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.

Design Competition Rules

Eligibility Requirements

- All AIAA Student members are eligible and encouraged to participate. Membership with AIAA must be current to submit a report and to receive any prizes.
- Students must submit their letter of intent and final report via the online submission to be eligible to participate. **No extensions will be granted**.
- More than one design may be submitted from students at any one school.
- If a design group withdraws their final report from the competition, the team leader must notify AIAA Headquarters immediately.
- Design projects that are used as part of an organized classroom requirement are eligible and encouraged for competition.

Schedule

- Letter of Intent — 10 February 2018 (11:59 pm Eastern Time)
- Proposal delivered to AIAA Headquarters — 10 May 2018 (11:59 pm Eastern Time)
- Announcement of Winners — 31 August 2018 (11:59 pm Eastern Time)
    - Engine Design Competition dates
        - Letter of Intent – 14 February 2018 (11:59 pm Eastern Time)
        - Proposal submitted, via online submission site to AIAA Headquarters – 16 May 2018 (11:59 pm Eastern Time)
        - Round 1 evaluations completed – 30 June 2018 (11:59 pm Eastern Time)

Round 2 presentations at AIAA Propulsion and Energy Forum 2018

Categories/Submissions

- Team Submissions
    - Team competitions will be groups of not more than ten AIAA Student Members per entry.
- Individual Submissions
    - Individual competitions will consist of only one AIAA Student member per entry.
- Graduate
    - Graduate students may participate in the graduate categories only.
- Undergraduate
    - Undergraduate students may participate in the undergraduate categories only.
- Letter of Intent (LOI)

  - A Letter of Intent indicating interest in participating in the design competitions is required before submitting a final report.
  - All Letters of Intent must be submitted through the online submission system.
  - Letter of Intent must include student's names, emails, AIAA membership numbers, faculty advisor(s) names, emails, and project advisor(s) names and emails. Incomplete LOI's will result in the Team or Individual being ineligible to compete in the competition.
- Submission of Final Design Report
  Each team or individual must provide an electronic copy their design report as outlined below to the online Submission site
  - An electronic copy of the report in Adobe PDF format must be submitted to AIAA using the online submission site. Total size of the file cannot exceed 20 MB.
  - Electronic report files must be named: "2018_[university]_DESIGN_REPORT.pdf"
  - A "Signature" page must be included in the report and indicate all participants, including faculty and project advisors, along with students' AIAA member numbers and signatures.

  - Electronic report should be no more than 100 pages, double-spaced (including graphs, drawings, photographs, and appendices) if it were to be printed on 8.5"x11.0" paper, and the font should be no smaller than 10 pt. Times New Roman.
    - Engine Design Competition is limited to 50 pages.

Copyright

All submissions to the competition shall be the original work of the team members.

Authors retain copyright ownership of all written works submitted to the competition. By virtue of participating in the competition, team members and report authors grant AIAA non-exclusive license to reproduce submissions, in whole or in part, for all of AIAA's current and future print and electronic uses. Appropriate acknowledgment will accompany any reuse of materials.

Conflict of Interest

It should be noted that it shall be considered a conflict of interest for a design professor to write or assist in writing RFPs and/or judging proposals submitted if (s)he will have students participating in, or that can be expected to participate in those competitions. A design professor with such a conflict must refrain from participating in the development of such competition RFPs and/or judging any proposals submitted in such competitions.

Awards

The prize money provided for the competitions is funded through the AIAA Foundation. The monetary awards may differ for each competition, with a maximum award of $1,000. The award amounts are listed below.

Undergraduate Team Space Design – Robotic Lunar Crater Resource Prospecting

The top three design teams will be awarded certificates. One representative from the first place team *may be* invited by the Technical Committee responsible for the RFP to make a presentation of their design at an AIAA forum. A travel stipend *may be* available for some competitions, with a maximum travel stipend of $750 which may be used to help with costs for flight, hotel, or conference registration to attend an AIAA forum.

Aircraft Design Competitions

- Graduate Team Aircraft - Advanced Pilot Training Aircraft
- Undergraduate Team Aircraft – Hybrid-Electric General Aviation Aircraft (HEGAA)
    - 1st Place: $500; 2nd Place: $250; 3rd Place: $125
- Undergraduate Individual Aircraft – Close Air Support Aircraft (A-10 Replacement)
    - 1st Place: $1,000; 2nd Place: $500; 3rd Place: $300

Engine Design Competition

- Undergraduate Team Engine –Candidate Engines for a Next Generation Supersonic Transport
    - 1st Place: $500; 2nd Place: $250; 3rd Place $125

Space Transportation Competition

- Undergraduate Team Space Transportation – Pluto Orbiter
    - 1st Place: $500; 2nd Place: $250; 3rd Place: $125

Space Design Competition

- Undergraduate Team Space Design – Lunar Prospecting
    - 1st Place: $500; 2nd Place: $250; 3rd Place: $125

Structures Design Competition

- Graduate Team Structures – Fuselage Design
- Undergraduate Team Structures – Supersonic Wing
    - 1st Place: $500; 2nd Place: $250; 3rd Place: $125

Proposal Requirements

The technical proposal is the most important factor in the award of a contract. It should be specific and complete. While it is realized that all of the technical factors cannot be included in advance, the following should be included:

- Demonstrate a thorough understanding of the Request for Proposal (RFP) requirements.
- Describe the proposed technical approaches to comply with each of the requirements specified in the RFP, including phasing of tasks. Legibility, clarity, and completeness of the technical approach are primary factors in evaluation of the proposals.
- Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, systems analysis, method of attack, and discussions of new techniques should be presented in sufficient detail to permit engineering evaluation of the proposal. Exceptions to proposed technical requirements should be identified and explained.
- Include tradeoff studies performed to arrive at the final design.
- Provide a description of automated design tools used to develop the design.

Basis for Judging

The AIAA Technical Committee that developed the RFP will serve as the judges of the final reports. They will evaluate the reports using the categories and scoring listed below. The judges reserve the right to not award all three places. Judges' decisions are final.

*1. **Technical Content (35 points)***

This concerns the correctness of theory, validity of reasoning used, apparent understanding and grasp of the subject, etc. Are all major factors considered and a reasonably accurate evaluation of these factors presented?

*2. **Organization and Presentation (20 points)***

The description of the design as an instrument of communication is a strong factor on judging. Organization of written design, clarity, and inclusion of pertinent information are major factors.

*3. **Originality (20 points)***

The design proposal should avoid standard textbook information, and should show the independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the method show an adaptation or creation of automated design tools?

*4. **Practical Application and Feasibility (25 points)***

The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or insolvable problems.