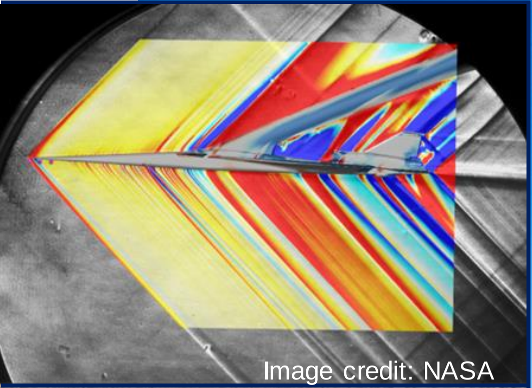
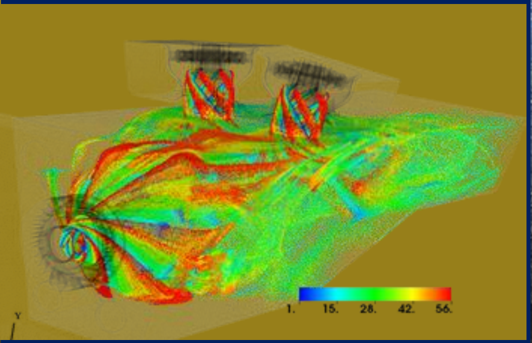


Image credit: NASA

Image credit: NASA

Image credit: NASA



Status and Advances in Commercial Supersonic Technology

173rd Meeting of the Aeronautics and Space Engineering Board
June 11-12, 2024

Lori Ozoroski, Manager, NASA Commercial Supersonic Technology Project

Illustration Credit: Lockheed Martin

Outline

Background

NASA Research Portfolio

Quesst Mission Progress/Status

Other Commercial Supersonic Progress

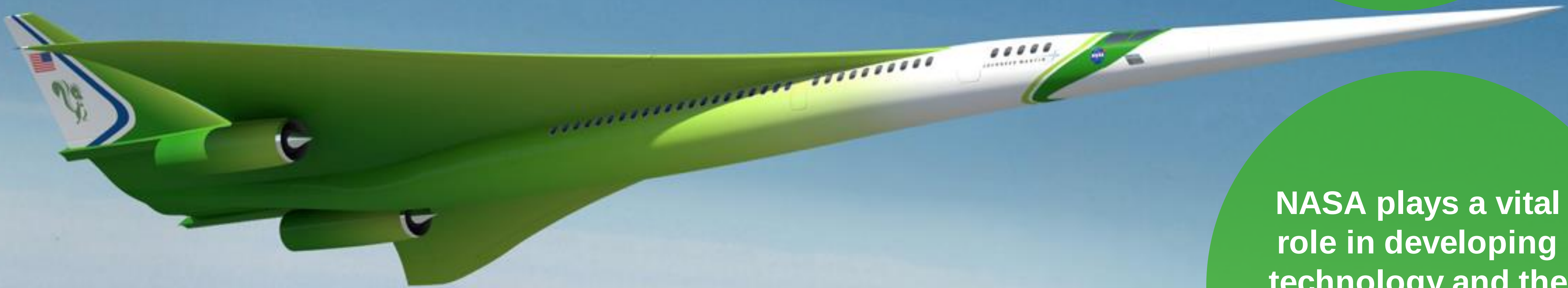
Summary

Vision for Commercial Supersonic Flight

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

- Evidenced by the appearance of several commercial programs despite lack of standards for en route noise or landing and takeoff noise, emissions

Overland Flight Restrictions based on unacceptable sonic boom noise are viewed as the main barrier to this vision



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 will also be environmentally responsible, affordable and sustainable

NASA plays a vital role in developing technology and the data that will enable this transformative new market

Illustration Credit: Lockheed Martin

Barriers to Practical Commercial Supersonic Aircraft

Environmental Barriers

Airport Noise

- Noise levels not louder than subsonic aircraft at appropriate airports

Sonic Boom

- Design for low noise sonic boom
- Understand Community Response

High Altitude Emissions

- No or minimal long-term impact at supersonic cruise altitudes

Light Weight, Durable Vehicles

- Low airframe and propulsion weight in a slender flexible vehicle operating at supersonic cruise temperatures

Efficient Operations

- Airspace-Vehicle interaction for full utilization of high speed

Efficient Vehicles

- Efficient airframe and propulsion throughout flight envelope

Efficiency Barriers

NASA Commercial Supersonics Technology (CST) Project Portfolio

Sonic Boom
- Improved CFD nearfield prediction capabilities
- Low sonic boom design tool development
- Technologies for boom mitigation and awareness
- Improved propagation modeling tools
- Community Response Testing
- Focus & secondary booms

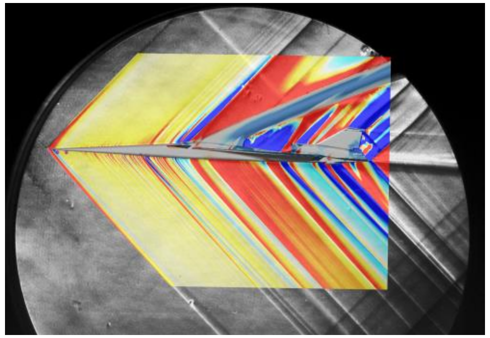
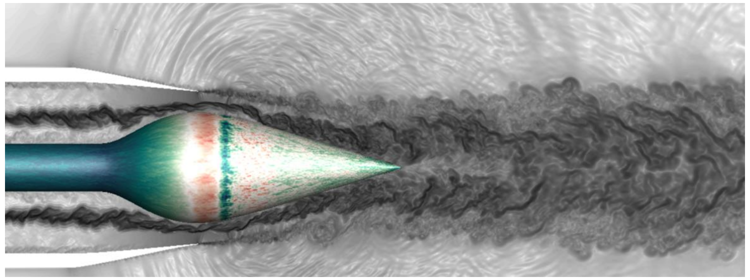
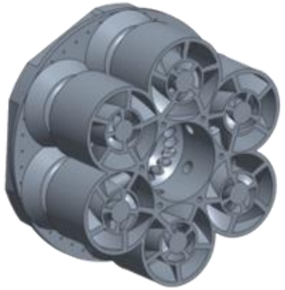


Illustration Credit: Lockheed Martin

Efficient Vehicles
- Enhanced CFD tools
- Highly integrated propulsion and airframe conceptual designs
- System level highly integrated multi-fidelity design methods
- Drag reduction technologies
- Advanced engine architectures

Airport Noise
- Reducing prediction uncertainty
- Improving system models
- Noise reduction technologies
- Highly integrated propulsion and airframe solutions

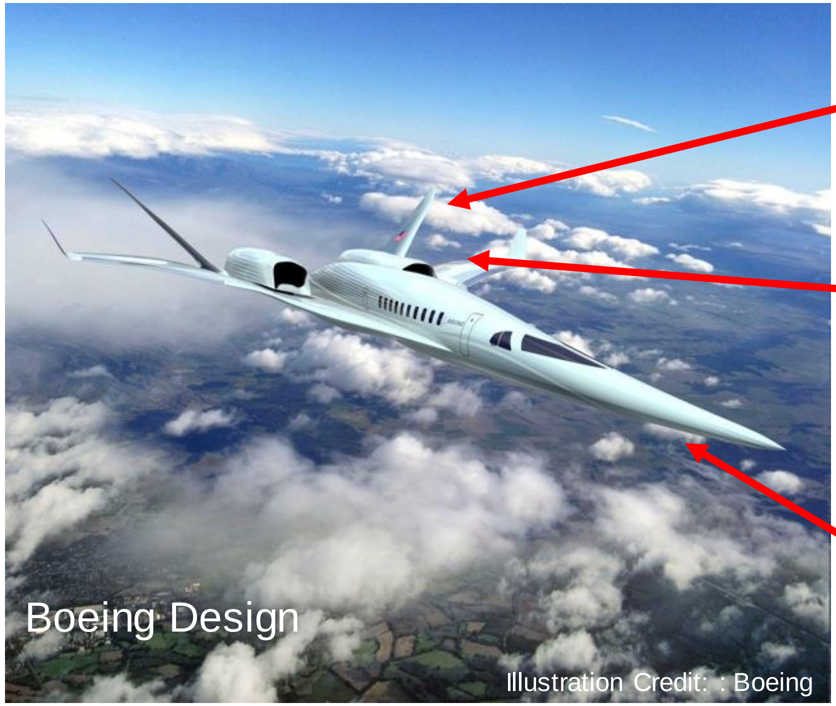




High Altitude Emissions
- Ultra Low NOx combustors
- Advanced high temp combustor materials
- Fuel composition impact on emissions

Addressing barriers to sustainable commercial supersonic flight

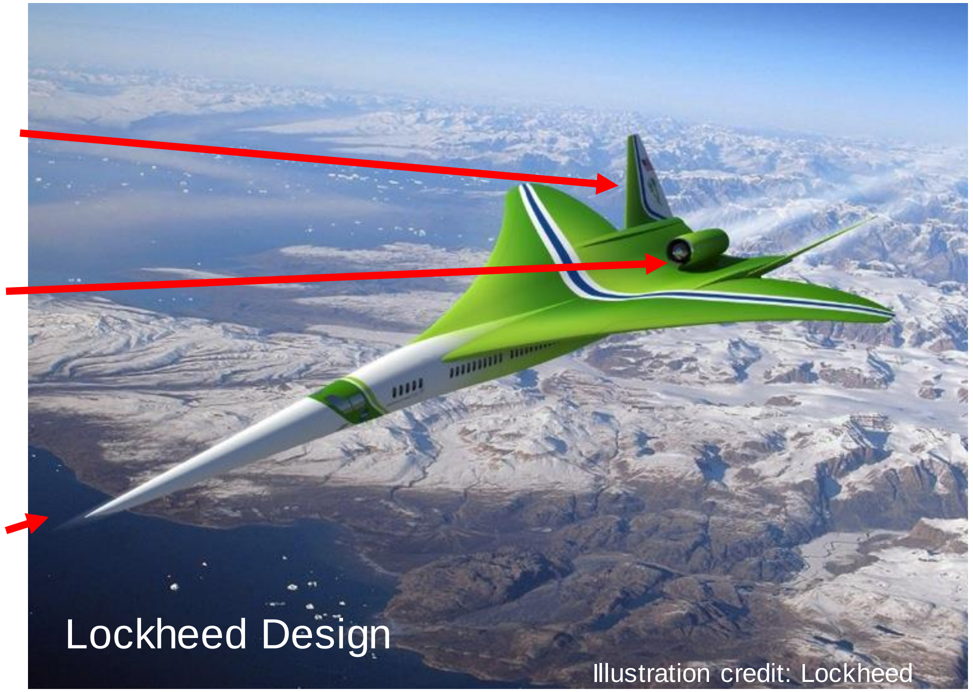
Catalyst: Design studies showing the potential for quiet supersonic airliners



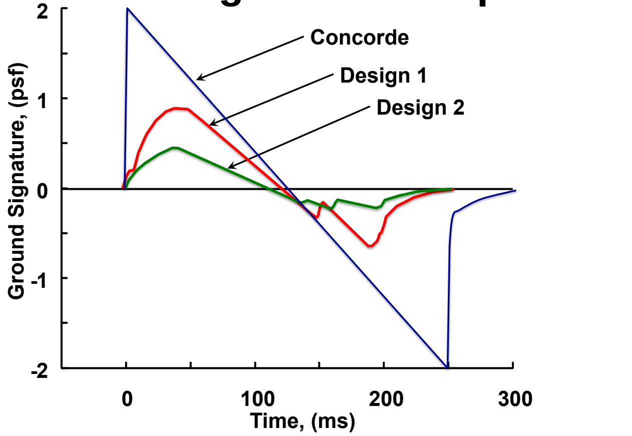
Unique empennage shape to control lift impact on signature

Propulsion installation minimizes contribution to signature

Integrated 3-D design of fuselage shape, wing planform camber & thickness



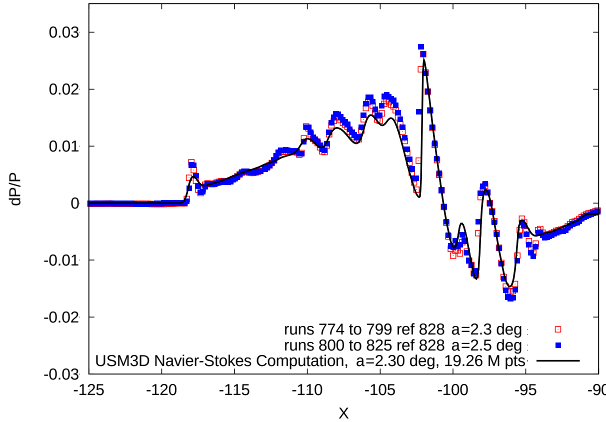
Ground signature comparison



Breakthrough Knowledge Advancement

Methodologies for the development of aircraft with shaped sonic boom signatures, particularly in the aft end of the vehicle where complex interaction between lift and volume effects takes place, have been applied to integrated systems level designs and validated through wind tunnel testing. Low boom targets have been met for small airliner type

Wind tunnel/analysis comparison



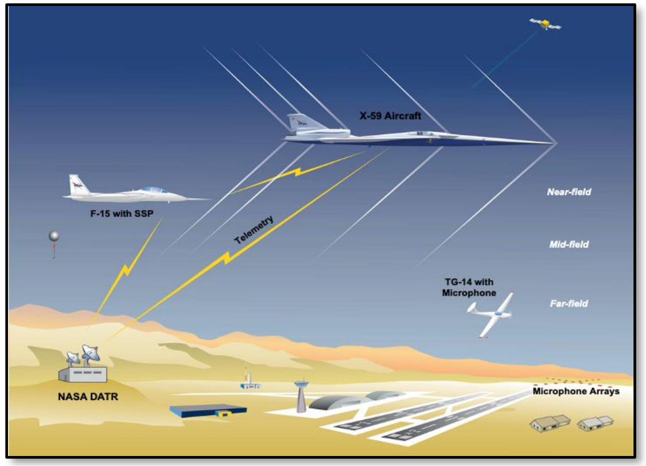
Quesst Mission Timeline

The Quesst mission generates key data to enable supersonic overflight standards based on acceptable sound levels

Credit: *Lockheed Martin*

Phase 1 – X-59 Aircraft Development

- Aircraft design, fabrication, and ground test
- Checkout and envelope expansion



Phase 2 – Acoustic Validation

- Detailed ground and flight measurements
- Validation of sonic boom signature and prediction tools

Credit: *Lockheed Martin*

Phase 3 – Community Response

Community response overflights, ground measurements, and surveys over representative communities across the U.S.

Phase 1: Building the X-59 – A Team Effort

LOCKHEED MARTIN

Prime Contractor for design, fabrication, integration and test


Image credit: NASA

F414-GE-100 Engine
Supplied by General Electric

Over 50 Companies Worldwide


Image credit: Lockheed Martin

Supplier Manufactured Components

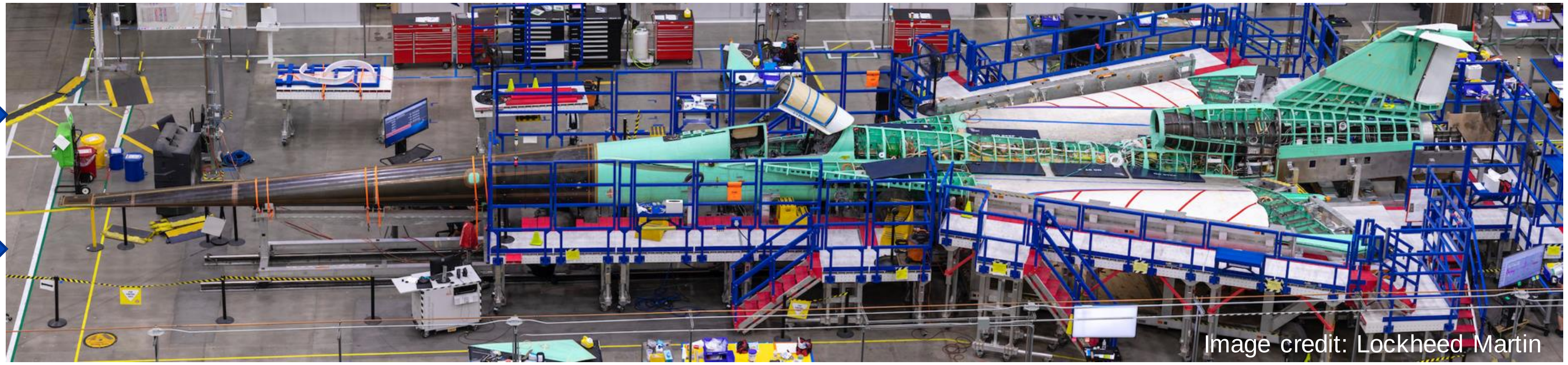


Image credit: Lockheed Martin

NASA


Illustration credit: NASA

Key systems:
- eXternal Vision (XVS)
- Flight Test Instrumentation (FTIS)


Image credit: NASA


Image credit: Lockheed Martin

Donor aircraft components and other GFE:
Over 500 items from landing gear to canopy


Image credit: NASA

Ground Service Equipment
Over 100 items

Overview of X-59 Aircraft

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

Long nose to shape forward shock

External and forward visions systems for forward visibility

Conventional Materials and Fabrication

Completely new airframe design needed to create quiet supersonic acoustic signature

- Numerous systems from high performance aircraft to minimize qualification cost and schedule

Single GE-F414 engine with standard nozzle to minimize cost and schedule

NASA Airworthiness processes leading to certification as a public use aircraft

Design Parameters

- **Length: 99 ft**
- **Span: 29.5 ft**
- **Speed: Mach 1.4 (925 mph)**
- **Altitude: 55,000 ft**

Major external design features are traceable to airliner designs

Illustration Credit: Lockheed Martin

X-59 Aircraft Rollout – January 2024

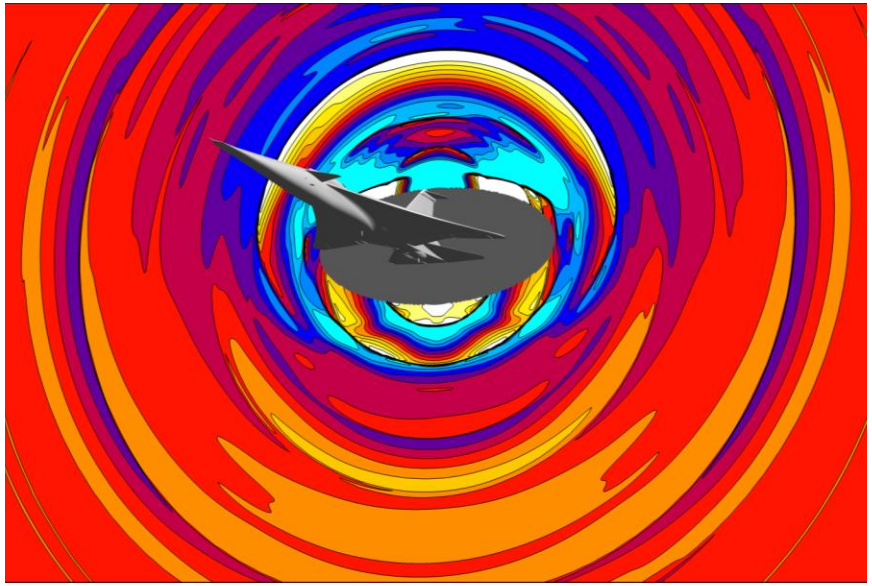
Photo Credit: Lockheed Martin

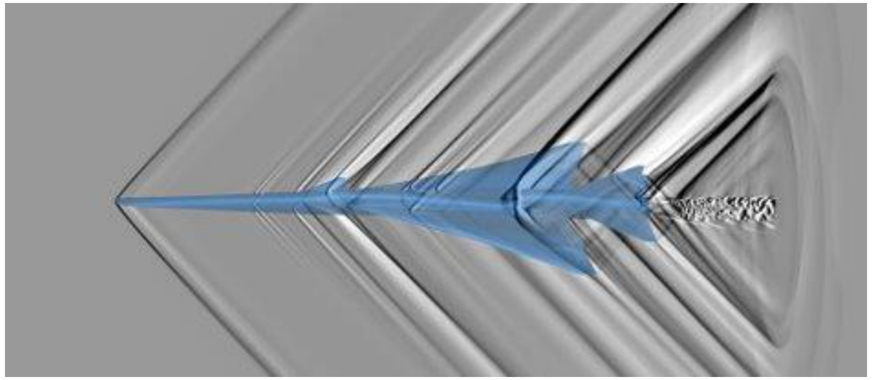
Phase 2 Acoustic Measurements

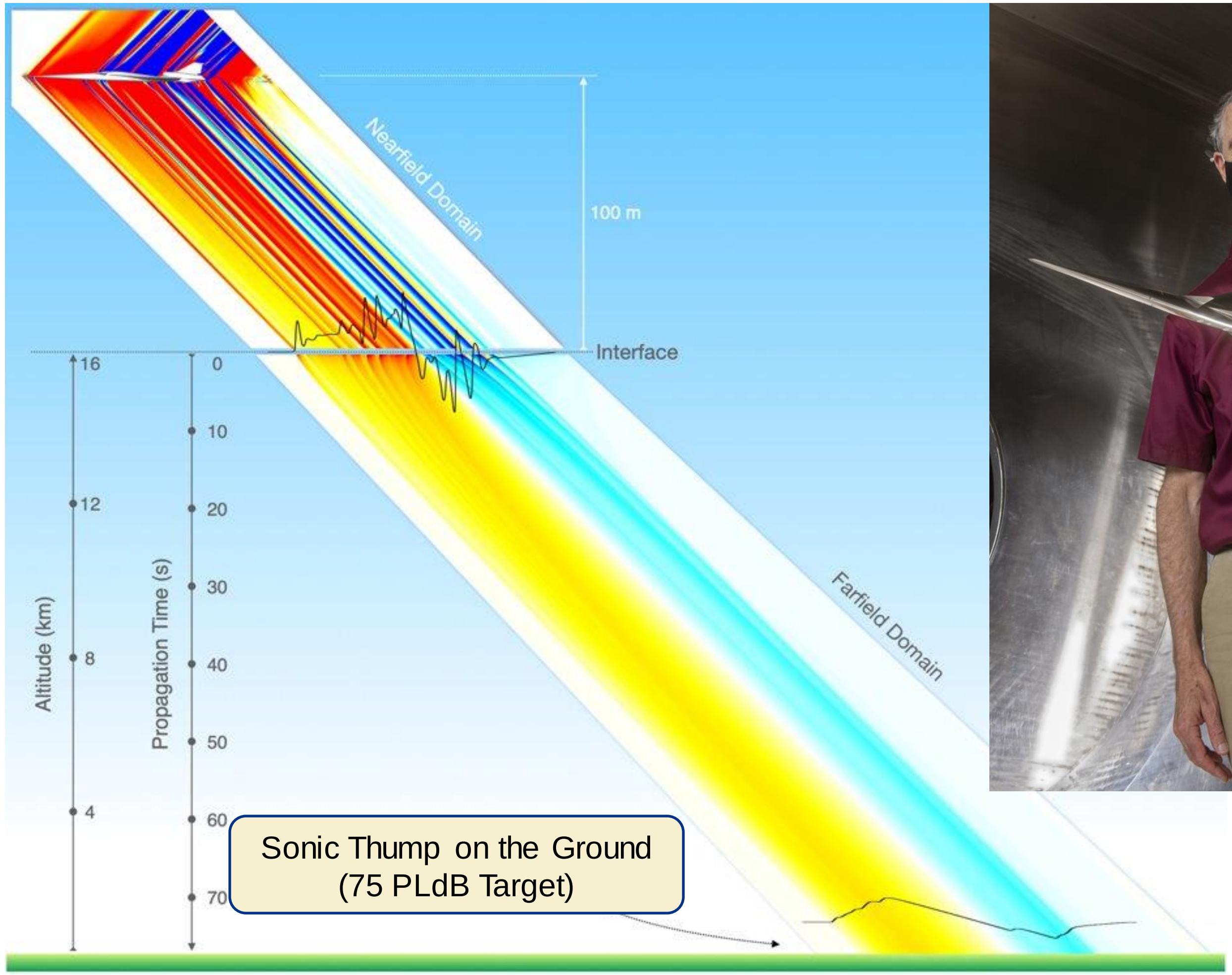
Image credits: NASA

- New State-of-the Art Ground Recording System (GRS) developed by Crystal Instruments, Inc.
- In January 2024, NASA completed a series of risk reduction tests for Phase 2 logistics & GRS deployment
- Progress continues on airborne acoustic measurement systems (Shock Sensing Probe, ALIGNS, In-flight Schlieren)

Phase 2 Acoustic Predictions

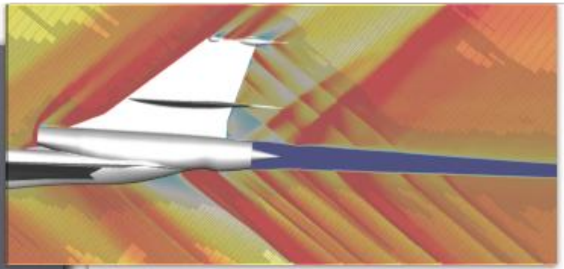


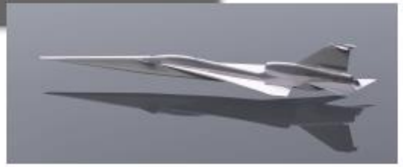




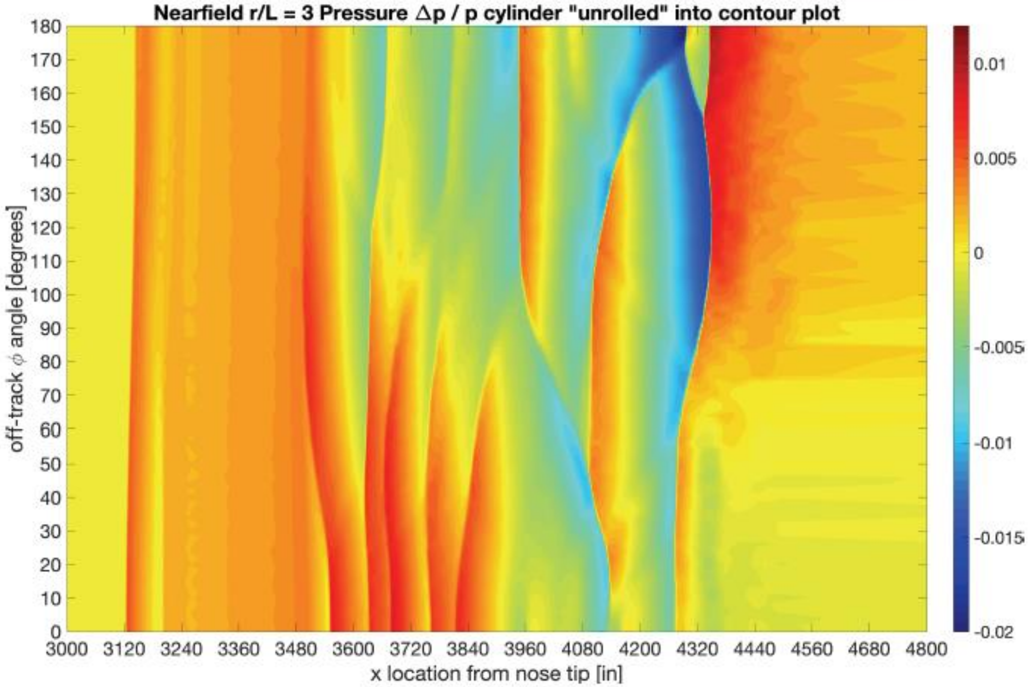
- Significant improvements in computational tool accuracy have been validated through wind tunnel experiments
- Refinements to acoustic propagation tools and atmospheric turbulence models
- Tools are ready for use in support of acoustic validation and community testing

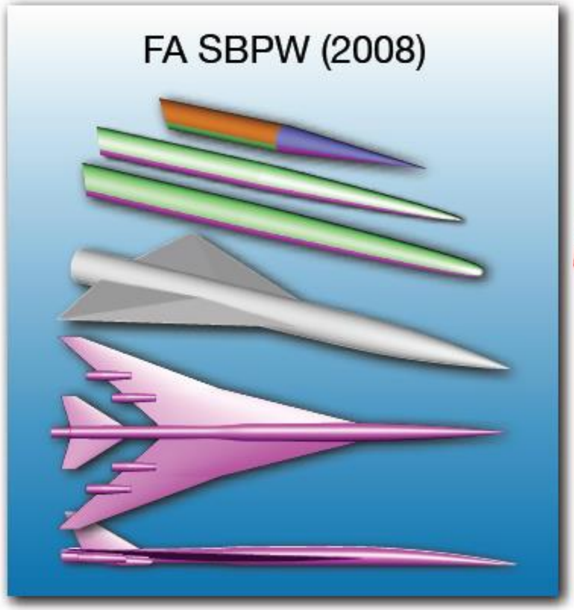
Nearfield Simulation Development to the Present





Third AIAA SPBW (2020)



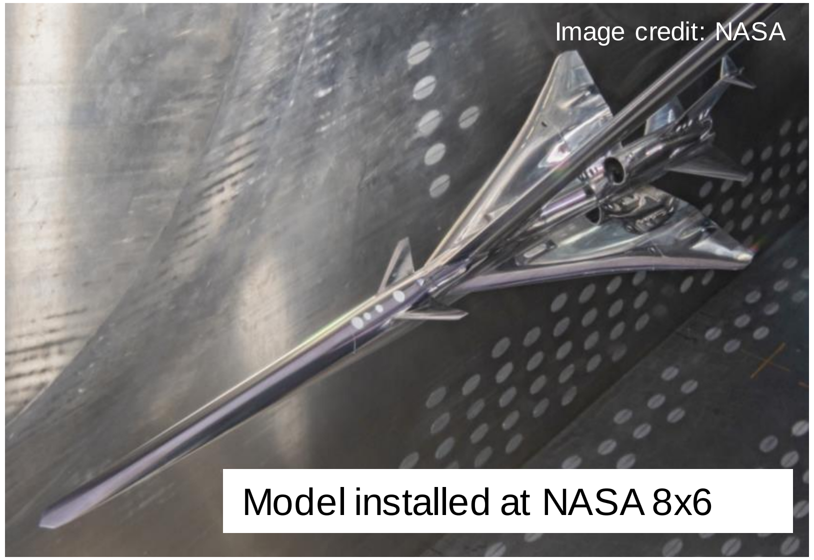


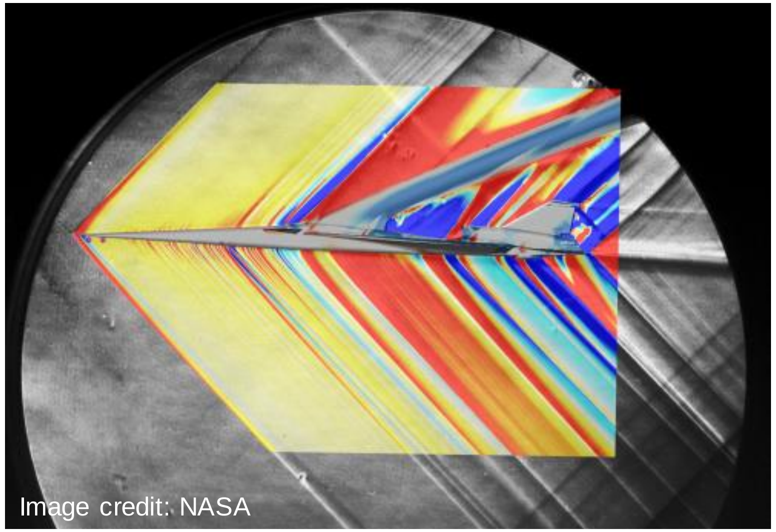
Progress
from nearfield-only on-track simulations on simplified geometries with no propulsion **to** full ground boom carpet X-59 simulations with propulsive and secondary flow paths

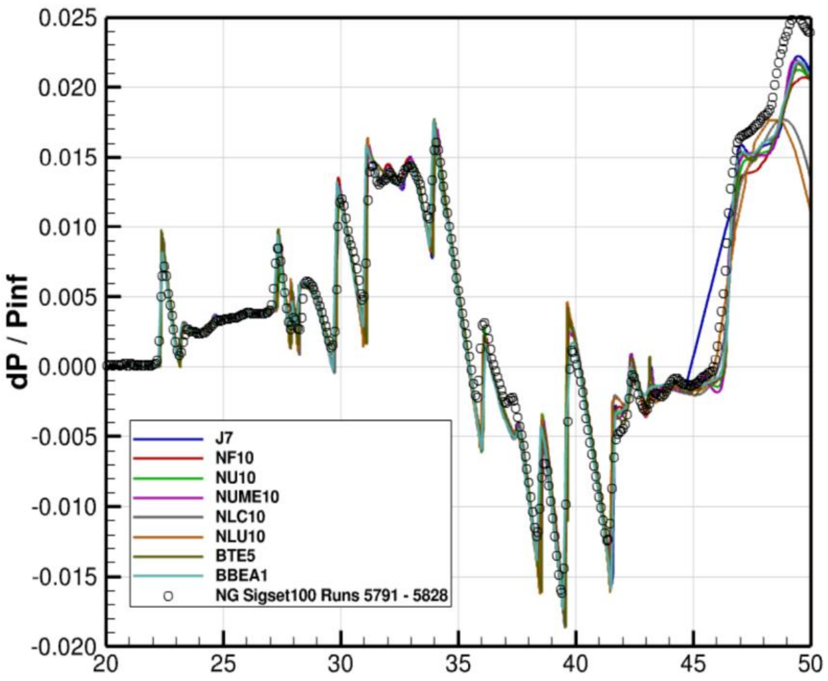
Cart3D

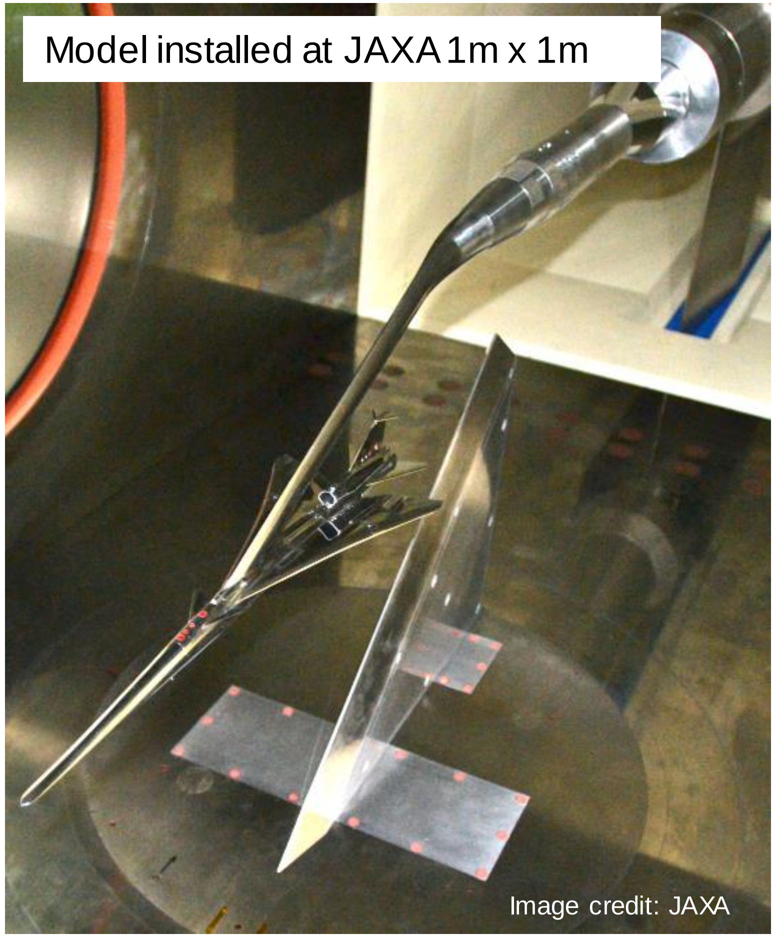
NASA's Quesst mission continues to drive the State-of-the-Art in sonic boom prediction

X-59 Sonic Boom Wind Tunnel Testing Collaboration







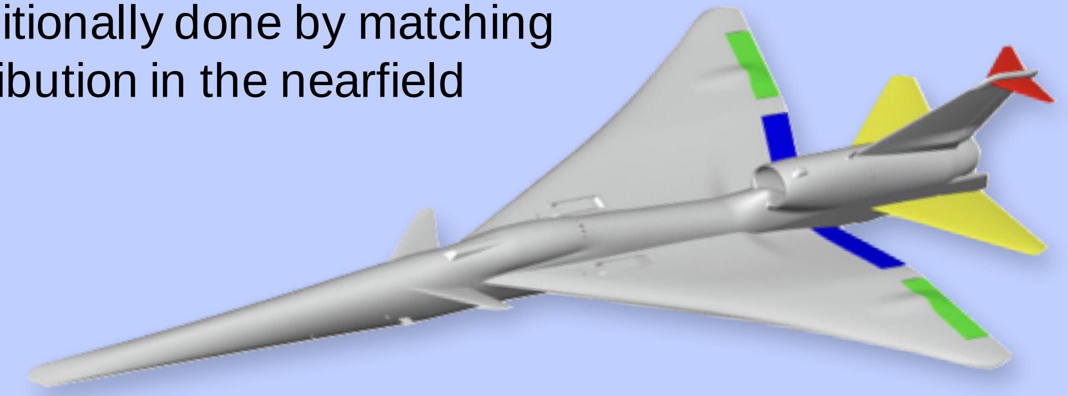


X-59 sonic boom predictions from multiple computational fluid dynamic codes validated by data from two collaborative US and JAXA wind tunnel tests.

Ground Noise-Based Shape Optimization

Developed integrated capability to directly optimize aircraft shape and/or control settings to minimize noise experienced at ground level

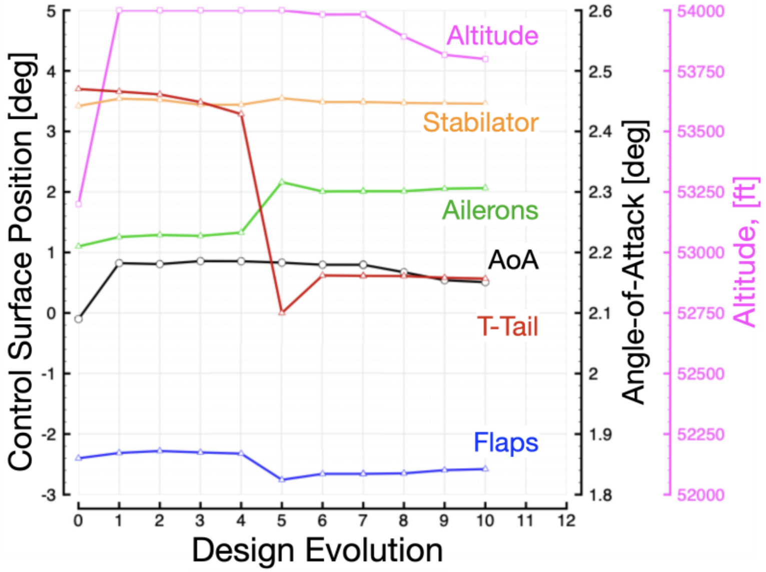
Low-boom design traditionally done by matching a target pressure distribution in the nearfield



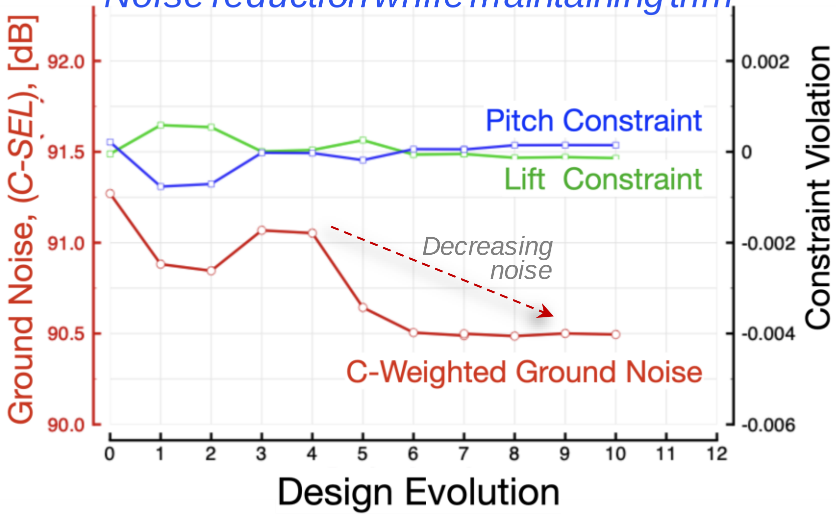
Directly couple both nearfield CFD and atmospheric propagation codes and their sensitivities through the fully-coupled primal-adjoint system

In use within the Quesst mission to optimize control surface deflections for low-boom flight testing

Control surface deflection & altitude

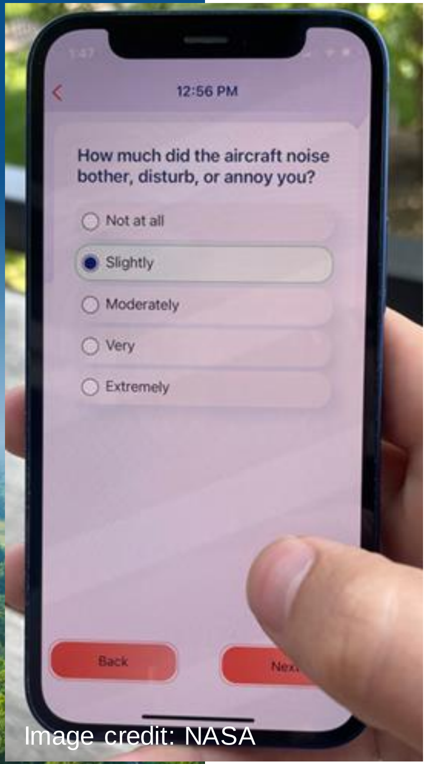


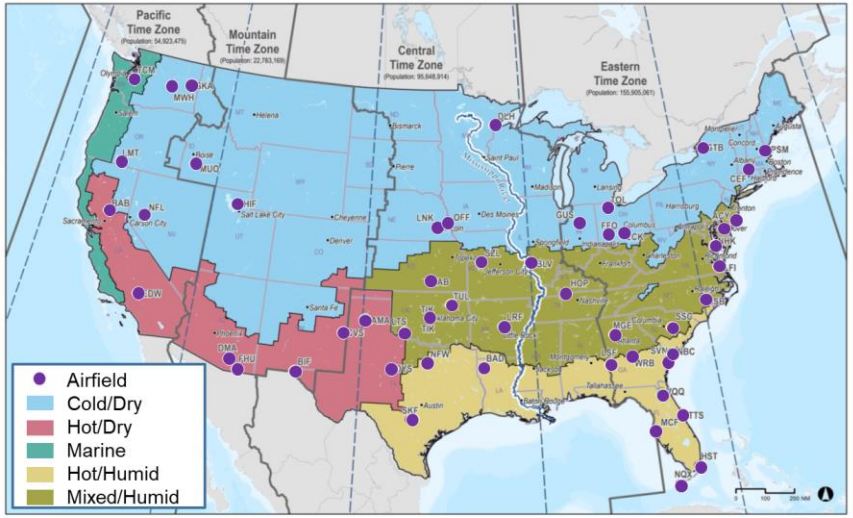
Noise reduction while maintaining trim

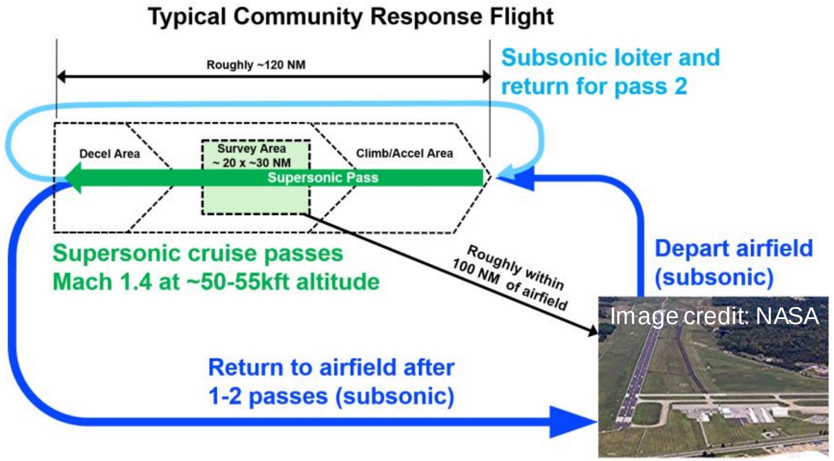


Actively maturing technology for robust shape optimization of future aircraft

Phase 3 Community Testing

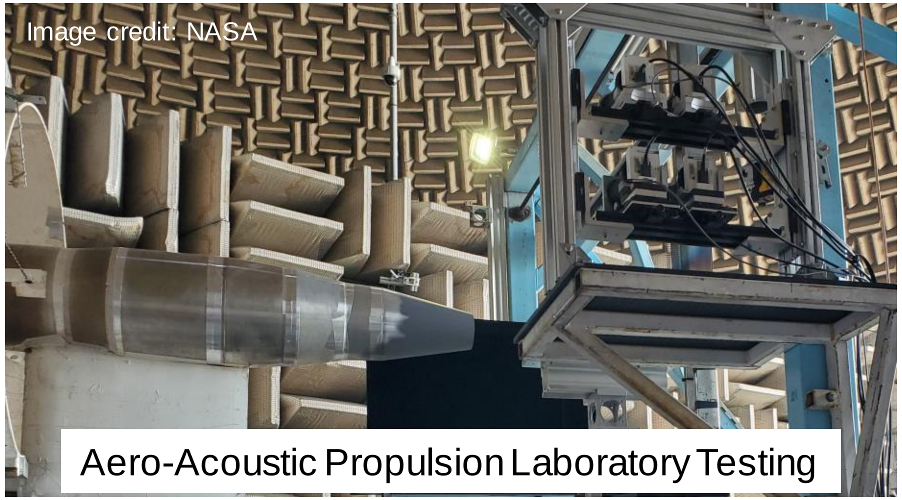


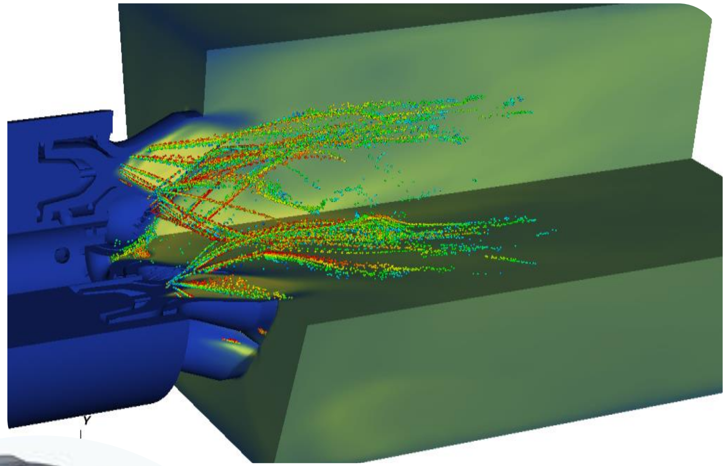


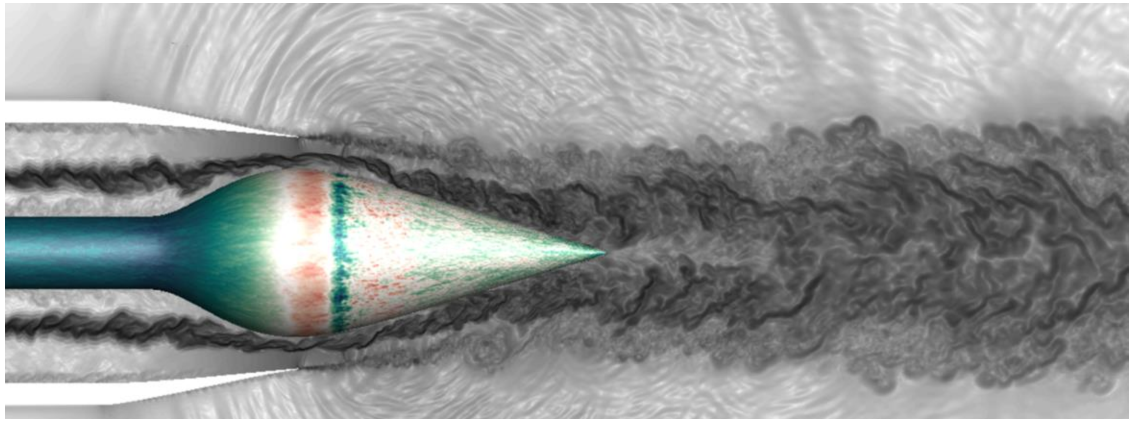


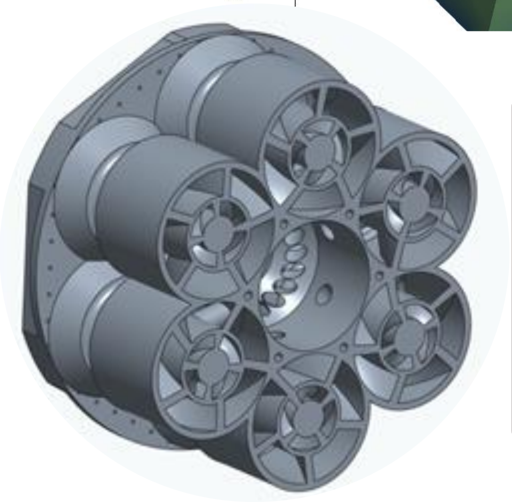
- Community test campaign design continues with government team and industry contractors
- In November 2023, NASA completed a test in Nashville of the survey methods for use in Phase 3
- Continued engagement with FAA, International Civil Aviation Organization-Committee on Aviation Environmental Protection (ICAO-CAEP) and the international research community
- Airfield and community selection process is ongoing

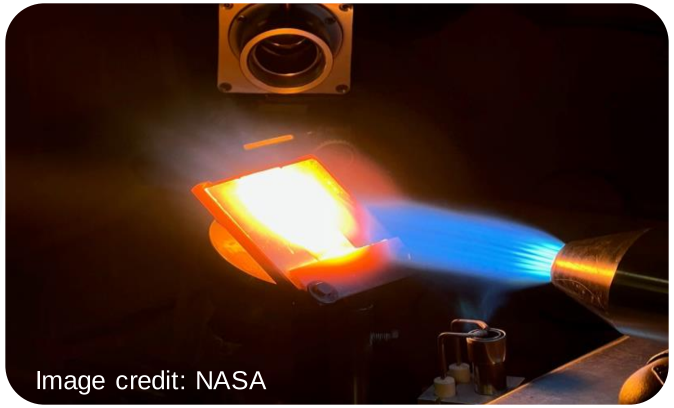
Supersonic Aircraft Airport Noise & Emissions Research











- Improvements to noise prediction tool chain
- Significant reduction of prediction uncertainty
- Informed proposed FAA rule for supersonic aircraft

- Low emissions combustion design studies
- Studies of the fuel composition impact on emissions
- High temperature material testing

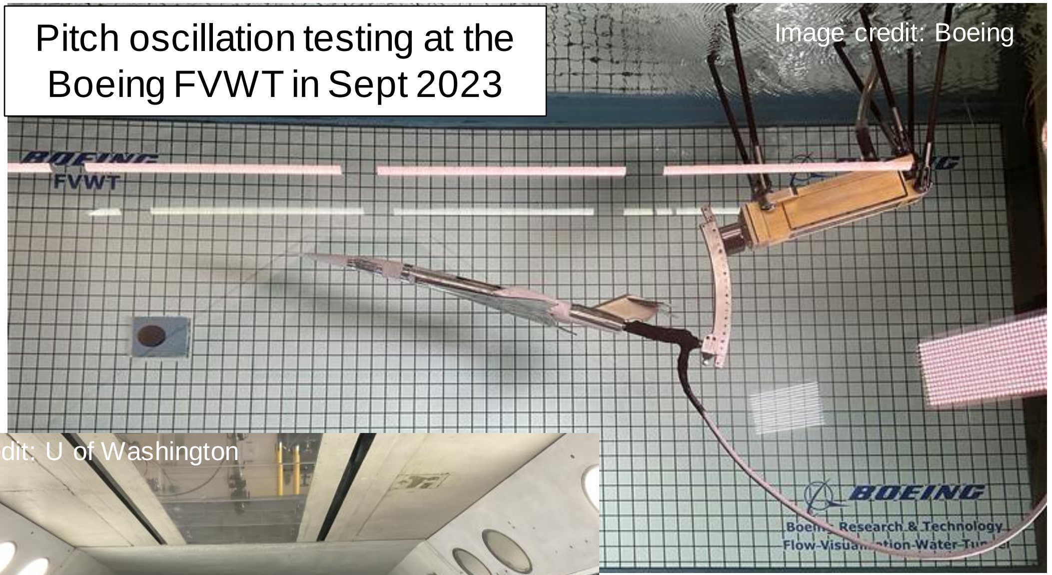
Low Speed Flight Characteristics:
NASA Supersonic Configurations at Low Speed (SCALOS)

Five-year university led research effort focusing on the applied aerodynamics, handling qualities, and stability and control of low-boom supersonic configurations at low speeds

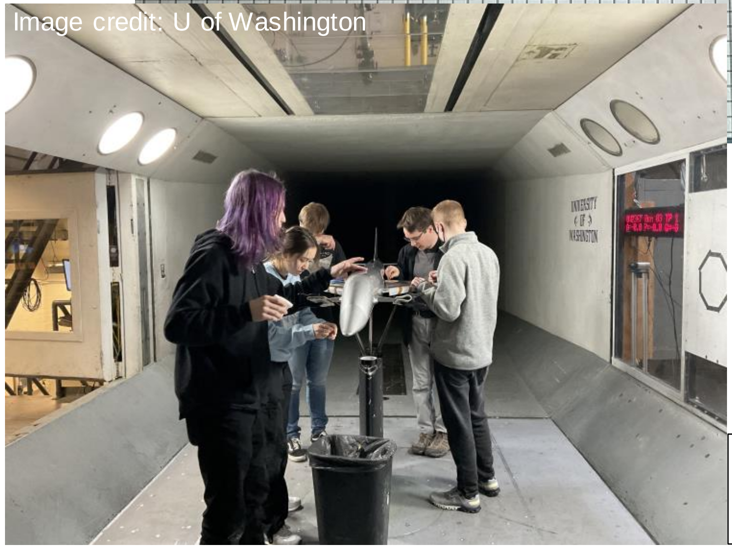
Participants:

- University of Washington
- The University of Michigan
- Stanford University
- Boeing Research and Technology

Over 50 undergraduate and 6 graduate students have contributed to the SCALOS project



Pitch oscillation testing at the Boeing FVWT in Sept 2023



UW students working on model

Training the next generation of researchers to understand the design drivers for low-speed aerodynamics and handling characteristics of low-boom supersonic configurations

Recent Market/Demand Studies for Commercial High-Speed Aircraft

Summary of recommendations from latest SpaceWorks study:

NASA and FAA should continue their efforts to enable and permit overland supersonic flight

- Potential to drastically increase market size six-fold and increase access to providers
- Provides more robust business cases for supersonic/hypersonic developers and operators

In the meantime, enact a two-phase "leader-follower" strategy to allow markets and technology to mature

- First-to-market transoceanic "leader" aircraft in Mach 1.5-2 range - high demand routes
- "Follower" aircraft designed to address growing and/or newly emerging markets via further technology improvements (longer, range, higher speeds, etc.)

Continue investments in critical aircraft technologies, particularly in the areas of:

- Engine fuel efficiency and emissions
- Takeoff noise
- Aircraft and engine structures/materials

Continue investment in Sustainable Aviation Fuels (SAF) with further exploration of LNG and LH2 viability

- Supply of all alternative fuels needs to be orders of magnitudes greater

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High-Speed Vehicle Conceptual Design & Technology Roadmapping

Development of New Commercial High-Speed Roadmaps

- Contracted N+ studies based on recent high-speed market studies to develop concepts and technology roadmaps in the Mach 2-5 range
- Deliver near and far term non-proprietary concepts
- Develop prioritized technology roadmaps to identify technologies for future investment in FY25 and beyond
- Synergize with technologies identified in the reusable hypersonic roadmap developed jointly with DoD

Contracts were awarded to teams led by Northrop Grumman and Boeing

Final study results will be available later this year

Northrop Grumman

Boeing

Technology Roadmaps Will Help Identify Potential Areas For Future NASA Investments

Summary

- NASA Aeronautics is leading the nation in the development of tools and technology to overcome the barriers to a future affordable, acceptable and sustainable commercial supersonic market

- NASA Aeronautics is progressing on the Quesst Mission with goals to:
  - Demonstrate low boom technology
  - Provide validation data and validated computational tools to academia and industry
  - Provide experimentally valid data to the FAA and ICAO on the response to quiet sonic booms

- NASA Aeronautics will continue to support the development of standards and regulations for future commercial supersonic aircraft

Image Credit: Lockheed Martin

Quesstions?