



# **CRYOGENIC FLUID MANAGEMENT PORTFOLIO PROJECT (CFMPP)**

## **Guidelines for In-Space Cryogenic Propellant Transfer (ISCPT)**



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- Propellant Transfer Relevance to Artemis
- Document Background
- Document Organization
- Assumptions
- Settled Propellant Transfer
- Unsettled propellant transfer
- Cryocoupler design and construction
- Safety / Potential Hazards
- How to get your copy



# Propellant Transfer Relevance to Artemis

- The ability to perform in-space cryogenic propellant transfer is critical to the success of the Artemis campaign.
- The Human Lander System (HLS) for the Artemis Program includes two vehicles – the SpaceX “Starship” and the Blue Origin “Blue Moon Mark II”.
- The concept of operations for both spacecraft requires the transfer of cryogenic propellants in space:
  - Starship - LO<sub>2</sub> and LCH<sub>4</sub>
  - Blue Moon - LO<sub>2</sub> and LH<sub>2</sub>



# Relevance to Artemis – Starship Lander

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



NASA has awarded SpaceX a contract to develop its HLS Starship for use on Artemis III, the mission that will put the next two Americans on the surface of the Moon, including the first woman.

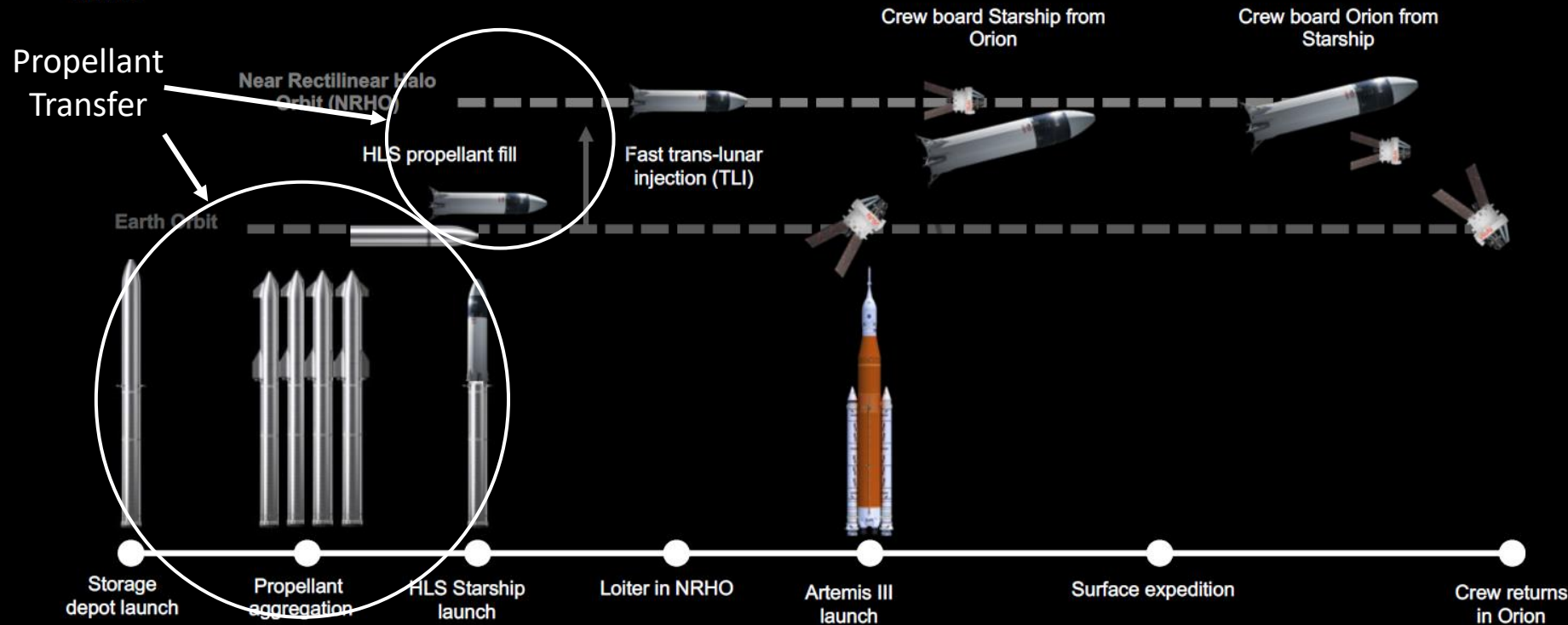


Image credit: SpaceX

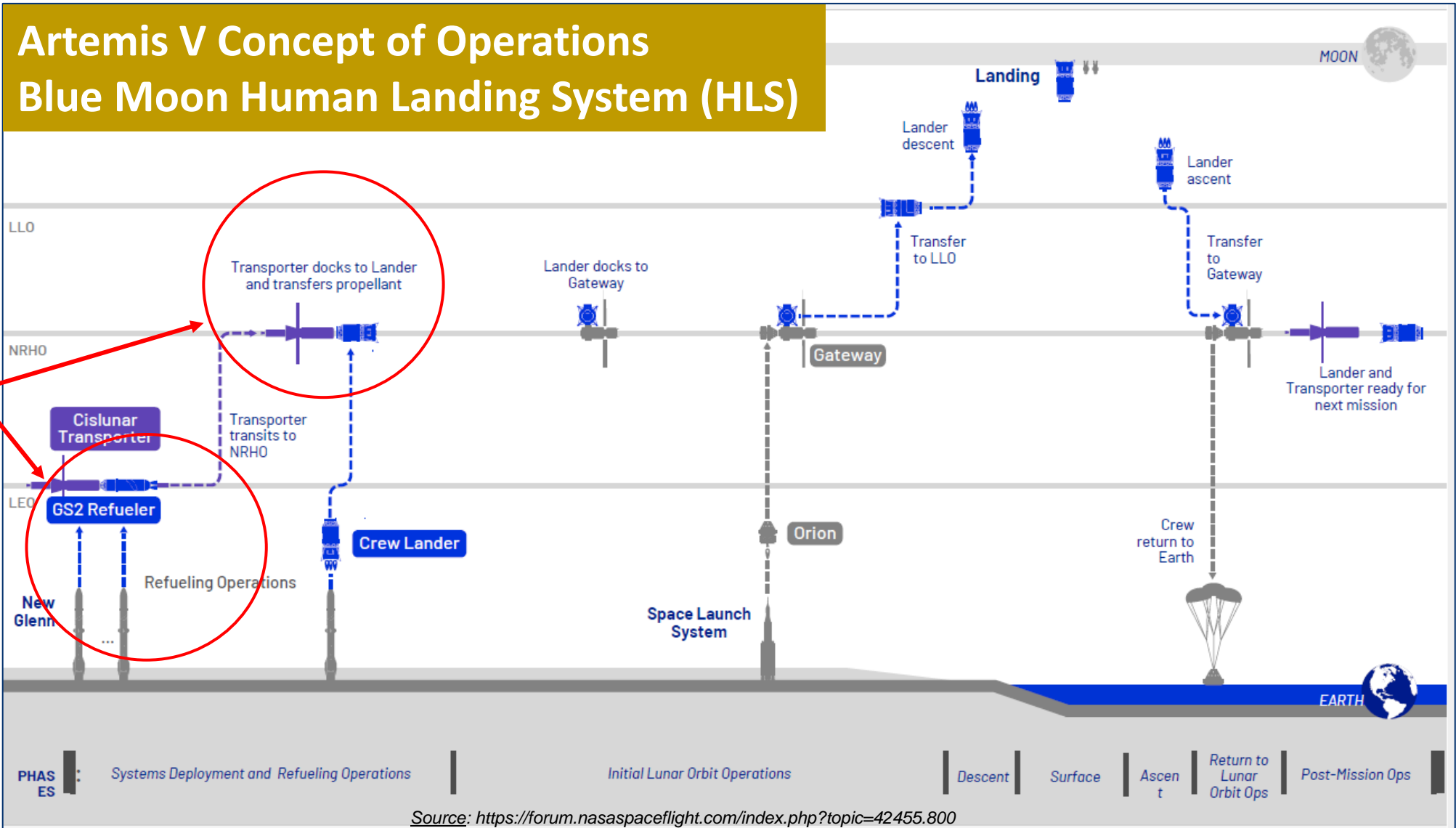
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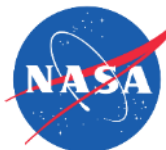
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# NASA Relevance to Artemis – Blue Moon Lander

## Artemis V Concept of Operations Blue Moon Human Landing System (HLS)

Propellant Transfer





# Document Background

- In late 2023, the Project Manager for the [MSFC] CFM Portfolio Project Office tasked a small group of engineers to write a document describing in-space propellant transfer.
- Since propellant transfer between independent spacecraft has never been demonstrated, the consensus was that trying to develop a NASA *standard* was not appropriate. Instead, a guidelines document that could assist planners in developing high-level conops was thought to be more useful.
- The document was baselined in January 2025 as CFM-DOC-008 *Guidelines for In-Space Cryogenic Propellant Transfer (ISCPT)*. (42 pages)



# Document Organization

- 1.0 Purpose/Scope
- 2.0 Applicable Documents
- 3.0 Assumptions
- 4.0 Procedure – Settled Propellant Transfer
- 5.0 Procedure – Unsettled Propellant Transfer
- 6.0 Guidelines for Cryocoupler Construction
- 7.0 Safety Considerations
- Appendix A: Definitions
- Appendix B: Acronyms

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National Aeronautics and  
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ST01

Cryogenic Fluid Management (CFM)

Portfolio Project Office

## Guidelines for In-Space Cryogenic Propellant Transfer (ISCPT)

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- Space vehicles attempting in-space propellant transfer are docked together.
- The docking of the propellant supply spacecraft and the propellant receiving spacecraft accomplishes the alignment of the cryocoupler halves.
- Cryocoupler design is based on passive coupler halves that feature a moving element. The halves open and close through the process of vehicle mating and demating, and they function to isolate the flow when closed.
- Electrical grounding between the propellant supply spacecraft and the propellant receiving spacecraft is accomplished in conjunction with docking.
- Transfer hardware and receiving tank status have been assessed to be suitable for transfer. Examples of assessments include valve actuations, transfer line leak checks, and electrical pin out checks.

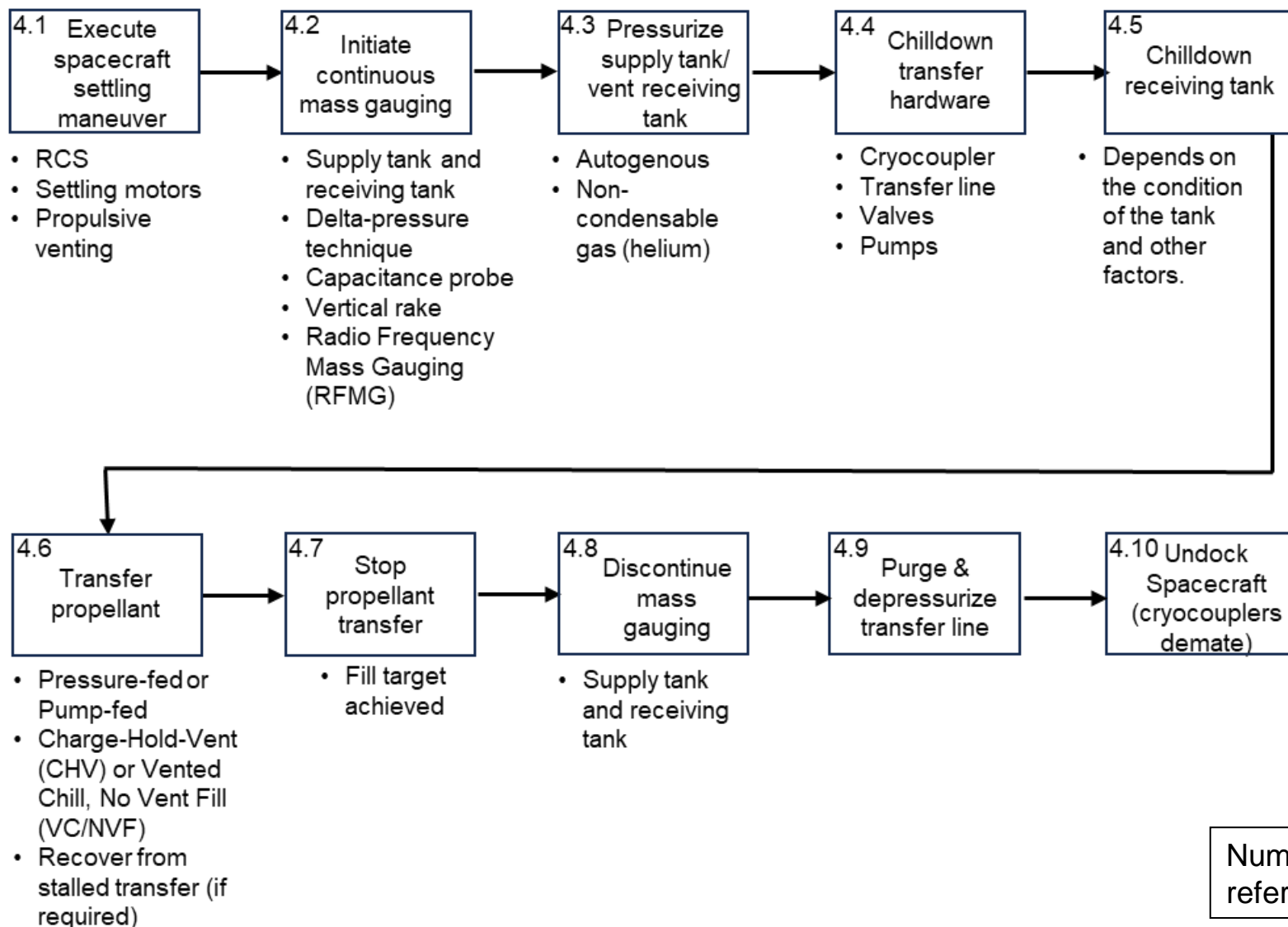


# Settled Propellant Transfer

- Settled Propellant Transfer allows acquisition, tank pressurization, and mass gauging to be accomplished with more conventional methods.
- Micro-acceleration(s) of the docked space vehicles are used to settle propellants prior to initiating transfer operations.
- Micro-accelerations may also be needed during transfer operations to maintain settled conditions.
- Settling can be accomplished via RCS, Settling Motors, or Propulsive Venting.



# Settled propellant transfer – block diagram



Numbers within individual blocks refer to document sections.

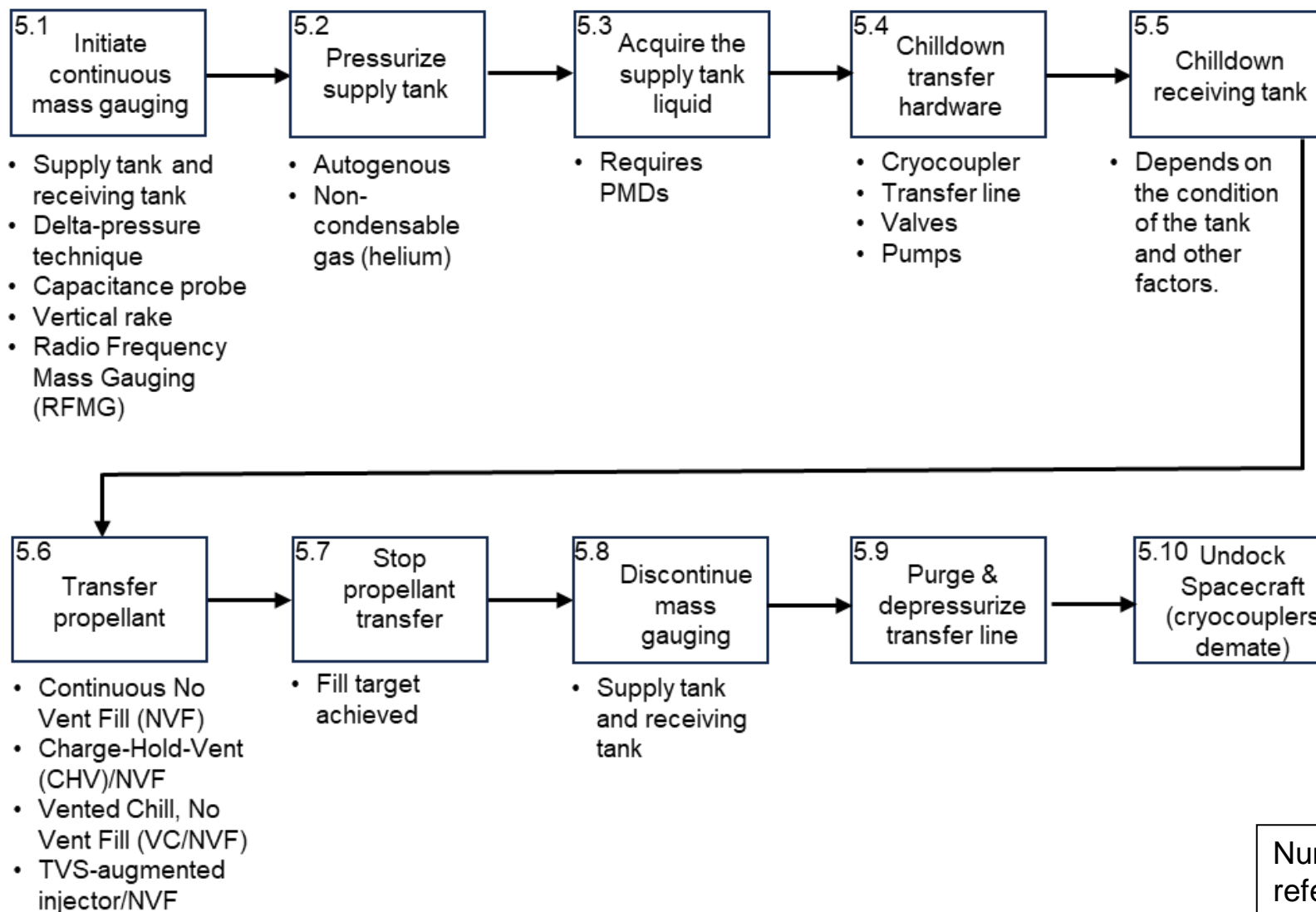


# Unsettled Propellant Transfer

- Requires novel methods and technology since the propellant distribution within the supply tank is not known. One of the main risks when performing unsettled transfer is venting liquid propellant overboard.
- The technique used to chill the hardware and transfer the propellant depends on the initial state of the transfer line and the receiving propellant tank. Chill-down of the transfer line and the receiving tank might occur simultaneously.
- Continuous mass gauging is needed for both the supply tank and the receiving tank.

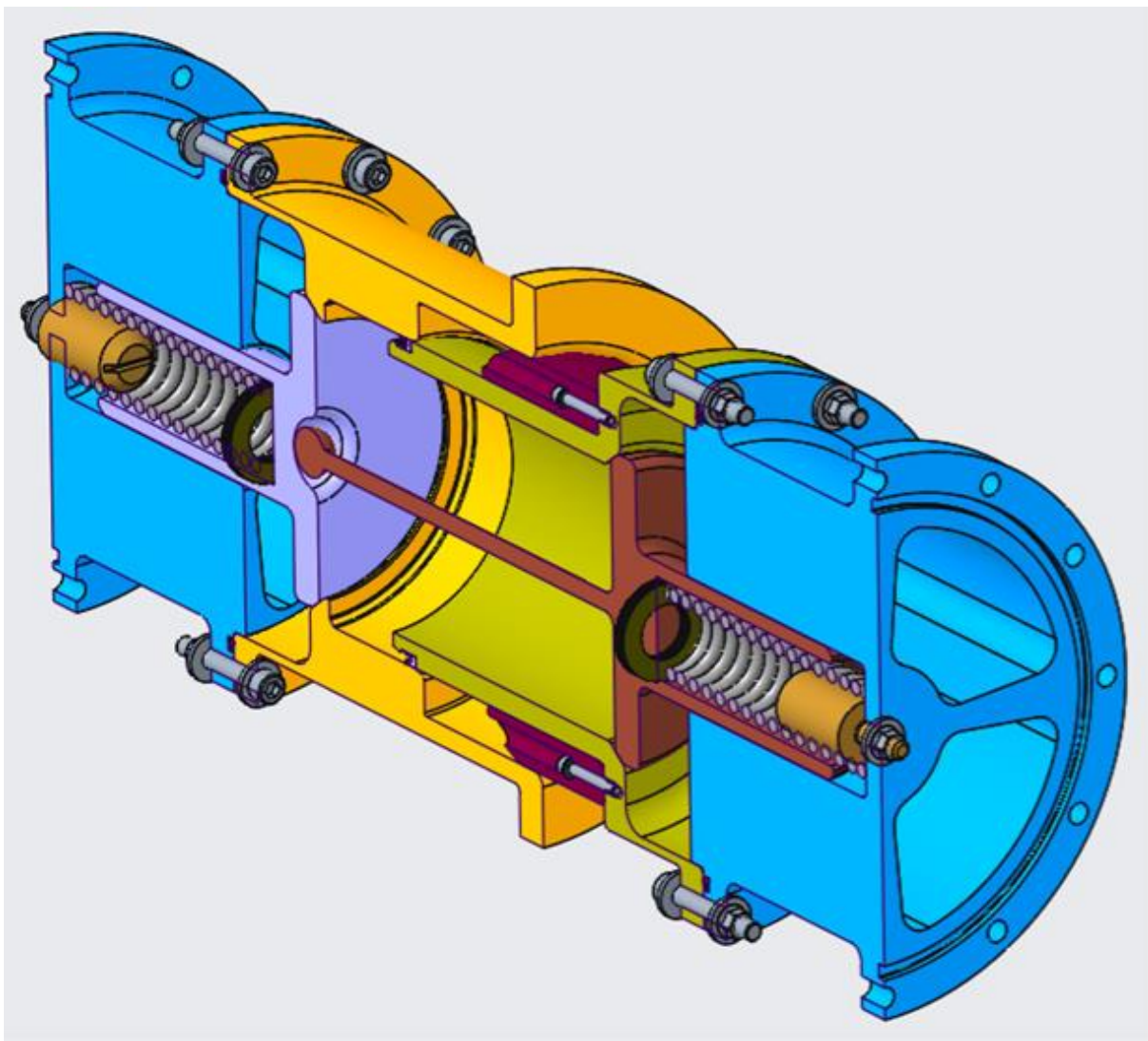


# Unsettled Propellant Transfer – block diagram



Numbers within individual blocks refer to document sections.

- Cryocouplers fall into one of two categories: actively controlled or passively controlled, and they may be completely active, completely passive, or a combination of the two.
- A cryocoupler may be a unidirectional or bi-directional flow mechanism and consists of a male and female half. When joined, the cryocoupler allows for the safe transfer of propellant or oxidizer from one spacecraft to another.
- The guidelines document offers recommendations regarding acceptance and qualification testing, as well as design and construction standards for cryocouplers.



- Emerging Technology
- No commercial products yet
- Uni-directional or bi-directional
- Active or passive or combination
- Male and female halves



# Safety/Potential Hazards

- Systems safety methodology for production of space vehicles and spaceflight is already established within industry.
- The ISCPT guidance discusses the following potential hazards:
  - Propellant leakage
  - Uncontained propellant or propellant vapors
  - Electrostatic discharge
  - LOX flammability
  - Foreign object debris (FOD)
  - Cryogenic fluid state change
  - Unintended propulsive venting
  - Changes in flight dynamics

- The ability to perform in-space cryogenic propellant transfer is critical to the success of the Artemis Program.
- The transfer of cryogenic propellants in microgravity between independent spacecraft has never been demonstrated.
- The Guidelines document described in this briefing is designed to assist planners in developing high-level conops for space missions.
- Copies are available upon request.



# How to get your copy

- CFM-DOC-008 has been marked 'CUI//SP-FEDCON' – releasable to Federal employees and Contractors only.
- Send email request to:

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