2023-2024 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. Report 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

Human Enabled Venus Robotic Exploration

Background

From the National Academies Planetary Science Decadal Survey:

> *"Venus is once again back in the spotlight. In the coming years and decades, we will continue to develop the recently emerging view of Venus as a complex, active world, augmented by new spacecraft data, ever more sophisticated climate modeling, and the finding of an increasing number of Venus-size rocky worlds in close proximity to their host stars. And with more and more attention focused on understanding and mitigating human-driven climate change on Earth, Venus' runaway greenhouse provides a dramatic example of a planet where self-regulating climate feedbacks have failed.*
>
> *What we have also learned over the past decade in particular is that if we are to fully understand Venus, then we need to study it as a system. No one set of measurements will solve the mystery that is Venus, just as no one mission has answered all our questions of Mars, nor of the Moon, nor any planetary body. But as important as new measurements of the closely coupled Venus surface, atmosphere, and space environment are, it is just as important that we have sufficient laboratory data to predict, calibrate, and make sense of such measurements as well."*

From the Keck Institute Space Studies Workshop Final Report Title "Meeting with the Goddess: Venus Science Enabled by Human Proximity."

> *"The Human Proximity Era of Venus Science: Surface investigations from ROVs*

Perhaps the greatest scientific advantage of astronaut proximity to Venus is for near-real time and rapid control of robotic vehicles over and on Venus; and for responding in real time to serendipitous discoveries or other changes. Thus, while the crew will have a scientific plan to execute, they will be flexible in how they execute it; this "flexecution" approach to field science has been ratified by the Apollo lunar surface expeditions and numerous analog field geology exercises.

Given the wide variety of terrains revealed by Magellan's relatively low resolution global mapping, and the wide range of surface ages including probably zero age actively forming volcanic terrains, it is likely that some of the surface terrains of highest science and exploration value will be extremely complex and varied. The exploration of such environments will be greatly facilitated by human-in-the-loop decisions enabling surface exploration with remote vehicles operated by astronauts working from near-Venus space.

Having humans within a light-minute to a light-second or less from Venus would enable a fast-driving rover to cover many geologic units in a short time, thus maximizing scientific productivity at Venus' harsh mean surface temperature of ~464˚C. Advances in high-temperature power sources and electronics could enable a ~week long surface survival of such a robotic asset. By driving many times faster than the Mars rovers with a human directing the speed and direction of travel, coupled with near-real time audio, image and video uplink, and teleoperated sample selection and handling, geologic surveys would be efficient. The rover would only need to stop for geochemical analysis, such as from laser induced breakdown spectroscopy (LIBS), Raman spectroscopy, or x-ray diffraction (XRD); multispectral stereo imaging would occur during the fast-paced drive, allowing for geomorphometric, topographic, and compositional mapping from the resulting dataset. Astronauts would respond almost immediately to serendipitous discoveries and adjust the rover's actions accordingly. However, wheeled, driveable rovers are only one class of remotely operated vehicle possible for Venus. Near-surface, or variable altitude aerial vehicles that float like balloons, or fly like airplanes or fan-driven drones are others."

Design Requirements and Constraints

- Design a robotic science mission that maximizes science return with human in the loop as part of the mission operation. Primary goal is to help answer: "What added science can be achieved with crew around Venus?"
    - Clearly define science objectives as part of the mission design and describe how human in the loop provides additional science return as compared to fully autonomous robotic mission. (Refer to the National Academies Planetary Science Decadal Survey to focus Science Objective needs).
    - Provide a detailed description of the scientific approach, including traceability of specific measurements to science objectives, planned observations, design of the science instruments, data and/or sample collection method, data and/or sample collection storage process, and data and/or sample collection periods.
    - Describe the full integrated concept of operation for the end-the-end robotic mission. From launch, deployment, transit, arrival at Venus, operational needs prior to crew arrival, the interaction of the orbital crew with the robotic system, and final disposal or post crew directed operations.
    - Describe in detail the operational concept of the crew-robotic interaction, what actions are required by the crew, how the science data is gathered, and how the orbital crew is directly supporting the robotic mission and enabling added science value.
- The RFP request focus on the robotic science mission, making the following assumption on the crewed mission:
    - The design and implantation of the crewed portion of the mission is outside the scope of this RPF
    - Assume a crew of 4 in parking orbit around Venus as dictated by the robotic mission need.
    - The operational mission with crew in the loop should be no more than 30 Earth days in duration.

- Describe in detail communication line of sight, communication data rate, parking orbit orientation and period, and other potential operational needs on the crew systems to support the robotic mission.
- Describe in detail, any specialized equipment, instrument, or other system that are needed to be part of the crew system to enable the necessary science return. This specialized equipment can be delivered as part of the crew transportation system. While the team is not required to analyze the impact of these specialized equipment on the crew transportation system, they need to be accounted for within the overall mission cost constraint.

- 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 system 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.

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

- The cost for the mission shall not exceed $1 Billion US Dollar (in FY23), including development, hardware, and operation cost of the robotic science mission. The cost cap does not include the crewed mission portion, as the crewed mission portion is out of scope of this study. However, if specialized equipment is required to support the robotic mission, the cost of these system needs to be accounted for within the cost constraint.

- The mission should launch no later than December 31, 2037. With completion of the crew operated science mission no later than December 31, 2039.

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 the *RFP 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. 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.

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) Mission and operation summary – an integrated roll up of all the subsystems into a mass and power Work Breakdown Structure, showing mass and power budget, broken into subsystems, with description of the margin assigned to each system based on industry standards. 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.

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

8) 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

National Academies of Sciences, Engineering, and Medicine. 2022. Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032. Washington, DC: The National Academies Press. https://doi.org/10.17226/26522 https://nap.nationalacademies.org/catalog/26522/origins-worlds-and-life-a-decadal-strategy-for-planetary-science

Keck Institute for Space Studies. 2022. "Meeting With the Goddess: Venus Science Enabled by Human Proximity." California Institute of Technology, Pasadena, CA. https://doi.org/10.7907/68mv-np46