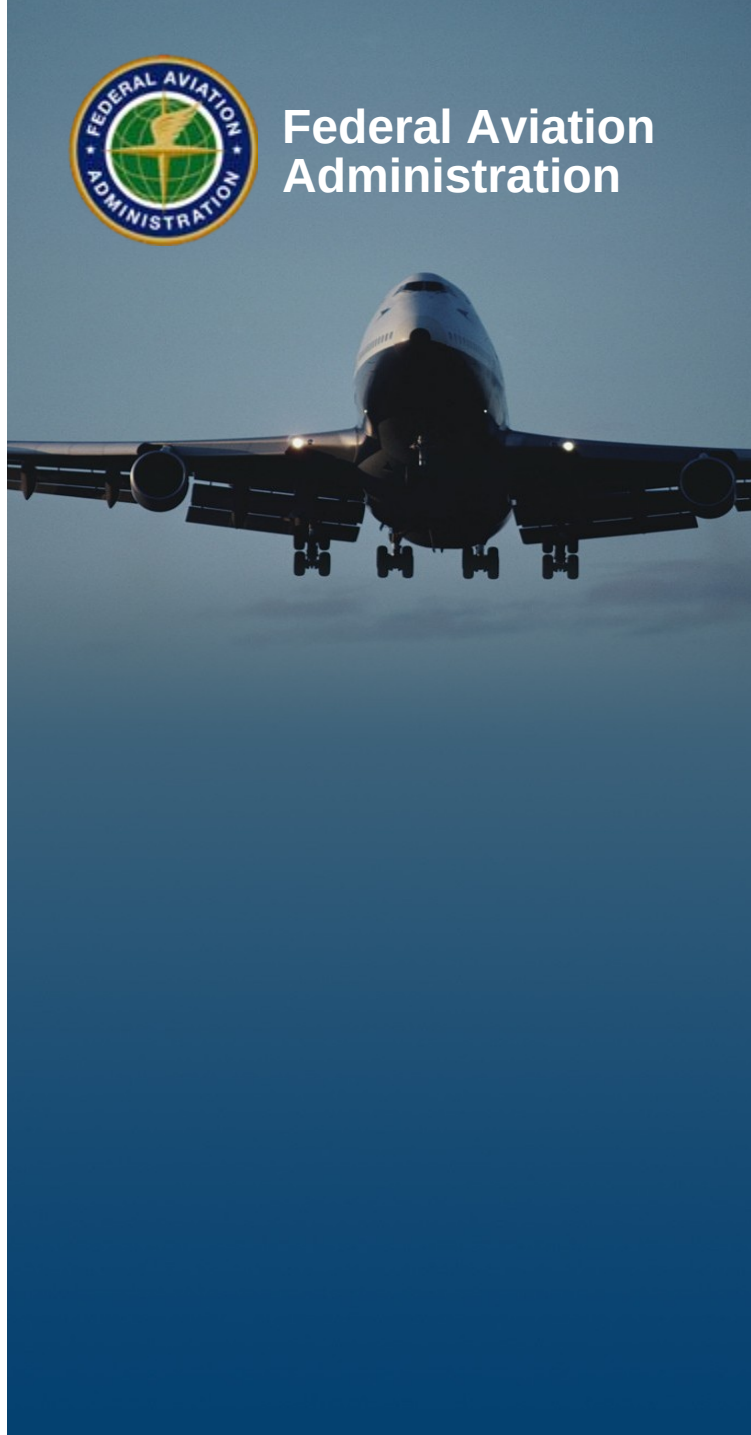
Particle Image Velocimetry for FAA Fire Safety Research



Presented to: International Aircraft Systems Fire Protection Working Group

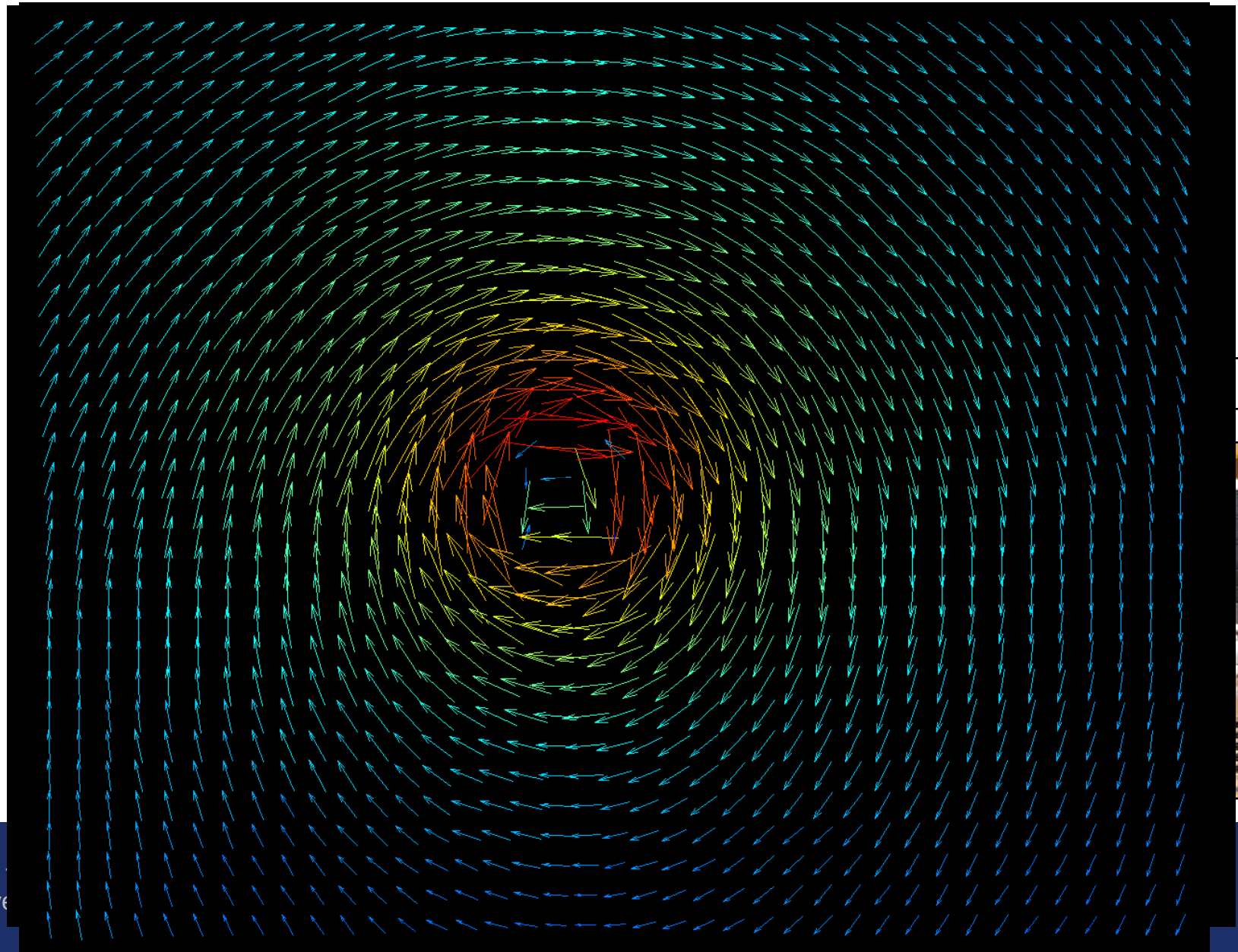
By: Robert Ian Ochs

Date: Tuesday, November 17 2009

What is Particle Image Velocimetry?

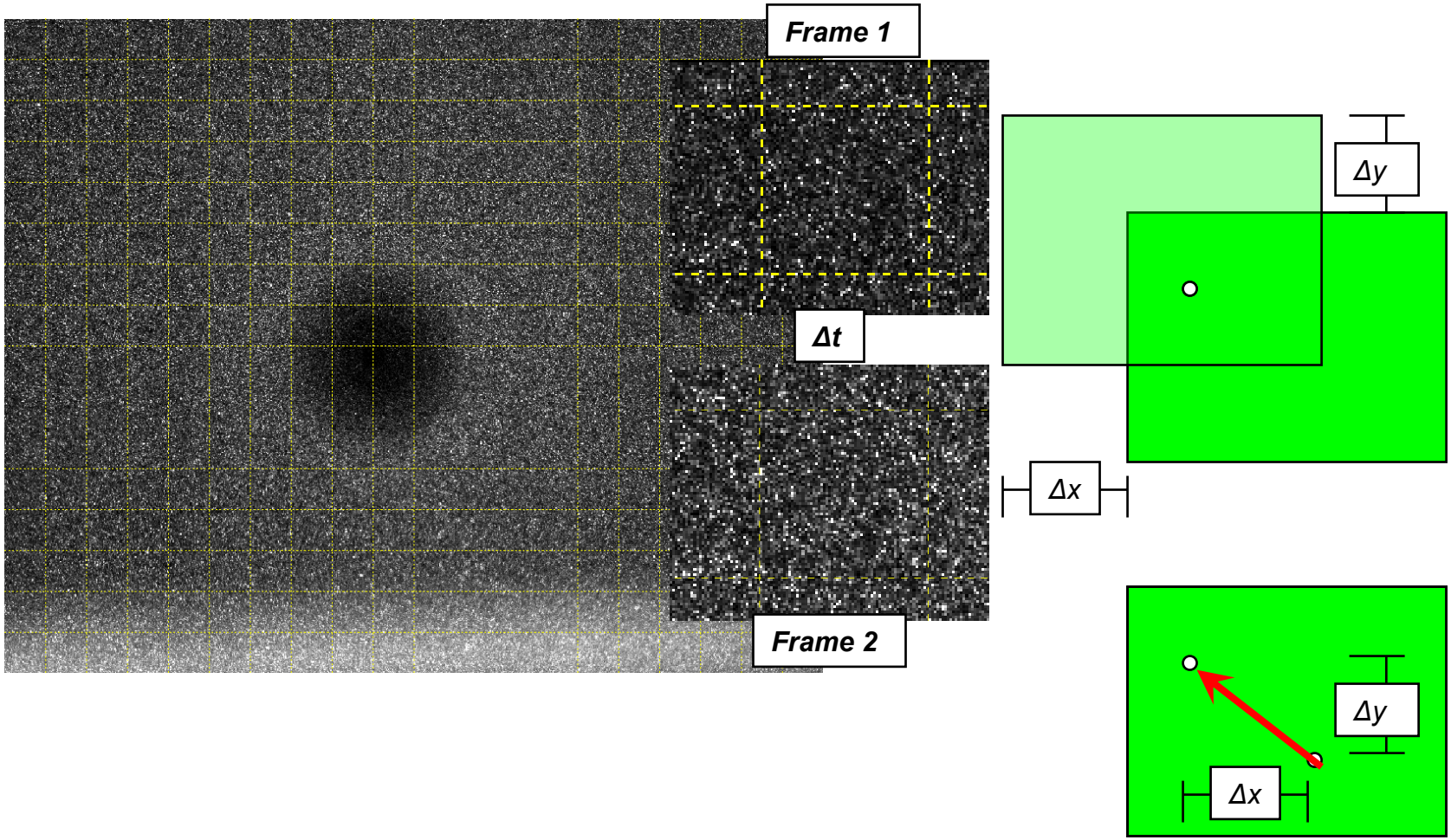
- **PIV is an instantaneous, whole-field, non-intrusive fluid flow measurement technique**
  - *Whole field: can resolve an entire vector field over a wide range of measurement area sizes (μm→m)*
    - *Other techniques (hot-wire, pitot probe, LDV) resolve velocity at a single point in the flow field, must traverse entire field in order to obtain whole-field measurement*
  - *Instantaneous: creates a snapshot of the vector field over a very short period of time (ns-μs)*
  - *Non-intrusive: utilizes cameras and laser light sheet illumination; no probes intruding in the flow field*

How Does PIV Work?



PC

PIV Analysis

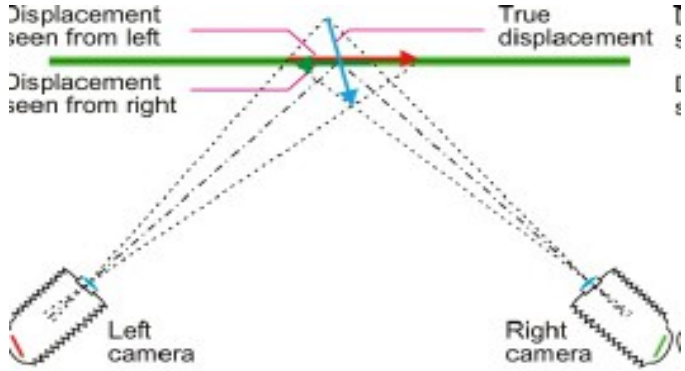


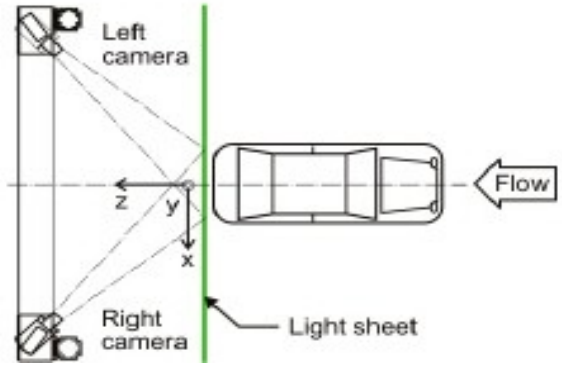
Data From PIV Measurements

- **In-plane (2 component) velocity vector field**
  - Instantaneous vector field at different time intervals
    - Flow fluctuations (turbulence intensity)
  - Mean
- **Vorticity (rotation rate)**
- **Streamlines**
- **Additional data…**

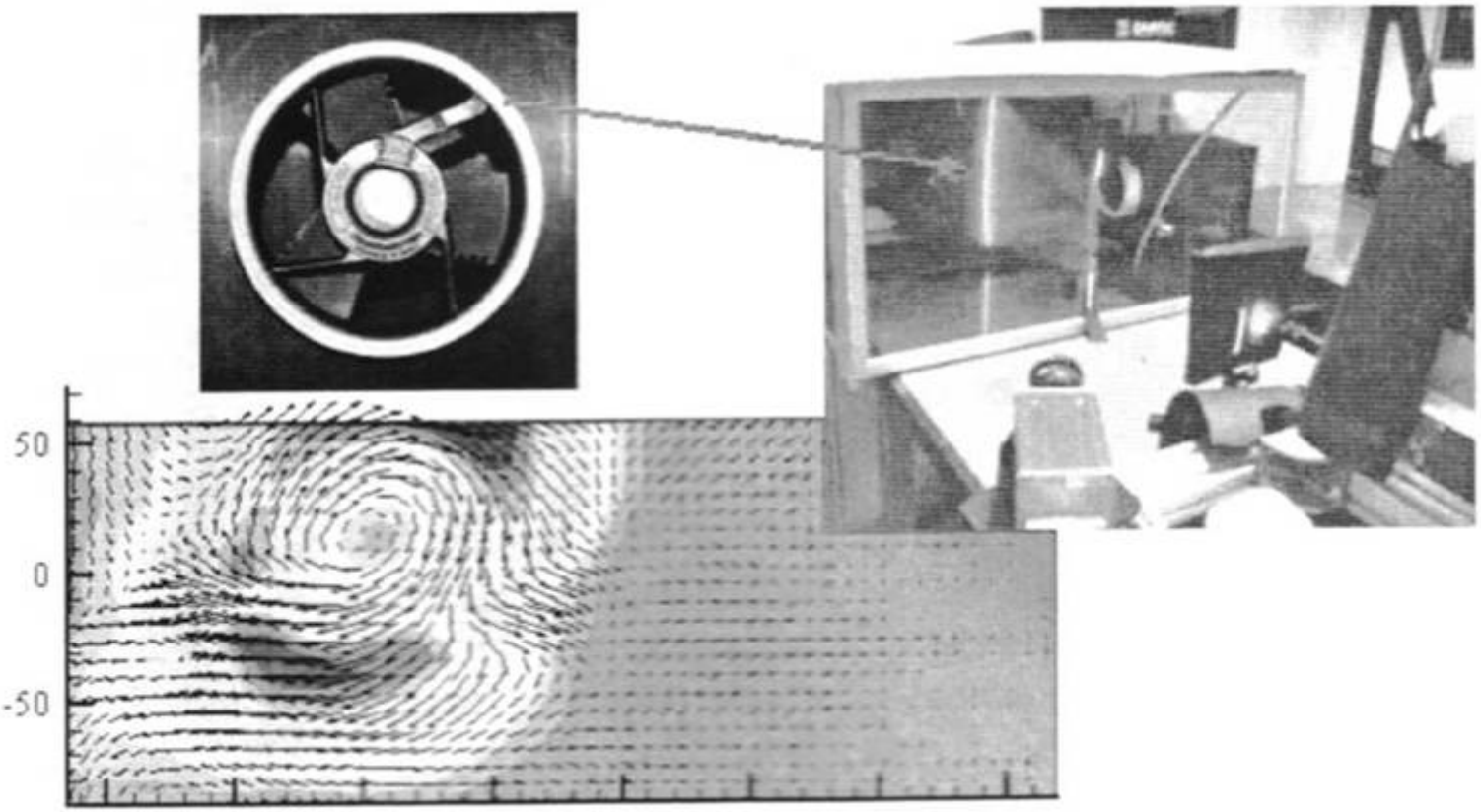
Stereoscopic 3D PIV

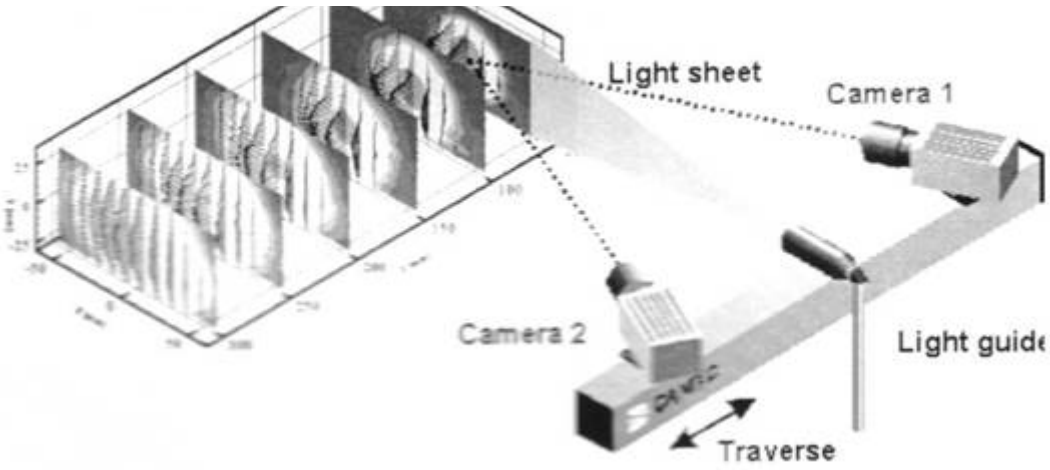
- Based on same fundamental principle as human eyesight
  - "When we look at a given object, our left and right eyes see two similar but not identical images. The brain compares the two images and interprets the slight variations to rebuild the three dimensional information of the object observed."
    - 2 cameras → 2 eyes
    - Computer and software → brain
- We use this technique to obtain the out-of-plane velocity component (z)
- This is used to fully characterize the flow in the measurement plane





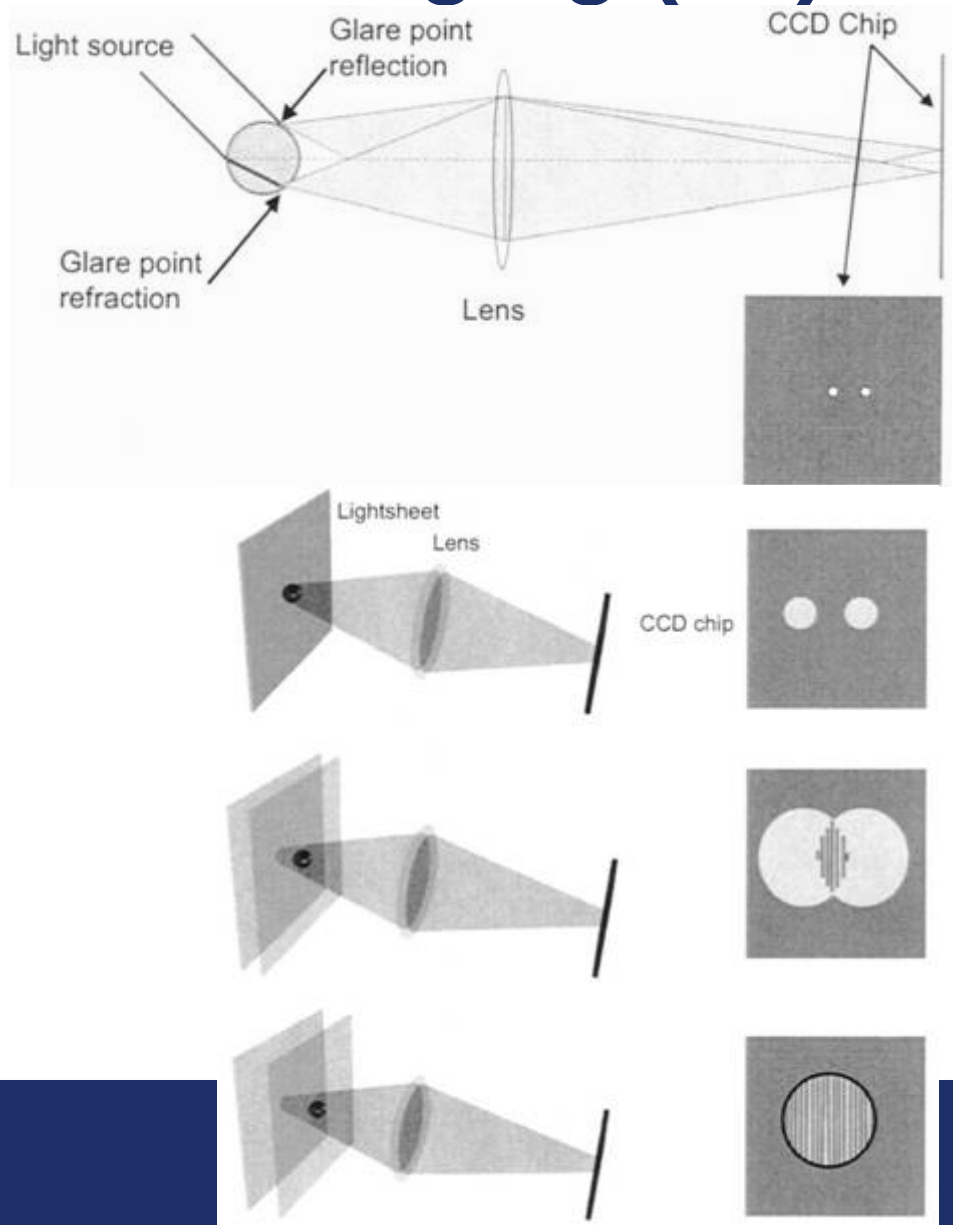
Stereoscopic 3D PIV



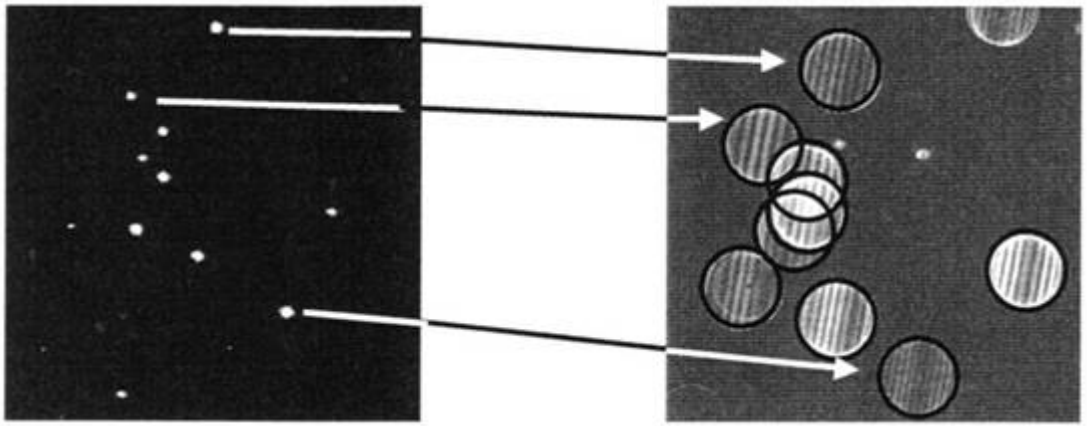


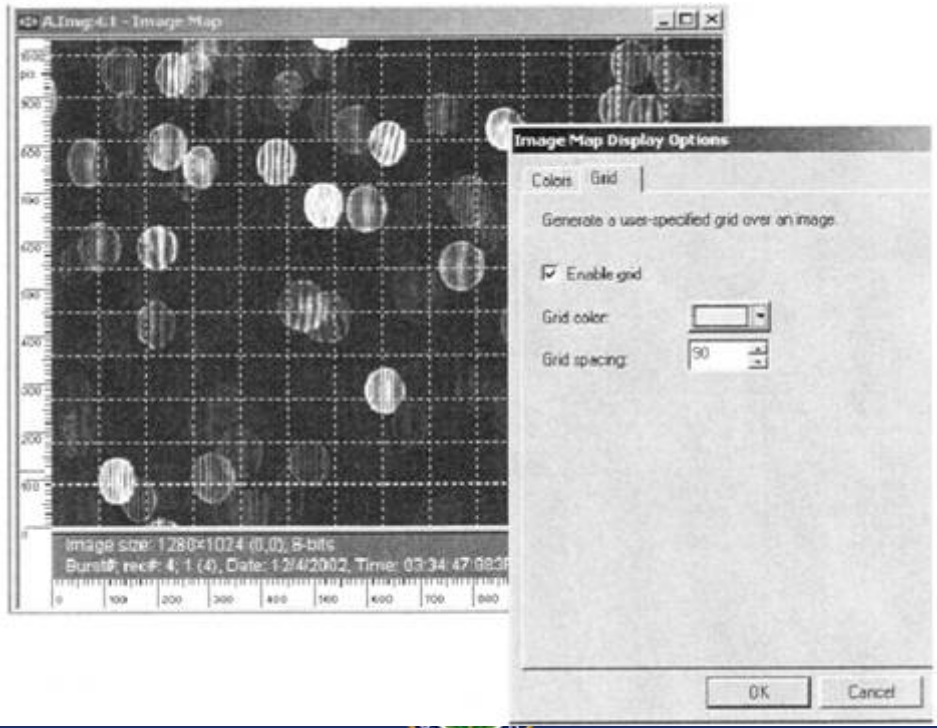
Interferometric Particle Imaging (IPI)

- Based on the interference of the relection and refraction glare points from an illuminated transparent particle
- 2 cameras see the same image, one is focused, the other defocused
- As the degree of defocusing increases, the two glare points merge into one single unified image with interference fringes
- It is possible to determine the distance between the glare points, or the size of the particle, from the frequency of the interference fringes in the defocused image.



Interferometric Particle Imaging (IPI)

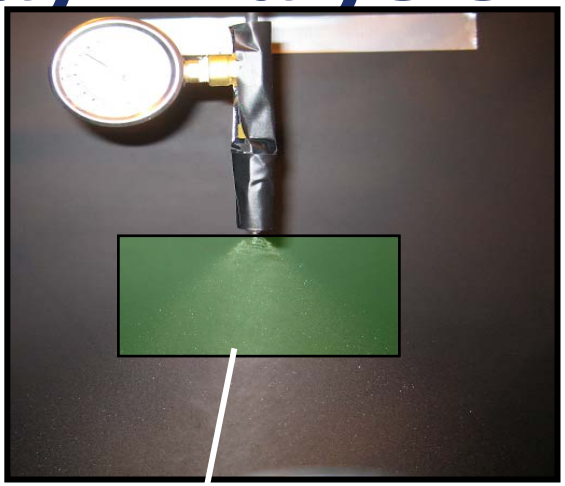


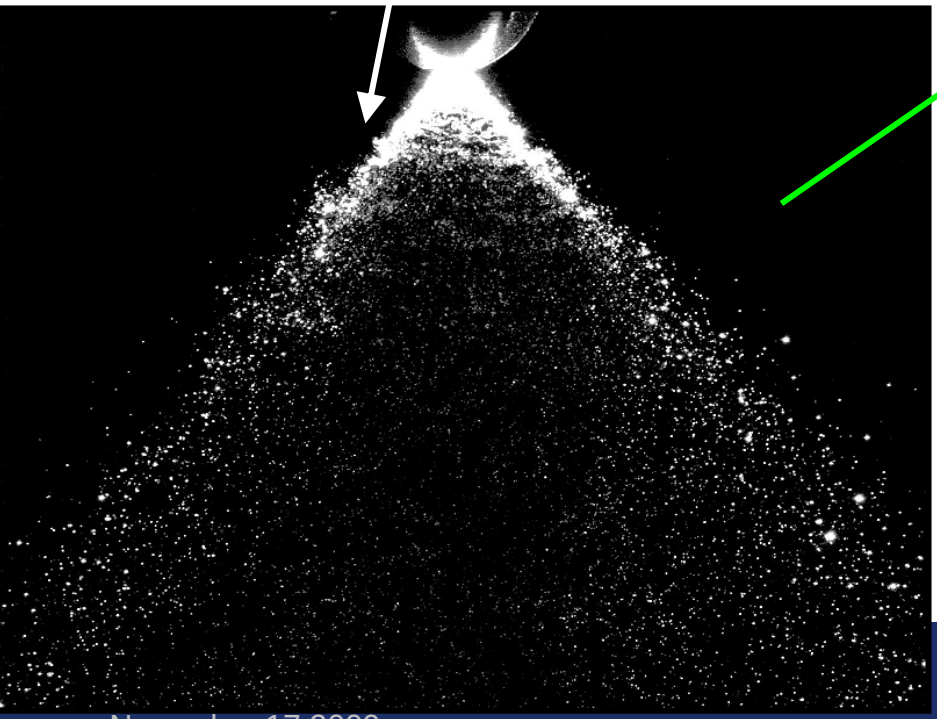


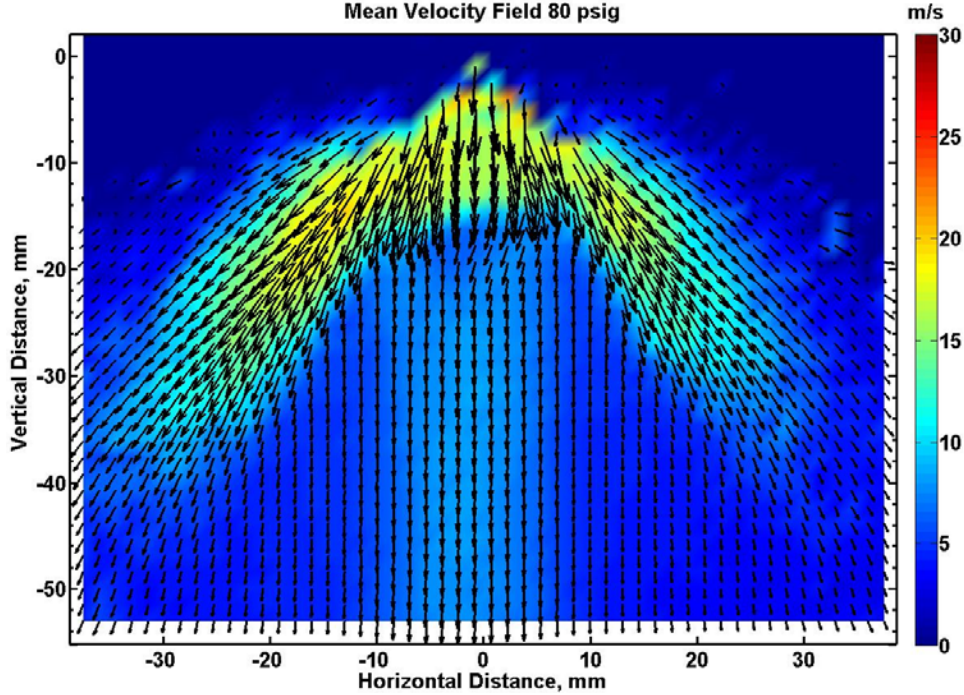
Current PIV Research – Burner Analysis

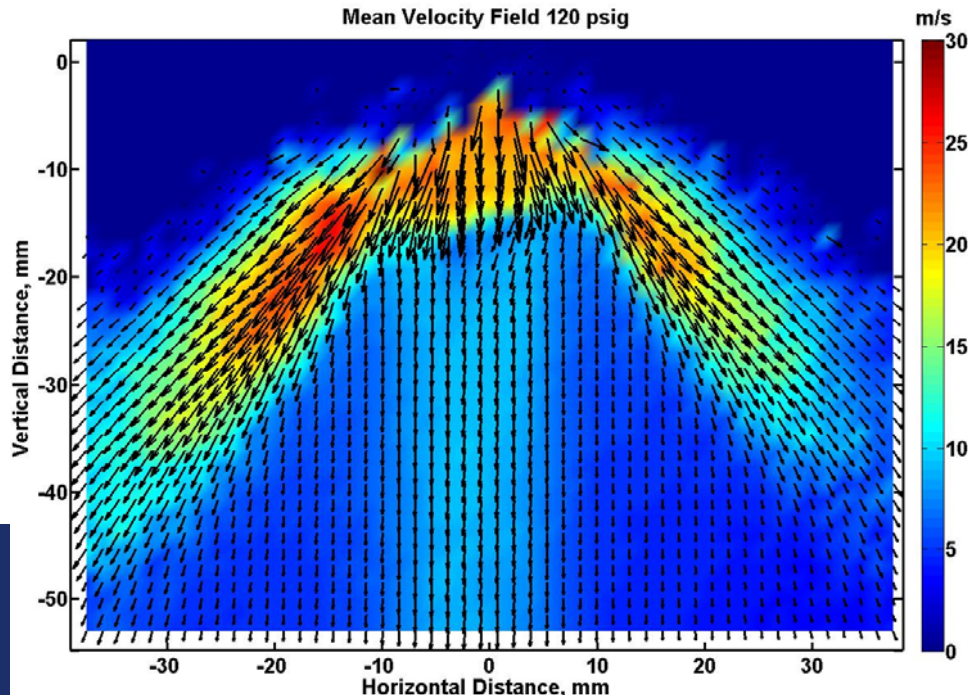
- **The FAA utilizes a modified oil burner to simulate the effects of a jet fuel fire on an aircraft fuselage, interior components, and components in fire zones**
  - The specified burner is a typical home heating oil burner
  - Burner uses JP8 or Jet A jet fuel
- **Burner flame characteristics scaled directly from measurements made from full scale pool fire testing**
  - Heat flux
  - Temperature
  - Material burn-through times
- **The burner is used to measure the fire worthiness of aircraft materials**
  - Seats, thermal-acoustic insulation, cargo liners, and powerplant components and firewalls

Spray Analysis

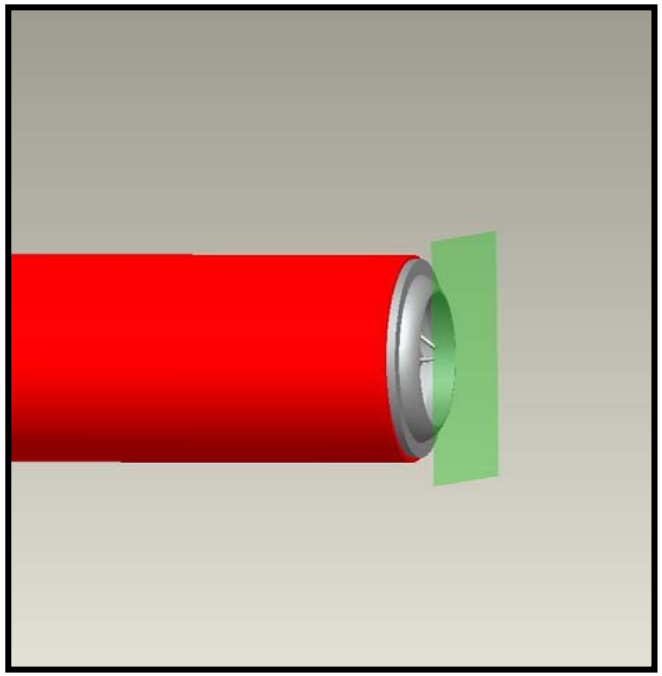


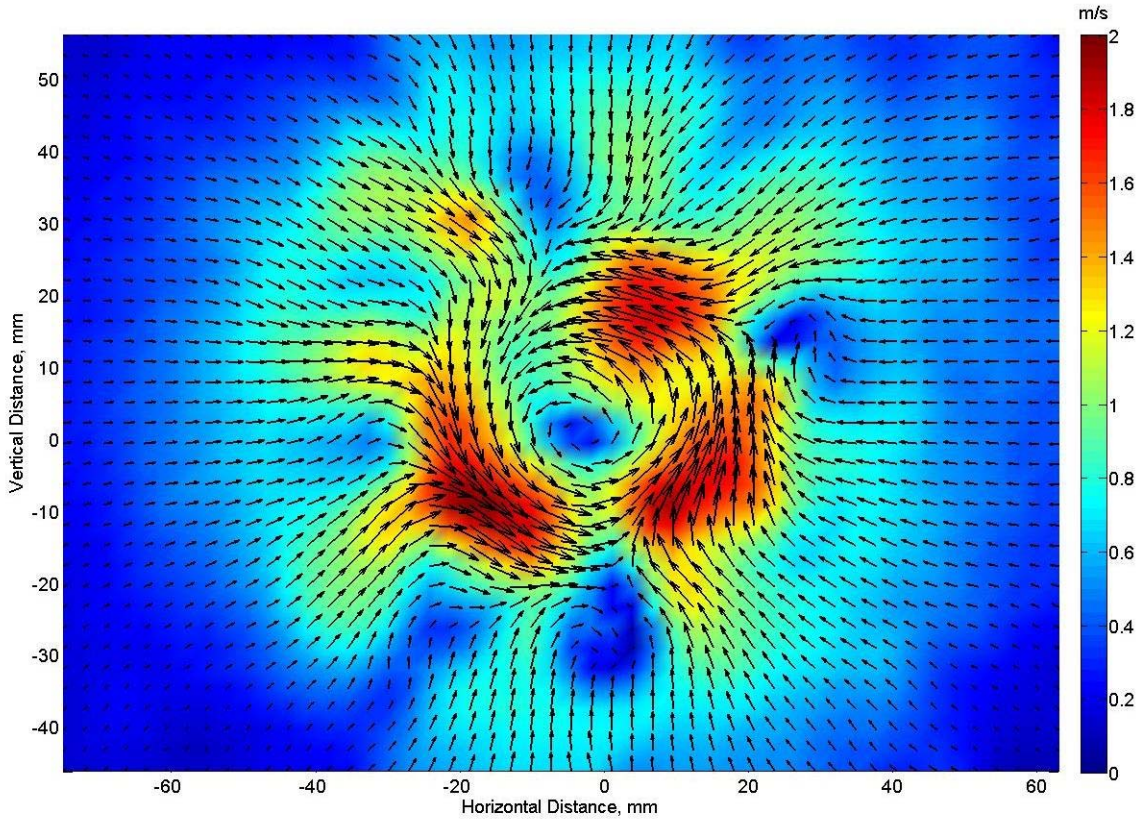






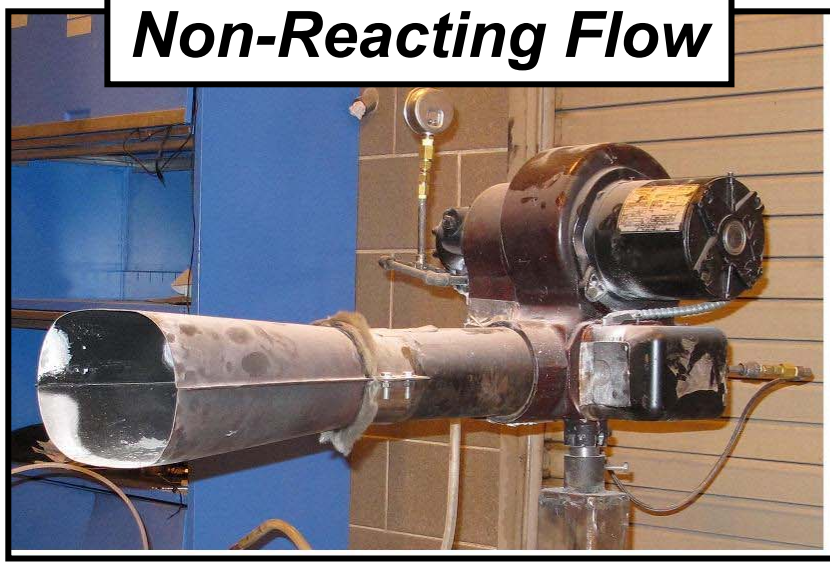
Air Flow Measurements



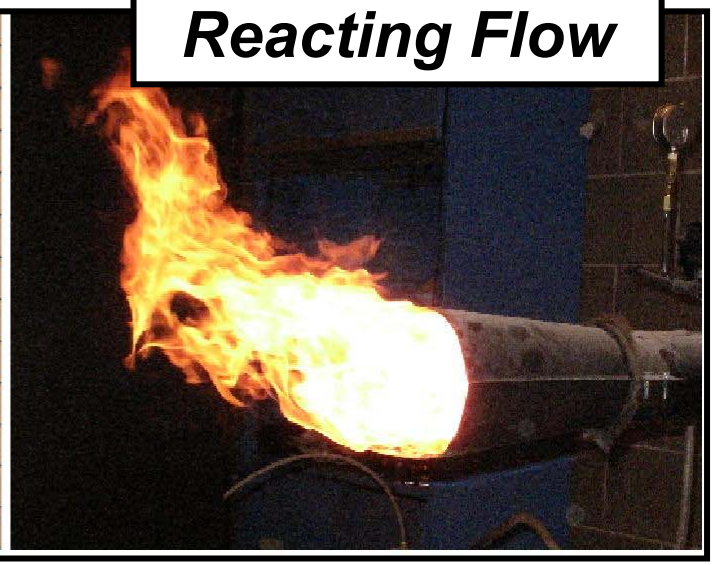


Experimental Setup

Non-Reacting Flow



Reacting Flow



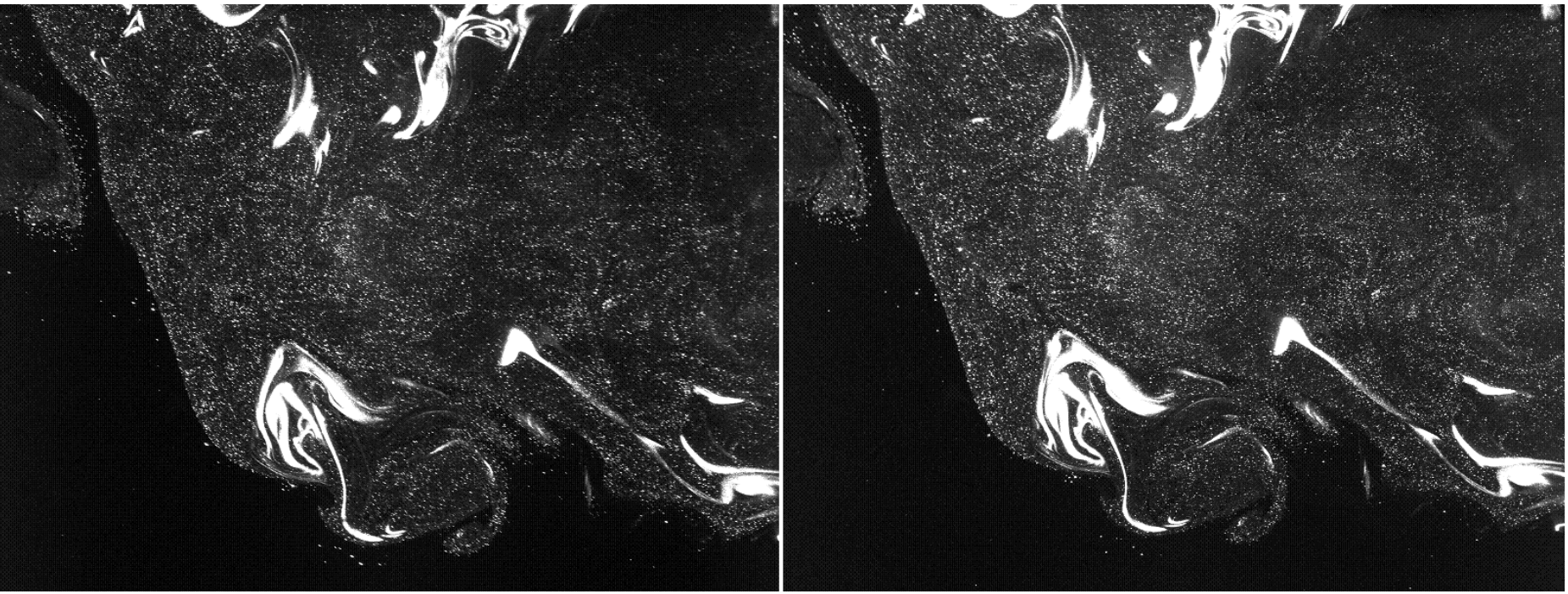
Burner Settings

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

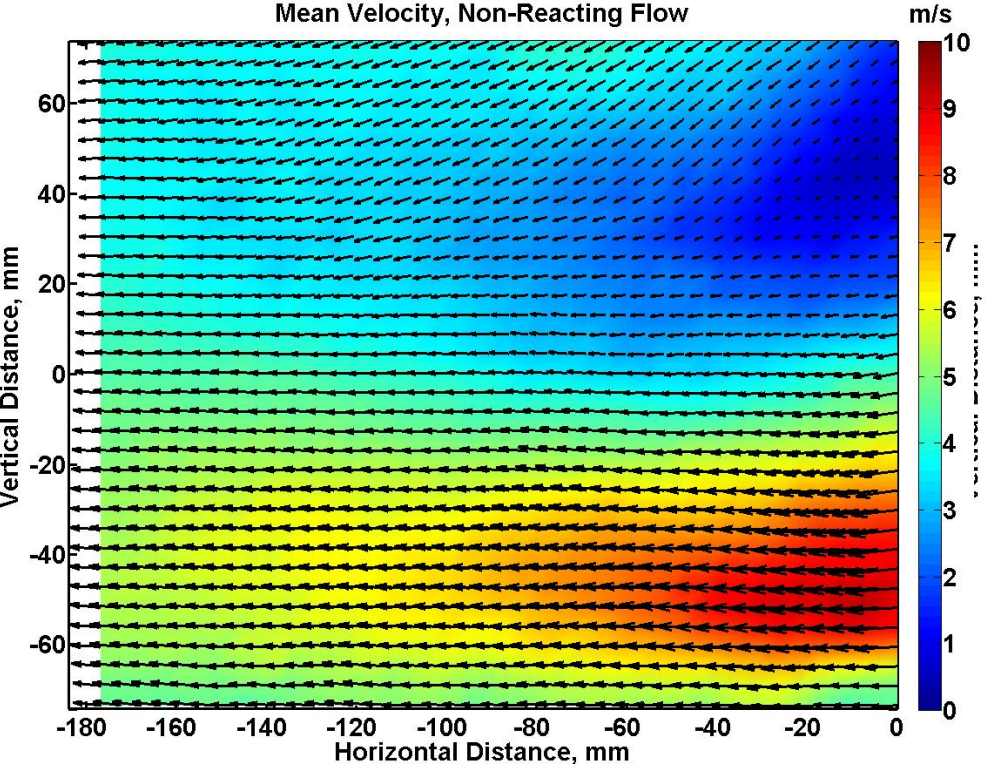
PIV Settings

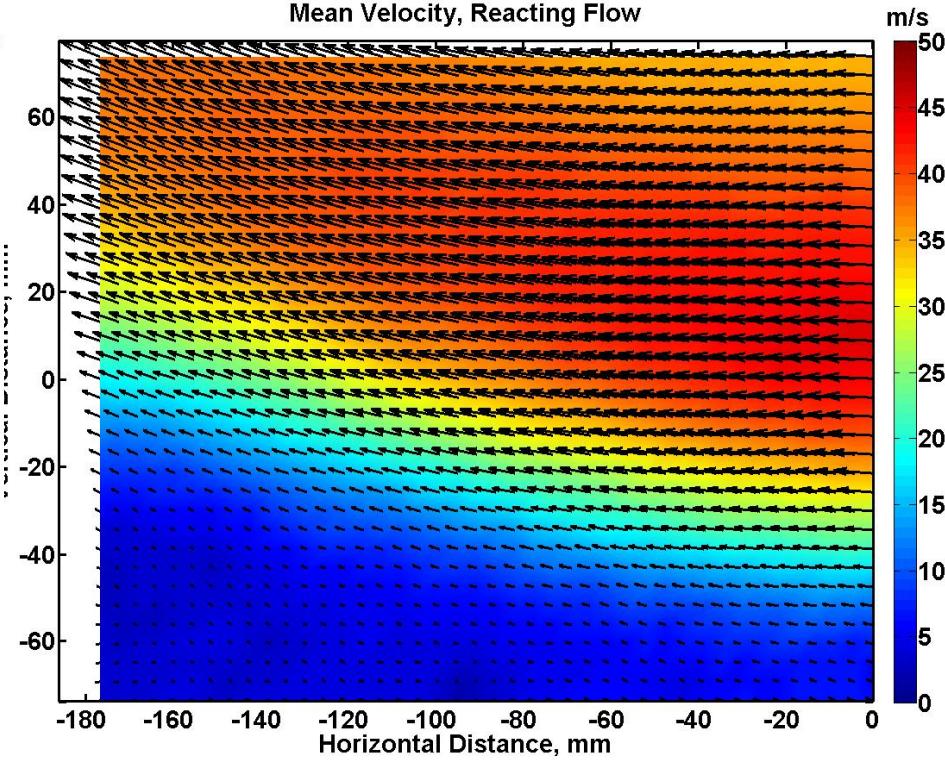
Seed Particles:	Aluminum Dioxide, 30 micron
Measurement Plane:	180 mm x 150 mm
CCD:	1600 x 1200 px
Lenses:	105 mm F2.8 macro
Lens Filters:	Narrow band, 532 nm ± 3 nm
Light Source:	120 mJ Nd:YAG dual head laser
Δt, non-reacting / reacting:	750 µs / 500 µs

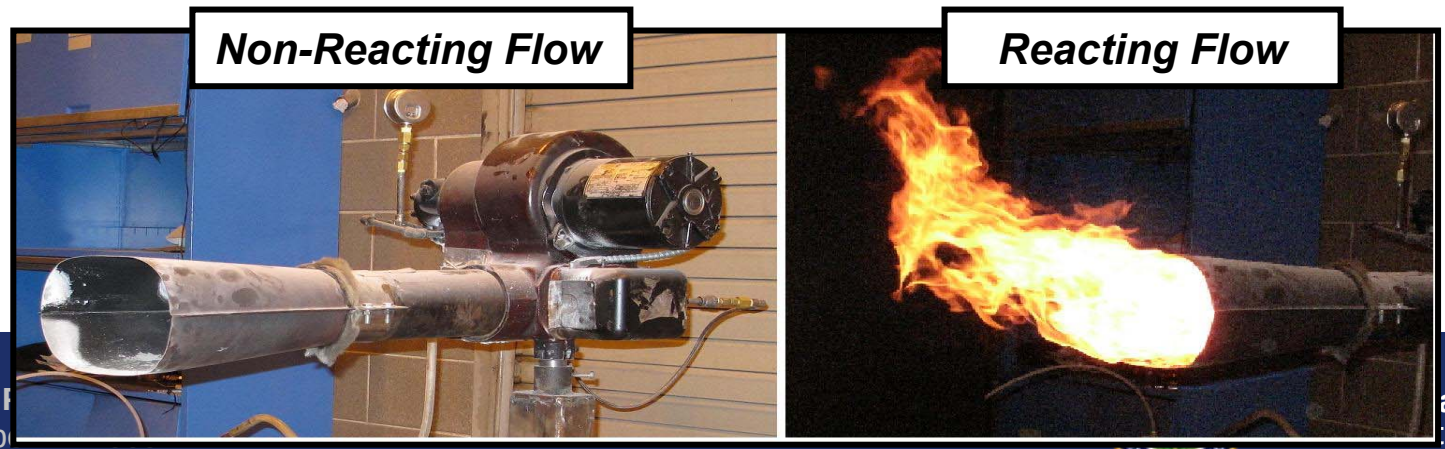
PIV Images – Reacting Flow



Comparison: Non-reacting vs. Reacting Flow

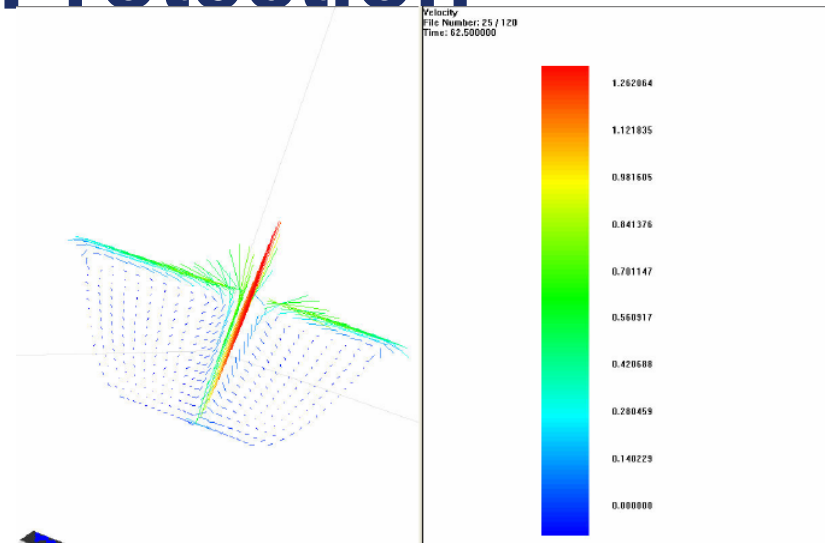


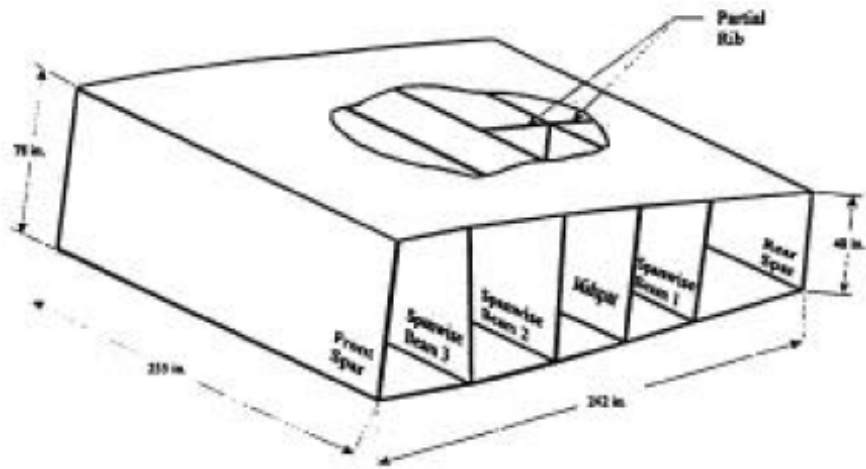




PIV for Systems Fire Protection Research

- **Smoke Transport CFD Model Validation**
  - Study flow field of buoyant plume in a cargo compartment
- **Extinguishment Sprays**
- **Flow in a compartmentalized fuel tank**





Questions?

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