Facility Improvement & Data Optimization (FIDO) Efforts at the NASA NTF

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Subject Category: Test Facilities, Transonic Wind Tunnel
Key Words: Modifications / Upgrades
What is FIDO

• A concentrated, multi-year effort to improve NTF’s overall capabilities

• An institutionalization of lessons learned from the STARBUKS project (Subsonic Transonic Applied Refinements By Using Key Strategies)

• This multi-million dollar effort is making improvements to our
  – Accuracy and Validation
    • Improved repeatability / data quality for results that can be trusted
  – Productivity
    • Completing required testing in a timely manner
  – Reliability
    • Keep the facility operational without interruption
STARBUKS Summary

Accuracy & Validation
- Data Acquisition System (Test SLATE)
- Mach Measurement System
- Facility Automation System
- Cooling Coil Trailing Edge Fairings
- Fixed Fairing Extension
- Alt. Probes Locations (RTD on Cooling Coil)
- Test Section Visibility
- Balance Calibrations

Productivity
- Cryogenic Active Damper
- Balance Limit Alarm (BLAMS) Upgrade
- Inlet Guide Vane (IGV) ΔT Mitigation
- Continuous Pitch

Reliability
- High Pressure Air Reducing Station
- Drive Coupling
- IGV Hydraulic Pipe Repair

Phase I Testing
- Check Std Test 214
- CRM Test 215

Phase II Testing
- Flow Calibration Test 217
- CRM Data Flow Quality Test 218

See Paryz AIAA 2014-1481
FIDO Improvements Roadmap

**Accuracy & Validation**
- Tunnel configuration selection
- Mach stability ±0.0005
- Conditional sampling (off-line)
- Validate RTD array on cooling coil

**Productivity**
- Mach control methodology
- 2nd throat actuation
- Conditional sampling (on-line, real-time)
- Increase access housing heating
- Optimized nitrogen injection
- Continuous sweep

**Reliability**
- Liquid nitrogen pump health monitoring
- Minimize nitrogen system hammering

Phase I Testing
- Check Std Test 219
- Flow Survey Rake Test 216A
- Completed

Phase II Testing
- Calibration Extension Test 220
- Turbulence Survey Rake Test 216B
- CRM Test 221

CRM – Common Research Model
FIDO Projects and Tests

• 5 Major Projects
  – Test Section Movables (2\textsuperscript{nd} Throat)
    ▪ Tunnel configuration selection
    ▪ Mach control methodology
    ▪ 2\textsuperscript{nd} throat actuation
  – Conditional Sampling
    ▪ Off-line [Complete]
    ▪ On-line real-time
  – Increasing Access Housing Heating
  – Proportional Liquid Nitrogen (LN2) Injection
    ▪ Optimized nitrogen injection
    ▪ Minimize nitrogen system hammering
  – LN2 Pump Health Monitoring

• 5 Experimental Entries
  – Test 219 Check standard [Pathfinder]
    ▪ Mach control methodology
    ▪ Continuous sweep optimization
  – Test 216A&B Flow survey rake
    ▪ Validate RTD array
    ▪ Verify turbulence reduction from STARBUKS [Deferred due to budget]
  – Test 220 Calibration extension
    ▪ Mach control methodology
  – Test 221 CRM validation
    ▪ Validation of combined system upgrades
30 Years of High Reynolds Number RDT&E

The Highest Reynolds Number Transonic Facility Operating in Air

The Highest Reynolds Number Transonic Facility Operating Cryogenically

<table>
<thead>
<tr>
<th>Test Section</th>
<th>8.2 x 8.2 x 25 Feet (2.5 x 2.5 x 7.6 meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>14.7 to 133 psia; 1 to 9.0 atm.; 1.01 to 9.1 bar</td>
</tr>
<tr>
<td>Air Operations</td>
<td>N₂ Operations</td>
</tr>
<tr>
<td>Mach No.</td>
<td>0.2 to 1.05</td>
</tr>
<tr>
<td>Reynolds No. Max</td>
<td>20x10^6 / ft (65x10^6 / m)</td>
</tr>
<tr>
<td>Temperature</td>
<td>90° to 150°F (32° to 65°C)</td>
</tr>
</tbody>
</table>
Test Section Movables (2nd Throat)
Accuracy & Validation, Productivity

- **Improve Mach stability (physical)**
  - Target ±0.0005 Mach number for transonic conditions
  - Part of original NTF design for “superior Mach control”
- **Project components**
  - Develop a robust instrumentation package to determine wall position
  - Develop a remote wedge system for the fixed fairing to minimize support system induced dynamics
- **Planned to be operational in Summer 2015**
- **Requires calibration extension**

See Chan AIAA 2015-#### and Jones AIAA 2015-####
Conditional Sampling
Accuracy & Validation, Productivity

- Improve data quality
  - Reject data samples that do not meet requirements

- Off-line: available
  - Performance penalty due to longer data samples required
  - Need ~2 seconds of valid data
  - May need to acquire 10-12 sec

- On-line: in development
  - Stop acquiring data when samples meet specified criteria
  - Alleviates most of performance penalty

\[ C_D \pm 0.0001 \]

\[ \text{Avg 1st 2 Sec} \]
Increasing Access Housing Heating Productivity

• **Target**
  – 50% reduction in model access time

• **Current system**
  – 20 kW convection heater
  – 2 torch heaters (convection)
  – 2 IR lamps for sting base

• **Approach**
  – Replace torch heaters with medium-wave (mw) IR heaters
  – 4 mwIR heaters with independent control using an 4 optical pyrometers for surface temperature measurement
  – New articulating arm structure
Proportional Liquid Nitrogen (LN$_2$) Injection
Accuracy & Validation, Reliability

• **Current system**
  – 336 injection nozzles controlled by 12 binary (butterfly) valves
  – 8 programmed injection patterns

• **Proposed changes**
  – Replace binary valves with proportional (ball) valves
  – Update the automation hardware
  – Revise control system
  – Incorporate RTD array for fine temperature control

• **Proposed benefits**
  – Optimized LN$_2$ injection
  – Minimized LN$_2$ system dynamics
  – Improved reliability of LN$_2$ system

• **Planned to be operational in Summer 2015**
Cooling Coil RTD Array

- Double dual total temperature probes (RTD) have been installed at 9 locations in 21ft x 21ft pattern
  - 36 temperature sensors
    - 18 for data
    - 18 for control
  - Represents 5ft wing span in the test section
LN2 Pump Health Monitoring
Reliability

• **Goal**
  – Make LN$_2$ system more robust
  – Limit pump trips
  – Measure/predict pump health

• **Current system**
  – Monitoring of 12 accelerometers
  – 6 internal/6 externally mounted

• **Planned changes**
  – Motor current based monitoring of the two largest pumps
  – Consolidate accelerometers and current signals
  – Assess two solutions for trending and analysis
    ▪ Simple spectral analysis with peak frequency recording
    ▪ Data recorder with high level analysis capability
Check Standard Model (PF1) – Test 219
Accuracy & Validation, Productivity

• **Purpose**
  – Verify Mach stability for the Mach 0.90 choke configuration of 2nd throat used for CRM
    ▪ Determine whether model size affects tunnel choke (PF1 is 70% of CRM in size)
    ▪ Determine the extent of Mach variation benefit as a function of Mach number
  – Verify control and data system updates
    • Conditional sampling
    • Continuous pitch/sweep optimization
    • Temporal alignment of balance and reference conditions from new Mach Measurement Sys.
  – Gather fluctuating pressure data on test section walls, arc sector, and high speed diffuser to check noise propagation

• **Test Conditions**
  – Mach number: $0.70 \leq M \leq 0.88$
  – Dynamic Pressure: $766 \text{ psf} \leq Q \leq 1040 \text{ psf}$
  – Reynolds number (c): $2.5 \times 10^6 \leq \text{Re} \leq 2.8 \times 10^6$
  – Total Pressure: 21.5 psi
  – Temperature: +120° F
  – Angle-of-Attack: $-2^\circ \leq \alpha \leq +4.5^\circ$

See Chan AIAA 2015-#### and Jones AIAA 2015-####
Rake Test 216 A&B
Accuracy & Validation

• **Purpose**
  – Verify flow reference measurements
  – Evaluate circuit flow line changes on reference conditions and their uniformity
    ▪ Arc-sector fixed fairing extension
    ▪ Cooling coil trailing edge fairings
  – Validate cooling coil RTD array
  – Document improvements to test section flow quality [*T216B only*]
  – Understand flow dynamics

• **Sensors used**
  – Unsteady pressure sensors
  – Hot-wire sensors [*T216B only*]
  – Resistive Temperature Devices
  – Total pressure probes

• **Results**
  – Reference conditions verified
  – RTD array validated
  – Continuous sweep used successfully
  – Dynamic pressure fluctuations documented by Jones AIAA 2015-####

• **Test 216B deferred due to budget**
Purpose:

- Extend centerline Mach and buoyancy calibration for use of the 2nd throat
  - Previous testing demonstrated requirement
  - Planned as a correction to the existing calibration
- Planned for late-Summer 2015
Planed full system demonstration of FIDO projects: Fall 2015
Summary

• Several upgrade projects are in progress at the NASA LaRC National Transonic Facility (NTF) to incorporate lessons learned from the STARBUKS project.

• This multi-year effort is enhancing NTF’s overall capabilities by improving the Accuracy and Validation, Productivity, and Reliability capabilities at the NTF.
Questions?