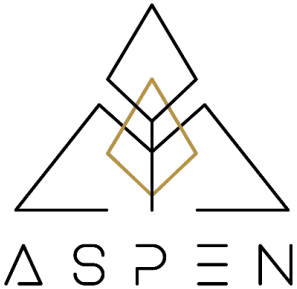

SIMULATION AND EXPERIMENTAL VALIDATION OF AN INDUCTIVELY HEATED SOLID-CORE NUCLEAR THERMAL ROCKET MODEL

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The Advanced Spacecraft Propulsion and Energy (ASPEN) Laboratory

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USC Viterbi
School of Engineering

AIAA
SHAPING THE FUTURE OF AEROSPACE

Hyperion-I Campaign Introduction

- First project of USC's Advanced Spacecraft Propulsion and Energy (ASPEN) Laboratory
- Three phase campaign to model solid core Nuclear Thermal Rocket Engines (NTRE's)
- NTRE's:
  - Show promise for high thrust and high efficiency missions
  - Can compete with conventional chemical engines in terms of payload and mission time

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Hyperion-I Campaign Phases

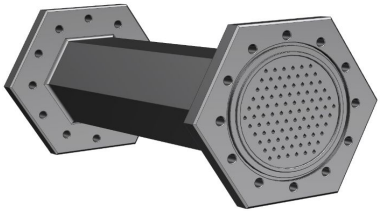
Phase I

- 3/16” OD 316SS Tube
- $T_{exit} < 350$ K

Phase II

- Maraging Steel
- 7 teardrop channels
- $T_{exit} < 500$ K

Phase III



- Maraging Steel
- 61 teardrop channels
- $T_{exit} = 900$ K

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Phase I Purpose and Goals

- Assess functionality of experimental design
  - Feed system
  - Inductive heating method

- Temperature and pressure data acquisition
  - ΔT
  - Exit temperature

} Compared to ANSYS multiphysics model outputs

- Remedy systems for Phases II and III if needed

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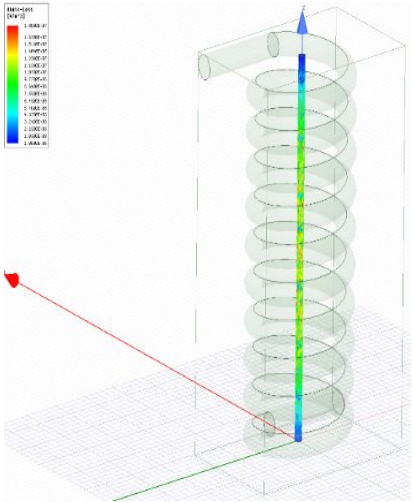
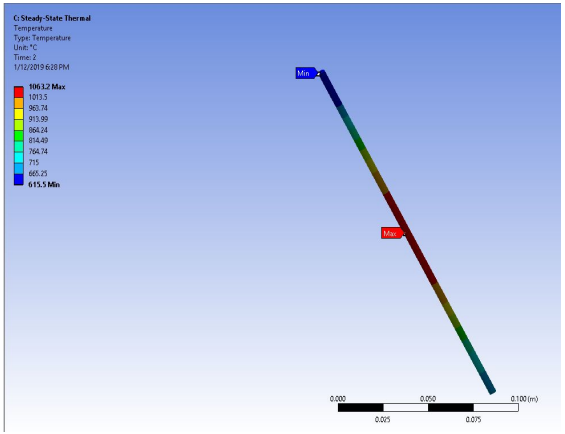
ANSYS Multiphysics Model

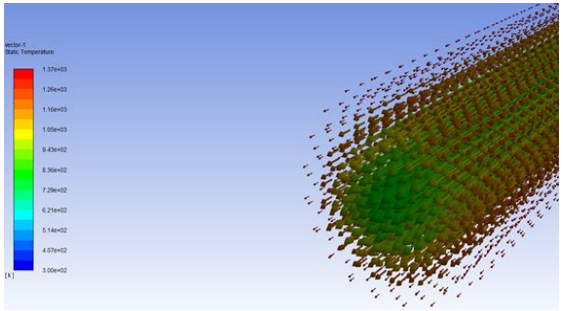
Electromagnetic



Thermal



CFD



Ohmic Loss Contour →

Volumetric Heat Map →

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ANSYS Model Results

Working Fluid: Nitrogen

Inlet Temp: 300 K (26.86 ℃)

Outlet Temp: 340 K (66.85 ℃)

Max Test Article Temperature: 400 K (126.85 ℃)

Experimental Setup

- Test stand designed for all Hyperion I Phases
- Feed System leak and proofed prior to hot flow

	Phase I	Phase III
Test Duration	15 min	15 min
Mass Flow Rate	0.00025 kg/s	0.05 kg/s
Inlet Pressure	500 psi	1000 psi
Induction Heater Current	306-310 Amps	N/A

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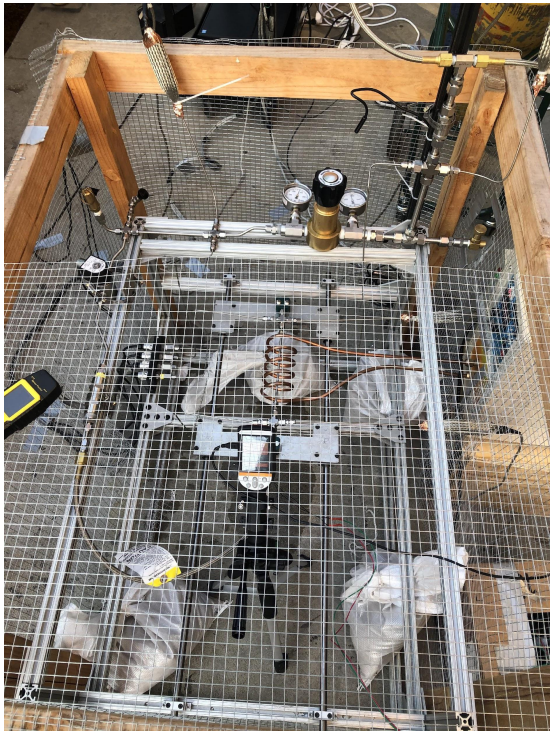
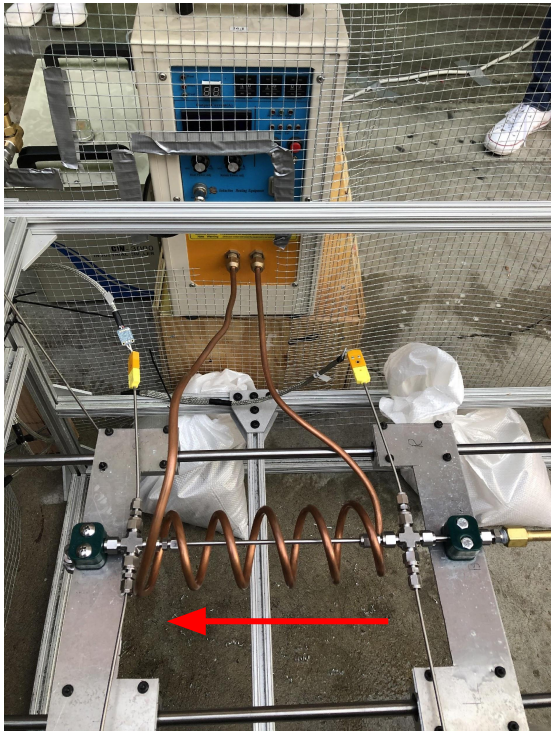
Experimental Setup – Feed System





Experimental Setup – Data Acquisition

Main Data Acquisition System: NI USB-6211
Omega K-Type thermocouples and Omega PX309 pressure transducers at the following stations:

- Before the regulator
- After the regulator
- Before the test article
- After the test article

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Experimental Setup – Data Acquisition

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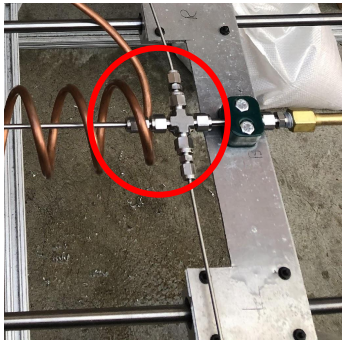
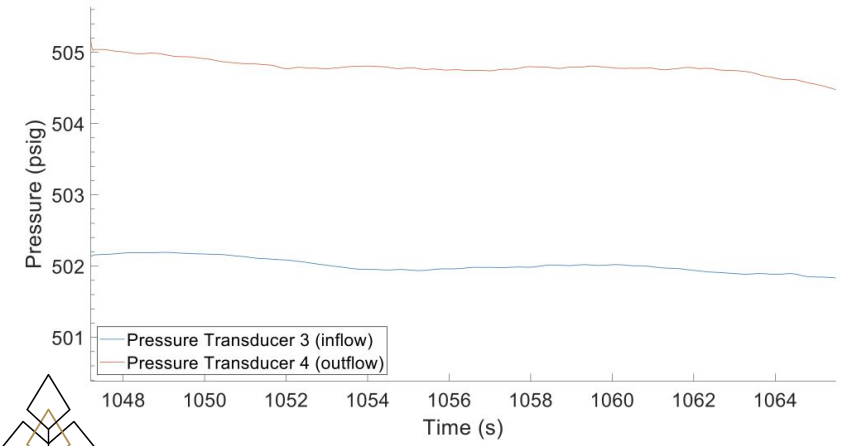
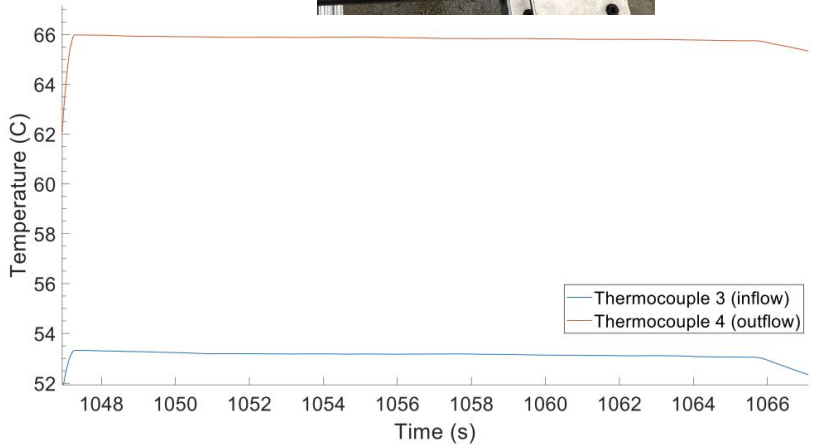
Results and Discussion

ΔP: 3 ± 2 psi
Inlet Temperature: 53 ± 2 ℃
Outlet Temperature: 66 ± 2 ℃
ΔT: 13 ± 4 ℃







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Conclusion

- Hardware design and operation of induction furnace worked nominally
- ΔT result must be determined from another trial for comparison with ANSYS model
- Phase II and Phase III testing is possible with the current hardware with only small modifications necessary

	Experiment	ANSYS
T_{outlet}	66±2 ℃	66.85 ℃
ΔT	13±4 ℃	40 ℃

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Phase II

- Objective: Scaled-down version of full core testing
- Addition of load cell to measure thrust and Isp

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