Gateway Science Summary

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Agenda

• Focus areas for Gateway utilization
• External/internal Gateway payload capabilities
• Science workshop
  – Top science/engineering outcomes
  – Gateway resources
  – Payload/resources comparison
• Other workshops
• ISS Lessons Learned
• Targeted science-related Gateway studies
Gateway Utilization – Four Focus Areas

1. **Technology:** Identifying high-priority technologies for Gateway demonstration:
   - Evolve its initial capabilities or enable new capabilities for human exploration.
   - Stimulate the development of commercial technologies for operations in cislunar space
   - Request For Information (RFI) released May - numerous responses received

2. **Commercial:** Developing overall commercialization strategy for gateway:
   - Identifying commercial uses of a Gateway beyond NASA plans
   - Released RFI on Gateway commercial in June – responses received 4 August

3. **International:** Enabling collaboration between interested parties:
   - International Space Station partner discussions ongoing, working on strategy to involve international, non-ISS partners (ongoing)

4. **Science and Research:** Identifying potential science opportunities, and how gateway infrastructure can support various investigations:
   - Identifying science events and forums to raise awareness and obtain requirements insight
   - Targeted Gateway studies increasing science potential
   - SMD/HEOMD-hosted Denver Gateway science workshop (February)
     - Revising current Gateway utilization ground rules & assumptions
Gateway Utilization Locations

- All elements will have *external* payload accommodations
  - Inflatable concepts are under study

- All pressurized volumes may have *internal* payload accommodations
  - Distribution of accommodations under study
Gateway Workshop Summary
Workshop sponsored by NASA HQ (HEOMD & SMD), JSC, MSFC & GSFC

Three driving rationale for the workshop:

• Engage the science community with respect to the scientific potential of a lunar Gateway

• Discuss potential scientific investigations leveraging the Gateway
  – Including the scope of possible instruments
  – Using the Gateway infrastructure

• Discuss what resources the Gateway would have to provide to facilitate different types of scientific investigations
Science Workshop Format

• Introductory briefings on NASA plans, ISS lessons learned, Gateway orbit options
• ~180 Talks, ~300 Attendees
  • Government, academia, industry, international
• One day of discipline-focused sessions in five venues – 5-20 minutes per abstract
  • Heliophysics
  • Earth Science
  • Astrophysics & Fundamental Physics
  • Lunar & Planetary
  • Life Sciences and Space Biology
• Cross-cutting discussions
  • Orbits, Human exploration, Potential future capabilities, Space Weather
  • External Instruments
  • Samples
  • Telerobotics & Leveraging Infrastructure
  • Internal Instruments
Science Workshop Analysis

• ~180 abstracts proposed 220 investigations
  – Each proposed instrument included parameter and usage information:

<table>
<thead>
<tr>
<th>Instrument Parameter:</th>
<th>Instrument Usage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>Orbit Considerations</td>
</tr>
<tr>
<td>Volume</td>
<td>Field of View (FOV) requirements</td>
</tr>
<tr>
<td>Power</td>
<td>Requires use of airlock</td>
</tr>
<tr>
<td>Thermal requirements</td>
<td>Crew interaction required?</td>
</tr>
<tr>
<td>Daily data volume</td>
<td>Will astronaut presence be disruptive?</td>
</tr>
<tr>
<td>Current TRL</td>
<td>Does the instrument present a risk to the crew?</td>
</tr>
<tr>
<td>WAG cost &amp; basis</td>
<td>Other consumables or gateway requirements?</td>
</tr>
<tr>
<td>Duration of experiment</td>
<td>Special sample handling requirements</td>
</tr>
<tr>
<td>Other parameters</td>
<td>Need for telerobotics?</td>
</tr>
</tbody>
</table>

– ~7,200 data items returned

• Top Science and Resource takeaways
• Detailed Gateway resources
• Selected comparisons to existing Gateway Groundrules and Assumptions
  – Mass, power, volume, communication data rates
Workshop Top Science Takeaways

• Gateway, in a NRHO, offers unique opportunities for some Earth, Heliophysics, Astrophysics and fundamental physics investigations

• With the addition of additional transportation infrastructure (LLO tug/pallet, surface access, sample return capability) Gateway can enable additional important lunar science

• Externally mounted sample collection with controlled pointing can collect samples and provide important science about cometary material, solar composition, interstellar particles, and near Earth objects

• Radiation environment of the Gateway can provide important tests of the effects of radiation on biological organisms.

• Science utilization extremely constrained until the presence of an external robotic arm

• Need to coordinate with international partners on sharing/allocation of science resources - avoiding duplication, maximizing science
Workshop Top Engineering/Resource Takeaways

• External payloads with a variety of desired look directions, and many benefit from precise pointing and/or long duration stare capability

• Ability for external (i.e. in vacuum) delivery of science elements

• Contamination concerns (gateway exosphere & optical payloads passing through the hab)

• Interest in internal analysis equipment (multi-use, flexible and configurable)

• Automation of internal payload interactions (automated systems and robotics)

• Science can generate large amounts of data

• Farside of the Moon is a unique radio science location, need to consider Gateway RF noise

• Enhancement of generic gateway capabilities can facilitate science (GPS – nav & timing)

• Lunar science needs significant transportation infrastructure investment
• Assume a central data recorder for payloads
  – Instruments send to central SSDR, Gateway handles downlink

• Onboard data computing capability

• Large amounts of data
  – Potential for terabytes daily feasible required depending on science payloads
  – Need for laser com or send hard drives back to Earth

• Need to determine the gateway’s vibrational environment (crewed and uncrewed)
  – Vibration isolation potentially required for majority of optical payloads

• Potentially consider generic telescope facility
  – Photons sent to multiple sensors
  – Sensors possibly inside gateway (easier to swap with improved/different sensors)
  – Might require optically pure window
Gateway Internal Payloads

• **Significant amount of volume could be utilized for internal experiments**
  – Neutron/radiation detection, neurocognitive function, radiation and microgravity effects, behavioral health, gardening and food evaluation, waste reclamation
  – Need / opportunity for a separate science module?

• **Interest in multi-use analytical equipment**
  – Multi-use glove box, configurable
  – Partly a result of assumed limited downmass capability?

• **On-board storage and distribution of space radiation environmental data (external/internal)**
  from payloads as available meta-data for other payloads, especially Space Biology or HRP.
Gateway Infrastructure Capabilities

• Capability to deploy CubeSats/SmallSats from the Gateway
  – Interior payload source via a science airlock
  – Externally using the robotic arm to remove a satellite/pre-packaged deployer from an unpressurized logistics module.
  – Deployment capability of up to 12U identified as likely candidates

• Provide communication relay or navigation aid for other orbiting/lunar surface assets
  – Small spacecraft/cubesats, farside locations, polar regions, and steep terrain

• Teleops of space/surface assets conducted by Gateway crew or by Earth payload operators
  – Installation, assembly, and deployment of external instruments
  – Management of samples collected from free flyers and robotic landed missions
  – Extend lifetime of internal Gateway experiments into uncrewed Gateway modes
    • autosampling, programmed fluid delivery or fluid/water delivery, programmed or human-in-the-loop measurements
  – General maintenance.
Samples – Specific Gateway Resources

• Ability to install, and retrieve dust collectors on the gateway in different look directions, avoiding contamination from the gateway.

• Ability to dock, or berth, a sample return vehicle with or without crew present
  – Need for a science airlock

• Some internal volume needed of science support equipment, in addition to experiments
  – Glove box (multi use) and analytical equipment
  – Emphasis on in-situ analysis (assumption of limited downmass to Earth)

• Many Space Biology and HRP return samples will require on-board and return cold stowage capability

• External analytical equipment possible
  – Decrease need to open “dirty” lunar samples inside the gateway
• **Current Groundrule:** For each crewed Gateway mission starting with Gateway Mission (GM)-2, a minimum of 1,000 kg shall be available for utilization.

• If instruments were equal priority and without considering other parameters, ~90 accommodated by a 1000 kg allocation

• Only 2 instruments are >1000 kg
• **Current Groundrule:** Gateway shall provide a minimum of 4kW power during SEP operations and crewed operations for Utilization. Gateway shall provide a minimum of (TBD)kW power during non-SEP operations for Utilization.

• 50 concepts in the 100s W range, almost all concepts <500 W, 3 concepts in 4-9 kW power range
Science Workshop: Internal Volume Analysis

- **Current Groundrule:** The Gateway shall provide at least 1 (TBD) m$^3$ within each of the Habitation Elements, for powered payloads.
- 1 m$^3$ could support 29 smallest of 36 payload proposals providing volume data
- Currently assuming all SLPSRA payloads are internal and all others are external
- Total sum of internal payloads: 12.5 m$^3$ (single largest 8 m$^3$, sum of all other concepts is 4.5 m$^3$)
- Assumption of 100% efficient packing in these values - need to factor in additional volume margin due to varying payload geometries and packing configurations
• **Current Groundrule:** The Gateway shall provide 5.15 Tbits/day (644GB) allocation for utilization downlink.

• Factoring in the possibility of high drivers being selected and considering the need for additional margin (e.g. hi definition video), 644GB/day appears to be a reasonable baseline assumption for daily data downlink needs from onboard experiments and Gateway systems.
International Gateway Science-Focused Events

1. **ESA Science Workshop**
   - European science community
   - NASA workshop outcomes provided to ESA
   - Using results to advise ESA industry studies on Gateway elements

2. **CSA Science Meeting**
   - Invited Canadian scientists
   - NASA workshop outcomes provided to CSA

3. **JAXA Gateway Science Workshop**
   - Provided NASA workshop data templates & outcomes
   - Informing JAXA contributions

• All agencies are participating in the Gateway design and development process
Key ISS Lessons Learned for Gateway

1. Target obtaining science support from key science stakeholder communities
   - Engage SMD and science communities early
   - Build stakeholder support to aid funding and long term sustainability
   - Align Gateway capabilities with key stakeholder needs (e.g. sample/sample return, astrophysics, heliophysics, human research, Earth/Moon observations)

2. Consider Utilization location within Program Office
   - Goal of Gateway operations - touches all systems and needs all systems
   - Systems view of Utilization sets up competition with other Gateway systems resources rather than supported by other resources

3. Consider new accommodation of internal experiments (i.e. different than Express Racks)
   - Incorporate modern improvements – software upgrades, plug and play, standard interfaces, automation, structural improvements
   - Legacy experiment considerations
   - Balance between crew and automation/robotics

4. Prioritizing science among Gateway users and partners
   - ISS evolved to current prioritization processes
   - Start defining processes now
Near Term Science Utilization Activities

- **Providing GPS/Navigation on the Gateway**
  - Precision timing/location for physics experiments, facility capability for instruments or cislunar/surface assets

- **Utilization during uncrewed periods**
  - Defining Gateway internal environmental conditions for experiments - requirements
  - Developing ConOps to optimize automation planning, robotic system potential designs
    - Established Software/Autonomy working group

- **External location of experiments**
  - Field of View studies, vent location designs, shadowing, exosphere analysis (includes NRHO)

- **Logistics**
  - Advocating for dual use logistics vehicles (supply, secondary missions/tugs, experiments)

- **External arm delivery**
  - Protecting earlier delivery in Gateway assembly sequence

- **SLPSRA**
  - Detailed studies on potential internal science experiments and identifying common facility lab systems