National Aeronautics and Space Administration

NATO Blunt Body Transition Group - Progress at JSC

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Overview

- **Exploration Flight Test 1 (EFT-1) Overview**
- **HIEST Apollo Capsule Analysis**
  - Testing Overview
  - CFD with DPLR
  - 2D Stability Analysis
- **Continued Work**

Exploration Flight Test 1 (EFT-1) Overview

- **First flight test of the Orion Multi-Purpose Crew Vehicle (MPCV) scheduled for September 2014.**
  - Orbital flight test with high-energy entry designed to test thermal protection system design and measure aerodynamic and aerothermodynamic environments (including boundary layer transition).
  - Instrumentation will include pressure measurements, in-depth temperature measurements, and radiometer data.
- **Vehicle currently at Kennedy Space Center undergoing flight readiness testing.**

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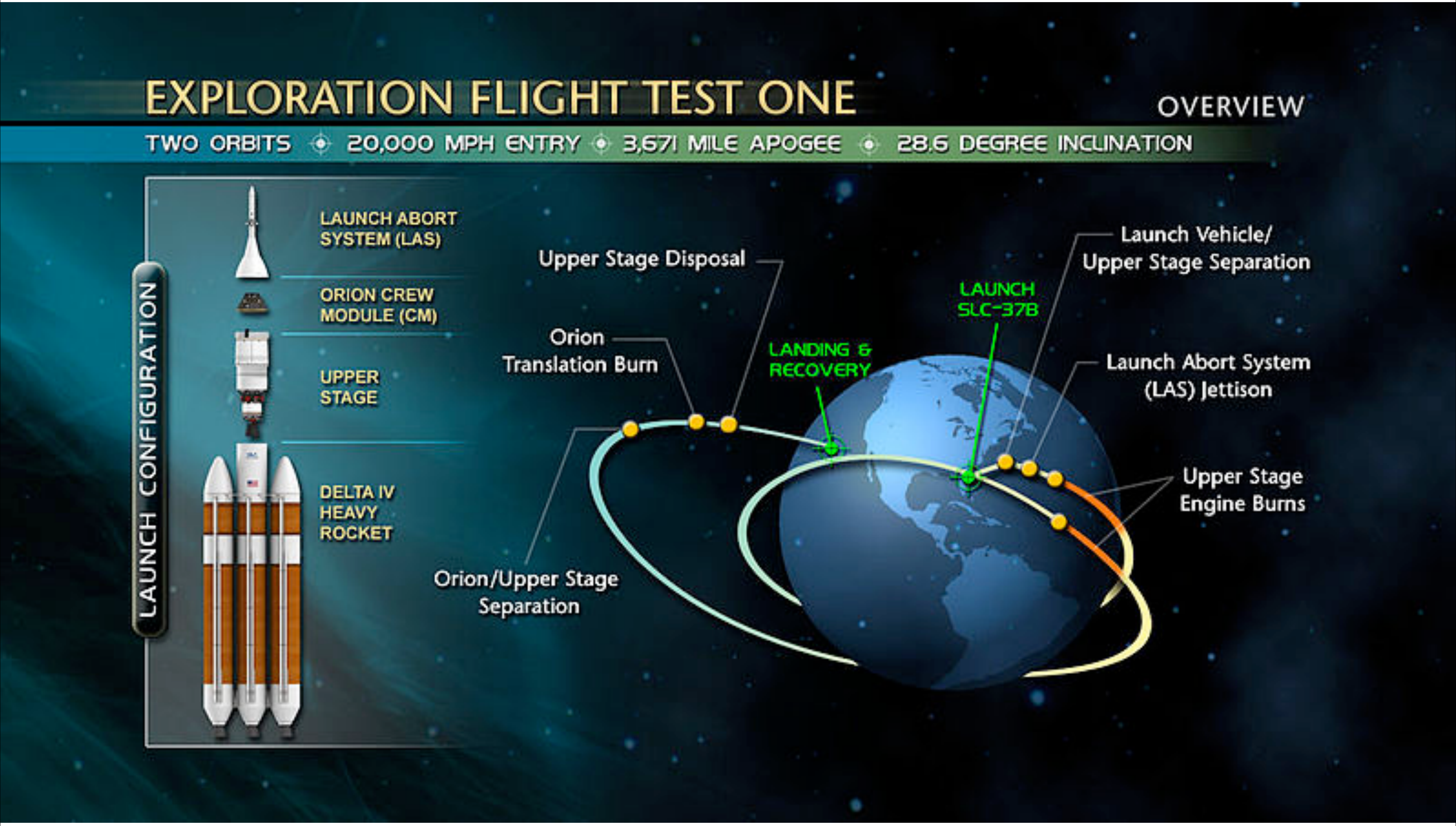
EFT-1 Mission Overview



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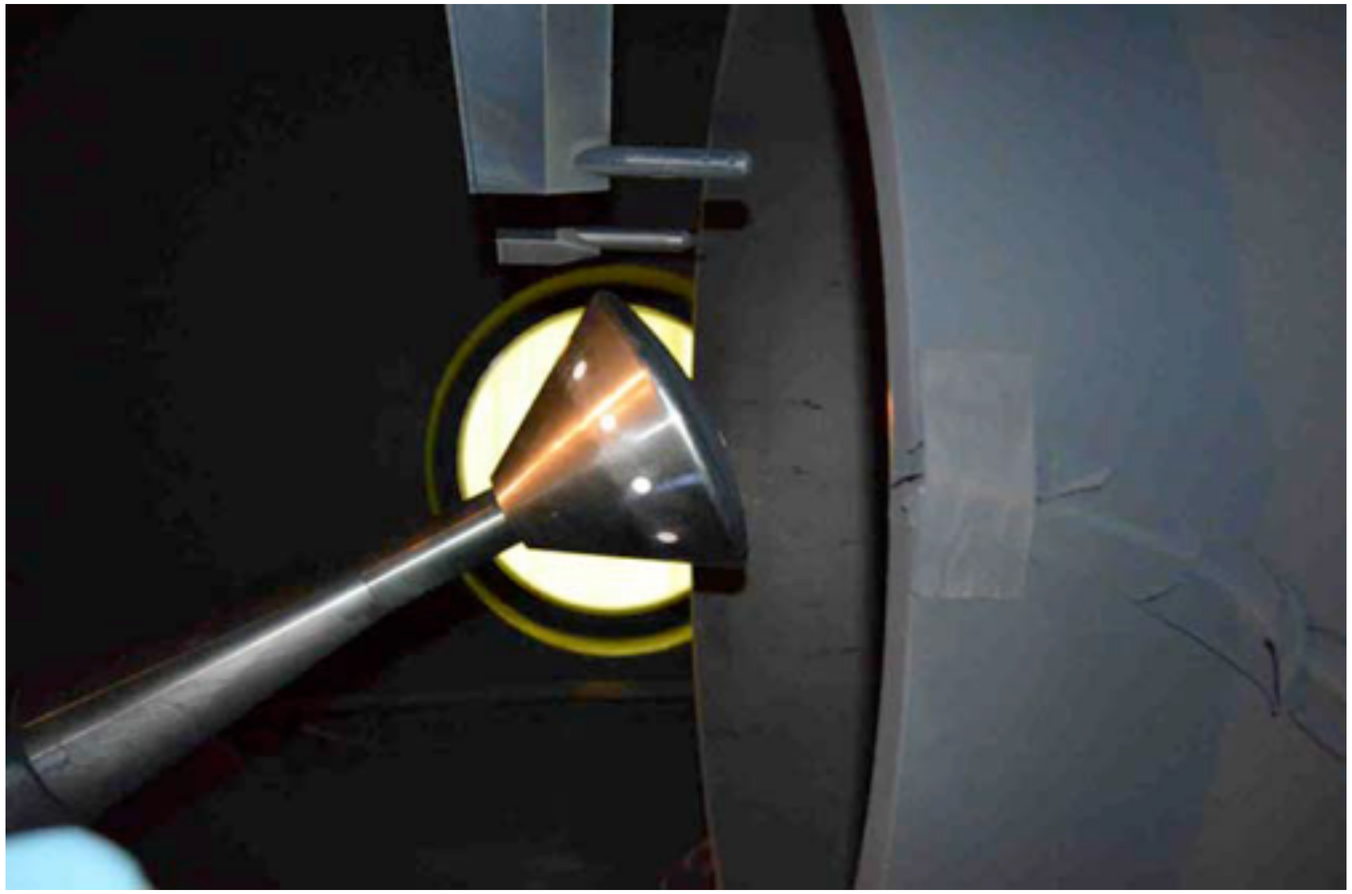
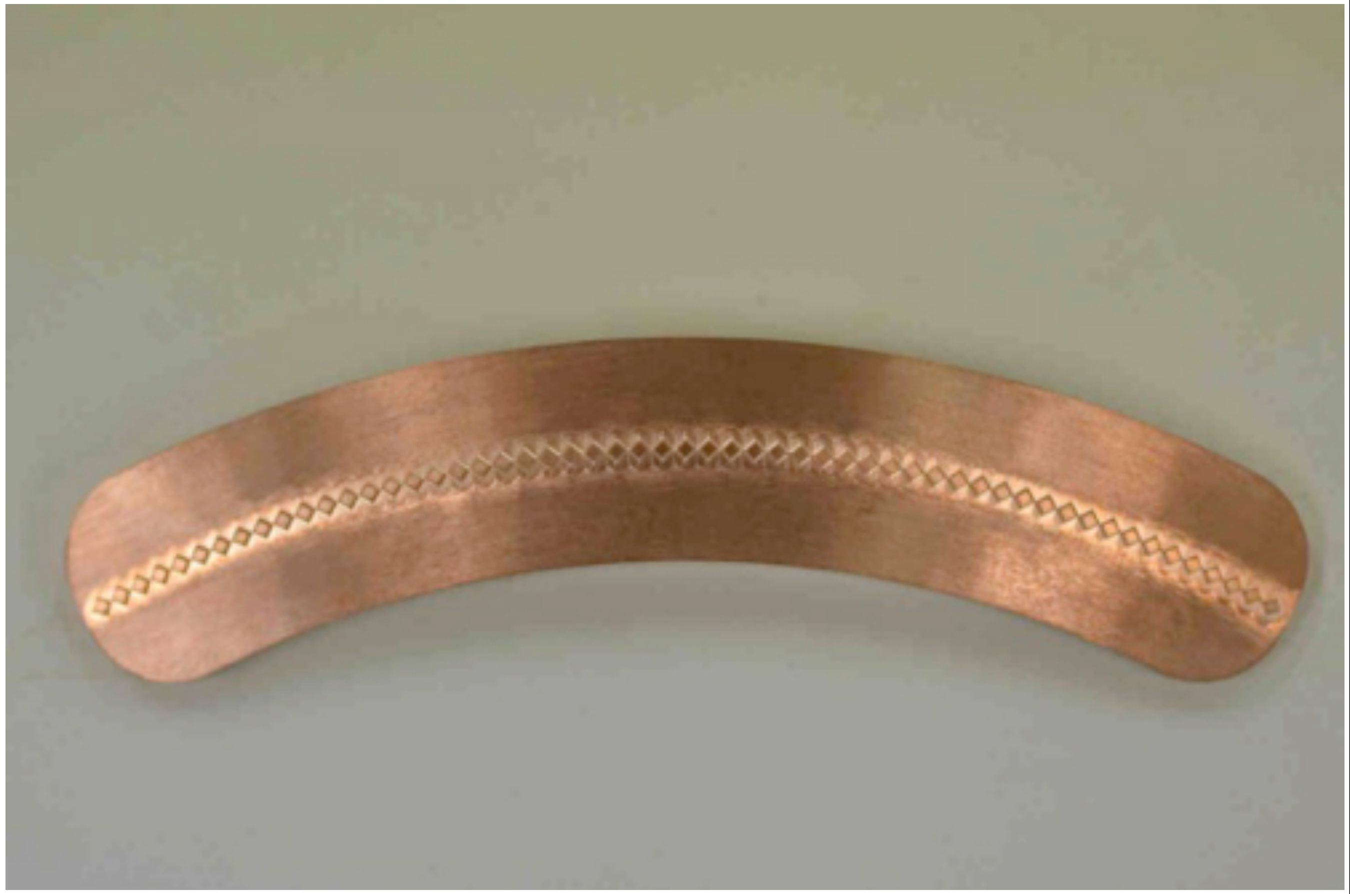
HIEST Testing and Analysis Overview

- **6% scaled Apollo Crew Module model tested in the JAXA High-Enthalpy Shock Tunnel (HIEST)**
  - Smooth and tripped configurations tested over a range of freestream enthalpy conditions.
  - One condition where data showed natural transition and many runs where flow remained laminar over entire capsule heatshield.
- **Freestream conditions obtained by simulating stagnation flow conditions from nozzle plenum.**





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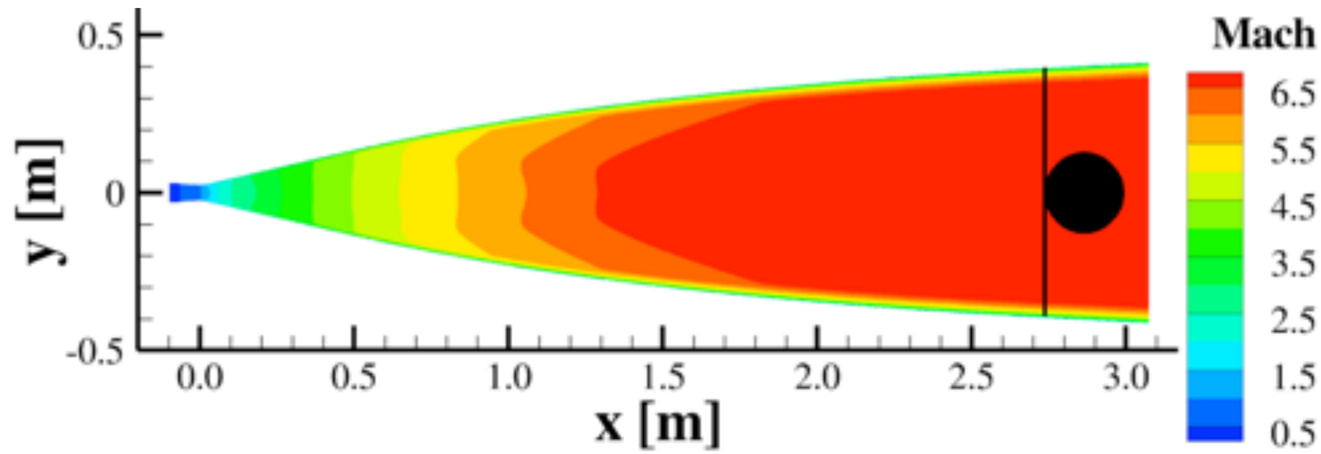
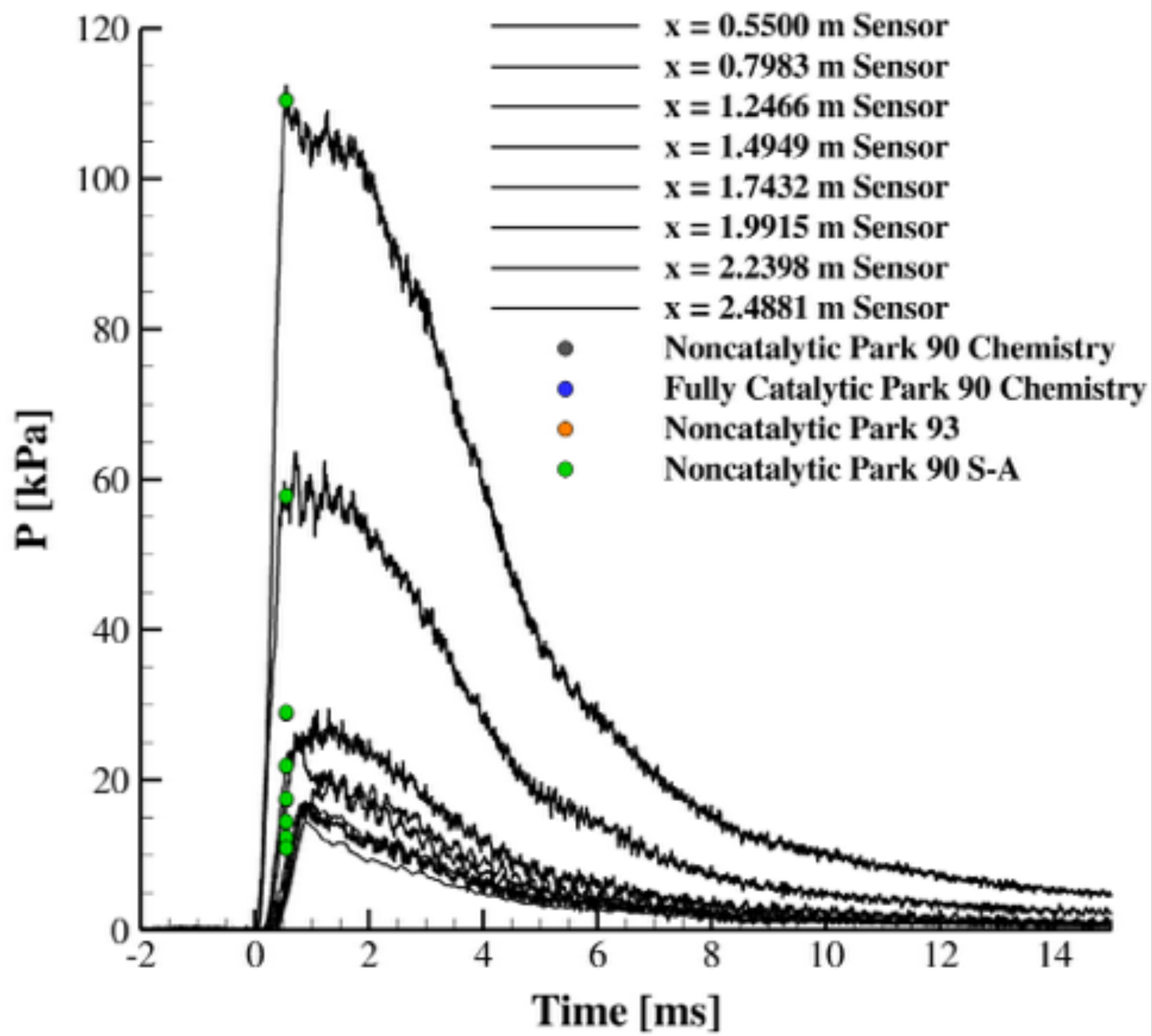
HIEST Test Data

- **Data presented here (one or two pictures) will be coming from an AIAA paper already approved by DAA #30219**

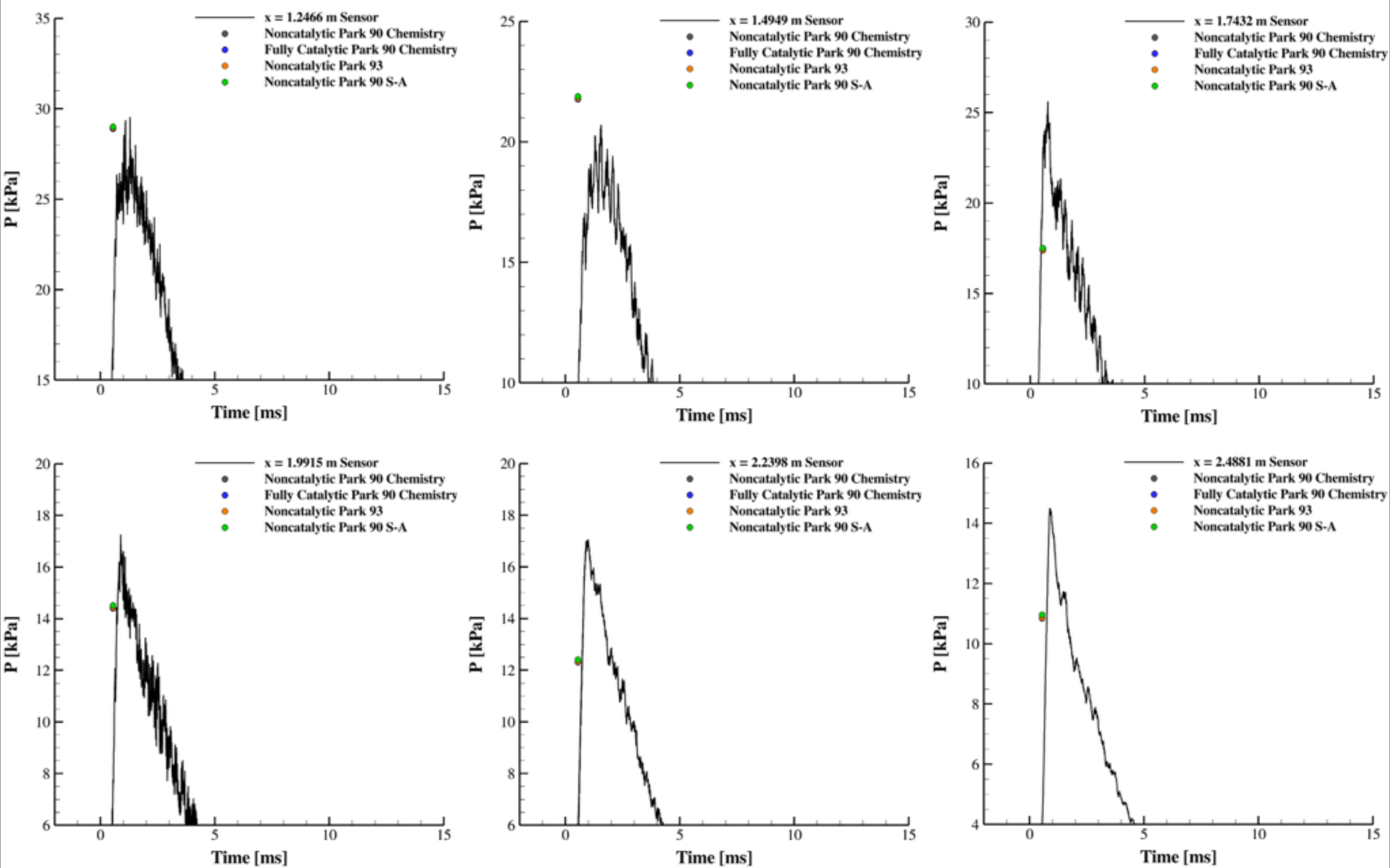
Computational Analysis - Nozzle Pressures

- **Shot 2341 nozzle pressure data was compared to steady state computations.**
  - Pressure predictions are within ~5% of the measured values assuming a constant measurement time for all sensors (0.55 ms).
    - These differences would be affected by constant measurement time assumption.
  - Sensors near the throat are well predicted by the simulations, but sensors farther down the nozzle are not as well predicted.
    - May indicate modeling errors in high enthalpy expanding flow.
    - As expected, chemistry and turbulence modeling had little effect on steady state pressures down nozzle.
- **Plan to evaluate nozzle pressures and wall heat flux for other test runs.**



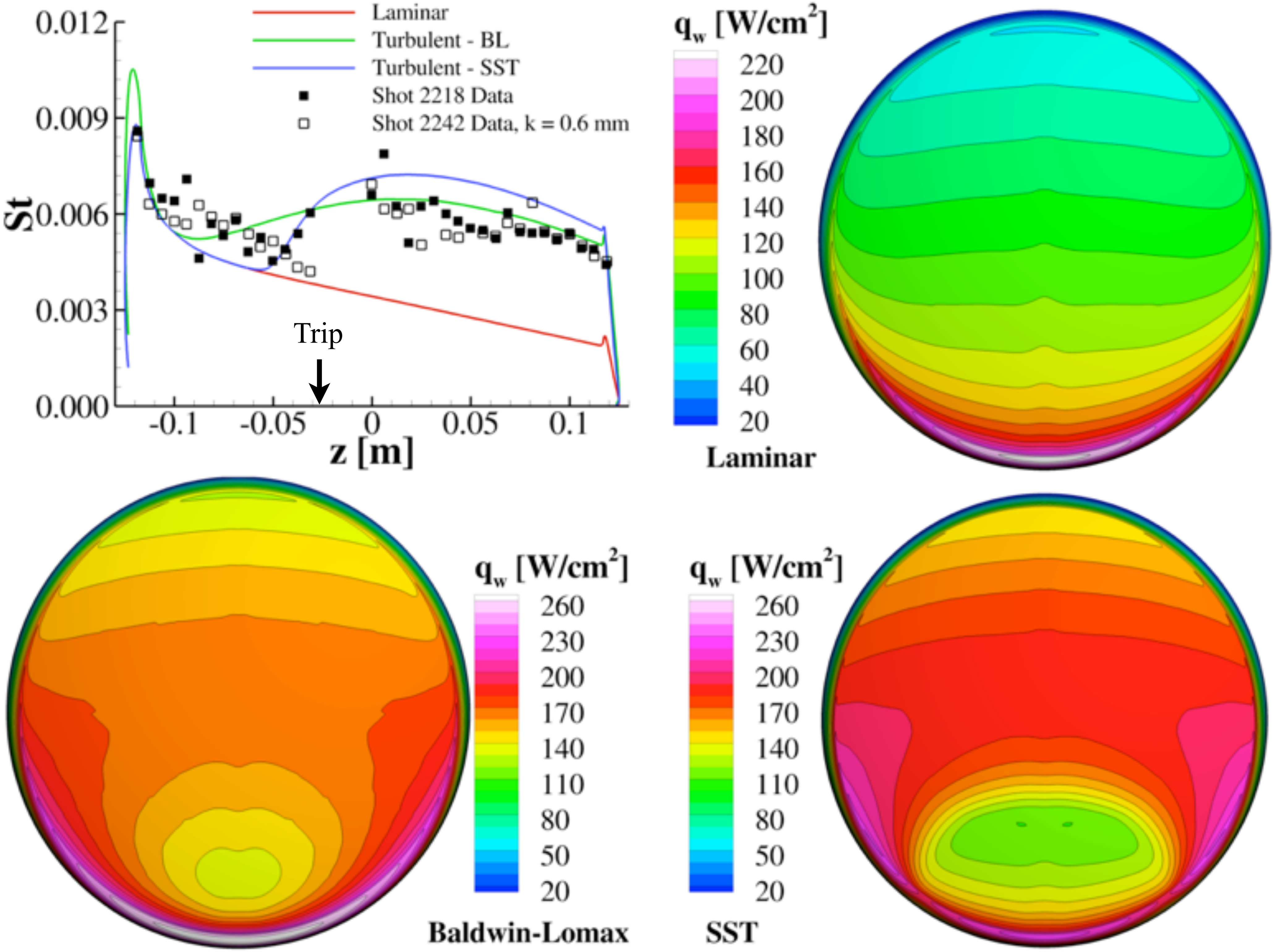


Computational Analysis - Nozzle Pressures



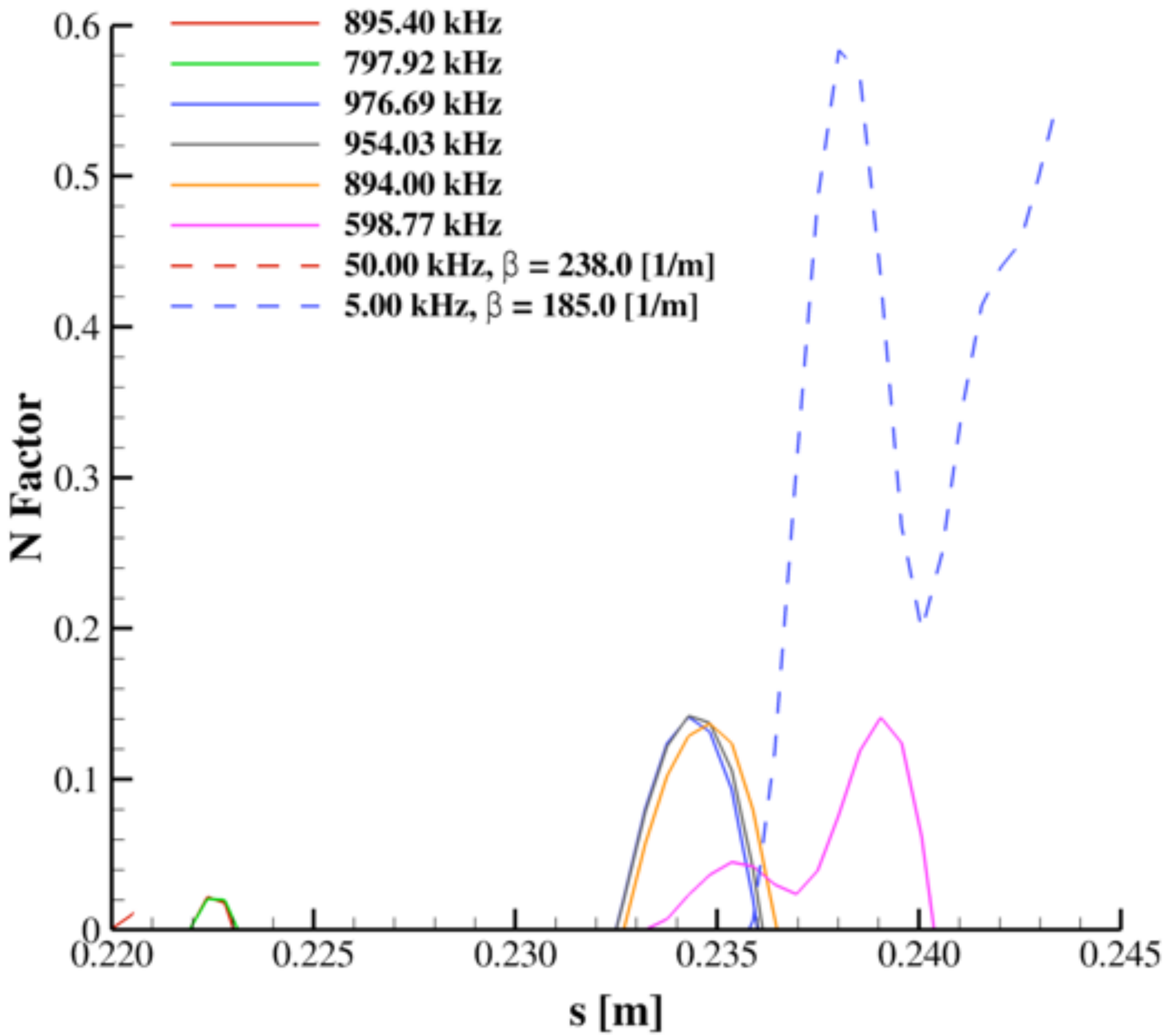
Capsule Computational Results

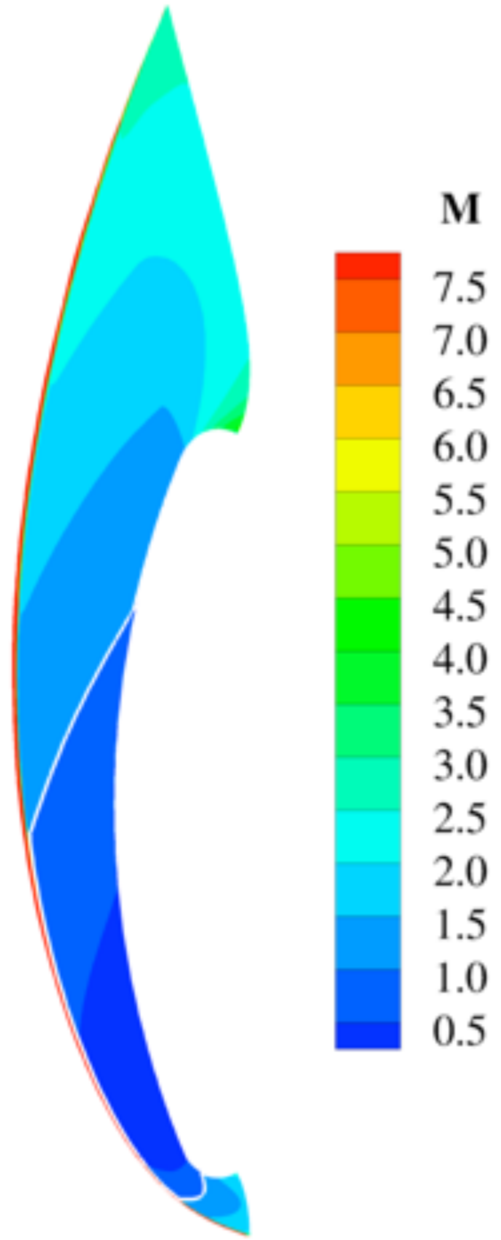
- **Shot 2218 showed natural transition, so this case was chosen for initial stability analysis.**



2D Stability Analysis

- **Performed 2D stability analysis along centerline slice of mean flow solution for shot 2218 using U. of Minnesota STABL software.**
  - Resulting 2D and oblique N factors were small (less than 1) over a large range of frequencies.
  - Few disturbance frequencies were amplified, and none were amplified before the edge Mach number exceeded sonic conditions.





Mean Flow Solution

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Continued Work

- **Subsonic region behind shock in blunt body flow may be allowing other interactions or another disturbance mode to be dominating the flow and causing transition.**
  - Post-test pictures would show if any roughness effects may be influencing transition.
  - Much work on testing and analysis of blunt body transition has been done since this 2D stability analysis presented here.
- **Geometry may be a good case for a 3D stability analysis or transient growth analysis.**
- **Continued Work**
  - Study of other smooth body runs from HIEST facility without transition may provide insight into instability mechanisms and disturbances in the boundary layer.
  - Continuing to look for other blunt body, open literature data sets for comparison and analysis.
  - AIAA paper with HIEST data was presented in January (AIAA 2014-0434, H. Tanno, et al.) and results of numerical analysis will be presented in June (L. Kirk)