



## NASA SBIR 2009 Phase I Solicitation

### X8 Cryogenic Systems

The Exploration Systems architecture presents cryogenic storage, distribution, and fluid handling challenges that require new technologies to be developed. Reliable knowledge of low-gravity cryogenic fluid management behavior is lacking and yet is critical for Altair and Ares in the areas of storage, distribution, and low-gravity propellant management. Additionally, Earth-based and lunar surface missions will require success in storing and transferring liquid and gas commodities. Some of the technology challenges are for long-term cryogenic propellant storage and distribution; cryogenic fluid ground processing and fluid conditioning; liquid hydrogen and liquid oxygen liquefaction processes on the lunar surface. Furthermore, specific technologies are required in valves, regulators, instrumentation, modeling, mass gauging, cryocoolers, and passive and active thermal control techniques. The technical focus for component technologies is for accuracy, reduced mass, minimal heat leak, minimal leakage, and minimal power consumption. The anticipated technologies proposed are expected to increase reliability, increase cryogenic system performance, and are capable of being made flight qualified and/or certified for the flight systems and dates to meet Exploration Systems mission requirements.

## Subtopics

### X8.01 Cryogenic Fluid Transfer and Handling

Lead Center: KSC

Participating Center(s): ARC, GRC, GSFC, JSC, MSFC, SSC

This subtopic solicits cryogenic storage and transfer technologies to enable NASA Exploration goals. This includes a wide range of applications, scales, and environments on ground, in orbit, and on the Lunar or Martian surface. Specifically:

- Passive thermal control for ZBO (zero boil-off) storage of cryogenics for both long term (>200 days for LOX/LH<sub>2</sub>) on the lunar surface and short term (14 days for LH<sub>2</sub>, LOX) on orbit. Insulation for both ground and flight.
- Active thermal control for long term ZBO storage for lunar surface and space applications. Technologies include 20 K cryocoolers for Mars missions, cryocooler integration techniques, heat exchangers, distributed cooling, and circulators. Scavenging of residual propellants.

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- Zero gravity cryogenic control devices including thermodynamic vent systems, spray bars and mixers, and liquid acquisition devices.
  - Advanced spacecraft valve actuators using piezoelectric ceramics. Actuators that can reduce the size and power while minimizing heat leak and increasing reliability.
  - Propellant conditioning and densification technologies for Earth based applications, scaled for Altair or EDS tanks. Destratification technologies and recirculation systems for homogeneous tank loads. Reliability and operability upgrades over past densification systems.
  - High capacity liquid oxygen pump systems capable of delivering high quality of liquid over a wide flow range between 500 GPM to 2000 GPM are sought. Special emphasis on variable control pumping, parallel pumping, system reliability and robustness, and advanced pump sealing technology is needed.
  - Liquefaction of oxygen on the Lunar surface, including passive cooling with radiators, cryocooler liquefaction, or open cycle systems that work with HP electrolysis. Efficiency, mass savings, and reliability upgrades are needed. Heat pumps, switches, and heat pipes to control energy flow at low temperatures. Deployable radiators and radiation shields.

## **X8.02 Cryogenic Instrumentation for Ground and Flight Systems**

**Lead Center:** GRC

**Participating Center(s):** JPL, KSC, MSFC, SSC

This subtopic includes technologies for reliable, accurate cryogenic propellant instrumentation needs in-space, on the lunar surface, and on the Earth. Innovative concepts are requested to enable accurate measurement of cryogenic liquid mass in low-gravity storage tanks, to enable the ability to detect in-space and on-pad leaks from the storage system, and to address other cryogenic instrumentation needs. Cryogenic propellants such as hydrogen, methane, and oxygen are required for many current and future space missions. Proposed technologies should offer enhanced safety, reliability, or economic efficiency over current state-of-the-art, or should feature enabling technologies to allow NASA to meet future space exploration goals.

Propellant mass gauging provides accurate measurement of cryogenic liquid mass ( $\text{LH}_2$ ,  $\text{LO}_2$ , and  $\text{LCH}_4$ ) in low gravity storage tanks, and is critical to allowance of smaller propellant tank residuals and assuring mission success. Both low-gravity gauging (measurement uncertainty

Leak detection technologies impact cryogenic systems for space transportation orbit transfer vehicles, lunar surface, and launch site ground operations. These systems will be operational both in atmospheric conditions and in vacuum with multiple sensor systems distributed across the vehicle or a region of interest to isolate leak location. Methane and hydrogen leak detection sensors with milli-second response times and 1 ppm detection sensitivity in air are desired for ground and launch operations.

Other cryogenic instrumentation needs include:

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- Miniature cryogenic pressure sensors (0 - 1 atm) for use under MLI blankets.
  - Zero dead-volume in-line pressure sensors for use in liquid hydrogen flow streams.
  - Real-time in-situ measurements of ppm levels of N<sub>2</sub>, O<sub>2</sub>, and H<sub>2</sub>O in gaseous helium purge streams. Sensors that can survive the temperature range 20 K - 300 K and the vibration loads on a launch platform are especially desired.
  - Minimally intrusive in-situ measurements of liquid hydrogen and liquid oxygen purity levels in real time. The goal is to accurately measure cryogenic propellant liquid purity levels (99% - 100% purity) in ground test stands during test operations. Helium and nitrogen impurity levels are of specific interest, but the sensors must be able to measure overall purity level of the cryogenic liquid.
  - Minimally invasive cryogenic liquid flow measurement sensors for rocket engine feed lines, and sensors to detect and quantify two-phase flow (bubbles) within the feed lines.
  - Non-intrusive flowmeters for high-pressure (up to 6,000 psi) gaseous helium distribution lines are sought for flow rates ranging from a trickle flow up to 1500 SCFM. Ultrasonic clamp-on flowmeters are especially desired, but must be able to sense the flow through 2" Schedule-XX pipe (0.436" wall thickness).
  - Position indicators and long life application of the instrumentation for deep space missions.