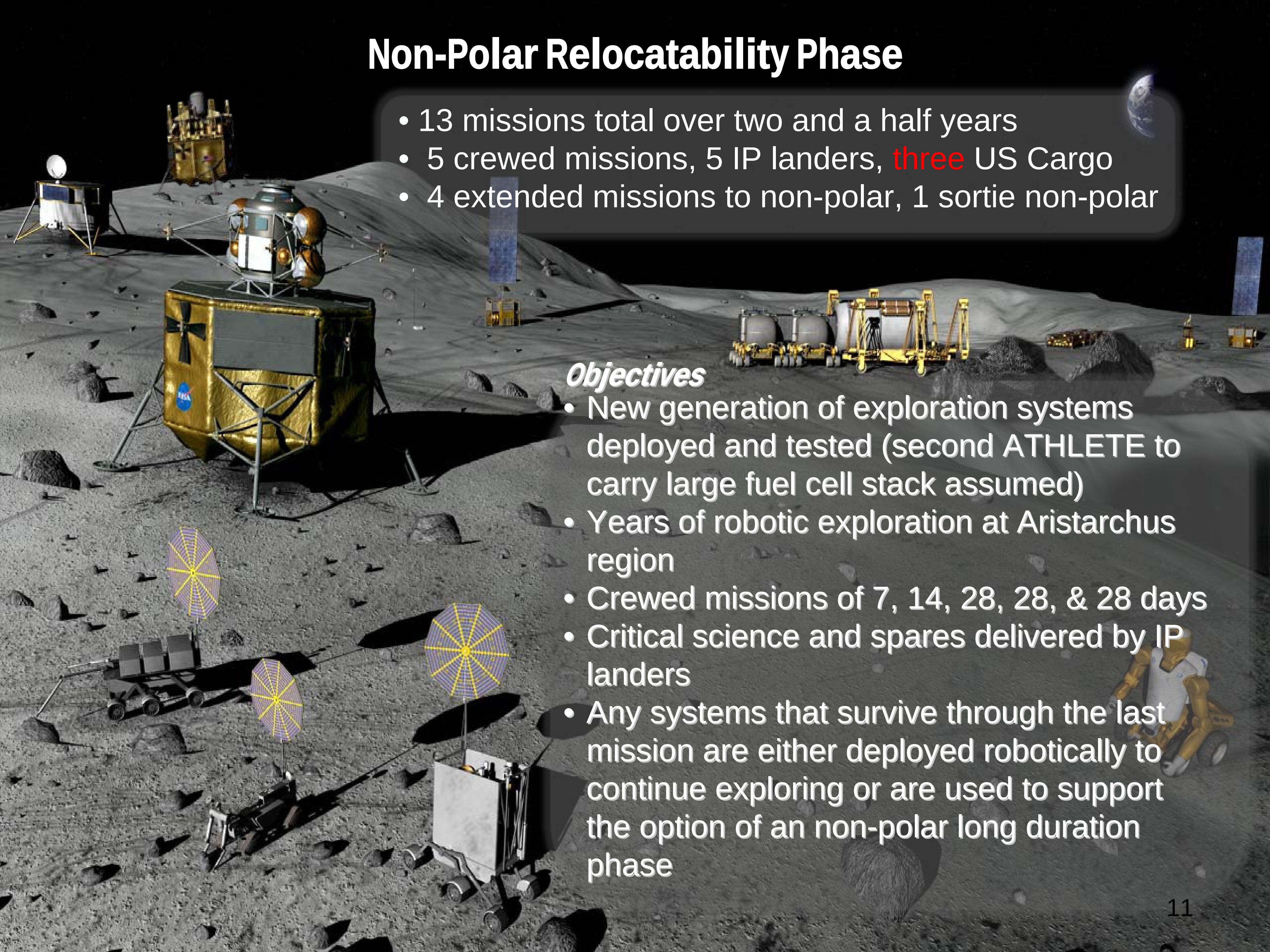
Polar Relocatability Phase

- 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



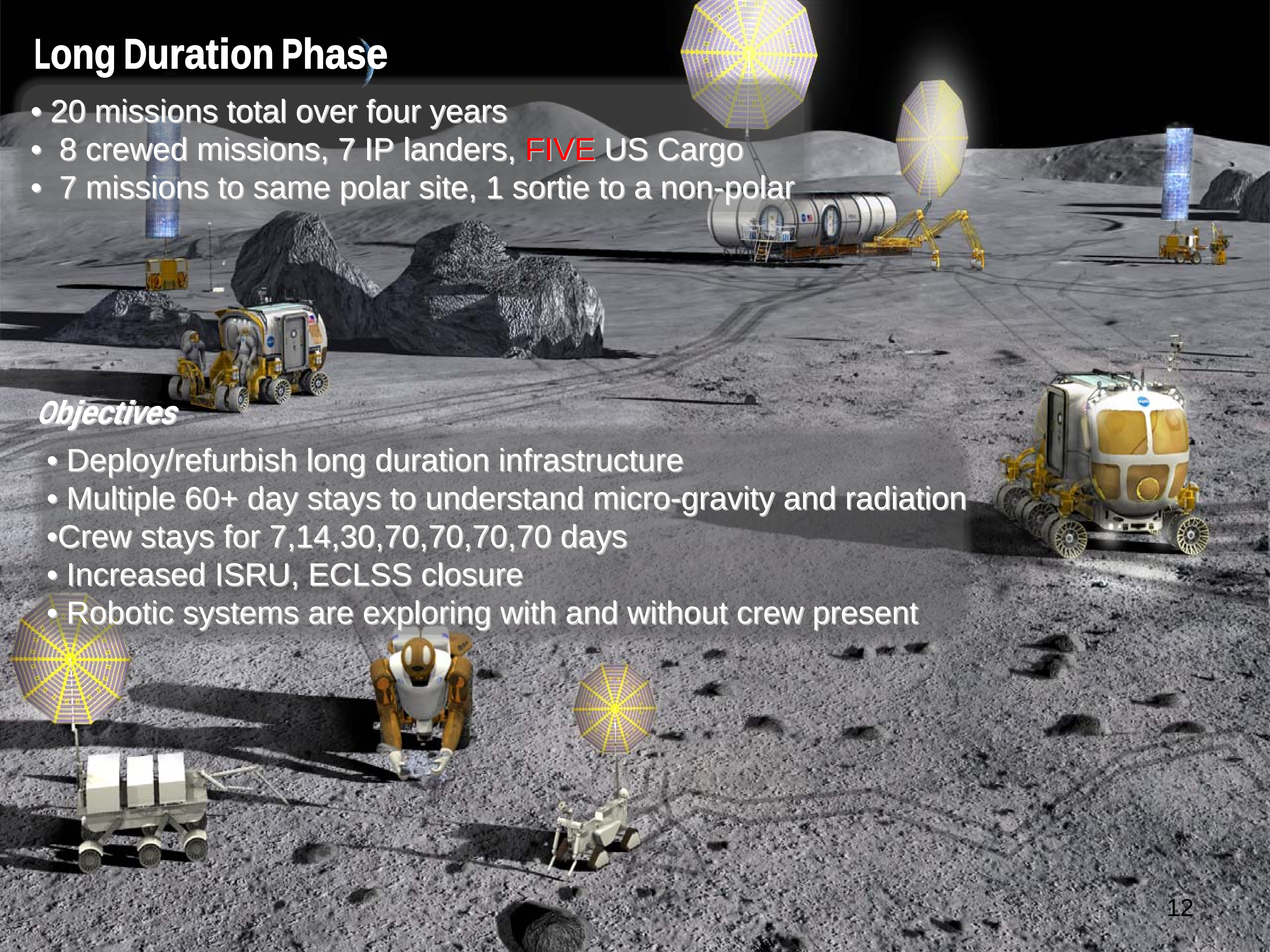
- 13 missions total over two and a half years
- 5 crewed missions, 5 IP landers, three US Cargo
- 4 extended missions to non-polar, 1 sortie non-polar

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

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.