2021 – 2022 AIAA Foundation Undergraduate Space Mission Design Competition

I. RULES

1. All undergraduate AIAA branch or at-large Student Members are eligible and encouraged to participate.

2. An electronic copy of the report in MS Word or Adobe PDF format must be submitted to AIAA Student Programs. All materials, including letters of intent and final reports, **must be submitted online via www.aiaa-awards.org – AIAA will not accept for submission any materials mailed to the AIAA office.**

3. A "Signature" page must be included in the report and indicate all participants, including faculty and project advisors, along with their AIAA member numbers.

3. Design projects that are used as part of an organized classroom requirement are eligible and encouraged for competition. Designs submitted must be the work of the students, but guidance may come from the Faculty/Project Advisor and should be accurately acknowledged.

4. The top three design teams will be awarded certificates for their accomplishment. Money awards pending funding availability. Certificates will be presented to the winning design teams for display at their universities, and a certificate also will be presented to each team member and the faculty/project advisor. Representative from each of the top three place design teams will be offered an opportunity to present the team's work at the AIAA ASCEND Conference. Teams are responsible for their own travel arrangements and conference registration. AIAA may provide a small stipend, pending funding availability.

5. Projects should be *no more than 100 (total) double-spaced typewritten pages and typeset should be no smaller than 10 pt Times* (including graphs, drawings, photographs, and appendices) on 8.5" x 11.0" paper. Up to five of the 100 pages may be foldouts (11" x 17" max).

6. More than one design may be submitted from students at any one school. Team competitions will be groups of not more than ten AIAA branch or at-large Student Members per entry. Individual competitions will consist of only 1 AIAA branch or at-large Student Member per entry.

II. 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 and keyed accordingly:

1. Demonstrate a thorough understanding of the Request for Proposal (RFP) requirements.

2. 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.

3. Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, systems analyses, 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.

4. Include tradeoff studies performed to arrive at the final design.

5. Provide a description of automated design tools used to develop the design.

III. 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.

IV. Request for Proposal

Martian Moons Exploration Excursion Vehicle

Background

To achieve the audacious goal of landing human on the surface of Mars and returning them safely back to Earth, an incremental exploration approach provides the safest and most sustainable results. Therefore, NASA and international partners are planning the next steps of human exploration by first establishing assets near the Moon and Lunar surface where astronauts will build and test the systems that are needed for deep space exploration with eventual human missions to the surface of Mars. This approach ensures all of the systems used for Mars exploration are thoroughly tested in the relevant environment. The biggest challenge with Mars surface mission is the development of large scale Mars descent systems. The largest payload ever landed on the surface of Mars currently is the Perseverance Rover at just over 1 metric ton of landed payload mass. To support a crewed surface mission, the landed payload mass capability must be increased by order of magnitude, which presents significant challenge to the exploration architecture roadmap.

Without the landers to bring the surface assets and the crew to the surface of Mars, the incremental exploration strategy stalls with the crew reaching Martian orbit. Previous architecture analysis proposed the possibility of crew exploration of the Martian moons to provide more time for the descent system to be developed and tested. Unfortunately, these endeavors typically involves development of additional hardware that does not directly contribute to the efforts of surface missions and potentially draws resources away from the primary mission. Thus, these missions are typically not considered within a Mars surface mission integrated exploration strategy. However, with the recent proliferation of commercial launch services and the interests in commercial space endeavors, these missions could potentially take on new life without creating significant detours from the primary mission. A low cost, commercially procured, Martian Moon Exploration Excursion vehicle could provide the bridge in the incremental path between the Martian orbit and the surface, allowing for more experience with operating crew missions away from Earth's sphere of influence and preparing for the eventual surface missions.

Design Requirements and Constraints

- Design an Exploration Excursion Vehicle (EEV) for the Martian Moons: Phobos and Deimos
    - The EEV should have the capability to support 2 crew members to visit both Martian moons
    - The total mission shall not exceed 30 days, including transit time from the Deep Space Transport (DST) vehicle to the destination and back.
    - The EEV should be able to support sample retrieval from each destination, with a minimum sample retrieval mass of 50 kg from each moon.
    - The 2 crew member will remain inside the EEV during the mission, with no planned EVA capability
    - The team can decide to plan for a single sortie to visit both moons, or multiple sorties from the DST, as long as the total duration not exceed 30 days

- Research and define appropriate scientific objectives for the crew to during the mission sortie, to include the sample retrieval at the destination
    - The EEV should have the ability for the 2 crew members to conduct exploration of the moons to produce significant scientific understanding of the moons.
    - These scientific objectives should advance our knowledge of both moons and improve our capability to explore future destinations across the solar system
    - Describe scientific experiment equipment that are necessary to achieve these scientific goals
    - Up to 200kg of science equipment can be delivered to the EEV with the crew on the DST, but they are limited to what the crew can carry into the EEV through the pressurized tunnel
    - Describe the sample retrieval mechanism and how the samples will be stored during the sortie and how the sample will be transferred to the DST for the return trip to Earth. The sample must be quarantined from the crew until Earth arrival for scientific study

- Design and define the mission operations, including orbit transfer, station keeping, and other maneuvers necessary for mission sortie
    - The EEV shall autonomously dock with the DST, and 2 crew will transfer into the EEV to begin the mission sortie
    - Discuss the mission modes and maneuvers required to complete the roundtrip missions to visit both Martian moons
    - Discuss the time and operation required at each destination to support the science objective as defined by the team

- Describe in detail how the vehicle will be deployed to Mars in preparation for the crew arrival.
    - Assume the Crew arrives in a DST vehicle in a Mars 5-sol parking orbit ~~on January 1, 2040~~ in the summer of 2040, between May and August, the EEV must already be in 5-sol orbit awaiting for Crew arrival before ~~this date~~ the crew arrive in this mission opportunity[1]
    - Discuss the launch opportunity for the EEV and the propulsion system required to deliver the EEV to Mar and the interplanetary trajectory for the EEV
    - Describe the selection of launch vehicle and the selection process that led the team to the decision

- 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

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[1] RFP UPDATED March 1, 2022

- Discuss selection of subsystem components and the values of each of the selection and how the design requirements drove the selection of the subsystem

- The cost for the vehicle shall not exceed $1 Billion US Dollar (in FY21), including the launch cost.

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 necessary. 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 with the exception of the 5 page executive summary which must be place at the beginning of the report.

1) Requirements Definition – the report should include the mission and design requirements at the vehicle, system, and subsystem level. The requirements definition should demonstrate the team's understanding of the RFP *Design Requirements and Constraints* and lay the foundation for the design decisions that follow.

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 in *Design Requirements and Constraints*. The report should show that the team has performed historical analysis of similar concepts to evaluate the merits and deficiencies of previous designs, and demonstrate that alternative concepts were considered while providing justification for the chosen concept.

3) Trade Studies – the report should include the trade studies for the vehicle architecture, mission operations, and subsystem selections, and must discuss in detail how the system level requirement are developed from mission requirements by describing the pro and cons of each subsystem options. The report must discuss how each subsystem level decision is made, with description of the selection metrics and their associated weightings when appropriate, and provide detailed discussions on how each decision impact system level metrics such as cost, schedule, and risk.

4) Design Integration and Operation – The report should discuss how the trades selected in section 3 are integrated into a complete architecture. This section should discuss design of all subsystems: structures, mechanisms, thermal, attitude control, telemetry, tracking, and command, electric power, propulsion, payload and sensors, and the mission concept of operations. Discussion on the extensibility of the overall system design and how it can support future exploration mission should be included. A mass and power budget must be included, broken down by subsystem, with appropriate margins assigned to each system based on industry standards. The report must clearly describe all of the tools and methods utilized for the system and subsystem design and provide brief description of the inputs, outputs, and assumptions for the design. A discussion on the validation of the tools and methods must be included. A summary table should be prepared showing all mass, power, and other resource requirements for all flight elements/subsystems with the appropriate mass and power margins clearly labeled and discussed.

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 other requirements for the design. Estimates should cover design, development,

manufacture, assembly, integration and test, launch operations and checkout, in-space operations, and final delivery to the Martian surface and return to the Earth. Use of existing/commercial off-the-shelf hardware is strongly encouraged. Advanced technology utilization must be fully costed with appropriate cost margin applied. A summary table should be prepared showing costs for all WBS elements distributed across the various project life cycle phases. The report should discuss the cost model employed and describe the cost modeling methods and associated assumptions in the cost model. The cost analysis should provide the appropriate cost margin based on industry standards.

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. Any advanced technology assumption should have corresponding technology development schedules and costs associated with the technology and appropriate contingency plans should be discussed.

7) Summary and References. A concise, 5 page "Executive Summary" of the full report must be included and clearly marked as the summary at the beginning of the report. The executive summary should provide a clear sense of the project's motivation, process, and results. References should be included at the end. A compliance matrix, listing the page numbers in the report where each these section as well as the items identified under the *Design Requirements and Constraints* and *Deliverables* sections can be found, is mandatory.

Supporting Data

Technical questions can be directed to Patrick Chai (patrick.r.chai@nasa.gov) or studentprogram@aiaa.org