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Designing and testing of an HDPE-N_2O hybrid propulsion engine

Authors

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Abstract

- Hybrid propellant engines use both solid (HDPE fuel) and liquid (N_2O liquid) propellants for better thrust control and simplicity.
- Study focuses on the impact of combustion chamber length on engine performance.
- Engine features include an L-shaped mount, spark ignition, and gaseous nitrogen purging.
- 2D axisymmetric CFD model with K-ε SST RANS used to simulate combustion reactions.
- Experimental results validate CFD exhaust outflow simulation, providing insights into thrust, temperature, and pressure distributions.

Design & Methodology

Theoretical development for engine sizing & performance	Experimental tests: Pressure testing, Cold flow testing
CFD simulations for performance estimation	Hot Fire Testing

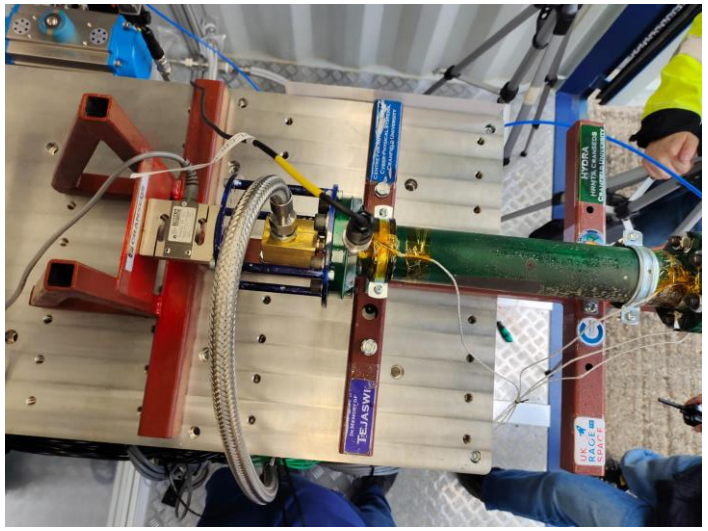


Figure 1: Finalised engine mounted on test stand right before hot test firing

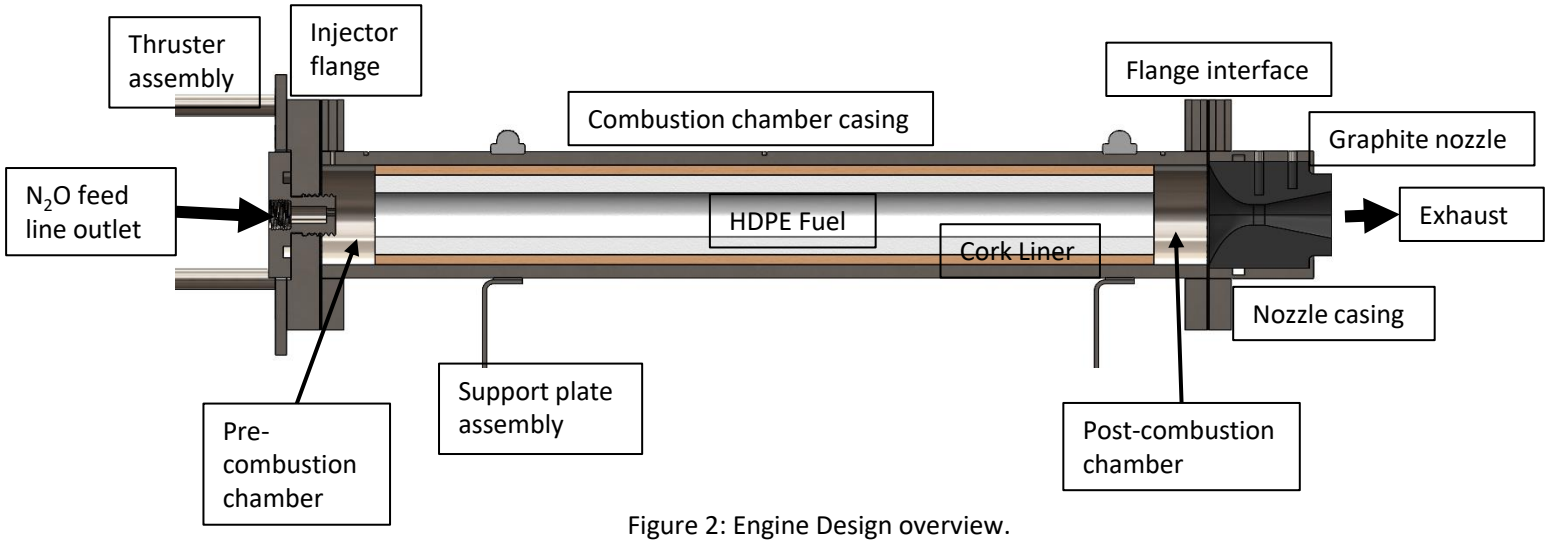


Figure 2: Engine Design overview.

Design & Methodology

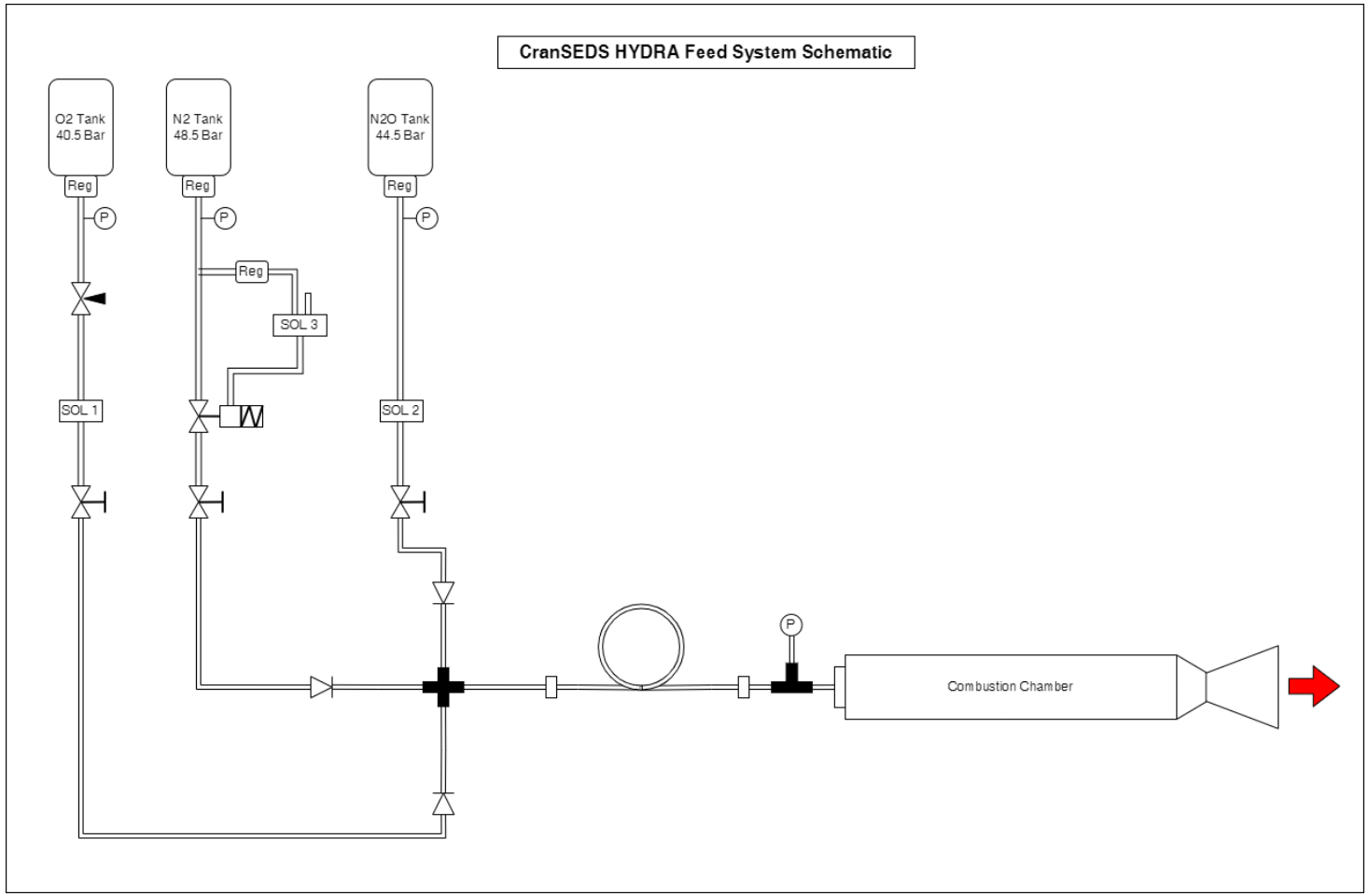


Figure 3: Feed line design schematic.

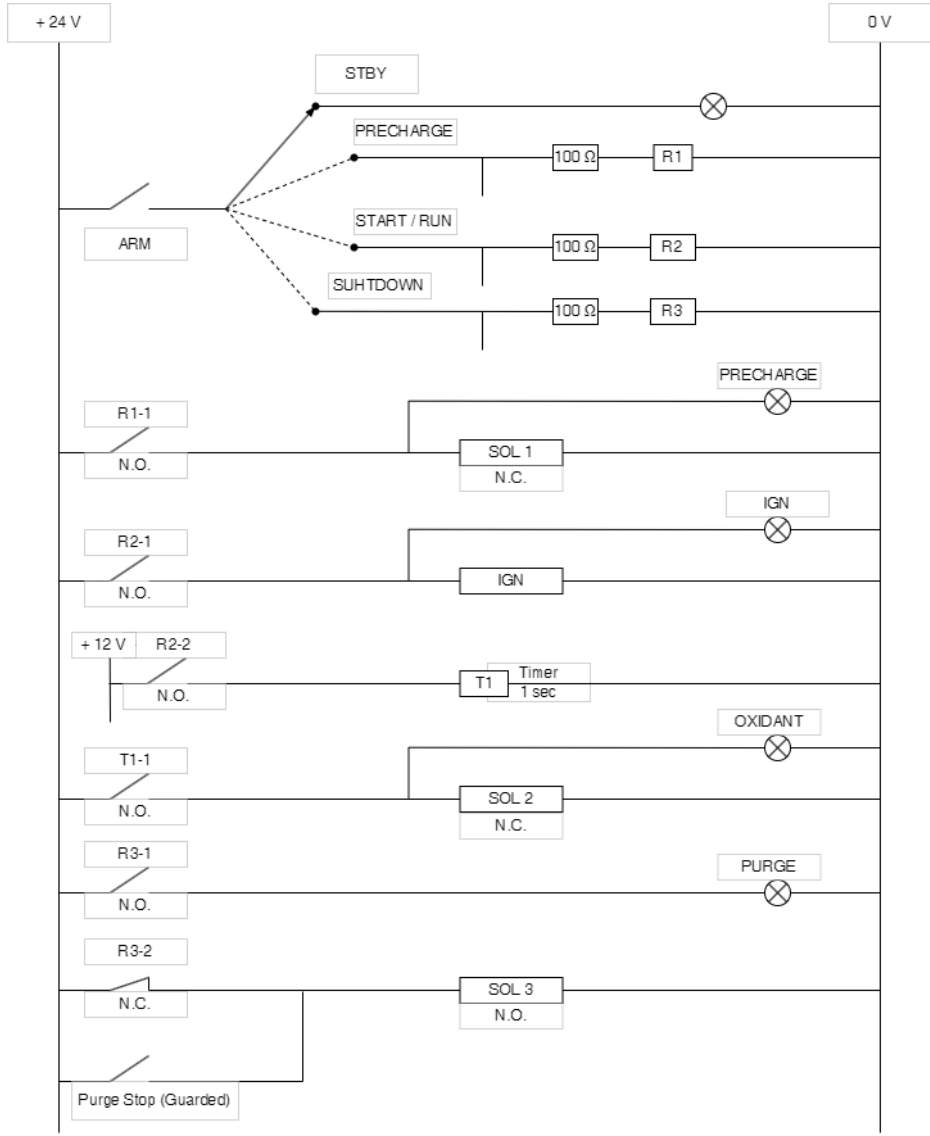


Figure 4: Control box schematic.

CFD Simulations

- Density based transient solver with a steady state asymmetric flow
- Energy model and standard k-ε viscous model
- Propellent used is N_2O without species transport due to 2-D model of nozzle
- Pressure inlet = 335 kPa at 3375 K temperature, Pressure outlet = 101.325 kPa at 300K temperature and symmetry is considered as wall for boundary conditions.
- Coupled solution methods is used and the solution is initialised at the inlet.
- Solution through 5000 iterations and for pressure, velocity, density and temperature values and plots.

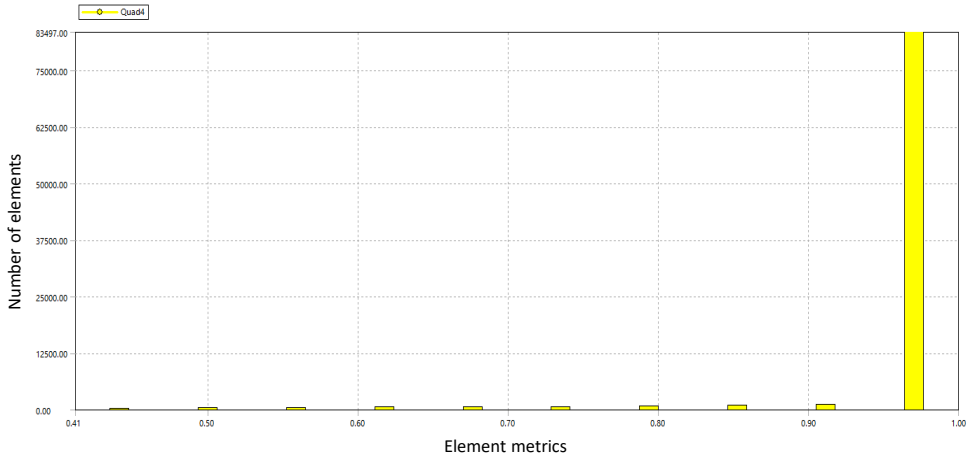


Figure 5: Quality metric of simulation mesh (Jacobian)

- The computational value of thrust varies from 327.3 N which is around 9.1% of the predicted value of 300N
- The mass flow rate is equal to 0.1765 kg/s which is around 7.88% of the predicted value (0.1636 N)
- The thrust is constant and then there is a sudden drop as we move along the length of the nozzle.

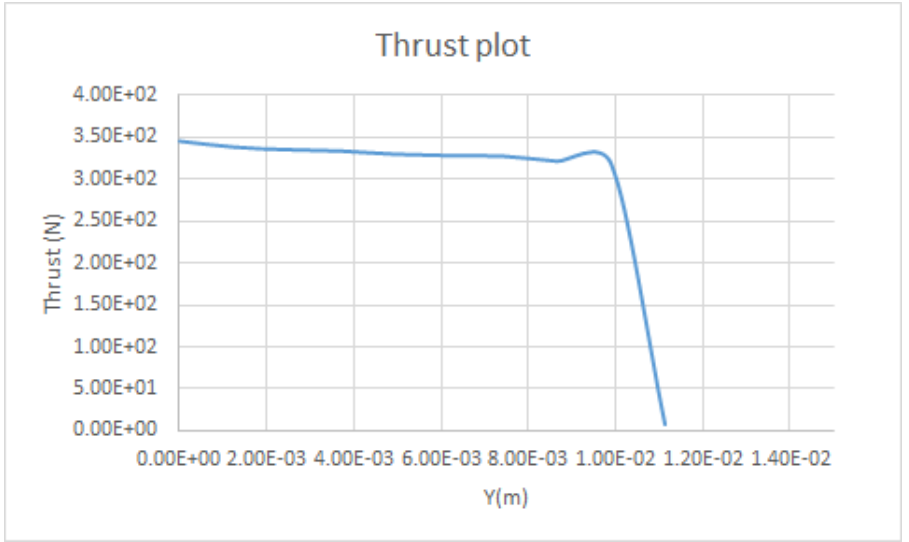


Figure 6: CFD simulation thrust plot results.

Physical System Testing & Validation

Figure 7: Pressure test setup

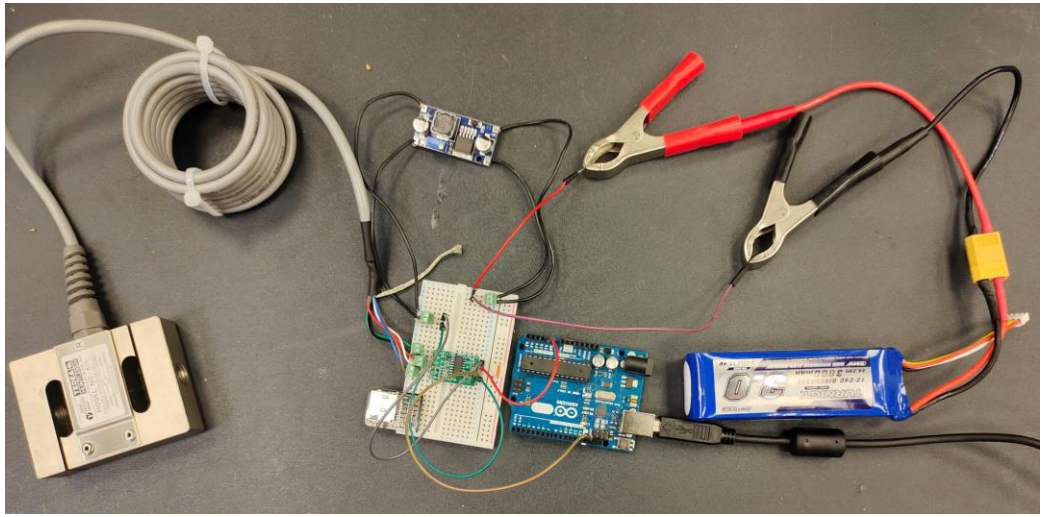


Figure 8: Load cell DAQ test setup

Figure 9: Control box test setup

Feed-line system and data acquisition server board for hot-fire testing supplied and operated by Protolaunch UK as official testing partner for Race2Space UK competition 2023 and 2024

Figure 10: Hot fire test setup

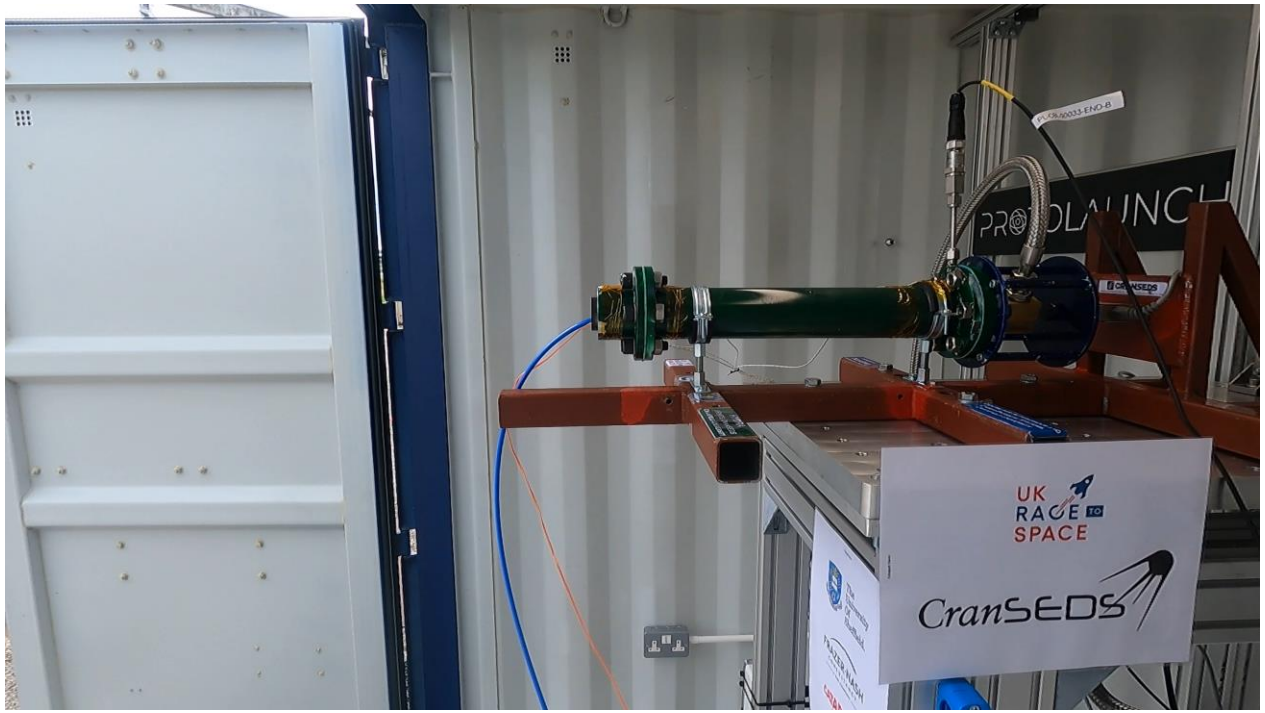


Figure 12: Hot fire testing video: 300N engine

Figure 13: Hot fire testing video: 500N engine

Results and Findings

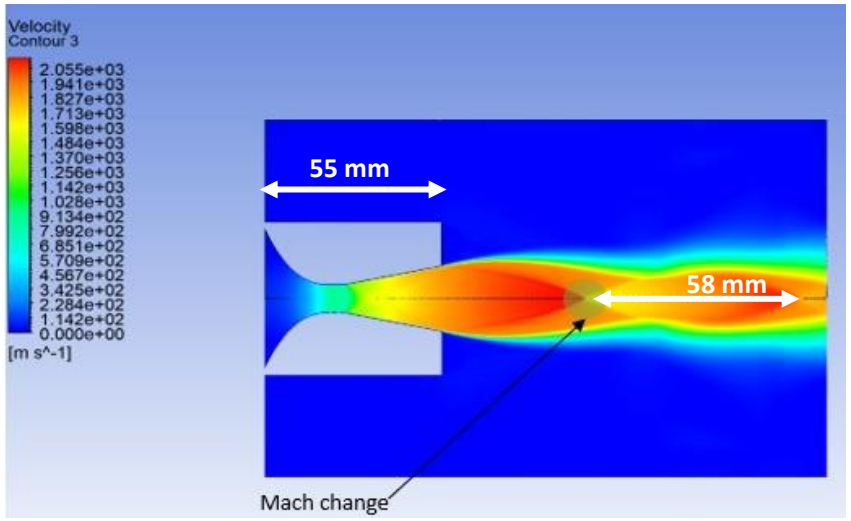


Figure 15: Ansys Fluent simulations: Velocity

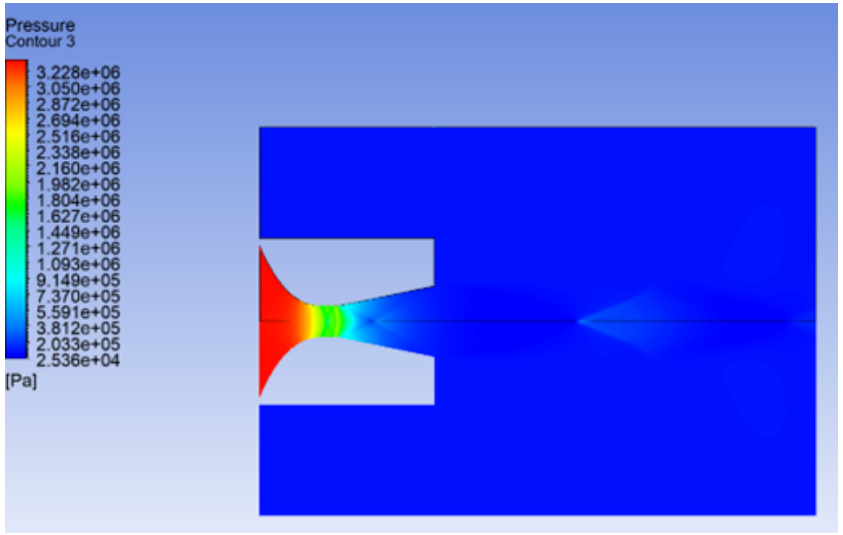


Figure 16: Ansys Fluent simulations: Pressure

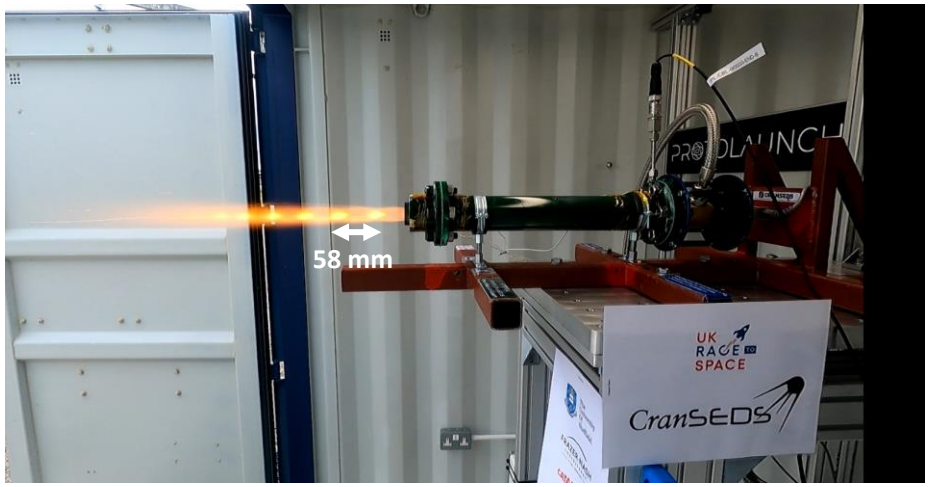
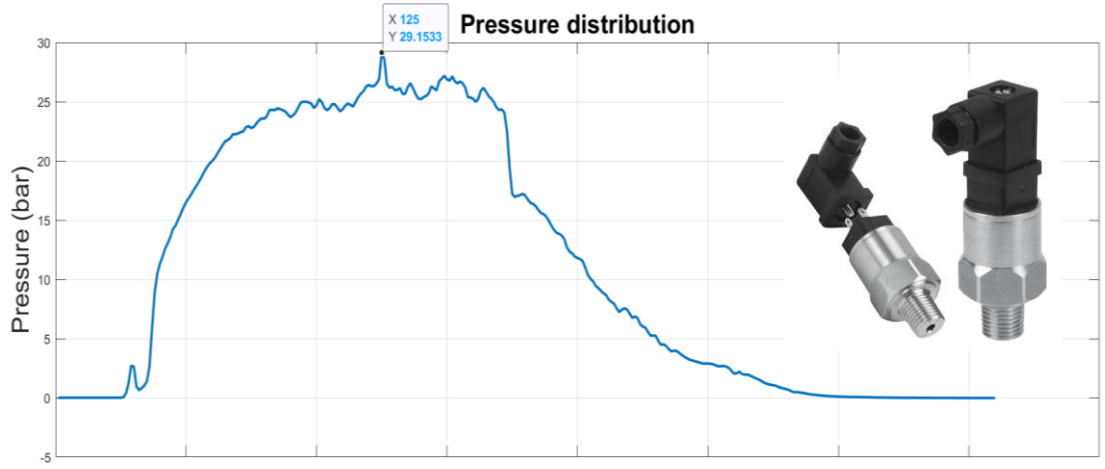


Figure 17: Hot fire testing; Stabilised flow with Mach diamonds generation



chamber using Omega PX-119 1.5 kgi pressure transducer

Results and Conclusions

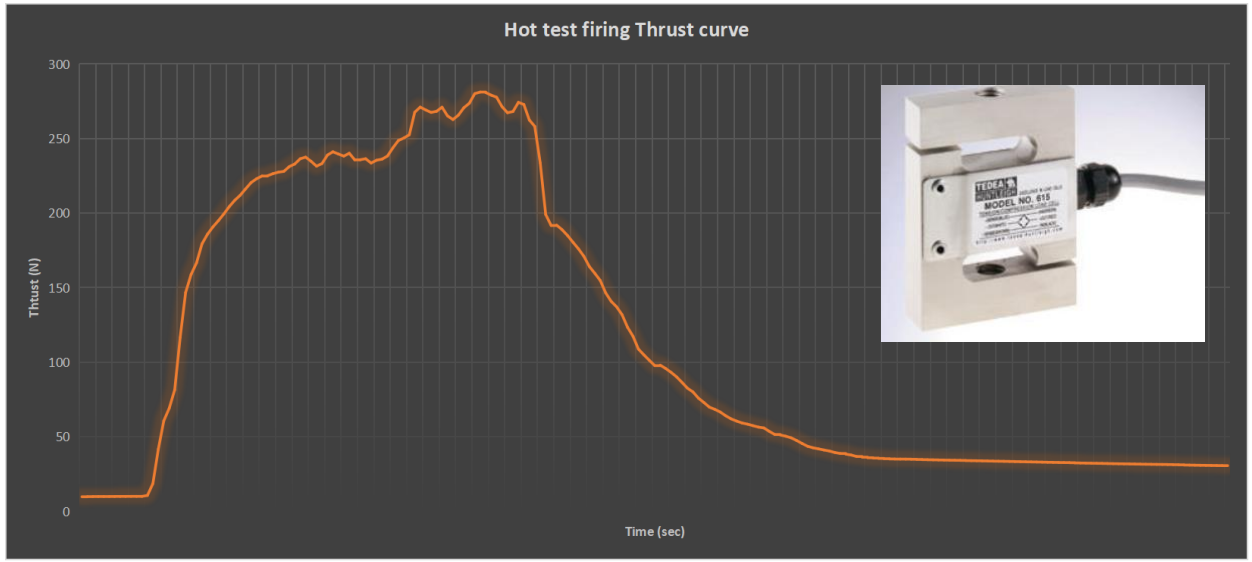


Figure 19: Thrust curve measured using Tedea Huntley 615 industrial grade load cell

Performance Metrics:

Estimated pressure: 30.00 bars
Peak pressure estimate in simulations: 32.28 bars
Peak pressure from test firing: 29.15 bars

Estimated thrust: 300.00 N
Peak thrust estimate in simulations: 327.3 N
Peak thrust from test firing: 284.60 N

Estimated temperature: 3000 K
Peak temperature estimate in RPA simulations: 2940 K
Peak temperature (exhaust thermocouple) from test firing: ~1446.4 K

- **Effective designing approach for hybrid propellant based rocket engine.**
- **Requires further extensive development and screening for threshold dropout for the post combustion chamber length**

Thank you for your attention!

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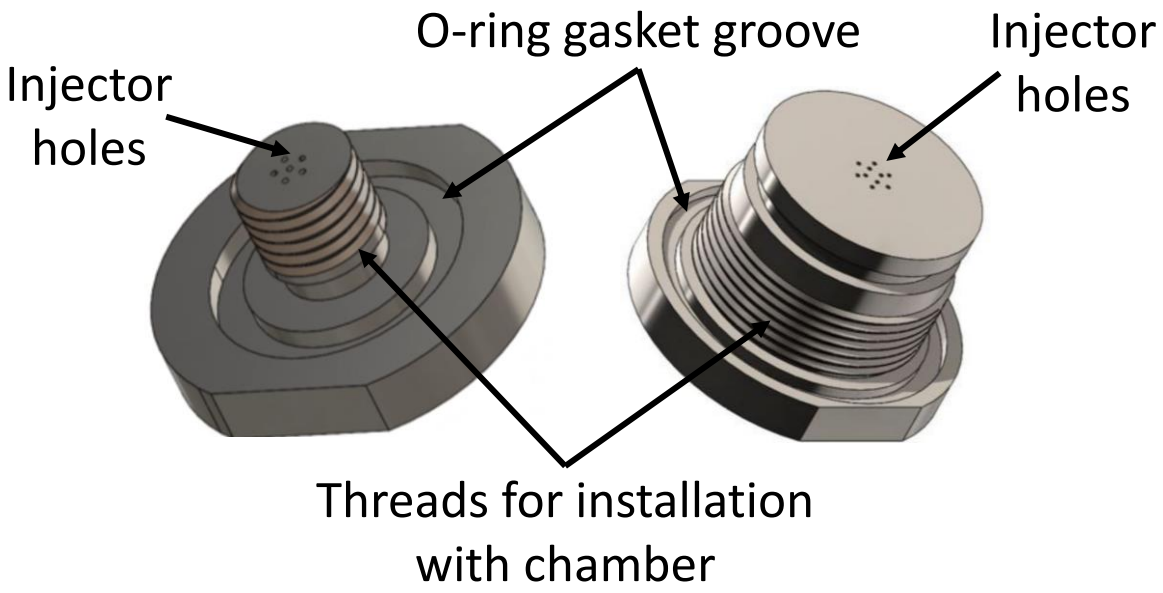
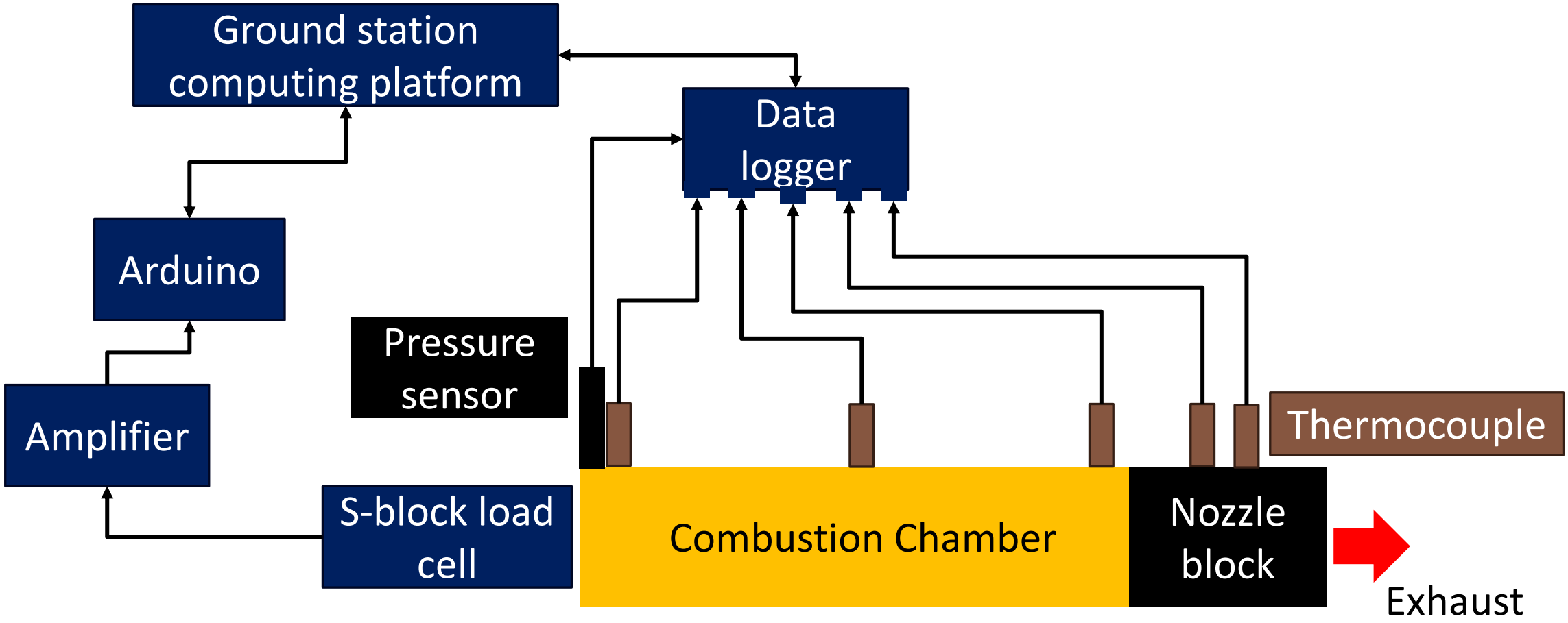

O-ring gasket groove
Injector holes
Injector holes
Threads for installation with chamber


Ground station computing platform
Data logger
Arduino
Pressure sensor
Amplifier
Thermocouple
S-block load cell
Combustion Chamber
Nozzle block
Exhaust