Request for Proposal

Robotic Lunar Crater Resource Prospecting

Background

NASA is designing crewed exploration missions to beyond low-Earth orbit destinations. These missions utilize an incremental buildup of technologies and elements starting in cis-lunar space, continuing to Near-Earth Asteroids followed by the Martian moons, and finishing on the surface of Mars. Any campaign of crewed exploration missions requires large quantities of resources to enable the crew to successfully live and explore away from Earth. These resources can either be delivered from Earth to in-space aggregation locations with existing or emerging launch systems, or they can be extracted from other celestial bodies. The most coveted resource to support crewed exploration missions is water.

Water covers approximately 70% of the Earth's surface and is the most important resource to sustaining life. Many NASA science missions to other planetary bodies have an explicit goal of searching for water. For crewed missions, water is the cornerstone of the environmental control and life support system for the crew. In addition, water can be broken down into hydrogen and oxygen molecules to provide propellant for the propulsion systems. The discovery and utilization of water from in-situ locations could potentially increase the performance and reduce the cost of exploration missions, relative to reliance on delivery from Earth.

The second phase in NASA's exploration plan is to establish systems in the cis-lunar "Proving Ground." Cis-lunar space will be utilized for exploration element aggregation and will serve as a gateway to exploration destinations. This makes the Moon an excellent potential location for in-situ resource collection in support of exploration missions. Several lunar probes, including Japan's Kaguya[1], India's Chandrayaan[2], and NASA's Lunar Reconnaissance Orbiter[3], have shown evidence of water on the lunar surface. The highest concentration of water is likely to be in the polar regions and in deep impact craters; these areas are subjected to less solar heating that would otherwise vaporize the water. Prior to designing an in-situ resource utilization system, robotic missions are needed to evaluate the quantity and accessibility of water on the Moon.

Design Requirements and Constraints

The project should:

- Design a robotic mission to the surface of the Moon with the explicit goal of determining the locations and quantities of water deposits (ratio of water to regolith) in two lunar craters.
- Select a mission architecture and vehicle design that maximizes the science data return within the cost and schedule constraints.

- Perform trade studies on various mission designs at the architecture and system levels to demonstrate the fitness of the chosen mission and system design. Trades should include vehicle architecture, launch vehicles, science instruments, orbital mechanics, spacecraft subsystem level designs, and other mission level system trades. It is highly desirable to use technologies that are already demonstrated on previous programs or currently in the NASA technology development portfolio. Trades should be assessed on the bases of benefit, risk, and cost.
- Provide a detailed description of the scientific approach, including traceability of specific measurements to science objectives, planned observations, design of the science instruments, and collection periods.
- Discuss the selection of target locations and the values of each of the selected sites, including the assessment criteria.
- Design and define the mission operations, including launch, orbit transfer, station keeping, and other maneuvers necessary to achieve mission goals.
- Describe the surface experiment operations and communication data plans.
- The cost for the mission shall not exceed $500 Million US Dollars (in FY17), including launch vehicles.
- The mission shall complete its primary scientific mission no later than December 31, 2024.

Deliverables

This project will require a multi-disciplinary team of students. Traditional aerospace engineering disciplines such as structures, propulsion, flight mechanics, orbital mechanics, thermal, electric power, attitude control, communications, sensors, environmental control, and system design optimization will be involved. In addition, economics and schedule will play a major role in determining design viability. Teams will make significant design decisions regarding the configuration and characteristics of their preferred system. Choices must be justified based both on technical and economic grounds with a view to the extensibility and heritage of any capability being developed.

The following is a list of information to be included in the final report. Students are free, however, to arrange the information in as clear and logical a way as they wish.

1. Motivation and Objective - should include the goals and objectives of the mission.
2. Requirements Definition - should include the mission requirements and design requirements at the mission, system, and subsystem level.
3. Trade Studies - should include the trade studies for the mission architecture and mission operations.

4. Concept of Operations - a detailed concept of operations should be included to describe all phases of the mission and to demonstrate the realization of the science requirements set in section 2.

5. Design Integration and Operation - should discuss how the trades selected in section 3 are integrated into a complete package. This section should discuss design of all subsystems: structures, mechanisms, thermal, attitude control, telemetry, tracking, and command, electric power, propulsion, scientific payload and sensors, interface with the launch vehicle, and mission concept of operations. A mass and power budget should be included, broken down by subsystem, with appropriate margins. The ground system proposed for operation shall also be included. A summary table should be prepared showing all mass, power and other resource requirements for all flight elements/subsystems with appropriate PDR-level margins.

6. Cost Estimate - a top level cost estimate covering the life cycle for all cost elements should be included. A Work Breakdown Structure (WBS) should be prepared to capture each cost element including all flight hardware, ground systems, test facilities, and other costs. Estimates should cover design, development, manufacture, assembly, integration and test, launch operations and checkout, in-space operations, and disposal/decommissioning. Use of existing/commercial off-the-shelf hardware is strongly encouraged. A summary table should be prepared showing costs for all WBS elements distributed across the various project life cycle phases.

7. Schedule - a mission development and operation schedule should be included to demonstrate the mission meets the schedule deadline established in the RFP. Schedule margin should be applied to appropriate areas with funded schedule reserve detailed in the cost estimate.

8. Summary and References - a concise, five-page summary of the full report should be included and clearly marked as the summary. References should be included at the end. A compliance matrix listing the page numbers in the report where each these sections, as well as the items identified under the "project should" section can be found, is mandatory.

Additional Contacts

All technical questions pertaining to this RFP should be directed via e-mail to Patrick Chai (patrick.r.chai@nasa.gov) or William Tomek (william.g.tomek@nasa.gov).

Any updates to this RFP will be posted on the AIAA Design Competitions web site http://www.aiaa.org/DesignCompetitions/

References

[1] Kaguya (Selene). <www.kaguya.jaxa.jp/index_e.htm> Japan Aerospace Exploration Agency.

[2] Sundararajan, V. "Indian Lunar Space Exploration Program – Chandryaan I and II Missions." AIAA 2012-5324.

[3] Christensen, A., Eller, H., Reuter, J., Sollitt, L. "Ice on the Moon? Science Design of the Lunar Crater Observation and Sensing Satellite (LCROSS) Mission." AIAA 2006-7421.