

# Integrated Refrigeration and Storage of LNG for Compositional Stability

CryogenicsTestLab KENNEDY SPACE CENTER

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### Introduction

- Many future launch vehicles are planning to use liquefied natural gas (LNG) in combination with liquid oxygen (LOX)
- LNG as a rocket fuel
  - Highly efficient, widely available, and low cost
  - Clean combustion characteristics, improving refurbishment and reusability
  - Can self-pressurize ullage of tanks (reduces helium usage)
- Compositional changes due to preferential boiloff (or weathering) occur
- Integrated refrigeration and storage (IRaS) can provide active heat extraction (i.e. refrigeration) to eliminate weathering)

# Experimental Cryostat Apparatus

- 400-liter vertical vacuumjacketed cylindrical vessel (cryostat) with an integrated pulse tube cryocooler (approximately 50 W at 100 K)
- RTDs and 1.6-mm
   diameter liquid sample
   tubes on vertical rake for
   5 liquid levels



# Objectives

- 1. Compare composition changes of LNG using traditional boiloff/venting to using IRaS
- 2. Study feasibility and cost-effectiveness of long-term storage using active refrigeration
- 3. Investigate feasibility and benefit of densified LNG

# **Experimental Approach**

#### Test steps

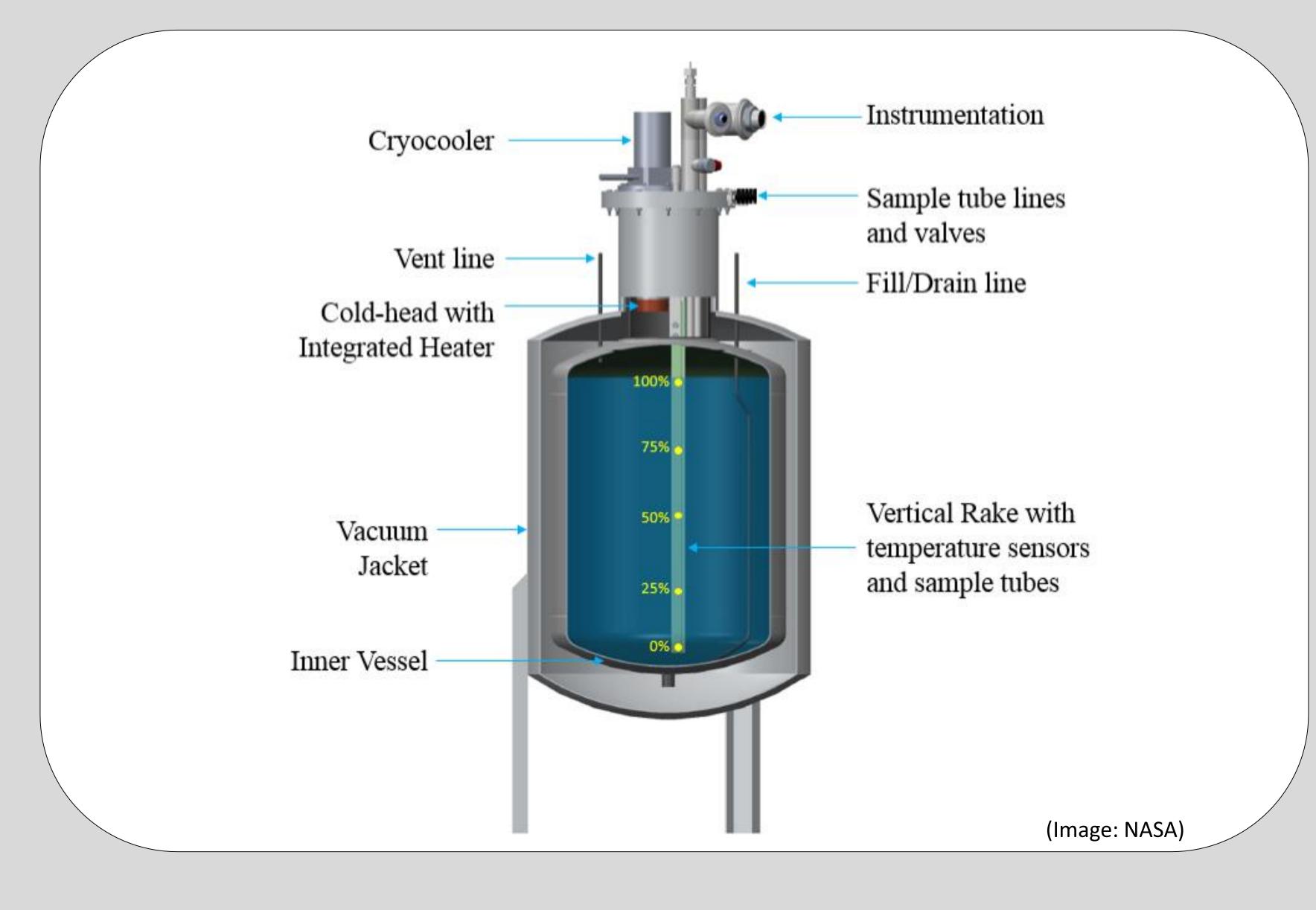
- 1. Fill with LNG and leave vent open
- 2. Sample LNG while LNG evaporates, until tank is empty
- 3. Fill cryostat with LNG again
- 4. Close vent and turn on cryocooler
- 5. Adjust heater controls for zero boiloff (ZBO)
- 6. Allow zero boil-off for 2 weeks

#### Sampling procedure

- 1. Continuously analyze vent output with mass spectrometer (only during boiloff test)
- 2. Three times a week, sample each of the five liquid levels
- 3. Once a week, sample each of the five liquid levels using a gas analyzer

# Modes of Operation

- Boiloff: Without refrigeration, in order to determine a baseline in the change in composition, and to study stratification of the LNG (boiloff test)
- Zero boiloff: Cryocooler active to determine the operational parameters of the IRaS system for eliminating the weathering as well as stratification effects in the bulk liquid



# Sampling Methods

- Sampling two different ways
- Precisive 5-283 Gas Analyzer from MKS (Infrared /optical analyzer)
- Mass spectrometer

#### Gases measured

Methane Ethane Propane Iso-Butane n-Butane Pentanes

CO2

## Status

- $LN_2$  boiloff test performed for heat leak approximation. The heat leak during this test was < 22 W.
- Cryostat with integrated cryocooler and heat exchanger built and in place
- Connecting hardware, instrumentation, and data-recording setup in-work
- Sourcing LNG