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

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Credit: Lockheed Martin Corporation
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)

History – Formulation and Concept Studies

<table>
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<tr>
<th>Concept Development</th>
<th>Pre-Phase A Concept Studies</th>
<th>Phase A Concept &amp; Technology Development</th>
<th>Phase B PD &amp; Technology Completion</th>
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<tr>
<td></td>
<td>Concept Formulation Studies (CFS)</td>
<td>LBFD Concept Refinement Studies (CRS)</td>
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<td>KDP A/B</td>
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- **Mission Concept Review (MCR)**: 9/2013
- **Mission Design Review (MDR)**: 3/2014
- **Systems Requirements & Design Review (SRDR)**: 9/2015
- **Aircraft Systems Requirements Review (ASRR)**: 6/2016
- **KDP A/B**: 8/2016
- **Preliminary Design Complete**: 6/2017
- **PDR**: 2/2018

FY13 FY14 FY15 FY16 FY17 FY18

- FY13: Pre-Phase A Concept Studies
- FY14: Phase A Concept & Technology Development
- FY15: Phase B PD & Technology Completion

**QueSST Preliminary Design**

**Preliminary Design Review (PDR)**

**LBFD Project**
Sonic Boom 101

Sonic Boom with Atmospheric Effects

Macro atmospheric effects:
- Pressure
- Temperature
- Winds

Micro atmospheric effects:
- Atmospheric absorption (relative humidity)
- Turbulence effects

Ground level

Altitude, ft
~60,000
~30,000
~2,000

Boom Signature Carpet
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.
## Mission Requirements

<table>
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<tr>
<th>Key Mission Requirements</th>
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<tr>
<td>Ground signature traceability (indoor) - with peak acoustic energy $\leq 10$ Hz</td>
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<tr>
<td>Ground signature loudness (outdoor) $\leq 75$ 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 $\leq 76$ PLdB and $\leq 1.4$ PLdB RMS</td>
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<td>Cruise Mach $\geq 1.4$</td>
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<td>Two passes $\geq 50$ nm in length per flight, passes $\geq 20$ 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

Conventional Tail Arrangement simplifies stability and control challenges

Wing Shielding to reduce impact of inlet spillage on sonic boom

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

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

Fixed Canard provides nose-up trim

F-16 Block 25 Landing Gear & Flight Systems

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

Extended Nose with area shaping to reduce forward shock

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
Other Concept Assessments

Inlet Flow / Vortex Generators

- C606
  - \( h_{\text{vg}} = 2.4 \text{ in} \)
  - \( L_{\text{vg}} = 4.1 \text{ in} \)
  - \( \alpha_{\text{vg}} = 12 \text{ deg} \)
  - \( N_{\text{vg}} = 8 \)

- VGs #6B
  - \( h_{\text{vg}} = 0.5 \text{ in} \)
  - \( L_{\text{vg}} = 2.5 \text{ in} \)
  - \( \alpha_{\text{vg}} = 20 \text{ deg} \)
  - \( N_{\text{vg}} = 16 \)

- VGs h75
  - \( h_{\text{vg}} = 0.75 \text{ in} \)
  - \( L_{\text{vg}} = 3.75 \text{ in} \)
  - \( \alpha_{\text{vg}} = 20 \text{ deg} \)
  - \( N_{\text{vg}} = 10 \)

- Alt #2
  - \( h_{\text{vg}} = 1.2 \text{ in} \)
  - \( L_{\text{vg}} = 9.0 \text{ in} \)
  - \( \alpha_{\text{vg}} = 20 \text{ deg} \)
  - \( N_{\text{vg}} = 6 \)

Structural Modeling

C607 Finite Element Model

Trade Studies (Brake vs Drag Chute)

- Brake Energy (million Btu)
- Brake Application Speed (knots)
- Landing Distance (ft)

- 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.
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<tr>
<th>Commercial Supersonic Technology (CST) Project</th>
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<td>QueSST Planning, Concept Development and Preliminary Design</td>
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<td>ASRR</td>
<td>PDR</td>
<td>Post-PDR Option</td>
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<td>CST Community Response Research</td>
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<th>Low Boom Flight Demonstration (LBFD) Project</th>
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<td>LBFD Aircraft Design, Build &amp; Validate</td>
<td>RFP Release</td>
<td>Contract Award</td>
<td>DPDR</td>
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<td>Envelope Expansion</td>
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<th>Sonic Boom Noise Standard (FAA - ICAO)</th>
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<td>CAEP 11 Metric Validation</td>
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<td>CAEP 12 Prelim Sonic Boom Standard</td>
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<td>CAEP 12 Prelim Sonic Boom Standard</td>
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- **CST Milestones**
- **LBFD Milestones**
- **NASA Input to CAEP**

**CAEP** – Committee on Aviation and Environmental Protection
**ICAO** – International Civil Aviation Organization
**ASRR** – Aircraft Systems Requirement Review
Any Questions?