PIV Measurements on the FAA Fire Test Oil Burner

Particle Image Velocimetry Applied to Fire Safety Research

Presented to: International Aircraft Materials Fire Test Working Group

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Federal Aviation Administration

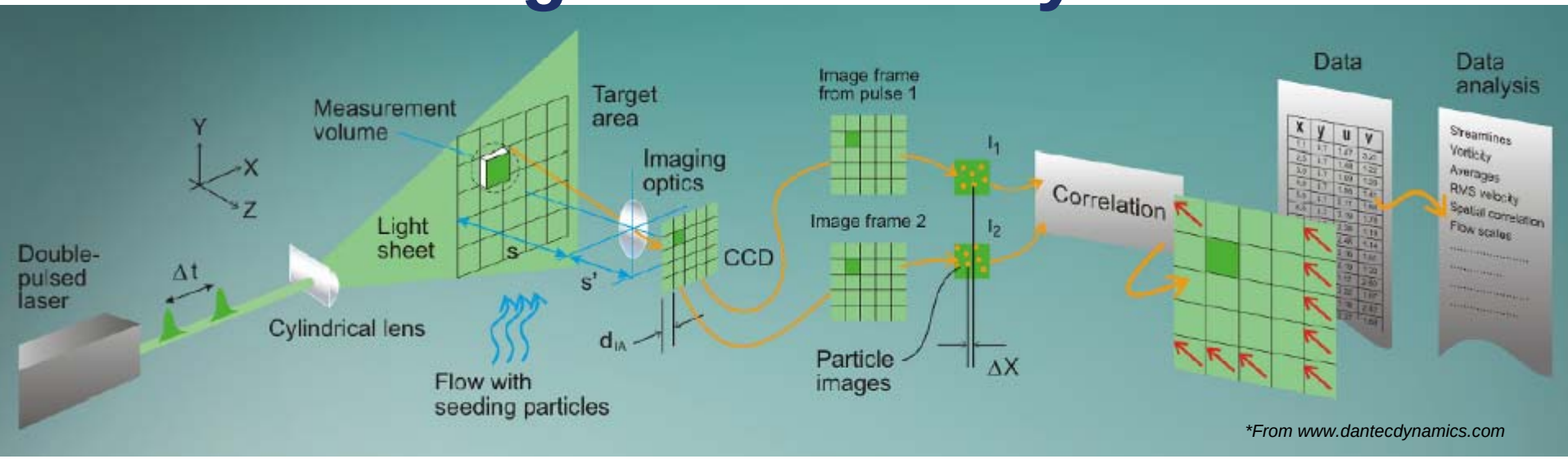
Outline

- **Motivation**
- **Objectives of Study**
- **Acquired Data**
- **Summary and Future Work**

Motivation

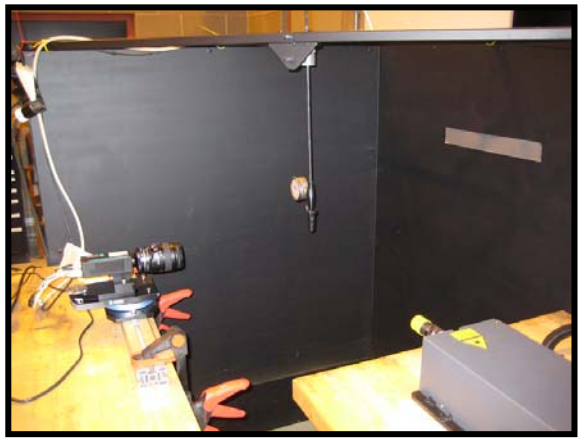
- **The FAA specifies a modified oil burner to simulate the effects of an external fuel fire on an aircraft fuselage and interior components**
  - The specified burner is a typical home heating oil burner
  - Burner fueled by Jet-A
- **Burner flame characteristics scaled directly from measurements made from full scale pool fire testing**
  - Heat flux
  - Temperature
  - Material performance
- **Difficulty with achieving calibration and inconsistency of burner performance worldwide has led to the need for a more in-depth, fundamental physical understanding of the thermo-fluidic processes**
- **The objectives of this study are:**
  - Determine the key parameters that affect burner performance
    - Study parameters individually
    - Study interactions of parameters
  - Increase burner consistency and reproducibility
  - Develop new internal components based upon what is learned
    - New components will have higher tolerances than original components

Particle Image Velocimetry

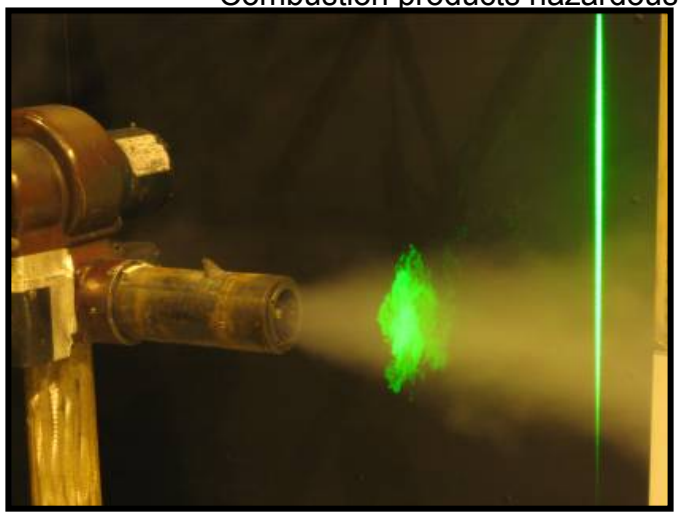


- **Particle Image Velocimetry (PIV)**
  - Fluid flow measurement technique
  - Measures the displacement of small particles entrained in the flow over a short period of time and calculates the velocity at discrete points
- **Key Advantages**
  - Non-intrusive measurement of flow
  - Whole-field measurement; can resolve wide range of flow field areas ($\mu m^2 \rightarrow m^2$)

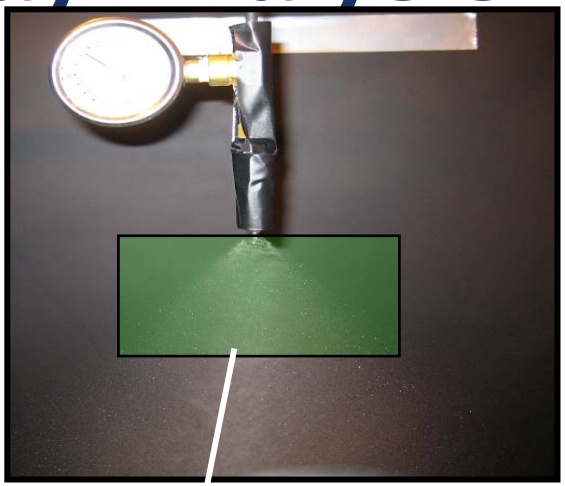
Can PIV Be Used to Study Flow Properties of the Fire Test Burner?

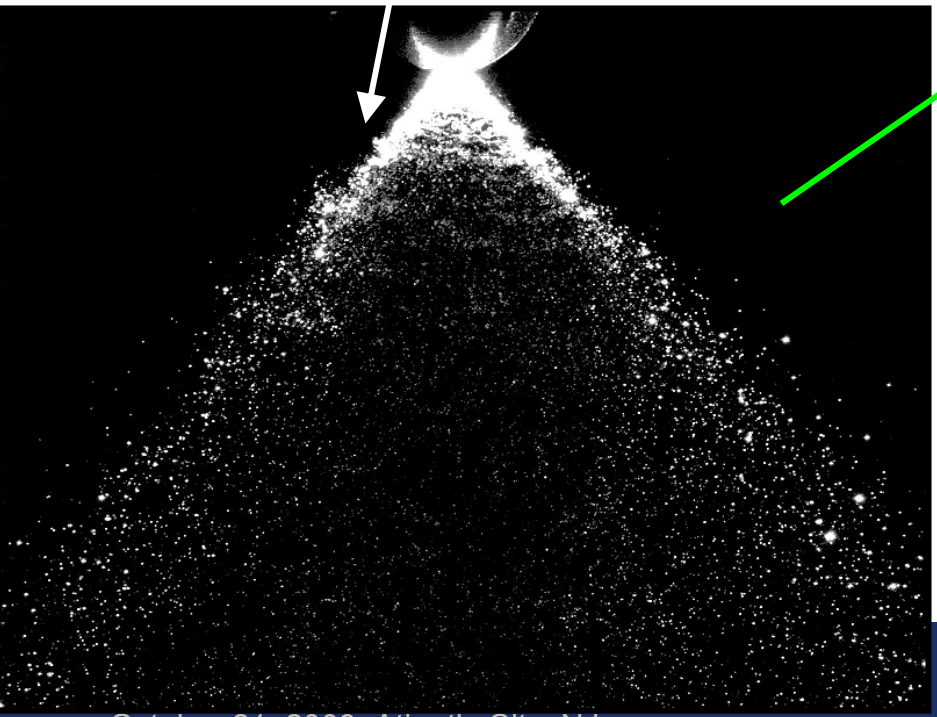


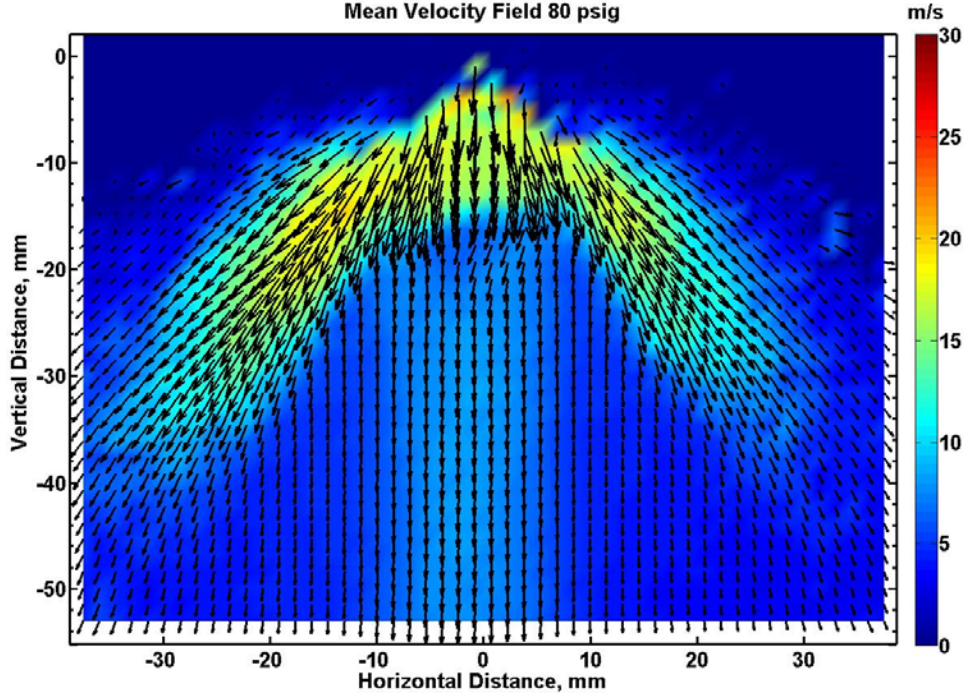
- **PIV was chosen for this research due to it's whole-field, non-intrusive flow measurement capability**
- **The burner can be divided into different studies:**
  - Fuel Spray
  - Swirling Jet Flow
  - Combined Fuel Spray / Air Flow
  - Burner Flame
- **Combustion presents many technical challenges for PIV**
  - High temperatures
  - Broadband, intense flame luminosity
  - Intense thermal radiation
  - Combustion products hazardous to health and equipment

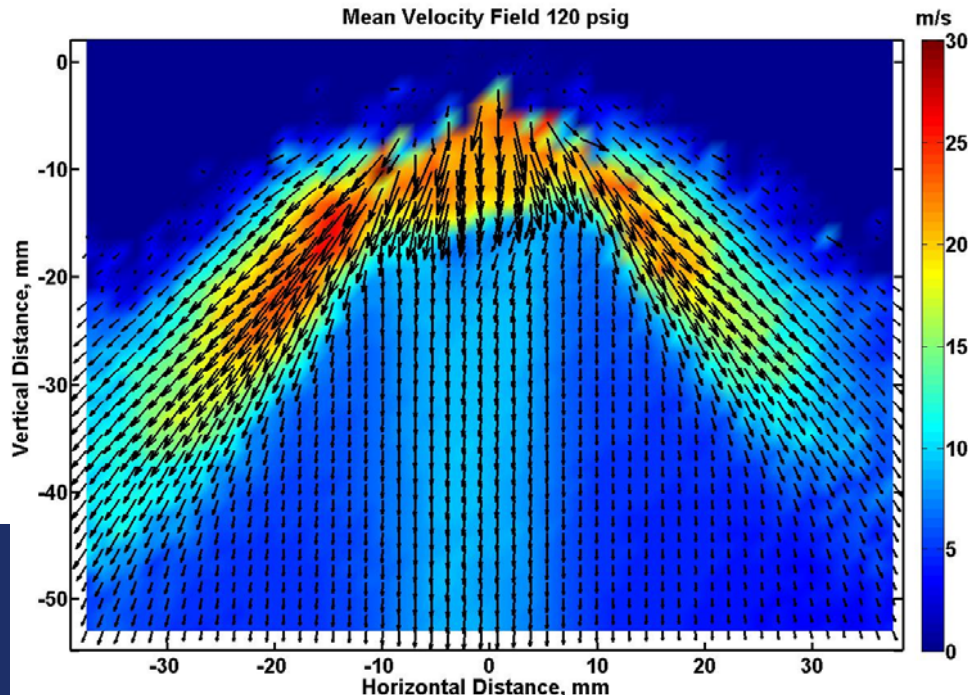


Spray Analysis





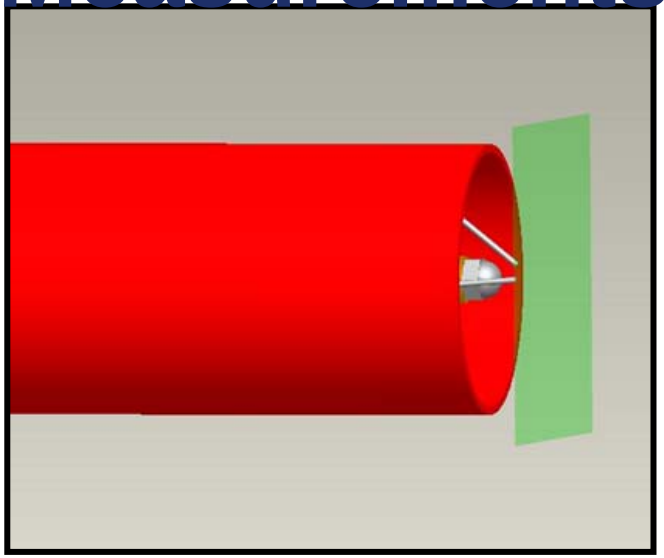


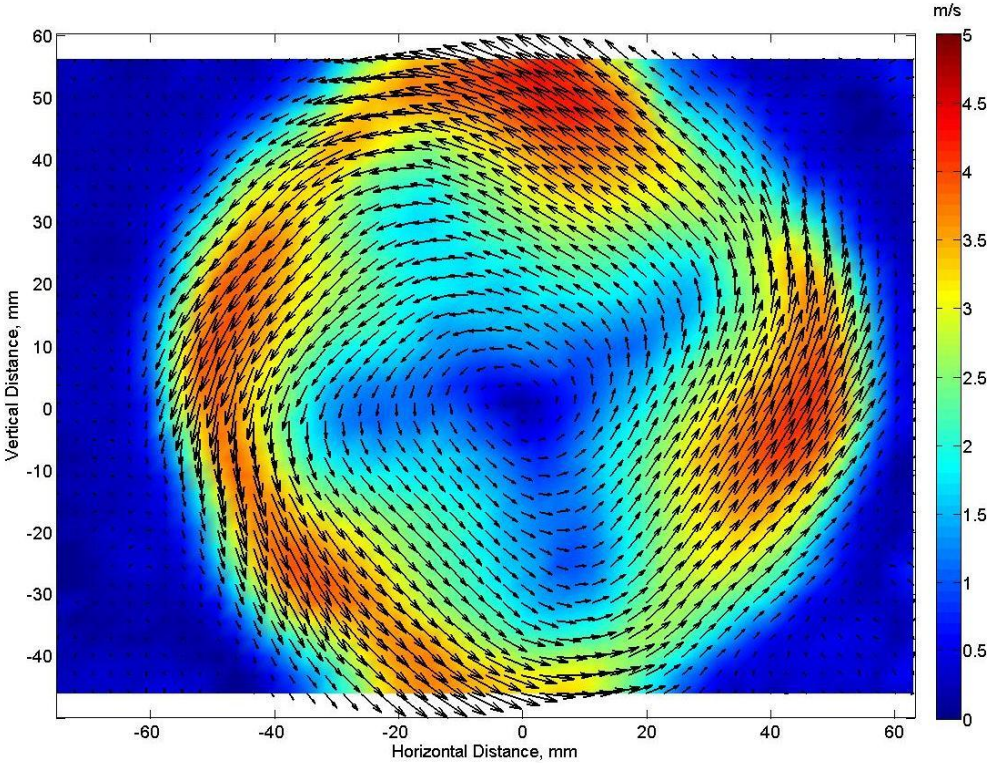


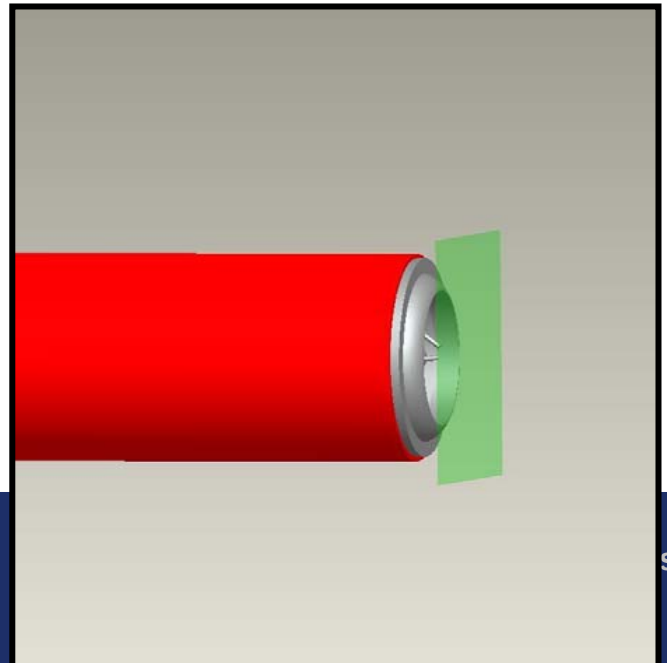
Future Measurements - Spray

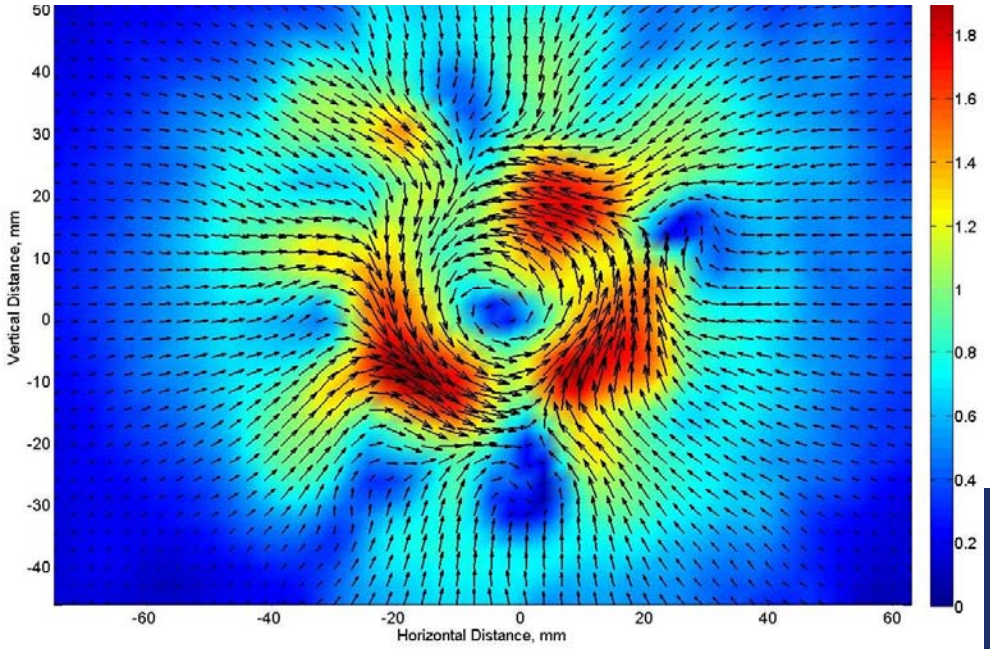
- **Study various spray properties**
  - Effect of viscosity on velocity field (vary fuel temperature)
  - Obtain sizing information in less dense regions of spray, study effect of viscosity (temperature) on droplet size
  - Study nozzles for uniformity of spray pattern by rotating measurement plane

Air Flow Measurements









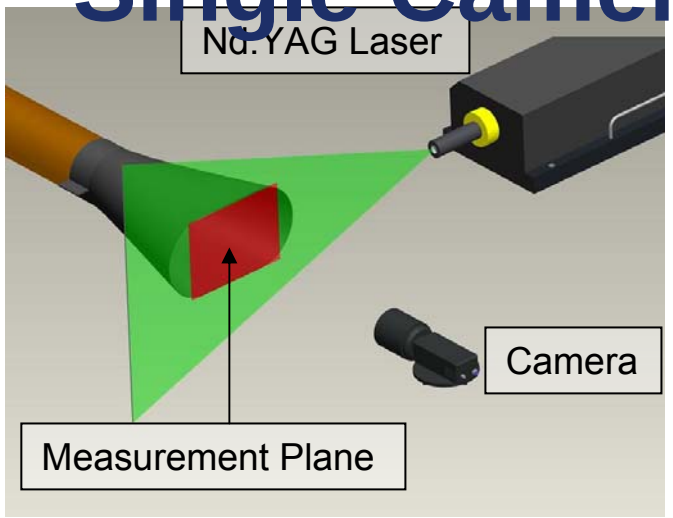
Analysis

- **The effect of the turbulator is apparent in the flow field measurements**
- **The magnitude of the in-plane velocity on the periphery of the flow field is significantly reduced by the action of the turbulator, from ~4 m/s to ~1 m/s**
- **The regions of high velocity on the edges of the flow are compressed into the central region of the flow by the turbulator**
- **This centralized high rotation region is intended to interact with the high mass, high momentum fuel droplets in the spray cone**

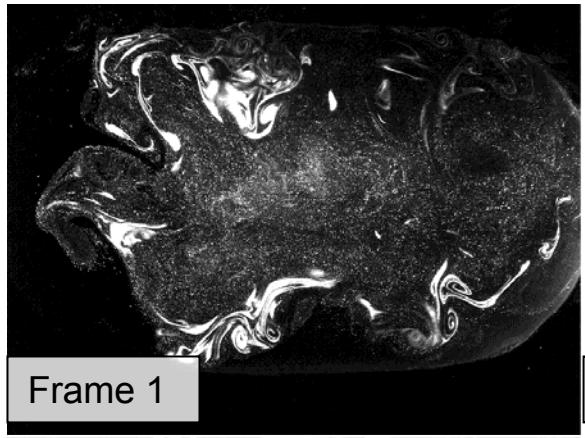
Future Measurements

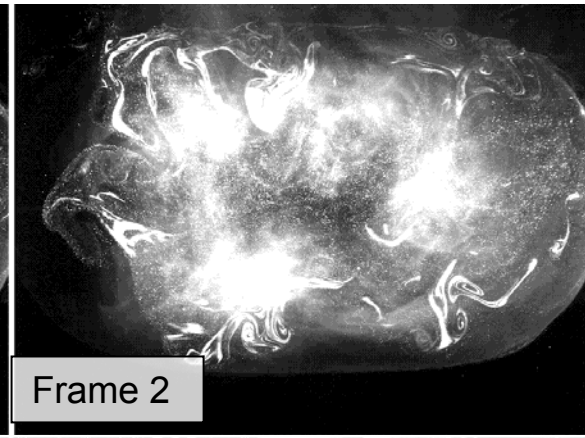
- **Make similar iterative measurements at locations downstream**
  - Study behavior of swirling air flow as a function of axial location (stereo-PIV)
  - This may give insight into optimal location, orientation of stator and turbulator
- **Perform same measurements, study effect of variables**
  - Various Re
  - Fuel spray as seeding, study interaction of airflow on fuel spray

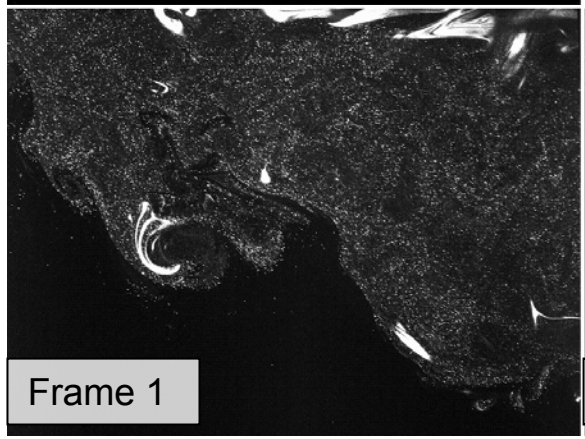
Acquired Images – Reacting Flow Single Camera

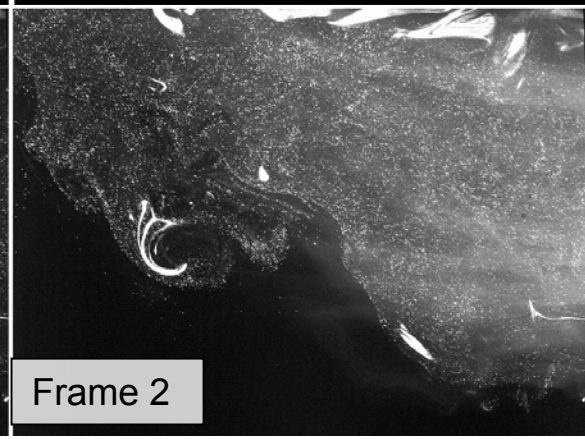


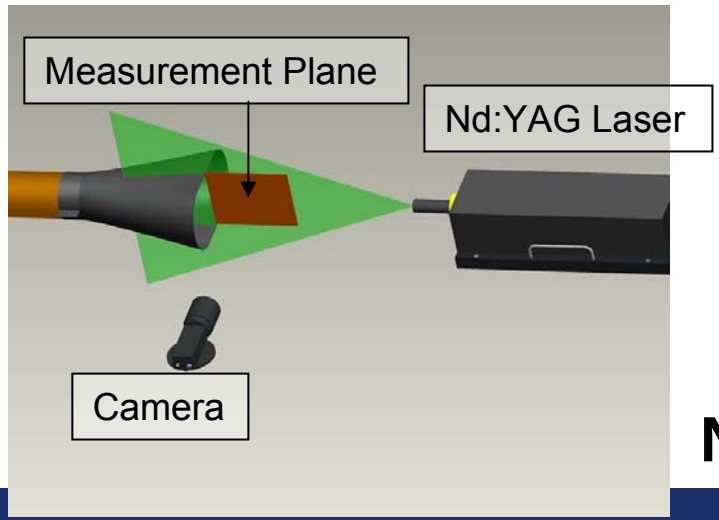
Parallel Plane





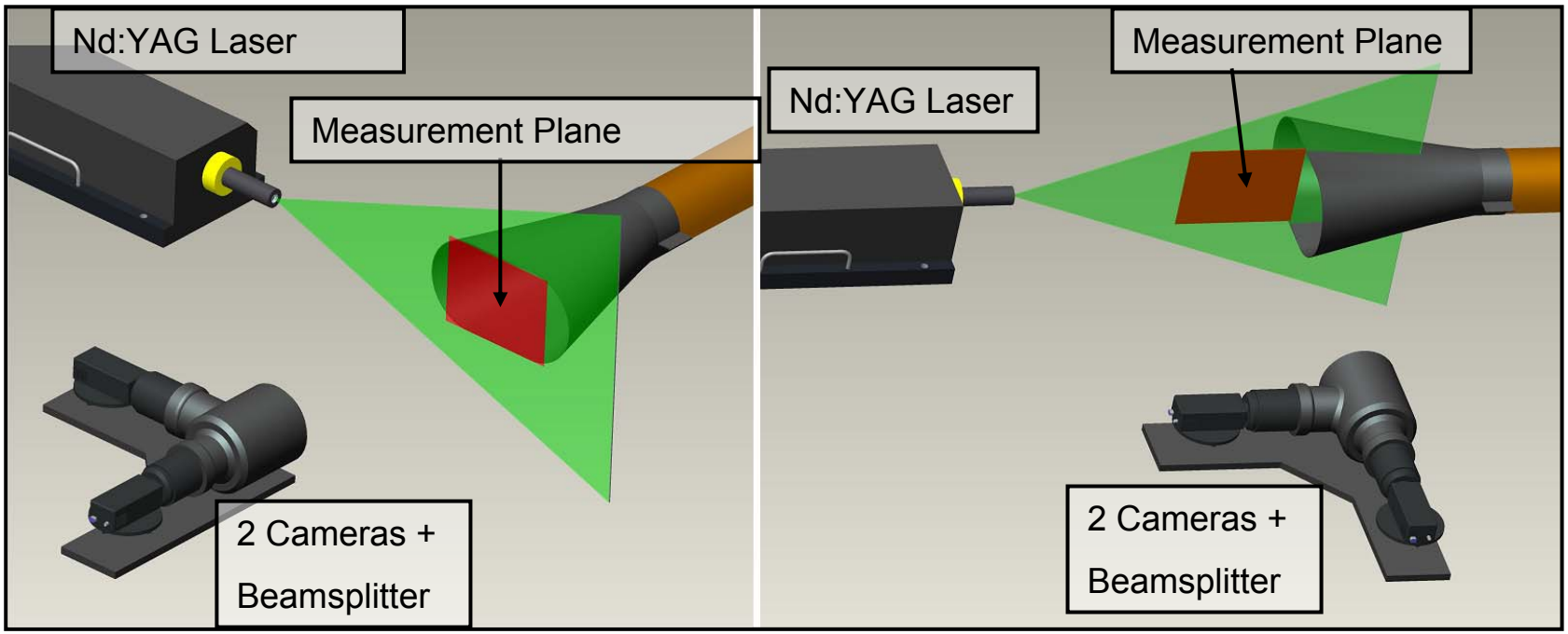






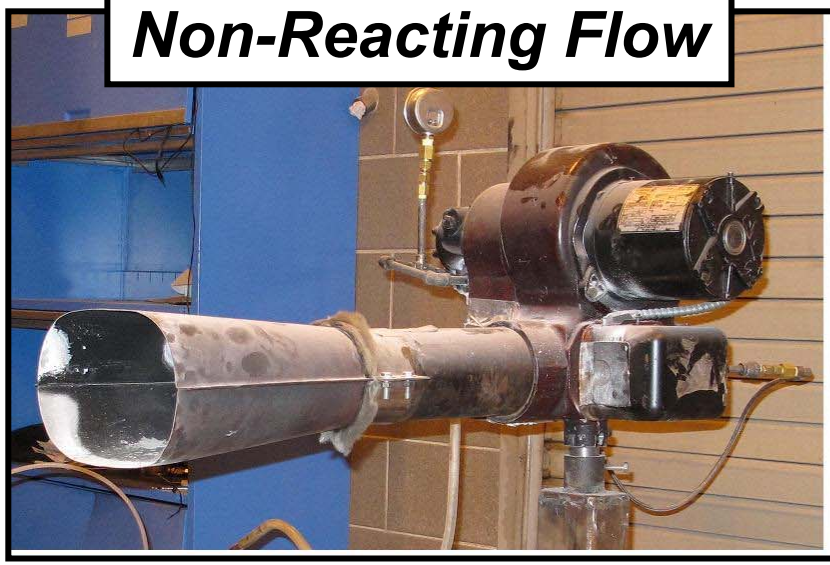
Normal Plane

PIV Setup –2 Cameras

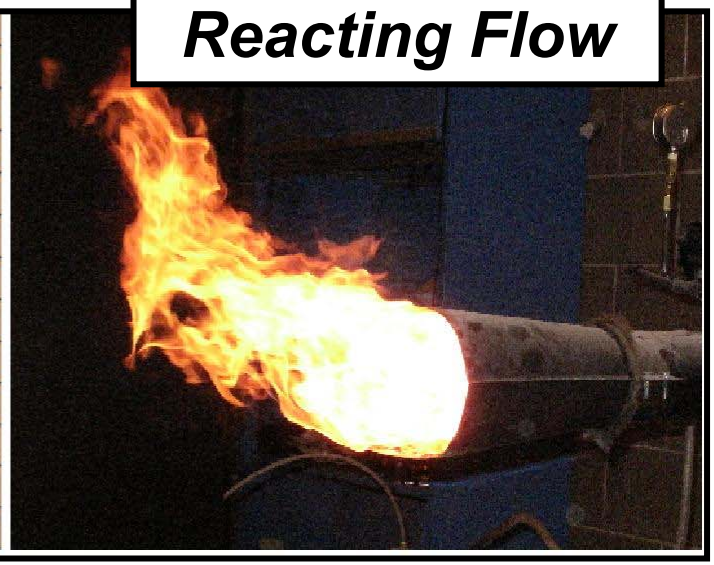


Experimental Setup

Non-Reacting Flow



Reacting Flow



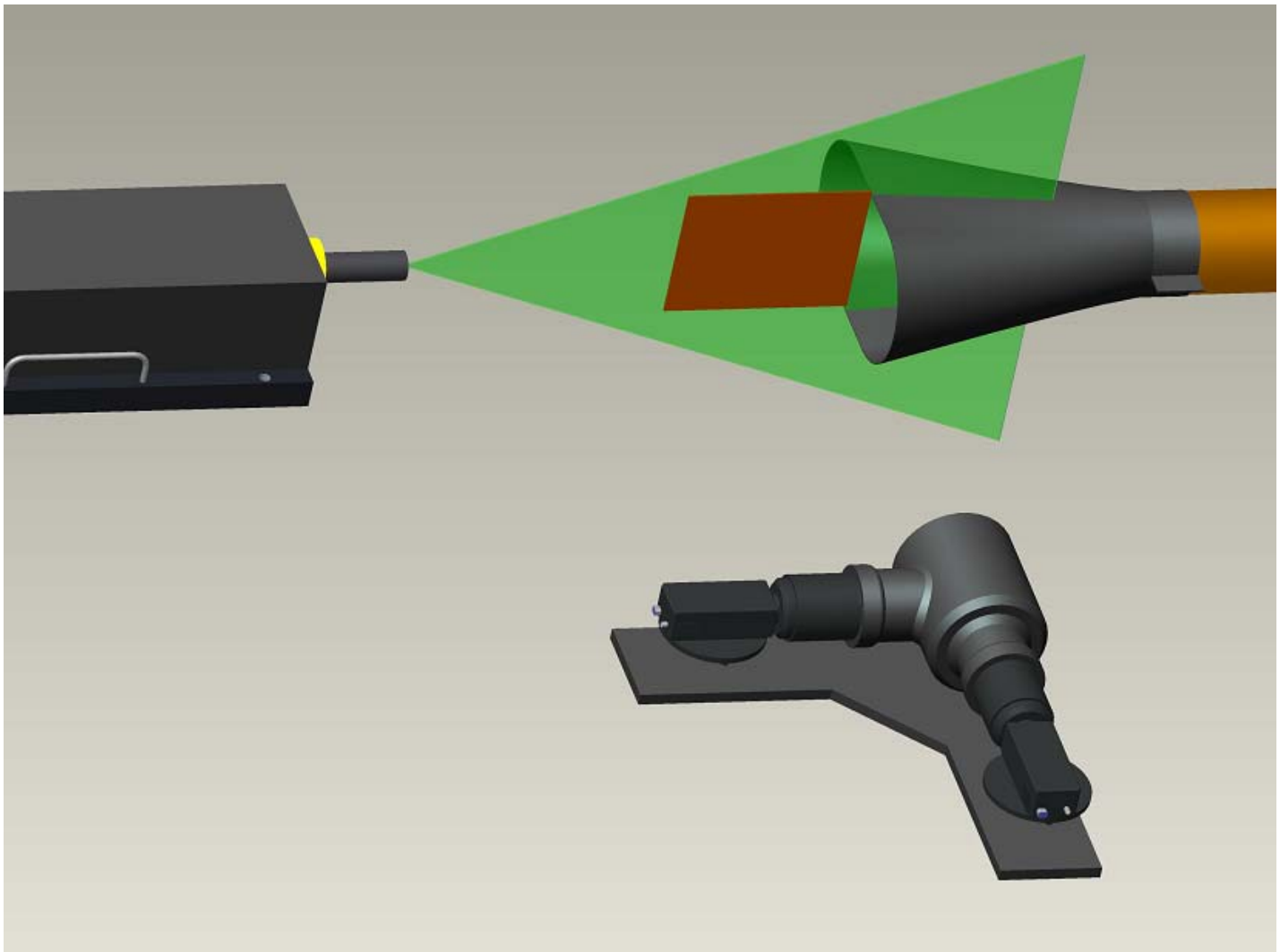
Burner Settings

Fuel Flow Rate	126 ± 6.3 mL/min
Fuel Type	ASTM K2 or Jet-A
Inlet Air Flow Rate	1.89 ± .11 m^3/min
Minimum Average Flame Temperature	1255 K
Minimum Average Heat Flux	11.9 W/cm^2

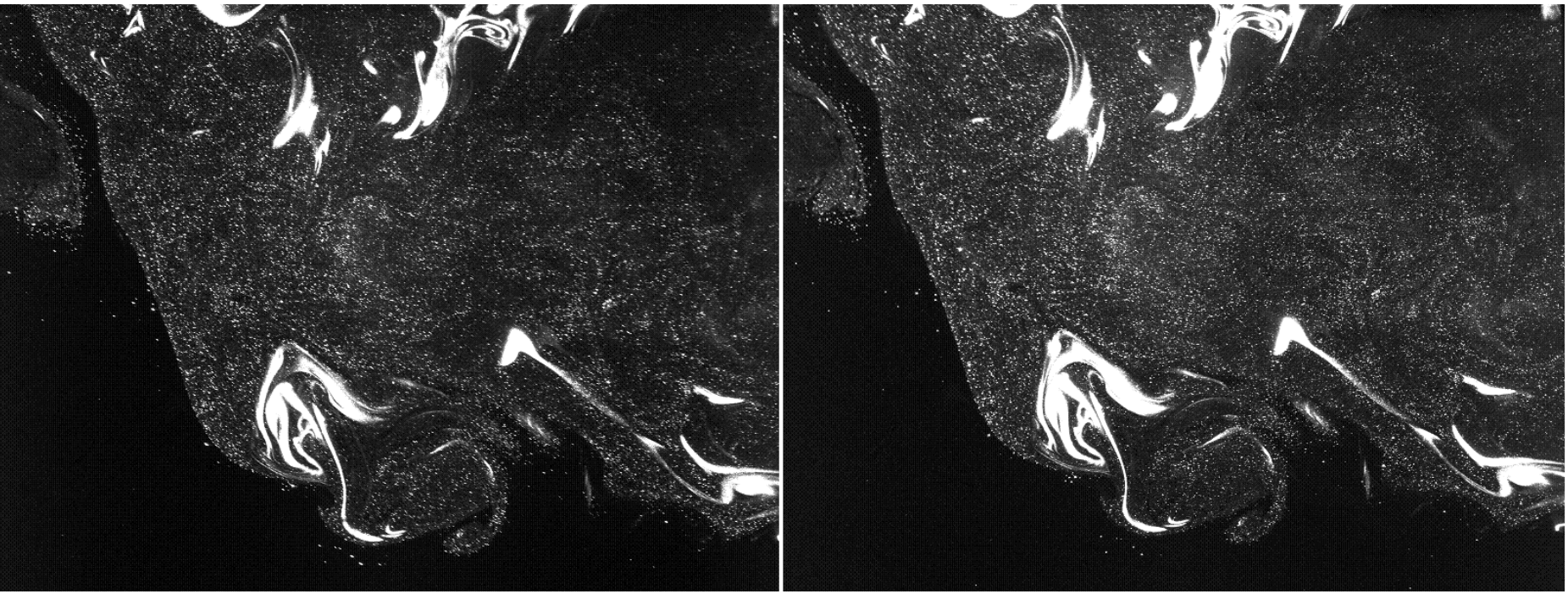
PIV Settings

Seed Particles:	Aluminum Dioxide, 30 micron
Measurement Plane:	180 mm x 150 mm
CCD:	1600 x 1200 px
Lenses:	105 mm F2.8 macro
Lens Filters:	Narrow band, 532 nm ± 3 nm
Light Source:	120 mJ Nd:YAG dual head laser
Δt, non-reacting / reacting:	750 µs / 500 µs

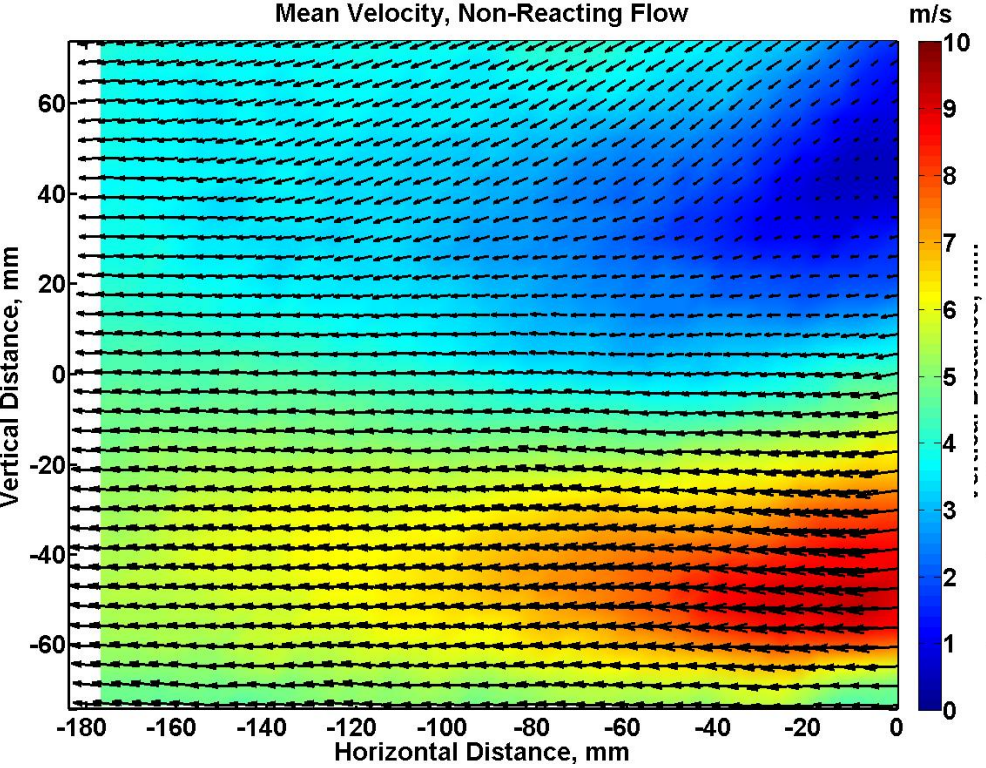
Normal Plane

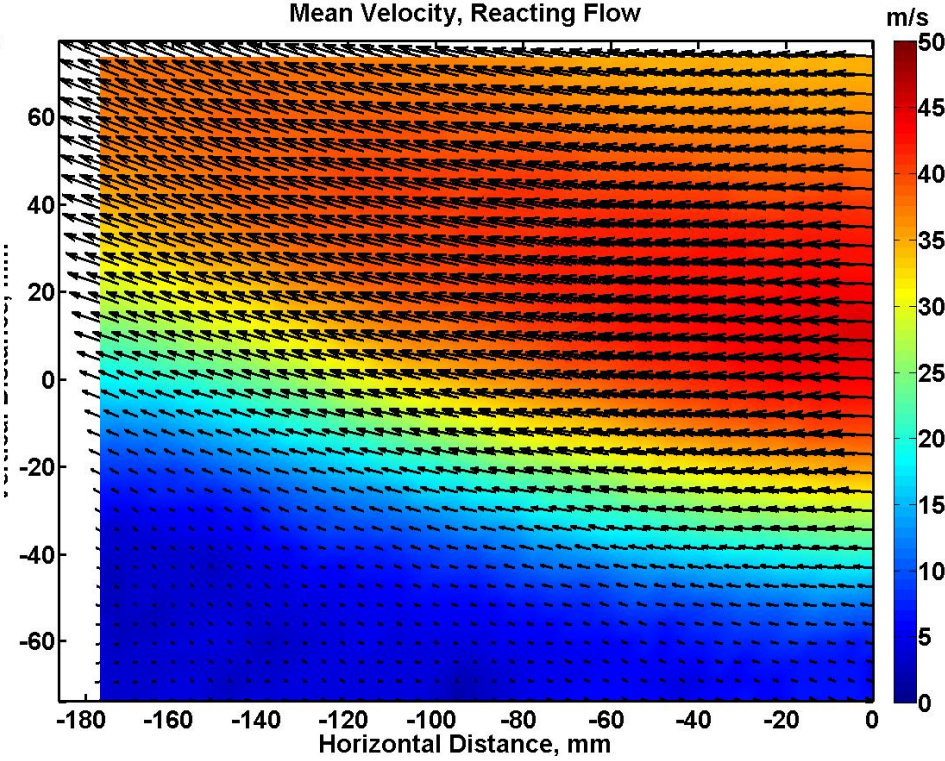


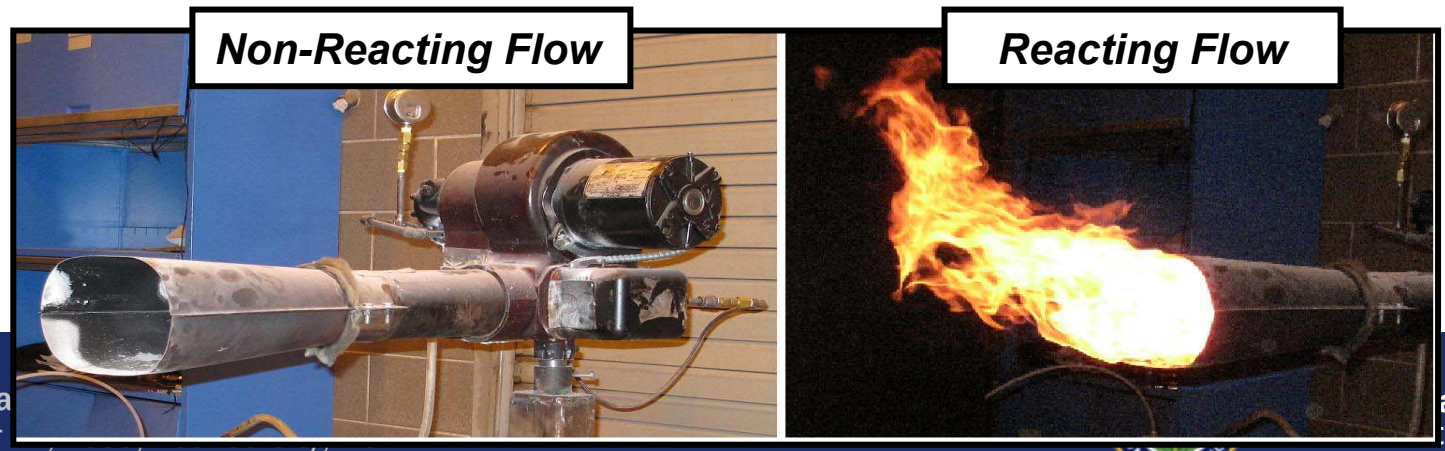
PIV Images – Reacting Flow



Comparison: Non-reacting vs. Reacting Flow







Summary

- **PIV can be used to analyze the various components of the FAA Fire Test Burner**
- **Preliminary measurements were made of the swirling burner exit air flow and spray nozzle flow**
- **A dual camera and beam splitter arrangement was used to perform PIV measurements in a highly sooting, turbulent burner flame**
- **Future Work**
  - Perform independent and combined analyses of spray flow and burner air flow
  - Determine effect of variations in air and fuel flow on mean flame velocity
  - Investigate different swirl methods and spray nozzles to develop a next-generation burner that provides more consistent, reproducible results

Questions, Comments, Concerns…?