NASA Cryogenic Propellant Management Technology Efforts

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Overview - Currently Funded Efforts

Space Technology Mission Directorate (STMD):
Technology Demonstration Missions (TDM) Program
- eCryo Project - Integrated systems and component technology demonstrations
- CELSIUS Project – Cryogenic Encapsulating Launch Shroud and Insulated Upper Stage – Paragon
- Propellant Transfer Study – In-space propellant transfer/refueling - Space X

Game Changing Development (GCD) Program
- 20 W, 20 K Cryocooler – Reverse Turbo Brayton - Creare
- Reduced Gravity Cryogenic Transfer - NASA / University of Florida
- 150 W 90 K Cryocoolers - Lockheed Martin, Northrop Grumman & Creare
- Solar White Testing – Cryo thermal coating evaluations
- Densified Hydrogen Loading Demo
- Vented Chill/No Vent Fill with TVS Augmentation

Small Business Innovative Research (SBIR)
- Four Phase I efforts – Critical components, tank configurations, and analytical capability
- Three Phase II efforts – Innovative Cryo-Cooler, advanced insulation, and liquid acquisition devices

Human Exploration and Operations Mission Directorate (HEOMD):
Space Life & Physical Sciences Research & Applications (SLPSRA)
- Zero Boil Off Tank (ZBOT) Experiment – Surrogate fluid ISS Experiments

Advanced Cis-lunar Surface Systems (ACSC)
- Cryogenic Fluid In-situ Liquefaction for Landers (CryoFILL) – Demonstrations of liquefaction and loading technologies

NextStep BAA - Appendix E – Refueling Studies and some hardware demos, funded by both HEOMD and STMD
Evolvable Cryogenics (eCryo) Overview

Develop, integrate, and validate cryogenic fluid management technologies (CFM) at a scale relevant to and meeting the mission needs for NASA missions and SLS/Stages.

**Themes:**
- Technology development for extended missions focused on the needs of the SLS Exploration Upper Stage (EUS).
- Evolutionary development of new CFM technologies demonstrating near term gains which are shared with industry.
- Increase capabilities of analysis tools to perform predictive simulations for missions with in-space cryogenic systems.

**Technology Demonstrations:**
- Use existing Agency assets and infrastructure to mature cryogenic propellant technologies
  - Testing ranges from components to entire systems
  - Scale of testing will be limited only by facility capabilities.
  - Subsystem tests and system tests need not use flight-like components

**Products:**
- **Structural Heat Intercept Insulation Vibration Evaluation Rig (SHIIVER):** Implement vapor cooling and multilayer insulation onto a large liquid hydrogen tank that is representative of a cryogenic stage.
- **Development & Validation of Analysis Tools (DVAT):** Advancement of numerical tools to model cryogenic fluids in both settled/unsettled conditions.
- **Radio Frequency Mass Gauge (RFMG):** Test and demonstrate RFMG technology on the International Space Station.
- **COMPLETED: Improved Fundamental Understanding of Super Insulation (IFUSI):** Improve the capability of designing cryogenic multilayer insulation (MLI) blankets for large cryogenic upper stages.
- **COMPLETED: Integrated Vehicle Fluids (IVF):** Evaluate the extensibility of the IVF concept for use on the SLS Exploration Upper Stage (EUS).
- **COMPLETED: Large Scale Leakage Fixture (LSLF):** Demonstrate valve seat technology for long duration storage applications.

**Team:**
- GRC (lead), MSFC
- Industry Partners: ULA (on IVF)
- International Partners: CNES, JAXA, DLR

**Images:**
- SHIIVER Test Article
- RFMG for ISS Demonstration
- SHIIVER Stack in Chamber
- D VAT: CFM Analysis
- IFUSI: MLI Testing
- SLS/Stages
STMD - Game Changing Development Projects

• **20 W, 20 K Cryocooler**
  Develop a prototype 20W 20K Reverse Turbo Brayton (RTB) Cryocooler for ground demonstration applicable to Zero Boil Off (ZBO) storage of liquid hydrogen for Nuclear Thermal Propulsion and liquid hydrogen stages, tugs, and landers.

• **Reduced Gravity Cryogenic Transfer**
  Design, ground and flight test a line chill down testing to investigate performance benefits of coatings and optimal valve duty cycling on transfer line chill down in low-g. Design, ground and flight test a tank-to-tank chill down test rig to investigate optimal liquid injection methods and optimal chilldown methods to minimize amount of propellant used to chill down hardware in low-g. Provide datasets for validating multimode and CFD models for line chill down, and tank chill down and fill.

• **150 W 90 K Cryocoolers**
  Take advantage of existing developments on non-RTB cryocoolers to assess the viability at 90 K cryocooler systems for exploration. One Reverse Turbo Brayton cycle, and two pulse tube coolers in work.

• **Solar White Testing**
  Solar White aims to test new thermal control coatings for cryogenic applications. CRCC developed solar simulator designed to test thermal control coatings under simulated deep space solar conditions. High vacuum, 12K background, & 1 sun solar spectrum

• **Densified Hydrogen Loading Demo**
  Demonstrate loading of a flight vehicle with densified hydrogen and run a simulated NTP Con Ops Mission (ground loading, ascent, parking orbit)

• **Vented Chill/No Vent Fill with TVS Augmentation**
  Demonstrate VC/NVF with and without a TVS Augmented Injector on a larger propellant
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<th>Company</th>
<th>Title</th>
<th>Year/Type</th>
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<tbody>
<tr>
<td>Converter Source, LLC</td>
<td>Innovative Stirling-Cycle Cryocooler for Long Term In-Space Storage</td>
<td>2016/Phase II</td>
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<td>of Cryogenic Liquid Propellants</td>
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<td>Quest Thermal Group</td>
<td>Multi Environment MLI: Novel Multi Functional Insulation for Mars</td>
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<td>Missions</td>
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<td>Creare, Inc</td>
<td>Lightweight, Reliable Cryogenic Screen Channel Acquisition Devices</td>
<td>2018/Phase II</td>
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<td>with High Expulsion Efficiency</td>
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<td>Gloyer-Taylor Laboratories, LLC</td>
<td>Low Boil off Transfer Lines</td>
<td>2019/Phase I</td>
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<td>Gloyer-Taylor Laboratories, LLC</td>
<td>High Pressure BHL Spherical Cryotank</td>
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<td>Combstion Research and Flow</td>
<td>Simulation of Chill down Process with a Sub-grid Boiling Model</td>
<td>2019/Phase I</td>
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<td>Paragon Space Development</td>
<td>Ellipsoidal Propellant Tank (EPT)</td>
<td>2019/Phase I</td>
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Space Life & Physical Sciences Research & Applications (SLPSRA)

• Zero-Boil-Off Tank (ZBOT) Experiments
  Use small-scale simulant-fluid tests aboard the ISS to study the underlying fluid physics of tank pressurization & pressure control in order to help optimize in-orbit propellant storage & transfer design and provide microgravity data for Storage Tank CFD model validation:
  2. ZBOT-NC: Effect of Non-Condensable Gases (2022)
  3. ZBOT-AC: Active Pressure Control - Spray-Bar Droplet & Broad Area Cooling (2025)
  4. ZBOT-FT: Filling & Transfer (Potential International Collaboration)

Advanced Cis-lunar Surface Systems (ACSC)

• Cryogenic Fluid In-situ Liquefaction for Landers (CryoFILL)
  NASA’s Advanced Cis-lunar Space Capabilities program is looking to develop a liquefaction system for use on the moon or Mars to liquefy propellant produced in-situ. The CryoFILL technology demonstration hardware will eventually be delivered for an ISRU integrated system test.