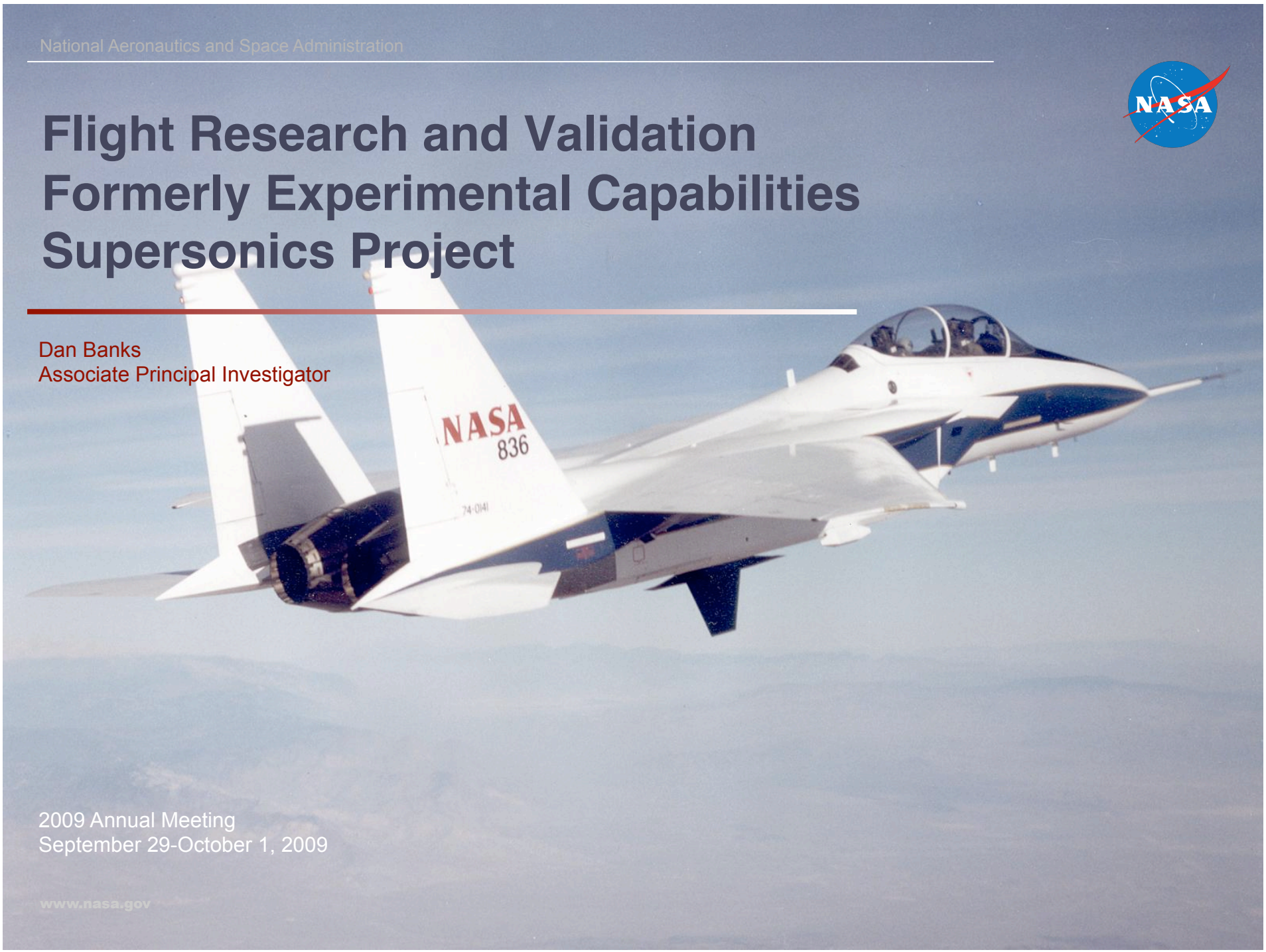
Flight Research and Validation Formerly Experimental Capabilities Supersonics Project

Dan Banks
Associate Principal Investigator



2009 Annual Meeting
September 29-October 1, 2009

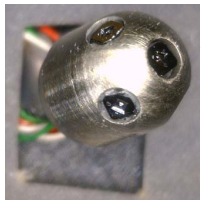
Agenda

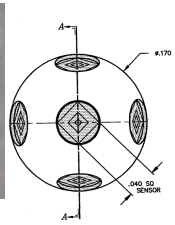
- Introduction
- Experimental Capabilities (FY'09)
- Flight Research and Validation (FY'10)
- Summary

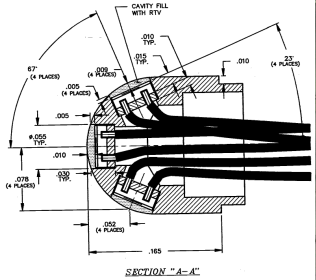
Introduction

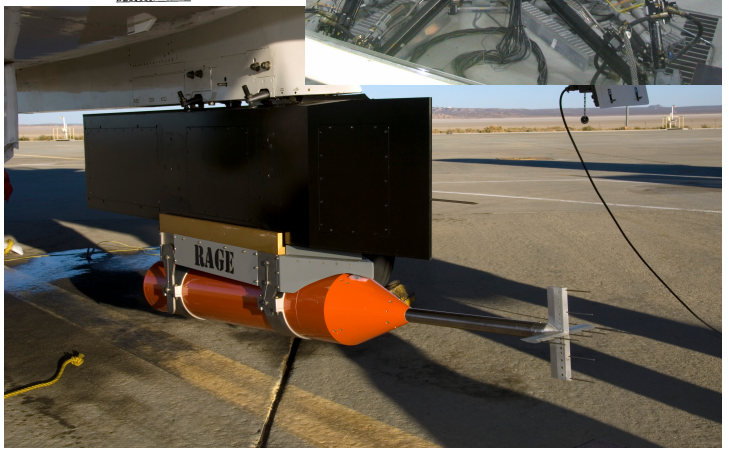
- In FY10 Experimental Capabilities will be reorganized into Flight Research and Validation
- Many EC projects have matured to the point that they are being implemented into their parent project (no longer an emerging capability)
- Cross center coordination on many small projects is not efficient nor expedient
- Expertise for flight projects resides at DFRC and that for wind tunnel projects resides at LaRC and ARC

Experimental Capabilities (FY'09): Portfolio



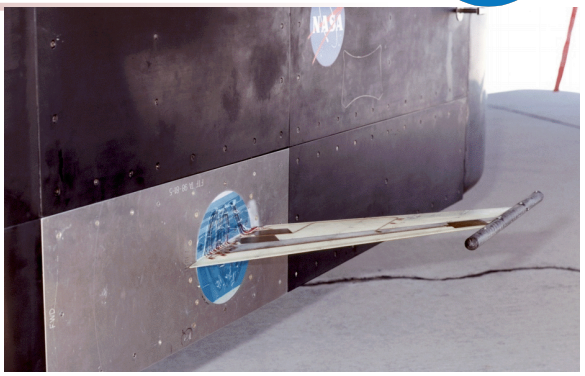




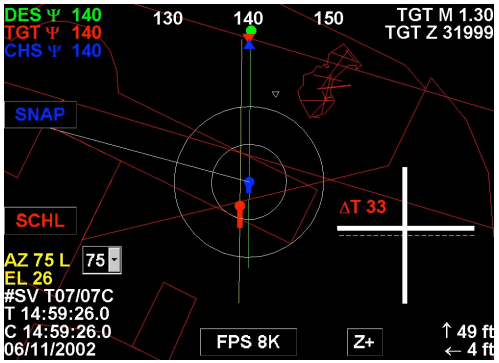


- **NRA**
  - Eagle Probe
  - Kulite probe
- **Advanced Flight Simulator (LaRC)**
  - Cockpit Motion Facility
  - Flying Qualities Guideline Development
  - Rigid/Flexible Flight Control
- **Flight Test Capabilities (DFRC)**
  - Advanced In-Flight IR Thermography
  - In-Flight Schlieren
  - F-15B Centerline Instrumented Pylon (CLIP) Flow Calibration
  - F-15B Propulsion Flight Test (PFTF) Fixture Flow Field Survey
- **Ground Test Capabilities (LaRC/ARC)**
  - Develop Laser Induced Thermal Acoustics (LITA) for supersonic wind tunnel
  - Construction and lab demo of LITA shock strength measurement system

Flight Research and Validation (FY'10): Portfolio

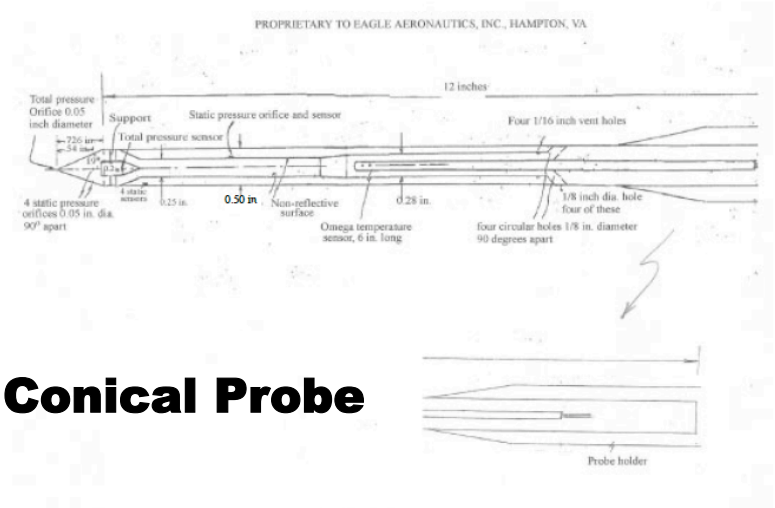


- **NRA**
  - Eagle Probe
- **Flight Projects**
  - Channeled Centerbody Inlet Experiment (CCIE)
  - Supersonic Boundary layer Transition test (SBLT)
  - Aero-elastic Test Wing –2 (ATW-2)
  - G-V External Vision Systems (G5 XVS)
- **Flight Test Technique Development**
  - Air-to-Air Schlieren (A2A)
  - In Flight Background Oriented Schlieren (BOS)
  - Dynamic Inertia Measurement Technique (DIM)
  - Advanced In-Flight IR Thermography (AIR-T)

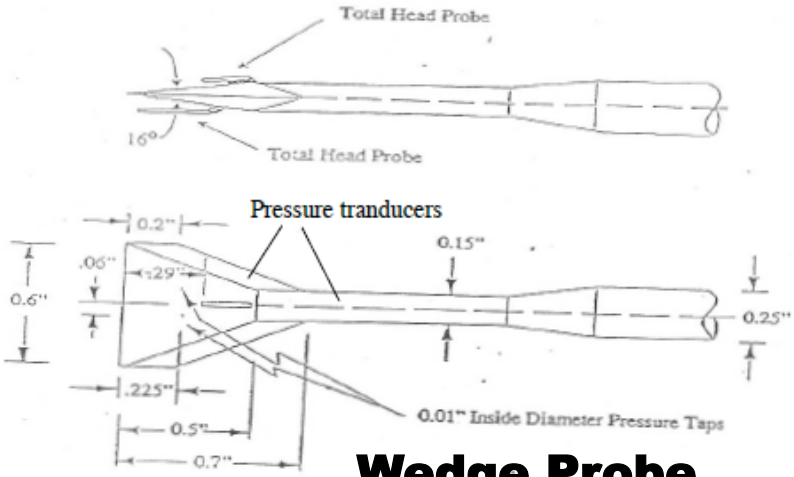


NRA: Eagle Aeronautics – Wedge and Conical Supersonic Probes

- High accuracy probes for shock wave characterization
  - >local Mach number, flow angle, total pressure and temperature, static pressure and temperature, velocity and speed sound
- Conical probe and wedge probe delivered
- Data algorithms ready for validation
- Wind tunnel test, waiting for 2nd entry (sensor failure)
- Flight test prep initiated, test 2/3QFY'10



Conical Probe

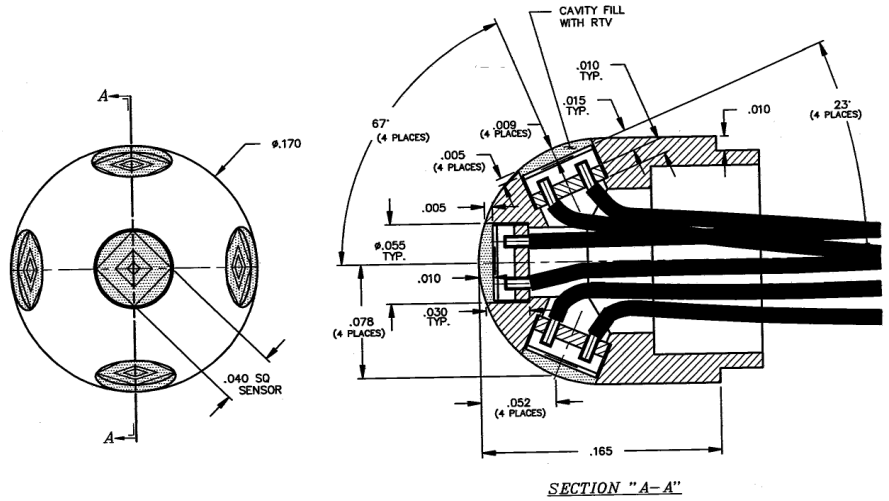


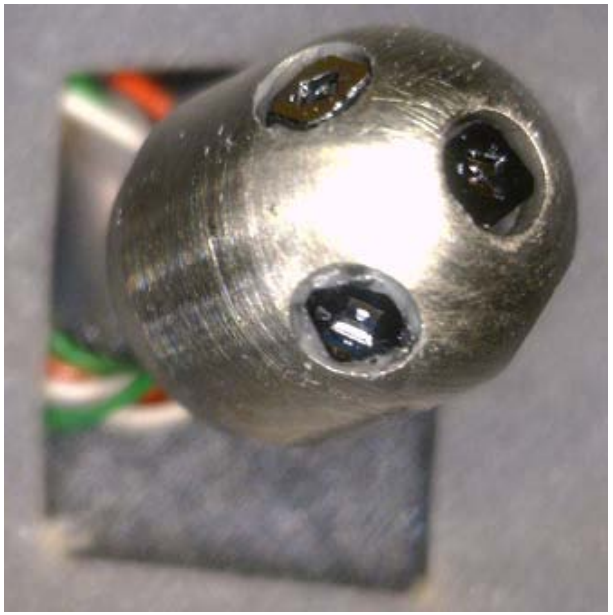
Wedge Probe

NRA: Development of Fully Integrated Miniature High Frequency Flow Probe Utilizing Advanced MEMS Leadless SOI Technology

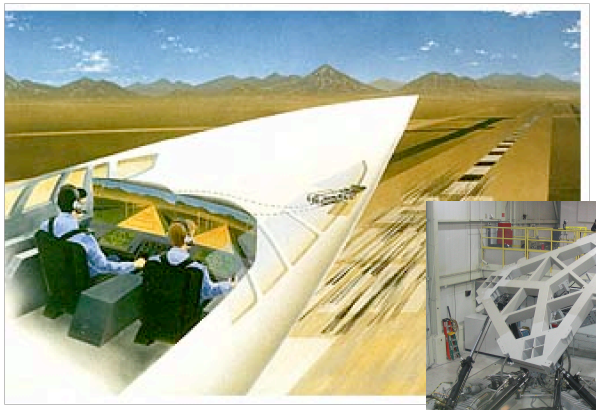
NASA Miniature 5-Sensor Flow Angle Probe

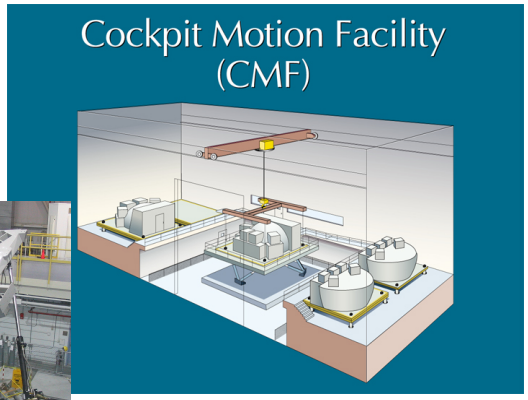
- 0.170 diameter 5-hole head
- Five Surface Mounted Kulite Sensors
- Differences of surface static pressures used to infer
  - Total Pressure
  - Mach Number
  - Two Flow Angles
  - Spatial Resolution 0.052 inch minimum
- Frequency Response up to 4kHz minimum.
- Flow Angle Accuracy
  - 0.5 º to 1.0 º over ± 35º range
- Prototype Assembly Completed
- Delivered to MIT Gas Turbine Laboratory (GTL) for Calibration
- Tests underway





Advanced Flight Simulation



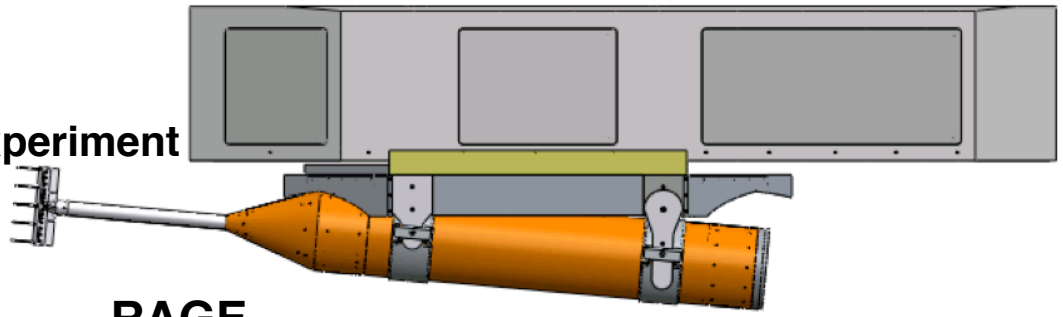


- **Advanced Flight Simulator**
  - Complete preparations for operation of LaRC Cockpit Motion Facility to support flexible aircraft piloted simulation studies
  - Unique simulation capability with high bandwidth
  - Ready for operation 2QFY'10
- **Flying Qualities Guideline Development for Flexible 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
  - Initiated first of three-phase piloted sim study; data report due Summer 2010
- **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
  - Tunnel test completed 4QFY'09

Propulsion Flight Research
RAGE and CCIE

RAGE – Rake Air Gage Experiment

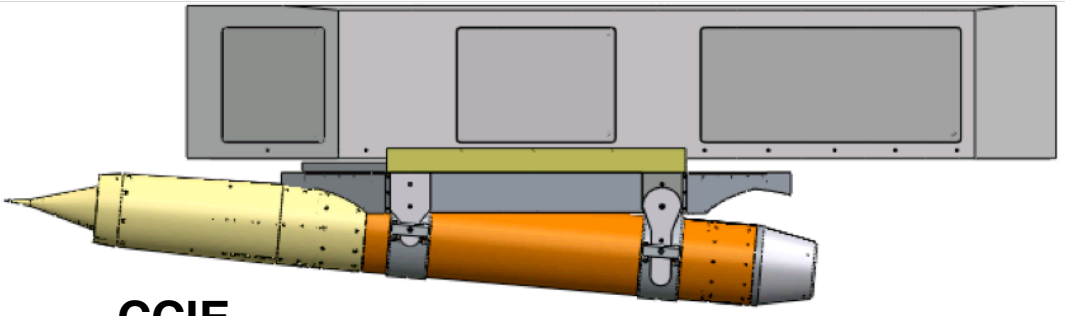
CCIE – Channelled Centerbody Inlet Experiment



RAGE

Measure flow angularity and local air data in front of Propulsion Flight Test Fixture (PFTF) under F-15B research aircraft. Test completed – August'09.

Rake Air Gage Experiment (RAGE) mounted under F-15B.

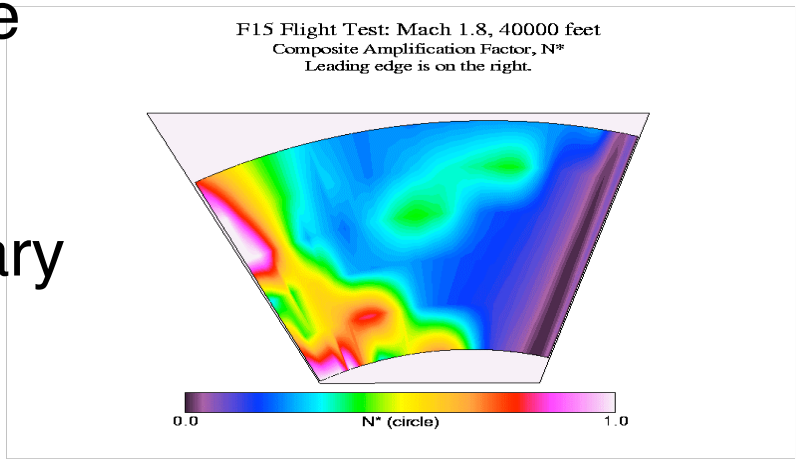


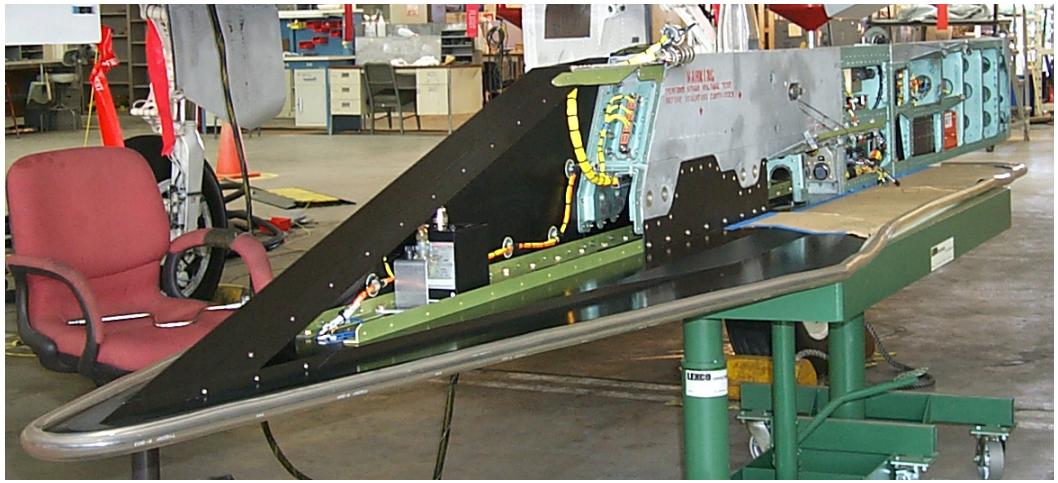
CCIE

Quantify inlet flow with special designed channelled centerbody. Scheduled to fly in FY'10.

Centerline Instrumented Pylon (CLIP) Flow Calibration

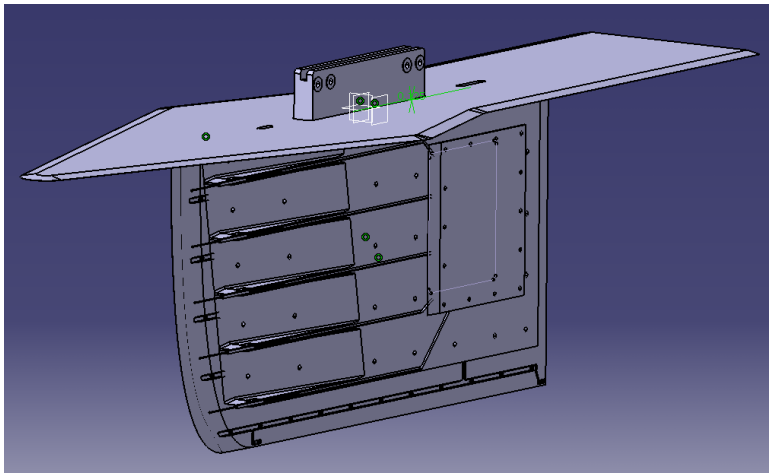
- Obtain flow survey to determine local Mach, angularity, and freestream turbulence prior to large-scale Supersonic Boundary Layer Transition Test (SBLT)
- Partnered with Aerion Corp.
- Combined with SBLT Test





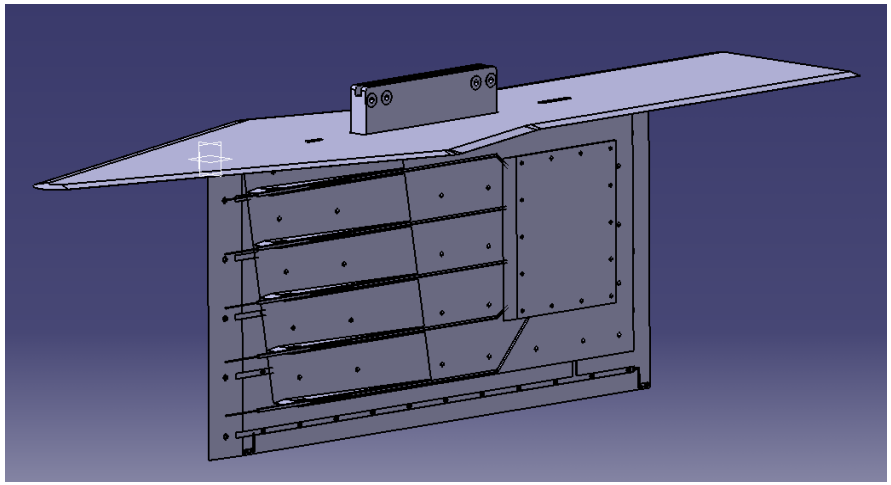
Supersonic Boundary Layer Transition Test (SBLT)

- To investigate high Reynolds number boundary layer transition transition in flight.
  - Flat plate test article
  - Mixed transition laminar flow test article
  - Testing begins 1/2QFY'10



Laminar Flow Test Article

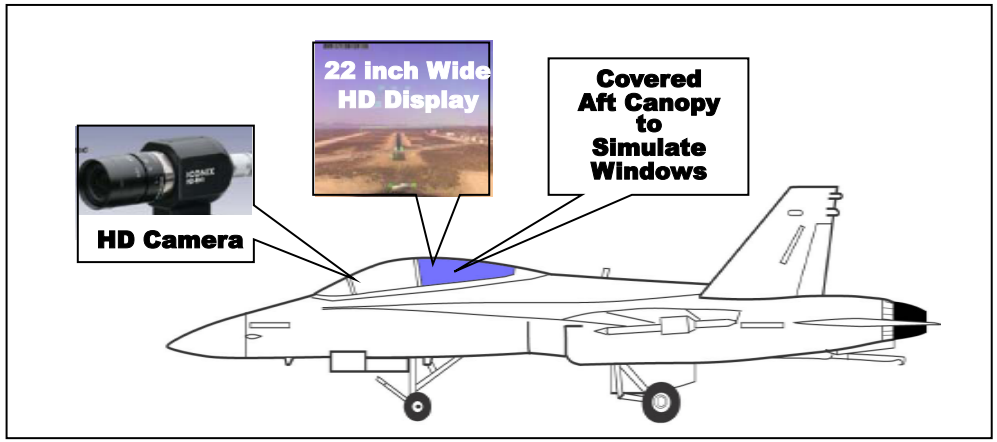
Flat Plate Test Article on F-15B



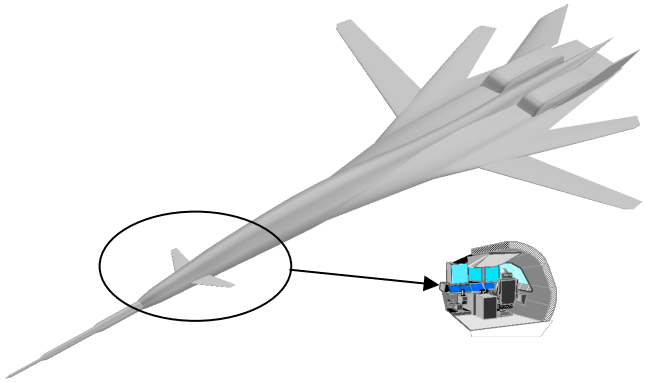
Flat Plate Test Article

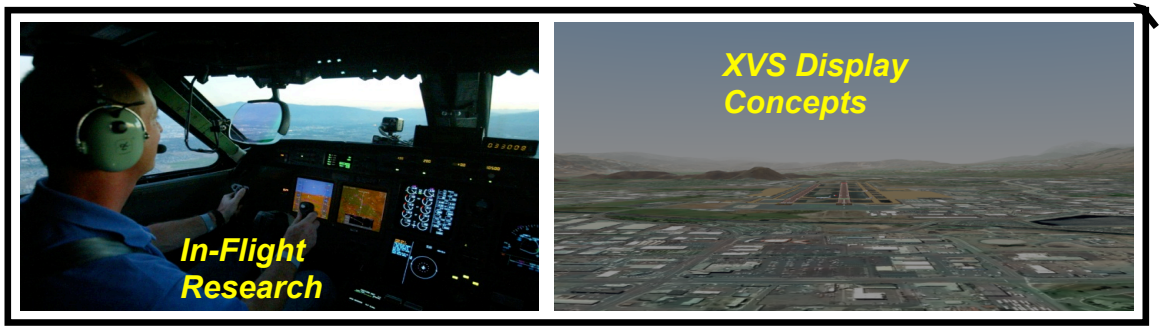
External Vision Systems (XVS), F-18 Test

- Joint Project Between Gulfstream & NASA
- Objectives:
  - Demonstrate Safe Day / Night VFR Ops
  - Determine Effects of Reduced Peripheral Visibility
  - Determine Optimum Side/Top Window Locations For Later Application
- 14 Data Collection Flights Accomplished 4Q08
  - 11 Day VFR And 3 Night VFR Flights
  - 7 Day VFR Flights Against Instrumented “Target” NASA Aircraft
- 4 Evaluation Pilots (3 GAC And 1 FAA)
  - 2 NASA Safety Pilots
- Completed, All objectives met



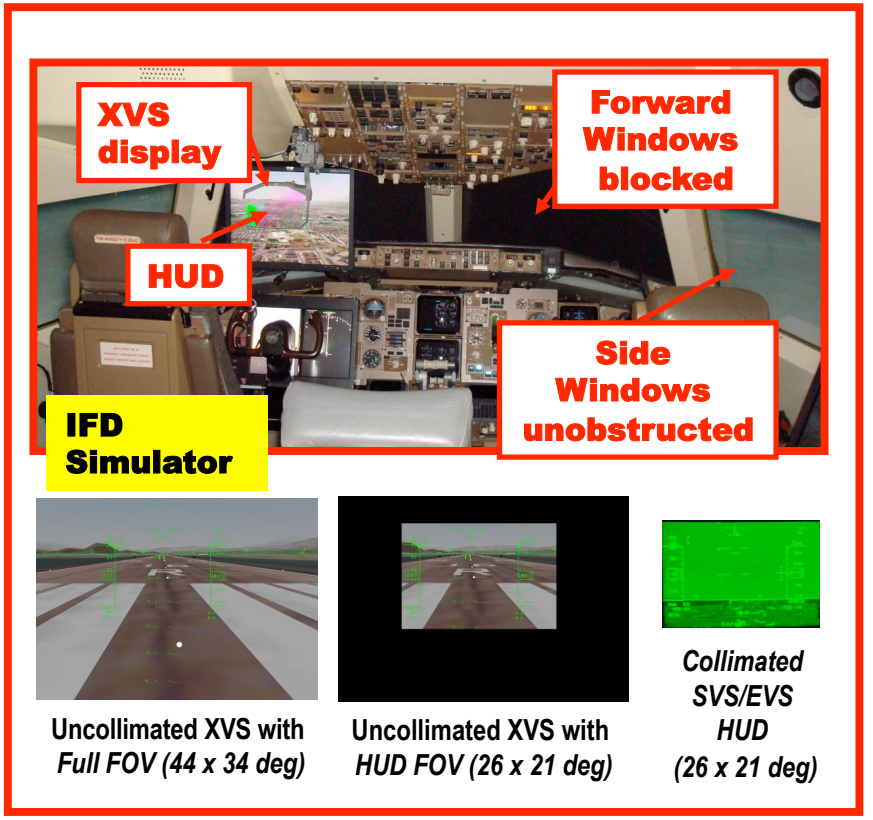
External Vision Systems, G5 Test

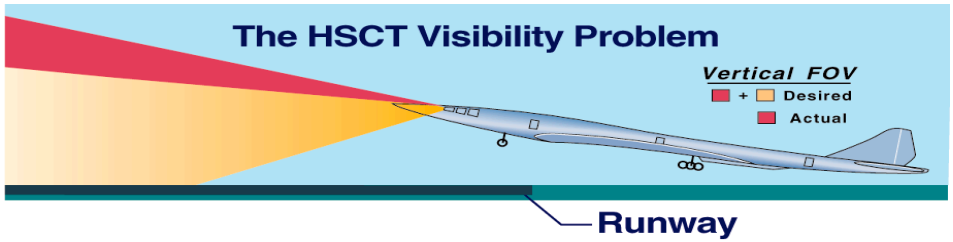




Develop eXternal Visibility Systems (XVS) Technology Enabling Replacement of Pilots' Forward View Windows

- Display, Sensor, And Associated Systems Requirements Development – Low-Boom Supersonic Aircraft Flight Deck.
- Cooperative flight test on large business class aircraft planned

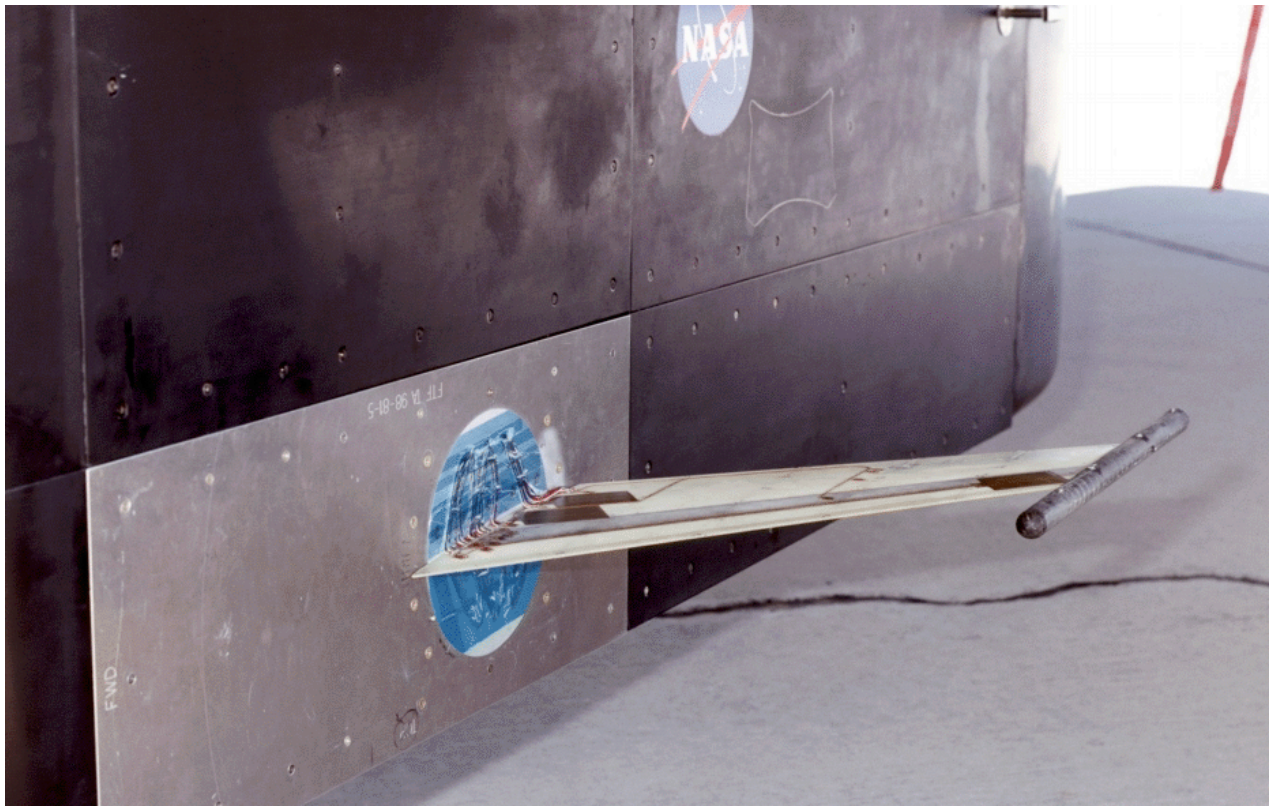




Aero-Elastic Test Wing -2

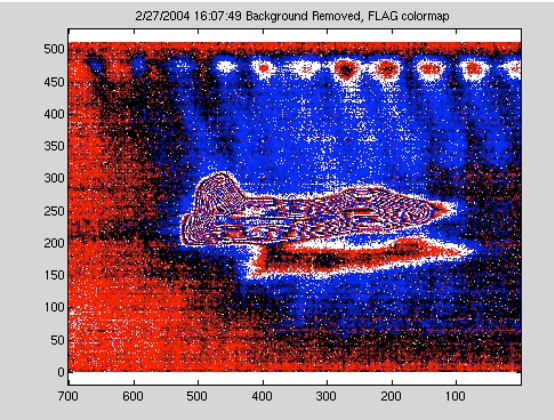
Active/Adaptive Flexible Wing Motion Control

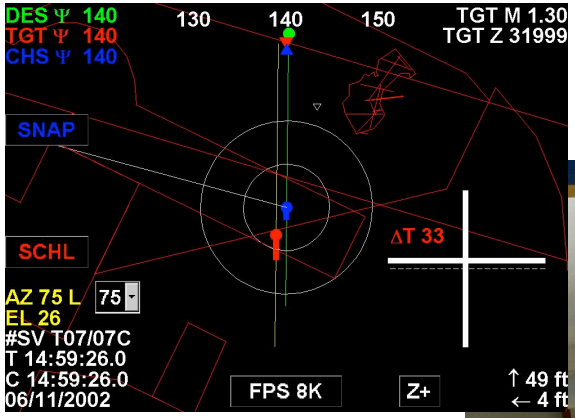
Increase aerodynamic performance of an aircraft with flexible wings through the use of the active control as well as on-line parameter estimation, adaptive notch filtering, and health monitoring techniques (SUP/SFW joint effort). Flight test 1/2QFY'10



Air-to-Air Schlieren

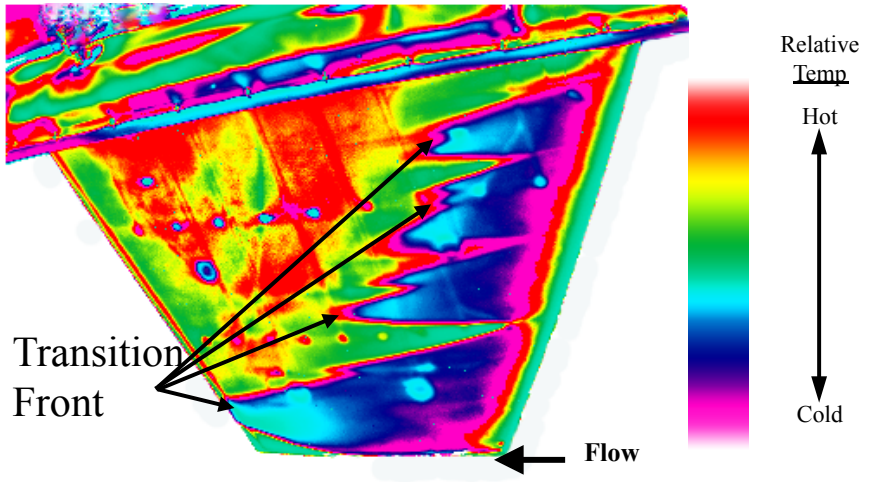
- Validation test by 2QFY'10
- Obtain high quality Schlieren image with good spatial resolution. Will allow determination of shock location and relative strength in-flight.
- Unique capability to validate shock location and relative strength for sonic boom prediction and MDAO studies.





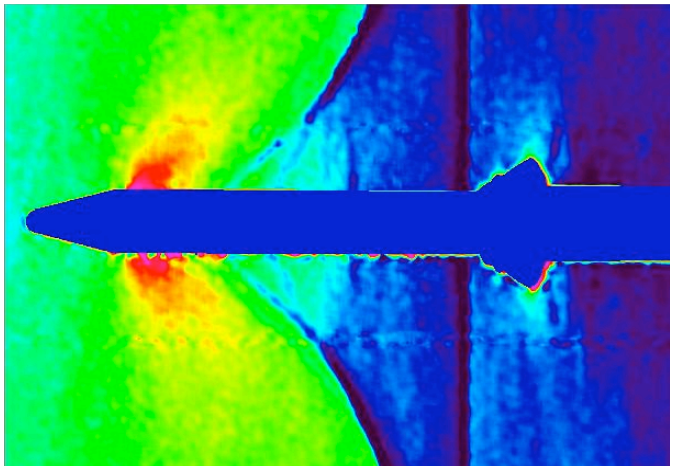
Advanced IR Thermography

- Validation tests completed 7/2008
- Obtained high quality (spatial and thermal resolution) analog and digital thermographic images
- Capability targeted for high Reynolds number in-flight transition tests Q1 FY'10 (part EC FY09, all FRV FY10)

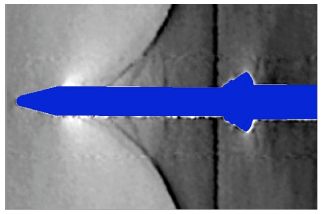


Background Oriented Schlieren (BOS)

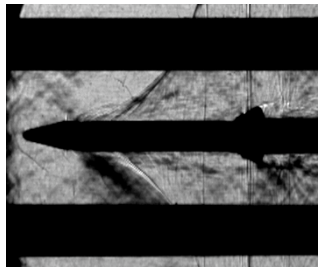
BOS vs. Real Schlieren, ARC 11-Ft TWT, M=1.05



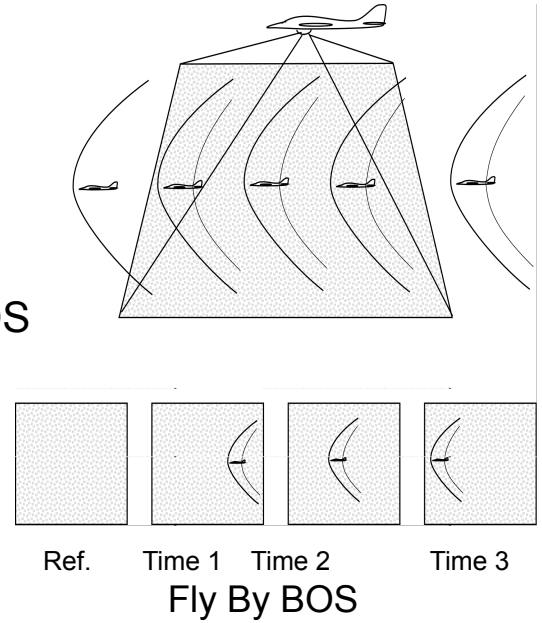
Color Contour BOS



Gray-scale Contour BOS



Real Schlieren image



Fly By BOS

A Synthetic Schlieren technique based on the distortion of known background pattern. In compressible fluids the distortion is caused by changes in the refractive index as a result of density gradients.

Modifying an existing IR pod and installing new camera and optics to validate air-to-air BOS on F-15B. Conduct preliminary tests on T-34C.

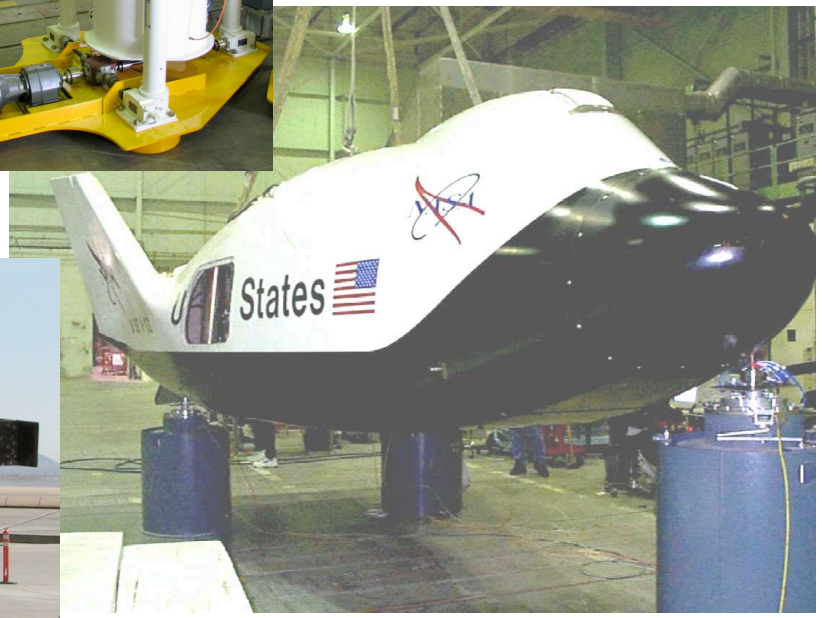
Dynamic Inertia Measurement (DIM)

Deliverable(s): Measured moments and products of inertia (MOI) for two test structures that simulate full scale atmospheric and space flight vehicles. This measurement activity will provide:

- Validated assessment of DIM Method accuracy
- A Complete suite of instrumentation, software, and analysis techniques for DIM utilization on actual flight vehicles

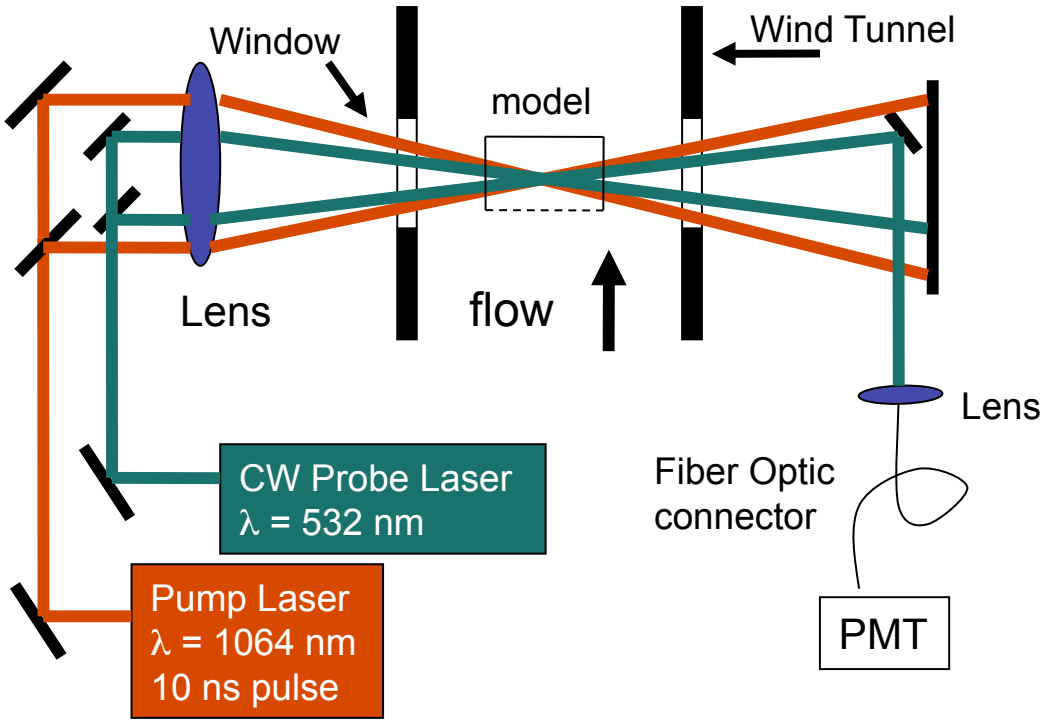
Objectives: Mass Properties Determination to support Vehicle Flight Dynamics and Control development and verification

- reduce the time and vehicle risk inherent with the measurement of MOIs of full scale atmospheric and space flight vehicles
- enable increased accuracy of measured MOIs



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 μm by 1 cm
- Time resolution
  - ~ 1 μsec (subsonic flow)
  - ~ 10 sec (supersonic flow)
- Novel tool for shock-strength measurement (sonic boom reduction)
- Completed lab demo



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

Summary

- Supersonics Experimental Capabilities will be re-organized into “Flight Research and Validation” for FY’10

- Ground test techniques have matured and moved into supporting technical challenge area

- Validating flight research and test techniques migrated into FRV