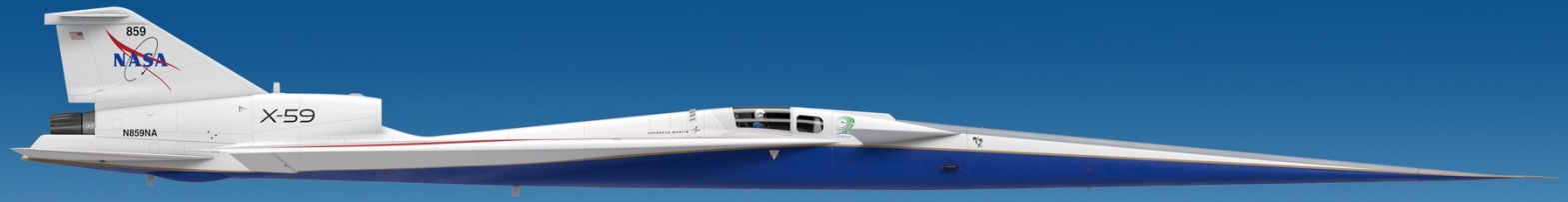
NASA's Quesst for Quiet Supersonic Flight



DATAWorks 2023

April 26, 2023

Peter Coen, Quesst Mission Integration Manager

Image credit: NASA

Presentation topics

- Quesst mission background and overview
- Mission elements
  - Phase 1: X-59 Aircraft Design and Fabrication
  - Phase 2: Acoustic Validation
  - Phase 3: Community Response Tests
- En route noise standard development
- Data challenges
- Concluding remarks

The vision for commercial supersonic flight

Exciting new market potential seen for supersonic civil aircraft

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

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

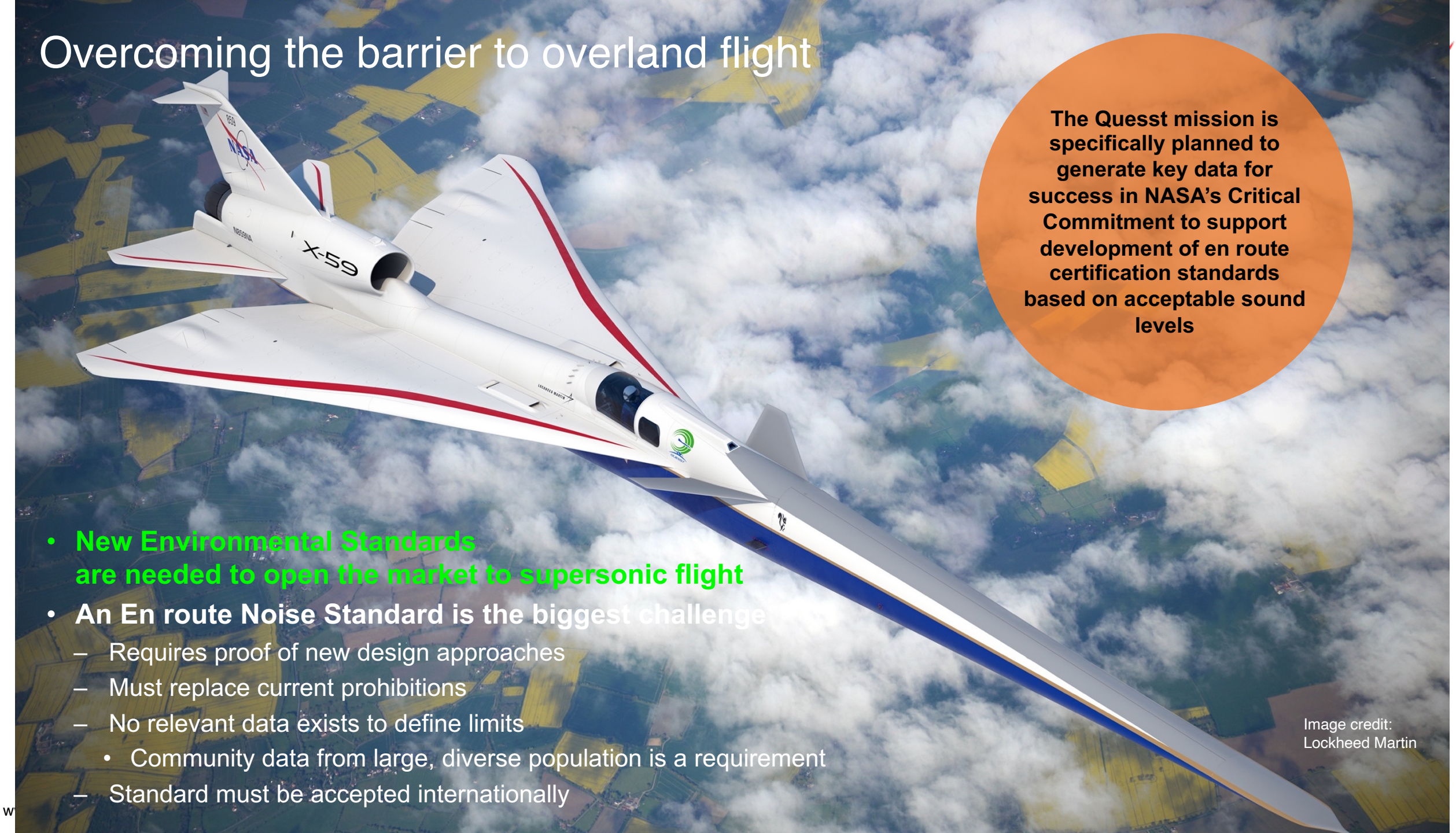
The vision of the High-Speed Commercial Flight Community is a future where fast air travel is available for a broad spectrum of the traveling public.

- Future supersonic aircraft will have an environmental impact that is compatible with a sustainable global aviation transportation system

NASA's Vision for the future of Aviation includes the Transformative impact of High Speed, Sustainable Flight

Credit :Lockheed Martin

Overcoming the barrier to overland flight



The Quesst 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

- **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

Image credit: Lockheed Martin

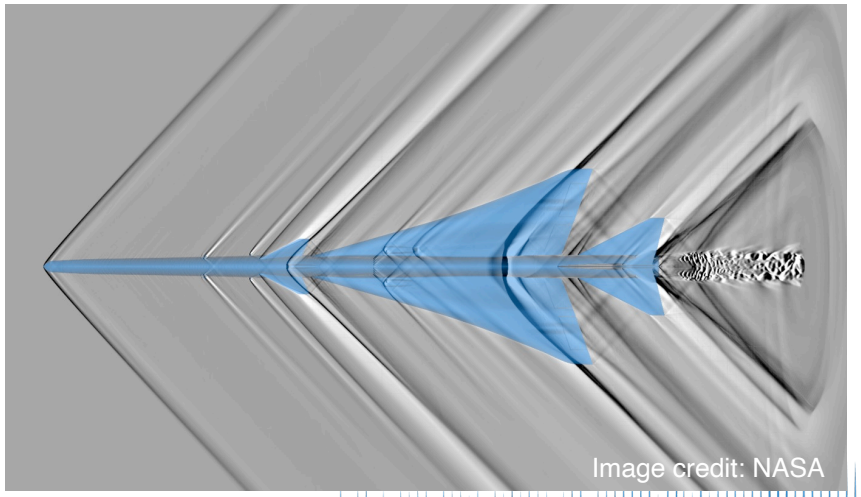
How do we quiet the boom?

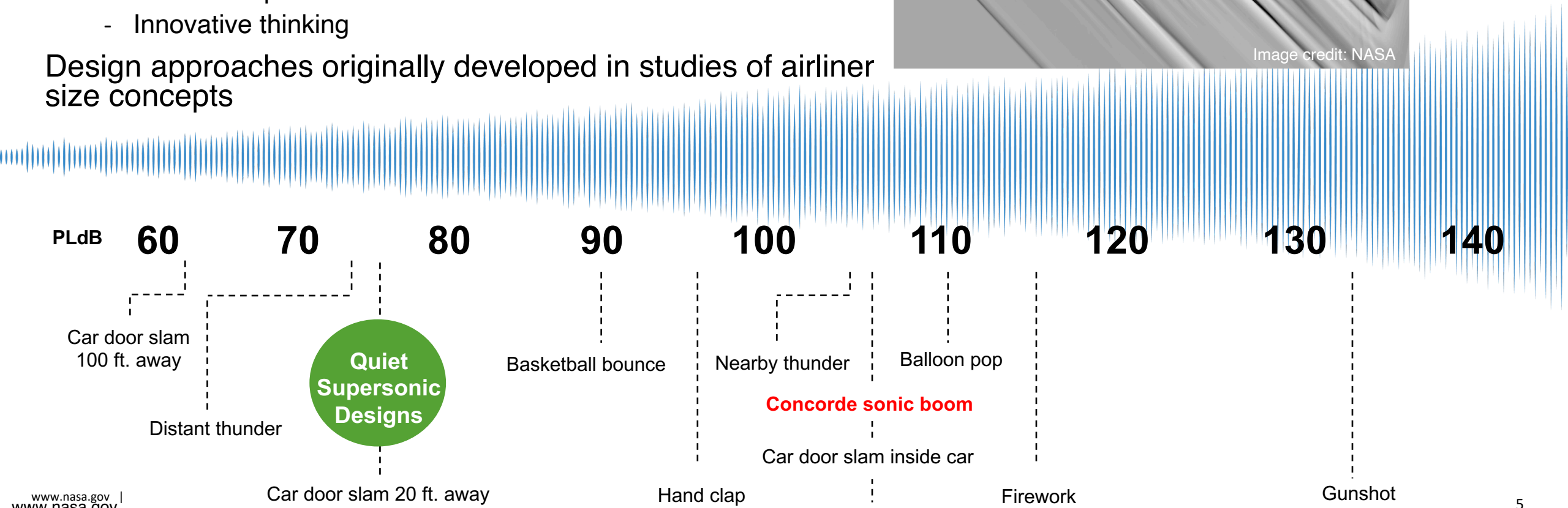
Acoustic pressure wave is “shaped” by controlling the strength and position of shock waves generated by aircraft components

Important advances:

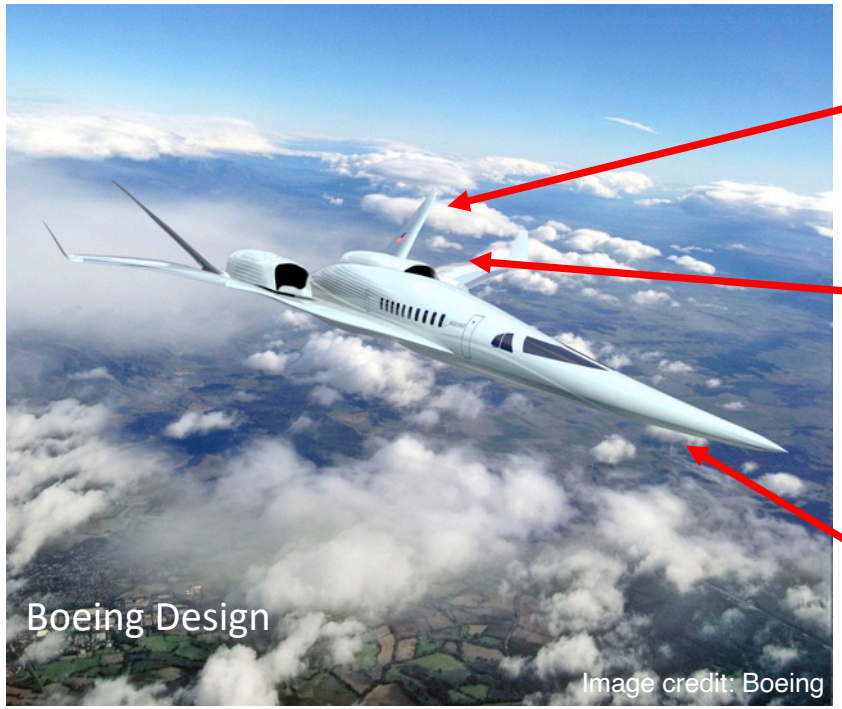
- Higher fidelity analysis
- Integrated design systems
- Faster computers
- Innovative thinking

Design approaches originally developed in studies of airliner size concepts





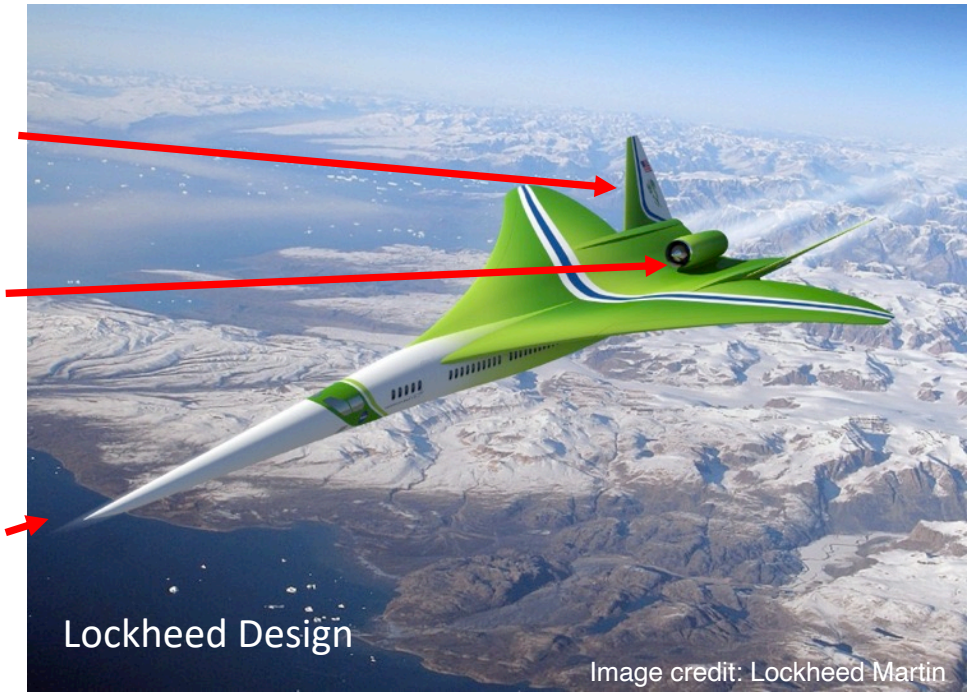
Catalyst: Design studies showing the potential for quiet supersonic airliners



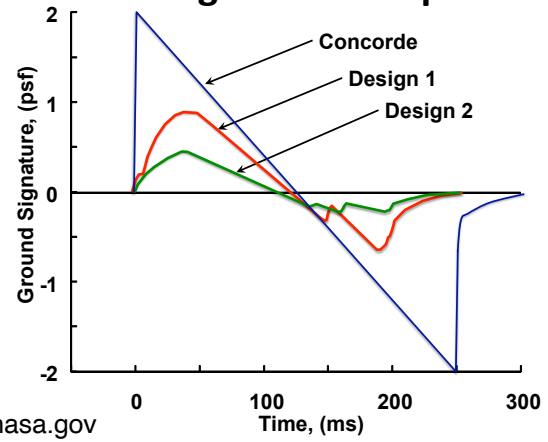
Unique empennage shape to control lift impact on signature

Propulsion installation minimizes contribution to signature

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



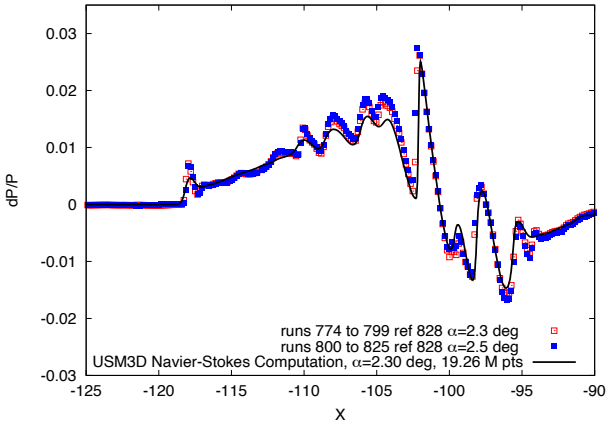
Ground signature comparison



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 aircraft; but methods are applicable to larger and smaller vehicles.

Wind tunnel/analysis comparison



Why do we think the “thump” is quiet enough?

Indoor human response and annoyance is the main concern for public acceptance

Laboratory Tests

Small Community Tests

Quiet Supersonic Flights 2018
Galveston, Texas

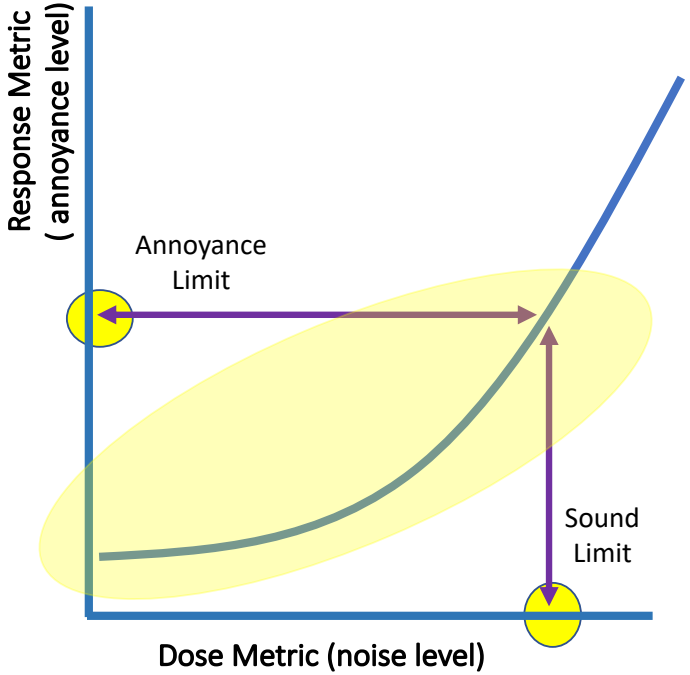
Large Community
Risk Reduction

- Tests of increasing complexity have provided preparation and confidence
- Ready to take the next step with flight testing over very large communities

Quesst Goal: Define community response at an international scale

Objective: Create a robust dose – response relationship for community annoyance vs appropriate noise metrics

- Large populations, large number of representative responses
  - 10k to 100k, depending on survey method employed
  - Varied community settings including representative:
    - Geography and climate
    - Home and building construction
    - Community demographics, etc.
- Tests in multiple locations, ideally international
- A range of exposures required, possibly including normal booms
- Up to a maximum of 6-8 daily exposures
- Sufficient test duration to establish effect of repeated exposure
- Engage the international research & regulatory community to ensure data acceptance



Notional Dose-Response Curve

Community overflight with an aircraft that produces representative sounds is the most effective approach to achieving this goal

Quesst mission overview and the X-59 aircraft

Community test requirements drove the X-59 design

- The acoustic signal must effectively replicate that of future larger supersonic commercial aircraft.
- The X-plane must conduct community overflight tests using normal commercial aircraft flight maneuvers.

Use the X-59 Research Aircraft to gather data on community response to quiet supersonic flight

Phase 1: Research Aircraft Development (2018-24)

- Design, fabrication, ground test, and envelope expansion

Phase 2: Acoustic Validation (begins 2024)

- Detailed ground and flight measurement to prove design

Phase 3: Community Response Testing (begins 2025)

- Overflights, sound measurement, surveys

X-59 aircraft details

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

External and forward vision 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

T-tail to minimize aft shock

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

Wing shielding to minimize impact of inlet spillage on sonic boom

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

Conventional tail arrangement to simplify stability and control considerations

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

Image Credit: Lockheed Martin

Phase 1: Building the X-59 – A team effort

LOCKHEED MARTIN

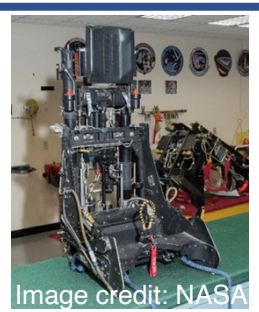
Prime Contractor for design, fabrication, integration and test

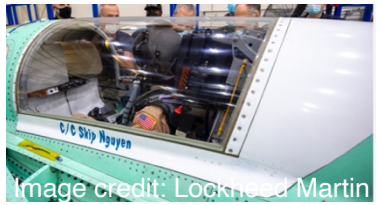
F414-GE-100 Engine
Supplied by General Electric

Over 50 Companies Worldwide

Supplier Manufactured Components

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





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

Ground Service Equipment
Over 100 items

X-59 build progress

Manufacturing & subsystems installation essentially complete

Photo Credits: Lockheed Martin

Structural loads and fuel systems completed in Fort Worth

Flight instrumented landing gear installed

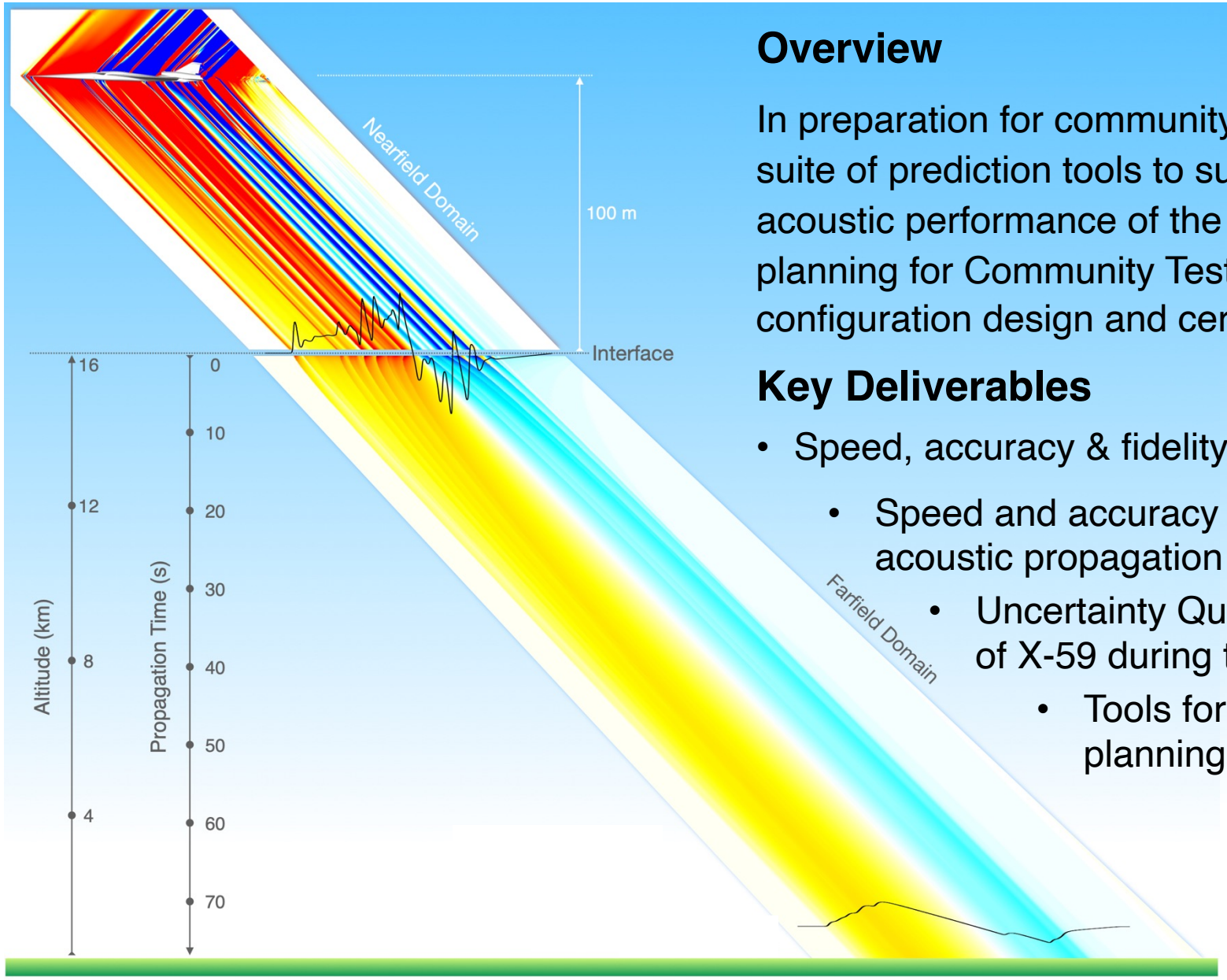
rearview shot of NASA's X-59 tail after its recent installation of the lower empennage, or tail section, in late March at Lockheed Martin Skunk Works in Palmdale,

Engine & Empennage Installed

Cockpit Systems Installed

Current focus: Powered systems checkouts (SCOs) prior to move from build facility to run stall

Phase 2: Prediction tools and validation



Overview

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.

Key Deliverables

- Speed, accuracy & fidelity improvements to CFD tool suite
  - Speed and accuracy improvements, turbulence effects in acoustic propagation tools
    - Uncertainty Quantification capability for ground loudness of X-59 during test cruise flight
      - Tools for exposure level and flight trajectory planning

Image credit: NASA

Phase 2 : Acoustic validation testing

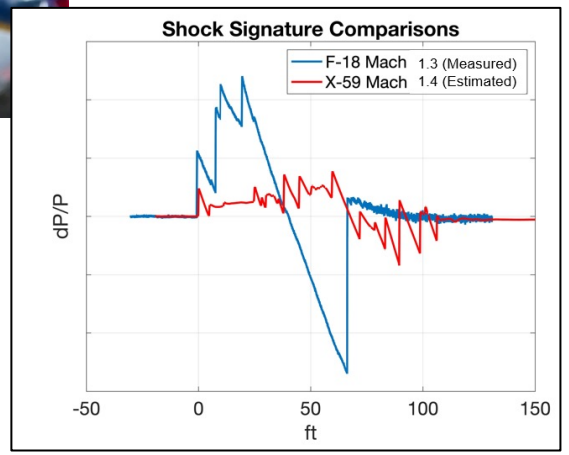
Objective

- Plan and execute a test series to validate ground acoustic signature loudness is acceptable for community response testing and to gather airborne and ground data that will be used to anchor day of test prediction

Shock Sensing Probe mounted on NASA F-15

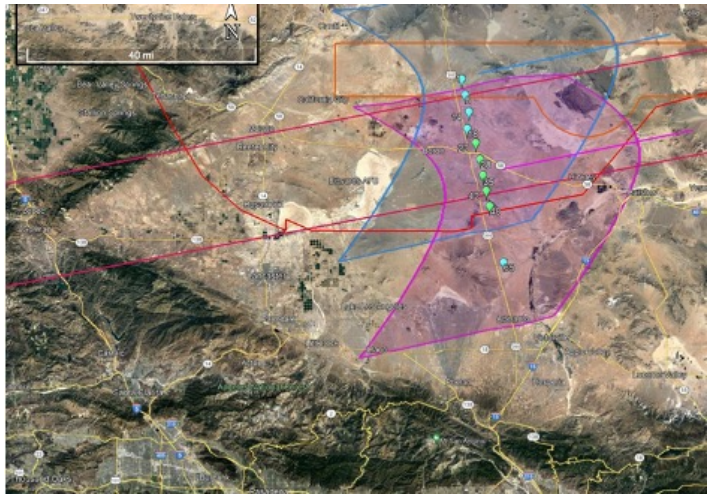
Requirements

- Aircraft and measurement systems to record shock pressure data near the aircraft
- Ground Recording System capable of capturing ground level sound measurements over a large area
- Safe and efficient test execution
  - Adaptable to changes in aircraft availability weather, etc



Comparison of shock pressure data

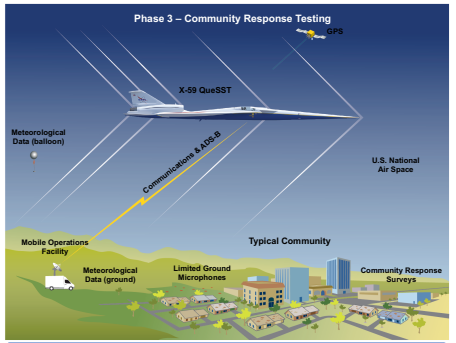
Ground Recoding System unit



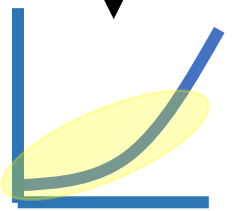
Extent of ground measurement array

Phase 3: Community response testing

- 4-6 tests planned starting in 2025 with a first test flown from NASA Armstrong
- Test site selection
  - Airfield meeting X-59 operational requirements
  - Ensure representativeness
  - Deployment coordination/logistics
  - Public engagement
- Survey Design and Analysis
  - Participant recruitment
  - Data analysis/statistical methods
  - Tests of survey implementation, automated data processing methods
- Exposure Design and Estimation
  - Acoustic monitor placement strategies
  - Recording and extraction of signature
  - Characterization of carpet over test area (combining prediction and measurements)
- Developing Dose-Response Relationship and Delivery to ICAO
  - Matching exposure levels with participant location
  - Aggregating of multiple community test results
  - Ensuring validity/acceptance of technical approach



- **Exposure Estimation**
- **Community Surveys**

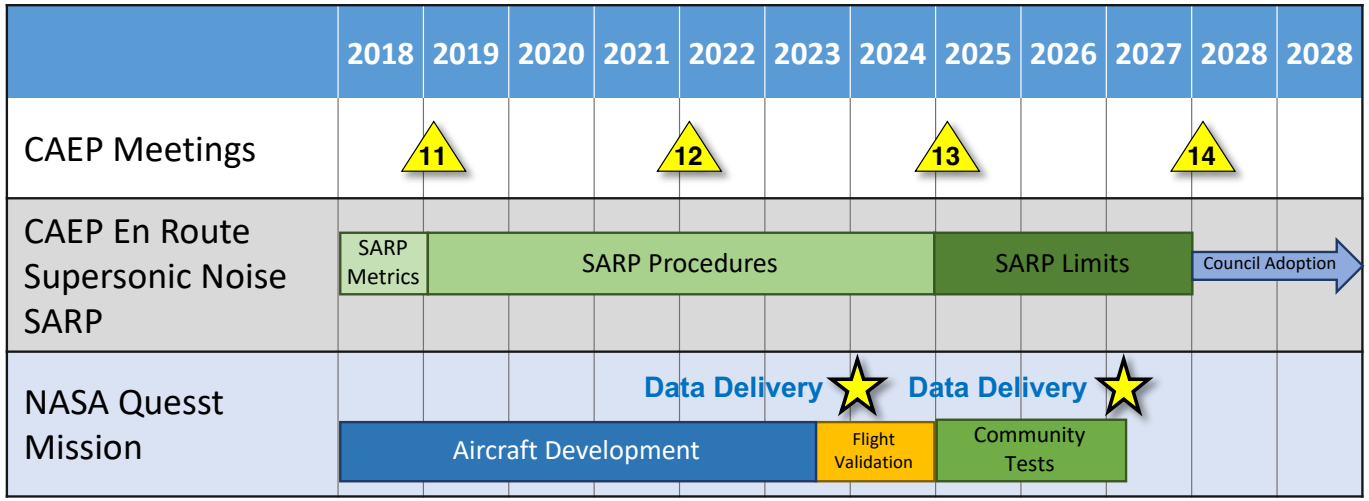


Dose-Response Relationship

Data to ICAO for use in Standards

ICAO-CAEP standards development

- International Civil Aviation Organization, Committee on Aviation Environmental Protection
  - Creates “Standards and Recommended Practices” (SARPs) addressing international civil aviation environmental impact
    - In general , SARPs include a metric, a procedure and a limit for a particular impact
    - Regulatory agencies (e.g., FAA) implement SARPs in ICAO Member States as certification regulations and procedures
- Since the start of the CAEP 10 cycle (2013), the CAEP Aircraft noise working group has been tasked with developing a standard for supersonic en route noise
  - CAEP 10 & 11: Metrics focus
  - CAEP 12 & 13 (current): Procedures focus
  - CAEP 14 (2025– 28): Limits focus,
- NASA data and analysis is key to each element of the standard development
- Current goal is to bring the completed standard forward for acceptance by the full Committee at CAEP 14



CAEP & Quesst Timeline in 2022

Quesst mission data challenges

- Uncertainty
  - Understand and manage many sources in predictions, measurement and responses
- Analysis
  - Determining exposure level for individual responses
- Ensuring representativeness
  - Maximizing desired variability under operational constraints of the X-59
- Sparse observations of high annoyance
- High variability between test sites
- Bias introduced by public outreach associated with tests
- Handling, processing and security

Concluding remarks

- The Quest mission is focused on overcoming the technical and regulatory barriers to quiet supersonic flight over land
  - Critical Commitment to deliver data to ICAO on community response to quiet overflight sounds
- The development of a new supersonic X-plane is the core of the mission
  - Fantastic team effort on accomplishments to date
  - X-59 aircraft is undergoing powered system check out and will fly in 2023
- Preparation for acoustic validation and community overflight tests is also progressing
- Near term focus is on completing an X-59 aircraft that is safe to fly in the National Airspace System and meets the mission performance goals
- NASA is engaged with the FAA and ICAO in the development of an international standard for sound levels for supersonic overland flight
- NASA seeks the broadest possible engagement with the international research and regulatory community to support acceptance of Quesst Results
- The airplane may be cool, but it's the data that's important

Quesstions?

Please attend Session 2A at 1:30 today to learn more about the Quesst Community testing

For more information on the Quesst mission, visit www.nasa.gov/quesst