Ground Test Strategy for a Nuclear Thermal Propulsion Engine

David Coote

NASA/Stennis Space Center

Propulsion and Energy Forum, 9-11 July 2018

Duke Energy Convention Center, Cincinnati, Ohio

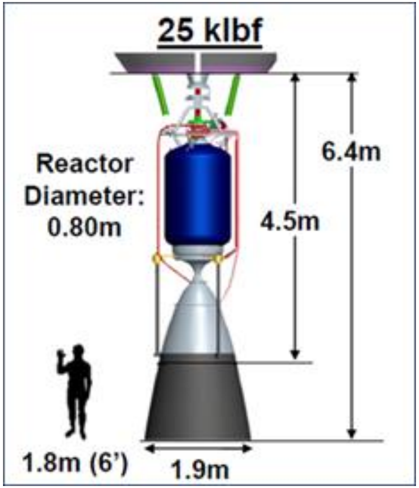
Introduction

- Nuclear Thermal Propulsion (NTP) is directly relevant to the Agency's vision, mission, and long-term goal of expanding human presence into the solar system and to the surface of Mars
  - Provides the fastest trip time of all currently obtainable advanced propulsion systems.
  - Offers high energy density and a specific impulse roughly double that of the highest performing traditional chemical systems.
- NTP project is funded through the Space Technology Mission Directorate's (STMD) Game Changing Development (GCD) program
  - Goal is to determine the feasibility and affordability of a Low Enriched Uranium (LEU)-based NTP engine with credible cost and schedule confidence.

Introduction

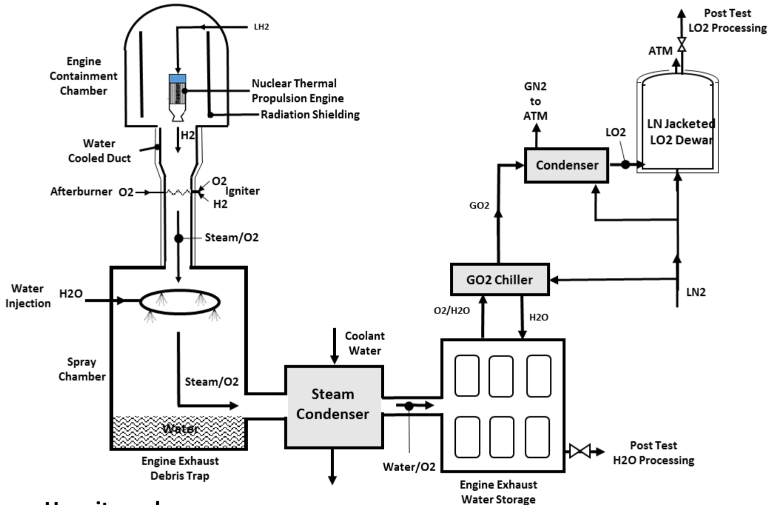
- An NTP engine has substantial commonality with conventional liquid rocket engines.
  - Primary difference is replacing combustion of propellants with heating of a single propellant via a nuclear reactor.
  - Exhaust may contain radioactive particles and noble gases due to a reactor anomaly or failure.
- NASA has developed the Rocket Exhaust Capture System (RECS) concept to capture and isolate NTP engine exhaust from the environment to mitigate the related environmental risks.

- **Driving Requirements**
  - Thrust: 25k lbf
  - Burn time: 50 min + 10% margin = 55 min burn
  - Exhaust temp: 2850K
  - Hydrogen flow rate: 28 lbm/s
  - Max allowable back pressure: 25 psia
  - Meet regulatory requirements for dose rates



Preliminary Engine Architecture

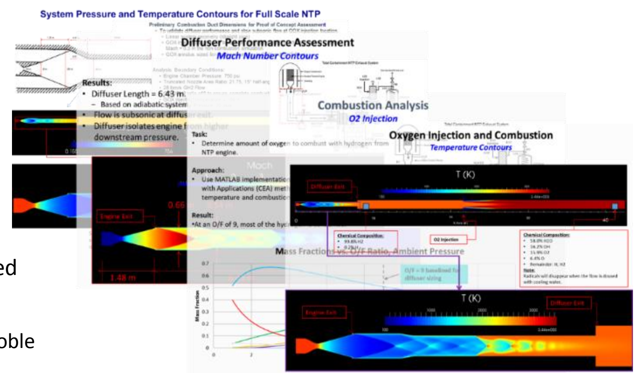
Nuclear Thermal Propulsion Ground Test Strategy - Rocket Exhaust Capture System -



Strategy:

- Fully contain engine exhaust
- Methodically drain containment vessels after test to ensure proper filtration

Preliminary system sizing and performance analysis of this concept have been completed and no operations performance issues have been identified



All system operating pressures and temperatures and fluid supply and flow requirements are well within existing chemical rocket propulsion test capability and experience

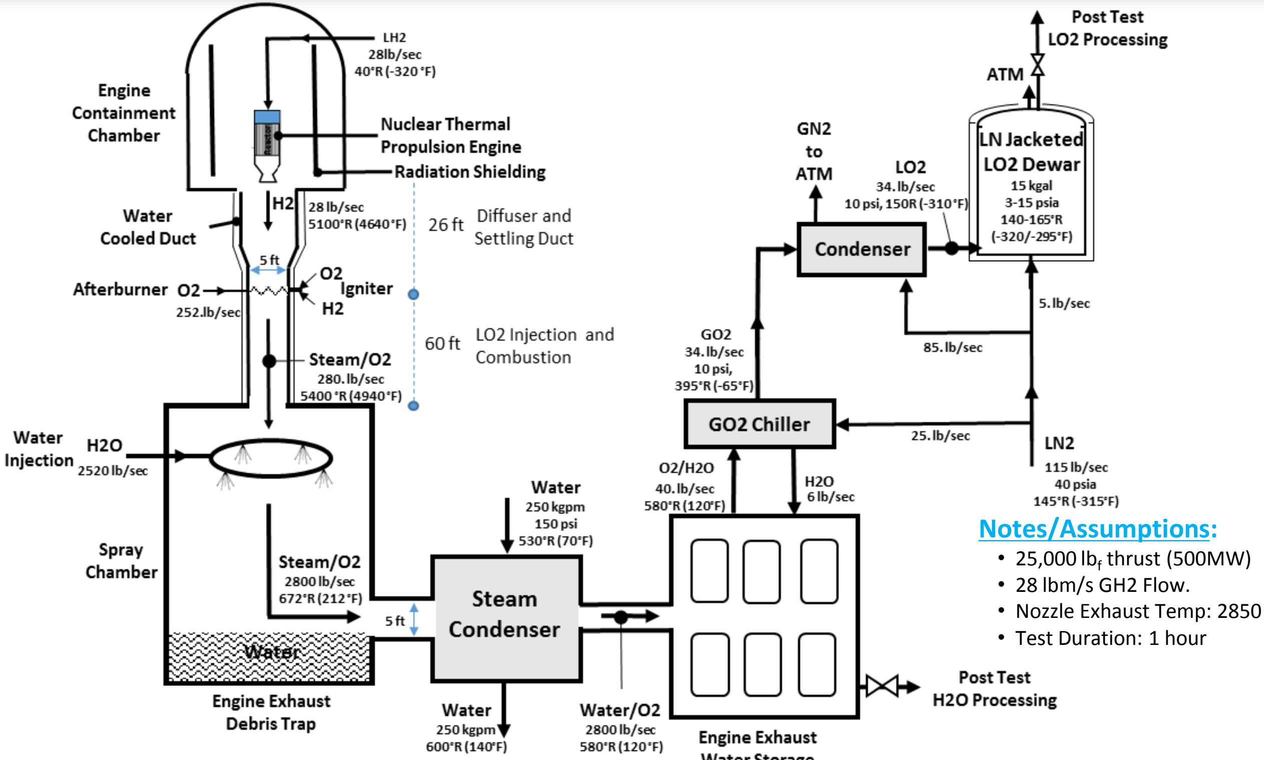
How it works:

- Hot hydrogen exhaust from the NTP engine flows through a water cooled diffuser that transitions the flow from supersonic to subsonic to enable stable burning with injected LO2
  - Products include steam, excess O_2 and potentially, a small fraction of noble gases (e.g., xenon and krypton)
- Water spray and heat exchanger dissipates heat from steam/O2/noble gas mixture to lower the temperature and condense steam
- Water tank farm collects H_20 and any radioactive particulates potentially present in flow
  - Drainage is filtered post test
- Heat exchanger-cools residual gases to LN2 temperatures (freezes and collects noble gases) and condenses O2
  - LO2 Dewar stores LO2, to be drained post test via boil-off

Rocket Exhaust Capture System

Preliminary System Sizing - 25 klbf Engine

SPACE TECH'S GAME CHANGING DEVELOPMENT PROGRAM



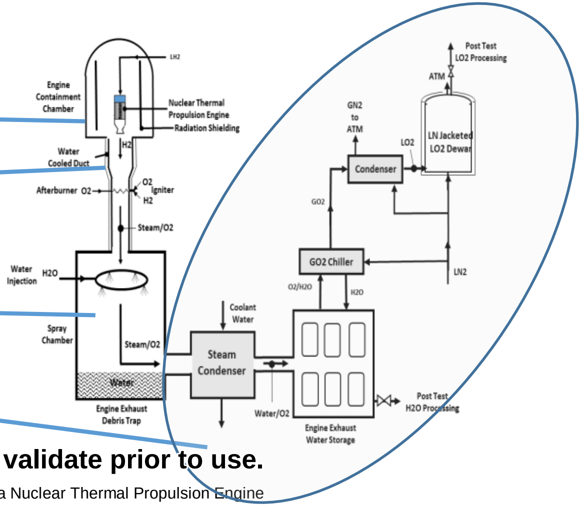
Notes/Assumptions:

- 25,000 lb_f thrust (500MW)
- 28 lbm/s GH2 Flow.
- Nozzle Exhaust Temp: 2850 K
- Test Duration: 1 hour

RELEASED - Printed documents may be obsolete; validate prior to use.

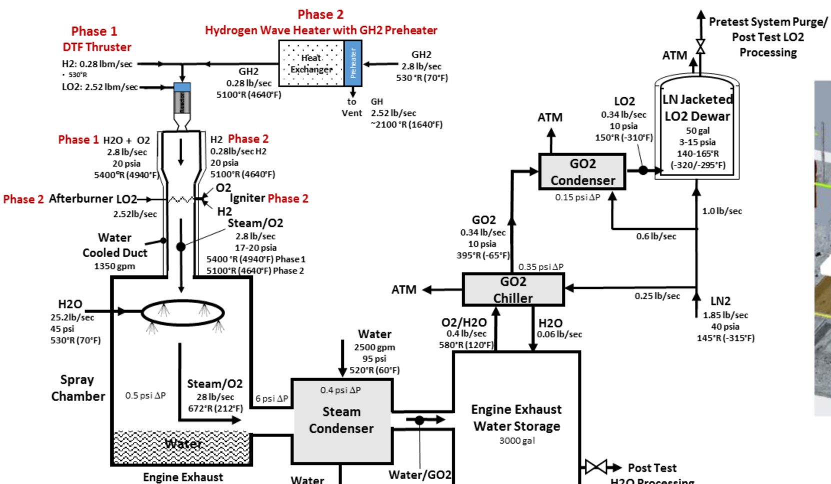
Rocket Exhaust Capture System Is Expected to Be Built at NASA's Stennis Space Center (SSC)

- SSC's A3 test facility and its supporting propulsion test infrastructure is uniquely suited to accommodate NTP engine system development and specifically, the RECS implementation requirements.
  - Most of the RECS major structural elements are readily available.

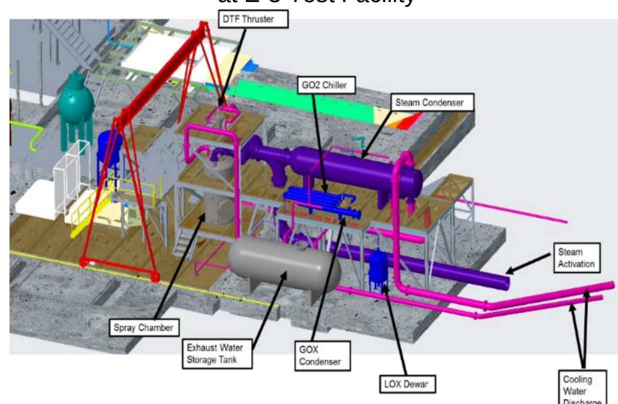


Rocket Exhaust Capture System
Subscale Test Project

- Phase 1 Objective: Demonstrate the basic performance of the RECS to capture, contain, process, and store rocket exhaust effluents
  - Utilizes an existing, well-characterized DTF Thruster (~250 lbf) to simplify H2 afterburning
- Phase 2 Objectives: Demonstrate
  - Stable H2 combustion flame holding following LO2 injection
  - Back pressure control in the settling and combustion duct sections during NTP engine simulated transient start and shutdown H2 flow conditions
  - Simulation of NTP engine start and shutdown transient flow conditions using a Hydrogen Wave Heater



Project Initiated in 4Q17
at E-3 Test Facility

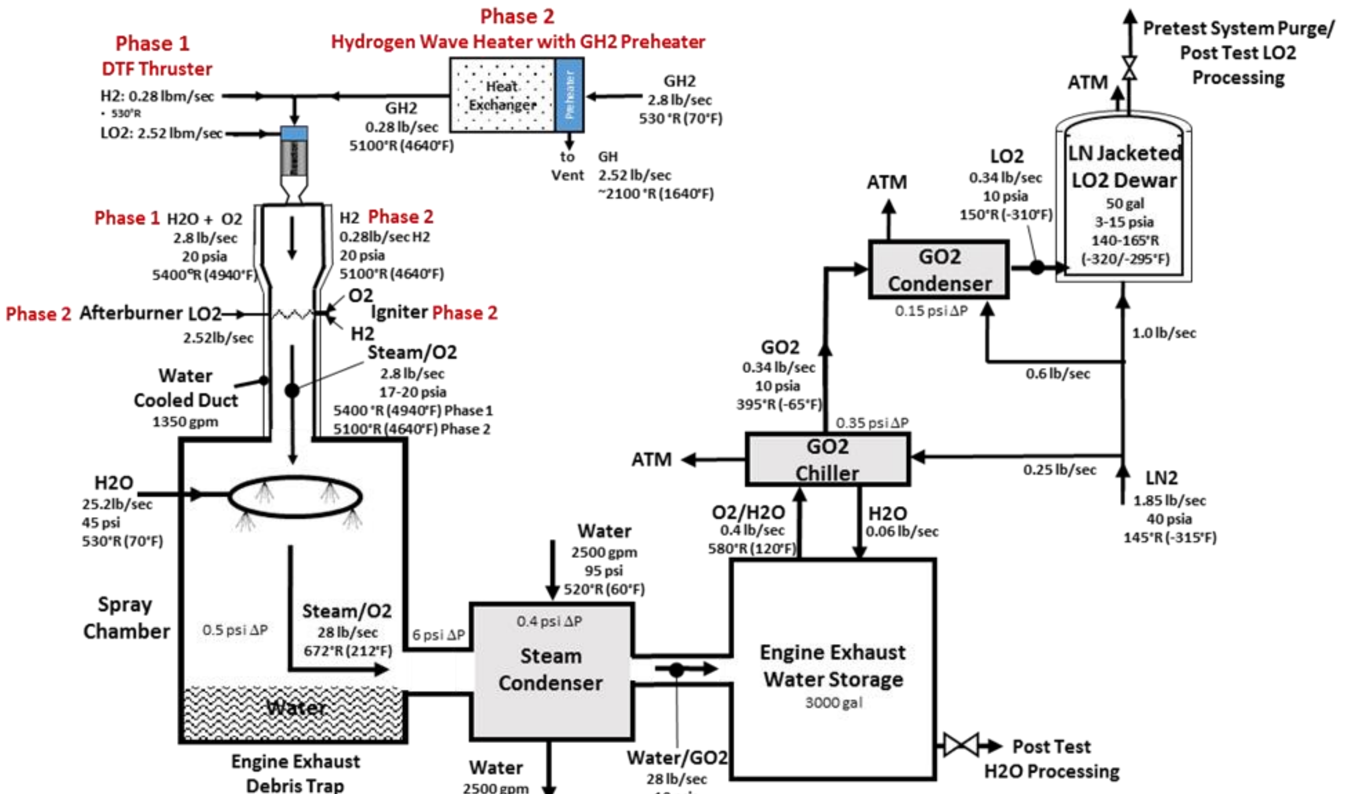


Testing Begins Jan-19

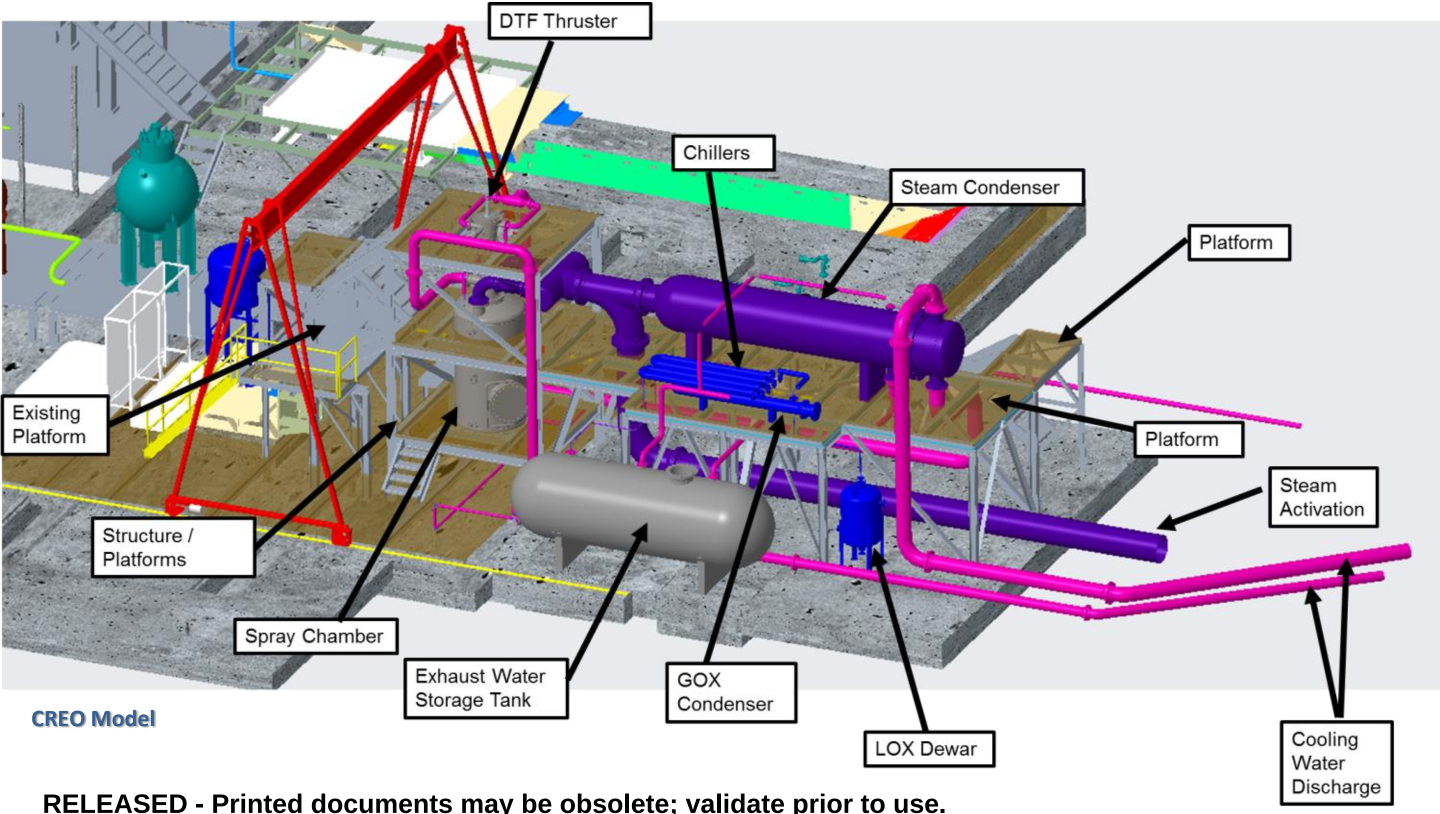
Rocket Exhaust Capture System Subscale Test Project

Preliminary System Sizing (10% Full Scale Demonstration)

Nuclear Thermal Propulsion – Low Enriched Advanced Propulsion



RECS-Subscale System Layout
at SSC's E3/C1 Test Facility



CREO Model

Summary

- NTP is directly relevant to the Agency's vision, mission, and long-term goal of expanding human presence into the solar system and to the surface of Mars
- The RECS concept captures and isolates NTP engine exhaust from the environment to mitigate the potential environmental risks.
- SSC has substantial existing infrastructure to support RECS testing.
- A Subscale RECS test project is in work at SSC
  - Will demonstrate the basic performance of the RECS to capture, contain, process, and store rocket exhaust effluents
  - It is a critical element of the NTP project
    - Will support site licensing, proof-of-concept validation, and engineering insight to the full scale system.