

2025 HuLC Advanced Cryogenics for In-Space Applications

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HLS Propulsion MPS/CFM Sub-System Lead





What is Cryogenic Fluid Management (CFM)

- CFM is a NASA term used to describe a suite of technologies that store, transfer, and measure ultra cold fluids such as liquid hydrogen, liquid oxygen , liquid methane and others.
- Traditional cryogenic propellants not suitable for deep space missions
 - Cryogenic propulsion stages uses mostly for launch vehicles
 - In-space propulsion typically uses storable propellants or advanced systems
- Current state-of-the-art CFM technologies are inadequate or unproven for missions like Artemis 3 and beyond
- NASA has identified key deep space architectures and missions which will require safe storage of cryogenic propellant...

Cryogenic Storage & Transfer Technologies

Advanced Commercial Upper Stages



High-Performance Deep Space Chemical Propulsion



ISRU Propellant Storage & Utilization



Nuclear Propulsion



Power Distribution & Transmission



Advanced Thermal Management



Efficient Ground Processing

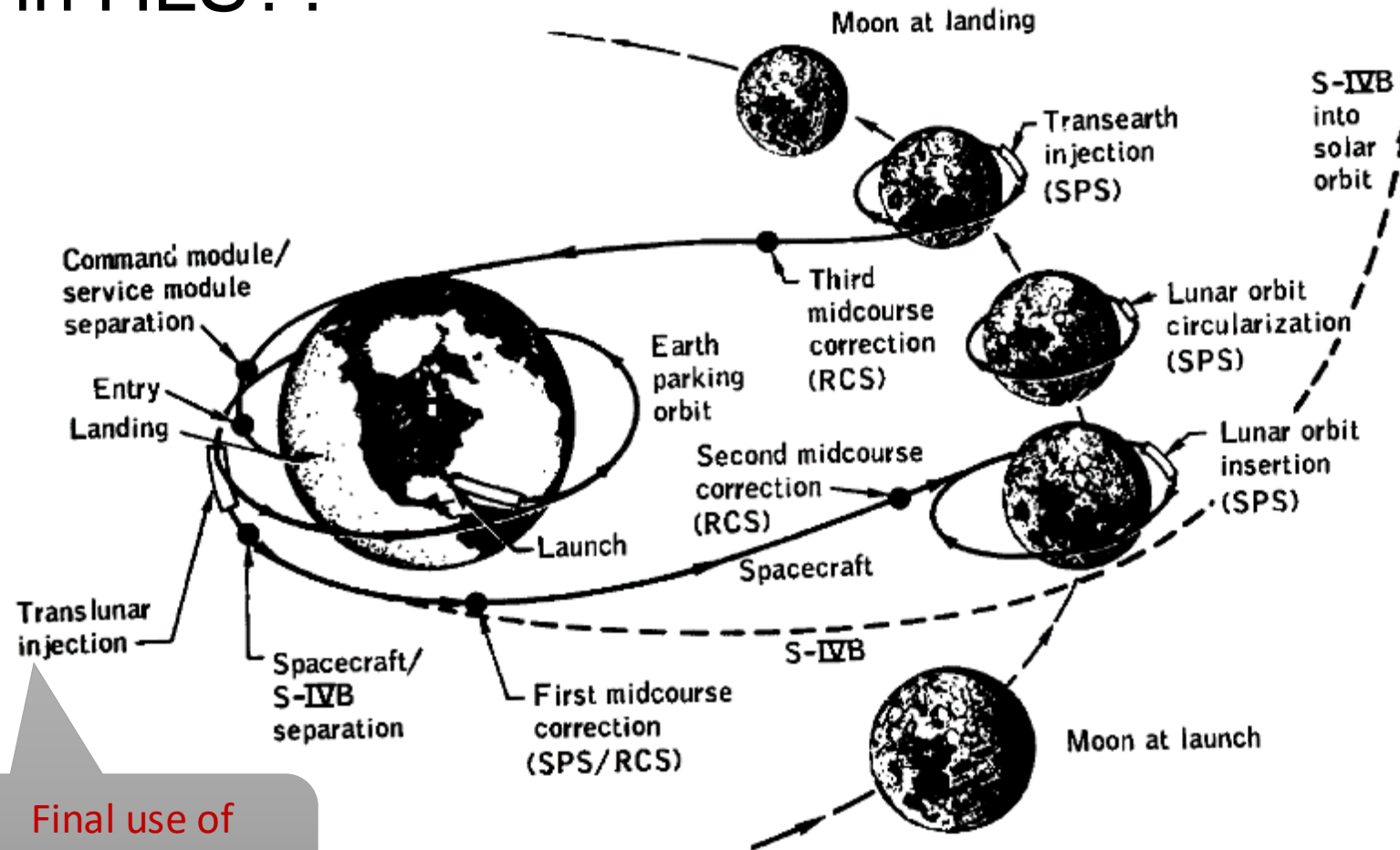


On Orbit Propellant Depots





Why CFM in HLS??



Final use of cryogenic propellant (8 hrs)

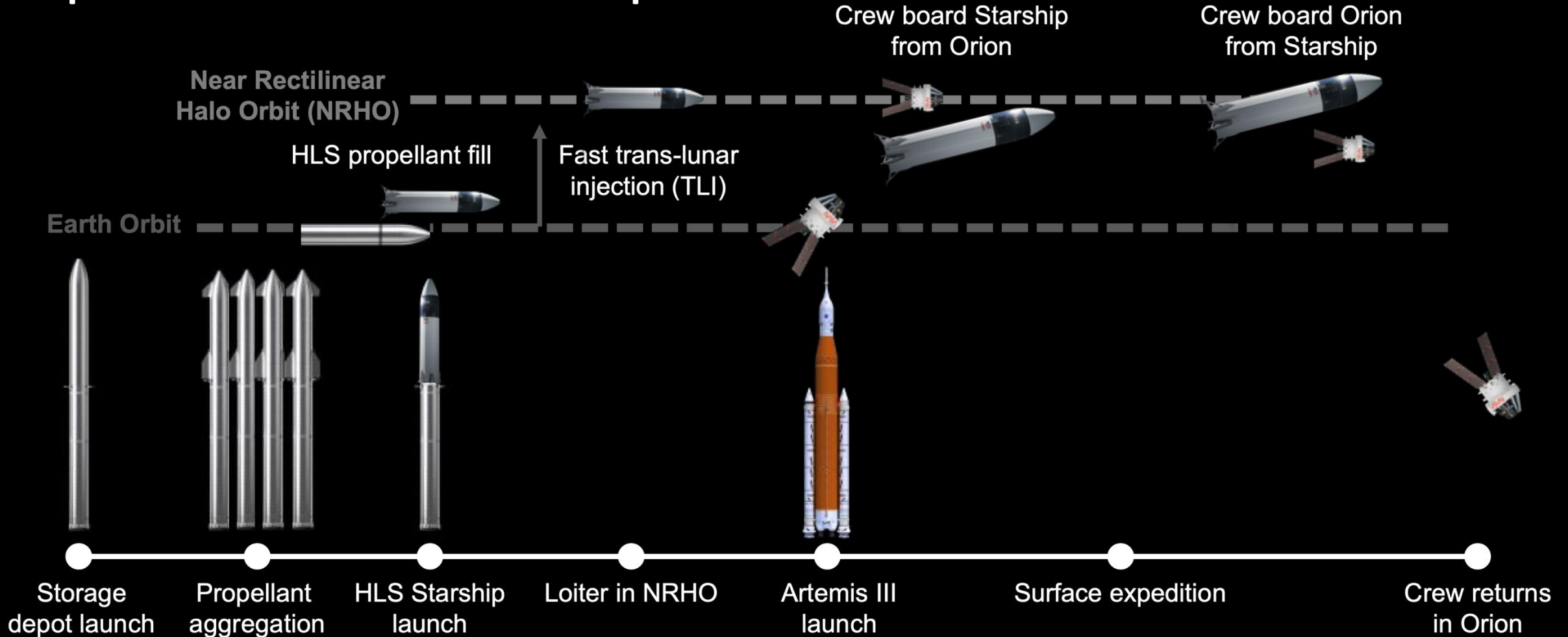
nttrs.nasa.gov– Apollo 8 Mission Report

Figure 3-1.- Apollo 8 mission profile.

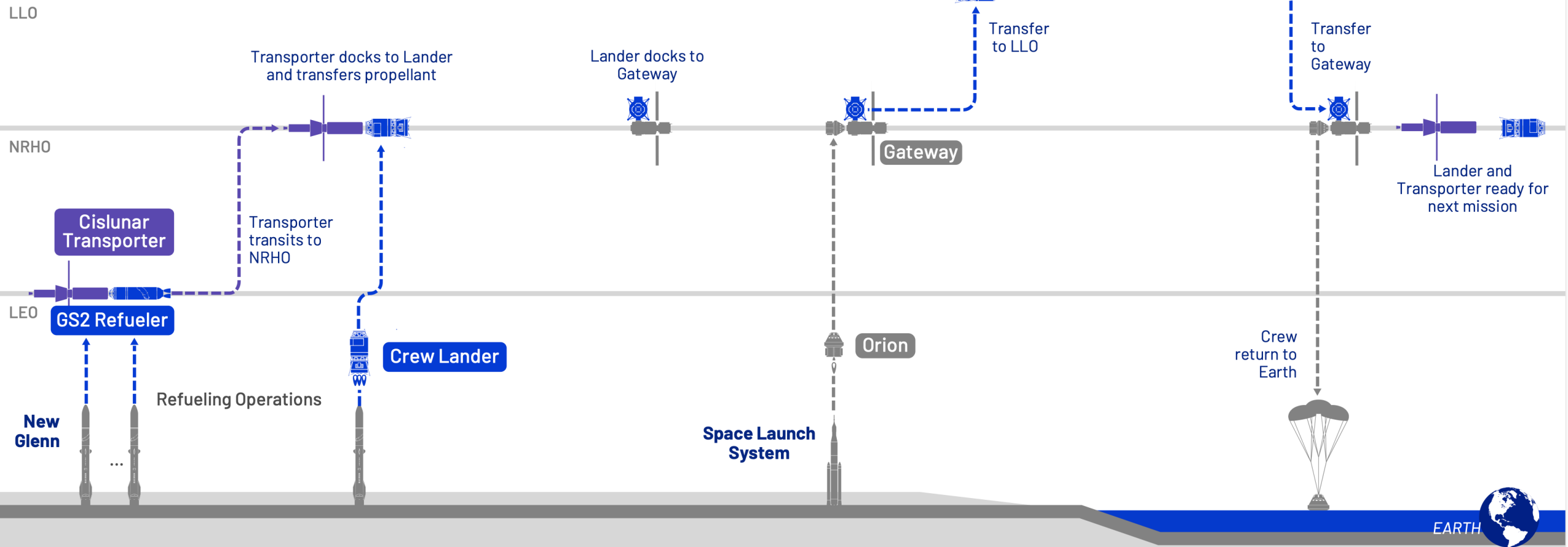
Idea Credit: Noah Rhys, Yetinspace

Starship Human Landing System (HLS) Artemis III Concept of Operations

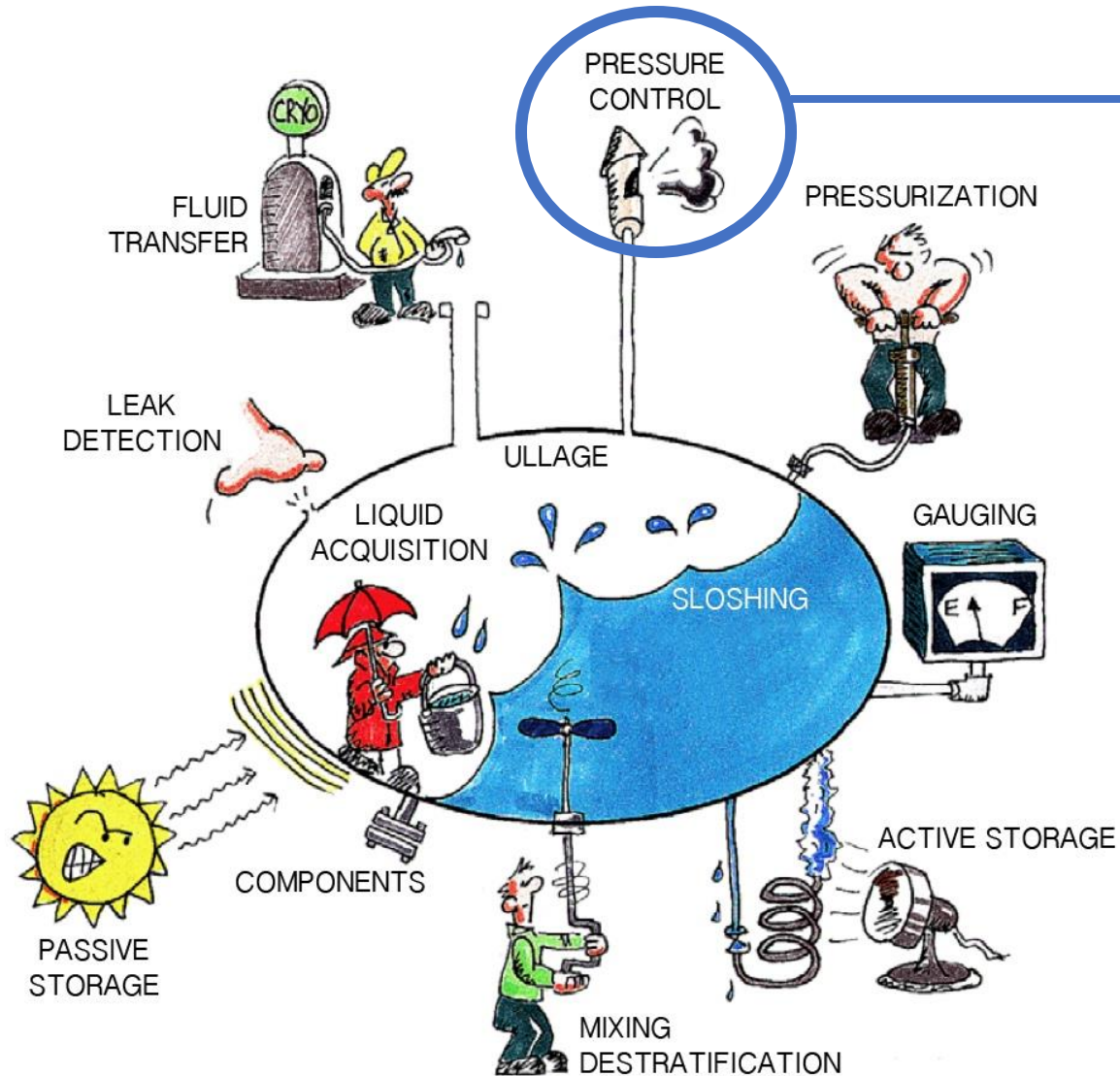
Space X Lunar Starship



Blue Origin Blue Moon Lander



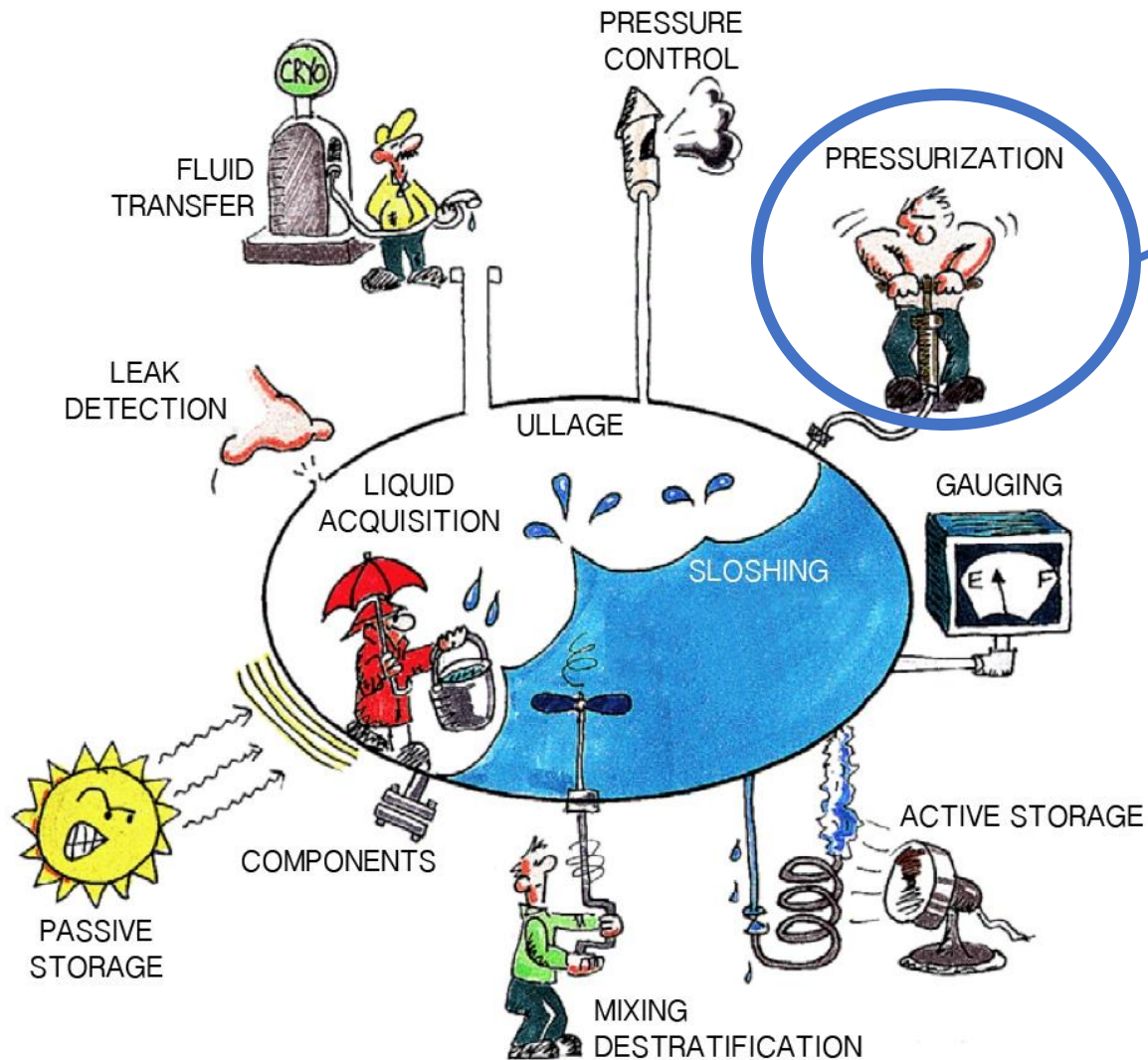
CFM Challenges for HLS



- How do you control the pressure of cryo tanks for months?
- Ways of utilizing vented propellants to cool other systems (thermodynamic vents systems)
- Can this pressurized gas be re-utilized?

Courtesy of NASA GRC

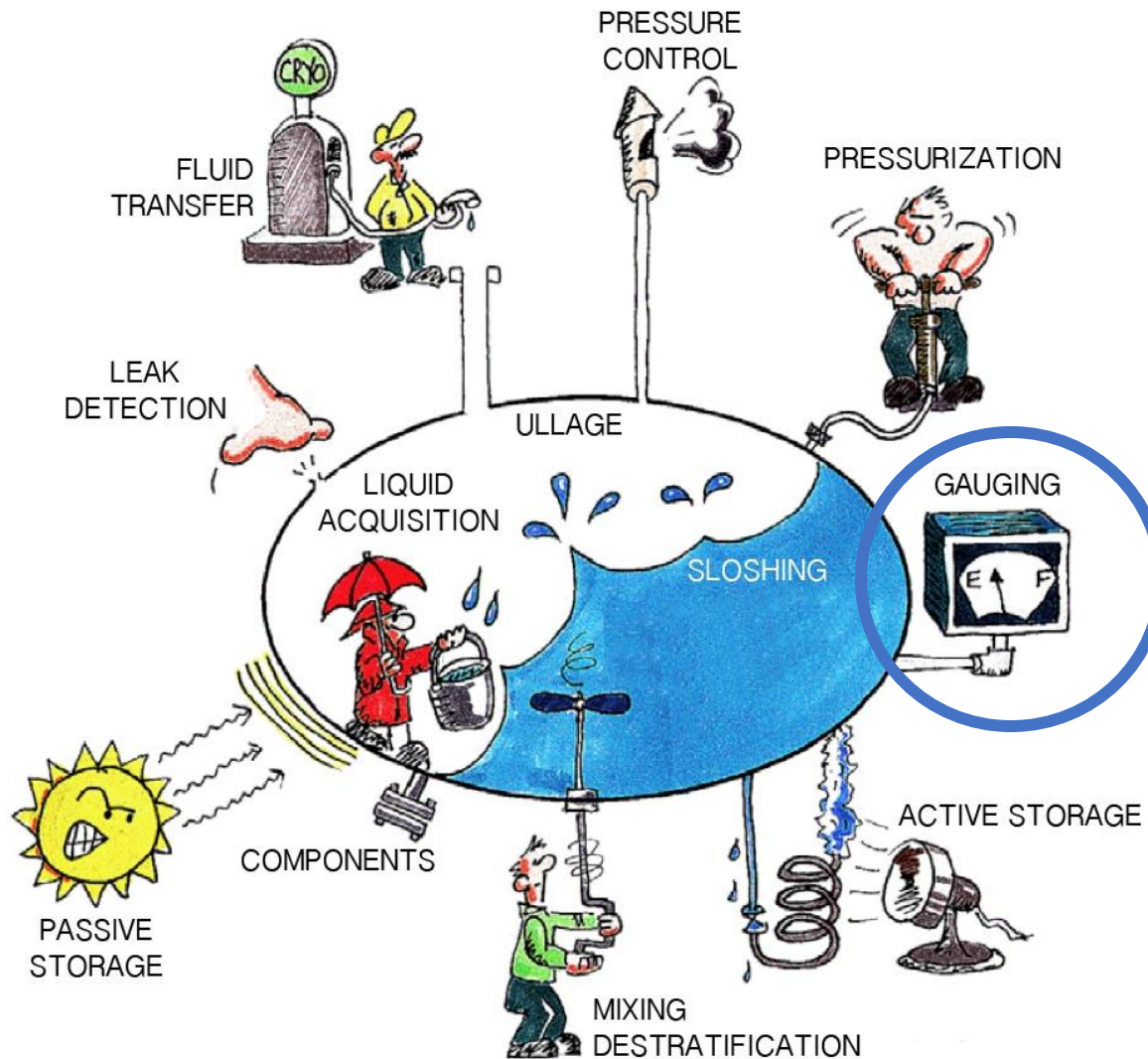
CFM Challenges for HLS



- Helium traditionally used but not suitable for long duration missions
- Novel ways of reutilizing cryo propellants to self press i.e. autogenous pressurization

Courtesy of NASA GRC

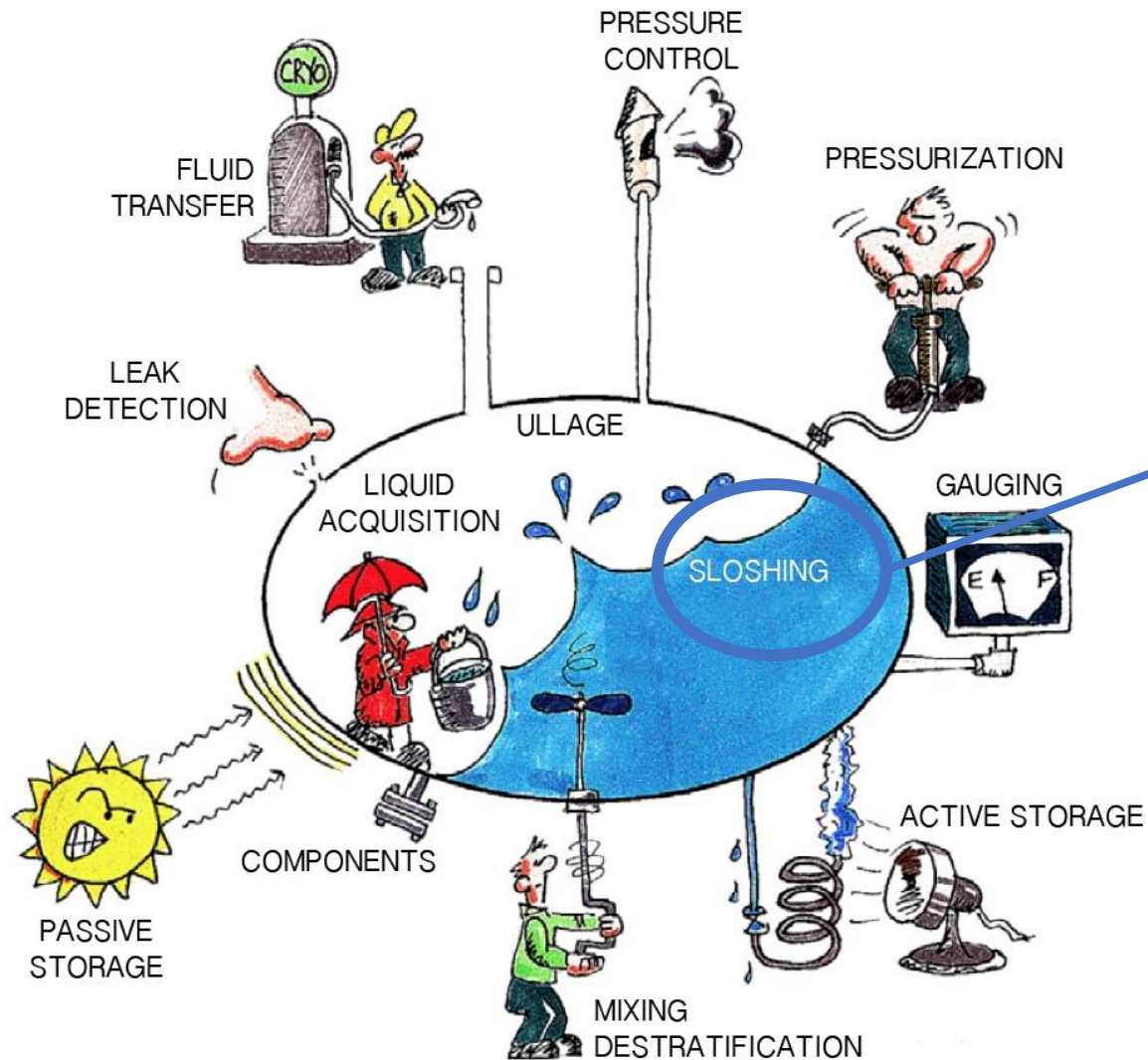
CFM Challenges for HLS



- Liquid Mass Gaging very easy on the ground
- How do you measure liquid mass in a zero gravity environment?
- What non-intrusive methods are there to accurately measure propellant mass/volume in an enclosed space?
- Current SOA is deltaP sensors

Courtesy of NASA GRC

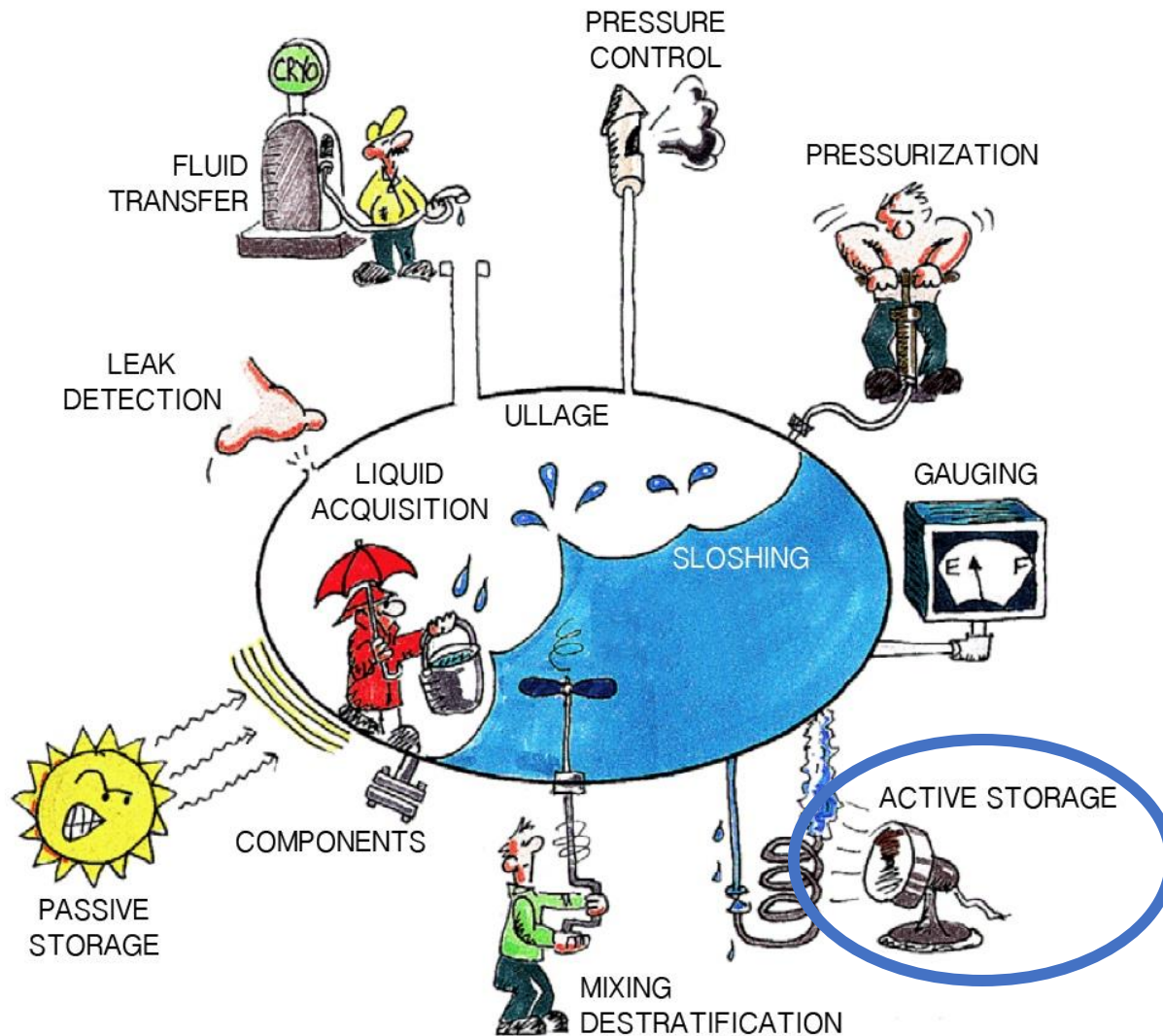
CFM Challenges for HLS



- Propellant sloshing during dynamic events like vehicle docking or landing can lead to catastrophic mission failures
- Multi physics modeling of large quantities of propellant on orbit
- Slosh mitigating devices in the tanks to prevent slosh amplification

Courtesy of NASA GRC

CFM Challenges for HLS



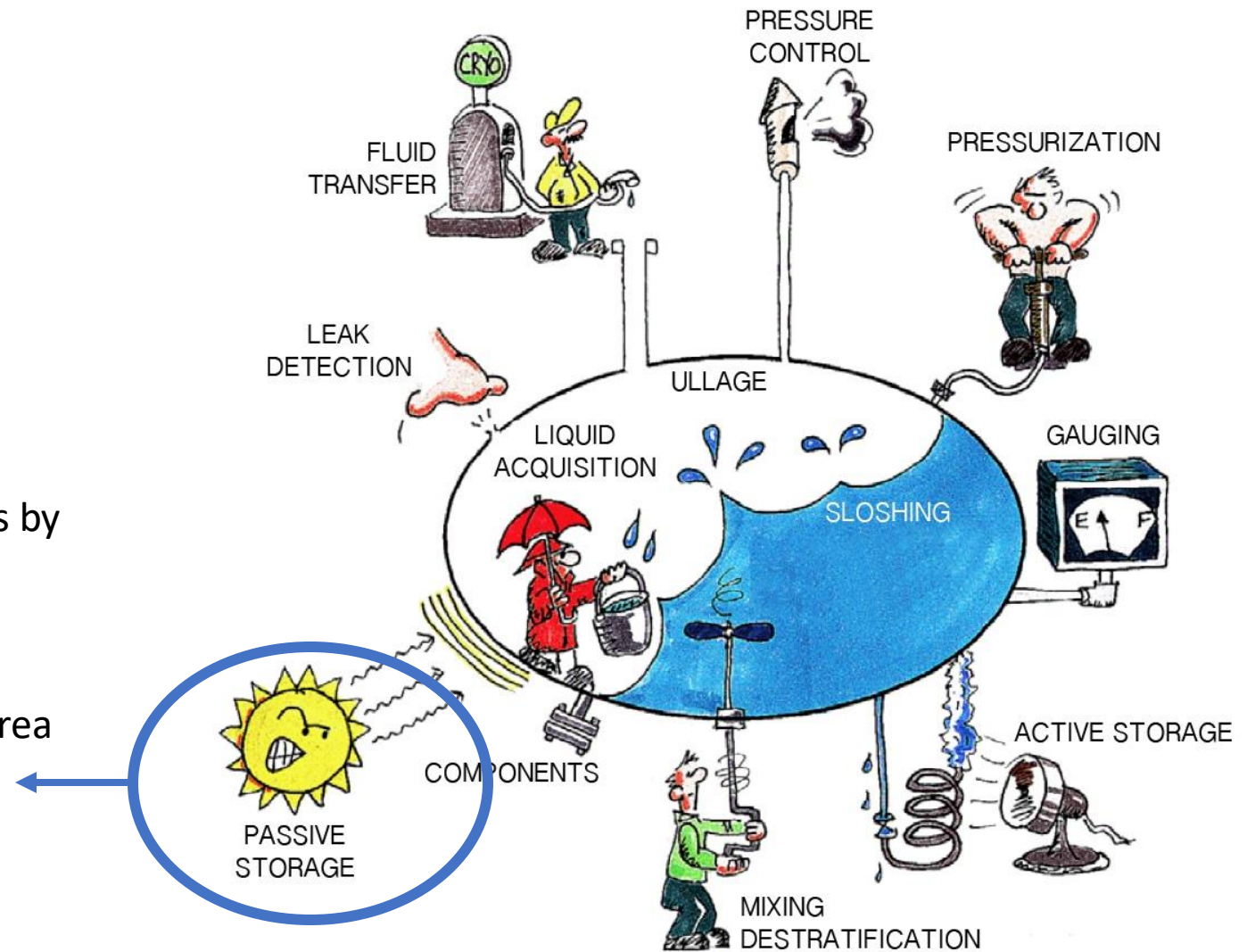
Courtesy of NASA GRC

- In order to achieve Zero boiloff (ZBO), all heat going to the propellant must be intercepted
- Cryocoolers exist in industry but are heavy and require large amounts of power input
- Methods of efficient distribution of the cooling power to the propellant

CFM Challenges for HLS



- Majority of heat leak to the propellants is by radiation (solar, earth albedo, engine soakback)
- What new concepts are there that help radiate energy away from large surface area cryo tanks?
- Examples are radiative blankets i.e Multi Layer Insulation

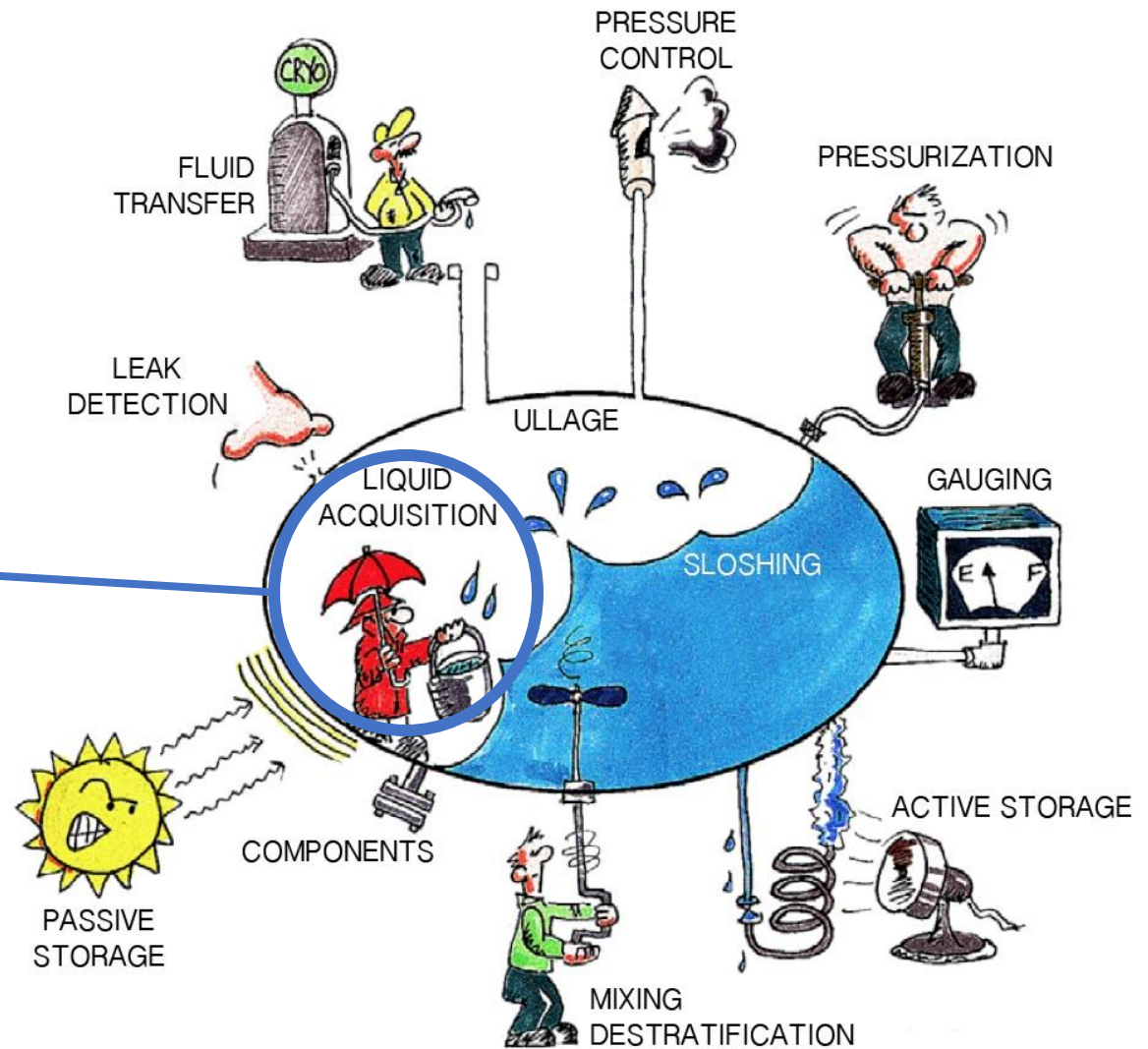


Courtesy of NASA GRC

CFM Challenges for HLS



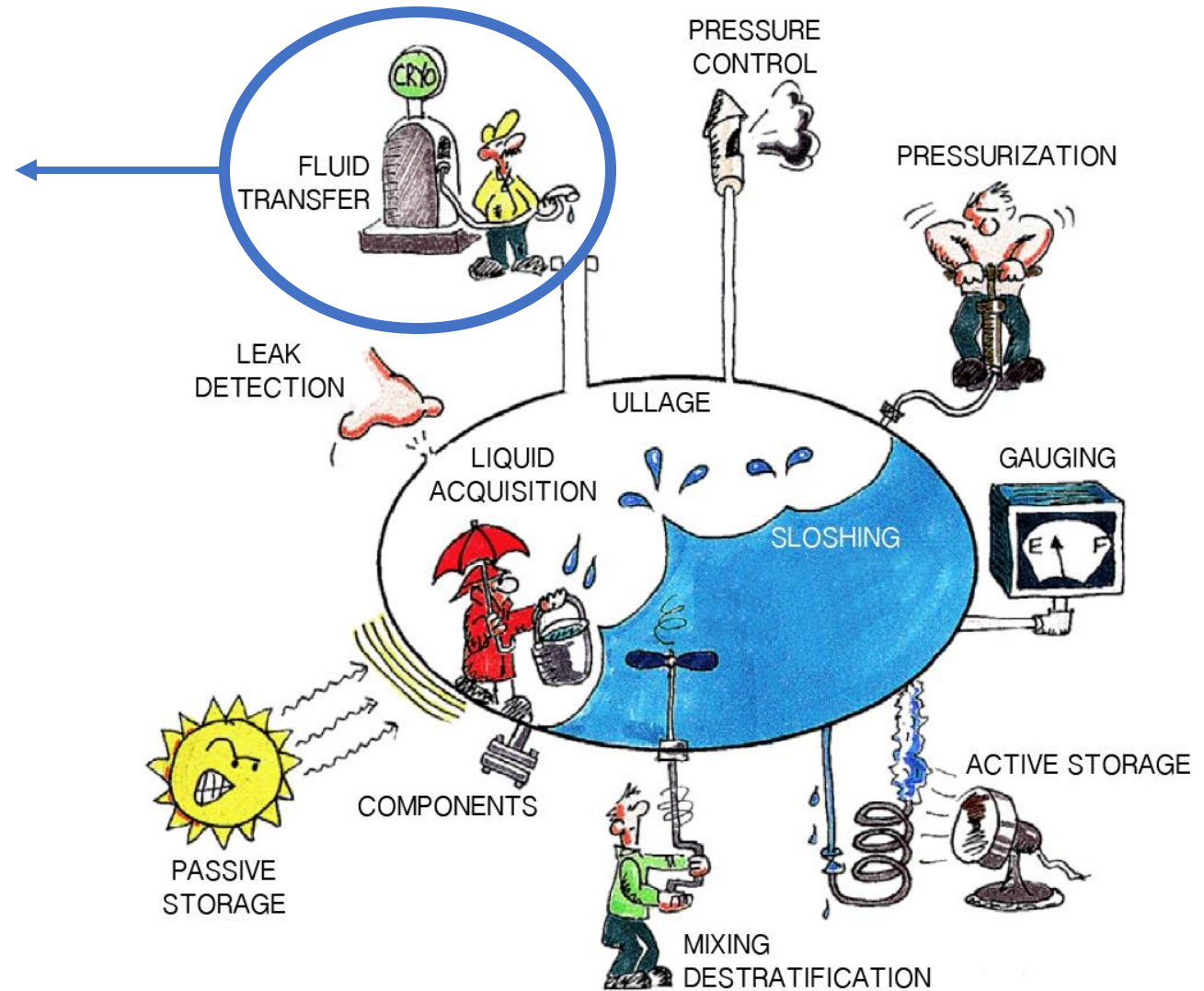
- How to do move propellant out of the tanks in a unsettle condition?
- Take advantage of non-gravity forces acting on the cryo like surface tension or capillary interactions to acquire liquid propellant



CFM Challenges for HLS



- What are the on-orbit operations of transferring multiple tons of cryogenic liquids from one vehicle to another?
- How do you ensure you have a leak tight seal for propellant transfer (automated cryogenic quick disconnect couplers)
- What are the thermodynamics that need to be modeled in zero gravity
 - Line chilldown
 - Tank chilldown
 - Propellant mixing
 - Efficient transfer schemes



Courtesy of NASA GRC



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