NASA Supersonic Research Strategy - 2021

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Vision for Commercial Supersonic Flight

Market interests and opportunities for commercial supersonic flight are strong and growing

- Evidenced by the appearance of several commercial programs
- Progress continues on efforts to overcome the barriers to widely available supersonic flight.

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



National Research and Policy agencies play a central role in developing the data needed for the regulation change that is essential to enabling this new market

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

Barriers to Practical Supersonic Commercial 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

Efficiency Barriers

Light Weight, Durable Vehicles

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

Efficient Vehicles

- Efficient airframe and propulsion throughout flight envelope

Efficient Operations

- Airspace-Vehicle interaction for full utilization of high speed

Solutions to barriers drives selection of our 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 exists to define limits
    - Community data from large, diverse population is a requirement
  - Standard must be accepted internationally

Overview of 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

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

Image Credit :Lockheed Martin

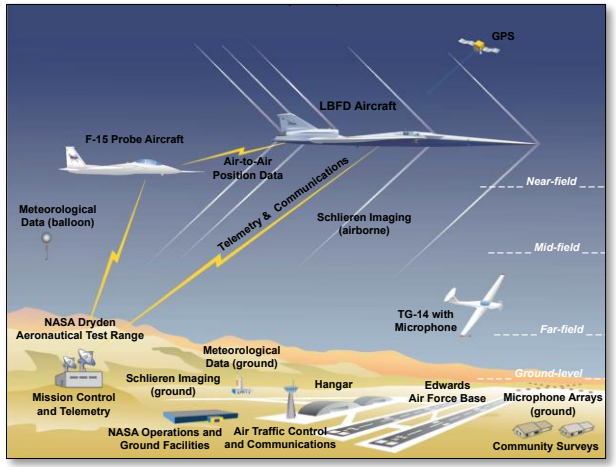
Low-Boom Flight Demonstration Mission Overview



Phase 1 – Aircraft Development

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

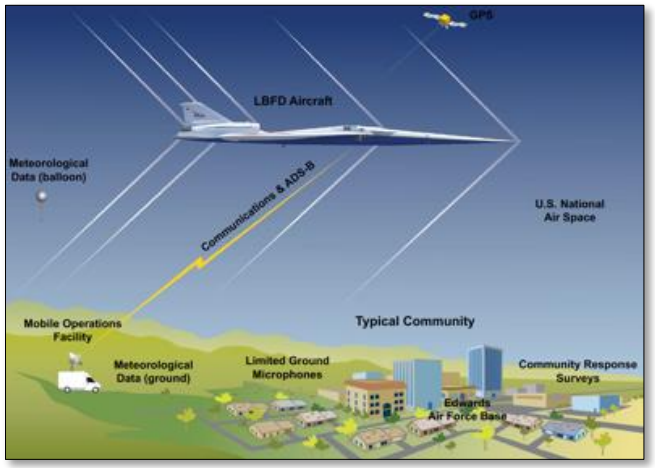
First Flight
Summer 2022



Start
Spring 2023

Phase 2 – Acoustic Validation

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



Phase 3 – Community Response

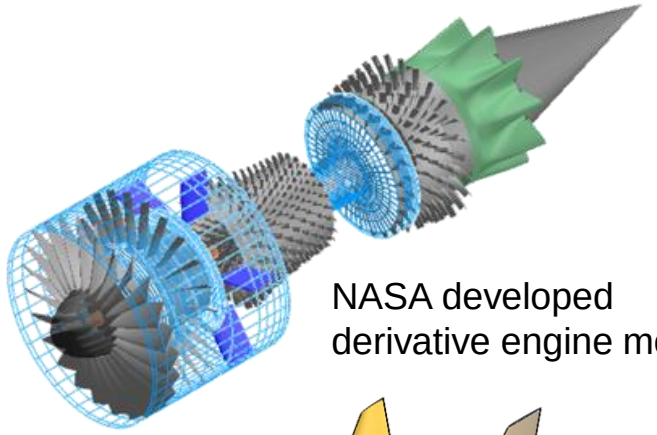
- Initial community response overflight study based at NASA AFRC
- Multiple campaigns (3 to 4) over representative communities across the U.S.

Start
Spring 2024

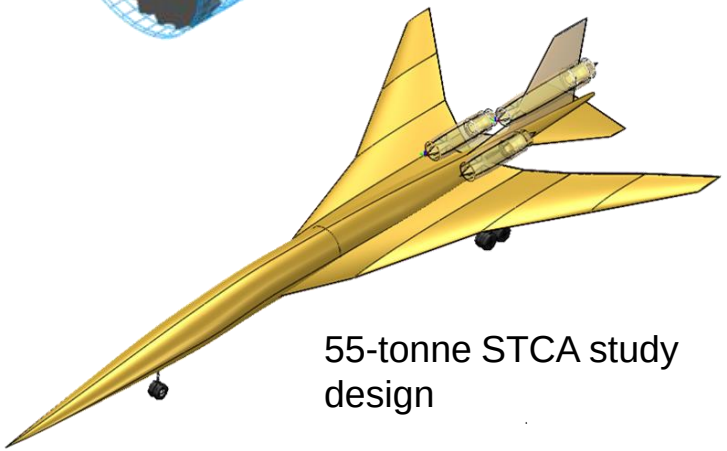
Systematic Approach Leading to Community Testing

NASA Provides Key Support to LTO Standards Efforts

- 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



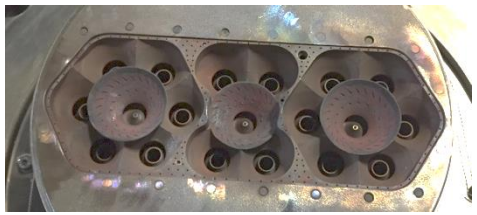
NASA developed derivative engine model



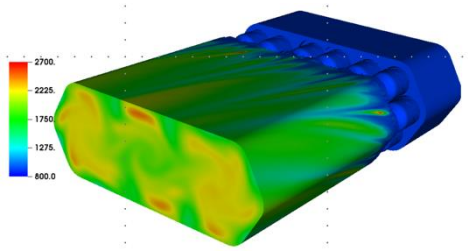
55-tonne STCA study design

Environmental Acceptability: Emissions Research Theme

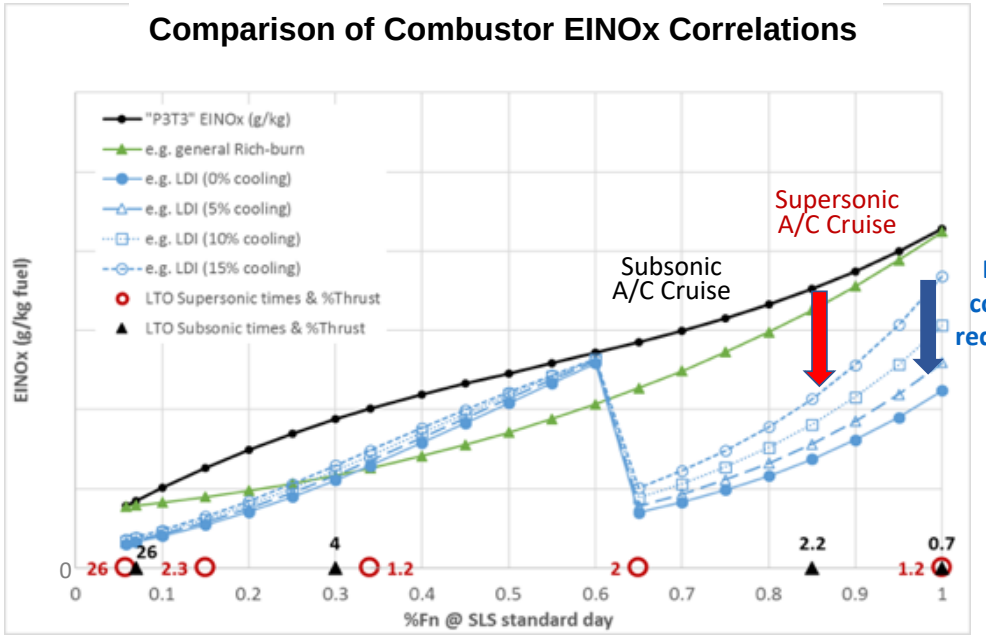
- CST has worked in partnership with NASA's subsonic research efforts to experimentally and analytically explore the applicability of advanced combustor technology to emissions reduction for supersonic aircraft
- NASA has engaged MIT to develop and improve global high altitude emission models and study 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 has been delayed until 2024 timeframe



Test Hardware



Computational Analysis



Hypersonic Technology Project Vision

Enable Routine, Reusable, Airbreathing Hypersonic Flight

Approach

- Conduct fundamental research to enable a broad spectrum of hypersonic systems and missions by advancing the core capabilities and critical technologies underpinning the mastery of hypersonic flight to ensure U.S. supremacy in hypersonics

Scope

- Fundamental research spanning technology readiness and system complexity levels
- Critical technologies enabling reusable hypersonic systems
- System-level research, design, analysis, validation
- Engage, invigorate and train the next generation of engineers

HTP Investment Areas in the Common Barriers to Reusable Hypersonic Flight



Conventional & Conformal Cryo-Tank Materials & Structures

Leading Edges, **Hot Structures, Advanced Materials and Manufacturing, & Static Seals**

Control Surfaces, Airframe Integrated Acreage TPS Strategies & **Dynamic Seals**

Vehicle Flow Physics (High Speed Boundary Layer Transition, aerodynamics, aero-heating), drag, trim, etc…

System Analysis methods development/ validation, System Level Uncertainty Quantification Methods, (-ilities, cost)

Propulsion/ Vehicle **Control and advanced sensor technologies**

Innovative High Speed Inlets, Nozzles & Vehicle Integration Technologies & **Dynamic Seals**

Turbine Thermal Management and Wide Operating Range Technologies

DMRJ Durability, Thermal Management, and **Wide Operating Range Technologies, CMC HEX**

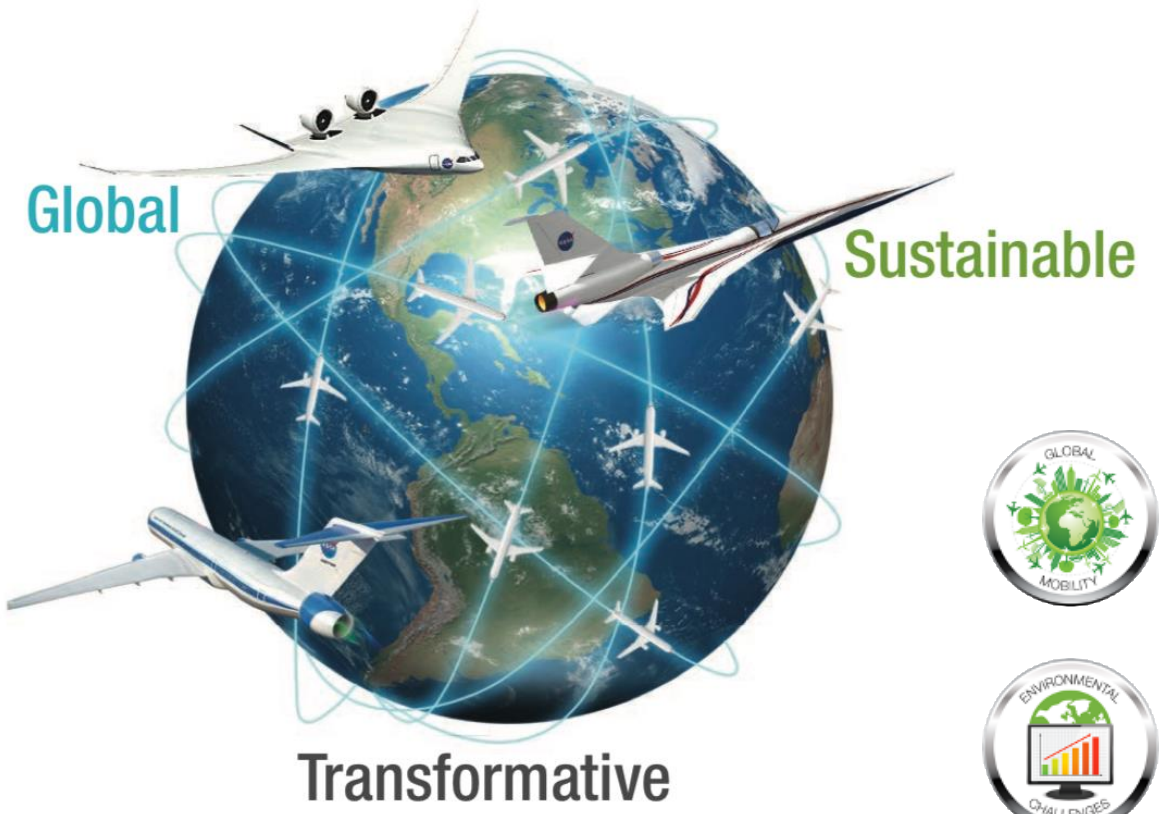
Combined Cycle Mode Transition & Propulsion Integration Technologies

- **RT-1/TC-1: Systems Design & Analysis**
- **RT-2/TC-2: Propulsion Techs**
- **RT-3: Vehicle Techs**
- **RT-4: High Temp, Durable Materials**



NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century



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

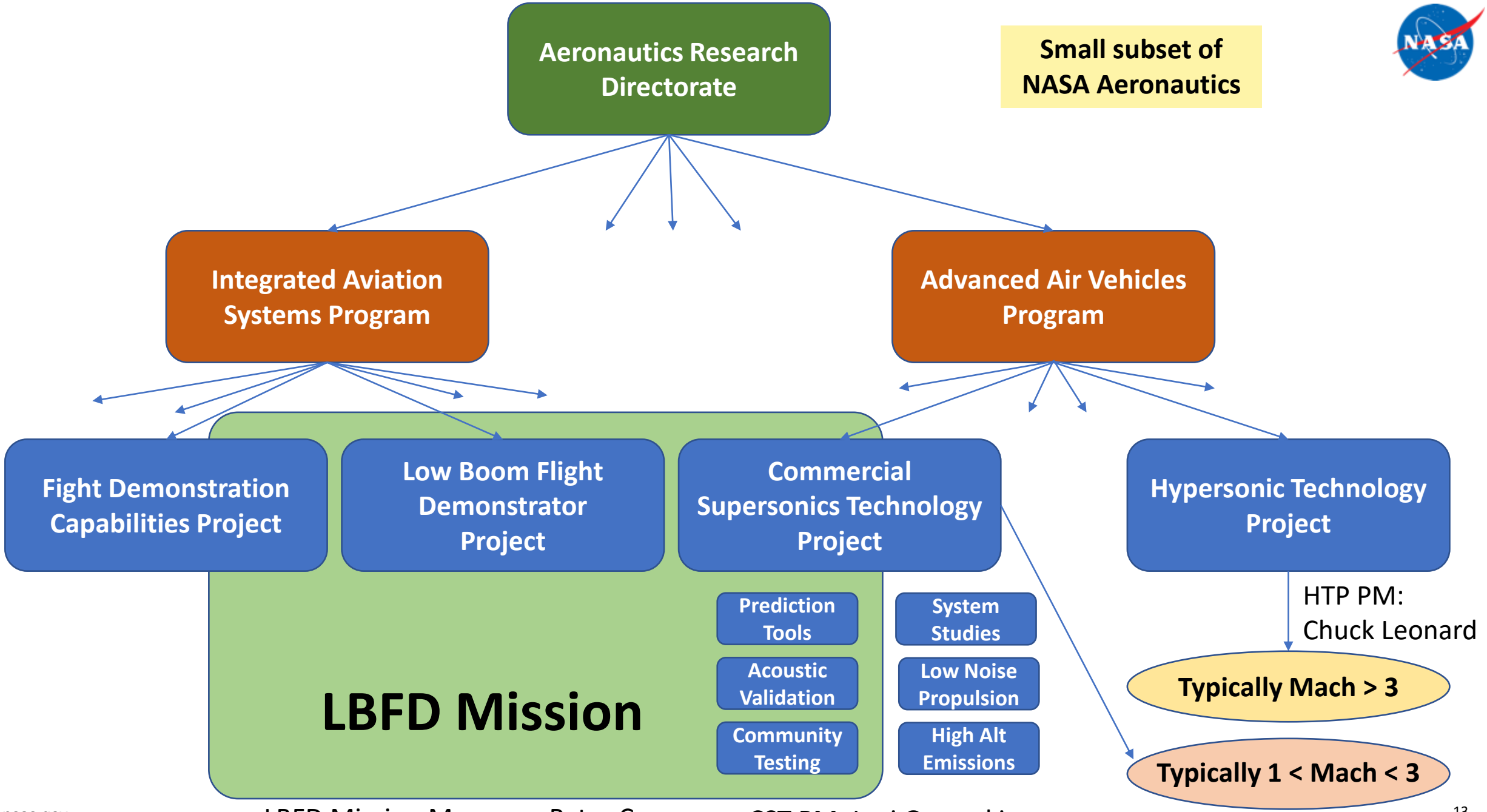
Innovation in Commercial Supersonic Aircraft
- Achieve practical, affordable commercial supersonic air transport

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

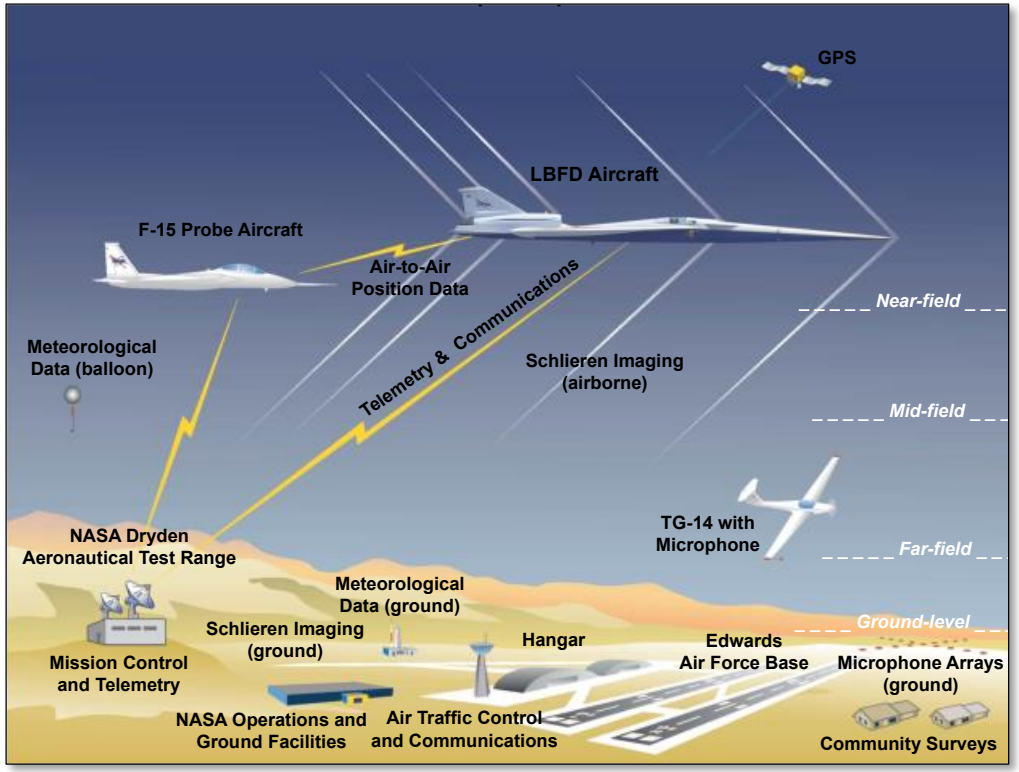
In-Time System-Wide Safety Assurance
- Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

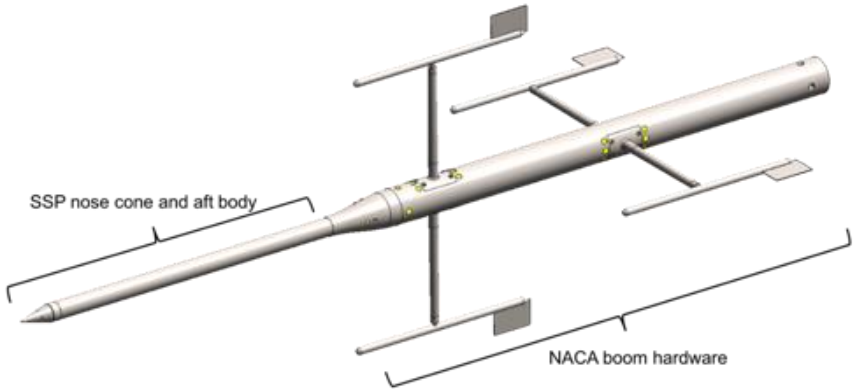
Assured Autonomy for Aviation Transformation
- Safely implement autonomy in aviation applications


Aeronautics Research Directorate
Small subset of NASA Aeronautics
Integrated Aviation Systems Program
Advanced Air Vehicles Program
Fight Demonstration Capabilities Project
Low Boom Flight Demonstrator Project
Commercial Supersonics Technology Project
Hypersonic Technology Project
HTP PM: Chuck Leonard
LBFD Mission
Prediction Tools
Acoustic Validation
Community Testing
System Studies
Low Noise Propulsion
High Alt Emissions
Typically Mach > 3
Typically 1 < Mach < 3
LBFD Mission Manager: Peter Coen
CST PM: Lori Ozoroski

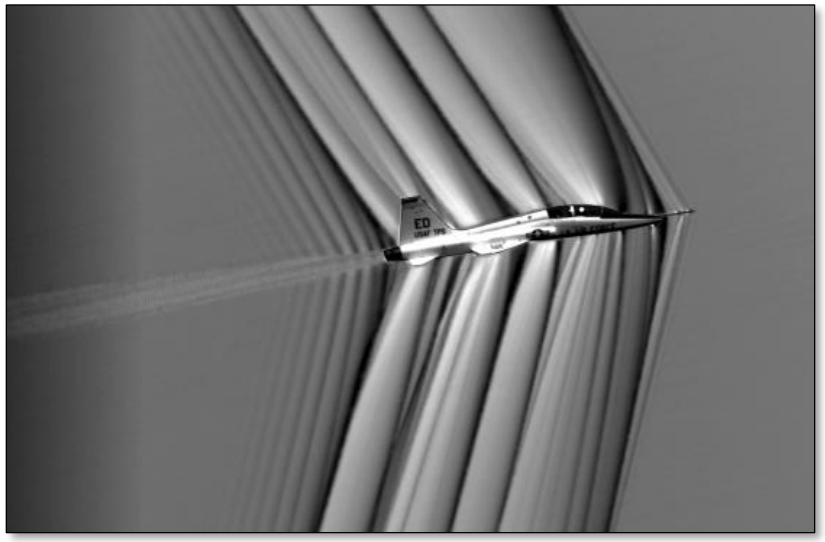
Acoustic Validation Test Planning and Execution

- 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





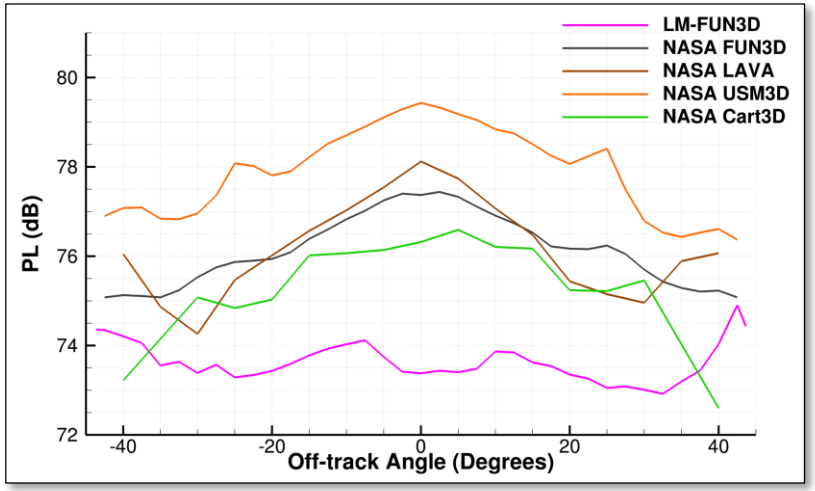
Shock Sensing Probe



Advanced Air-Air Schlieren Imaging

Prediction Tools and Validation

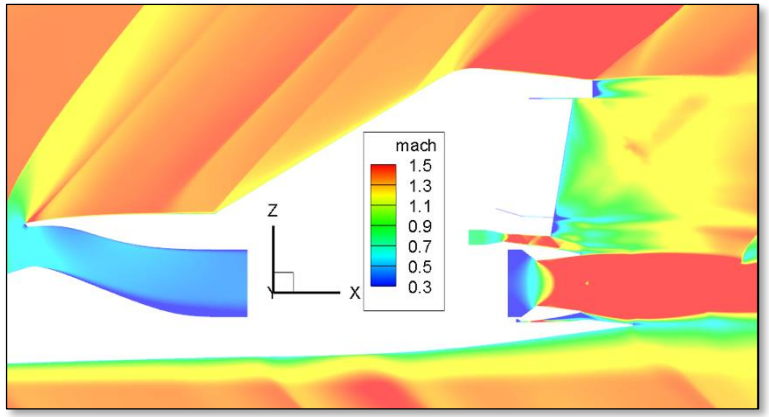
In preparation for community response testing, NASA will provide a suite of prediction tools to support timely and accurate validation of the acoustic performance of the X-59 aircraft, rapid pre-flight exposure planning for Community Testing, and provide a foundation for future configuration design and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



Sonic Boom Prediction



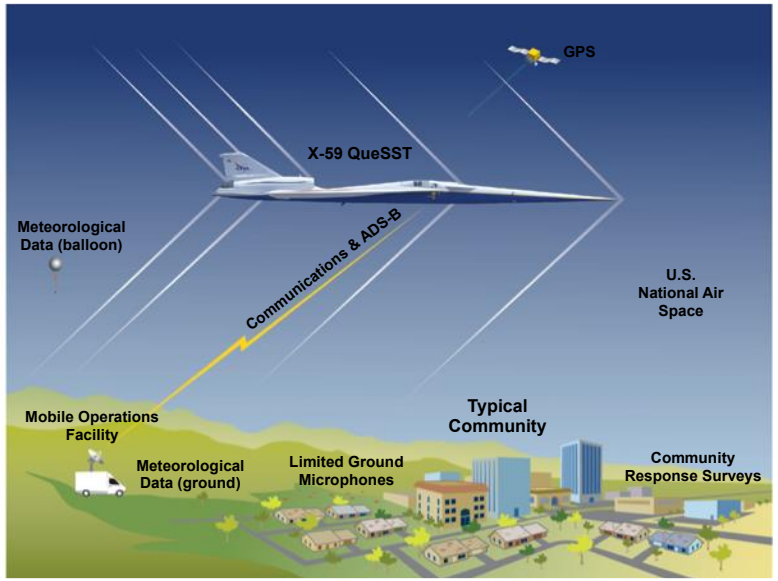
High Fidelity CFD



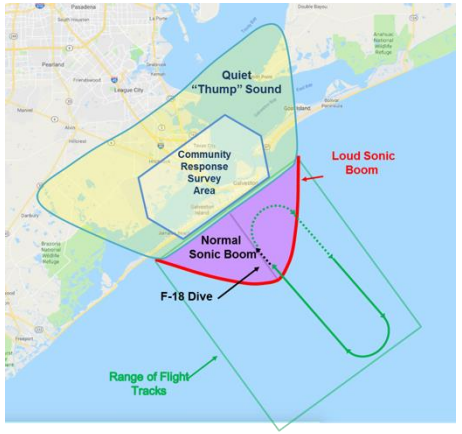
Uncertainty Quantification

Community Test Planning and Execution

- Create a robust community response relationship for annoyance vs appropriate noise metrics
- Large populations, large number of representative responses
- Range of 6-8 daily exposures required
- 4-5 test campaigns in different locations around the U.S.
- Engage the international research & regulatory community to ensure data acceptance







Quiet Supersonic Flight 2018
Galveston, Texas

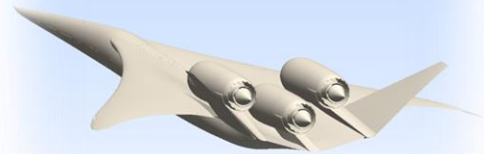
Environmental Acceptability: Airport Noise Research Theme

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.

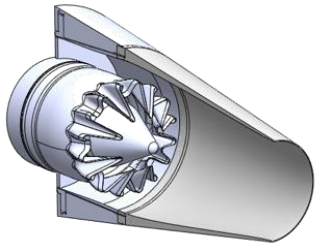




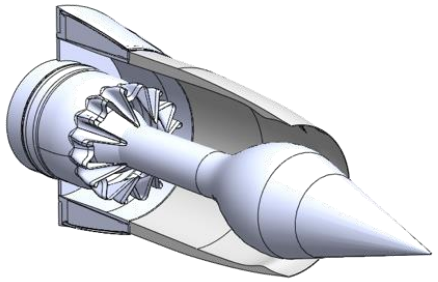
Top-mounted propulsion study concept

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



Int. Plug/ Int. Mixer



Ext. Plug/ Int. Mixer

Near Term Nozzle Concepts

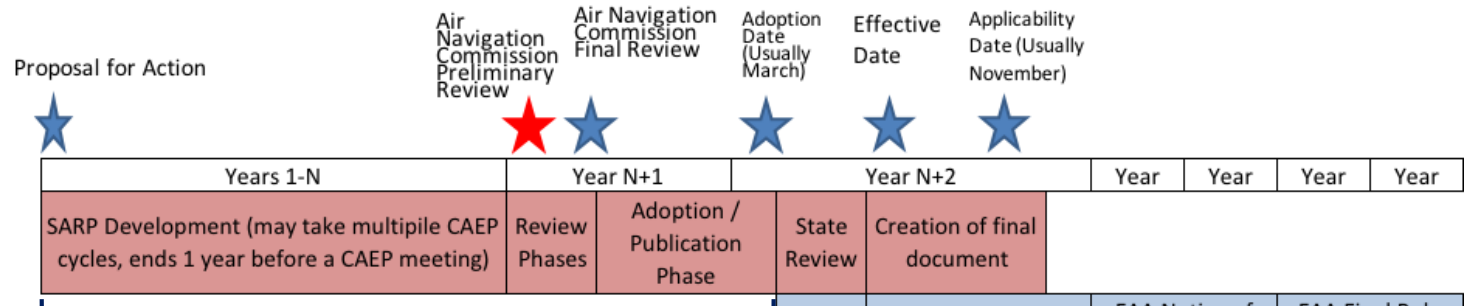
ICAO/CAEP standards development overview

ICAO SARP Process

FAA (or other National Airworthiness Authority (NAA)) Rulemaking

- Large, complex world government organization
  - FAA is US Representative & implements US regs.
- Framework for Standard
  - **3 elements**
    - **Metric**
    - **Procedures**
    - **Limits**
- For an en route noise standard, flight data supports all 3 elements
  - Community response data is vital for defining limits

Standards and Recommended Practices (SARP) & Rulemaking Process Timeline



- WG leads development of SARPs
- Process generally takes 1-2 CAEP cycles but can take longer
- WG reports to SG during the cycle and to CAEP at meetings

- Rulemaking process by FAA or other NAA lags SARP process
- Implements SARP in member states regulations

Effectively the end to technically driven phase of the CAEP process

SARP – Standard and Recommended Practices WG- CAEP Working Group SG- CAEP Steering Group

Summary Remarks

- 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
- Current standards efforts focus on LTO in response to near term market entrants
  - NASA analysis and independent data plays a key role
  - Standards are key to longer term market interests as well
- NASA's strategy includes efforts addressing longer term research leading to the development of increasingly capable supersonic commercial aircraft