Fundamental Aeronautics Program

Supersonics Project

Channeled Center-body Inlet Experiment Overview
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Channeled Center-body Inlet Experiment: Outline

- Experiment Description
  - Overview
  - Configuration
  - Flight Test Objectives
  - Test Points
  - Instrumentation
- Precursor Testing
- Flights
- Preliminary Data
- Future Work
Channeled Center-body Inlet Experiment:
Experiment Description - Overview

• Proof of concept experiment flown on NASA’s F15B T/N 836
  – Tested biconic supersonic inlet concept developed by Techland Research Inc.
    via a NASA SBIR contract
    • Inlet design features a unique method of off-design flow matching via movable
      channels rather than translating center-body
  – Pressure data was collected over a series of off design Mach numbers and
    mass flow conditions for two fixed geometry inlet configurations to determine
    differences between the two (with emphasis placed on distortion) as well as
    for comparison to CFD
    • Channeled Center-body
    • Equivalent Area Smooth Center-body
  – The design Mach number for the channeled center-body inlet is Mach 2.5, and
    the off-design condition of primary interest was Mach 1.5
Channeled Center-body Inlet Experiment:
Experiment Description - Configuration
Channeled Center-body Inlet Experiment: Experiment Description – Flight Test Objectives

• The primary research objective was to define the channeled center-body inlet flow as well as the equivalent area smooth center-body flow, and compare the two at off-design conditions. Evaluate the concept against the current norm for axisymmetric.

• The secondary research objective is to compare these flight results with current CFD predictions. Evaluate CFD predictive / design capabilities.
Six configurations were planned for flight
- Two center-body configurations
- Three fixed geometry nozzles to set mass flow
Two steady state test points planned per flight (Local Mach 1.3 and 1.5 at Aircraft Altitude of 40,000 ft)
## Channeled Center-body Inlet Experiment:
### Experiment Description – Instrumentation

### F-15B Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Qty</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
<th>SPS</th>
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<tr>
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<td>Aircraft total temperature</td>
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<td>deg</td>
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<tr>
<td>Noseboom angle of sideslip, deg</td>
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<td>deg</td>
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### Primary Experiment

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<tr>
<th>Experiment</th>
<th>Qty</th>
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Channeled Center-body Inlet Experiment: Precursor Testing

- PFTF Envelope Expansion / Cone Drag Experiment (CDE) 2001/2002
  - Performance -- defined max Mach test capability
  - Propulsion -- assessed force balance function, accuracy, and repeatability
  - Aerodynamics/propulsion -- assessed local flow quality
  - Verified acceptable handling quality characteristics
  - Instrumentation -- verified system function
  - Structural dynamics -- flutter clearance

- Local Mach Investigation (LMI) 2004
  - Provided local flow data for future propulsion flight experiments.
Channeled Center-body Inlet Experiment: Precursor Testing

Rake Airflow Gage Experiment (RAGE) 2008/2009

• Characterized flowfield at multiple locations on the inlet aerodynamic interface plane at the centerbody tip before flight test of the Channeled Centerbody Inlet Experiment
• Better enabled CFD comparisons by examining flow uniformity for more of the stream tube to be ingested
**Channeled Center-body Inlet Experiment:**

**Flights – Test Points (flown)**

<table>
<thead>
<tr>
<th>Date</th>
<th>CCIE Flight</th>
<th>Centerbody</th>
<th>Ath/Ain</th>
<th>836 Flight</th>
<th>Result</th>
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<tr>
<td>8/17/2011</td>
<td>1</td>
<td>Channeled</td>
<td>0.529</td>
<td>416</td>
<td>Steady state data collected at local Mach 1.3 and 1.5</td>
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<td>compressor stall</td>
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<td>compressor stall</td>
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<td>11/8/2011</td>
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<td>1.5</td>
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<td>1.5</td>
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<tr>
<td>12/14/2011</td>
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<td>Additional test points for local flow investigation flown. Data</td>
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<td>1/5/2012</td>
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<td>426</td>
<td>Repeat of Flight 422 local Mach 1.5 test point, and additional</td>
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<td>test points for test method evaluation: 0.5-2.0 G POPU performed</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to examine transients and a series of points varying angle of</td>
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<tr>
<td></td>
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<td>attack by varying local Mach and holding mass flow constant by</td>
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<tr>
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<td></td>
<td></td>
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<td>varying altitude were performed.</td>
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Channeled Center-body Inlet Experiment: Flights – Additional Test Points

- The CCIE on 836 offered an opportunity to obtain additional local flow and inlet performance data that would directly benefit CCIE and future experiments using the PFTF
  - Further quantified the local flow underneath the airplane
  - Gathered additional inlet performance data to provide additional flight data to benchmark computational models and aid in the design of future PFTF experiments
  - Evaluate test techniques and transient angle of attack capability

- The objectives of the additional flight were as follows:
  1) Characterize the local flow field out to a higher local Mach number (nominally 1.65 local Mach)
  2) Obtain steady state ECB data at 1.49 local Mach (repeated test point)
  3) Determine how changes in aircraft angle of attack affect the local flow properties and the inlet performance (POPU)
  4) Characterize inlet performance with respect to local flow angle, controlling for a constant mass flow rate
### Channeled Center-body Inlet Experiment: Flights – Additional Test Points

<table>
<thead>
<tr>
<th>Objective</th>
<th>CB</th>
<th>Ath</th>
<th>Local Mach Number</th>
<th>Aircraft Mach Number</th>
<th>Aircraft Altitude [Kft]</th>
<th>Local Qbar (psf)</th>
<th>Aircraft Qbar (psf)</th>
<th>Maneuver</th>
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<tbody>
<tr>
<td>Local Flow/Inlet Performance</td>
<td>Smooth</td>
<td>0.532</td>
<td>1.0-1.65</td>
<td>1.0-1.9</td>
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<td>300-1000</td>
<td>300-989</td>
<td>Accel</td>
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<tr>
<td>Local Flow/Inlet Performance</td>
<td>Smooth</td>
<td>0.532</td>
<td>1.65</td>
<td>1.9</td>
<td>40</td>
<td>1000</td>
<td>989</td>
<td>Steady</td>
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<tr>
<td>Inlet Performance</td>
<td>Smooth</td>
<td>0.532</td>
<td>1.49</td>
<td>1.65</td>
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<tr>
<td>Local Flow/Inlet Performance</td>
<td>Smooth</td>
<td>0.532</td>
<td>1.49</td>
<td>1.65</td>
<td>40</td>
<td>746</td>
<td>746</td>
<td>0.5-2g POPU</td>
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<tr>
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<td>1.60</td>
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<tr>
<td>Flow Angle - 1.0°</td>
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<td>Flow Angle 0.0°</td>
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<td>30.1</td>
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<td>*Flow Angle + 2.0°</td>
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<td>1.28</td>
<td>28.6</td>
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* Not Flown
Channeled Center-body Inlet Experiment: Preliminary Data – Test Conditions (representative)
Channeled Center-body Inlet Experiment: Preliminary Data – Pressure Recovery

Test Condition Averaged Pressure Recovery

Local Mach

Condition Averaged Pressure Recovery

416-C-529 1.5
416-C-529 1.3
416-C-529 1.3 repeat
419-C-532 1.5
419-C-532 1.3
419-C-532 1.3 repeat
420-C-548 1.5
420-C-548 1.3
420-C-548 1.3 repeat
421-S-529 1.5
421-S-529 1.3
421-S-529 1.3 repeat
422-S-532 1.5
422-S-532 1.3
422-S-532 1.3 repeat
423-S-548 1.5
423-S-548 1.3
423-S-548 1.3 repeat
426-S-532 1.5
Channeled Center-body Inlet Experiment:
Preliminary Data - Mass Capture Fraction

Test Condition Averaged Mass Capture Fraction

PRELIMINARY
Channeled Center-body Inlet Experiment:
Preliminary Data – Distortion Rake Port Locations

- Rake 1 (θ = 10°)
- Rake 2 (θ = 35°)
- Rake 3 (θ = 60°)
  - Ring 1 (r = 4.305 in)
  - Ring 2 (r = 3.866 in)
  - Ring 3 (r = 3.414 in)
  - Ring 4 (r = 3.087 in)
  - Ring 5 (r = 2.187 in)
Channeled Center-body Inlet Experiment: Preliminary Data – Distortion (basic)

Test Condition Averaged Distortion

Local Mach

Condition Averaged Rake Distortion

PRELIMINARY
Channeled Center-body Inlet Experiment:
Preliminary Data – Distortion (basic) separated by component

PRELIMINARY
Channeled Center-body Inlet Experiment: Preliminary Data – Total Pressure Contours

Flight 416 Ath/Ain .529 Rake Total Pressure (Channeled M=1.5 Run)

Flight 421 Ath/Ain .529 Rake Total Pressure (Smooth M=1.5 Run)

PRELIMINARY
Channeled Center-body Inlet Experiment:
Preliminary Data – Total Pressure Contours (Smooth variation)

Flight 421 Ath/Ain .529 Rake Total Pressure (Smooth M=1.5 Run)

Flight 421 Ath/Ain .529 Rake Total Pressure (Smooth M=1.5 Run)

Flight 421 Ath/Ain .529 Rake Total Pressure (Smooth M=1.5 Run)

PRELIMINARY
Channeled Center-body Inlet Experiment:
Preliminary Data – Total Pressure Contours (movies)

Flight 416 Ath/Ain .529 Rake Total Pressure (Channeled M=1.5 Run)

Flight 421 Ath/Ain .529 Rake Total Pressure (Smooth M=1.5 Run)

PRELIMINARY
Channeled Center-body Inlet Experiment: Future Work

- Data analysis and comparisons
  - Flight to Flight
  - Flight to CFD
- Data sharing
  - Data to GRC and Techland Research Inc
  - Data to Naval Air Warfare Center, Weapons Division at China Lake
- Reporting
- Extended capabilities studies
  - Variable geometry nozzle (turn 6 flights into 2-4 flights)
  - Force balance updates / calibration
  - Splitter plate to clean up local flow
- Examine follow on testing possibilities
  - Buzz studies in flight
  - If warranted further examination of channeled center-body configuration
    - Full-face distortion measurements
    - Distortion correction (flow fences etc)