The current NASA baseline in-space stage for transporting crew and cargo between cis-lunar space and the Mars system is a hybrid concept consisting of a low-thrust Solar Electric Propulsion (SEP) system combined with a high-thrust chemical system. Much like hybrid cars here on Earth, this hybrid transport utilizes the high-thrust chemical system when additional acceleration is needed, such as to start and stop close to planetary bodies, and then switches to the more efficient low-thrust electric system deeper in space. This combined approach provides an efficient system with the potential for multiple reuses.

Theme 1 challenges teams to design a version of this stage that uses innovative combinations of operations and technology to improve on the NASA baseline. Primary requirements for proposed reusable hybrid propulsion stage concepts include:

- Launched partially fueled on a block 1A SLS, or partially fueled with the baseline habitat (~20 t without logistics) on a block 2B SLS (reference SLS planners guide)
- Refuelable in cis-lunar space via propellant launched from Earth on SLS or any other launch system
- Once fueled and provisioned in cis-lunar space:
  - can transport the baseline habitat with crew and logistics (~49 t total: 22 t hab and 27 t logistics) on a conjunction class round-trip mission to a 5-sol Mars orbit, departing from and returning to a lunar distant high-Earth orbit
  - can also transport (separately) a fully burdened Mars lander (~50 t) to a Mars 5-sol orbit, and return (stage only) back to cis-lunar space so the stage can be reused
- Uses no more than 750 kW BOL (Beginning-of-Life) solar arrays
- Nuclear-powered propulsion concepts are not allowed
- Minimum 15-year lifetime (in space)
- Capable of supporting, at a minimum, three trips to and from Mars

Capabilities and technologies implemented in this concept should be ready for deployment and operations by 2029 and fit into the existing NASA budget extrapolated out to that time.

Theme 2: Artificial Gravity Reusable Crewed Deep Space Transport

The current NASA baseline vehicle for transporting crew and cargo between cis-lunar space and the Mars system is a hybrid concept consisting of a low-thrust Solar Electric Propulsion (SEP) system combined with a high-thrust chemical system interfaced to a large monolithic habitat that transports the crew to Mars and back on a ~1100-day conjunction class mission. This configuration assumes the crew can function for years in a microgravity environment with countermeasures limited to exercise and medical systems.

Theme 2 challenges teams to provide a Mars gravity level during the majority of the time the crew is on the conjunction class mission, while using the same hybrid propulsion stage described in Theme 1. In-space assembly may be used to enable this theme, as well as a broader spectrum of launch vehicles as needed. Primary requirements for proposed artificial gravity system concepts include:

- All of the same requirements listed in Theme 1, with one exception:
  - Baseline habitat will be launched partially outfitted and supplied on a SLS block 1A or block 1B. The size and mass of the fully provisioned baseline habitat should be used, but augmentations and changes in floor plan can be considered for artificial gravity application.

Capabilities and technologies implemented in this concept should be ready for deployment and operations by 2029. Identify what additional budget authority is needed, if any, to enable this concept.
Theme 3: Propellant Resupply Capability

The reusable in-space transportation systems assumed in NASA Mars architectures and identified in Themes 1 and 2 require many metric tons of electric propulsion and chemical propellants to support each Mars mission.

Theme 3 challenges teams to design a system to provide these propellants, including the selection of ground infrastructure to process, load, and maintain the propellants on the launch vehicle(s) of choice, the cadence of the delivery fleet, the propellant tankers that deliver the propellants to the Deep Space Transport, and the systems on the tankers for maintaining and transferring the propellant and docking to the Deep Space Transport. Disposal/reuse of the tankers should also be considered.

Primary requirements for proposed propellant resupply capability concepts include:

- Refueling of the Deep Space Transport occurs in cis-lunar space via propellant launched from Earth, on SLS or any other launch system
- Propellant resupply must support one crewed orbital Mars mission every other opportunity beginning in 2033 and Mars surface mission cargo delivery beginning in 2037 (the requirements for which are available in the open literature, or can be derived from collaborating with a team working on Theme 1 or Theme 2), with the ability to be expanded to support crewed Mars surface missions later
- Nuclear-powered propulsion concepts are not allowed

Capabilities and technologies implemented in this concept should be ready for deployment and operations by 2029. Identify what additional budget authority is needed, if any, to enable this concept.

Teams responding to Theme 3 may focus on one of the following options:

- **Option 1:** Design the propellant resupply capability for the NASA baseline concept
- **Option 2:** Partner/"team" with a university responding to either Theme 1 or Theme 2 to develop a propellant resupply capability for their deep space transport concept.

University A would still be competing with University B for RASC-AL categories, but preference would be given to teamsing universities in the proposal and midterm review gates if they are of good quality. This will be a more challenging approach, but better representative of how both Industry and NASA must partner with other organizations to solve complex engineering problems. To help facilitate this, the RASC-AL website will post a list of all NOI responses.

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

- Adherence to the requirements and constraints of the selected topic and the design competition
- Synergistic application and engineering analysis of innovative capabilities and/or new technologies for evolutionary architecture development to enable future missions, reduce cost, and/or improve safety
- Technical merit and rationale of mission operations in support of an exciting and sustainable space exploration program
- 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 considerations in trading various design options
- Realistic assessment of project schedule and test plan, as well as realistic development and annual operating costs (ie, budget)
- Realistic assessment of partnering and cost sharing scenarios based upon commercial profitability and the ability of international partners to participate given their limited budgets

Helpful Resources: Teams should thoroughly review these four documents on the recommended reading list (found on the RASC-AL Resources Page):

- NASA's Advanced Exploration Systems Mars Transit Habitat Refinement Point of Departure Design
- Integrated Hybrid campaign description from EMC
- Hybrid End-to-End Piloted Trajectory Details
- SLS Mission Planner's Guide

For more information, visit [http://rascal.nianet.org](http://rascal.nianet.org)