APA-20 Low Sonic Boom Flight Demonstration

APA-20. Special Session: Sonic Boom Activities IV - Low Sonic Boom Flight Demonstration
Chair(s): David Richwine (NASA-Langley Research Center)
2:00 PM - 5:30 PM; Courtland

2:00 PM - 2:30 PM	Oral Presentation. Overview of NASA High Speed Project Research and Progress *Peter Coen; David M. Richwine*
2:30 PM - 3:00 PM	Oral Presentation. ICAO Supersonics Task Group (SSTG) Status and Progress *Sandy Liu; Victor Sparrow*
3:00 PM - 3:30 PM	Oral Presentation. Boeing Low-Boom Flight Demonstrator (LBFD) Concept Formulation Study *Tony Antani; H. Welge; Shreekant Agrawal; Chet Nelson; Todd Magee; Steve Holllowell; Harvey Schellenger*
3:30 PM - 4:00 PM	Oral Presentation. Lockheed Martin Low-Boom Flight Demonstrator (LBFD) Concept Formulation Study *Michael Buonanno; John M. Morgenstern*
4:00 PM - 4:30 PM	Oral Presentation. Advanced Adjoint Optimization Capabilities in SU2 for the Design of a Low-Boom Flight Demonstrator *Juan J. Alonso; Francisco Palacios; Trent W. Lukaczyk*
4:30 PM - 5:00 PM	Oral Presentation. The Need for Speed *Robert Cowart*

National Aeronautics and Space Administration

Overview of NASA High Speed Research

NASA's Fundamental Aeronautics Program

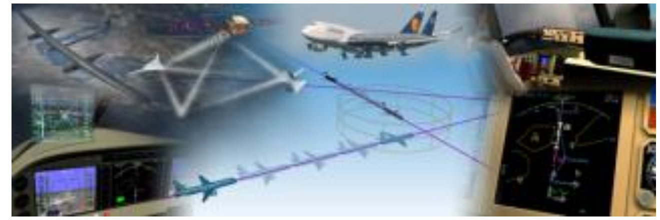
Peter Coen
David Richwine

AIAA Aviation Conference
June 2014
Atlanta, GA
www.nasa.gov

NASA Presentation Objectives

- Summarize programmatic status
- Review High Speed Project research themes and technical challenges
- Summarize recent research activities and progress
  - Low sonic boom design
  - Low noise propulsion for low boom aircraft
  - Community response to low sonic boom
- Introduce potential next steps in High Speed Project research
  - Low Boom Flight Demonstration

NASA Aeronautics Programs 2014

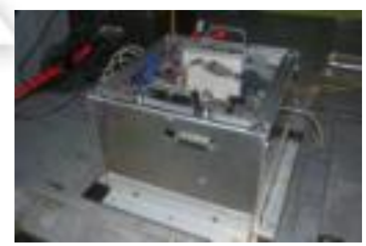


Integrated Systems Research Program

Airspace Systems Program

Fundamental Aeronautics Program

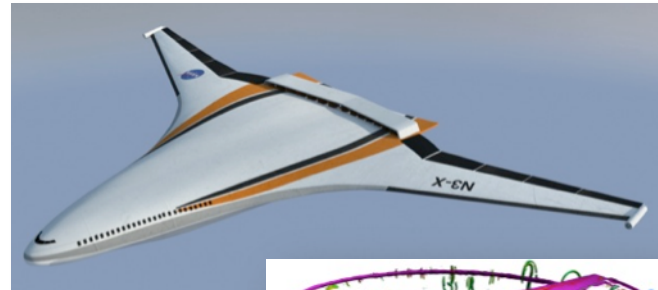
Aviation Safety Program

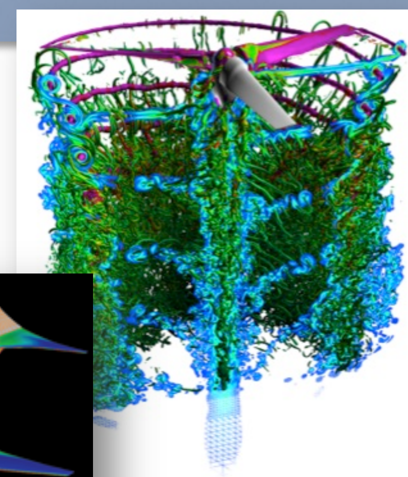


Aeronautics Test Program

Fundamental Aeronautics Program 2014

Conduct fundamental research that will generate innovative concepts, tools, technologies and knowledge to enable revolutionary advances for a wide range of air vehicles.



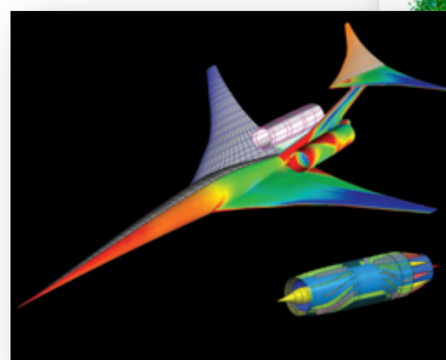


Fixed Wing (FW)

Explore and develop technologies and concepts for improved energy efficiency and environmental compatibility of fixed wing, subsonic transports.

Rotary Wing (RW)

Develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles.



High Speed (HS)

Tool and technology development and validation to address barriers to high speed flight.

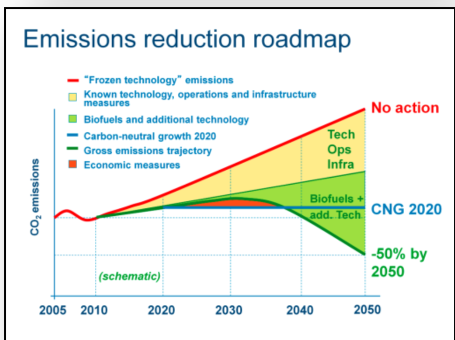
Aeronautical Sciences (AS)

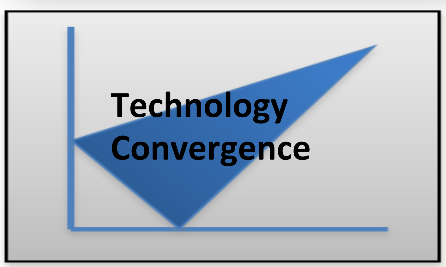
Enable fast, efficient design & analysis of advanced aviation systems by developing physics-based tools and methods for cross-cutting technologies.

NASA Aeronautics Restructure for 2015

Aligns Organization with New Strategic Direction

3 Mega-Drivers





6 Strategic Research & Technology Thrusts

Safe, Efficient Growth in Global Operations
- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

Innovation in Commercial Supersonic Aircraft
- Achieve a low-boom standard

Ultra-Efficient Commercial Transports
- Pioneer technologies for big leaps in efficiency and environmental performance

Transition to Low-Carbon Propulsion
- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

Real-Time System-Wide Safety Assurance
- Develop tools for use in a prototype of an integrated safety monitoring and assurance system

Assured Autonomy for Aviation Transformation
- Develop high-impact aviation autonomy applications

Overcoming the Barriers to Practical High Speed Vehicles

Environmental Barriers

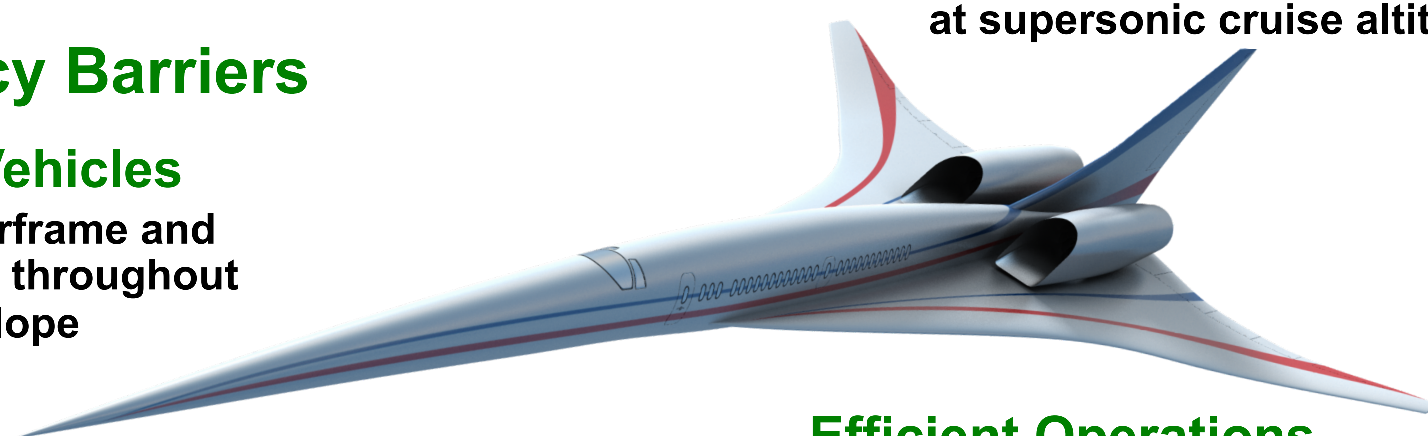
Sonic Boom
- Design for low noise sonic boom
- Understand community response

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

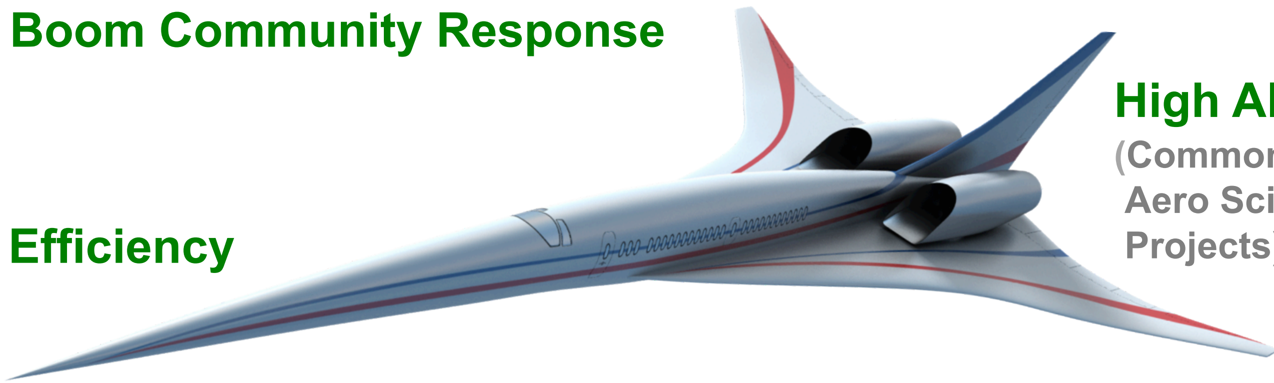
High Speed Research Themes FY 13-17

Research Themes Focus on Low Boom Flight Demonstration Readiness & Preparation for Potential Next Tech Challenges

Integrated Design Solutions for Revolutionary High Speed Aircraft

Airport Community Noise

Sonic Boom Community Response



High Altitude Emissions
(Common content in NASA FAP Aero Sciences & Fixed Wing & Projects)

Cruise Efficiency

Flight Systems

Aeroservoelasticity

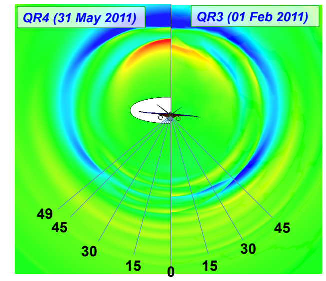
Light Weight, Durable Engines/Airframes
(Current Effort Focused in Aero Sciences Project)

Research Themes, Technical Challenges & Key Deliverables

Research Themes	Technical Challenges 2013-2017	Additional Research Areas 2013-2017
Integrated Design Solutions for Revolutionary High Speed Aircraft	**Low Sonic Boom Design Tools:** Tools and technologies enabling the design of supersonic aircraft that reduce sonic boom noise to 80 PLdB validated as ready for application in a flight demonstrator	• Supersonic Inlet & Nozzle design • FEM for conceptual design • N+2 Tech assessment
Understand and Measure **Sonic Boom Community Response**	**Sonic Boom Community Response Metric & Methodology:** Validated field study methodology, survey tools and test protocols to support community studies with a demonstrator aircraft	• Sonic boom propagation • Experimental techniques for low boom atmospheric effects
Minimize the **Airport Community Noise** Impact of High Speed Aircraft	**Low Noise Propulsion for Low Boom Aircraft:** Design tools and innovative concepts for integrated supersonic propulsion systems with noise levels of 10 EPNdB less than FAR 36 Stage 4 demonstrated in ground test	
High Altitude Emissions	No Technical Challenge level investment in these Research Themes during this time period	Civil sup. emissions impact
Cruise Efficiency		Perf., transition control
Aeroservoelasticity		Aero-propulso-servo-elasticity
Flight Systems		External vision, boom display

Low Sonic Boom Design: Technical Challenge Summary

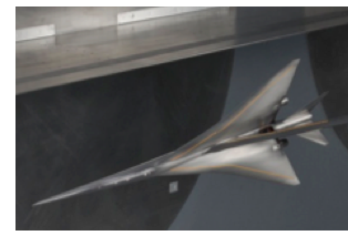
2012: Develop and wind tunnel validate tools for low boom airframe design



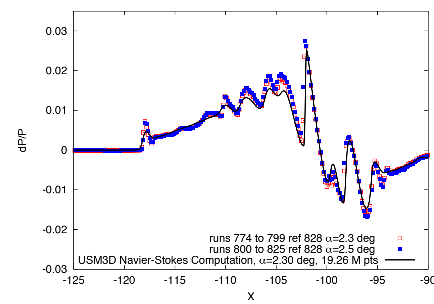
2013: Refine and further validate tools for low boom airframe design

Incorporate detailed nacelle models and inlet flow effects and validate with wind tunnel test

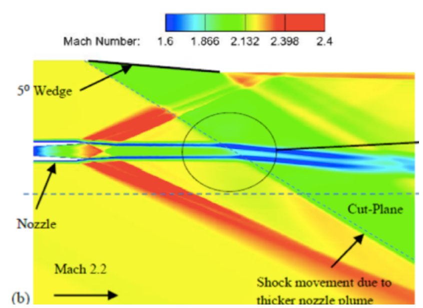
Develop prediction models for nozzle flow effects

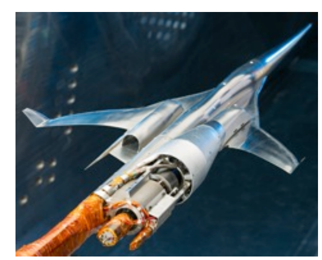


2014: Validate nozzle flow and shock interaction predictions with wind tunnel test



2015: Robust design, atmosphere and flight condition sensitivities





Nozzle Flow and Shock Interaction Test (2014)

Objectives:

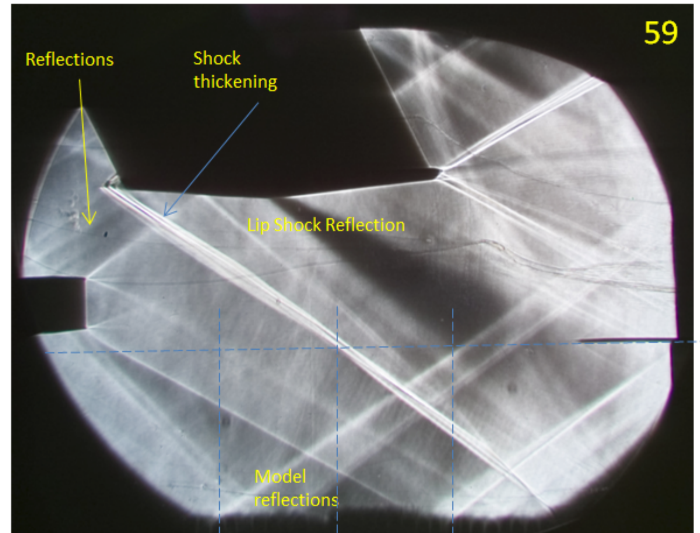
- Develop validation data for nozzle flow and shock-plume interactions.

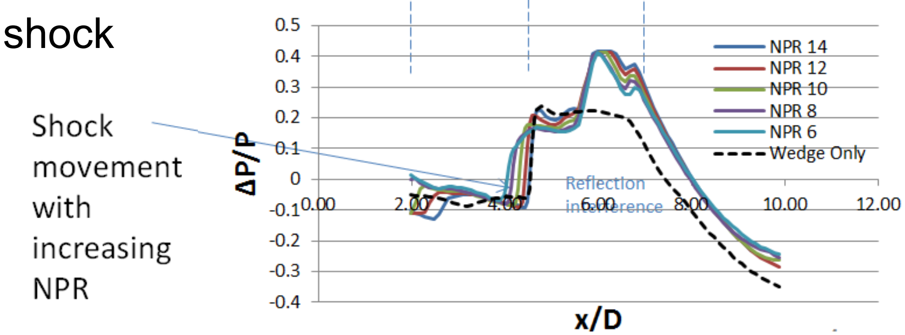
Approach

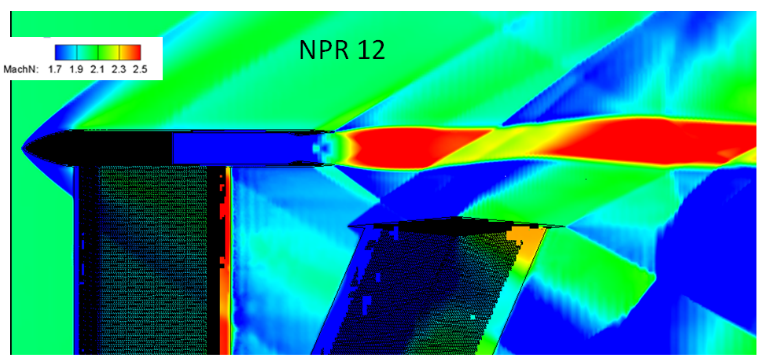
- Initial test of isolated nacelle and shock generating wedge
  - Measure pressures, collect Schlieren and PIV flow visualization data
- Identify additional test and validation requirements

Status

- Jet plume induced shock thickening revealed
- Demonstrated nozzle pressure ratio effect on shock position
- Detailed CFD validation in progress

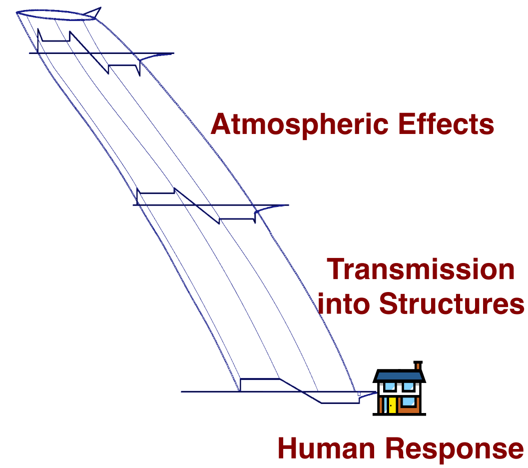


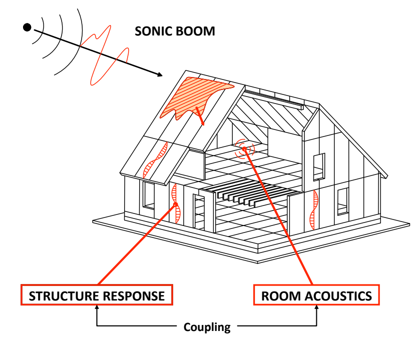


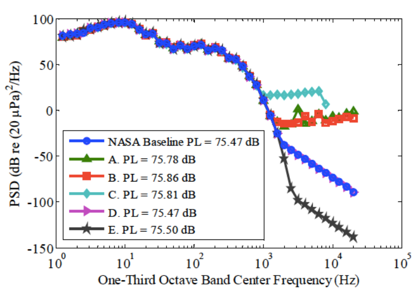


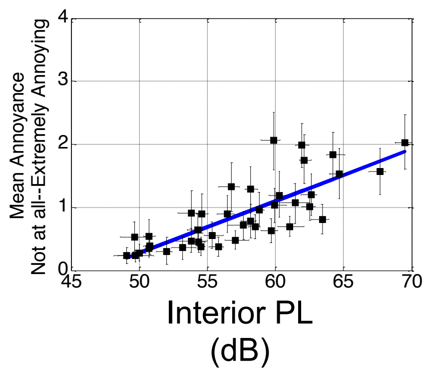
Sonic Boom Community Response Progress

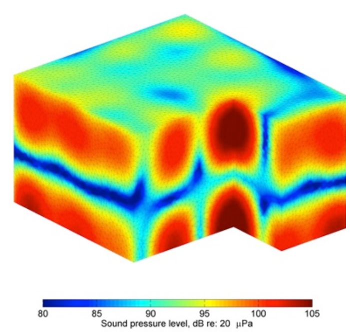
- Overall goals are to understand propagation and response to low noise sonic boom
- Recent focus: understanding boom interaction with structure and the impact on indoor annoyance
- Interior Effects Room (IER) is a valuable tool
  - Recent testing includes:
    - Validation of annoyance models
    - Effect of rattle on annoyance
  - Impact of aircraft scale on boom annoyance
- New full-frequency structural response model developed and validated
- Atmosphere propagation tool comparison
- Support for FAA-ICAO Supersonic Task Group (SSTG)

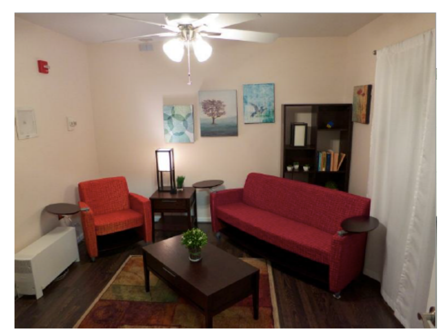






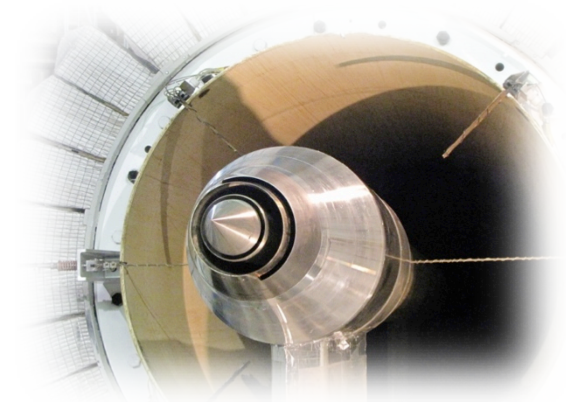


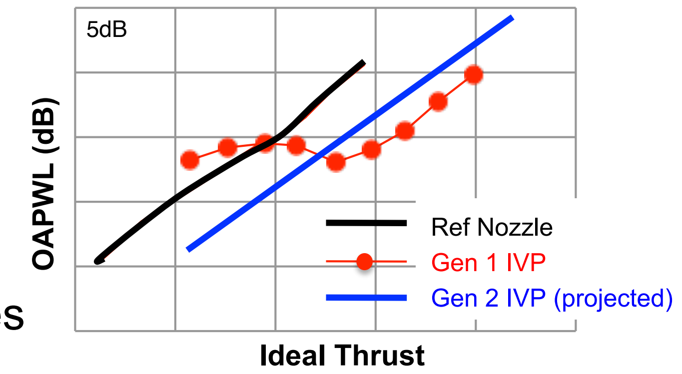


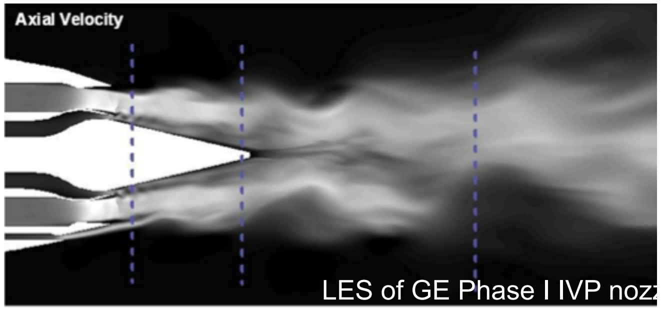


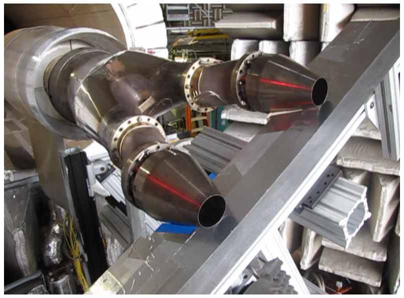
Low Noise Propulsion Progress

- Inverted Velocity Profile (IVP) Nozzle identified as a good candidate to meet noise goals
  - Unpredicted unsteady separation in model scale hardware led to shortfall in initial design performance
  - LES, DES analysis, new acoustic measurement techniques led to identification and solution to problem
  - Revised model successfully tested
- Exploration of other concepts and effects continues
  - Offset stream concepts
  - 2-D, High aspect ratio nozzles
  - Twin jets and proximity effects
  - Jet-surface interactions
- Inlet and fan noise and interaction effort starting
- Concepts providing additional margin to new noise rules are being sought









High Speed Technical Challenge Progress Summary

Sonic Boom

- Methodologies for the development of aircraft with shaped sonic boom signatures, particularly in the aft end of the vehicle, have been applied and validated through wind tunnel testing. Low boom targets for N+2 configurations have been met; methods are applicable to N+1 and N+3 vehicles as well.
- *Next Steps: Full carpet optimization, detailed propulsion effects*

Airport Noise

- Revised three stream nozzle concept meets goals with margin
- Initial inlet and fan assessment completed
- *Next Steps: Integration effects, Assessment and optimization of additional concepts*

Cruise Emissions

- NO_X goals demonstrated in flametube testing
- *Next Steps: reduce combustion dynamics, Emissions impact assessment*

Balanced Goals for Practical Civil Supersonic Aircraft (Technology Available)	NASA N+2 Validation Study Goals	N+2 System Validation Results
Design Goals		
Cruise Speed	Mach 1.6 -1.8	Mach 1.6 - 1.8
Range (n.mi.)	4000	4000 - 5500
Payload (passengers)	35-70	35-80
Environmental Goals		
Sonic Boom	*85 PldB (revised)*	*79 - 81 PLdB*
Airport Noise (cum below stage 4)	10 EPNdB	*12 EPNdB*
Cruise Emissions (Cruise NOx g/kg of fuel)	< 10	*5*
Efficiency Goals		
Fuel Efficiency (pass-miles per lb of fuel)	3.0	1.6 – 3.1

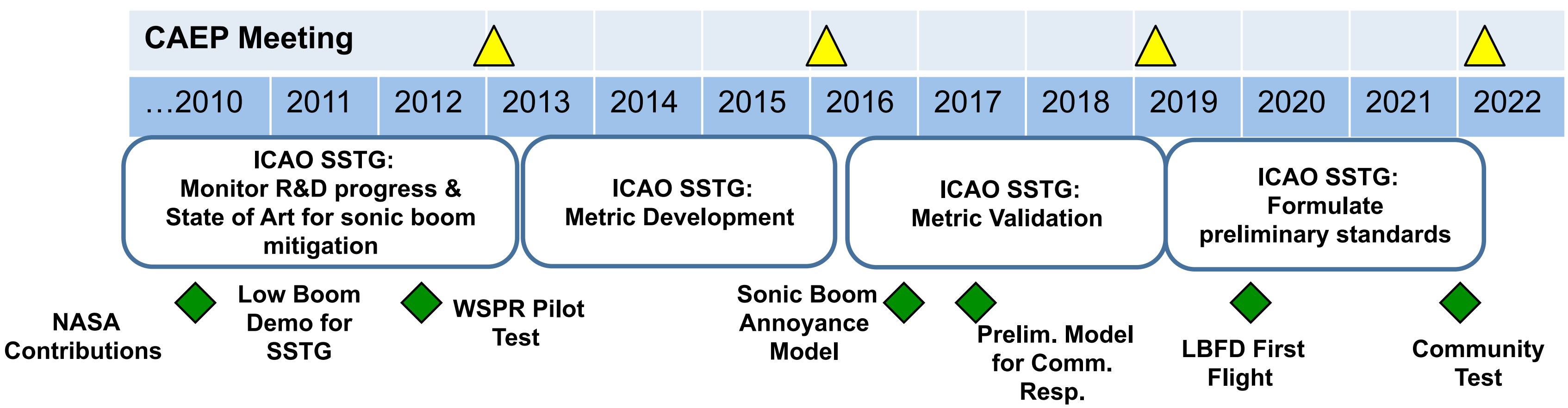
Boeing Concept

Lockheed Concept

Proposed Future Direction: Low Boom Flight Demonstration

Research & leadership to overcome the sonic boom barrier and open the door for development of a new generation of supersonic civil transport aircraft

- Research Justification – Benefit to the Nation
  - U.S. Aerospace leadership
  - Market potential of supersonic flight
  - NRC identified research need
  - Data required to develop regulation for boom noise
- LBFD Approach Justification
  - Timeline to a boom noise standard paces future products
  - Technical readiness has been demonstrated
  - Feasible and affordable concepts have been identified
  - Opportunities for valuable partnerships



Low-Boom Flight Demonstration (LBFD) Approach

Research & leadership to overcome the sonic boom barrier and open the door for development of a new generation of supersonic civil transport aircraft

Requirements:

- Validate sonic boom reduction technology in flight
- Demonstrate that noise from sonic booms can be reduced to a level acceptable to the population residing under future supersonic flight paths.

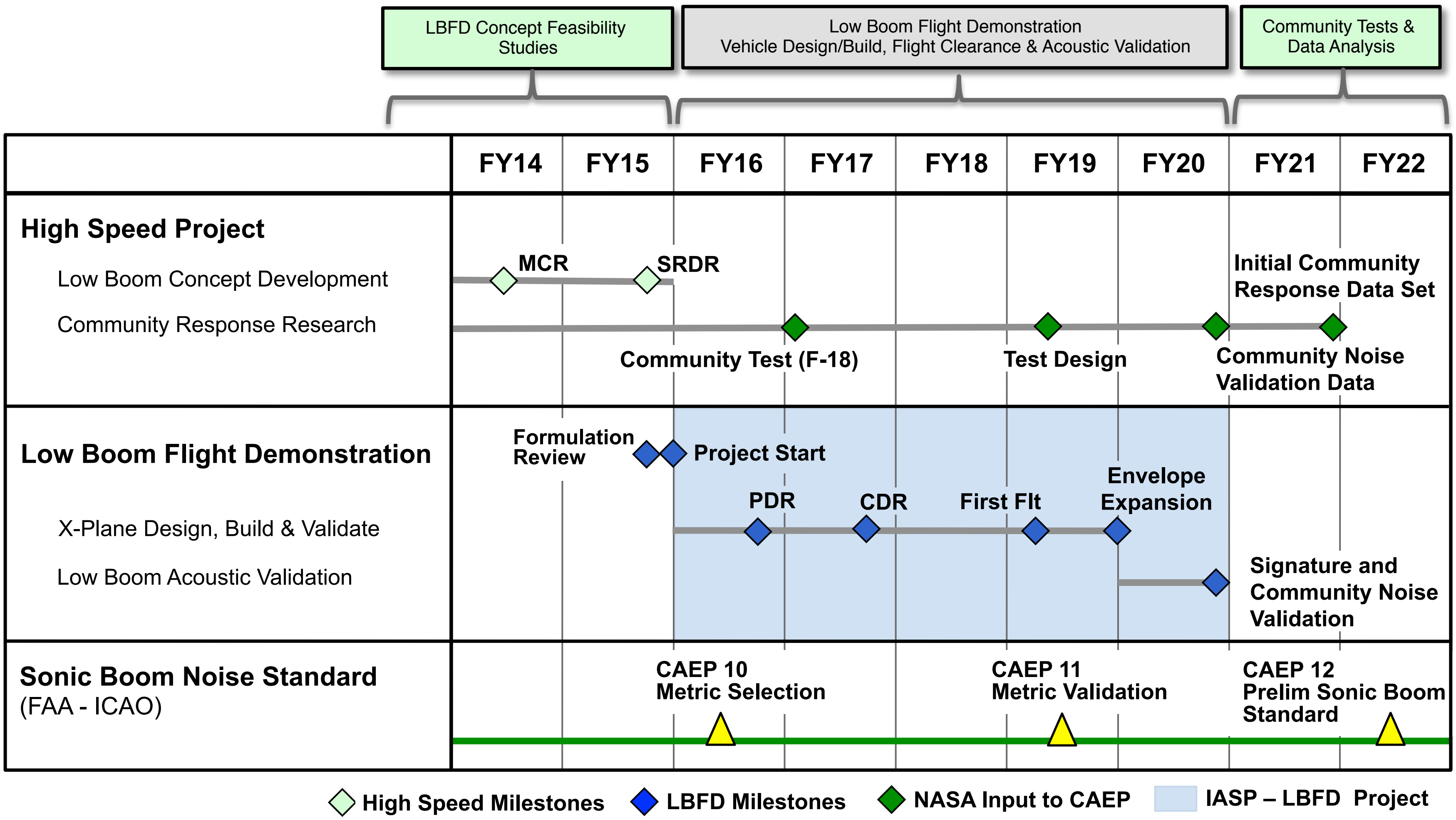
Approach:

Revitalize the excitement of manned X-Planes using a focused and cost-effective approach

★ *Determine feasibility and affordability of sub-scale vehicle based demonstration*

- Obtain program approval
- Formulate procurement strategy and partnerships
    - Vehicle design and fabrication
    - Community overflight response data development
- Prove aircraft safe for flight in public airspace
- Validate sonic boom signature data and conduct initial acceptability test in restricted airspace
- Conduct a series of community overflight response tests

Potential LBFD Timeline and Interactions



Approval required prior to detailed formulation and project start

Proposed LBFD Mission Requirements

- Ground signature traceable to that of a civil supersonic airliner - needed for community overflight research to support the development of a noise-based standard for supersonic overland flight.
- Fully shaped ground sonic boom at design low-boom overflight cruise conditions with a maximum sonic boom of ≤ 75 PLdB (calculated loudness level (Perceived Level (PL), dB).
- Minimal ground signature variability due to non-standard atmospheric conditions
- Fully supersonic cruise conditions (Mach ≥ 1.4).
- Capable of at least 2 supersonic cruise passes over a single community area during a single flight with passes spaced at least 20 minutes apart
- Ability to create variability in the ground carpet signatures of up to 10 PLdB
- Manned aircraft capable of day and night flight operations in the public airspace
- Sufficient vehicle performance margin to allow for variation of off-design and focus-boom flight conditions

LBFD Concept Formulation Study

- High Speed Project tasked with conducting concept feasibility studies and research to inform the decision process regarding a potential flight demonstration
- Primary objectives of the proposed LBFD Project are two-fold
  - flight validation of design tools & technologies applicable to low sonic boom
  - creation of community response data that will support the development of a noise-based standard for supersonic overland flight
- NASA initiated the LBFD Concept Feasibility Studies (Formulation) Study March 2013
- Goals of the LBFD Concept Formulation Study were to define LBFD mission & vehicle requirements, provide a concept definition consistent with these requirements, and provide concept formulation planning and documentation
- Phase I - Concept Formulation Studies were completed in Spring 2014
- Phase II - Concept Refinement Studies awarded June 2014

Concluding Remarks

- NASA Aeronautics restructuring increases focus achieving overland supersonic flight
  - Project continues focus on validating tools as ready for flight demonstration
- High Speed Project making substantial progress
  - Successful partnerships and collaborations
  - Low sonic boom and low noise propulsion goals are achievable
  - Progress in low boom design, low noise propulsion, sonic boom modeling & other areas
- Low Boom Flight Demonstration is the desired next step
  - Research progress has resulted in high level of interest and excitement
  - NASA LBFD project formulation studies ongoing
  - No decision yet on project start

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