Flowpath Design for a Mach 10 Oblique Detonation Flight Experiment

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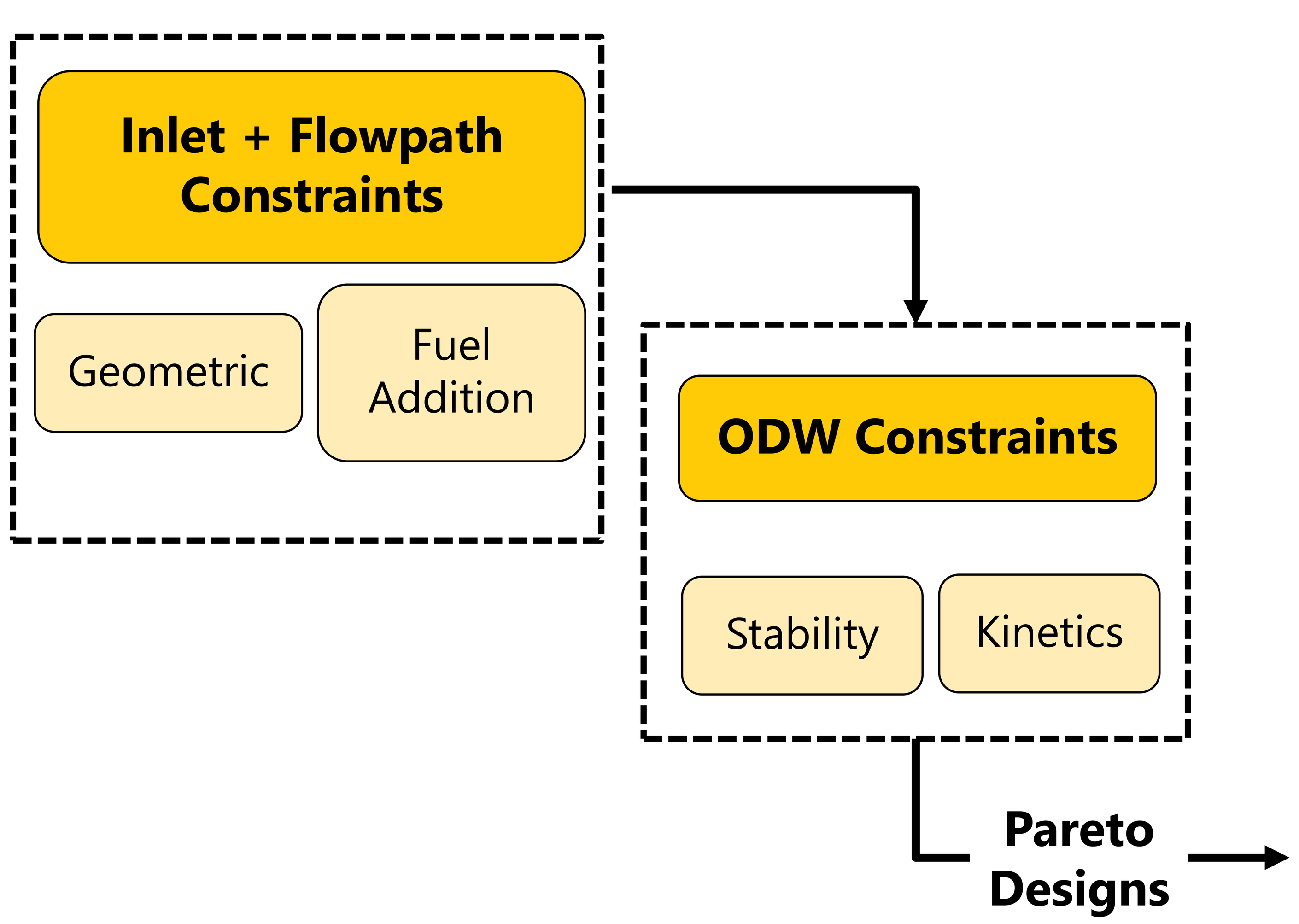
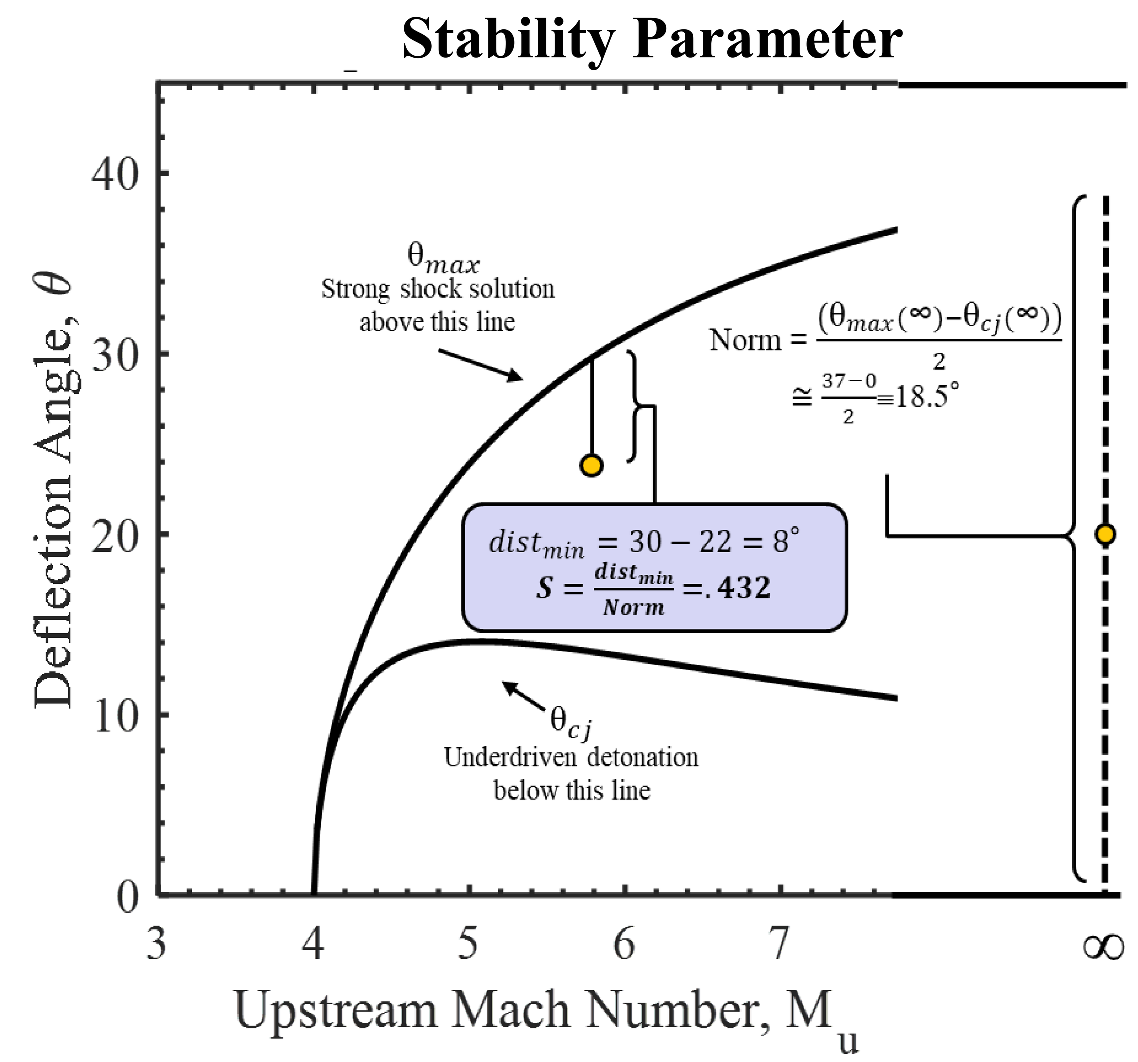
Introduction

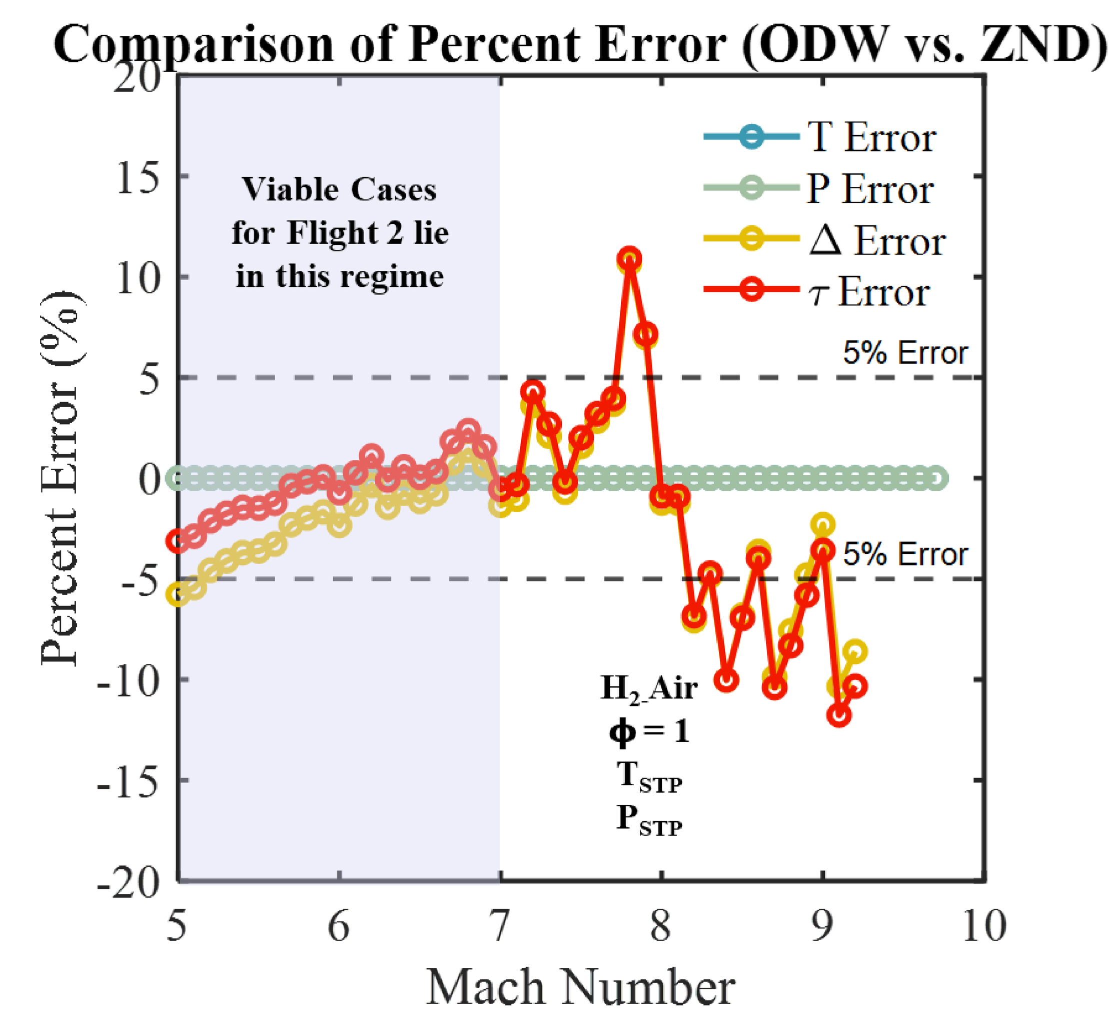
The Oblique Detonation Wave Engine (ODWE) is a theoretical propulsion system capable of enabling sustained hypersonic flight in the Mach 10–17 regime. To advance the development of such engines, the Propulsion and Energy Research Laboratory (PERL) is conducting a Mach 10 sounding rocket flight experiment aimed at stabilizing an Oblique Detonation Wave (ODW) in flight. Flight two focuses on the design and optimization of an internal engine flowpath – deviating from the external flight one design - as well as the development of computational tools to accurately model ODW behavior, hypersonic inlet dynamics, and fueling processes. This project focuses on using different optimization techniques and vehicle requirements to tailor-down possible designs and create the optimal Inlet-Combustor flowpath.

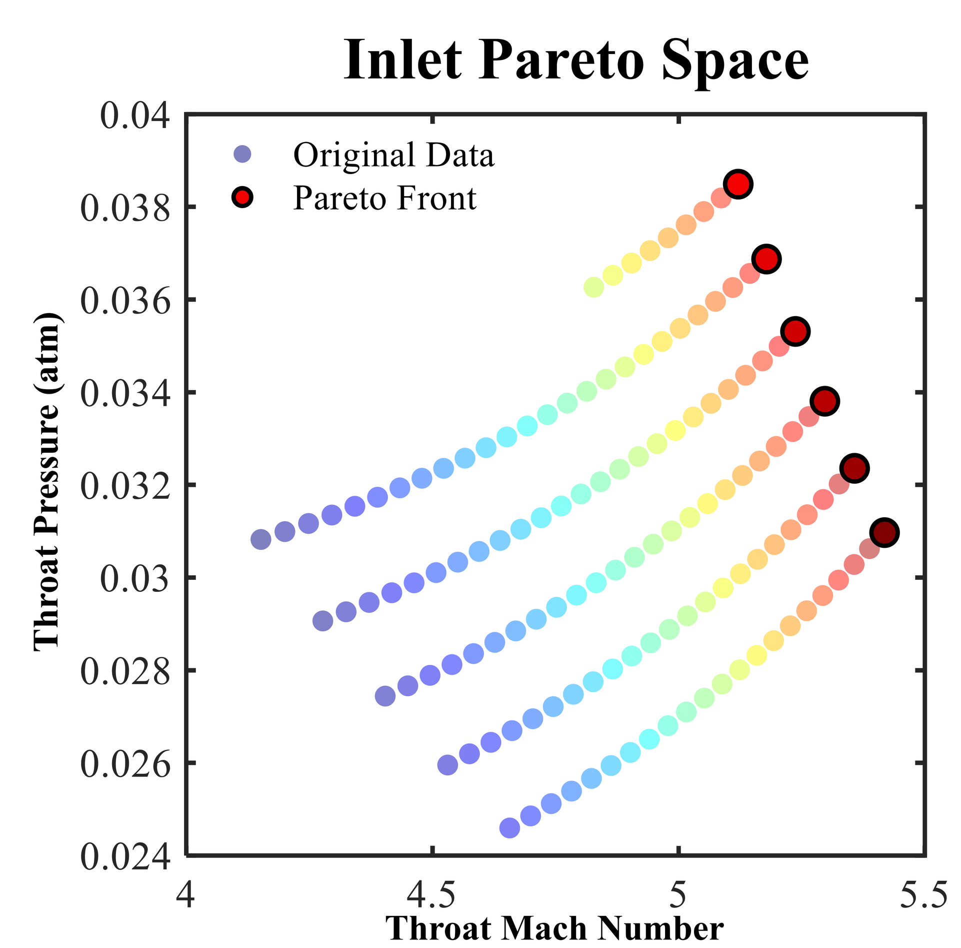
Objective

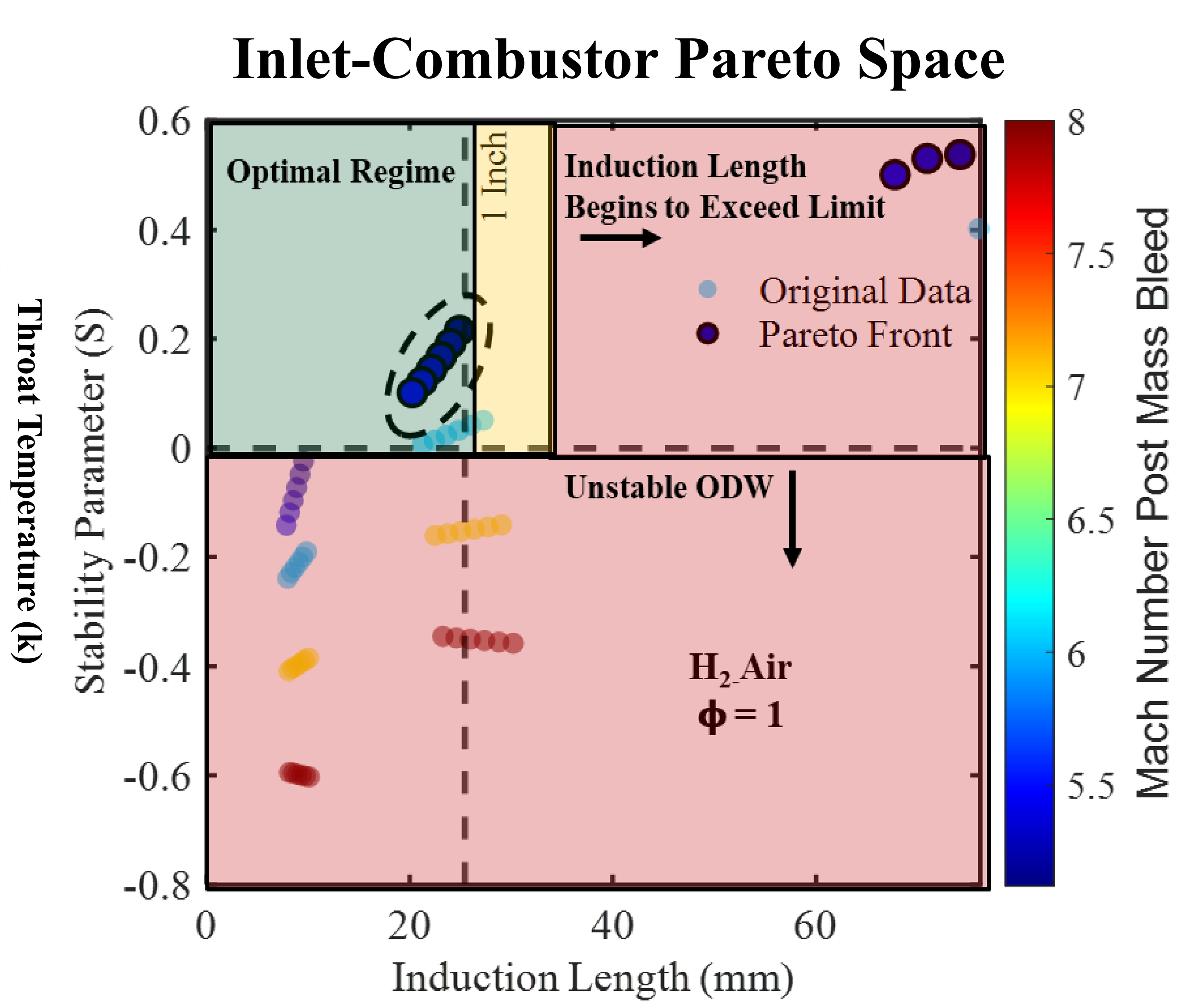
1. Produce a stable oblique detonation using NC12H26
   a. Ensure payload startability (assess need for mass relief and shroud usage)
2. Enable the largest range of altitudes and trajectories for ease of experiment
3. Interface with Z1Z1Z2 Platform
   Alternative Platform: TTO
   Alternative Platform: TTIM
4. Allow ample space to fit optical diagnostics and instrumentation in test section

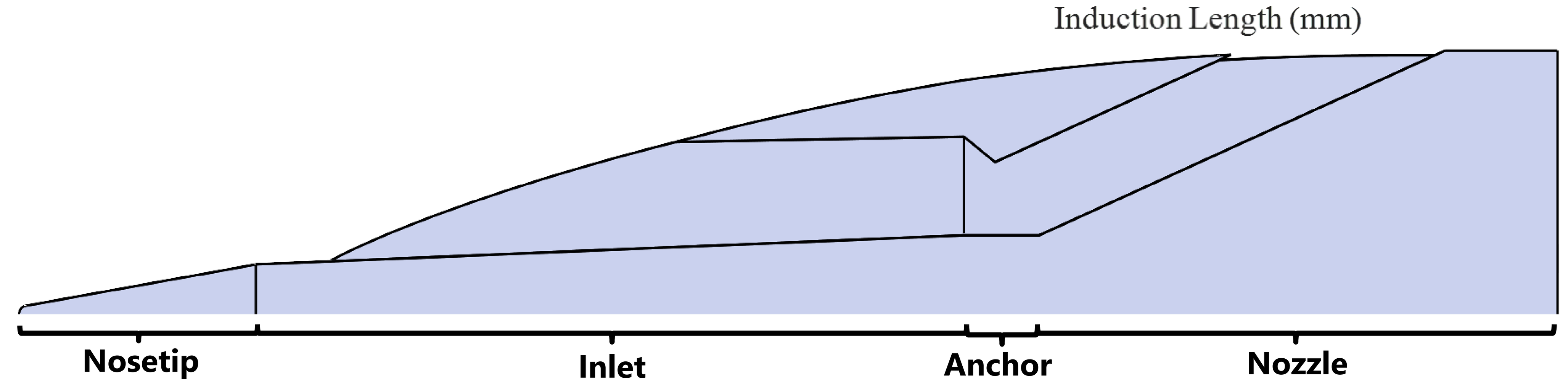












ODW Characteristic	Parameter	Dimensions	Parameter
Induction Length	0.7 in	Payload Length	90 in
Induction Time	25 μs	Planar Ramp Angle	2°
Stability Index	0.22	Inlet Length	40 in
Leading Shock Angle	7°	Capture Diameter	5 in
Inlet Stagnation Loss	0.80 %	Throat Diameter	4.1 in
Pressure at ODW Start	2 kPa	Anchor Length	2 in
Mach at ODW Start	9	Anchor Angle	30°

Geometric parameters are rounded to avoid recreation of this device. Graphical renderings of the flowpath are not to scale

Results

- A successful quasi-1D model was created to calculated post-detonation conditions
- Post-detonation conditions were successfully coupled to a 0D ignition delay time reactor, showing meaningful comparison in induction scales when compared to classical Zeldovich-von Neumann-Doring (ZND) analysis
- The ability to stabilize an ODW in relevant hypersonic flight conditions has been shown to be feasible
- Hypersonic inlet designs for an ODWE seemingly converge on a capture device with minimal initial compression

Discussion

The results seemingly suggest that the feasibility of the enclosed flight experiment design should be initially viable. However, a careful balance will need to be struck detonation angle and mass addition. This will mean possibly operating in fuel lean conditions. Furthermore, the ODW seems to operate best in higher Mach conditions, meaning the range of the experiment may need to be expanded. In the end, Multi Order Optimization (MOO) techniques were able to identify multiple designs for a feasible experiment flowpath

Next Steps

Current work **completed but not shown**
- Jet-A and NC12H26 sweep
- Alternative inlet designs and inlet truncation,
- Choking due to contractions and heat addition

Current work **to be completed**
- Different aromatic compound sweeps,
- CFD on low inlet startability cases,
- full reacting CFD analysis,
- Effects of launch supplier nose tip variations
- Liquid injection mass addition solver

Acknowledgements

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