EMBRY-RIDDLE
Aeronautical University

Testing Procedures Documentation

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1 Introduction

1.1 Purpose

This test plan outlines the approach and framework for testing the chemical propulsion system of the Mars transfer vehicle. The testing framework covers all propulsion-related components, including RS-25 engines, cryocoolers, propellant tanks, attitude control thrusters (ACTs), and associated structural and fluid systems. The objective is to validate these components under simulated operational conditions to ensure performance, safety, and reliability.

The testing strategy includes structural verification through FEA simulations, thermal and fluidic assessments for cryogenic systems, vibration testing under launch conditions, and propulsion system performance evaluations. This ensures that each component operates correctly both independently and as part of the integrated vehicle. Testing will also confirm compatibility between fuel and oxidizer transfer systems, thermal management solutions, and engine performance characteristics.

1.2 Project Overview

This project focuses on developing and testing a chemical propulsion system for a long-duration crewed mission. The system consists of six RS-25 engines, cryogenic propellant tanks, cryocoolers for thermal regulation, and ACTs for attitude and trajectory control. These components are integrated into the spacecraft's structure and must withstand extreme launch forces, prolonged exposure to space conditions, and sustained high-thrust operations.

The primary objectives of this test plan are to ensure that:

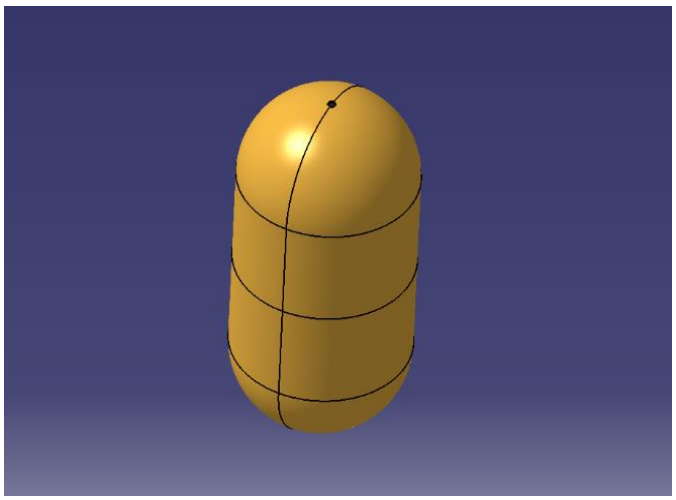
- The propulsion system functions reliably in vacuum conditions.
- Cryogenic cooler maintains fuel at required temperatures during long-duration spaceflight.
- The structural integrity of the tanks and engine mounts is validated under expected loads.
- The ACTs provide necessary attitude adjustments with precision.
- The RS-25 engines operate at expected thrust levels and efficiency without failure.

2. Testing for Individual Components

2.1 Testing Objectives

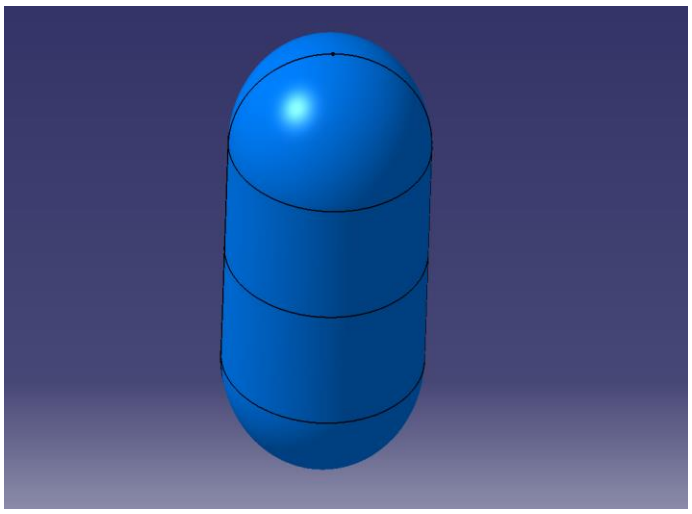
Propellant Tanks – Liquid Hydrogen

1. Series Number: 1 of 3
2. Part Number: 1
3. CAD Model:



Propellant Tanks – Liquid Oxygen

1. Series Number: 2 of 3
2. Part Number: 2
3. CAD Model:

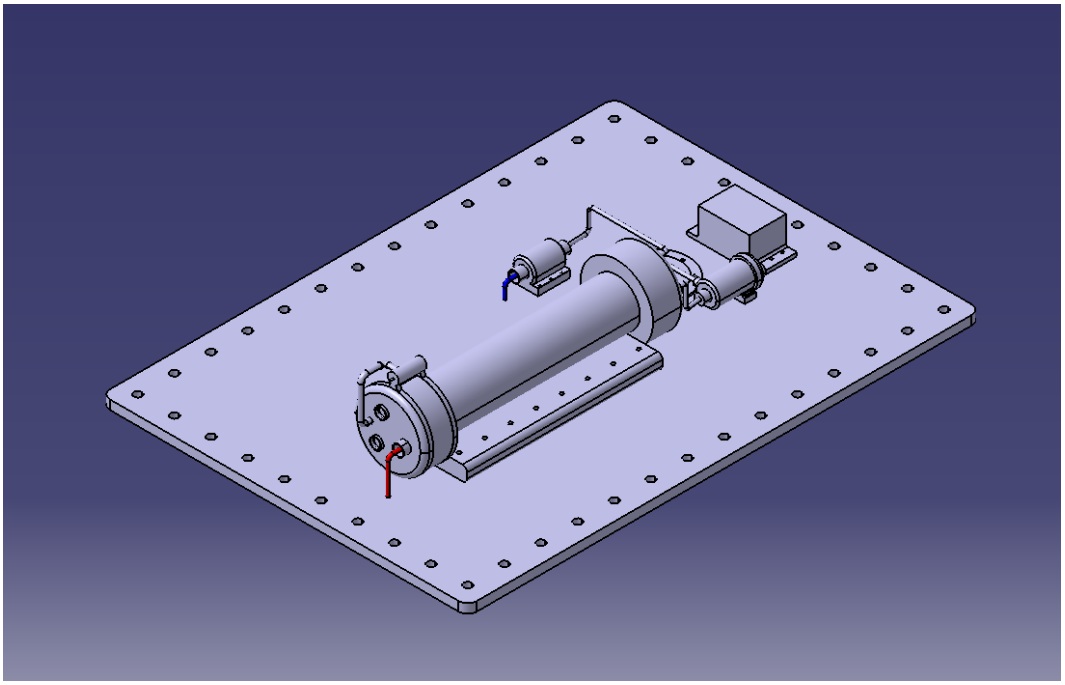


Propellant Tanks – Helium

1. Series Number: 3 of 3
2. Part Number: 3
3. CAD Model:

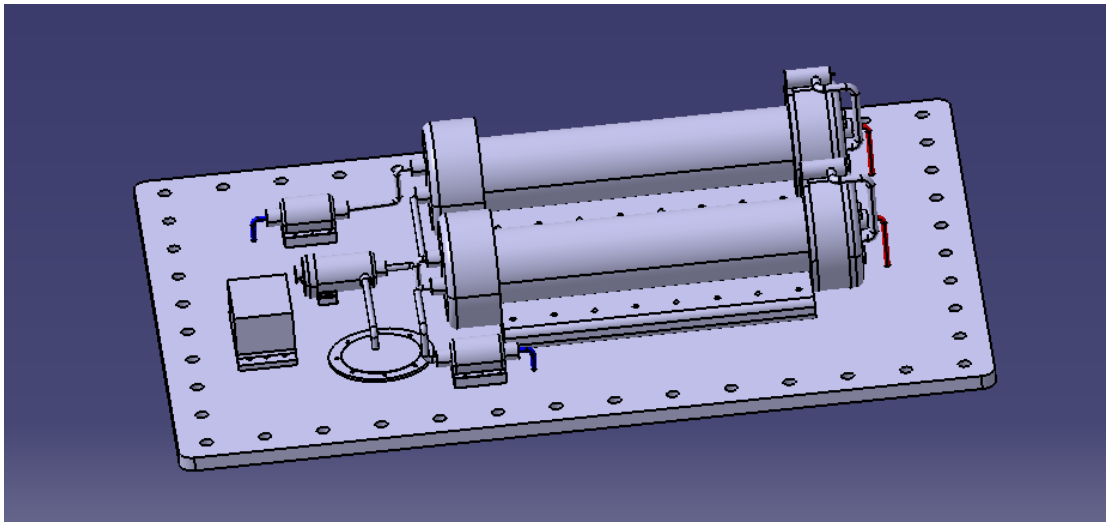
Cryocooler System - Single Stage

4. Series Number: 1 of 2
5. Part Number: 1
6. CAD Model:



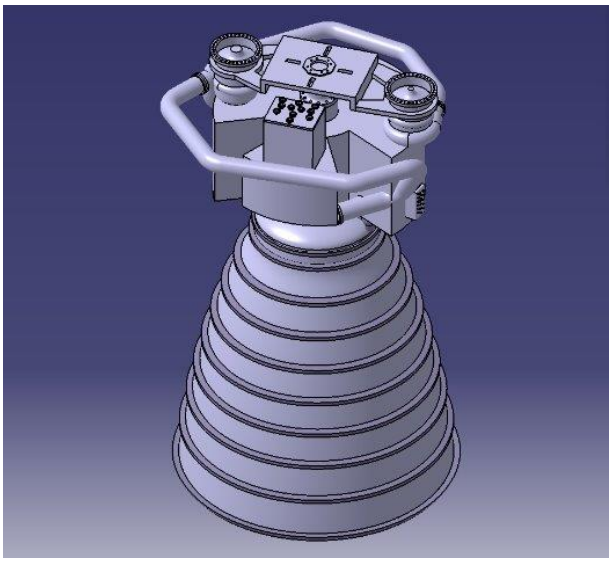
Cryocooler System – Two Stage

1. Series Number: 2 of 2
2. Part Number: 2
3. CAD Model:



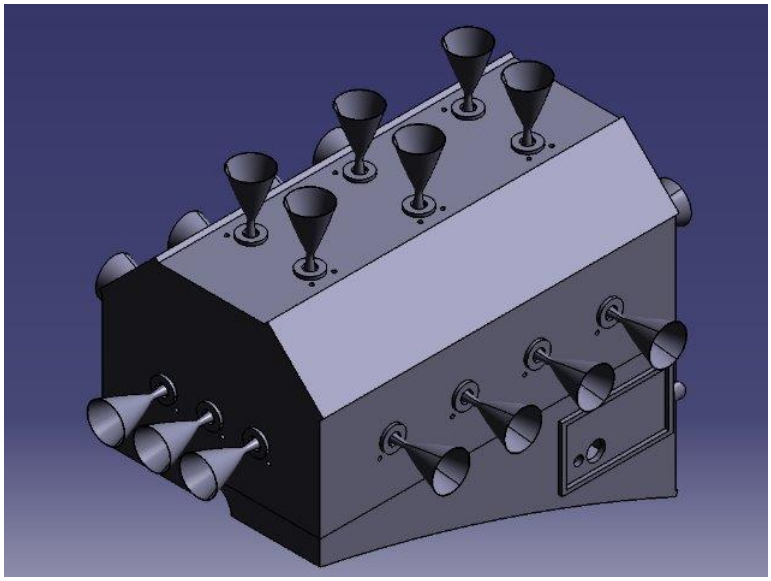
RS-25 Engines

4. Series Number: 1 of 1
5. Part Number: 1
6. CAD Model:



Reaction Control System (RCS)

1. Series Number: 1 of 1
2. Part Number: 1
3. CAD Model:



2.2 TYPE OF TESTING

Propellant Tanks

1. Required Test: Structural stress testing, cryogenic leak testing, pressure testing
2. Reasons: Validate the integrity of the tanks under extreme thermal and mechanical conditions

Cryocooler System

1. Required Test: Thermal load capacity testing, vacuum chamber simulation, heat transfer efficiency testing
2. Reasons: Ensure effective cooling of liquid hydrogen and liquid oxygen throughout the mission

RS-25 Engines

1. Required Test: Thrust performance testing, thermal stress evaluation, vacuum ignition testing
2. Reasons: Validate engine performance under expected mission conditions and ensure operational reliability

Reaction Control System (RCS)

1. Required Test: Precision firing tests, response time evaluation, fuel consumption efficiency testing
2. Reasons: Confirm that ACTs provide accurate and reliable attitude control

2.3 TESTING EQUIPMENT/FACILITIES

Propellant Tanks

1. Testing facility: Cryogenic materials testing lab
2. Equipment used: Pressure chambers, infrared thermal imaging, strain gauges

Cryocooler System

1. Testing facility: Thermal vacuum chamber
2. Equipment used: Heat flux sensors, vacuum simulation chamber, cryogenic cooling loops

RS-25 Engines

1. Testing facility: NASA Stennis Space Center test stand or equivalent
2. Equipment used: Thrust measurement devices, high-speed thermal cameras, fuel flow sensors

Reaction Control System (RCS)

1. Testing facility: Propulsion test lab
2. Equipment used: Vacuum chambers, precision pressure gauges, actuators for nozzle vectoring tests

2.4 Testing Procedures

Propellant Tanks

1. Pressurize tanks to mission-expected loads and measure deformation.
2. Conduct cryogenic fluid fill and monitor for leakage or material failure.
3. Evaluate structural integrity using strain gauges and thermal imaging.

Cryocooler System

1. Place cryocooler in a vacuum chamber to simulate space conditions.
2. Measure combustion efficiency and exhaust temperature.
3. Evaluate engine performance in simulated vacuum conditions.

RS-25 Engines

1. Conduct static fire testing to verify thrust output.
2. Measure combustion efficiency and exhaust temperature.
3. Evaluate engine performance in simulated vacuum conditions.

Reaction Control System (RCS)

1. Conduct precision firing sequences in a vacuum condition.
2. Measure response time and fuel efficiency.
3. Verify performance under expected mission conditions.

2.5 Results and Limitation

Propellant Tanks

- Results should not exceed allowable deformation limits.
- Tanks must maintain internal pressure without significant heat loss.
- Safety certification for cryogenic fuel containment required.

Cryocooler System

- Cooling efficiency should remain within operational thresholds.
- Temperature drop should match predicated performance values.
- Must maintain stability over extended mission duration.

RS-25 Engines

- Thrust output should match predicted values with less than 5% deviation.
- Must pass vacuum ignition and operational stress tests.
- No overheating or excessive wear should be observed.

Reaction Control System (RCS)

- Response time should be within mission-specified parameters.
- Fuel consumption must remain efficient under varying conditions.
- System should meet all safety certification requirements.

This document outlines the testing framework for the chemical propulsion system, ensuring that all components meet performance, safety, and mission requirements before integration into the final spacecraft assembly.