Overview of Experimental Capabilities - Supersonics

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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
• 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
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
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

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

ARC Fluid Mechanics Lab
32” x 48” Indraft Tunnel

GRC PIV run
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