Overview of Low-Boom Flight Demonstration Mission and X-59 QueSST Aircraft

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Presentation Topics

• Overview: NASA’s Aeronautics Strategy
• Barriers to Successful Supersonic Commercial Aircraft
• Sonic Boom 101
• Low-Boom Flight Demonstration Mission
• Overview of X-59 Aircraft Features and Design
• Aircraft Fabrication Video
• If time permits, X-plane Simulation (2019 Summer Interns)
NASA Aeronautics
NASA Aeronautics Vision for Aviation in the 21st Century

Global Sustainable
Transformative

U.S. leadership for a new era of flight

NASA’s Aeronautics Research Mission Directorate (ARMD) continues to evolve and execute the Aeronautics Strategy https://www.nasa.gov/aeroresearch/strategy

Safe, Efficient Growth in Global Operations
- Achieve safe, scalable, routine, high-tempo airspace access for all users

Innovation in Commercial Supersonic Aircraft
- Achieve practical, affordable commercial supersonic air transport

Ultra-Efficient Subsonic Transports
- Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy

Safe, Quiet, and Affordable Vertical Lift Air Vehicles
- Realize extensive use of vertical lift vehicles for transportation and services including new missions and markets

In-Time System-Wide Safety Assurance
- Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

Assured Autonomy for Aviation Transformation
- Safely implement autonomy in aviation applications
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 U.S. to support a positive balance of trade.
- New supersonic products lead to more high-quality jobs in the U.S.
  - 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 the regulation change that is essential to enabling this new market.
Overcoming the Barrier to Overland Flight

- New Environmental Standards are needed to open the market to supersonic flight
- An En route Noise Standard is the biggest challenge
  - Requires proof of new design approaches
  - Must replace current prohibitions
  - No relevant data exists to define limits
- Community data from large, diverse population is a requirement
  - Standard must be accepted internationally

The Low-Boom Flight Demonstration mission is specifically planned to generate key data for success in NASA’s Critical Commitment to support development of en route certification standards based on acceptable sound levels.
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 will not only be able to fly overland without creating an “unacceptable situation” but compared to Concorde and SST will be efficient, affordable and environmentally responsible.

The emerging potential market has generated renewed interest in civil supersonic aircraft

- Evidenced by the appearance of several commercial programs even with existing restrictions on overland flight and other challenges.
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

Boom Signature Carpet

Cruise boom signature
Transition focus boom signature
Primary boom carpet
Secondary boom carpet
Lateral cutoff boom signature
Secondary boom signature
Impulsive Noise Sources – Perceived Level, decibels (dB)

- Gunshot: 135 dB
- Firework: 130 dB
- Balloon pop: 125 dB
- Concorde sonic boom: 120 dB
- Car door slam recorded inside the car: 115 dB
- Nearby thunder: 110 dB
- Hand clap: 105 dB
- Nail struck by hammer: 100 dB
- Car door slam recorded outside the car: 95 dB
- Basketball bounce: 90 dB
- X-59 sonic thump: 85 dB
- Car door slam recorded across the street: 80 dB
- Distant thunder: 75 dB
- Car door slam recorded down the block: 70 dB
- Basketball: 65 dB
- Car door slam recorded across the street: 60 dB

Sources:
- Gunshot
- Firework
- Balloon pop
- Concorde sonic boom
- Car door slam recorded inside the car
- Nearby thunder
- Hand clap
- Nail struck by hammer
- Car door slam recorded outside the car
- Basketball bounce
- X-59 sonic thump
- Car door slam recorded across the street
- Distant thunder
- Car door slam recorded down the block
Low-Boom Flight Demonstration Mission Overview

**Phase 1 – Aircraft Development**
- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion

**Phase 2 – Acoustic Validation**
- In-flight and ground measurement capabilities
- Aircraft Operations / Facilities

**Phase 3 – Community Response**
- Initial community response overflight study based at NASA AFRC
- Multiple campaigns (4 to 5) over representative communities and climate across the U.S.

Systematic Approach Leading to Community Testing
Prediction Tools and Validation

Challenge

In preparation for community response testing, NASA will provide a suite of prediction tools to support timely and accurate validation of the acoustic performance of the X-59 aircraft, rapid pre-flight exposure planning for Community Testing, and provide a foundation for future configuration design and certification analysis of supersonic aircraft.

Acoustic Propagation

High Fidelity CFD

Uncertainty Quantification
Acoustic Validation Test Planning and Execution

Challenge

• Develop and demonstrate LBFD mission Phase 2 capabilities to safely measure in-flight:
  - Near-field acoustic characteristics of the LBFD aircraft
  - Atmospheric effects on the far-field acoustic pressure signatures
Community Test Planning and Execution

Challenge:

- Create a robust community response relationship for annoyance vs appropriate noise metrics
- Large populations, large number of representative responses.
  - 10k to 100k, depending on survey method employed
  - Varied community settings
- Range of 6-8 daily exposures required
- 4-5 test campaigns in different locations around U.S.
- Engage the international research & regulatory community to ensure data acceptance
Low Boom Flight Demonstration Mission

Concept of Operations – Representative Community Response Deployment

Systematic Approach Leading to Community Testing
X-59 QueSST Aircraft Features

**X-plane approach that meets key requirements in a cost-effective design**

- **External and forward visions systems for forward visibility**

- **T-38 aft canopy and ejection seat to minimize qualification cost and schedule**

- **Long nose to shape forward shock**

- **Fixed canard for nose-up trim at low-boom design point**

- **Large, unitized skins reduce parts count and manufacturing cost**

- **Wing shielding to minimize impact of inlet spillage on sonic boom**

- **F-16 landing gear and other systems from high performance aircraft to minimize qualification cost and schedule**

**Design Parameters**

- **Length**: 96.8 ft
- **Span**: 29.5 ft
- **Speed**: Mach 1.4 (925 mph)
- **Altitude**: 55,000 ft

**Image Credit**: Lockheed Martin
X-59 eXternal Vision System (XVS)

• XVS is designed to provide forward vision for X-59
  - Enhances mission performance for the community test phase

• System components
  - NASA developed 4k camera system
  - Display with integrated symbology
  - Commercial Enhanced Vision System (EVS) camera components

• System performance verified in recent flight test
  - X-59 hardware installed on NASA UC-12 aircraft
  - Several guest pilots compared normal vision and XVS on see-to-avoid and see-to-follow tasks

• Final component checkout, qualification and delivery for installation into X-59 aircraft

• NASA has maintained continuous engagement with FAA to ensure seamless NAS operations
X-59 QueSST Aircraft Wind Tunnel Validations

Low-and high-speed aerodynamic and Propulsion Airframe Interaction (PAI) wind-tunnel tests validate predictions and ensure readiness of the design

Credit: Lockheed Martin
Aircraft and cockpit simulations validate aircraft designs, systems, and performance – also used for pilot training and flight planning.
X-59 QueSST Aircraft Assessments

Sonic Boom

Aerodynamic Performance

Structural Modeling

Handling Qualities
X-59 QueSST Aircraft Fabrication and Integration

Aircraft Fabrication

Credit: Lockheed Martin

F414-100 Engine Testing and Delivery

Credit: General Electric
Low-Boom Flight Demonstration

The Vehicle

NASA's first purpose-built, supersonic X-plane in decades will soon take to the skies. Final design, construction, and assembly of the vehicle is targeted to be complete by 2021. A single pilot is to fly the 96.8-foot-long, 26.5-foot-wide aircraft powered by a single jet engine. Its design research speed will be Mach 1.42, or 540 mph, flying at 55,000 feet.

X-59 Specifications

www.nasa.gov/lowboom
X-59 QueSST Aircraft Fabrication Video