RASC-AL
Revolutionary Aerospace Systems Concepts Academic Linkage

NASA

Revolutionary Aerospace Systems Concepts

Academic Linkage (RASC-AL) is a student design competition that is sponsored by NASA and managed by the National Institute of Aerospace. RASC-AL is open to undergraduate and graduate university-level students studying fields with applications to human space exploration (i.e., aerospace, bio-medical, electrical, and mechanical engineering; and life, physical, and computer sciences). RASC-AL projects allow students to incorporate their coursework into real aerospace design concepts and work together in a team environment. Interdisciplinary teams are encouraged.

NOIs are due **November 8, 2013**, and abstracts are due **January 19, 2014**. Upon review of abstracts, selected teams and their faculty advisor will be invited to provide a written report, poster, and oral presentation at the 2014 RASC-AL Forum, June 17-19 in Cocoa Beach, FL. Each team will receive a stipend to help facilitate full participation in the competition, and the two top placing teams will receive a presentation slot at a major aerospace conference to present their concepts.

Background Information for RASC-AL Themes

The goal for this year's RASC-AL competition is to come up with a system design that leverages existing or planned space habitat/logistics carrier structures and to configure a small crew-tended outpost in cis-lunar space that can augment the Orion to stay at the cis-lunar destination for at least 30 days while also providing them an airlock based EVA capability. The entire outpost (including the first 30 days of logistics) must be delivered to cis-lunar space on a single existing or planned ELV. **Teams can choose one of the themes below to decide what mission the facility will enable Orion to complete. Within each theme, teams will select one or more enabling design elements to validate - either through detailed analysis or proto-type development.** This crew-tended outpost in cis-lunar space may be required to operate in conjunction with a possible asteroid redirect mission where the facility would be docked to the asteroid return vehicle to facilitate crewed exploration of the returned asteroidal material.

2014 NASA RASC-AL THEMES

Enabling Long Duration Missions through Holistic Habitat Design

Habitats designed for exploration missions are large, massive elements which must integrate many complex subsystems to support crew health throughout a mission. After the Orion crew capsule, the transit habitat is the next biggest "gear" in human exploration architectures. This is because it must be launched from the Earth's surface, injected into its destination transfer orbit, braked into orbit about the destination, then injected into the return trajectory back to Earth. Substantial mass reduction in the habitat system (which includes its structures, support systems and logistics) will result in significantly fewer launches or more mass available to decrease mission time and risk. So, significant reduction (on the order of 50%) of the injected habitat and its logistics systems from heritage based technology can yield huge benefits for human exploration.

Targeting mass reduction in a habitat system is more than just targeting each sub-system individually with mass cuts. It requires a fresh look at the interplay across primary/secondary structure, shielding, reliability, automation, maintenance, logistics packaging, sparing strategy (ORU vs. board level) repurpose/reuse/recycle of materials, and risk posture. Utilizing a systems perspective to identify novel ways these systems can interact could yield significant improvements, even in the absence of the application of advanced technologies and more so with them.

The following are some notional examples of system solutions which could be implemented on the cis-lunar outpost in preparation for enabling human exploration of deep space destinations:

Reliability, Maintainability and Automation: If current methods for maintaining and repairing systems are implemented for deep space missions, mass and volume requirements for spare parts could be very large. This is because many of these missions lack the option to abort and safely return home in the event of an emergency. Novel approaches such as low-level repair, commonality, scavenging, and in situ manufacturing offer the potential to significantly reduce the amount of spares that must be manifested. In addition, ISS crew currently spends the majority of their available time performing maintenance and fixing things. That is not why we send people to space. A combination of situational awareness (knowing something is about to fail), in situ diagnostics, standardized card level replacement units, and robots capable of doing routine maintenance can free crew time up for exploration and reduce risk.

Structures: Advanced materials offer the potential to significantly lighten primary and secondary structure. Current ISS heritage approaches have secondary structures sized for launch loads that are basically overdesigned for the rest of the life of the system in zero-G. An advanced secondary structure approach could be to design structure so that much of it could be discarded after launch or repurposed for other functions, such as: shielding, furniture, compartment walls, or melted down and remanufactured as spare parts.

Logistics: Heritage logistics systems used on ISS have a high tare penalty. Often times the mass of the pressurized carrier and the packaging materials containing the goods are more massive than the goods themselves. If this packaging can be reduced, discarded after launch, or repurposed through 3D printing/in-space manufacturing for alternate functions (like filters for ECLSS or radiation shielding), significant reductions in injected mass can be achieved. Of course closure of environmental systems can greatly reduce logistics needs, but only if the mass of the filters and spare parts does not exceed the savings in consumables!

Combining the three areas above (and possibly many others) into an integrated system design may be the only way we can enable sending humans into deep space. As these concepts are refined, system/sub-system prototypes need to be developed and tested to validate the design assumptions and drive out innovation. The team can focus on one of these innovations, and **demonstrate through analysis or prototyping** its potential benefit in the context of how it would enable future deep space missions as part of the overall focused cis-lunar outpost design.

Human Assisted Sample Return

A key potential function of a small crew-tended outpost in cis-lunar space revolves around crew support for exploration-enabled science. One particular such activity involves samples that may be returned from multiple destinations. A small crew-tended outpost in cis-lunar space could serve as a "sample return way-station" between a robotic spacecraft returning from a planetary exploration mission and Earth. It is expected that future robotic missions to exploration destinations, such as Earth's moon (in particular, the South Pole-Aitken Basin), NEAs, and Mars, will focus on planetary exploration and the collection and caching of samples for eventual delivery to Earth for detailed analysis.

For example, the recent Mars 2020 rover mission Science Definition Team Report noted as one of the four key features of the mission "Acquiring a diverse set of samples intended to address a range of Mars science questions and storing them in a cache for potential return to Earth at a later time." (Report of the Mars 2020 Science Definition Team, http://mepag.jpl.nasa.gov/reports/MEP/Mars_2020_SDT_Report_Final.pdf; p. 6). There are a number of issues regarding planetary sample return to a cis-lunar spacecraft that need to be addressed, such as:

- Tracking, capture, and docking/berthing of a sample return spacecraft from multiple destinations (in particular, NEAs, Earth's moon, and Mars)
- Acquisition of the sample from a robotic carrier spacecraft and safe transport into the cis-lunar spacecraft laboratory environment
- Careful handling of samples that may contain Mars microorganisms, including contamination control
- In-situ sample analysis (including both geological and biological samples)
- Sample curation, including preparation for safe Earth return (with the crew or via separate robotic spacecraft)

The team can focus on one or more of these functions, and **demonstrate through analysis or prototyping** the merits of one or more approaches to create an innovative solution for providing the required function as part of the overall focused cis-lunar outpost design.

Tele-operated Robot

On-orbit crew can provide unique capabilities to space exploration, however, as exploration continues beyond low-Earth orbit, communication delays, radiation, difficult surface terrain and other risks create needs for robotics to assist in crewed exploration. A crew tended cis-lunar facility could provide a unique proving ground for new technologies and increasing robotic capabilities in preparation for future exploration.

Robotic capabilities to consider include:

Teleoperation of a Lunar surface asset: As crew and robotics extend further from Earth, communications delays can limit the speed of operation, range of tasks that can be completed, and terrain that can be explored. While it is not practical to put the entire robotic support team in the vicinity of the asset, a small crew in the proximity to the asset can provide low-latency control and alleviate some of these issues. A cis-lunar facility in a distant retrograde or L2 orbit could be used to test these operations and capabilities while providing new scientific context of the lunar surface by operating an asset on the far side of the moon which has no direct communication to Earth.

Free-flying EVA inspection: Future exploration will require longer flight times and the increased need for inspection, maintenance, and potential repair of external components of the crewed systems. However, the radiation environment beyond low-Earth orbit, combined with the long mission durations, increases the risk of multiple EVAs. This risk can be addressed by having a tele-operated free-flying inspection scout that can be deployed to perform routine inspection and some minimal maintenance and repair.

EVA crew assistant: In the event that crewed EVA is required for maintenance or repair, EVA time can be minimized by utilizing a robotic assistant to increase the efficiency of the EVA. These assistants would work alongside the crew, responding to both IVA and EVA crew control. A tele-operated or voice commanded EVA assistant could also offer a new paradigm for EVA exploration of a captured asteroid where the robotic EVA assistant takes the place of the second human in the "buddy" system.

IVA crew assistant: Long duration exploration will require multiple routine tasks such as inspection, maintenance, monitoring science experiments, etc. that when added up can require a large amount of crew time. This not only reduces the other tasks that crew could be performing, but also reduces morale by requiring the crew to perform monotonous, repetitive tasks and increases the chances of human error. If a mission was designed to take advantage of an IVA assistant, it could alleviate these issues and also simplify the design of the crewed systems by eliminating the need for crewed access to certain systems.

The team can focus on one or more of these functions, and **demonstrate through analysis or prototyping** the merits of one or more approaches to create an innovative solution for providing the required function as part of the overall focused cis-lunar outpost design.

For all RASC-AL Projects, attention should be given to the following:

- Synergistic applications of NASA's planned current investments
- Unique combinations of the planned elements with new innovative capabilities/technologies to support crewed and robotic exploration of the solar system

Scenarios should address novel and robust applications, with an objective of NASA sustaining a permanent and exciting space exploration program.

Key elements that each RASC-AL project will be evaluated on include:

- Synergistic application of innovative capabilities and/or new technologies for evolutionary architecture development to enable future missions, reduce cost, or improve safety;
- Scientific evaluation and rationale of mission operations in support of an exciting and sustainable space exploration program;
- A mission concept of operations that includes what occurs at the facility before, during, and after crewed visits (over a period of years);
- Key technologies, including technology readiness levels (TRLs), as well as the systems engineering and architectural trades that guide the recommended approach;
- Reliability and human safety consideration in trading various design options; and
- Realistic assessment of project plan and execution of that plan, including inclusion of a project schedule and test plan, as well as development and realistic annual operating costs (i.e., budget).