NASA's Commercial Supersonic Research

IFAR Sustainable Aviation Workshop

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Presentation topics

- NASA Aeronautics Strategy
- Innovation in Commercial Supersonic Flight
- Low Boom Flight Demonstration Mission
- Landing and takeoff noise and emissions research
- Concluding remarks

NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

6 Strategic Thrusts

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

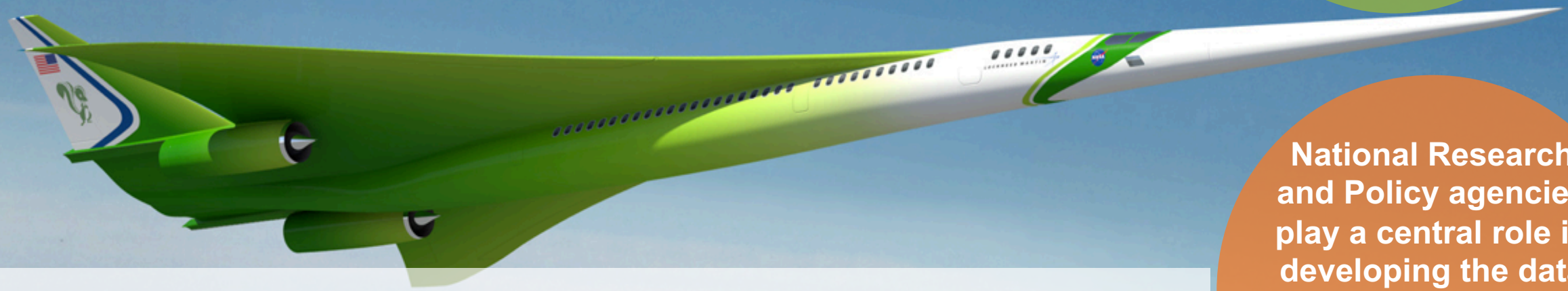
U.S. leadership for a new era of flight

The 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



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

Community outcomes and NASA research focus

	2015	2025	2035
Outcomes	Certification standards for supersonic commercial aircraft including overland flight based on acceptable sonic boom noise and Landing/Takeoff (LTO) noise and emissions	Introduction of Affordable, Low-Boom, Low-noise, and Low-emission Supersonic Transports	Increased Utility and Commercial Market Growth of Supersonic Transport Fleet
NASA Research Focus	**Deliver on Critical Commitment:** **Deliver to ICAO a database of community response to quiet supersonic aircraft flight over land** • **Scientifically valid data on community response to low noise supersonic overflight** • Improved tools and systems analysis supporting LTO standards development	• Technologies enabling the first and second generations of supersonic transports with **emphasis on acceptable community and en route noise and high-altitude emissions**	• Technologies enabling supersonic transports that are competitive in airline market with **emphasis on high efficiency** for improved economics • Technologies for supersonic airline operations in the airspace system

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

NASA's approach to design for quiet supersonic flight

Objective

- Develop and validate tools and design approaches to enable the development of supersonic airliners with very little perceived sonic boom noise:
- 75-80 PLdB ~ 30 less than Concorde or typical military aircraft – A sonic "thump" instead of a boom

Approach

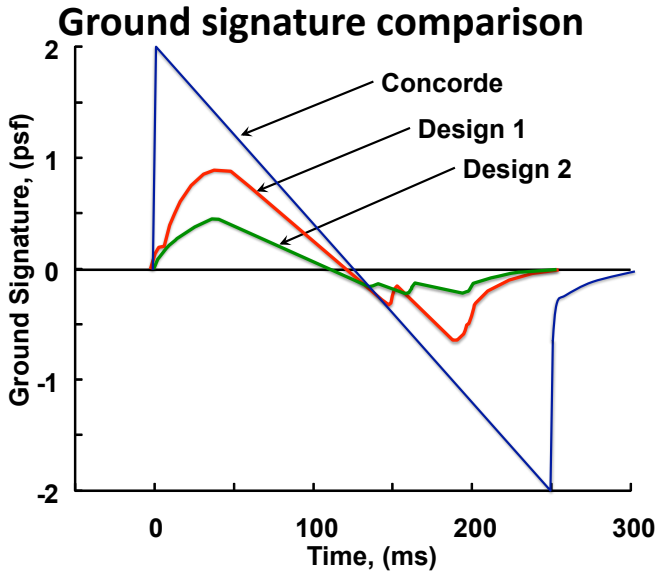
- Build on 40+ years of research in sonic boom minimization
- Improve usability, accuracy and speed of high-fidelity analysis tools for inclusion in the design process
- Develop new design targets that produce less noise, and allow more design flexibility
- Conduct validation studies in wind tunnels and in flight

Quiet Supersonic Configuration Features

Unique empennage shape to control lift impact on signature

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

Propulsion installation minimizes contribution to signature



NASA's approach to understanding human and community response

Vast body of international research from 1960's through 1990's indicates that the only significant problem with civil aircraft sonic boom is human response

- Seismic, building damage, aircraft to aircraft, etc. effects all found to be negligible

Since the 1990's many research organizations have made contributions to understanding human response to sonic booms and quieter impulsive sounds

1. **Laboratory studies**
   - Sophisticated loudspeaker-based simulators
   - Consistent, repeatable conditions
   - 10-50 test participants
2. **Field and small community studies**
   - Added realism, but participants generally had regular exposure to sonic booms
   - Aircraft generated sounds over a small area (F-18 "low-boom" dive)
   - 50-100 test participants
3. **Large community risk-reduction study**
   - NASA Quiet Supersonic Flights 2018 (QSF18), Galveston Texas
   - First test of community response in a "non experienced community" since 1980's
   - Aircraft generated sounds over a moderate area
   - 500 survey participants, thousands of others exposed to sounds

Sonic Boom Simulator

Interior Effects Simulator

Test Home

Subjective Response

Quiet Supersonic Flight 2018
Galveston, Texas

Next step: Fully realistic community overflights exposing very large areas and varied populations

NASA's Low-Boom Flight Demonstration mission

X-59 QueSST
(Quiet SuperSonic Technology)

X-plane approach focuses efforts on defining minimum set of key requirements that can be met in the most cost effective design

Design Parameters
- **Length:96 ft**
- **Span: 29.5 ft**
- **Speed: Mach 1.4 (925 mph)**
- **Altitude: 55,000 ft**

Key Requirements
- The acoustic signal of the X-plane must effectively replicate that of future larger supersonic commercial aircraft.
- The X-plane must conduct community overflight tests in a manner representative of typical flight operations of future aircraft.

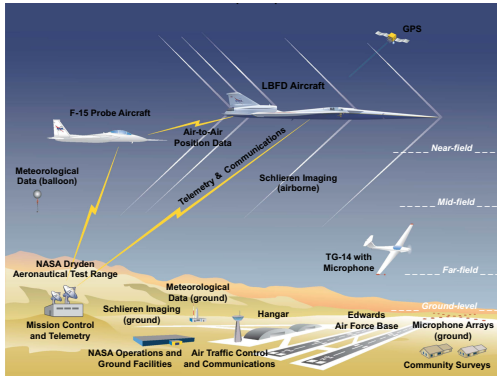
Key Derived Requirements
- New airframe design to achieve desired acoustic signal, with smallest size that meets key acoustic requirements
- Use of components from existing aircraft to reduce cost (F-18 engine, T-38 canopy and cockpit, F-16 landing gear, etc.)
- Payload capacity: single pilot/flight test instrumentation

Low Boom Flight Demonstration mission overview

Phase 1 – Aircraft Development – *In progress 2018-22)*

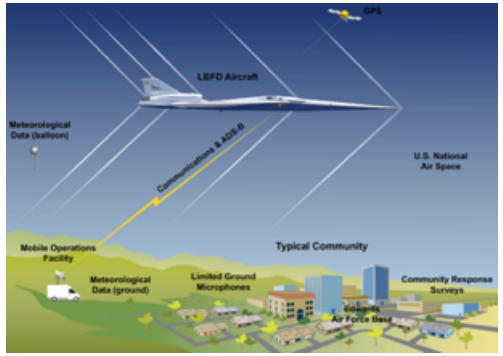
- Detailed design
- Fabrication, integration, ground test
- Checkout flights
- Subsonic envelope expansion
- Supersonic envelope expansion

Systematic Approach Leading to Community Testing



Phase 2 – Acoustic Validation – *Preparation 2018-22, Execution 2022-23*

- Aircraft operations & support, range operations, support aircraft
- In-flight measurement capabilities
- Ground measurement capabilities
- Validation of X-59 boom signature and prediction tools
- Development of acoustic prediction tools for Phase 3



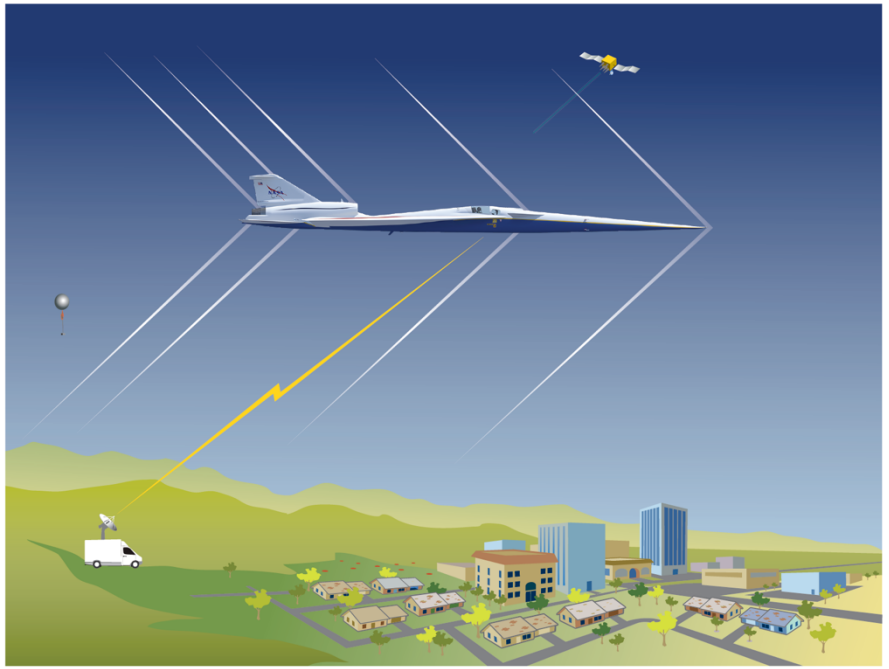
Phase 3 – Community Response Testing

Preparation 2020-24, Execution 2024-26

- Aircraft operations & support, deployment
- Ground measurement capabilities
- Ground crew operations
- Noise exposure design
- Community response surveys
- Data analysis and database delivery

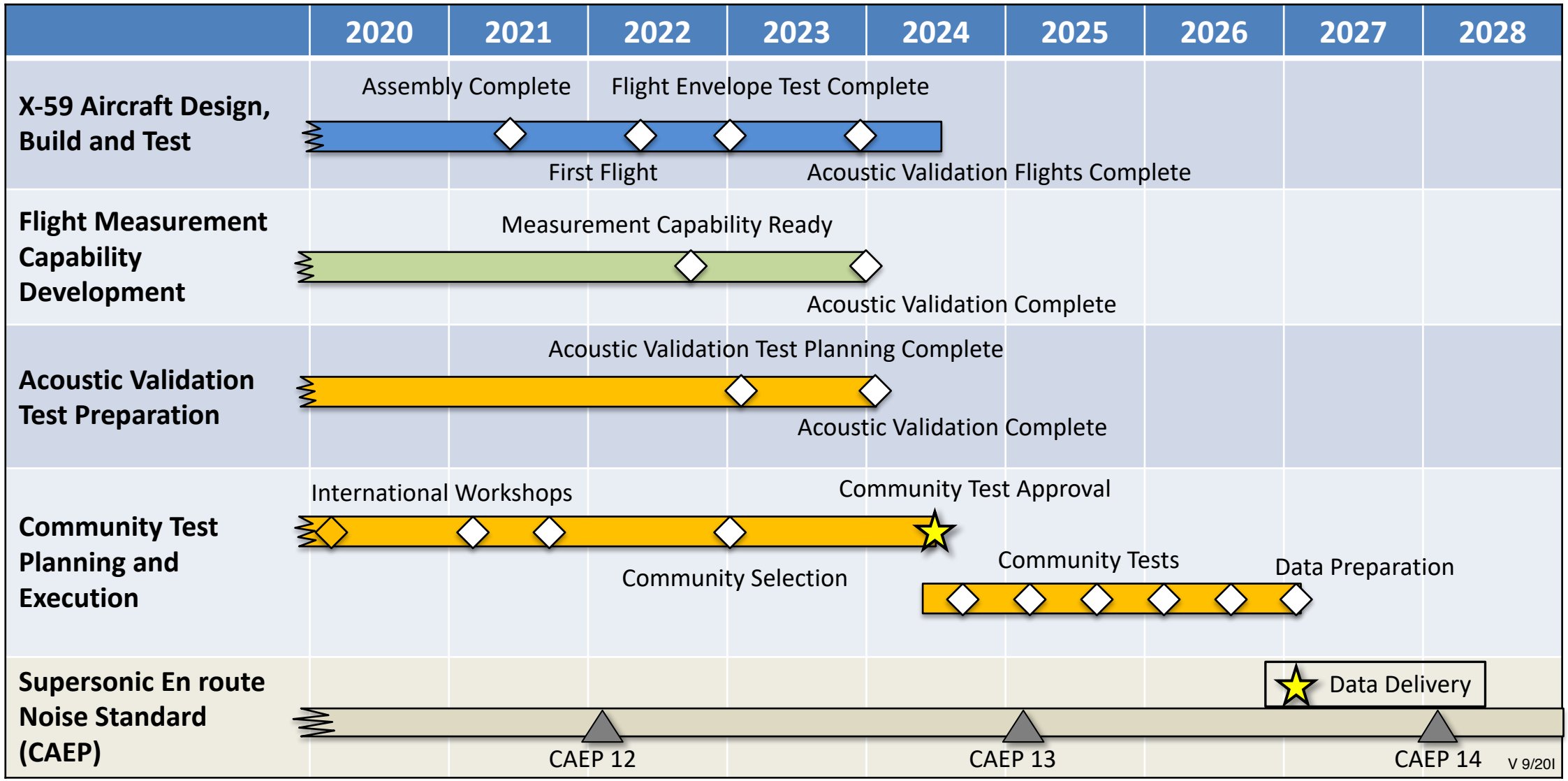
Community overflight testing creates a response database

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
- Range of exposures required, possibly including normal booms
- Up to a maximum of 6-8 of daily exposures (possibly including nighttime)
- Sufficient test duration to establish effect of repeated exposure
- Account for test aircraft operational limitations
  - Airfield facilities
- Engage the international research & regulatory community to ensure data acceptance

LBFD mission timeline



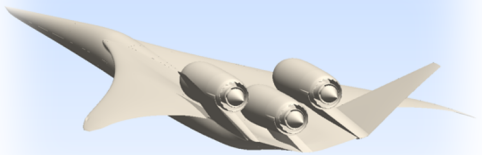
Sustainable Supersonic Flight: Airport noise and emissions

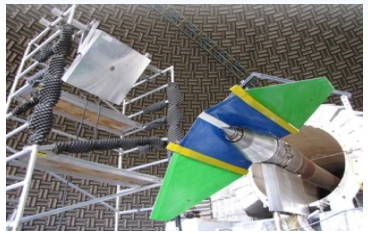
NASA's research portfolio includes efforts to reduce these impacts

Near Term: Improve quality of predictions needed for design, analysis and certification
Long Term: Technology and design approaches providing sustainable solutions for supersonic civil transport

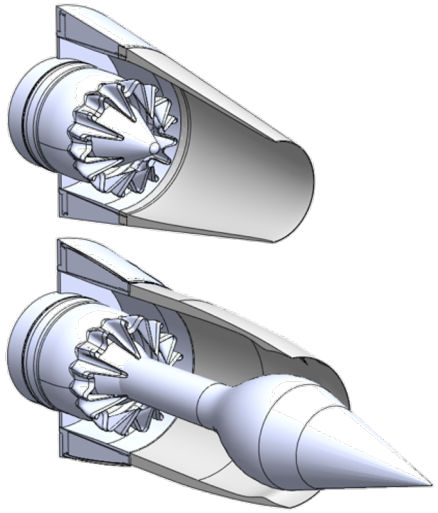
Landing and takeoff noise research

- Elements include: Integrated solutions including inlet and fan noise, Innovative concepts, tools and techniques and experimental validation





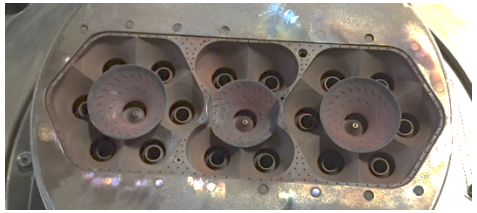
Top-mounted propulsion study



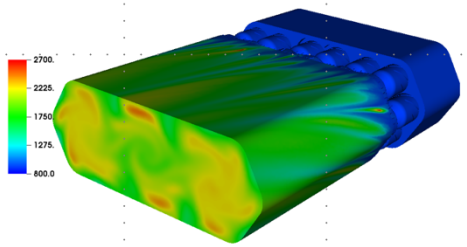
Nozzle Concepts

Emissions research

- Elements include: Lean burn combustion, combustor operation design, advanced materials, alternative fuel composition, tools and techniques and experimental validation



Test Hardware



Computational Analysis

Concluding 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
- NASA's strategy includes efforts addressing longer term research leading to the development of increasingly capable, sustainable supersonic commercial flight