Concepts Leading to a Sustainable Architecture for Cislunar Development

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Damn it Jim, I’m a Geologist not an Engineer

http://www.who2.com/blog/2011/09/who-was-the-horta-on-star-trek
Outline

▪ Introduction
▪ Assumptions
▪ Cislunar Development
  ▪ Strategic Missions
  ▪ Standalone Missions
▪ The 2107 Test Flight and Payload Opportunities
▪ What Could be Next
▪ Closing Thoughts
Introduction

- ISS industry partners working on concepts to develop an Exploration Platform in the Earth-Moon Libration System
  - Use ISS development methods
  - Use ISS residual assets
  - ISS not just a spacecraft but the expression of what great nations can accomplish working together
- Technology developed for ISS can be evolved and adapted to new exploration challenges
- Concepts have matured along with Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV – Orion)
- Exploration Platform provides
  - Flexible basis for future exploration
  - Reduces cost through re-use of expensive vehicles
  - Reduces number of launches needed to accomplish missions
Assumptions

- The SLS/MPCV will be built and launched per schedule
- A Human Tended Habitat at an Earth-Moon Lagrange Point will be the next human space flight target
- There will be an un-crewed test flight of the SLS/MPCV with an Apollo 8 like free return trajectory in 2017
- There is sufficient mass margin and volume on that launch for 1 or 2 small science/exploration payloads
- There are at least 2 approaches for exploration
  - Strategic
  - Stand Alone
- There are at least 3 approaches for the next step for human exploration (Global Exploration Roadmap uses the first 2)
  - Near Earth Object (NEO) First
  - Moon First
  - Cislunar First
- Whatever we take ought to be refuelable and reusable.
Cislunar First (Strategic Approach)

  - Proposes adding Cislunar-Next to Global Exploration roadmap in addition to evaluating Moon-Next and/or Asteroid-Next
    - On-orbit Servicing
    - Standardization
    - Fuel Storage
    - Materials processing
    - Energy collection and distribution
    - Other in-space utilities

- Spudis-Lavoie – AIAA Space 2011
  - Teleoperations
  - Prospect, Test, Demonstrate and Produce water from Lunar Resources
  - Architecture and Mission Sequence
Science Missions (Stand Alone Examples)

- South Pole Aitken Basin Sample Return
  - MoonRise
    - Human/Robotic/Telerobotic – Alkalai, et.al. this session
  - New Frontiers – Jolliff et.al.
- Schrödinger Telerobotic – Burns, et.al. – GLEX 2012
  - Geologic Exploration
  - Low frequency radio astronomy
- Aristarchus Plateau – Jolliff et.al. – LEAG 2001
  - Strategic/Stand Alone
- Landed Geophysical Package
  - Also strategic/stand alone
  - International Lunar Network (ILN)
  - Lunette – Discovery Class
WHAT NEXT?

- Lunar Reconnaissance Orbiter (LRO) data enables detailed exploration planning, landing site selection, and safe operations
  - Polar Volatile Explorer
    - Ascertain physical state, composition, and properties of polar volatile OH deposits
  - Lunar Roving Prospector
    - Long-duration instrumented rover
      - Arizona State University (ASU) Intrepid Mission
    - Possible L2 role
    - Provide critical ground truth to remote sensing datasets
  - Automated Sample Returns
    - South Pole Aitken – Early Solar System History
      - L2 outpost role there, too?
    - Recent lunar basalts – history of lunar interior
  - In-situ Resource Utilization (ISRU) Demonstration
THE NEXT LUNAR LANDING SITES

- Lunar poles
  - Sunlight + Volatiles
- **Aristarchus plateau**
  - Major ore deposit
  - Young basalts

- **South Pole-Aitken Basin**
  - Oldest lunar basin?
  - Sample of lunar mantle
Cislunar Development Meets National Needs

- Fuel Depots + dry launch
- L1/L2 Gateway
- Lunar ISRU is cornerstone
- Maximizes commercial opportunities
- Reduces cost of asteroid and Mars system expeditions
What are we trying to do?

**The Vision**

Expand human reach* to cis-lunar and beyond

**The Mission**

Establish a robotic and human presence on the Moon (as the closest planetary body) to learn how to use local resources of material and energy in order to live affordably off-planet and, in so doing, create new space faring capabilities

*Reach = the ability to send people and machines to any point within a given volume of space to perform whatever tasks are envisioned
Initial Steps

1. Communication/navigation satellites
   Polar areas out of constant Earth LOS; need comm, positional knowledge

2. Polar prospecting rovers
   Study and characterize water deposits, other substances, environment

3. ISRU demo
   Heat icy regolith to extract water; purify and store as ice in cold traps

4. Digger/Hauler rovers
   Excavate regolith, transport feedstock to fixed stations for water extraction

5. Water tankers
   Purify and store extracted water
Types of Missions

- **Strategic**
  - Resource Prospecting
  - ISRU Production testing
  - ISRU Production
  - Propellant storage and transportation (reusable landers)

- **Standalone**
  - South Pole Aitken (SPA) Sample return
  - Lunar Network
  - Low Frequency Radio observation
Types of payloads

- **Forward compartment**
  - Cubesats
  - Static Lander
    - Geophysical network package

- **Aft compartment**
  - Lander with prospecting rover
    - Discovery class
    - Google Lunar X Prize (GLXP) Class
## Proposed Future Robotic Lunar Missions 2013-2019

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<th>COUNTRY</th>
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<td>Europe</td>
<td>MoonNext</td>
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<td>2015-2018</td>
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Lunette – A Discovery class mission concept

Fig. 5. Conceptual flight system in cruise configuration.
Lunette as an ESPA ring class payload

Fig. 7. Lander configuration.
Chandrayaan-2 - Russian - Lander/India - Rover

http://www.russianspaceweb.com/luna_resurs.html
Luna Glob - Russia

http://www.russianspaceweb.com/luna_glob.html
Chang’è 3 - China

Chang’e 4 - China

Luna Grunt - Russia

http://www.russianspaceweb.com/luna_grunt.html
Selene 2 - Japan

http://moon-lore.com/web/mapping_missions.html
ESA - MoonNext

Astrium Space Transportation

OHB System

Thales Alenia Space

http://www.lpi.usra.edu/meetings/leagilewg2008/presentations/oct30am/Carpenter4037.pdf
Three optional payload locations

Forward Compartment
(If no docking mechanism)

Dimensions are approximate,
pending clearance analysis

SIM Bay
(Standard)

Aft Compartment
(If no main engine)

Image courtesy of Lockheed Martin Corporation
Notional Payloads
Aft Compartment Detail
Forward Compartment Detail
Science Payload Release & Lunar Capture

Science P/L Released:
• Payload released from Orion

WSB Maneuver:
• Payload performs burn for weak capture

Orbital Maneuver:
• Payload performs apoapsis lowering burn
• Gradually lower orbit to Low Lunar Orbit (LLO) and Descent Orbit Insertion (DOI)
Selected Breakout Session Findings: Science
[From Teleoperations Symposium outbrief - 2012]

- **Examples** of problems where low-latency telepresence *may* be enabling can be described further and quantitatively assessed:
  - Volatiles on the Moon (and their access, encapsulation) particularly within Permanently Shadowed Regions
  - Lunar farside astrophysical observatory (meter-wave radio) and surface geophysical/interior network
  - Mars surface biogeochemical sampling (and related issues) as part of the search for signs of ancient life
  - and many others, including those on outer planet satellites, Venus, small bodies

- **New science can be enabled via telepresence at places that are**
  - Distant (e.g., Mars, Titan)
  - Hostile to any reasonable form of human presence (25 K lunar polar regions, surface of Venus at 450 C, surface of Titan, surface of Mercury, meters underground on Mars or Europa, etc.)

- **Scientists must be engaged in technology development of required capabilities (i.e., science pull)**
  - The more science is involved *early* the better the tools for science will be integrated into useful capabilities
  - Related to *field science as an immersive process here on Earth* (where there is a large experience base)

- **Learn from MER and MSL surface-rover experience what increased telepresence is**
  - germane to in high-priority planetary field science
  - Take advance of lessons learned from high-latency telepresence (MER, MSL)

- **Contemporary commercial and defense telepresence activities are highly instructive, and even learning from Lunokhod may be of value.**

- **As latency is reduced is there a natural breakpoint where increase in complexity of tasks gives clear increase in value of science?**
  - For Moon: *if it is seconds, do from Earth; but if fractional seconds, do from orbit or Earth-Moon L2?*
Voyages
Charting the Course for Sustainable Human Space Exploration

http://www.nasa.gov/exploration/whyweexplore/voyages-report.html
From NASA’s Voyages

- **Capability driven approach**
  - Core evolving capabilities
  - Leveraged and reused instead of specialized, destination specific

- **Cislunar space will teach us about how humans live and work in space**
  - Build capabilities for future in-space activities and deep space exploration
  - Economic growth
  - Pave the way for future expeditions
  - Commercial and International collaboration

- **Precursor robotics**

- **Human-robotic interfaces**
  - Risk mitigation through telerobotics

- **Destination systems**
  - ISRU
    - Sustain human life off Earth with in-situ resources
  - Sustained presence
  - Long duration habitats
Refueling Tanker
Summary

- Cislunar Next provides best opportunities for a sustainable Space Exploration Architecture
- 2017 offers us an opportunity
  - Similar to LRO – Science Mission Directorate (SMD)/Human Exploration and Operations Mission Directorate (HEOMD) Joint Mission
- Exploration Platform provides flexibility for many different types of missions
- ISS not just a spacecraft but the expression of what great nations can accomplish working together
ISS

- Best Early Destination Beyond LEO
- Enables a Reusable Lunar Lander
- Departure Point for an Asteroid Mission
- In-Space Assembly & Servicing
  - Large Telescopes
  - Mars Missions
- Spudis/Lavoie cislunar transport node/waystation