The ultimate objective of this Cryogenic Fluid Management (CFM) Technologies solicitation is to demonstrate a variety of critical CFM technologies in a micro-gravity space environment via a deployable or non-deployable test bed.

The initial phase (Phase I) will identify and develop prototype experiments that could be integrated into a universal platform for demonstration of these experiments in their relevant micro-gravity environment.

The second phase (Phase II) of this solicitation would develop a universal and innovative test bed platform that could be launched as a secondary payload on an expendable launch vehicle.

State of the art: CFM technologies are, for the most part, limited to ground tests that do not provide a complete and accurate demonstration of the technologies in their true operational environment. This increases risk in the development of emerging technologies for future applications in the areas of space based propellant depots, low gravity descent and ascent operations, and future space or planetary based architectures.

Areas of interest:

The purpose of these experiments would be to allow testing of:

- Designs for fluid and propellant transfer plumbing
- Multi-layer insulation (MLI) designs
- Various mass gauging designs
- Thermal control and boil-off control designs in a true micro-gravity space environment

Sample technologies in current queue at NASA centers that require testing in such type of platform include:
• Vapor Cooling
• Orientation
• Para-ortho $\text{H}_2$ conversion
• Fluid Transfer Coupling
• Thermodynamic Vent System
• Automated Rendezvous and Docking
• Thick MLI blanket
• Broad area cooling (vapor cooled, active cooled)
• Sun Shield
• Mass gauge
  o Radio Frequency (RF)
  o Pressure Volume Temperature (PVT)
  o Level Sensor (Cryo-Tracker)

• Instrumentation
  o Cryo tracker
  o Mass flow rate (fill, vent)
  o Tank pressure
  o Temperature (liquid, vent, tank wall, transfer lines, structure)
  o System acceleration

• Liquid Acquisition Device (LAD)
• Settling
• Propulsion ($\text{H}_2/\text{O}_2$ thruster, solar thermal)
  o $\text{H}_2/\text{O}_2$ thruster
  o Solar thermal

• Propellant Positional Device (PPD) (magnetic, screen)
• Cryo-Cooler
• Mixing (Vehicle maneuvers (roll), pumps)
• Structural interface (conic, struts)

The identification and design of critical CFM components that could be utilized in future exploration architectures in the space environment are being solicited for this platform. The technologies and future development of the platform supporting them would allow demonstration and proof of concepts for the designs and hardware necessary for mechanisms such as fluid transfers in propellant depots and in planetary spacecraft prior to the actual full development, design, fabrication, and launch of hardware. These CFM technologies and platform would provide a simple, low cost and innovative method to prove technologies and could avoid large and costly design modifications or possible multiple launch requirements for future space based architectures.

A viable option for the low cost approach involves launching as a secondary payload on launch vehicles currently in use such as an Atlas V or Delta IV. Such launch vehicles hold a high level of design maturity, contributing to a huge savings in development costs. In addition, through riding as a secondary payload, a majority of the launch costs could be absorbed by the primary mission. In a typical launch vehicle configuration, the secondary payload is attached to a launch vehicle’s second stage propellant tank beneath the primary payload. After separation of the primary payload, the platform would either deploy and operate as a free flying spacecraft and perform the various
CFM demonstrations, or could remain attached to the propellant tank to prove fluid transfer capabilities, along with additional experiments. A third option is to utilize the residual propellants from the launch vehicle to fill a “receiver” tank on the platform, which would subsequently deploy to perform various additional demonstrations.

The platform would be processed and integrated in the typical fashion of spacecrafts launched today. A platform that remains completely passive (non-operational and containing no commodities) until separation of the primary payload greatly reduces ground-processing requirements. Individual experiments could also be integrated with the platform prior to integration to the launch vehicle to further reduce operational complexities.

The second phase of the project would design a platform so as to encompass additional requirements such as:

- The capability to support and integrate multiple CFM technology experiments per mission
- Demonstrating innovative, fluid transfer designs
- MLI designs
- Various mass gauging designs
- Thermal control and boil-off control designs
- Validation of CFD propellant models
- Testing of propellant management devices
- Mixing pumps
- Thermodynamic vapor cooling systems
- Environmental thermal shielding designs

Design of the platform would need to ensure that it does not impose additional risk to the mission success of the primary payload and is capable of remaining completely passive and inert until the primary payload is successfully deployed. This includes launching with empty tank(s), lines, etc., and maintaining the ability for residual cryogenic propellants to be transferred from the launch vehicle upper stage to the proposed secondary payload upon completion of the primary mission.

Optional configurations could include multiple tanks with self-contained fluids, however the use of residuals, with innovative propellant transfer lines, from an upper stage promotes cost savings in both the propellant commodities, pressurization systems required for pre-launch processing, limit hazard and safety concerns for the primary mission, and the passive nature reduces the complexities added in the analyses and operations required for integration with the launch vehicle and primary mission.

The platform, itself, would contain tank to tank fluid transfer capabilities, avionics, thermal control systems, telemetry capabilities and, if deployable, an attitude control system. The platform design would be capable of interfacing with the launch vehicle separation system and avionics. Additional potential experiments and uses include validation of CFD propellant models, testing of propellant management devices, mixing pumps, thermodynamic vapor cooling systems, and environmental thermal shielding designs.

Performance metrics: A platform that is capable of remaining passive and inert through completion of the primary mission on an EELV. The platform shall be capable of supporting at a minimum of four CFM demonstrations per mission. The designs for the experiments are to be such that they are capable of demonstrating CFM technologies supporting the operational requirements of future space based architectures in cryogenic temperature ranges.
For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and delivering a demonstration unit for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Demonstration of technical feasibility (TRL 3-4).

Phase II Deliverables: Prototype design and demonstration of innovative technology testing platform, capable of integrating multiple CFM experiments (TRL 4-6). A ready to launch version of this as an EELV secondary payload performing demonstrations of CFM technologies is highly desired.