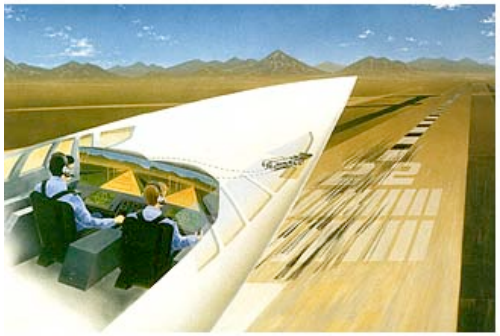
Overview of

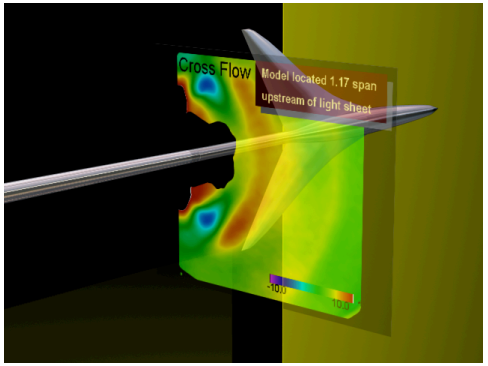
Experimental Capabilities - Supersonics

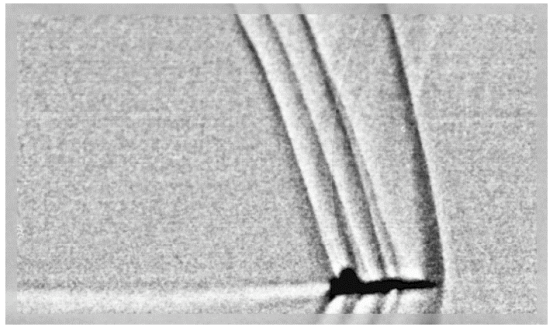
Dan Banks - API

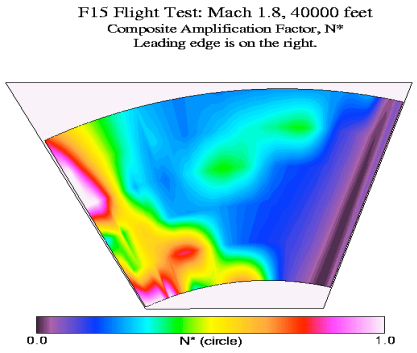


FAP Annual Meeting

October / November 2007







EC Objectives

- Develop the necessary tools, techniques, and methodologies to support validation in Supersonics challenge areas

- Develop experimental facilities and infrastructure applicable to supersonics research

SUP.11: **Elements**

- SUP.11.66 **NRA**
  - Working two potential awards from Round 3
- SUP.11.03 **Advanced Flight Simulator (LaRC)**
  - 11.03.01: Cockpit Motion Facility
  - 11.03.02: Flying Qualities Guideline Development
  - 11.03.03: Rigid/Flexible Flight Control
  - 11.03.04: Rapid Sim Model Exchange
- SUP.11.04 **Flight Test Capabilities (DFRC)**
  - 11.04.01: Advanced In-Flight IR Thermography
  - 11.04.02: In-Flight Schlieren
  - 11.04.04: F-15B Centerline Instrumented Pylon (CLIP) Flow Calibration
  - 11.04.05: F-15B Propulsion Flight Test (PFTF) Fixture Flow Field Survey
- SUP.11.05 **Ground Test Capabilities (LaRC/ARC)**
  - 11.05.01: Develop Laser Induced Thermal Acoustics (LITA) for supersonic wind tunnel
  - 11.05.02: Construction and lab demo of LITA shock strength measurement system
  - 11.05.03: Investigate variants of Doppler Global Velocimetry (DGV) technology
  - 11.05.04: EDL optical measurement (PIV) capability for rigid decelerator models
  - 11.05.05: EDL optical measurement (PIV) capability for flexible decelerator models

NRA

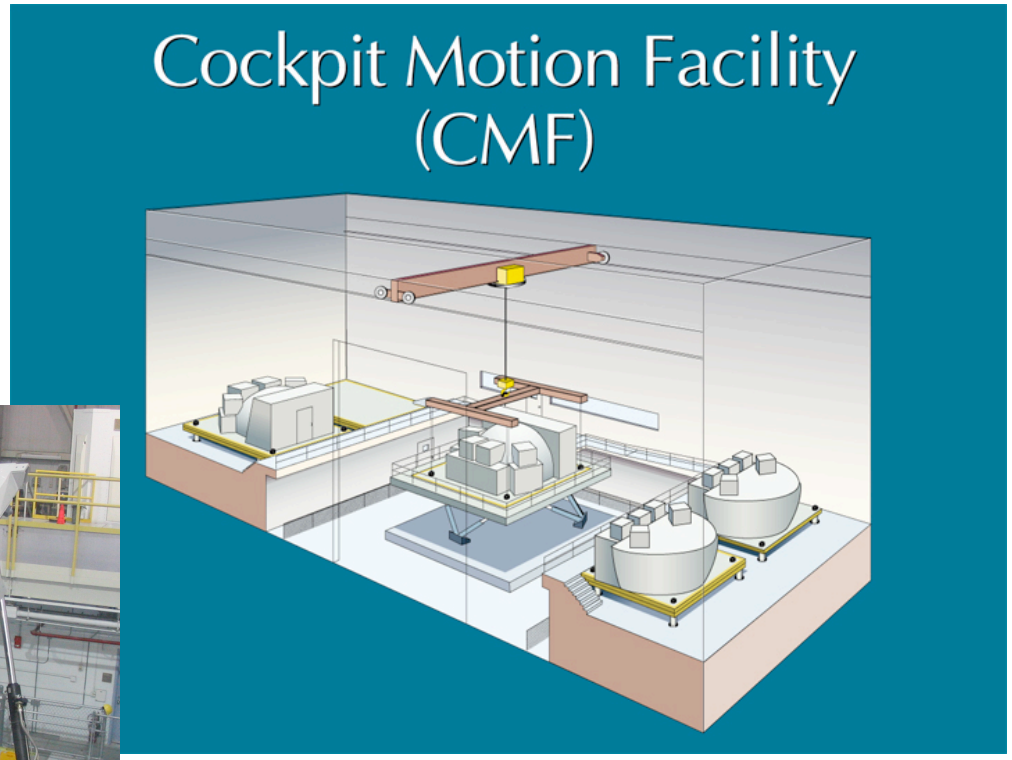
- Working two pending awards from Round 3
  - Ground test flowfield measurements
  - Flight test flowfield measurements

Advanced Flight Simulator
Flexible Aircraft Simulation Studies

- Complete preparations for operation of LaRC Cockpit Motion Facility to support flexible aircraft piloted simulation studies

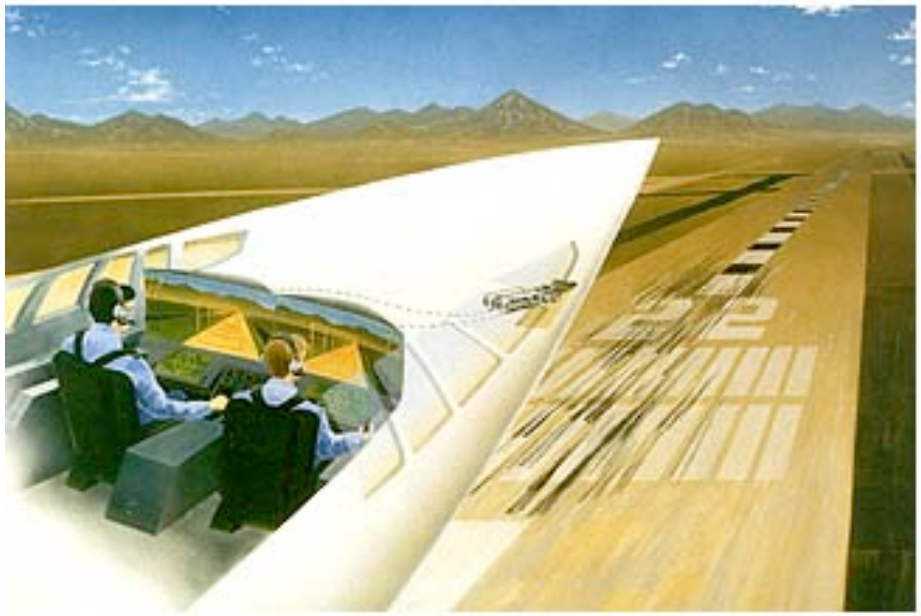
- Unique simulation capability with high bandwidth

- Ready for operation April 2008



Advanced Flight Simulator
Flying Qualities Guideline Development
for Flexible Supersonic Transport Aircraft

- Objective: Develop design guidelines to minimize adverse pilot/inceptor interactions during runway approach/landing due to aircraft flexibility
- Approach: Conduct piloted simulation study, using motion-based simulation facilities at LaRC
- Piloted sim study begins Nov 07

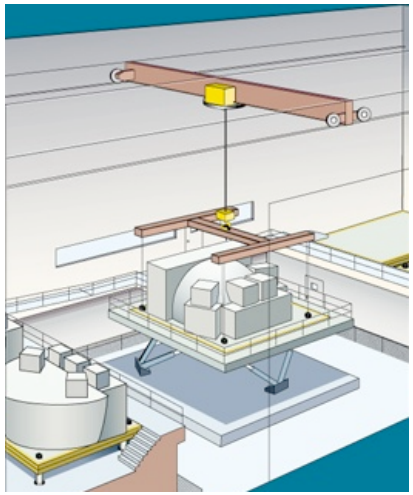


Advanced Flight Simulator
Rigid/Flex Flight Control

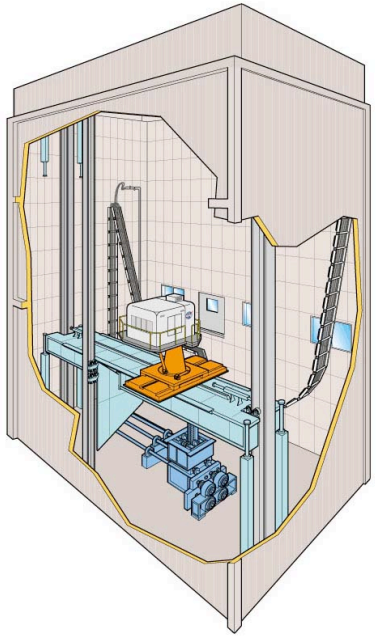
- Provide closed-loop wind-tunnel control laws for Semi-Span Supersonic Transport (S4T) model
- Goal: Simultaneously provide aeroelastic mode stabilization, ride quality enhancement while maintaining rigid-body maneuver margins
- Ready for tunnel test Jan 2009

Advanced Flight Simulator
Rapid Sim Model Exchange

- Goal: Reduce time required to exchange aero simulation models between Centers, industry by 90%
- Approach: Develop XML-based standard format to describe aero models, data, history, uncertainty with automatic verification capability
- Demonstration: Exchange non-trivial aerodynamic models between two Centers, mid-2008

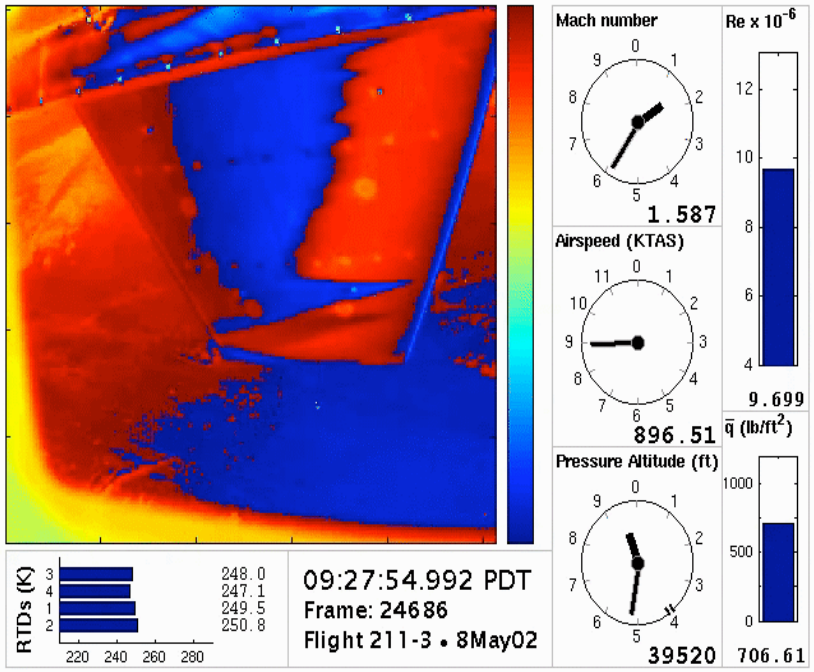


Minutes, not months



Flight Test Capabilities
Advanced In-Flight Infrared (IR) Thermography

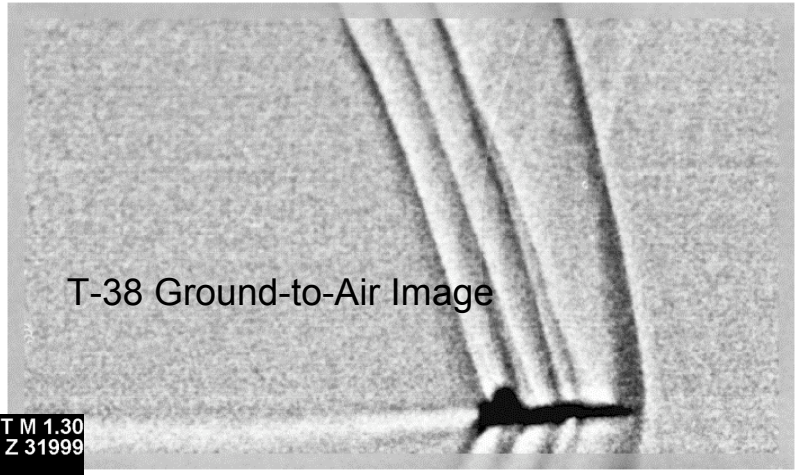
- Improved spatial and temperature resolution
- Raw digital output compatible with SOA image processing algorithms
- SOA image processing to extract smaller gradients

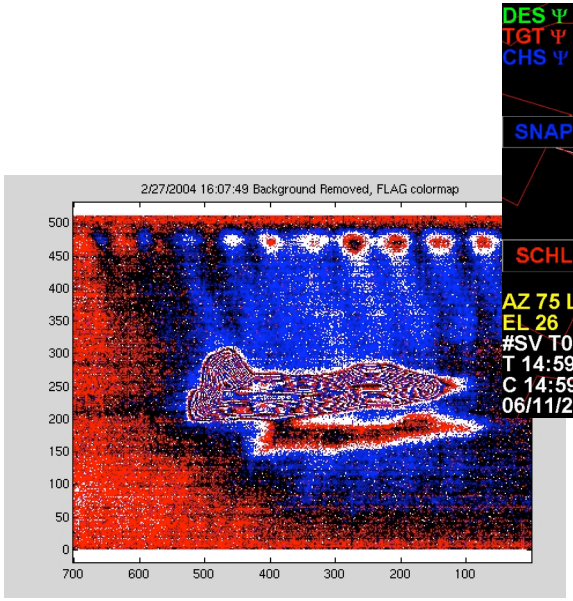


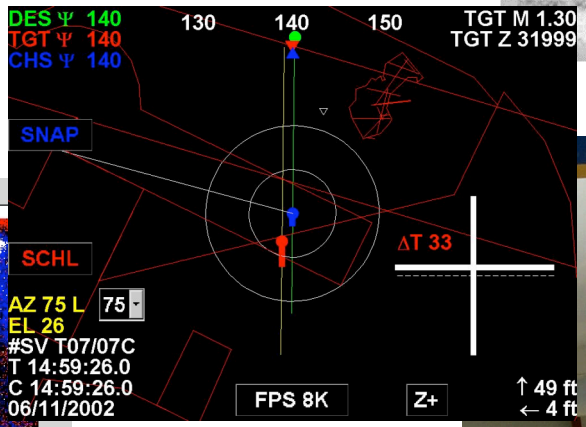
Advanced digital IR thermography analysis
Phase II Test 2002, Baseline Image 30° LE

Flight Test Capabilities
In-Flight Schlieren

- Obtain high quality Schlieren image with good spatial resolution
- Allow determination of shock location and relative strength

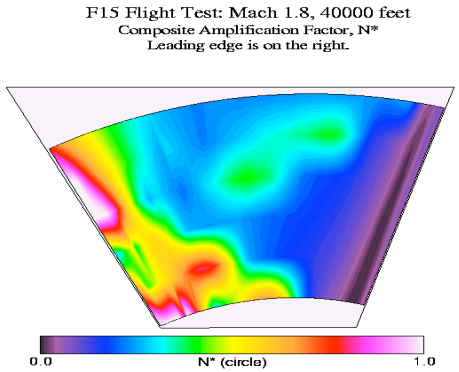


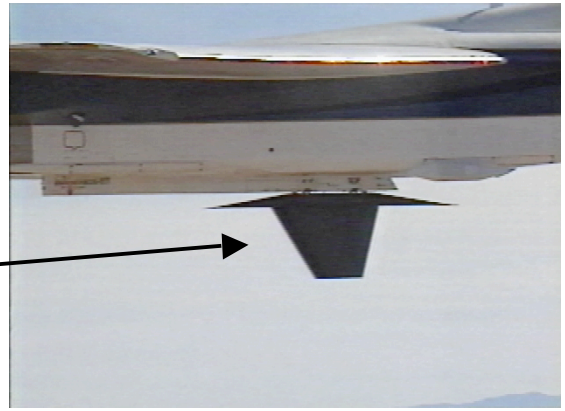




Flight Test Capabilities
CLIP Flow Calibration

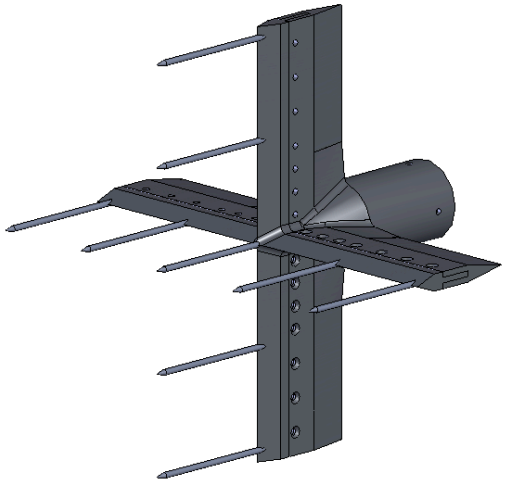
- Obtain flow survey to determine local Mach, angularity, and freestream turbulence prior to large scale Supersonic Boundary Layer Transition Test (S-BLT)
- Partnered with Aerion Corp. on S-BLT
  - Non-reimbursable SAA signed

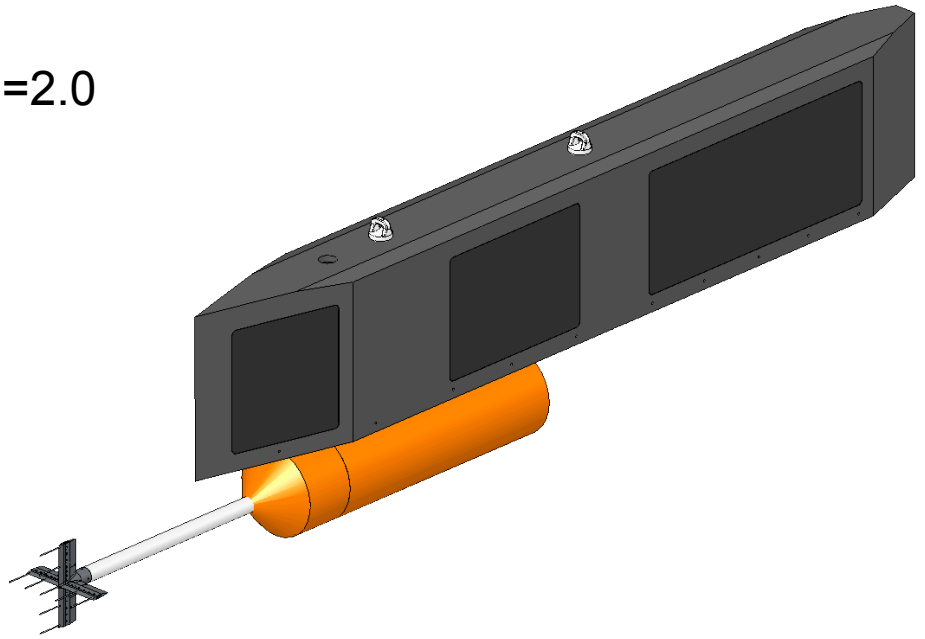




Flight Test Capabilities
PFTF Flowfield Survey

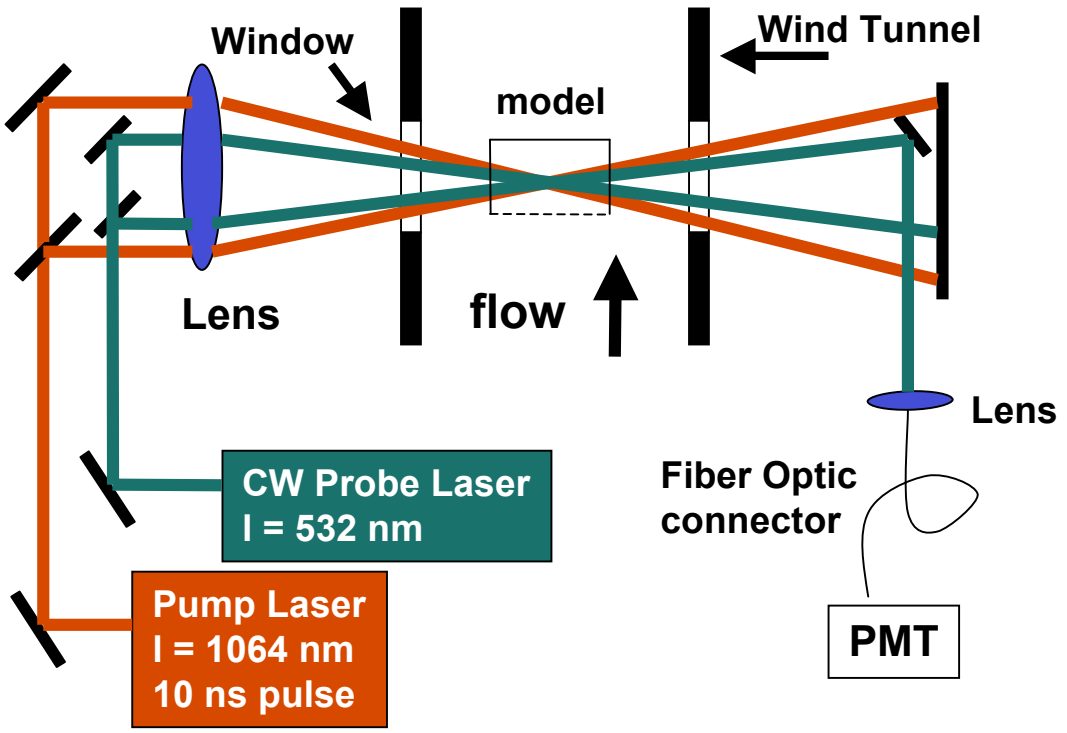
- Objectives
  - Measure flow angularity and local air data in front of Propulsion Flight Test Fixture (PFTF) under F-15B research aircraft.
- Approach
  - Nine 5-hole conical probes mounted on a rake
  - Rake attached to PFTF via experimental hardware that has already been flown on the PFTF
  - Flight test at h=40kft, Mach=2.0





Ground Test Capabilities
Laser-Induced Thermal Acoustics (LITA)

- Noninvasive, spatially resolved, off-body flow diagnostic (no seeding required)
- Measures: (a) velocity, (b) sound speed, (c) static temperature, & (d) static pressure
- Spatial resolution typically 200 mm by 1 cm
- Time resolution
  - ~ 1 msec (subsonic flow)
  - ~ 10 sec (supersonic flow)
- Novel tool for shock-strength measurement (sonic boom reduction)

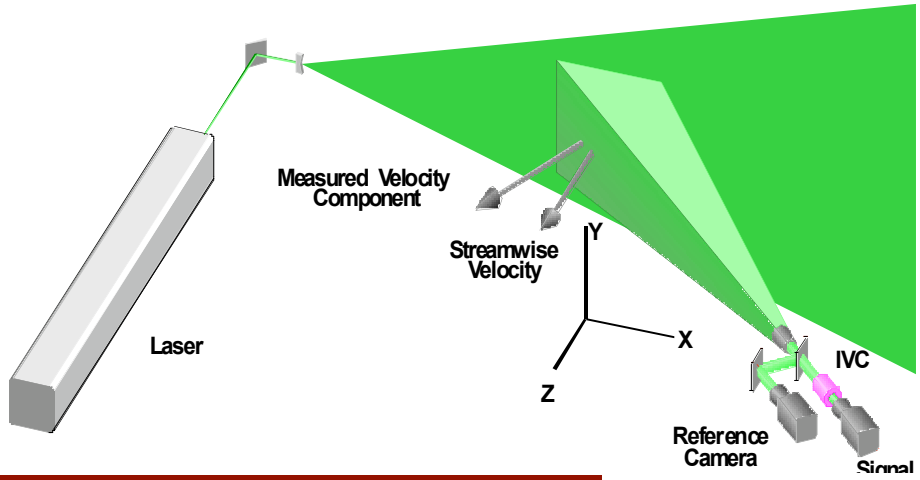


Typical Wind Tunnel Setup (line-of-sight required)

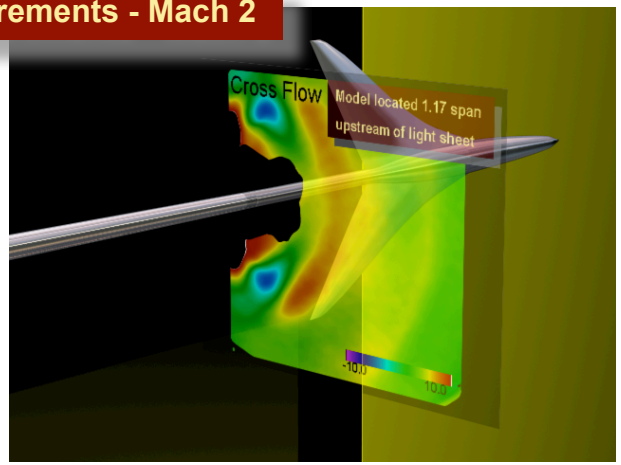
Ground Test Capabilities
Doppler Global Velocimetry (DGV)

- Four-component, fiber-optic based optical system
  - Over specified system – increased measurement accuracy
  - Fiber optics provides more versatile optical systems, lowers cost
- Yb:YAG laser
  - Five times more laser power
  - 110 V ac power
  - ~1000 times greater optical frequency tuning with long term stability
- Laser light sheet – Sequential two optical frequency operation
  - Single camera – reduced cost
  - Two cameras – increased measurement accuracy
- Multi-beam fiber optic transmission system
  - Boundary layer measurement capability

Doppler Global Velocimeter Configuration

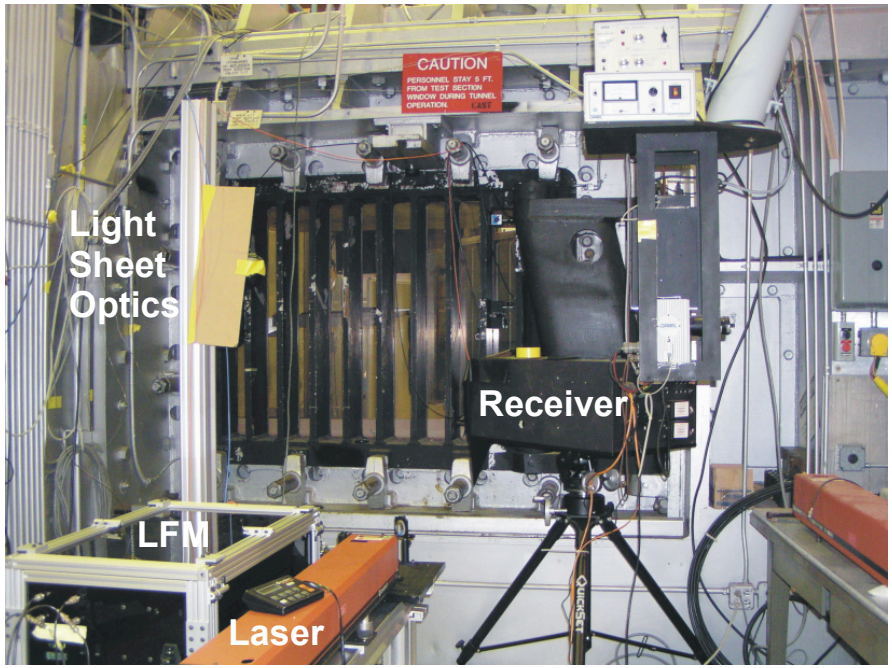


Crossflow Velocity Measurements - Mach 2

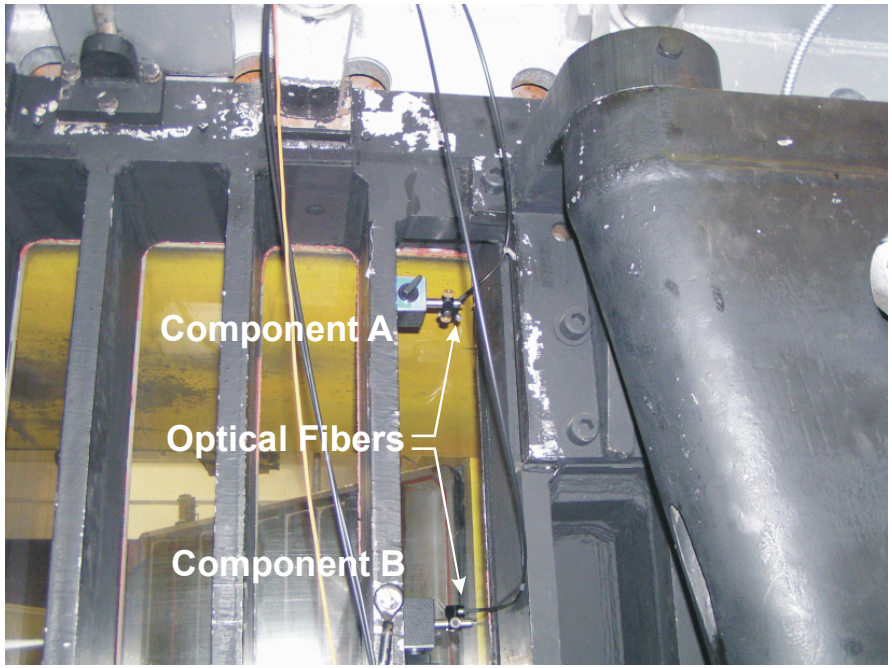


Ground Test Capabilities
Doppler Global Velocimetry (DGV)

Fiber-Optic, Three-Component DGV in the Unitary Plan Wind Tunnel



Doppler Global Velocimeter



Fiber-optic viewing system

Ground Test Capabilities
EDL Optical Measurement Capability (PIV) for Rigid/Flexible Decelerator Models

Entry, Descent and Landing Tests -

Particle Image Velocimetry

More details in following presentation

GRC PIV run

ARC Fluid Mechanics Lab
32” x 48” Indraft Tunnel

Concluding Remarks

- **Experimental Capabilities has been meeting objectives by**
  - Developing the necessary tools, techniques, and methodologies to support validation in Supersonics challenge areas
  - Developing experimental facilities and infrastructure applicable to supersonics research

- **Three main areas of development**
  - Advanced Flight Simulator
  - Flight Test Capabilities
  - Ground Test Capabilities