

# **COE CST Fifth Annual Technical Meeting**

## **Optical Measurements of Rocket Nozzle Thrust and Noise**

**PI (s): Rajan Kumar & Farrukh Alvi  
Student: Griffin Valentich**

***October 27-28, 2015  
Arlington, VA***



# Agenda

- Team Members
- Challenges and Motivation
- Task Description
- Test Facilities
- Schedule & Milestones
- Nozzle Design
- Future Work

# Team Members

- Team
  - Rajan Kumar & Farrukh Alvi
  - Griffin Valentich
- Organizations Involved
  - FSU / FCAAP
  - Space Florida
  - SpaceX



# Challenges & Motivation

**70% accidents in aerospace missions are due to engine malfunction or propulsion system failures!!**

**Rocket propulsion studies are limited (only National Labs. & big corporations)**

- **High temperature and pressure environment**
- **Complex chemistry – unstable fuels**
- **Large scale tests are expensive & require specialized rigs**
- **Need to develop high temperature pressure sensors – activity initiated under COE-CST**
- **Measure steady and transient loading on the nozzle and ground surface – material characterization**
- **Jet plume development and flow field analysis**
- **Nearfield & farfield noise measurement and prediction tools**
- **Study of next generation hybrid fuels**



# Tasks Description

- Development of a research plan based on state-of-art thrust and noise measurement techniques.
- Discussion with NASA /commercial launch engineers to ensure the transition of technology from laboratory to full-scale implementation.
- Design of a scaled nozzle and simulate realistic temperature and pressure conditions of the jet exhaust in the FSU jet facility
- Design and develop advanced optical techniques for thrust measurements and characterize its performance at controlled conditions.
- Refine and test the measurement techniques over a wide range of test conditions.



# Test Facilities

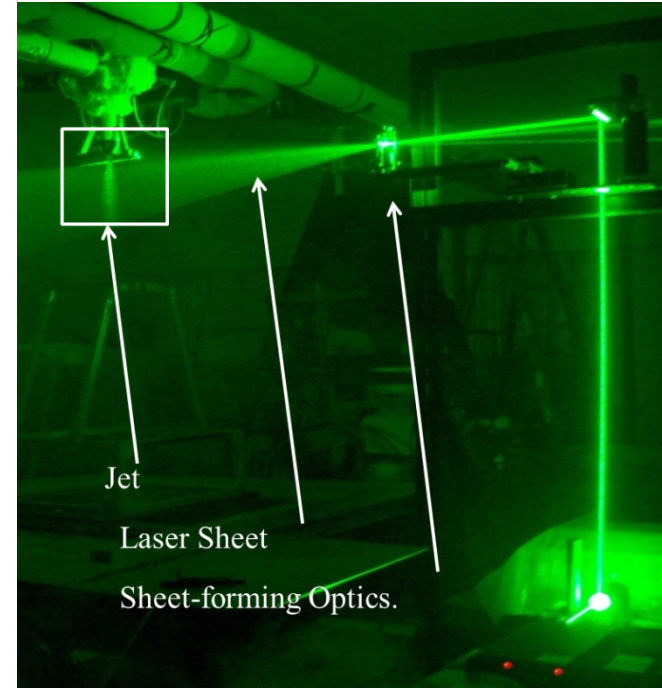


Nozzle

Ground Plate with  
Transducer Block

## Operational/Test Capabilities

- Mach Number = 0.5 - 2.5
- $T_o = 70 - 2000$  F
- $D_{Jet} = 25.4 - 76.2$  mm
- NPR = Under-ideal-over expanded
- Anechoic chamber: 5.8 m x 5.2 m x 4.0 m, Calibrated to 100 Hz



Jet

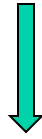
Laser Sheet

Sheet-forming Optics.

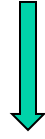
# Thrust Measurements

$$F = F_m + F_p$$

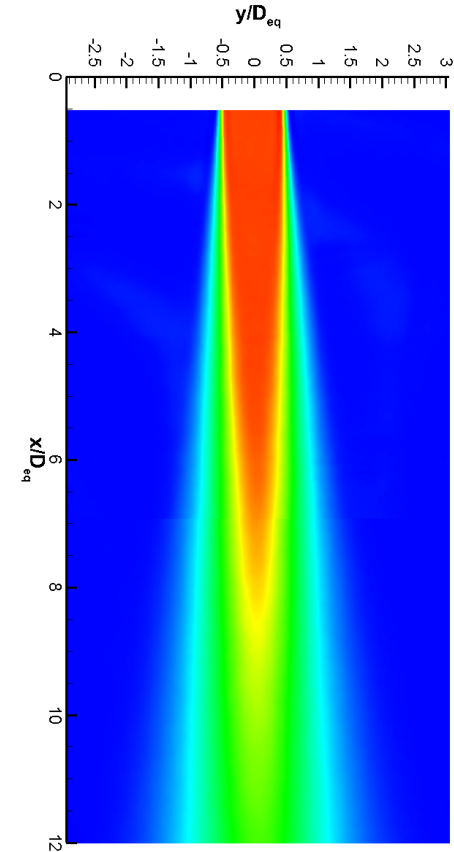
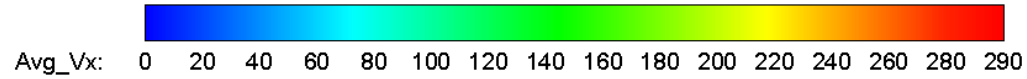
$$F = \dot{m}u_j + (p_e - p_a)A_j$$



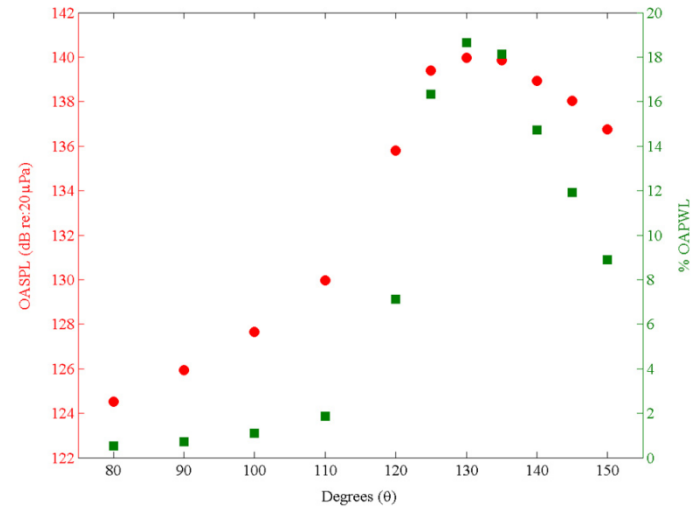
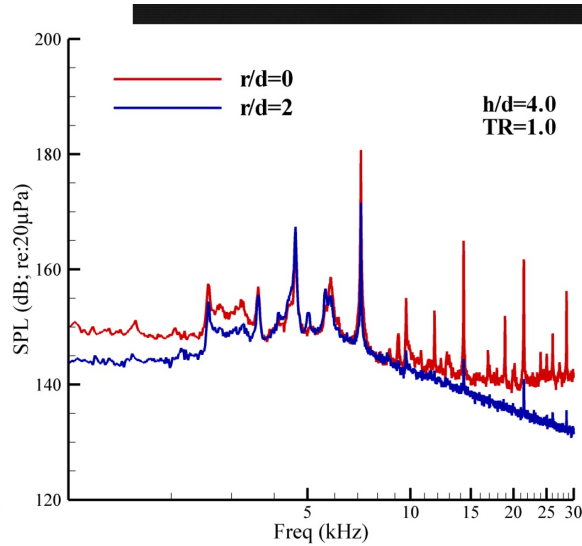
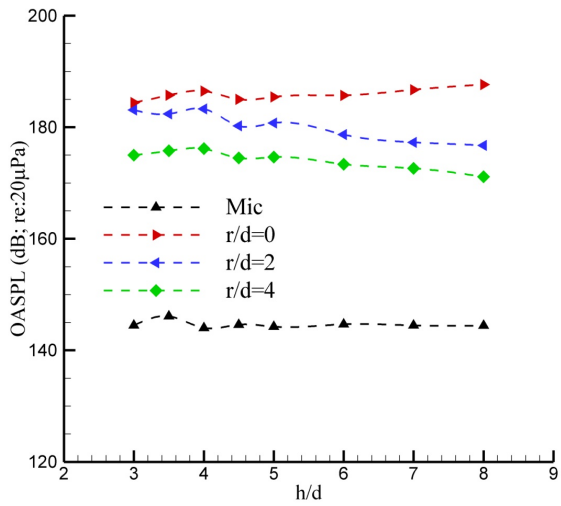
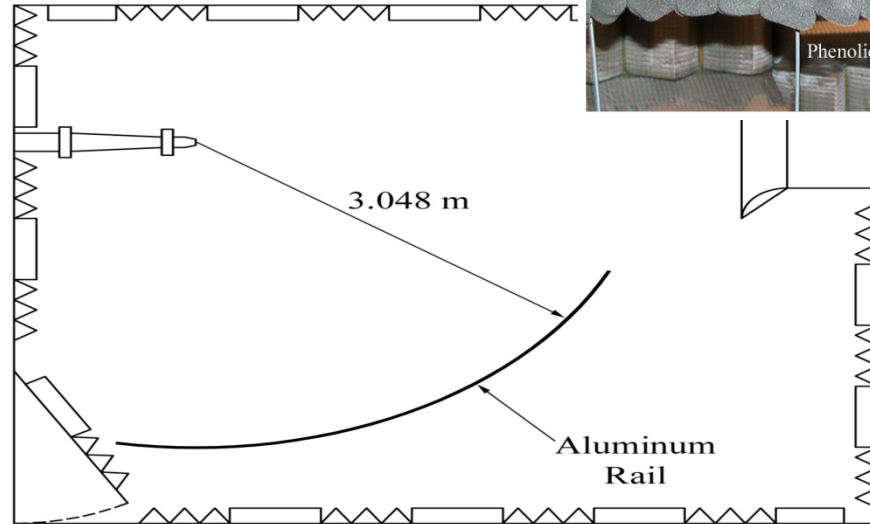
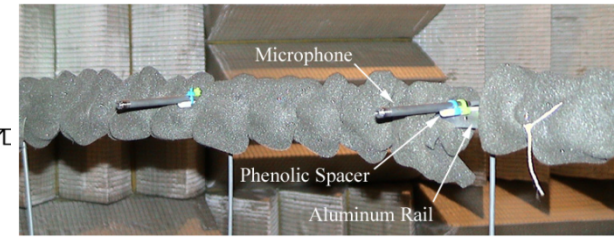
Measured  
using PIV



Measured using  
Pitot-static probe



# Noise Measurements

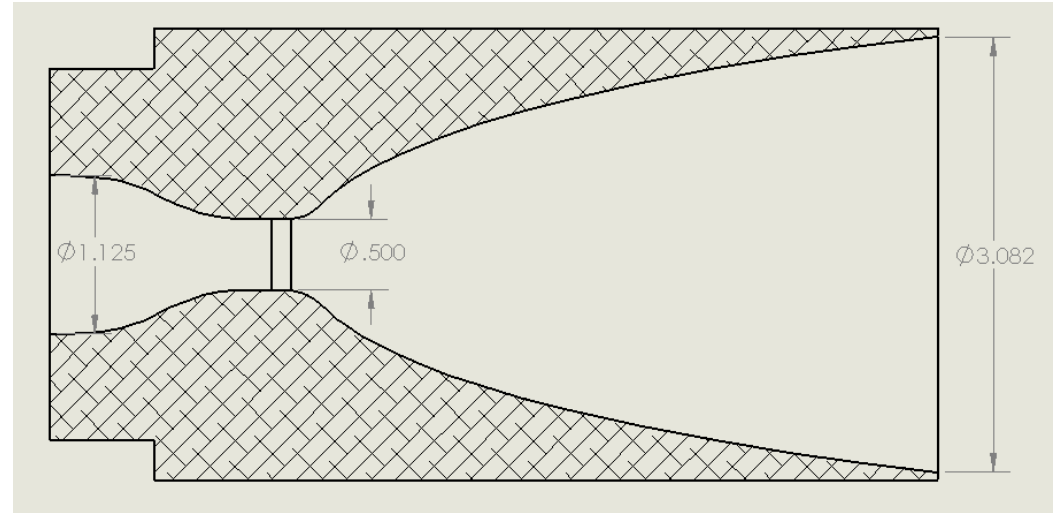




# Schedule and Milestones

Task	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Development of research plan	█	█	█									
Design and fabrication of nozzle		█	█	█	█							
Thrust measurements						█	█	█	█			
Noise measurements									█	█	█	█

# Preliminary Nozzle Design



Thrust optimized parabolic (TOP)  
contour nozzle

Design Mach Number: 5.6

$A/A^* = 38$

# Future Work

- Discussion with NASA / commercial launch manager (SpaceX).
- Detailed design to suit FSU jet facility and fabrication of TOP nozzle
- Instrumentation of jet facility to measure mass flow rate, exhaust velocity and pressure distributions at the nozzle exit