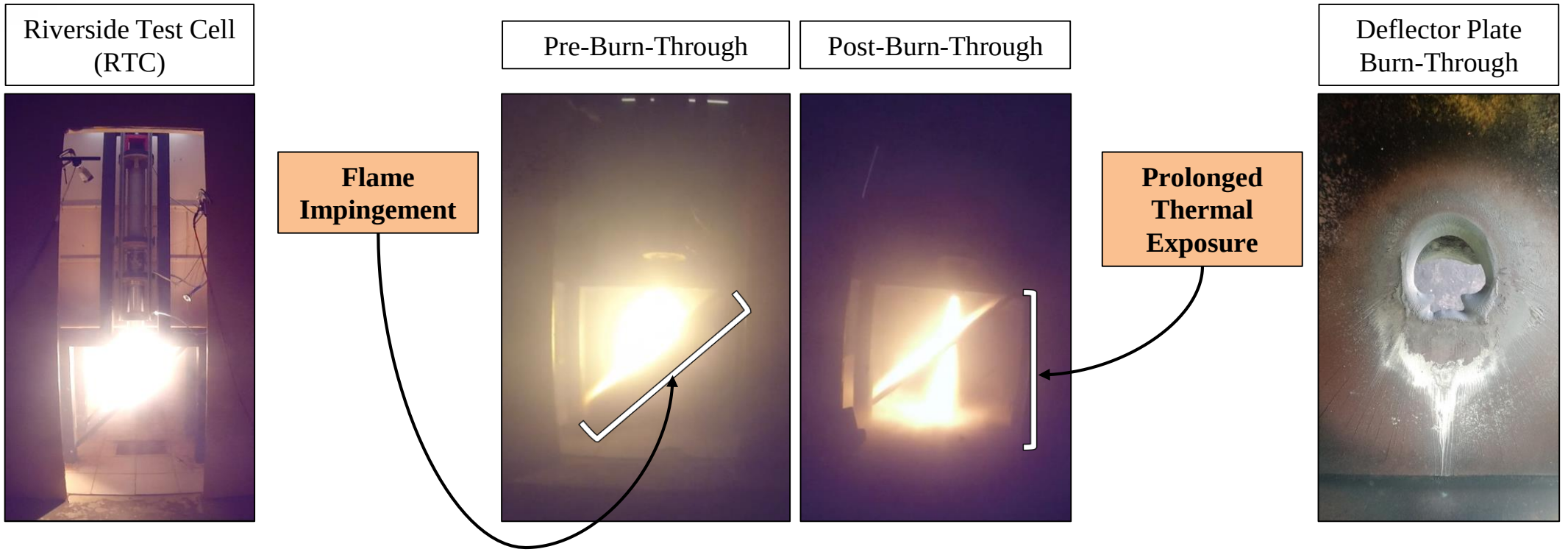
Texas A&M University
Sounding Rocketry Team

Deflector Plate CFD Study
Podium Session IREC 2017

Motivation

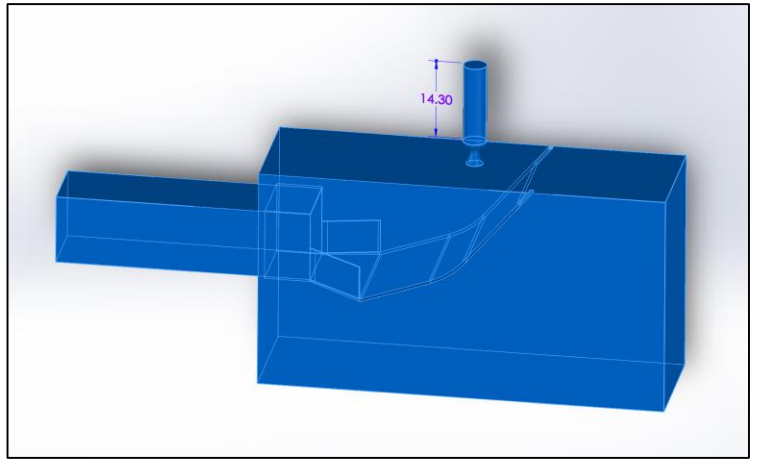
- Typical Static Engine Test
  - L-P class rocket engine
  - Volatile conditions
    - Mach 4+
    - 5,000+ °F
    - 20+ atm
- NP-915 Static Engine Test
  - Nominal burn
  - Complete burn-through of 0.25 in thick carbon steel plate
  - Damage to Riverside Test Cell (RTC)
  - Undesirable exhaust gas accumulation in cell enclosure
- Goals
  - Improve evacuation of exhaust gases through CFD optimization of deflector plate geometry
  - Improve material selection for deflector plate construction



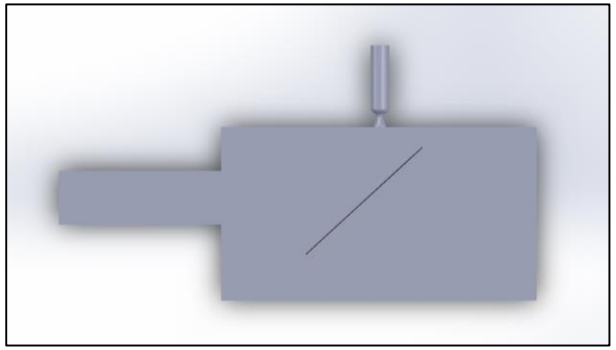
Testing: Pre-Processing

- Pre-Processing
  - 3 cases for simulation modeled to scale in Solidworks
    - **Control Case** – existing geometry – 47.45° (from vertical) slant
    - **Test Case #1** – 20° (from vertical) slant – curve – horizontal – exhaust manifold
    - **Test Case #2** – 40° (from vertical) slant – curve – 19.35° (from horizontal) slant – exhaust manifold

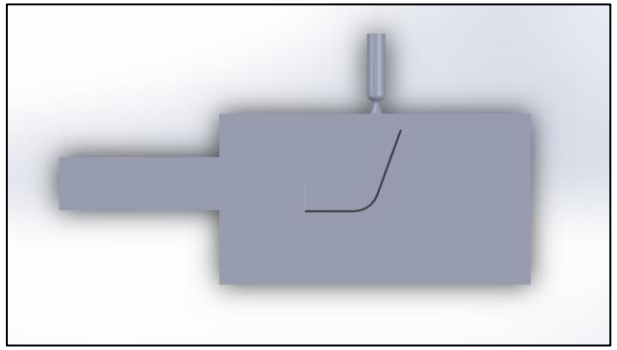
General Blueprint



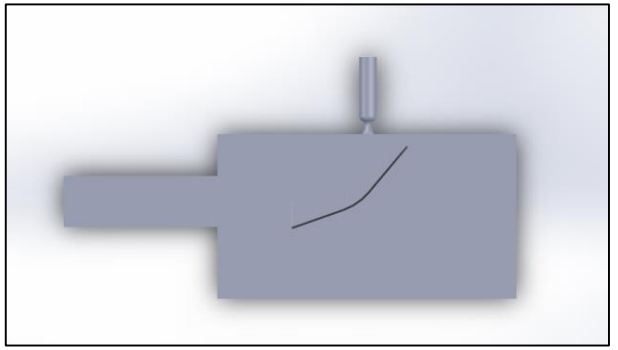
Control Case



Test Case #1

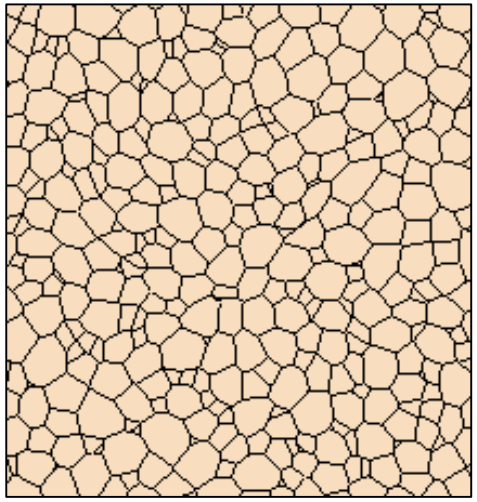


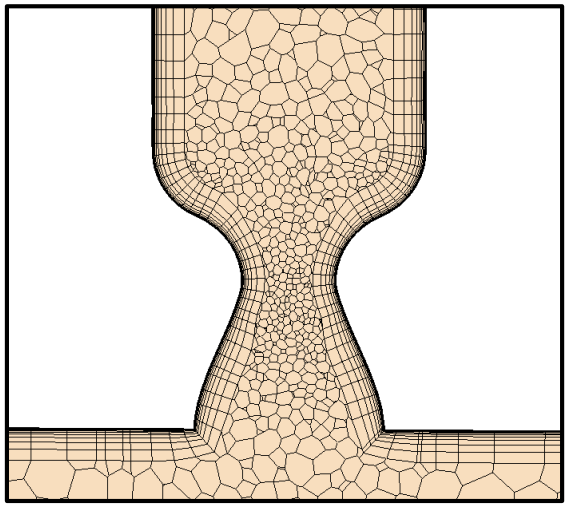
Test Case #2



Testing: Pre-Processing

- Pre-Processing
  - Boundary conditions established[1]:
    - Wall conditions – adiabatic, no-slip, with finite surface roughness
    - Pressure outlet conditions (vent) – environmental-extrapolated boundary at ref. conditions
    - Stagnation inlet conditions (nozzle) – supersonic static pressure, static pressure, temperature
  - Meshers selected:
    - Polyhedral (unstructured)
    - Automated surface remesher
    - Prism layers
    - Final cell counts: ~1.3 million cells





[1] Detailed in the extended abstract submitted before the 2017 IREC

Testing: Pre-Processing

- Pre-Processing
  - –Physics models selected:
    - Standard, steady, three-dimensional flow, assuming ideal air
    - Coupled energy and coupled flow
  - –Solvers selected:
    - Reynolds-Averaged Navier-Stokes (RANS) equations
    - K-epsilon (k-ε) turbulence model
    - Advective Upstream Splitting Method (AUSM) and Flux Vector Splitting (FVS) coupled inviscid flux function (2nd-order discretization)
  - –Courant-Friedrichs-Lewy (CFL) condition:
    - 2.0 for first 5,000 iterations
    - 5.0 for next 5,000 iterations

Approximately 2,000 wall-clock hours used for all simulations

(provided by Texas A&M University HPRC)

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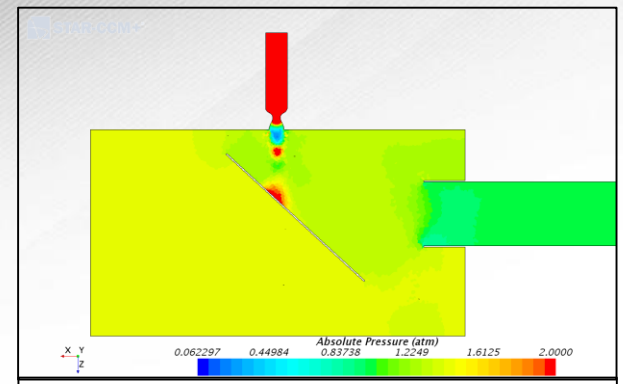
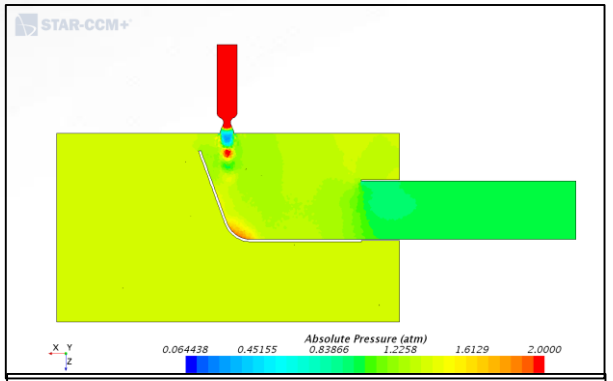
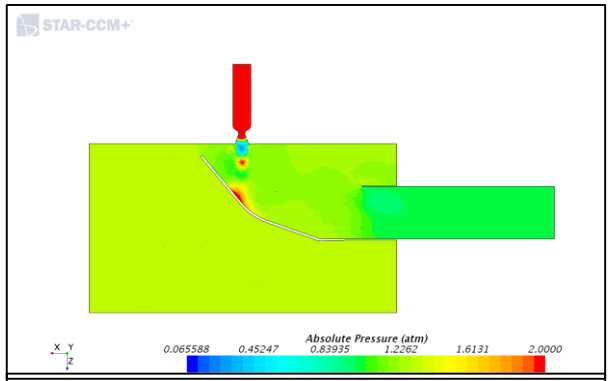
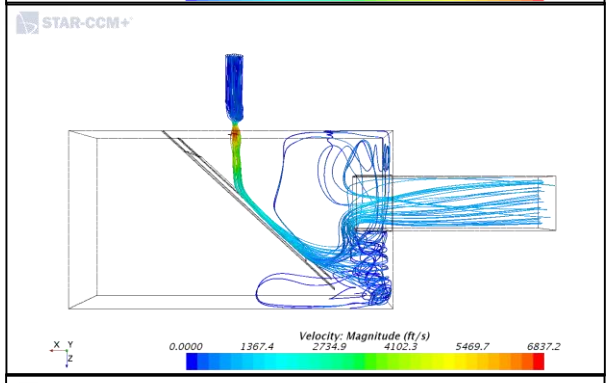
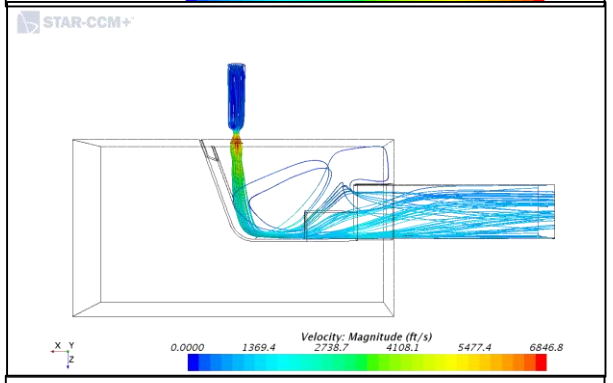
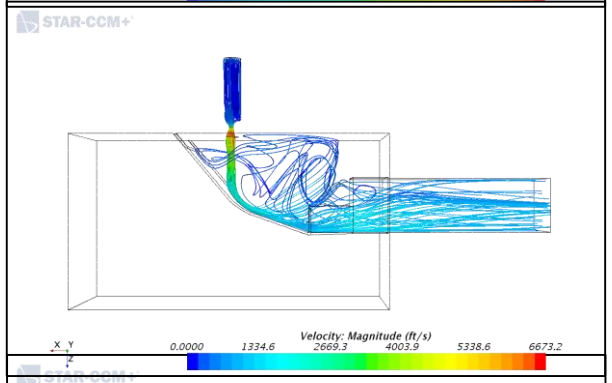
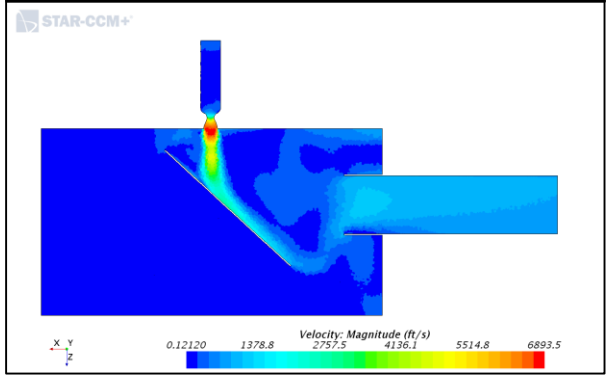
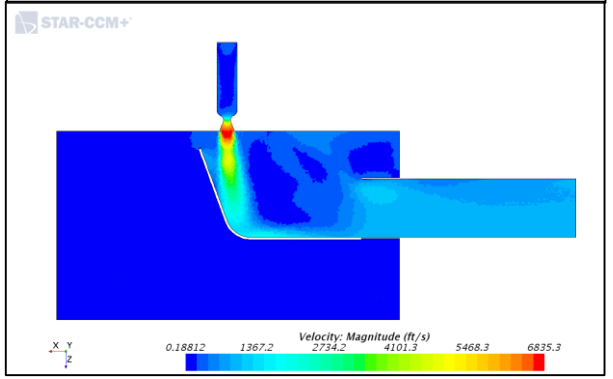
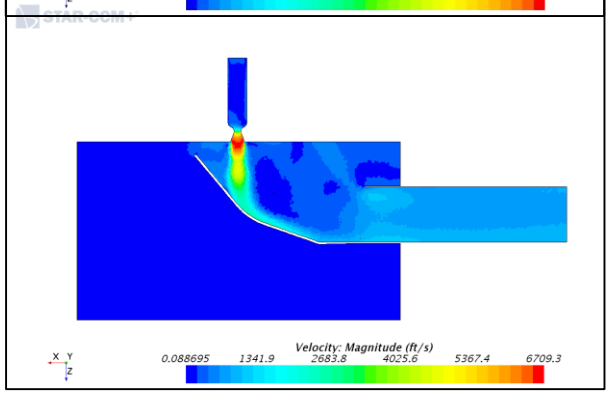
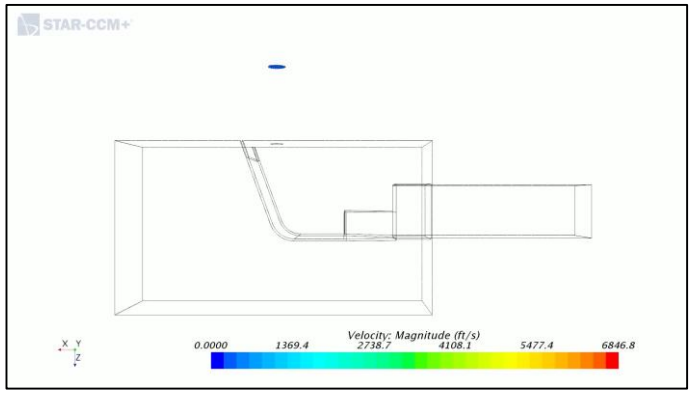
Results: Profiles

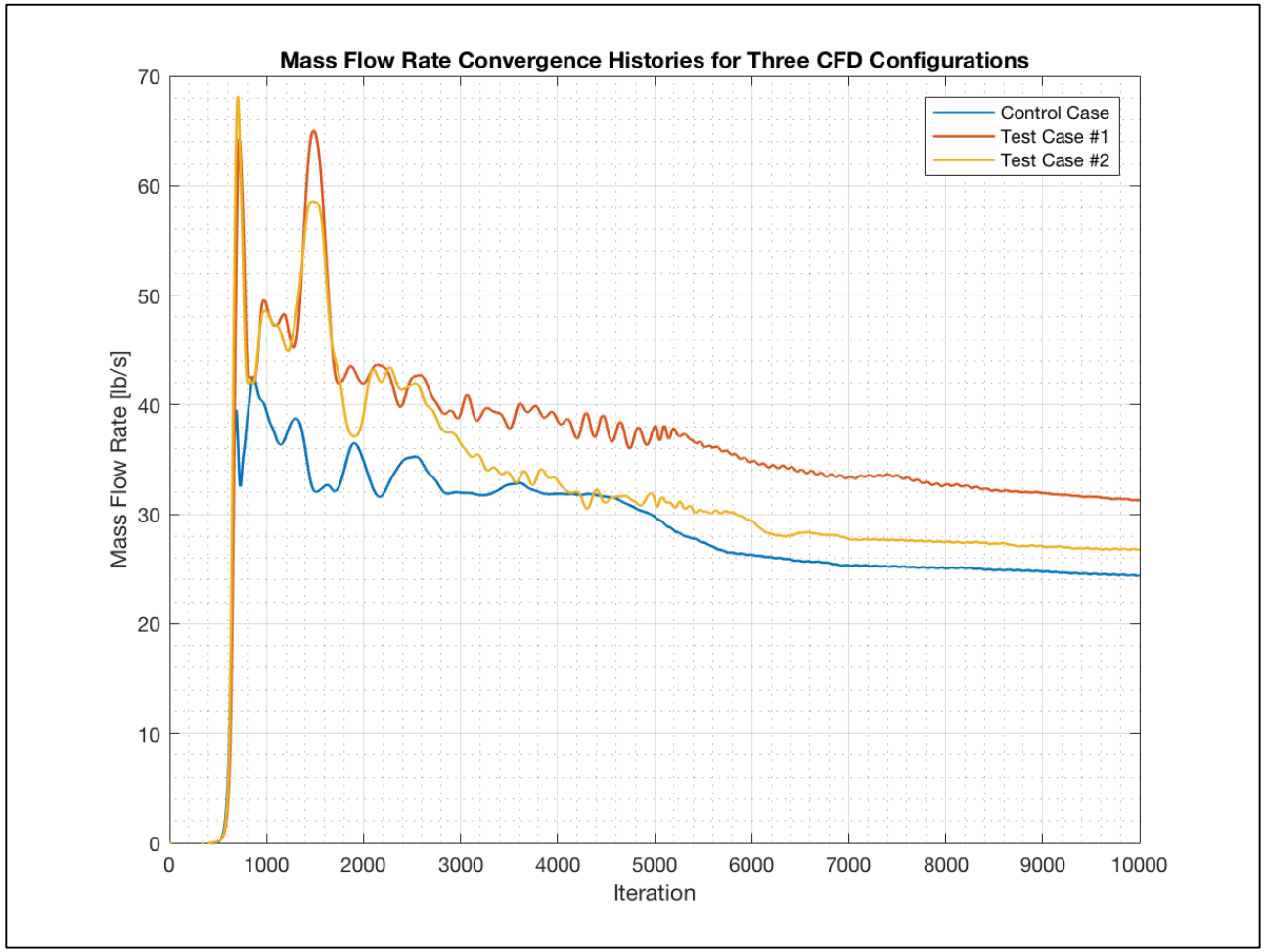
	Control Case	Test Case #1	Test Case #2
Pressure Profile			
Streamtube Profile			
Velocity Profile			

Results: Performance Metric

- *Mass flow rate used as a comparative metric*
  - Efficiency of evacuating exhaust gases
- 10,000 iterations performed to convergence

	Mass Flow Rate
Control Case	24.5 lb/s
Test Case #1	31.0 lb/s
Test Case #2	26.2 lb/s



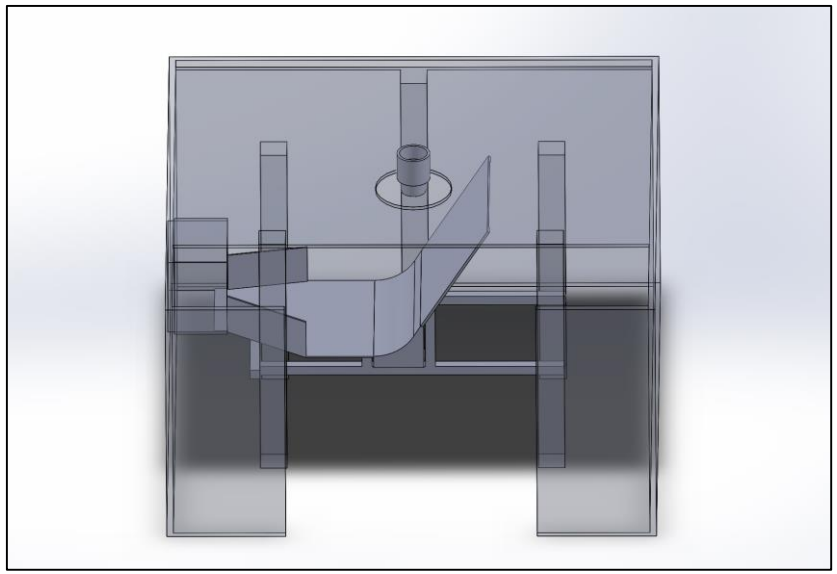


Implementation

- Deflector Plate Construction
  - –Materials:
    - Reinforced steel plates
    - Refractory concrete (improved thermal resistance)
  - –Geometry:
    - Flat steel plate (flow impingement)
    - Refractory cement curve
    - Flat steel plate
    - Exhaust manifold

Successful design enabled testing and validation of NP-915 Icarus II for Spaceport America Cup

Redesigned Geometry



Burn & Flow Deflection

Post-Burn

QUESTIONS?

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