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

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Presented at the
AIAA SciTech Conference
Aerospace Sciences Meeting (ASM)
5 - 9 January 2015
Kissimmee, FL

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

IMPROVED NTF

Phase I Testing

- ✓ Check Std Test 214
- ✓ CRM Test 215

Phase II Testing

- ✓ Flow Calibration Test 217
- CRM Data Flow Quality ✓ Test 218

☑ Completed

See Paryz AIAA 2014-1481

CRM – Common Research Model

NTF

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

IMPROVED NTF

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

NTF

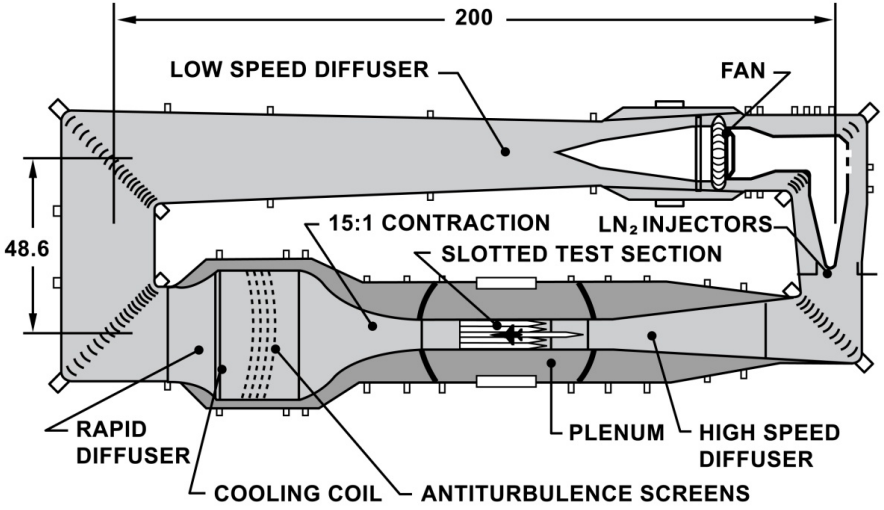
FIDO Projects and Tests

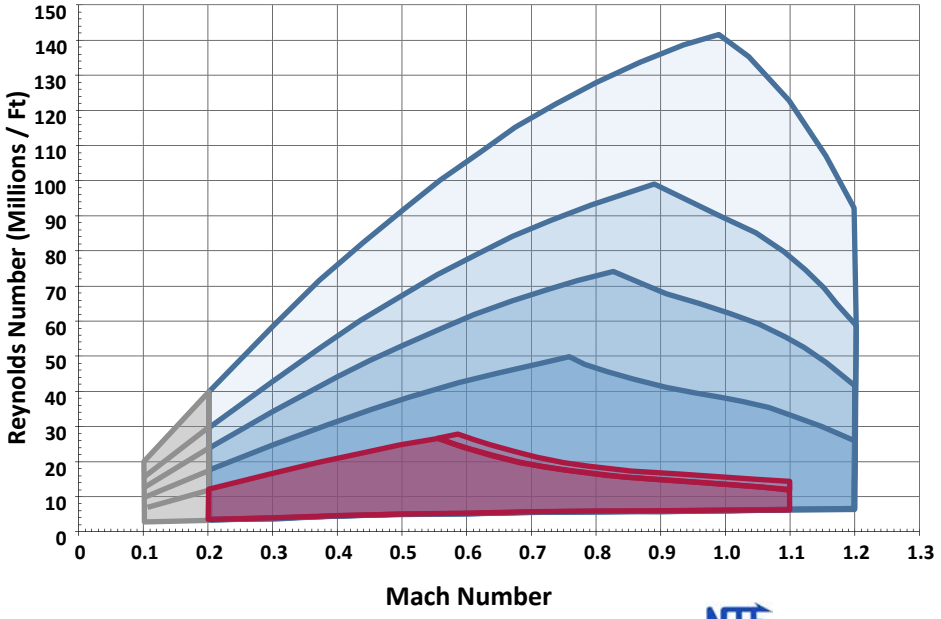
- **5 Major Projects**
  - **Test Section Movables (2nd Throat)**
    - Tunnel configuration selection
    - Mach control methodology
    - 2nd throat actuation
  - **Conditional Sampling**
    - Off-line [Complete]
    - On-line real-time
  - **Increasing Access Housing Heating**
  - **Proportional 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

National Transonic Facility – NTF

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

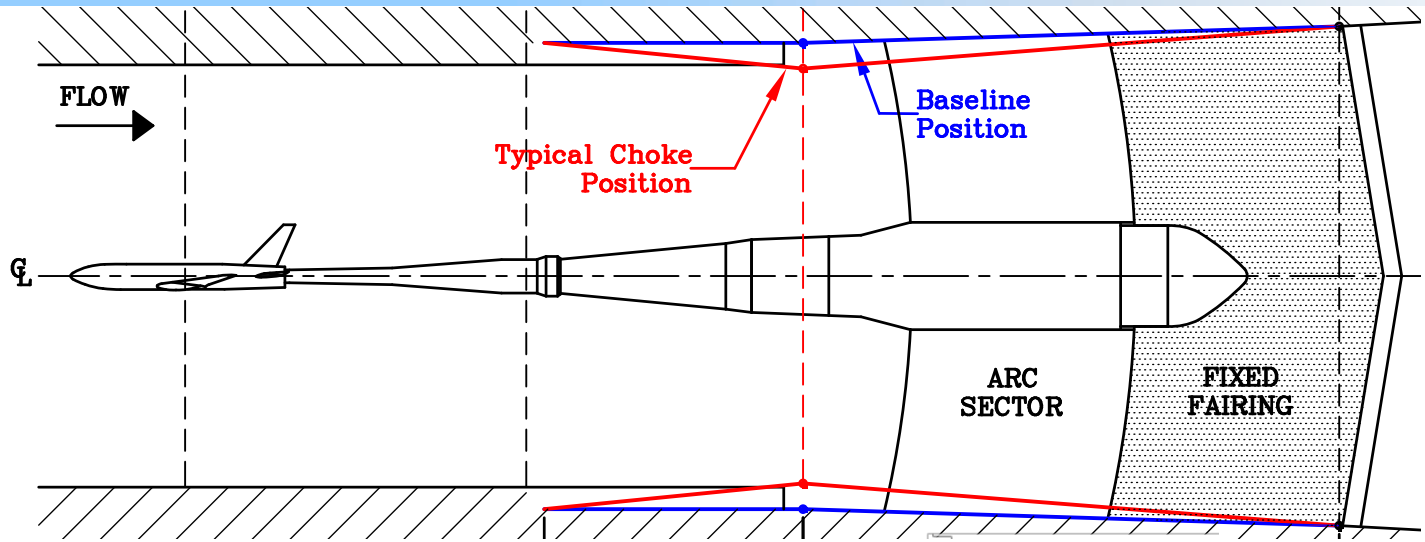
Test Section	8.2 x 8.2 x 25 Feet (2.5 x 2.5 x 7.6 meters)	
Pressure	14.7 to 133 psia; 1 to 9.0 atm.; 1.01 to 9.1 bar	
	Air Operations	**N_2 Operations**
Mach No.	0.2 to 1.05	0.2 to 1.20
Reynolds No. Max	$20x10^6$ / ft ($65x10^6$ / m)	$145x10^6$ / ft ($475x10^6$ / m)
Temperature	90° to 150°F (32° to 65°C)	-50° to -250°F (-45° to -157°C)



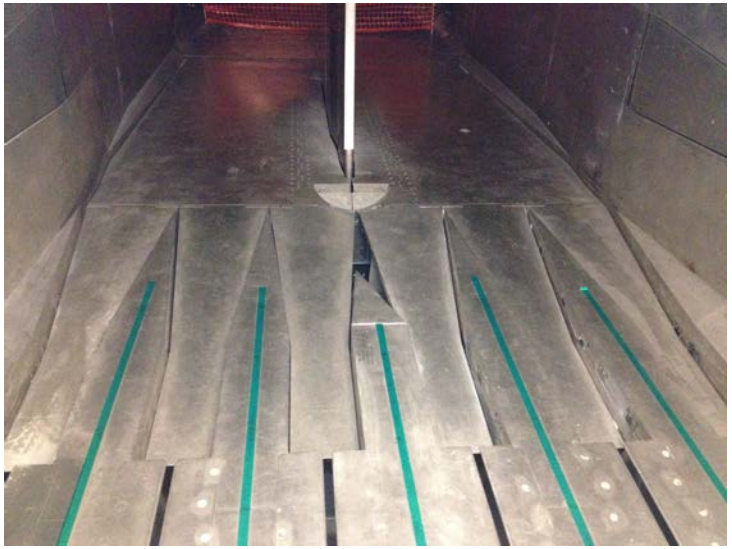


Test Section Movables (2nd Throat)

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 faring to minimize support system induced dynamics
- **Planned to be operational in Summer 2015**
- **Requires calibration extension**

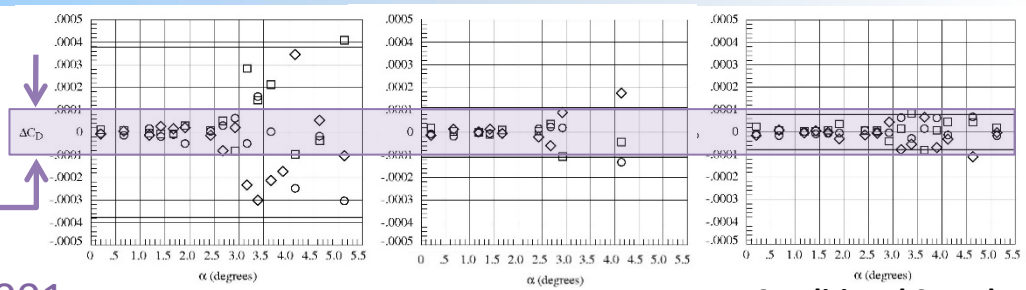


See Chan AIAA 2015-#### and Jones AIAA 2015-####

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

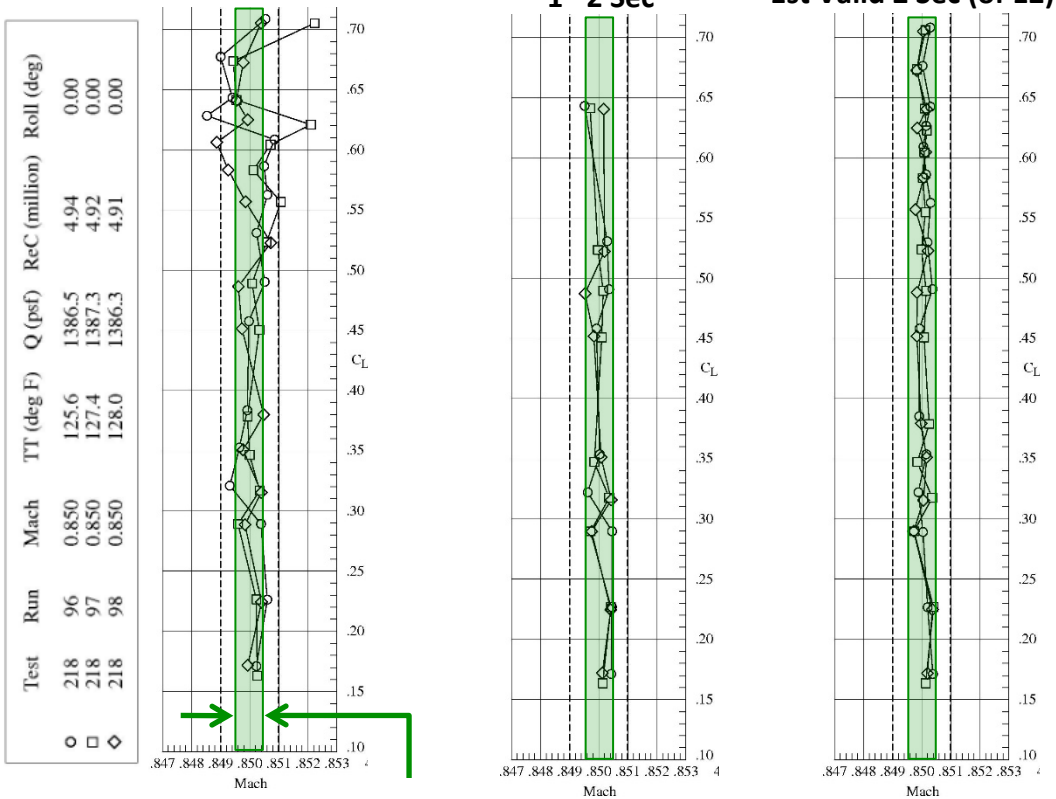


$C_D \pm 0.0001$

Avg 1st 2 Sec

Conditional Sample 1st 2 Sec

Conditional Sample 1st Valid 2 Sec (of 12)

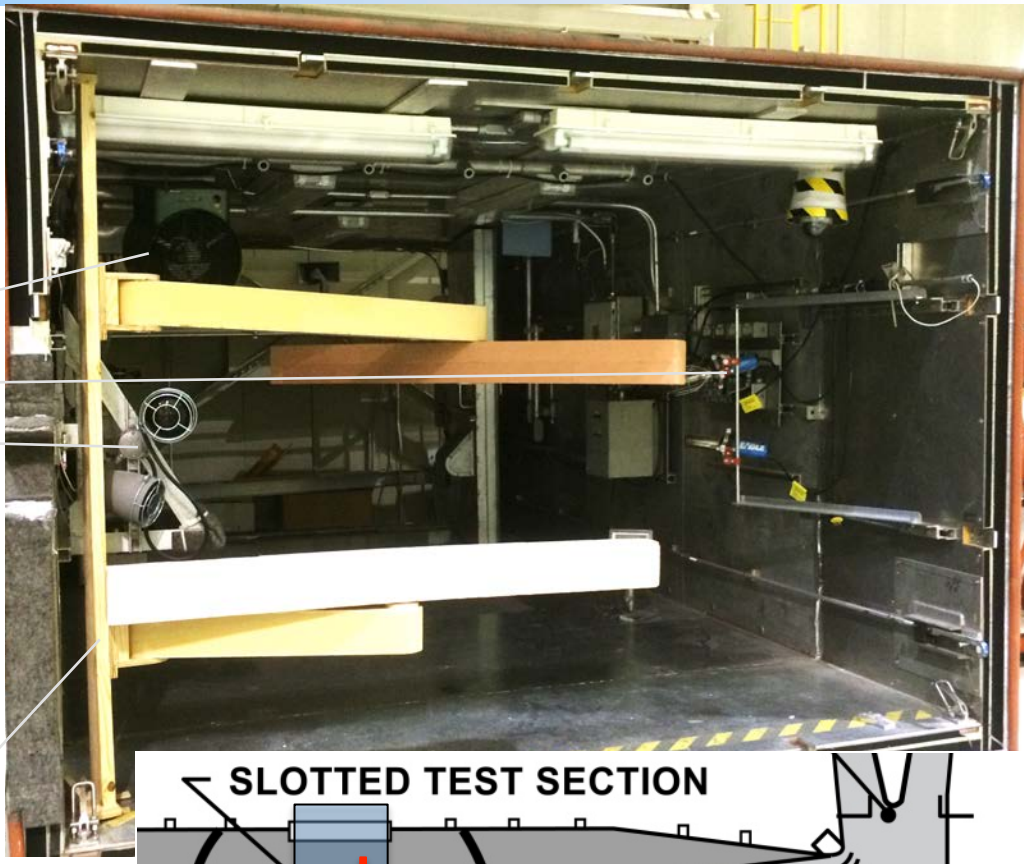


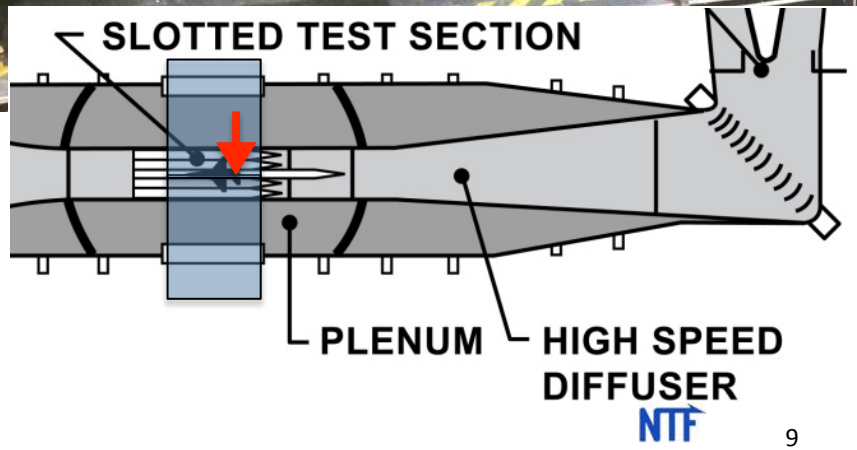
$M \pm 0.0005$

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

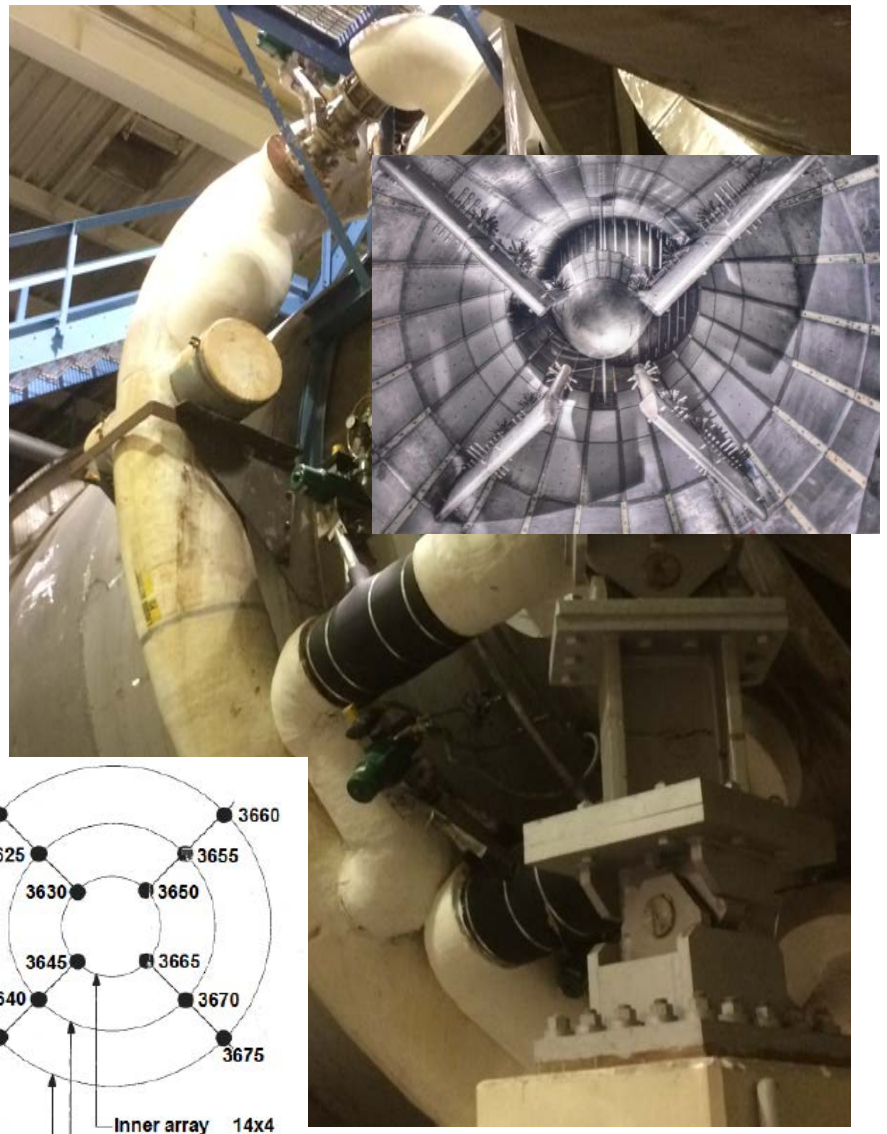




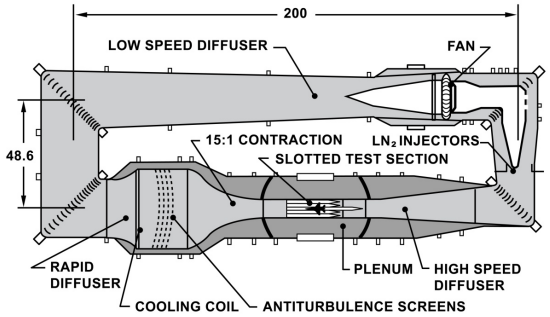
Proportional Liquid Nitrogen (LN_2) Injection

Accuracy & Validation, Reliability

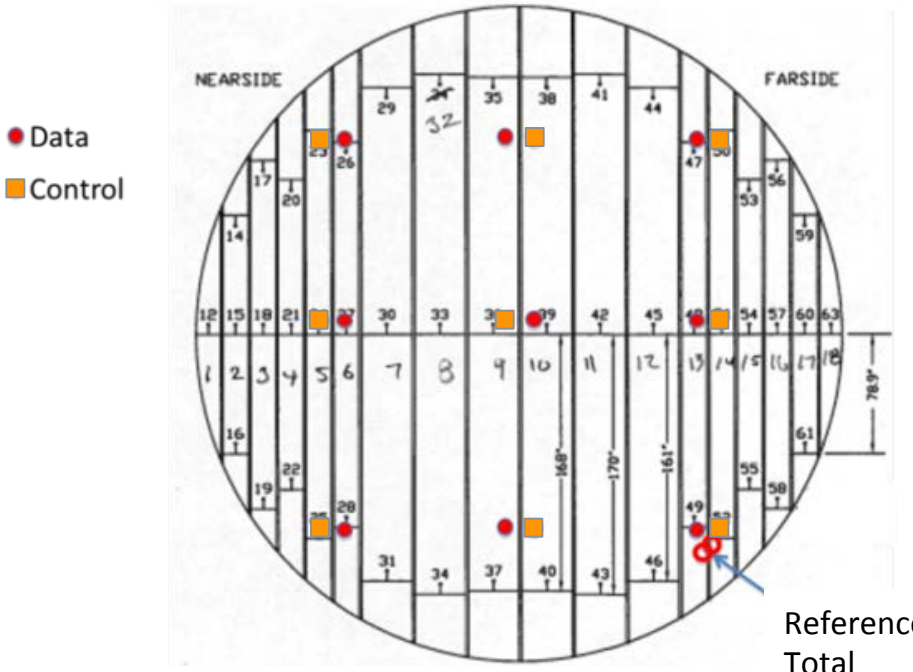
- **Current system**
  - 336 injection nozzles controlled by 12 binary (butterfly) valves
  - 8 programmed injection patterns
- **Proposed changes**
  - Replace binary valves with proportional (ball) valves
  - Update the automation hardware
  - Revise control system
  - Incorporate RTD array for fine 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**



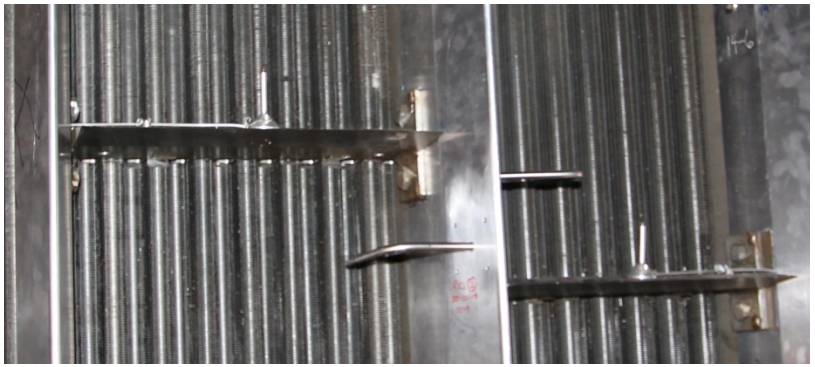
Cooling Coil RTD Array



- **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



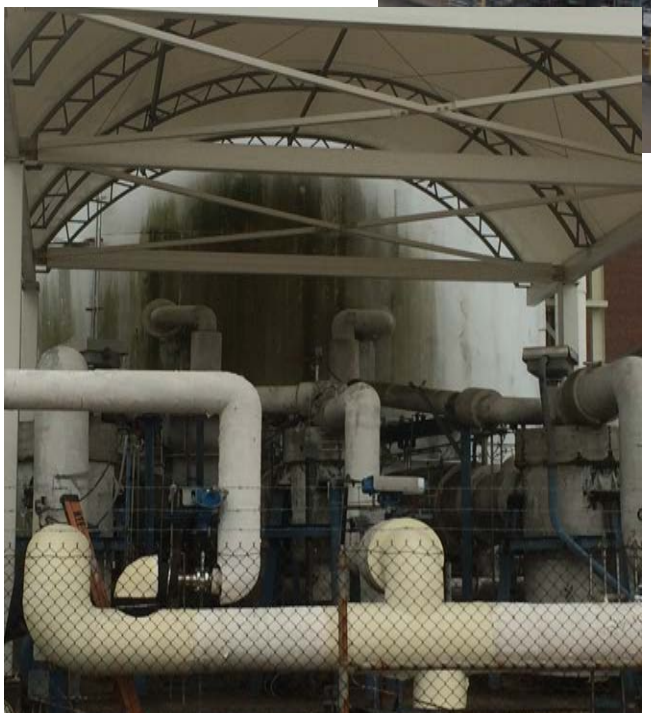
Reference Total Temperatures



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

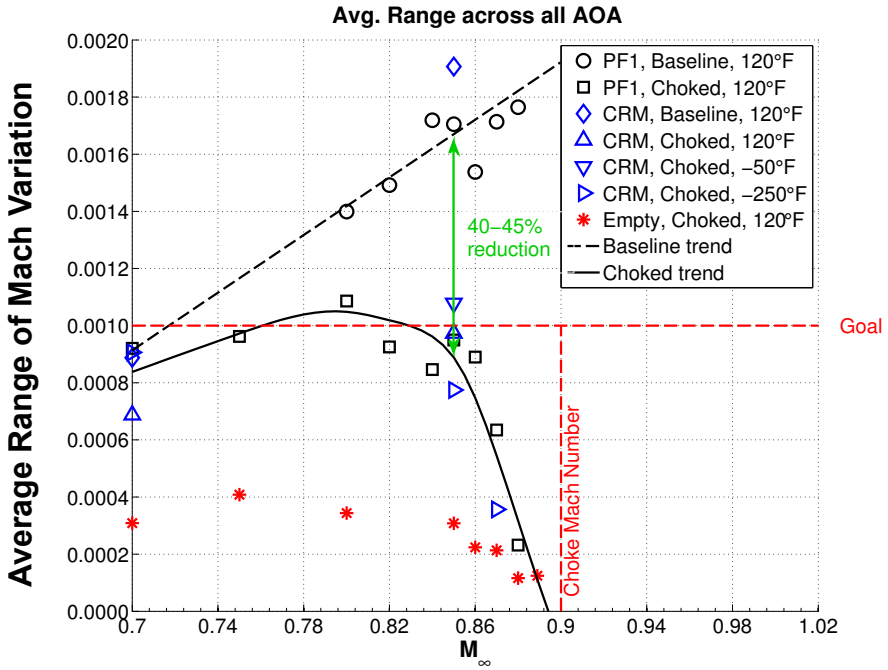


Check Standard Model (PF1) – Test 219

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

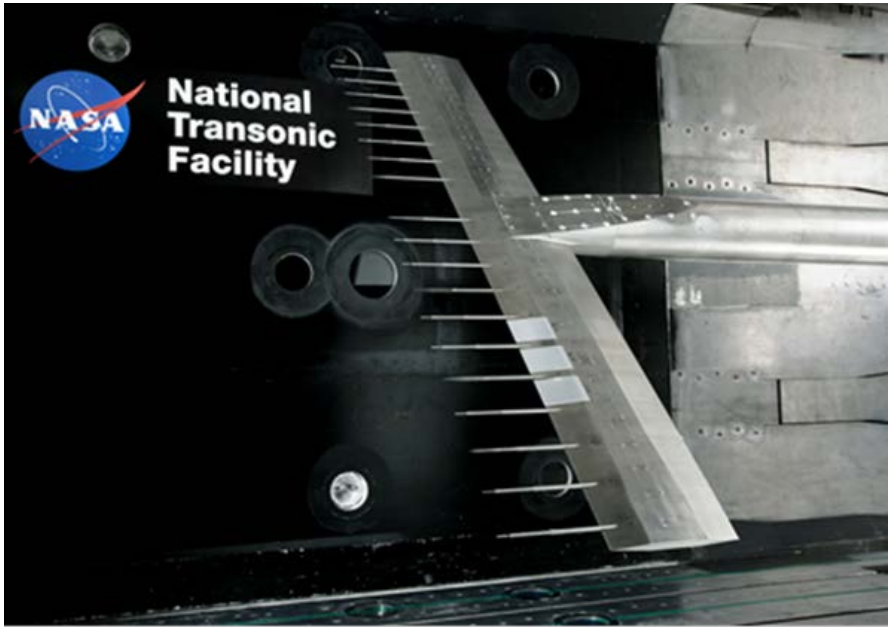


See Chan AIAA 2015-#### and Jones AIAA 2015-####

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**



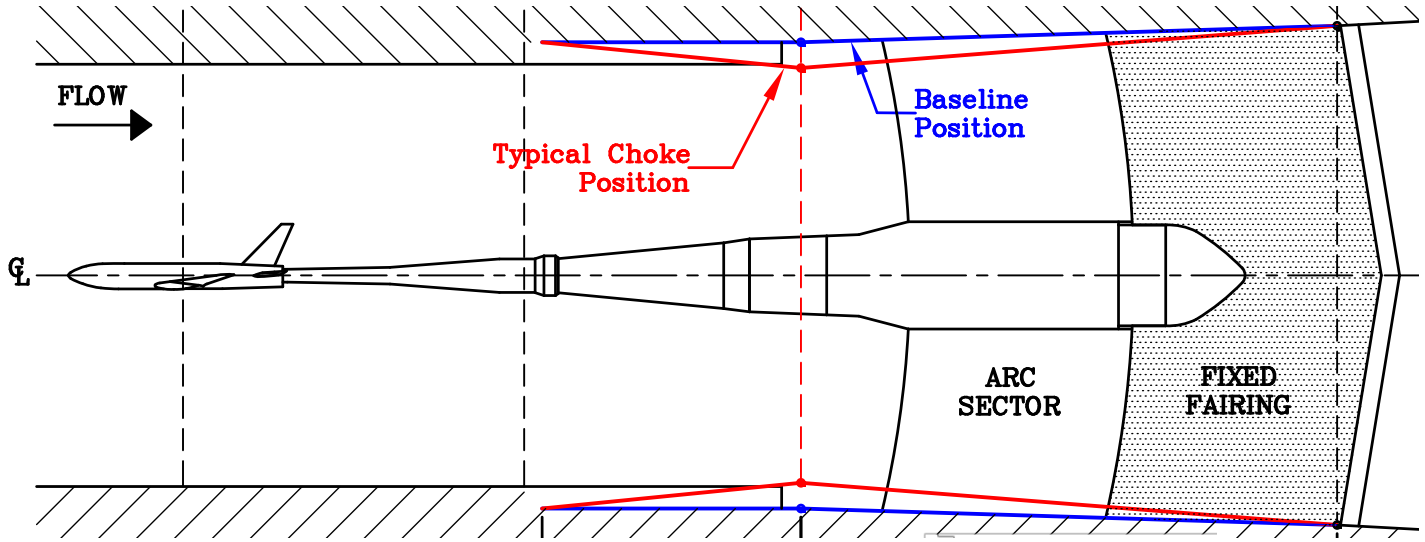
7ft Flow Survey Rake

Centerline Pipe Tunnel Calibration Test 220

Accuracy & Validation, Productivity

Purpose:

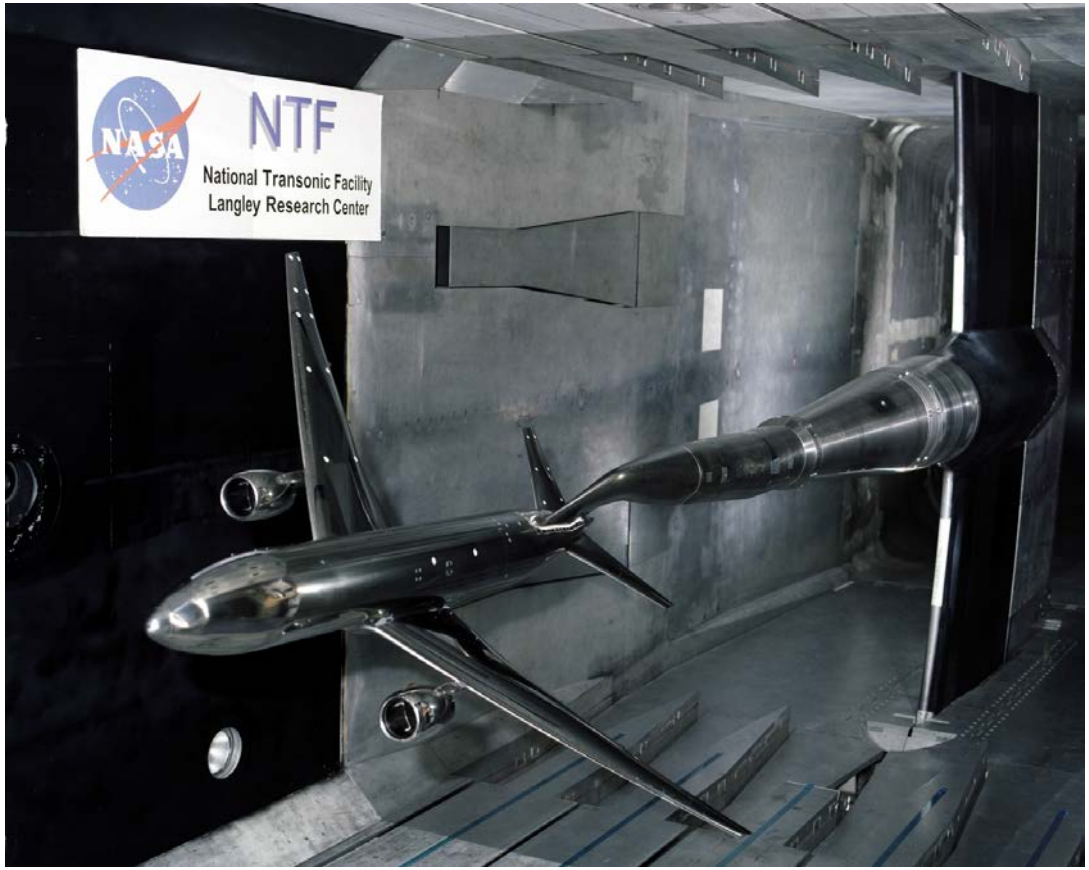
- **Extend centerline Mach and buoyancy calibration for use of the 2nd throat**
  - Previous testing demonstrated requirement
  - Planned as a correction to the existing calibration
- **Planned for late-Summer 2015**



Common Research Model Test 221

Accuracy & Validation, Productivity

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?