UNSTEADY ASSESSMENTS AND IMPROVEMENTS FOR THE NATIONAL TRANSONIC FACILITY

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Configuration Aerodynamics Branch
OUTLINE

• OBJECTIVES

• OVERVIEW OF NTF STARBUKS AND FIDO EFFORTS

• NTF CENTERLINE PIPE TEST

• NTF RAKE TEST

• NTF COMMON RESEARCH MODEL TEST

• CONCLUDING REMARKS
## Wind Tunnel Improvements Objectives

Focus on NTF

<table>
<thead>
<tr>
<th>General Wind Tunnel Requirements</th>
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<tbody>
<tr>
<td><strong>No. 1</strong> Accuracy and Validation (Repeatability/Data Quality)</td>
</tr>
<tr>
<td>– Results that can be trusted</td>
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<tr>
<td><strong>No. 2</strong> Productivity</td>
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<tr>
<td>– Complete required testing in a timely manner</td>
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<td><strong>No. 3</strong> Reliability</td>
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<tr>
<td>– Keeps working without interruption</td>
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### NTF – Recent Efforts
- **Subsonic Transonic Applied Refinements By Using Key Strategies (STARBUKS)**
- **Facility Improvements and Data Optimization (FIDO)**
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 Location (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

Common Research Model
- ✔ Completed

Check Standard Model
- ✔ Completed

See Paryz AIAA 2014-1481
FIDO IMPROVEMENTS ROADMAP

Accuracy & Validation
- Tunnel configuration selection
- Free stream Turbulence (Rake – TBD)
- 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
OBJECTIVES

- **Characterize empty tunnel pressure fluctuations**
- **Characterize wall unsteady pressure interactions with a model installed (Common Research Model)**
- **Determine the effectiveness of the second throat and vortex generators**
Centerline Pipe Test

Centerline Pipe Data to be used for Tunnel Calibration

Guy Wire Supports

Center Line Pipe

Mach vs. X (Feet)

Calibration Limits

Pipe to Cone Transition

0.0 0.2 0.4 0.6 0.8 1.0 1.2
-5 0 5 10 15 20 25 30

Mach

0.100 0.090 0.080 0.070 0.060 0.050 0.040 0.030 0.020
VORTEX GENERATORS ADDED TO MANAGE HIGH SPEED DIFFUSER SEPARATION

VORTEX GENERATORS LOCATED AT STATION 36’

VG SIZE AND SHAPE ARE NOT OPTIMIZED
BENEFITS OF VGs
EMPTY TUNNEL

VGs benefit Low Frequency Stability above Mach ~ 0.7

BENEFIT OF VGs on Low Frequency < 10 Hz
BENEFITS OF VGs (SPECTRA) EMPTY TUNNEL

VGs show benefit for empty tunnel (stabilizes low frequency and reduces broadband)

Baseline

W/ VGs

Guy Wire Shedding

=0.63'

MACH

-0.20
-0.40
-0.60
-0.80
1.00

\( \frac{p'}{q_{\text{STATION 33}}}^2, (\text{Hz}^{-1}) \)

\( f/L_{\text{STATION 33}} \) (L=1 foot)
TEST SECTION MOVABLES (2nd THROAT)

- **Improve Mach stability goals**
  - Target ±0.0005 Mach number for transonic conditions
  - Determine the influence of Mach stability on performance repeatability (e.g., Cd~0.0001)
- **2nd Throat development**
  - Develop a remote positioning system
    - Develop a motorized 2nd throat with 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

Chan AIAA 2015-0622 and Jones AIAA 2015-1557
2nd THROAT w/ CENTERLINE PIPE CONFIGURATION

The graph shows the Mach number (MACH) as a function of distance along the pipe (X, FEET) with two different conditions:

- **VGs**: Blue line indicating the presence of vortices generators.
- **NO VGs**: Red line indicating the absence of vortices generators.

Key features include:
- **Centerline Pipe**
- **Pipe-Cone Transition**
- **Re-entry Flaps**
- **Second Throat**
- **Movable Wall**

The graph highlights the effect of vortices generators on the flow characteristics within the pipe configuration.
RAKE TEST

RAKE DATA TO BE USED FOR EVALUATING FLOW UNIFORMITY

PROBE SPACING: Δ4"

NTF 7’ RAKE

BASELINE

SECOND THROAT CHOKED CONFIG
RAKE TEST SECTION UNIFORMITY

M = 0.85, \( \text{Re/ft} = 49.4 \times 10^6 \), \( T_o = -251^\circ F \), \( P_o = 44 \text{ psia} \)

SECOND THROAT CHOKED CONFIGURATION

RAKE DATA SHOWS UNIFORM FLOW AT STATION 13
COMPARISON OF CHOKED AND UNCHOKED CONDITIONS

RAKE p’17 Static DATA STATION 13’

M = 0.85, T_o = 120°F, P_o = 30 psia, q = 9.5 psi, Roll angle=0°

2ND THROAT CONFIGURATION

UNCHOKED
CHOKED

COMPOSITE SPECTRA
DASHED: \( \Delta f = 1\) Hz
SOLID: \( \Delta f = 10\) Hz

\( p' / q, (Hz^{-1}) \)

\( fL/U (L=1\) foot)
COMMON RESEARCH MODEL TEST

Engine Nacelles
Optional

Baseline

Second Throat Choked Config

-0.020 a = Second Throat
0.207 a = Second Throat

FAR SIDEWALL (9)
NEAR SIDEWALL (19)

MACH

X (FEET)

FAR SIDEWALL (9)
NEAR SIDEWALL (19)

MACH

X (FEET)
INFLUENCE OF COMMON RESEARCH MODEL

MODEL CONFIGURATION
- CRM AOA = 0.2°
- EMPTY TUNNEL (RAKE)

MODEL INTERACTIONS
- 1ST HARMONIC

COMPOSITE SPECTRA
- DASHED: Δf = 1Hz
- SOLID: Δf = 10Hz

SECOND THROAT CONFIGURATION
- CHOKED

(p'/q)^2, Hz^-1

fL/U (L=1 foot)

National Transonic Facility
NASA Langley Research Center

2nd Joint Conference of the STAI and SATA
June 7 - 11, 2015
**VGs Ineffective with Common Research Model**

Mach = 0.85, $Re_C = 10.0 \times 10^6$, $q = 12 \text{ psi}$, $T_o = -50^{\circ} \text{F}$, $P_o = 38 \text{ psi}$

- **Vortex Generator Configuration**
- **Model Interactions**
- **First Harmonic**
- **Second Throat Configuration Choked**

Plot shows the variation of $(p'/q)^2$, Hz$^{-1}$ with $fL/U$ ($L=1.0 \text{ foot}$). The red line represents all VGs, while the green line represents no VGs.
NTF TEST 218 – CRM
CONDITIONAL SAMPLING METHODOLOGY AND EFFECT

Measured drag force varies directly with measured Mach number variation

Mach variation increases at high AoA, probably due to separation (plot shows 3 repeat runs)

Conditional sampling only accepts and averages frames within a given Mach tolerance – given the correlation between Mach and drag, repeatability is improved
SUMMARY

• STARBUKS effort finished testing 27 September
  – Check Standard Model (CSM), Common Research Model (CRM), Centerline Pipe Calibration (CPC) and Flow Uniformity tests (Rake) have been completed

• FIDO effort continues
  – Desired data quality levels were achieved within series using computational and/or physical means
    • Preliminary Mach number variability to less than ±0.0005
    • Preliminary C\textsubscript{D} repeatability to less than ±0.0001 at cruise conditions

• Physical Means include VGs and 2\textsuperscript{nd} Throat
  – VGs were very effective in stabilizing low frequency characteristics associated with the high speed diffuser for empty tunnel configurations
  – VGs were NOT effective for the CRM transonic configuration
  – Choked second throat stabilized low frequency wind tunnel characteristics improving Mach number stability
Questions?

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Matthew Bailey
Roman Paryz

AIAA 2015-1557 Jones, et.al.
AIAA 2015-0622 Chan, et.al.
AIAA 2014-1481 Paryz
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
**Conditional Sampling**

- **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

\[
C_D \pm 0.0001
\]

\[
M \pm 0.0005
\]
**Correlation to the Speed of Sound**

**Mach = 0.85, Re_C = Vary, Station 13 Far Wall, Choked Configuration**

![Graph showing correlation between sound speed and Mach number](image)

- Model Interactions
- 1st Harmonic

<table>
<thead>
<tr>
<th>a (ft/sec)</th>
<th>T_o (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1105</td>
<td>122</td>
</tr>
<tr>
<td>941</td>
<td>-50</td>
</tr>
<tr>
<td>665</td>
<td>-250</td>
</tr>
</tbody>
</table>

Parameters used:
- Mach = 0.85
- Re_C = Vary
- Station 13 Far Wall
- Choked Configuration

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**Note:**
- The graph illustrates the correlation between the speed of sound and various parameters at different Mach numbers and Reynolds numbers.
- The 1st harmonic is highlighted to show the peak correlation points.
- Model interactions are marked to indicate areas of significant correlation.

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**Source:**
- National Transonic Facility
- NASA Langley Research Center

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CORRELATION WITH FREE STREAM VELOCITY

MODEL INTERACTIONS ARE NOT CORRELATED WITH MACH NUMBER

Station 13 Far Test Section Wall