



# **Cryogenic Propellant Storage & Transfer (CPST) Technology Demonstration for Long Duration In-Space Missions**

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# CPST Goal and Objectives



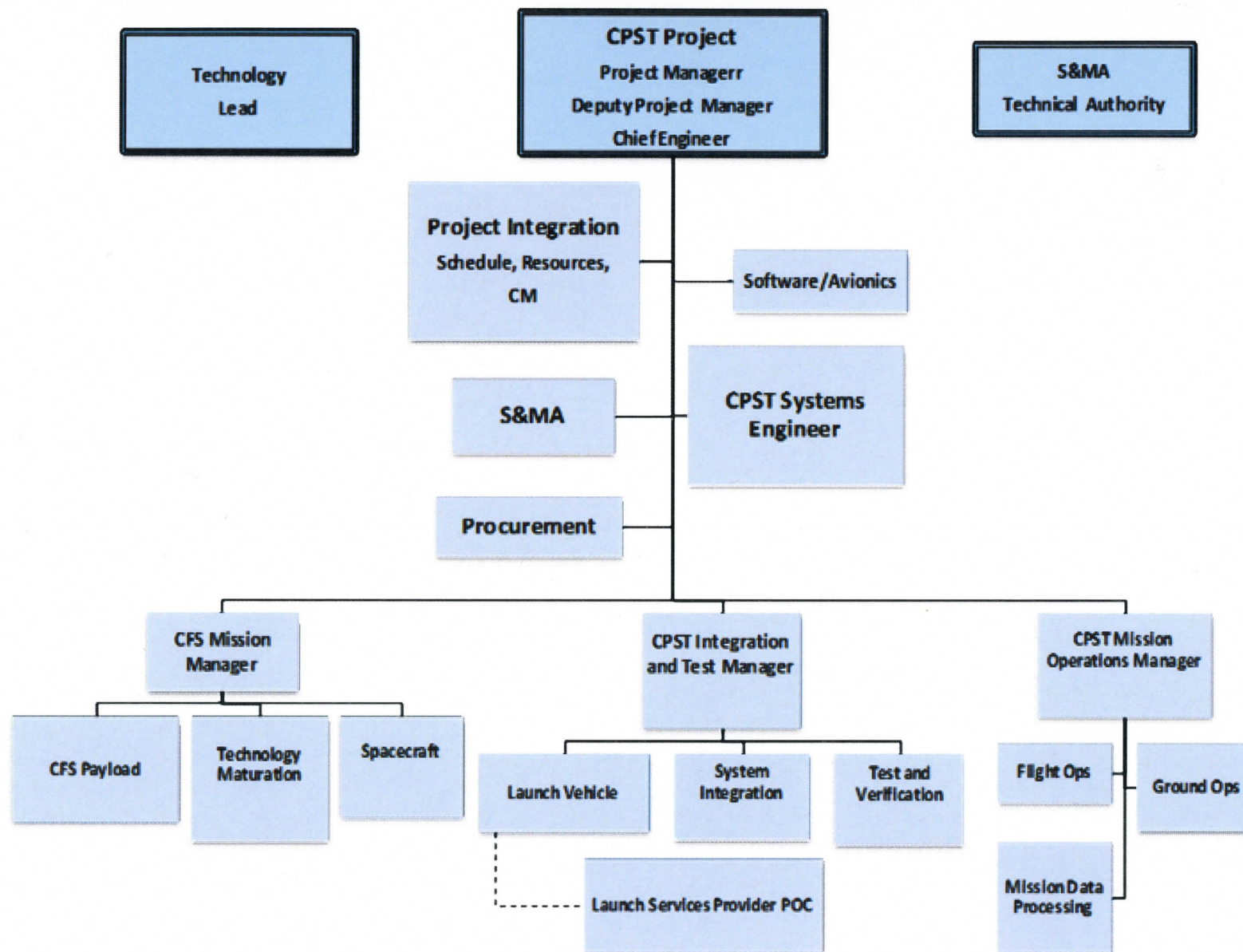
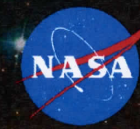
*CPST Goal Statement: Advance cryogenic propellant systems technologies for infusion into future extended in-space missions.*

## Objectives

- Store cryogenic propellants in a manner that maximizes their availability for use regardless of mission duration
- Efficiently transfer conditioned cryogenic propellant to an engine or tank situated in a microgravity environment
- Accurately monitor and gauge cryogenic propellants situated in a microgravity environment



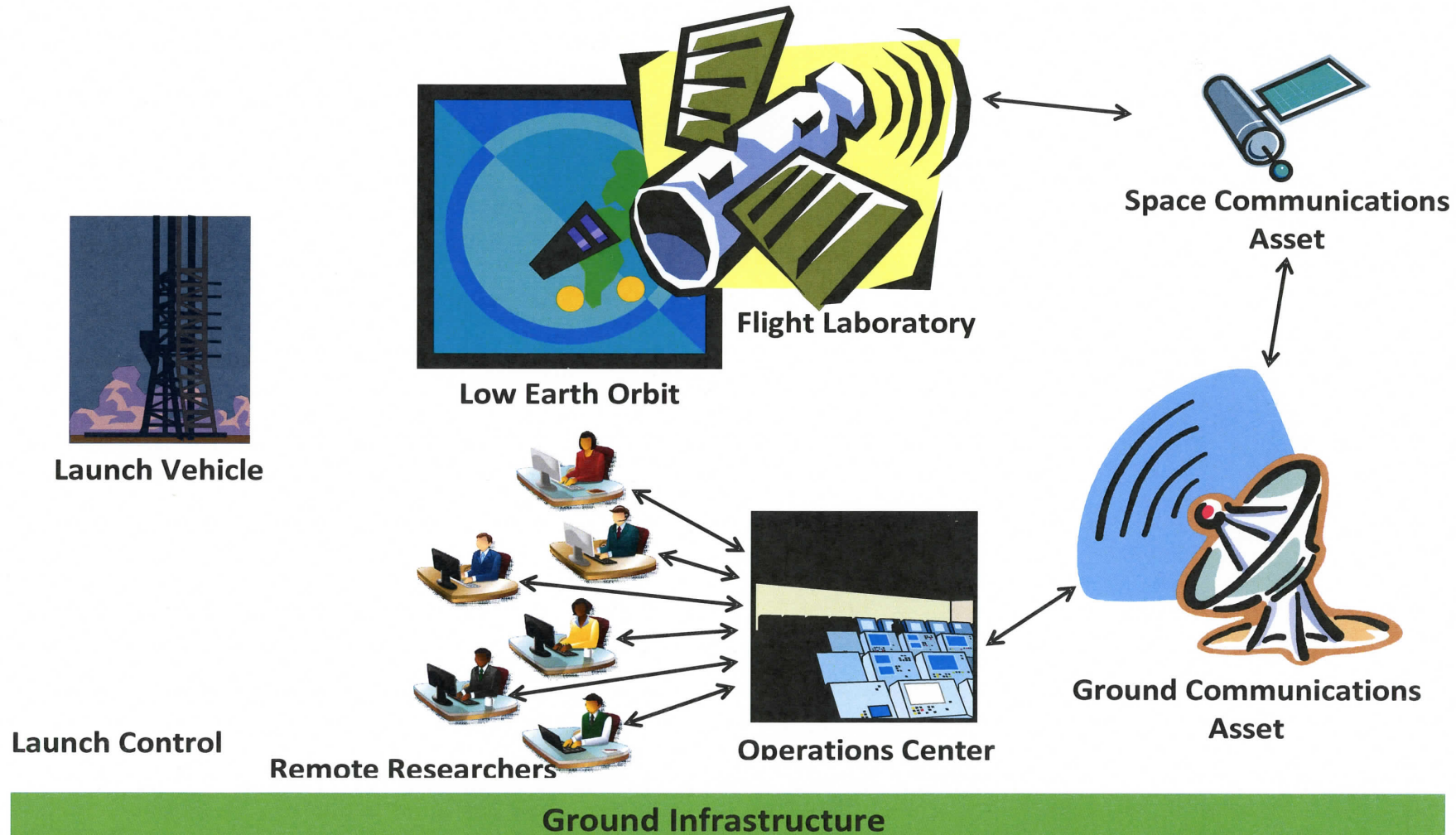
# CPST Project Organization



# Mission Overview

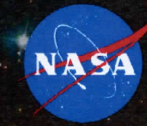


## Flight Demonstration System Mission Architecture





# Mission Timeline



Mission Demonstration	Month					
	1	2	3	4	5	6
Spacecraft & CFM Demo Systems Checkout	█					
LH2 Storage Tank Passive CFM Demo	█					
LH2 Storage Tank Active CFM Demo		█				
LH2 Transfer Demos		█		█		

### Storage Tank Passive CFM Demos include:

- Determination of passive thermal control performance
- Settled mass gauging
- Unsettled mass gauging
- Low-conduction structural concepts

### Storage Tank Active CFM Demos include:

- Determination of active thermal control performance
- Settled mass gauging
- Unsettled mass gauging
- Low-conduction structural concepts

### Propellant Transfer Demos include:

- Pump-fed propellant transfer
- Pressure-fed propellant transfer
- Settled propellant transfer
- Unsettled propellant transfer
- Transfer Tank and Transfer system conditioning
- Transfer rate measurement and vapor detection
- Settled and unsettled liquid acquisition
- Tank expulsion demos

**Tanks Sized to Provide (at least):**  
**6 Month Storage Demo for LH2**  
**2 Transfer Demo Series for LH2**



# CPST NASA Point of Departure Concept Recommended Technologies



Needs

Create the innovative new space technologies for our exploration, science, and economic future

Goals

Advance cryogenic propellant systems technologies for infusion into future extended in-space mission

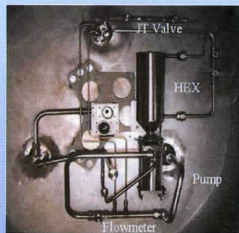
Objectives

Store cryogenic propellants in a manner that maximizes their availability for use regardless of mission duration

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Accurately monitor and gauge cryogenic propellants situated in a microgravity environment

Technologies



TVS components (installed in test tank)



Pulse-tube cryocooler

## LH2 Storage

Active thermal control: Broad Area Cooling (tubes on tank or tubes on shield)

Active thermal control: cryo-coolers (90K)

Passive storage: reduced penetration heat leak through MLI

Passive storage: low conductivity structural attachments

Tank Pressure Control: thermodynamic vent system (TVS)

Tank Pressure Control: mixing pumps

## LH2 Acquisition

Liquid Acquisition Devices (LADs)



Screen Channel Capillary LAD

## LH2 Transfer

Transfer Valves

Transfer Pump

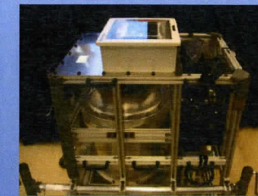
Line and Tank Chill-down

## LH2 Quantity Gauging

Capacitance Probe

Wet-Dry Sensor (Cryotracker)

Radio Frequency (settled/unsettled)



RF Gauge Test Rig



# CPST Technology Readiness Levels



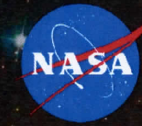
CPST Technology		TRL
		Now
1	Active Thermal Control: Cryocoolers w/ tube-on-shield heat collection	4
2	Thick Multilayer Insulation with Foam Substrate	4/6
3	Low Conductivity Structures: High Strength Composite Struts	4/6
4	Micro-G Pressure Control: Thermodynamic Vent System	5
5	Micro-G Pressure Control: Mixing Pumps	5
6	Unsettled Liquid Acquisition Devices	4/5
7	Micro-G Transfer Line Chilldown	4
8	Pressurization Systems	5
9	Settled Mass Gauging: Wet/dry silicon diode sensors	5
10	Unsettled Mass Gauging: Radio Frequency Gauging	5
11	Micro-G Tank Chilldown	5
12	Automated Leak Detection	5

\* Items with two TRLs listed are where there is a propellant dependence (hydrogen/oxygen)

- First 11 items address primary mission objectives
  - Leak detection is a secondary objective
- TRL highlighted in yellow indicates TRL is currently being advanced through the Technology Maturation portion of the project
  - Project goal is to have candidate technologies at TRL = 5 before mission authority to proceed (ATP)



# CPST Technology Maturation Activities



Task Name	Objective
LH2 Reduced Boil-off Active Cooling Thermal Demonstration	Demonstration of a flight representative active thermal control system for Reduced Boil-Off (RBO) storage of LH2 for extended duration in a simulated space thermal vacuum environment
LH2 Reduced Boil-off Broad Area Cooling Shield/MLI Structural Integrity	Assess the structural performance of an MLI / BAC shield assembly subjected to launch environmental representative loads
Composite Strut Thermal Performance in LH2	Measurement of heat leak due to composite struts integrated with MLI.
Liquid Acquisition Device (LAD) Outflow & Line Chill	Quantify the LAD stability (no LAD breakdown) due to transfer line chill down transient dynamic pressure perturbations during outflow
MLI Penetration Heat Leak Study	Measurement of heat leak due to struts penetration integrated with MLI.
Active Thermal Control Scaling Study	Conduct study to show relevancy of CPST-TDM active thermal control flight data to full scale CPS or Depot application
Thick MLI Extensibility Study	Assess optimum approach for attachment of thick (40-80 layer) MLI to very large tanks
Analytical tools	Continue development of tools to be validated by CPST
Pathfinder Integrated System Test (GTA)	Demonstrate flight-scale system operations & interactions; demo tank manufacturing; early software development
Instrumentation Advancement	Mature Radio Frequency Mass Gauge flight avionics and leak detection sensor system for vacuum environment



# NASA Internally Developed Point of Departure (POD) Mission Concept

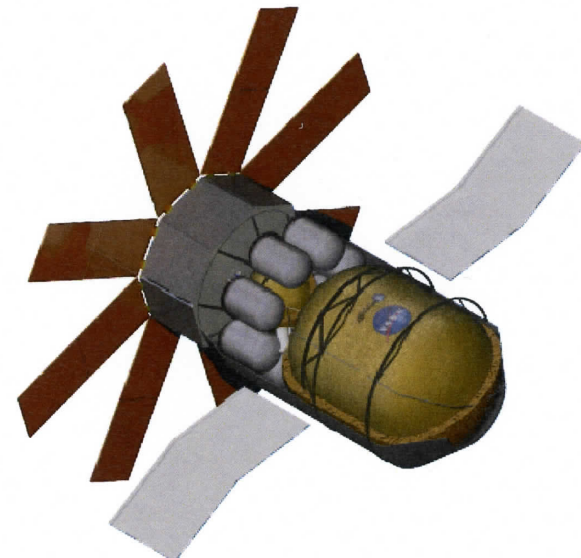


## NASA conducted an internal conceptual design study in 2011 with the objectives of

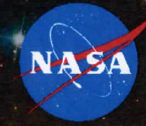
- defining a preliminary design concept to enable initial assessments of mission viability
- enabling early project formulation activities

### POD Salient Features

- Free flying spacecraft separate bus and cryogenic payload
- Downs-selected to flying a single fluid (LH2)
- A smaller secondary tank is included for propellant transfer demonstration
- Carries the full technology suite described earlier
- Loaded with LH2 on the PAD with a T0 disconnect



# Contractor Developed Mission Concepts



## Five contractor mission concept studies were conducted to augment the Government POD study

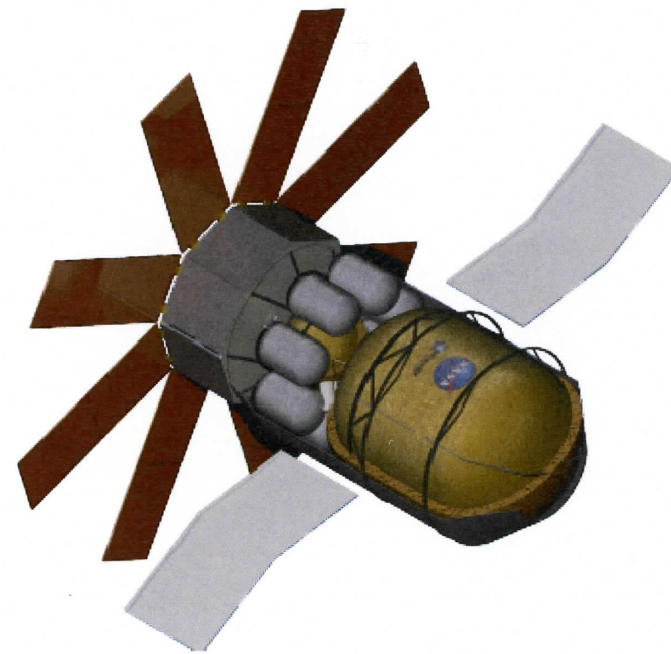
- Analytical Mechanics Associates, Ball Aerospace, Boeing, Lockheed Martin, and United Launch Alliance
- The overall objectives of the mission studied were the same as used for the NASA internal POD study
- Cost constraint was a primary challenge and the mission concepts brought various options into the trade space including:
  - Launch: dedicated launch vs. rideshare or dual manifest
  - Spacecraft Bus Function: payload/bus configuration vs. integrated bus functions
  - Loading propellants into the payload: ground loading vs. preloaded vacuum jacketed tanks vs. propellant scavenging from an upper stage
- Technology demonstration included in the concepts were overall similar to NASA POD, with some unique options
- Single fluid and two fluid options were provided by the contractors



# CPST Summary



- NASA is planning to fly a Cryogenic Propellant Storage and Transfer (CPST) technology demonstration mission in 2016.
- Project formulation is well underway.
- Mission Concept Review (MCR) was recently completed.
  - Based in a NASA in-house mission concept and five contractor developed mission concepts, mission feasibility was demonstrated.
- Preparation for System Requirements Review (SRR) underway.
- Technology Maturation activities are in progress to raise candidate technologies to TRL 5.



# CPST Points of Contact



Project Manager: Susan Motil; [susan.m.motil@nasa.gov](mailto:susan.m.motil@nasa.gov)

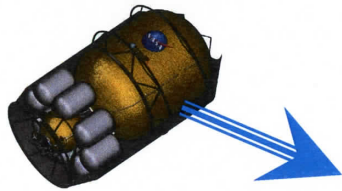
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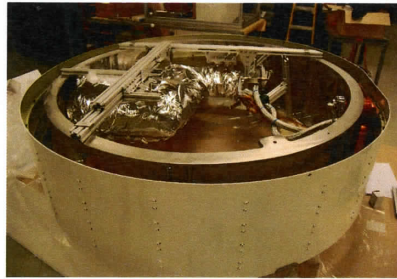
Chief Engineer: Bill Taylor; [william.j.taylor@nasa.gov](mailto:william.j.taylor@nasa.gov)



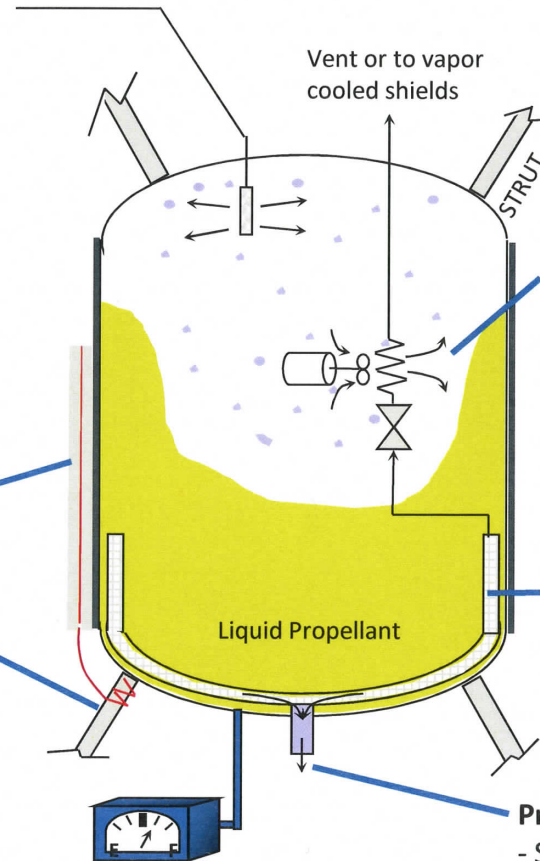
# Cryogenic Propellant Storage and Transfer Functions that CPST Can Demonstrate



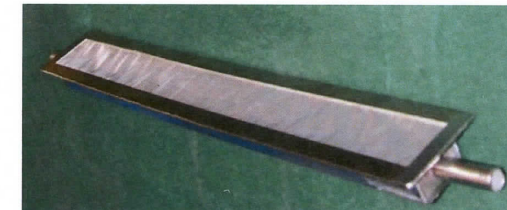
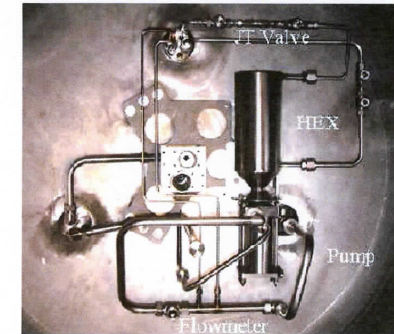
**Pressurization**  
 - Cold helium  
 - Autogenous



**Thermal Control**  
 - Insulation (launch environments and in-space)  
 - Vapor or actively cooled shields  
 - Low conductivity/ cooled support structure



**Pressure Control**  
 - Zero-g venting (thermodynamic vent and heat )



**Liquid Acquisition**  
 - Capillary retention devices LADs vanes, etc.

**Propellant Transfer**  
 - Settled/unsettled  
 - No-vent fill

**Propellant Gauging**  
 - Settled propellant/level sensors  
 - High accuracy micro-g techniques