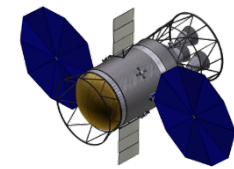


Mars Ascent Vehicle
Decent Module

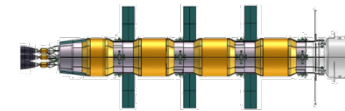
NASA's Path Toward Technology Development in Cryogenic Fluid Management

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LOX / LCH4
Solar Electric



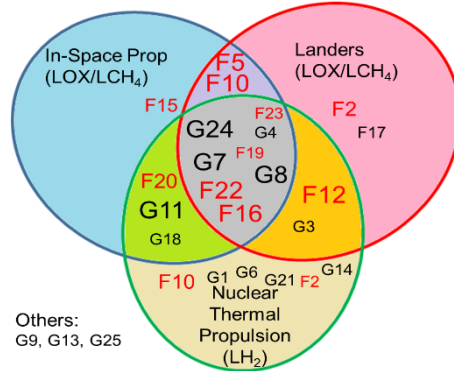
Nuclear Thermal Propulsion

- Advancements in Cryogenic Fluid Management are essential to enable NASA's planned long duration missions.
- Utilizing current State of the Art CFM technologies, long duration storage of cryogenics is limited to just hours.
- Some of NASA's planned missions require the storage of cryogenics for up to three to five years which will require not only optimized "passive" CFM technologies, but "active" systems (cryocoolers) as well.
- Some CFM technologies are mature enough to be infused into a vehicle design while others require further technology development.

Twenty Six CFM Technologies Identified by the Cryogenic Community at NASA

Technology	No
Advanced External Insulation	1
Autogenous Pressurization	2
Automated Cryo-Couplers	3
Cryogenic Thermal Coating	4
Helium Pressurization	5
High Capacity, High Efficiency Cryocoolers 20K	6
High Capacity, High Efficiency Cryocoolers 90K	7
High Vacuum Multilayer Insulation	8
Liquefaction Operations (MAV & ISRU)	9
Liquid Acquisition Devices	10
Low Conductivity Structures	11
MPS Line Chilldown	12
Para to Ortho Cooling	13
Propellant Densification	14
Propellant Tank Chilldown	15
Pump Based Mixing	16
Soft Vacuum Insulation	17
Structural Heat Load Reduction	18
Thermodynamic Vent System	19
Transfer Operations	20
Tube-On-Shield BAC	21
Tube-On-Tank BAC	22
Unsettled Liquid Mass Gauging	23
Valves, Actuators & Components	24
Vapor Cooling	25
Composite Tanks	26

CFM Elements Across Multiple Propulsion Applications



Others:
G9, G13, G25

Red numbers indicate technologies that need to fly to reach TRL 6. Does not capture effects of scale. Fluid specific technologies may be shown in multiple locations.

Technology Readiness Levels

Technologies	Current TRL	Gravity Dependant (Y/N)	Path to TRL 6	"Cross Cutting" or "Fluid Specific"
Low Conductivity Structures	6	No	Ground Test	Cross Cutting
High Vacuum Multilayer Insulation	5	No	Ground Test	Cross Cutting
Tube-On-Shield BAC	5	No	Ground Test	Cross Cutting
Valves, Actuators & Components	5	No	Ground Test	Cross Cutting
Vapor Cooling	5	No	Ground Test	Fluid Specific
Helium Pressurization	5	Yes	Flight Demo	Cross Cutting
MPS Line Chilldown	5	Yes	Flight Demo	Cross Cutting
Pump Based Mixing	5	Yes	Flight Demo	Cross Cutting
Thermodynamic Vent System	5	Yes	Flight Demo	Cross Cutting
Tube-On-Tank BAC	5	Yes	Flight Demo	Cross Cutting
Unsettled Liquid Mass Gauging	5	Yes	Flight Demo	Cross Cutting
Liquid Acquisition Devices	5	Yes	Flight Demo	Fluid Specific
Advanced External Insulation	3	No	Ground Test	Can Be Both
Automated Cryo-Couplers	4	No	Ground Test	Cross Cutting
Cryogenic Thermal Coating	3	No	Ground Test	Cross Cutting
High Capacity, High Efficiency Cryocoolers 90K	3	No	Ground Test	Cross Cutting
Soft Vacuum Insulation	3	No	Ground Test	Cross Cutting
Structural Heat Load Reduction	3	No	Ground Test	Cross Cutting
Propellant Tank Chilldown	3	Yes	Flight Demo	Cross Cutting
Transfer Operations	4	Yes	Flight Demo	Cross Cutting
High Capacity, High Efficiency Cryocoolers 20K	3	No	Ground Test	Fluid Specific
Liquefaction Operations (MAV & ISRU)	3	No	Ground Test	Fluid Specific
Para to Ortho Cooling	4	No	Ground Test	Fluid Specific
Propellant Densification	4	No	Ground Test	Fluid Specific
Autogenous Pressurization	4	Yes	Flight Demo	Fluid Specific

Can achieve TRL 6 through ground testing.

Flight Demo required to achieve TRL 6.

Technology "Long Poles" Development is needed.

Model Development for Cryogenic Fluid Management

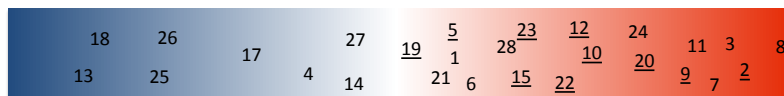
Technology / Model	Fluid/Model	CFD	Thermal	Other
Advanced External Insulation				●
Autogenous Pressurization	●	●		
Automated Cryo-Couplers				●
Cryogenic Thermal Coating			●	
Helium Pressurization	●	●		
High Capacity, High Efficiency 20 K Cryocoolers		●		●
High Capacity, High Efficiency Cryocoolers 90K		●		●
High Vacuum Multilayer Insulation				●
Liquefaction Operations (MAV & ISRU)	●	●	●	
Liquid Acquisition Devices		●		●
Low Conductivity Structures			●	
Line Chilldown	●	●		
Para to Ortho Cooling				●

Microgravity Sensitive
● Ready when sig data available
○ Needs Limited Model Development
○ Needs Significant Model Development

Technology / Model	Fluid/Model	CFD	Thermal	Other
Propellant Densification				
Propellant Tank Chilldown	○	●		
Pump Based Mixing	●	●		●
Soft Vacuum Insulation				●
Structural Heat Load Reduction			●	
Thermodynamic Vent System	●	●		●
Transfer Operations	●	○		○
Tube-On-Shield BAC	●			
Tube-On-Tank BAC	●	●		
Unsettled Liquid Mass Gauging				●
Valves, Actuators & Components				●
Vapor Cooling	○			○

Microgravity Sensitive
● Ready when sig data available
○ Needs Limited Model Development
○ Needs Significant Model Development

Heat Map of Technology Interest



No companies ← Interest Level → All Companies