



# **NASA Cryogenic Propellant Management Technology Efforts**

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# Overview - Currently Funded Efforts



## Space Technology Mission Directorate (STMD):

### Technology Demonstration Missions (TDM) Program

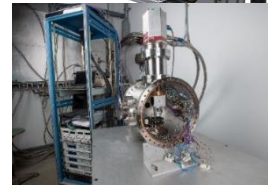
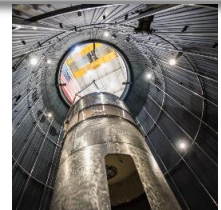
- eCryo Project - *Integrated systems and component technology demonstrations*
- CELSIUS Project – *Cryogenic Encapsulating Launch Shroud and Insulated Upper Stage – Paragon*
- Propellant Transfer Study – *In-space propellant transfer/refueling - Space X*

### 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*



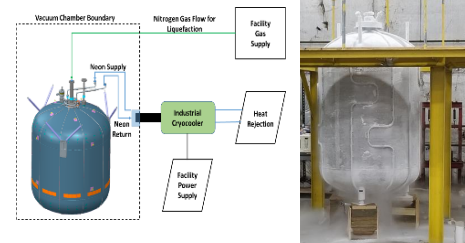
## Human Exploration and Operations Mission Directorate (HEOMD):

### 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**



**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



SHIVER Test Article



RFMG for ISS Demonstration



SHIVER Stack in Chamber

### Team:

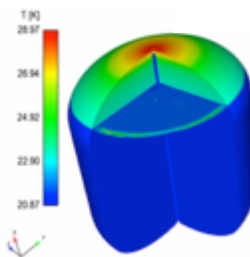
GRC (lead), MSFC

Industry Partners: ULA (on IVF)

International Partners: CNES, JAXA, DLR

### Products:

- **Structural Heat Intercept Insulation Vibration Evaluation Rig (SHIVER):** 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.



DVAT: CFM Analysis



IFUSI: MLI Testing



SLS/Stages



# STMD - Game Changing Development Projects



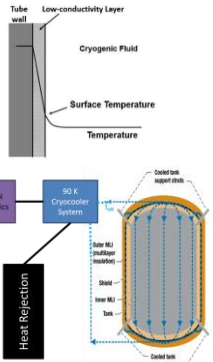
- 20 W, 20 K Cryocooler

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.



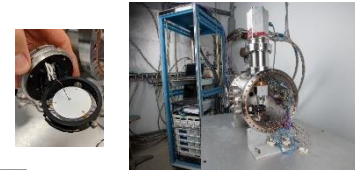
- Reduced Gravity Cryogenic Transfer

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.



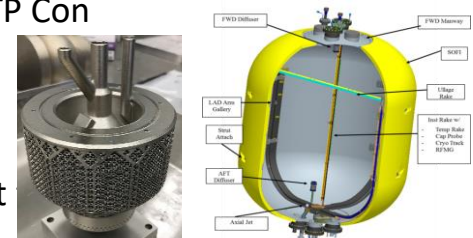
- Solar White Testing

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

# STMD - Cryogenic Fluid Management SBIRs



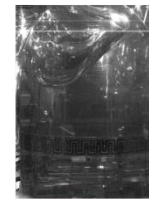
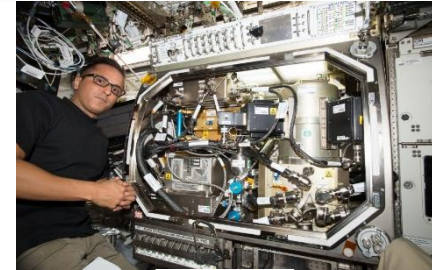
Company	Title	Year/Type
Converter Source, LLC	Innovative Stirling-Cycle Cryocooler for Long Term In-Space Storage of Cryogenic Liquid Propellants	2016/Phase II
Quest Thermal Group	Multi Environment MLI: Novel Multi Functional Insulation for Mars Missions	2017/Phase II
Creare, Inc	Lightweight, Reliable Cryogenic Screen Channel Acquisition Devices with High Expulsion Efficiency	2018/Phase II
Gloyer-Taylor Laboratories, LLC	Low Boil off Transfer Lines	2019/Phase I
Gloyer-Taylor Laboratories, LLC	High Pressure BHL Spherical Cryotank	2019/Phase I
Combustion Research and Flow Technology	Simulation of Chill down Process with a Sub-grid Boiling Model	2019/Phase I
Paragon Space Development Corporation	Ellipsoidal Propellant Tank (EPT)	2019/Phase I

## Space Life & Physical Sciences Research & Applications (SLPSRA)

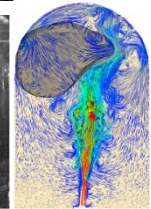
### • Zero-Boil-Off Tank (ZBOT) Experiments

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:

1. ZBOT-1: Self-Pressurization & Subcooled Jet Mixing (2017)
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)



White Light Image



CFD Model Simulation

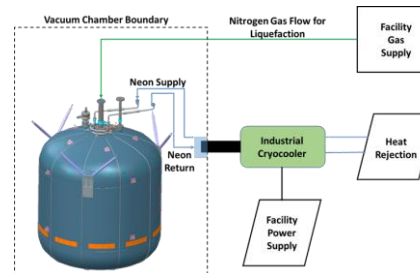


Particle Imaging Velocimetry

## 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.



PHPK Cryocooler



CryoZone Cryofan (left) and cold head Heat Exchanger (right)