Quiet SuperSonic Technology (QueSST) Aircraft Preliminary Design Status and Low-Boom Flight Demonstration (LBFD) Project Update

David Richwine, DPM for Technology
Jay Brandon, Chief Engineer

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Outline

• Overview and Relevance
• Concept of Operations
• Requirements
• QueSST Design Features
• Concept Assessment
• Wind Tunnel Validations
• Future Plans
Innovation in Commercial Supersonic Flight

Why?: Commercial supersonic flight represents a potentially large new market for aircraft manufacturers and operators world-wide

• Global demand for air travel is growing, which places a demand on speed

• Supersonic aircraft will be excellent export products that can be capitalized on by the US to support a positive balance of trade

• New supersonic products lead to more high-quality jobs in the US
  – Large potential market predicted: - business aircraft followed by larger commercial aircraft
  – Technology leadership established through initial products will lead to development of larger, more capable airliners

• The government plays a central role in developing the data needed for regulation change that is essential to enabling this new capability
Barriers to Commercial Supersonic Flight: Sonic Boom Noise and Overland Flight Prohibitions

- Planned introduction of supersonic commercial transports in 1970’s brought the problem of sonic boom noise to public attention
- Community overflight tests in the US and elsewhere showed sonic boom noise to be unacceptable
- Supersonic overflight restrictions followed
  - US: FAA Regulation (FAR) prohibits supersonic flight over US
  - Worldwide: ICAO Assembly Resolution – “No unacceptable situation for the public due to sonic boom”
- Restriction dramatically limited market potential for supersonic commercial aircraft

The vision of the Supersonics Community is a future where fast air travel is available for a broad spectrum of the traveling public.
- Future supersonic aircraft must be able to fly overland without creating an “unacceptable situation” and compared to Concorde, be efficient & green
- The creation of overland certification requirements based on acceptable noise levels will enable this vision
Background and Overview

Overcome the sonic boom barrier and open the door for development of a new generation of environment-friendly supersonic civil transport aircraft

Overall Requirement

- Demonstrate that noise from sonic booms can be reduced to a level acceptable to the population residing under future supersonic flight paths
- Create a community response database that supports an International effort to develop a noise based rule for supersonic overflight

Approach

- Partner with regulatory agencies and communities to create a roadmap for community response study and rule development – with Commercial Supersonic Technology (CST) Project in Phase 3
- Revitalize the excitement of manned X-Planes using a focused and cost-effective approach to design and operate a low boom research aircraft
- Partner with industry and OGAs to formulate, obtain approval and execute
Roles - Supersonic Overland Flight

- NASA has invested in supersonic tools and technologies in partnership with US industry
- Unique NASA role in development of demonstrator
- NASA leadership provides the key data required to determine certification standards for supersonic overland flight
Quiet SuperSonic Technology (QueSST) preliminary design has built a solid technical foundation moving forward with the Low-Boom Flight Demonstration (LBFD).
Sonic Boom 101

Sonic Boom with Atmospheric Effects

Altitude, ft
~60,000

~30,000

~2,000

Ground level

Macro atmospheric effects
Pressure
Temperature
Winds

Micro atmospheric effects
Atmospheric absorption (relative humidity)
Turbulence effects
Concept of Operations

Project Phases

Concept Studies

QueSST Preliminary Design

Phase 1 - Aircraft Development (LBFD)
- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion

Phase 2 – Acoustic Validation
- Aircraft Operations / Facilities (LBFD)
- Research Measurements (CST)

Proposed follow-on under CST

Phase 3 – Community Response
- Initial community response overflight study
- Multiple campaigns (4 to 6) over representative communities and weather across the U.S.
<table>
<thead>
<tr>
<th>Key Mission Requirements</th>
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<tr>
<td>Ground signature traceability (indoor) - with peak acoustic energy ≤ 10 Hz</td>
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<td>Ground signature loudness (outdoor) ≤ 75 PLdB throughout boom carpet</td>
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<td>Ground signature variability 70 - 80 PLdB</td>
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<td>Cruise deviations (turbulence) - ground signature ≤ 76 PLdB and ≤ 1.4 PLdB RMS</td>
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<td>Cruise Mach ≥ 1.4</td>
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<td>Two passes ≥ 50 nm in length per flight, passes ≥ 20 minutes apart</td>
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<td>Three flight operations / day</td>
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<td>Day and night flight operations in the public airspace</td>
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<td>IFR flight operations</td>
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<td>Forward visibility (see-to-avoid/land)</td>
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<td>Low/no-focus supersonic acceleration/climb performance</td>
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<td>Mission performance (hot day)</td>
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<td>Potential for alternate fuels</td>
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QueSST Aircraft Preliminary Design Overview

- **COTS engine**
  - Provides desired combination of performance and reliability, stock nozzle reduces complexity and cost

- **Extended Nose with area shaping to reduce forward shock**

- **Canopy, Seat, and Crew Escape Systems**
  - Workable moldline and minimizes qualification costs

- **Fixed Canard provides nose-up trim**

- **T-tail to minimize and tailor aft shock**

- **Wing Shielding to reduce impact of inlet spillage on sonic boom**

- **Conventional Tail Arrangement simplifies stability and control challenges**

- **F-16 Block 25 Landing Gear & Flight Systems**

- **Extended Nose with area shaping to reduce forward shock**

- **Fiber Optic Bending System (FOSS)**
  - Fiber optic strain measurement system to measure bending and twist of the wing and stabilator

- **Extended Vision System (XVS)**
  - Ultra-High Definition video display and symbology system to replace forward vision for the pilot

- **Flight Test Instrumentation System (FTIS)**
  - Sensor/data acquisition, time, data/audio/video recording, and telemetry for the research aircraft

- **Design provides a cost-effective solution to meet the low-boom design requirements, NASA-Provided Flight Systems and GFE are leveraged to enhance aircraft capabilities and provide key value added opportunities**
eXternal Vision System (XVS)

XVS - enabling technology - combination of Ultra-High-Definition (UHD) sensor, display, and image processing technologies to provide visibility of the external scene for the flight crew and comparable to forward-facing windows in conventional aircraft.
Concept Assessments

Sonic Boom

Aerodynamic Performance

Handling Qualities

Mach =0.40 , AoA =12.0
Other Concept Assessments

Inlet Flow / Vortex Generators

C606
\[ h_{vg} = 2.4 \text{ in} \]
\[ L_{vg} = 4.1 \text{ in} \]
\[ \alpha_{vg} = 12 \, \text{deg} \]
\[ N_{vg} = 8 \]

VGs #6B
\[ h_{vg} = 0.5 \text{ in} \]
\[ L_{vg} = 2.5 \text{ in} \]
\[ \alpha_{vg} = 20 \, \text{deg} \]
\[ N_{vg} = 16 \]

VGs h75
\[ h_{vg} = 0.75 \text{ in} \]
\[ L_{vg} = 3.75 \text{ in} \]
\[ \alpha_{vg} = 20 \, \text{deg} \]
\[ N_{vg} = 10 \]

Alt #2
\[ h_{vg} = 1.2 \text{ in} \]
\[ L_{vg} = 9.0 \text{ in} \]
\[ \alpha_{vg} = 20 \, \text{deg} \]
\[ N_{vg} = 6 \]

Structural Modeling

C607 Finite Element Model

Trade Studies (Brake vs Drag Chute)

Landing distance over 35ft obstacle.
Actual touchdown point is 2400ft beyond obstacle.

5000', Std-Day: 8200 ft
Sea level, Hot: 7000 ft

Aeroelastic deformation under 1-g cruise condition used to derive jig shape.
Wind Tunnel Validations

Low-and high-speed Aerodynamic and Propulsion Airframe Interaction (PAI) wind-tunnel tests to validate predictions/data and ensure readiness of the QueSST Preliminary Design

Credit: Lockheed Martin Corporation
**LBFD – Future Plans**

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<tr>
<th>Commercial Supersonic Technology (CST) Project</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
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<th>FY20</th>
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<tr>
<td>QueSST Planning, Concept Development and Preliminary Design</td>
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<td>CST Community Response Research</td>
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<td>ASRR</td>
<td>PDR</td>
<td>Post-PDR Option</td>
<td>Validated Field Study Methodology</td>
<td>Community Noise Validation</td>
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| Low Boom Flight Demonstration (LBFD) Project   |      |      |      |      |      |      |      |      |      |
| LBFD Aircraft Design, Build & Validate        |      |      |      |      |      |      |      |      |      |
|                                                | RFP Release | Contract Award | DPDR | CDR | First Flight | Boom Signature Validation | Envelope Expansion |

| Sonic Boom Noise Standard (FAA - ICAO)         |      |      |      |      |      |      |      |      |      |
| CAEP 10 Metric Selection                      |      |      |      |      |      |      |      |      |      |
| CAEP 11 Metric Validation                     |      |      |      |      |      |      |      |      |      |
| CAEP 12 Prelim Sonic Boom Standard             |      |      |      |      |      |      |      |      |      |

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<tr>
<th>CST Milestones</th>
<th>LBFD Milestones</th>
<th>NASA Input to CAEP</th>
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CAEP – Committee on Aviation and Environmental Protection  
ICAO – International Civil Aviation Organization  
ASRR – Aircraft Systems Requirement Review
Any Questions?