The ISECG Reference Architecture for Human Lunar Exploration

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Pat Troutman
NASA Langley Research Center
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
Crew Mission
First site
3 crewed missions
7 to 28 days

Crew Mission
Second site
4 crew
Up to 28 days

Systems Deployment
- 2 SPRs
- 2 tri-Athletes
- 2 PSU
- LLM

Robotic Precursors

Extended Stay - Relocation Exploration Mode

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

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)

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

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)
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

System Concept Validation

Site Exploration

Habitation Demonstration Unit

Portable Comm Tower

Communications & Navigation Concepts

Inflatable Attic (2011)

Mission Operations

Science Backroom

Participatory Exploration

Operations Concept Validation

Space Exploration Vehicle (SEV)
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.