NASA Commercial Supersonics Technology Strategy

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Presentation Topics

- Overview: NASA's Aeronautics Strategy
- Barriers to successful supersonic commercial aircraft
- Breaking the sonic boom barrier: The Low Boom Flight Demonstration Mission
- Achieving environmental acceptability:
  - Airport community noise
  - Emissions in the airport area and at high altitudes

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

ARMD continues to evolve and execute the Aeronautics Strategy *https://www.nasa.gov/aeroresearch/strategy*

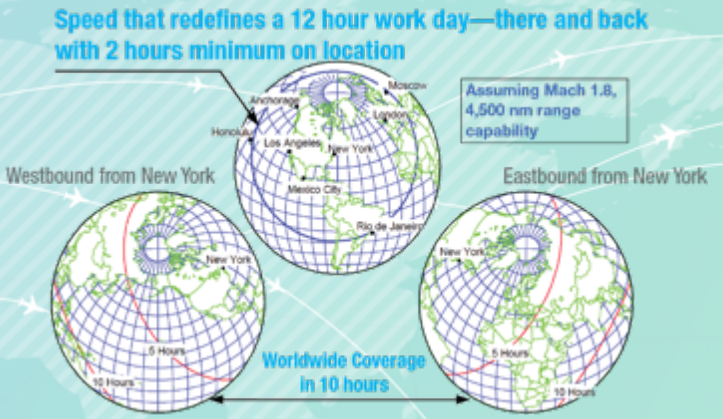
6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Transition to Alternative Propulsion and Energy
- Innovation in Commercial Supersonic Aircraft
- In-Time System-Wide Safety Assurance
- Ultra-Efficient Commercial Transports
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

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 manufacturing offer the opportunity to establish a new market segment with significant export opportunity and high-tech job growth
  - 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
- Technologies reducing the environmental impact of supersonic aircraft may benefit subsonic aircraft as well

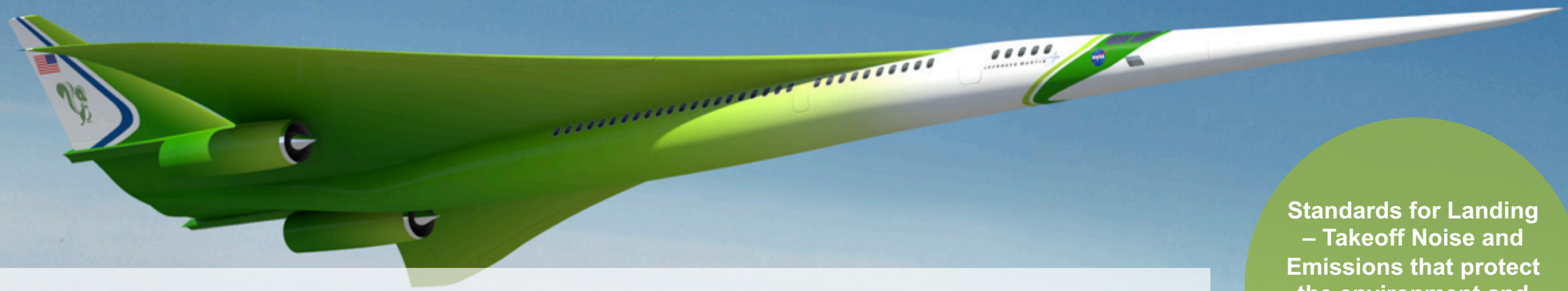
The government plays a central role in developing the data needed for the regulation change that is essential to enabling this new market

The Vision for Commercial Supersonic Flight

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

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



Standards for Landing – Takeoff Noise and Emissions that protect the environment and support early entrants are key to market development

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

Credit :Lockheed Martin

NASA's Vision supports evolving capabilities for Commercial Supersonics

Thrust 2 Community Outcome 2025
Certification standards for supersonic commercial aircraft including overland flight based on acceptable sonic boom noise and LTO noise and emissions appropriate for technical and economic viability

NASA Research Focus
Critical Commitment: Deliver to ICAO a database of community response to quiet supersonic aircraft flight over land

- Low boom design tools
- Fundamental data on the characteristics of low noise waveforms in real atmosphere
- Scientifically valid data on community response to low noise supersonic overflight

Additional Research Areas

- Robust Landing & Takeoff Noise and Emissions tools and technologies

Thrust 2 Community Outcome 2025+
Introduction of Affordable, Low-Boom, Low-noise, and Low-emission Supersonic Transports

NASA Research Focus
Technologies enabling the first and second generations of supersonic transports with emphasis on acceptable community and en route noise and high altitude emissions

Thrust 2 Community Outcome 2035+
Increased Mission Utility and Commercial Market Growth of Supersonic Transport Fleet

NASA Research Focus
Technologies enabling the first Technologies enabling supersonic transports that are competitive in airline market with emphasis on high efficiency and light weight for improved economics

Technologies for supersonic airline to interface with ATM

* Language includes proposed updates to the NASA Strategic Implementation Plan

Barriers to Practical Supersonic Commercial Aircraft

Environmental Barriers

Sonic Boom

- Design for low noise sonic boom
- Understand Community Response

Airport Noise

- Noise levels not louder than subsonic aircraft at appropriate airports

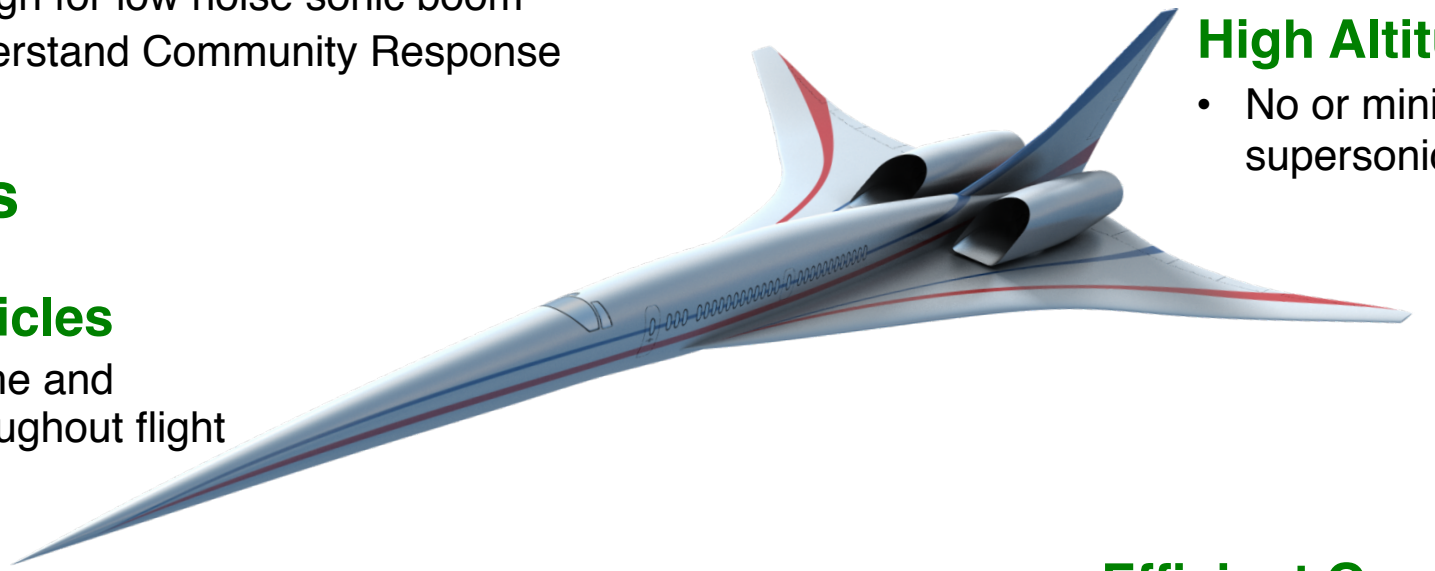
High Altitude Emissions

- No or minimal long term impact at supersonic cruise altitudes

Efficiency Barriers

Efficient Vehicles

- Efficient airframe and propulsion throughout flight envelope



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

Solutions to Barriers Drives Selection of Research Themes

Overcoming the Barrier to Overland Flight

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

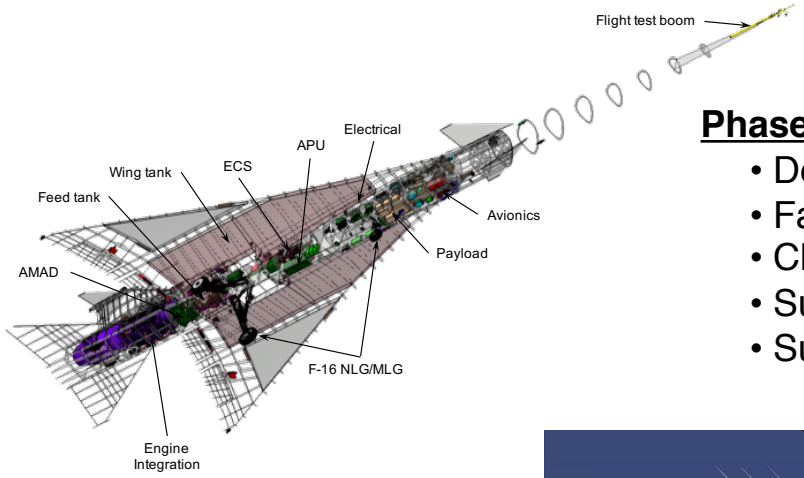
- **New Environmental Standards are needed to open the market to supersonic flight**
- **An En route Noise Standard is the biggest challenge**
  - Requires proof of new design approaches
  - Must replace current prohibitions
  - No relevant data on exists to define limits
    - Community data from large,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

Delivering on the Thrust 2 Critical Commitment

Key Elements:

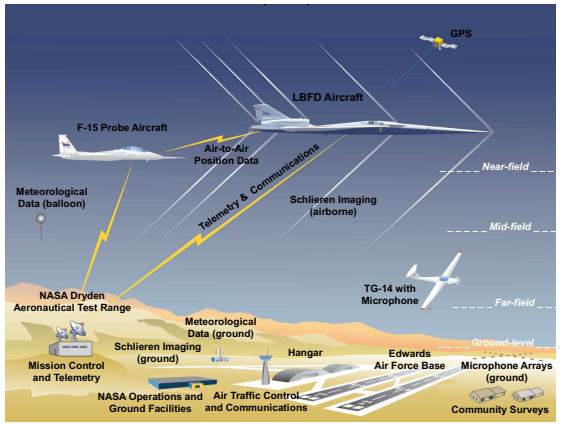
- **Integrated Design Solutions for Revolutionary High-Speed Aircraft** that provide the foundation for low-sonic boom aircraft design (complete 2015)
- **Validated Hardware** for overflight testing (supersonic acoustic signature generator)
  - Design, build and confirm the airworthiness of a Low Boom Demonstrator with acoustic characteristics representative of a commercial supersonic transport aircraft
  - Validate acoustic signature of the LBFD aircraft
- **Development of Test Methodology** that allows data to be gathered that accurately represents the community response to supersonic overland flight
- **Community Response Data** that is fully representative of a demographically diverse, non-biased population

Low Boom Flight Demonstration Mission Overview



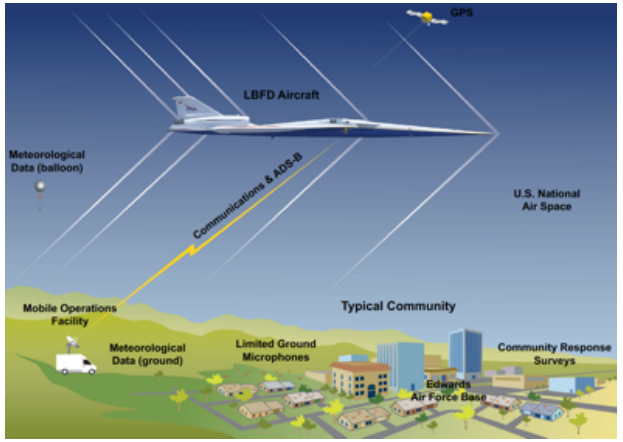
Phase 1 – Aircraft Development – FY18 – 22

- Detailed Design
- Fabrication, Integration, Ground Test
- Checkout Flights
- Subsonic Envelope Expansion
- Supersonic Envelope Expansion



Phase 2 – Acoustic Validation – FY22-23

- In-flight and ground measurement capabilities
- Aircraft Operations / Facilities



Phase 3 – Community Response (FY23-25)

- Initial community response overflight study based at NASA AFRC
- Multiple campaigns (4 to 6) over representative communities and climate across the U.S.

Systematic Approach Leading to Community Testing

Prediction Tools Validation

Challenge

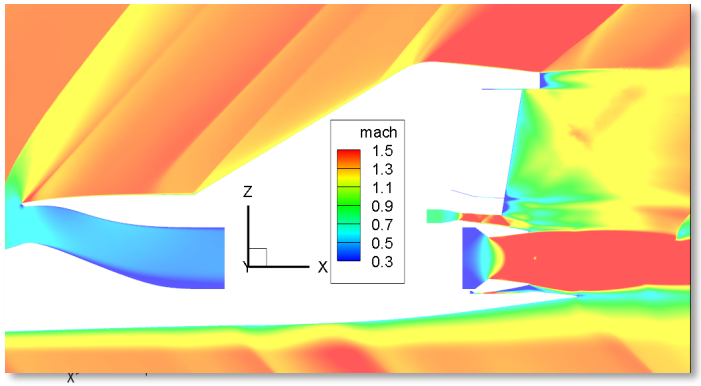
In preparation for community response testing, NASA will provide a suite of prediction tools to support timely and accurate validation of the acoustic performance of the LBFD aircraft, rapid pre-flight exposure planning for Community Testing, and provide a foundation for future configuration design and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

Key Deliverables

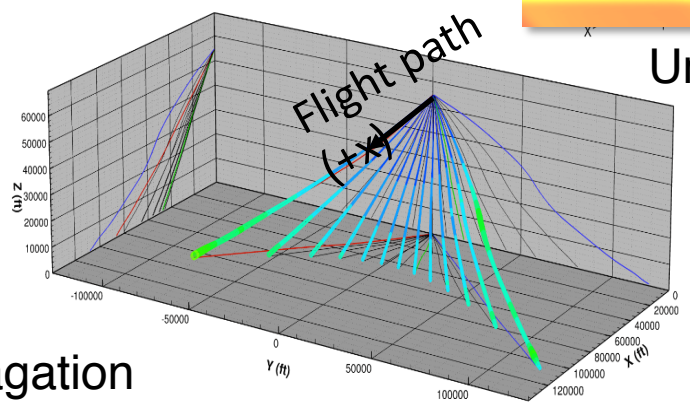
- High fidelity prediction toolset with quantified uncertainty
- Pre-test analysis supporting LBFD Acoustic Validation flights
- Near-real-time prediction capability for Community Response Test planning
- Data and tools based on rich LBFD data set supporting future design and certification efforts

Detailed presentations in sessions APA-21 and APA-25

High Fidelity CFD



Uncertainty Quantification



Acoustic Propagation

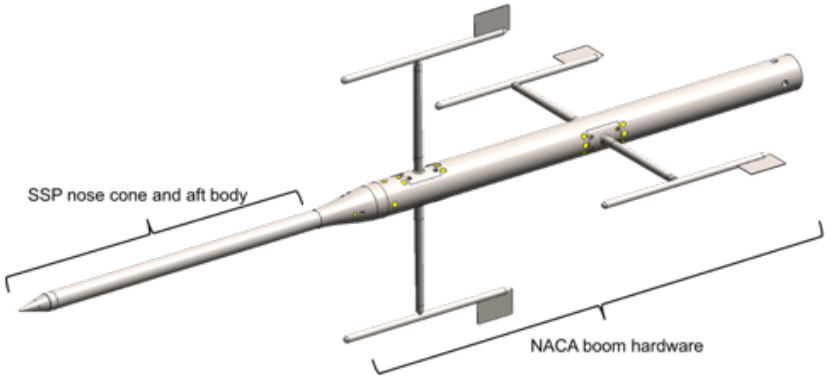
In Flight Acoustic Validation Measurement Capabilities

Challenge

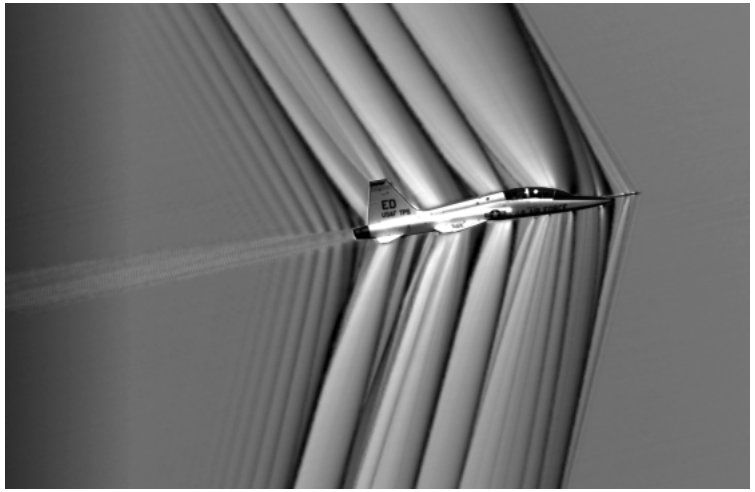
- Develop and demonstrate LBFD Mission Phase 2 capabilities to safely measure in-flight:
  - Near-field acoustic characteristics of the LBFD aircraft
  - Atmospheric effects on the far-field acoustic pressure signatures

Key Deliverables

- F-15D flight research instrumentation system
- Shock Sensing Probe for F-15D
- System for safe and efficient relative positioning of test and measurement aircraft (ALIGNS)
- Acoustically instrumented TG-14 aircraft
- Advanced pod-mounted schlieren imaging system



SSP integrated with NACA hardware



Advanced Air-Air Schlieren Imaging

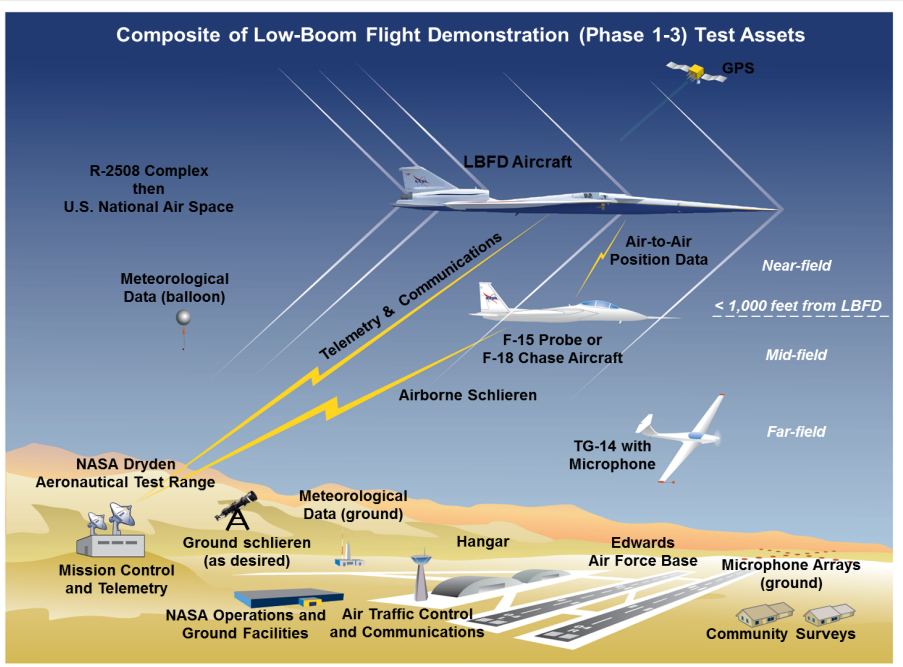
Acoustic Validation Test Planning and Execution

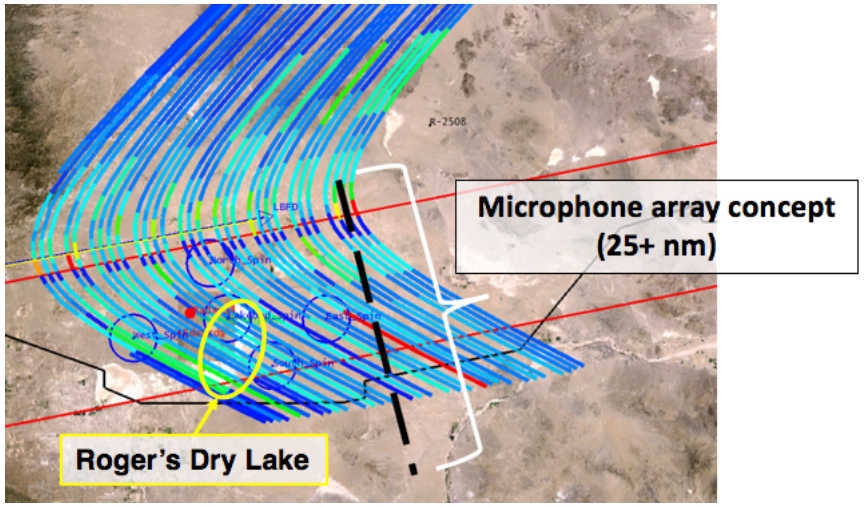
Challenge

- 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 sonic boom propagation and acoustics models in a real atmosphere.
- Coordinate multiple ground and flight assets to efficiently gather multiple data types

Key Deliverables

- Ground equipment for an unprecedented scale of measurements
  - Data for entire “carpet” under the flight track plus longitudinal array for turbulence effects
- Acoustic validation flight test plans
- Ground and air-air data collection and processing
  - Near/mid-field probing
  - Far-field and ground acoustic
  - Schlieren Imaging

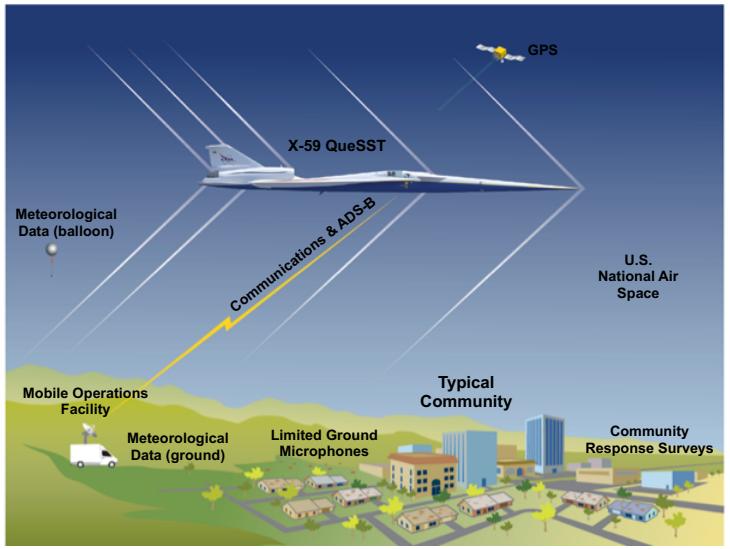




Community Test Planning

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

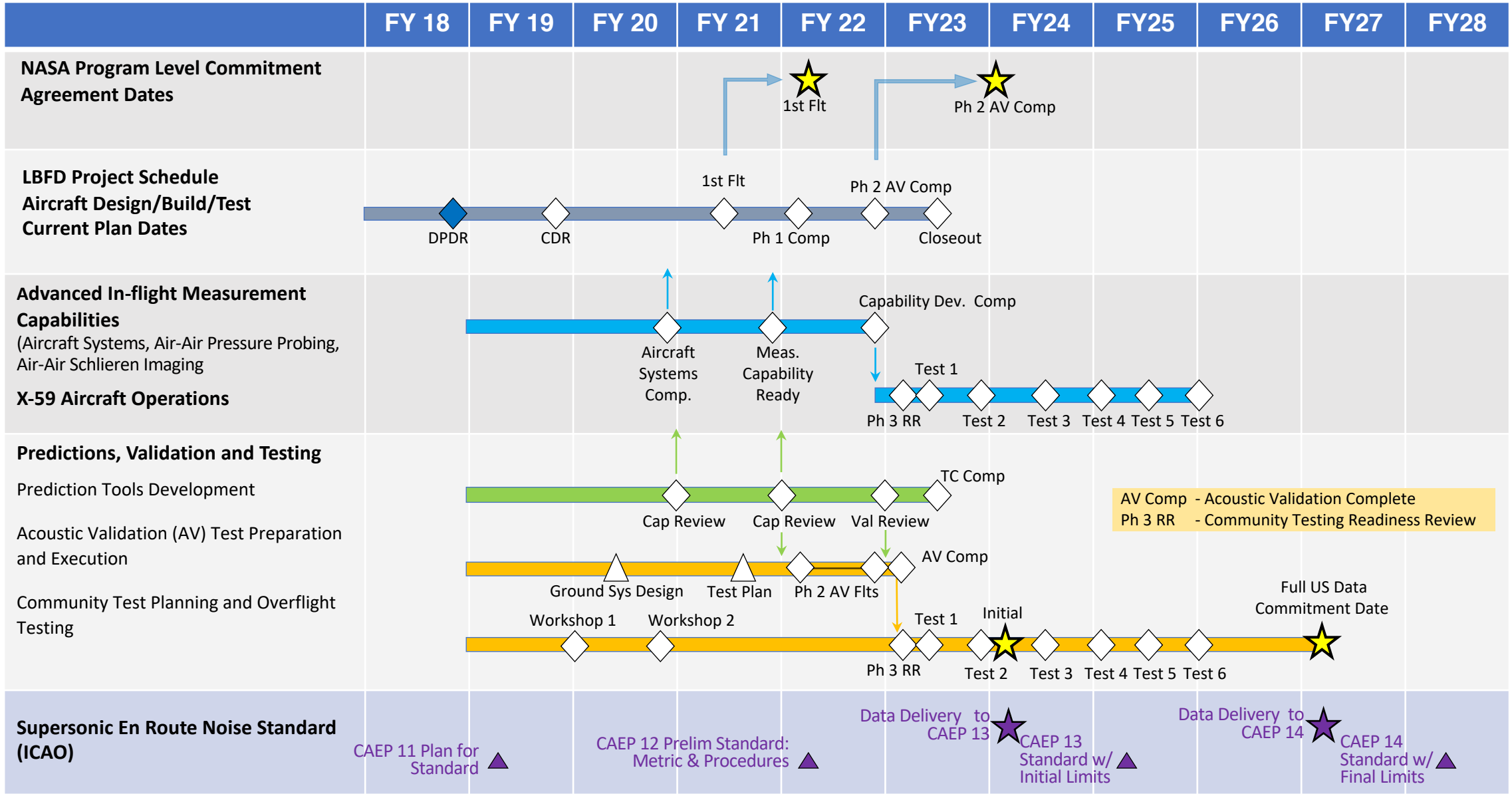
- Large populations, large number of representative responses.
  - 10k to 100k, depending on survey method employed
  - Varied community settings including representative:
    - Geography and climate
    - Home and building construction
    - Community demographics, etc.
- A range of exposures required, possibly including normal booms
- Up to a maximum of 6-8 of daily exposures
  - Night exposures may be required
- Sufficient test duration to establish effect of repeated exposure
- Account for test aircraft operational limitations
  - Airfield facilities
  - Scheduled and unscheduled maintenance and downtime
- 4-6 test campaigns in different locations
- Engage the international research & regulatory community to ensure data acceptance



Planning began in 2019 to support first community test in 2023

Risk reduction test completed in 2018, details in presentations by Cliatt and Rathsam , APA-21

Pulling it all together: **Notional** LBFD Mission Timeline



Environmental Acceptability: Airport Noise

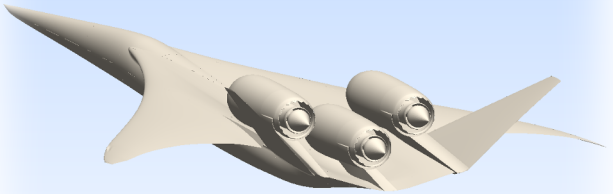
Focused Technical Challenge on jet noise reduction completed in FY16

Integration of noise prediction, innovative nozzles, and system modeling to achieve aggressive goals.

2013	2014	2015	2016
Multiple jet acoustic effect documented, modeled. Non-axisymmetric jet noise code created. IVPv2 design confirmed with LES.	Three-stream nozzle and IVPv2 tests completed. IVPv2 tests meet expectations First empirical models for three-stream and IVP nozzle systems	Aft-deck noise database acquired. Optimized engine cycle determined. Final candidate nozzles created.	Final isolated nozzles, system models validated. Integrated acoustic test articles created and tested. System predictions, acoustic goal validated.

Efforts continue in active Research Theme

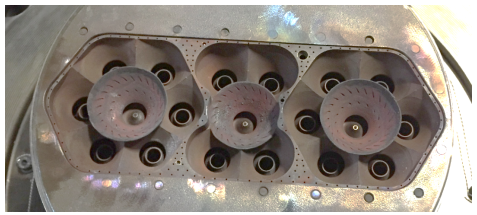
- Elements include: Integrated solutions including inlet and fan noise, Innovative concepts, Tools and techniques and Experimental Validation
- Future focused efforts anticipated to start in FY21



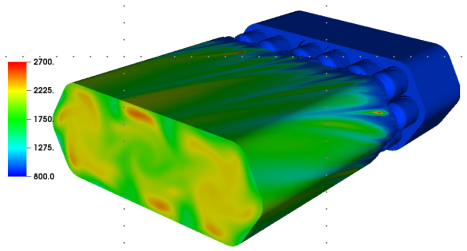
Top-mounted propulsion study concept

Environmental Acceptability: Emissions

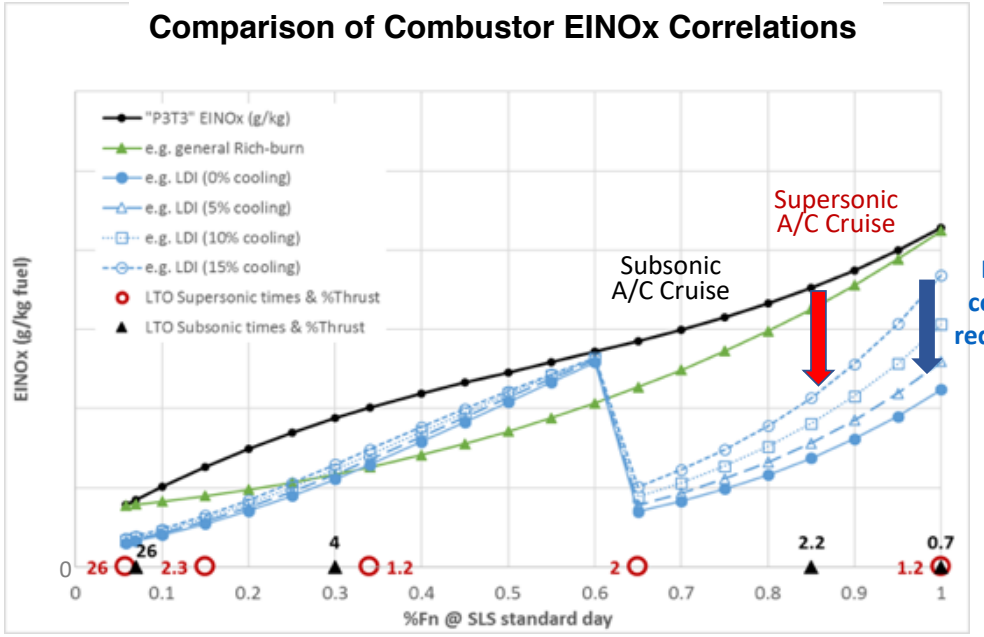
- CST has worked in partnership with NASA's subsonic research efforts to experimentally and analytically explore the applicability of advanced combustor technology to emissions reduction for supersonic aircraft
- NASA has engaged MIT to develop and improve global high altitude emission models and study impacts from future supersonic fleet scenarios
- An optimal technology suite has been identified
  - Lean-burn offers 1/3-1/2 less NOx and almost no nvPM emissions at cruise than rich-burn
  - Combustor design optimized for supersonic cruise, but enabled for landing-and-takeoff (LTO) low emissions
  - Next-gen CMC combustor liner with minimal cooling to reduce flame temperature
  - Optimized fuel composition control; alternative fuel opportunities
- Next steps
  - Identify partnership approaches for materials and fuels research
  - New Technical Challenge for supersonic specific combustor design anticipated in FY21



Test Hardware

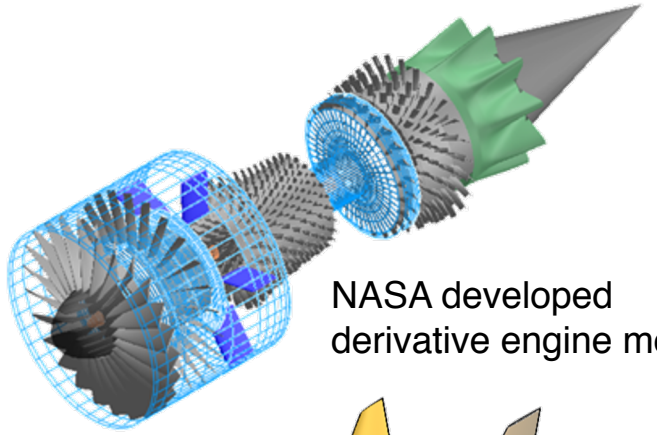


Computational Analysis

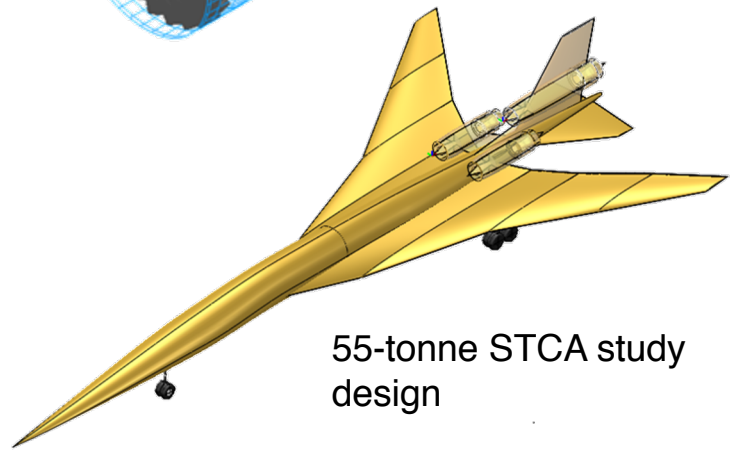


Near-term efforts: LTO Noise and Emissions Standards

- Emergence of near-term market entrants has spurred at need for certification standards
- FAA and ICAO are engaged in parallel, coordinated processes
- In addition to company data, both organizations need independent analysis and trade study data to inform the standards process
- NASA is supporting this effort with the development of Supersonic Technology Concept Aeroplanes (STCA)
  - Effort is coordinated with Industry for consensus on methods and assumption
  - Scope includes assessment of advanced procedures and technology/design trades
- NASA effort also includes targeted testing and analysis to reduce uncertainty in noise models



NASA developed derivative engine model



55-tonne STCA study design

Details to be presented at SciTech 2020

Summary

- NASA's Strategic Plan for Aeronautics calls for leadership in Innovation in Commercial Supersonic Flight
- Near-term focus in 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 NASA's Low Boom Flight Demonstration Mission
  - Coordinated development of tools, test hardware and methodology is key to success
- Planning for community overflight tests is underway
  - NASA seeks to engage the international community to insure broadest applicability of data
- NASA analysis and independent data is supporting near-term standards development that will help industry realize a supersonic commercial market
- NASA's strategy also includes addressing longer term research leading to the development of increasingly capable supersonic commercial aircraft