2023 AIAA Undergraduate Team Space 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 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 one of AIAA's Forum or 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 (10) AIAA branch or at-large Student Members per entry. Individual competitions will consist of only one (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 and provide clear and concise rationale for decisions.

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

Dual Lander Mars Ascent Vehicle

Background

NASA, along with industry and international partners, continue to explore options to achieve the horizon goal of landing humans on the surface of Mars by 2040 and returning them safely back to Earth. One of the most significant hurdles in achieving this ambitious goal is the return portion of this journey. Through the Mars science rover programs, NASA has gained significant experience with landing assets on the surface of Mars, but for a crewed mission, returning the crew safely back to orbit from the surface will be an unprecedented achievement. Despite the significant experience with launching systems from Earth's surface into orbit, launching hardware from the surface of a distant planet, with little to no ground support structure, and up to 20 minutes of communication delay remain the most significant challenge of any crewed Mars mission. In addition, limitation in the current entry, decent, and landing technology necessitates a piecewise approach in the assembly of the Mars Ascent Vehicle (MAV). The NASA Strategic Analysis Cycle 21 Human Mars Architecture[1], a two-lander approach to this problem was proposed. In this concept, the MAV lands on the surface of Mars without the propellant necessary for the ascent on one lander, while a second lander land the necessary propellant for the MAV. An autonomous robotic system is utilized to transfer the propellant to the MAV. This request for proposal seeks an innovative and cost-effective design for the implementation of this Mars surface concept.

Design Requirements and Constraints

- Design a two-lander concept to support returning two crew from Mars Surface to Mars 5-sol parking orbit
    - The two landers each have landed payload capacity of 25 metric ton (25,000 kg)
    - The landers are launched on 8.4m diameter payload fairing, and will be constrained by the fairing dimensions[2]

[1] https://ntrs.nasa.gov/citations/20210026448
[2] https://ntrs.nasa.gov/citations/20170005323

- One of the landers must also carry a 10kW Fission Surface Power unit and has a control mass of 5 metric ton (5,000 kg), this will supply the power necessary for the mission
    - Design all necessary elements to support this concept of operation, and provide detailed description of the operation of the concept
    - The two landers depart Earth no later than the 2037 mission opportunity, with Mars arrival in no later than July of 2038. The crew arrives at Mars mid-2040, and the MAV must be ready to support crew ascent by July 1, 2040.
    - The landers have landing accuracy of 1 km, team should describe operation assuming the two landers are ~1km apart from each other
    - Teams do not need to design or describe the transit from Earth to Mars, but should describe the overall operation of the concept starting with Mars landing and ending with the crew ascent to Mars 5-sol.
    - Teams should discuss packaging and integration with an entry, descent, landing system from current options that are being considered for landing payloads on Mars[3]

- Design elements to support the concept for returning crew from surface of Mars to orbit
    - The MAV should have the capability to support 2 crew members for the duration of the ascent from the surface to an awaiting Deep Space Transit (DST) vehicle in Mars 5-sol parking orbit
    - The MAV should also have capacity to return 50kg of Mars samples (in addition to the crew mass) from the surface to rendezvous with the DST in 5-sol.
    - Team should describe the operational concept for the MAV, determine performance requirements, and detail the concept of operation of the MAV from landing on the surface to rendezvous with the DST in the 5-sol parking orbit.
    - An autonomous robotic system should be designed to transfer propellant into the MAV
    - Describe any additional systems that are required to enable this 2-lander Mars ascent concept of operation

- Design and define the mission operations, including initial setup, system checkout, propellant transfers, and other operations necessary to prepare the MAV
    - Team should analyze and describe the power requirement of the various elements, and detail the operation to address their power needs, and discuss options if the single 10kW power source is insufficient to address the element's power needs
    - Team should provide a concept of operation to describe the propellant transfer process and timeline associated with such operation, including but not limited to, capacity of the transfer vehicle, traverse time, propellant loading time, etc.
    - Team should provide analysis on the communication delays between Earth and Mars and describe how the autonomous refueling operation would be impacted by the delays and any mitigation options for any communication blackouts

- 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

- The cost for the vehicle shall not exceed $4 Billion US Dollar (in FY22), including development, hardware, and operation cost of the elements. Cost of the landers and the launch vehicles are not included in this cost cap.

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[3] https://ntrs.nasa.gov/citations/20200002905

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

Cianciolo, A., et. al. "Human Mars Entry, Descent, and Landing Architecture Study: Phase 3 Summary." 2022 AIAA SciTech Forum. Orlando FL. https://ntrs.nasa.gov/citations/20200002905

Rucker, M., et. al. "NASA's Strategic Analysis Cycle 2021 (SAC21) Human Mars Architecture." 2022 IEEE Aerospace Conference. Big Sky, MT. https://ntrs.nasa.gov/citations/20210026448

Smith, D., et. al. "Space Launch System (SLS) Mission Planner's Guide." NASA Technical Publication. https://ntrs.nasa.gov/citations/20170005323