

## Request for Proposal

### Reusable Lunar Surface Access Vehicle

#### Background

NASA is leading the next steps into deep space near the Moon, where astronauts will build the systems that are needed for deep space exploration. The space near the Moon offers an excellent environment for testing the systems that are needed for extended exploration missions to other destinations like Mars. To support these missions, NASA is working with commercial partners to develop hardware to support missions around the Moon more ambitious than ever before. The first phase of this development effort will utilize current technologies to allow astronauts to gain operational experience spending weeks, rather than days, away from Earth. These missions will enable NASA to develop the techniques and systems that will solve the challenges that astronauts will face when traveling to Mars.

In addition to demonstrating the safe operation of the integrated Space Launch System launch vehicle and Orion spacecraft, NASA is also working with commercial and international partners to build a crew tended spaceport in lunar orbit within the first few missions that would serve as a gateway to deep space and the lunar surface. This Deep Space Gateway [1] would have a power and propulsion bus, a small habitat to extend crew time, docking capability, an airlock, and service by logistics modules to enable research and extend crew durations far beyond low Earth orbit. The Deep Space Gateway will be a staging point for all of the crewed expeditions to the Martian surface, serving as the primary location for the assembly, refurbishment, and refueling of the reusable Mars transit vehicle.

Although NASA is focusing on Mars exploration as its long-term mission planning goal, there are a plethora of exploration missions that can be conducted from the Deep Space Gateway that can extend our knowledge of the solar system and prepare for those future missions. NASA's international partners are keenly interested in the exploration of the lunar surface and the potential utilization of lunar resources. Establishment of a permanent lunar surface base could provide both experience for astronauts and potential resources that can be utilized to support the Mars missions. Routine and efficient access to the lunar surface will be critical in the development of these missions and will establish their effectiveness for supporting the deep space exploration missions. A reusable transportation system that can deliver crew and cargo from the Deep Space Gateway to the lunar surface will expand the capability for NASA and its partners to prepare to take humanity further out into the solar system.

#### Design Requirements and Constraints

- Design a reusable Lunar surface access vehicle
  - The vehicle should enable delivery of payload and/or crew to anywhere on the surface of the Moon from the Deep Space Gateway and back

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- The vehicle should be able to operate in either a crew delivery mode or cargo delivery mode. Design of the vehicle should allow for capability of switching between the two modes
- In crew mode, the vehicle should support a crew of four (4) astronauts for the duration of the transit from the Deep Space Gateway to the lunar surface and should support the crew without resupply from surface assets for a minimum of 24 hours on the surface
- In cargo mode, the vehicle should have a payload capacity of at least fifteen metric tons (15,000 kg) to the surface of the Moon and can return at least ten metric tons (10,000 kg) of payload from the surface back to the Deep Space Gateway
  - Payload to the surface could include components for surface habitat, rovers, or crew supplies
  - Payload back to the Deep Space Gateway could include materials or resources that was mined from the lunar surface
- The vehicle should be able to make multiple trips to the lunar surface and back to the Deep Space Gateway utilizing propellant resupply from the Deep Space Gateway
- Design and define the mission operations, including orbit transfer, station keeping, and other maneuvers necessary to deliver payload to/from the lunar surface
  - Assume the Deep Space Gateway is in a stable Near Rectilinear Halo Orbit[2,3]
  - Determine the propulsive cost and time of flight of a range of landing sites from equatorial to polar
  - Define the design requirements for trajectory and orbital maneuvers for both the crew and cargo mission modes and determine and describe the transit strategies for the both and discuss how each mode drives the design of the vehicle
  - Determine the station keeping, orbital phasing and rendezvous, and proximity operation for the vehicle, assuming the Deep Space Gateway is the passive vehicle in all docking sequence
- Perform trade studies on vehicle system options at the system and subsystem level to demonstrate the fitness of the chosen vehicle design. It is highly desirable to use technologies that are already demonstrated on previous programs or currently in the NASA technology development portfolio
- Discuss selection of subsystem components and the values of each of the selection and how the design requirements drove the selection of the subsystem
- Discuss the estimated lifetime of each of the components and determine the lifetime of the vehicle and number of surface trips the vehicle can be expected to make during its lifetime, and any potential replacement strategies that could extend the lifetime of the vehicle

- Describe in detail how the vehicle will be deployed to the Deep Space Gateway, whether any on-orbit assembly or rendezvous of components will be required and what system would be required to assist in the integration of the vehicle
- The cost for the vehicle shall not exceed \$10 Billion US Dollars (in FY17), including design development test and evaluation (DDT&E) and theoretical first unit (TFU)
- The cost cap includes launch costs to deploy the vehicle
- The vehicle shall make its first trip from the Deep Space Gateway to the lunar surface no later than December 31, 2028

## 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 but not exclusive. 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) Requirements Definition – should include the mission and design requirements at the vehicle, system, and subsystem level
- 2) Concept of Operation – A detailed concept of mission operation should be included to describe all phases of the mission and to demonstrate the realization of the mission requirements set in section 1
- 3) Trade Studies – should include the trade studies for the vehicle architecture and mission operations, should discuss in detail the how the system level requirements are developed from mission requirements and describe the pro and cons of each subsystem options and how the decisions are made to form the final vehicle concept
- 4) 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, payload and sensors, interface with the Deep Space Gateway, and mission concept of operations. A mass and power budget should be included, broken down by subsystem, with appropriate margins. A summary table should be prepared showing all mass, power and other resource requirements for all flight elements/subsystems with appropriate PDR-level margins.

5) 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 others. 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.

6) 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

7) Summary and References. A concise, 5-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 5 sections, as well as the items identified under the “project should” section can be found, is mandatory.

#### Supporting Data

Technical questions can be directed to Patrick Chai ([patrick.r.chai@nasa.gov](mailto:patrick.r.chai@nasa.gov)) or William Tomek ([william.g.tomek@nasa.gov](mailto:william.g.tomek@nasa.gov)).

#### References

[1] <https://www.nasa.gov/feature/deep-space-gateway-to-open-opportunities-for-distant-destinations>

[2] Whitley, R., et. al., “Cislunar Near Rectilinear Halo Orbit for Human Space Exploration.” NASA NTRS. JSC-CN-35648.

[3] Zimovan, E., Howell, K., David, D. “Near Rectilinear Halo Orbits and Their Application in Cis-Lunar Space.” IAA-AAS-DyCoSS3-125.

## 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 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 2019 (11:59 pm Eastern Time)
- Proposal delivered to AIAA Headquarters — 10 May 2019 (11:59 pm Eastern Time)
- Announcement of Winners — 31 August 2019 (11:59 pm Eastern Time)
  - Engine Design Competition dates
    - Letter of Intent – 14 February 2019 (11:59 pm Eastern Time)
    - Proposal submitted, via online submission site to AIAA Headquarters – 16 May 2019 (11:59 pm Eastern Time)
    - Round 1 evaluations completed – 30 June 2019 (11:59 pm Eastern Time)

Round 2 presentations at AIAA Propulsion and Energy Forum 2019

### 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.

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- 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 25 MB.
  - Electronic report files must be named: “2019\_[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

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listed below.

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 \$1,000 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 – Electric Vertical Takeoff and Landing (E-VTOL) Aircraft
- Undergraduate Team Aircraft – Thin Haul Transport and Air Taxi
  - 1<sup>st</sup> Place: \$500; 2<sup>nd</sup> Place: \$300; 3<sup>rd</sup> Place: \$250
- Undergraduate Individual Aircraft – Power Line Survey Unmanned Aircraft Systems
  - 1<sup>st</sup> Place: \$1,000; 2<sup>nd</sup> Place: \$500; 3<sup>rd</sup> Place: \$300

### **Engine Design Competition**

- Undergraduate Team Engine –Candidate Engines for Hybrid Electric Medium Altitude Long Endurance Search and Rescue UAV
  - 1<sup>st</sup> Place: \$500; 2<sup>nd</sup> Place: \$300; 3<sup>rd</sup> Place: \$250

### **Space Design Competition**

- Undergraduate Team Space Design – Reusable Lunar Surface Access Vehicle
  - 1<sup>st</sup> Place: \$500; 2<sup>nd</sup> Place: \$300; 3<sup>rd</sup> Place: \$250

### **Structures Design Competition**

- Graduate Team Structures – Design of the Structure for a VTOL Taxi
- Undergraduate Team Structures – Design of Deployable Solar Array Structure
  - 1<sup>st</sup> Place: \$500; 2<sup>nd</sup> Place: \$300; 3<sup>rd</sup> Place: \$250

### **Missile Systems Design Competition**

- Undergraduate Team Missile Systems - Design of a Long Range Strategic Missile
  - 1<sup>st</sup> Place: \$500; 2<sup>nd</sup> Place: \$300; 3<sup>rd</sup> Place: \$250

### **Proposal Requirements**

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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 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.