

Fundamental Aeronautics Program

Supersonics Project

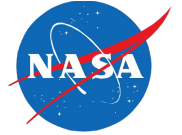
Cruise Efficiency-Airframe Overview

Linda Bangert, Technical Lead

2012 Technical Conference
March 13-15, 2012
Cleveland, Ohio
www.nasa.gov



Technical Challenge: Supersonic Cruise Efficiency - Airframe



Problem Statement:

Develop robust CFD-based methods for rapid design and analysis of supersonic cruise aircraft that are highly efficient, and have a low sonic boom.

What is our approach?

- **Advanced Efficient Analysis / Design Methods**

Develop computational algorithms and techniques for rapid high fidelity analysis of supersonic fluid flow phenomena, which will also contribute to multi-fidelity analysis / design tools.

- **Experimental Validation**

Validate concepts for design optimization of both high aerodynamic efficiency and low sonic boom.

- **Supersonic Flow Studies / Flow Control**

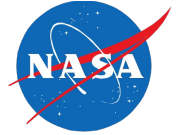
Study fundamental supersonic flow issues and apply flow control to specific supersonic problems.



- Validate high-fidelity low boom / low drag prediction and design codes for progressively more complex configurations (FY11- complete, FY13, FY15)
- Flight validation of low boom/low drag design, including propulsion effect completed (FY18)

- Codes validated with simple configuration (FY11)
- N+2 System Validation Phase 1 Wind Tunnel Tests Complete (FY11)

NASA Research Announcements



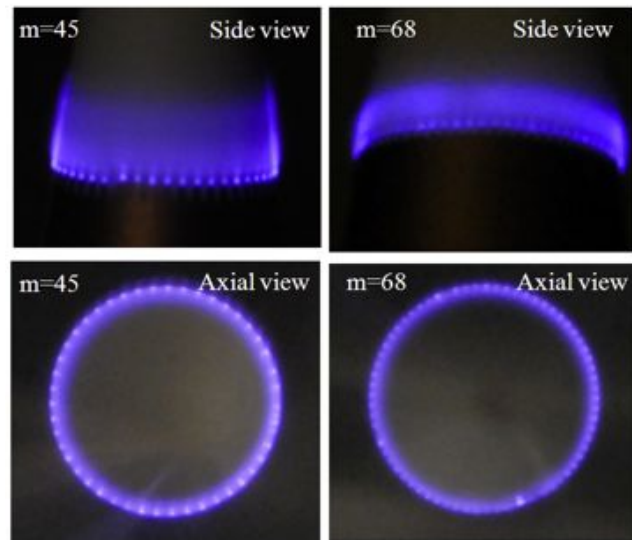
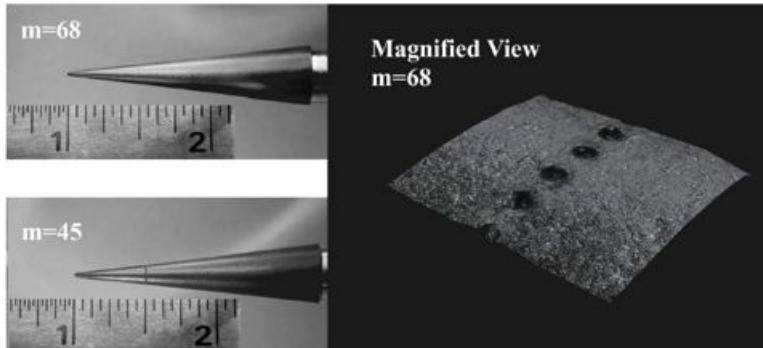
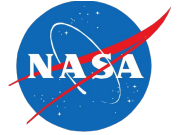
COMPLETE

- Adjoint-based Methodology for Time-Dependent Optimal Control - National Institute of Aerospace - Yamaleev / Diskin
- Plasma Bumps for Cross-Flow Turbulent Transition Prediction and Control - Notre Dame – Corke

ON-GOING

- System-Level Experimental Validations for Supersonic Commercial Transport Aircraft Entering Service in the 2018-2020 Time Period - Boeing - Magee
- N+2 Supersonic Validations - Lockheed - Norstrud

Plasma Bumps for Cross-Flow Turbulent Transition Prediction and Control



NRA Notre Dame – Corke Conclusions

- Demonstrated the presence of stationary cross flow vortices
- Demonstrated wave number receptivity to the passive roughness and active plasma roughness
- Proved the delay of turbulent transition with subcritically spaced micron-sized passive dimples in supersonic flow
- Turbulent transition due to the stationary cross flow instability should be delayed with subcritically spaced plasma roughness
- Plasma roughness can be used for drag reduction on supersonic aircraft

Reference:

Schuele, Chan Yong, "Control of Stationary Cross-Flow Modes in a Mach 3.5 Boundary Layer using Patterned Passive and active Roughness," PhD Dissertation University of Notre Dame, Dec. 2011.

Supersonics N+2 Validation Summary



Objective

- Validate solutions to key Tech Challenges for N+2 civil aircraft using integrated system level design concepts

Approach

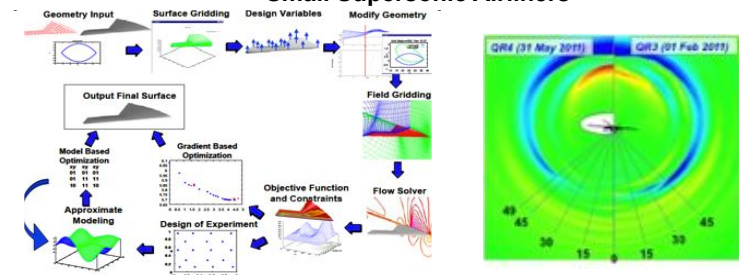
- Two NRA Awards
 - Boeing R&T supported by BCA
 - Lockheed Martin with subs Stanford, GE & Liberty Works (included validation of low noise nozzles)
- Significant in-house research and support
- New, efficient data collection techniques
- Validation testing at ARC 9x7

Status

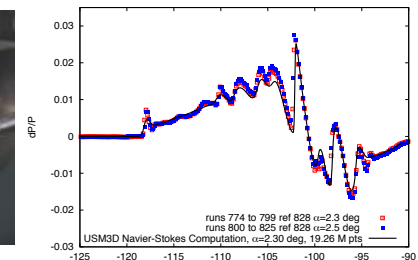
- Phase 1 testing complete - successfully validated basic design techniques, phase 2 underway



Boeing & Lockheed Concepts for N+2 (2025)
Small Supersonic Airliners



Innovative Design Processes and CFD Application

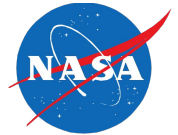


Wind Tunnel Validation of Design Sonic Boom Signatures

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 for N+2 configurations have been met, but methods are applicable to N+1 and N+3 vehicles as well.

Boom & Drag Prediction/Design Special Session at AIAA Applied Aero Conference, June 2011



Objective

- Improve high-fidelity boom and drag prediction/design codes and validate with a simple configuration

Approach

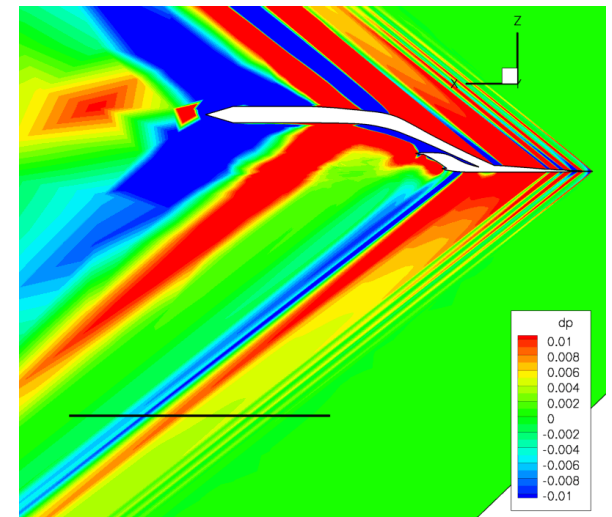
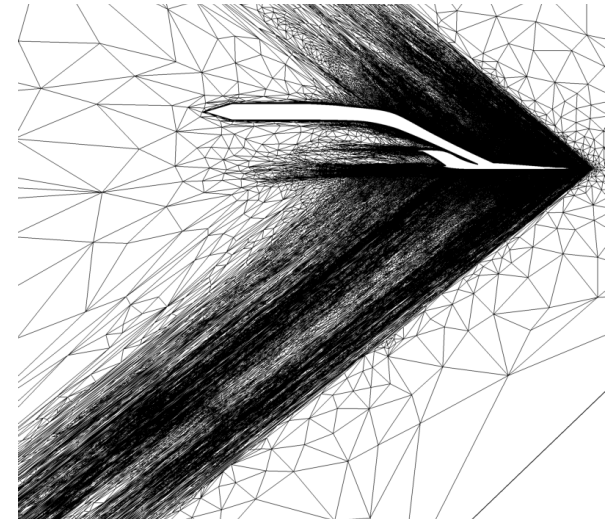
- Validate boom and drag with GRC 10x10 wind tunnel data obtained in partnership with Gulfstream
 - Same simple configuration for boom and drag (wing, body, vertical tail, nose spike, no horizontal tail or engine nacelles)
 - Boom and drag models physically different - scale and mounting system
 - Used same codes as in 2008 “Boom Workshop”, but with refinements (USM3D, AERO, FUN3D, AIRPLANE)

Status

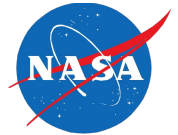
- Results presented at AIAA Applied Aero Conference, June 2011

Significance

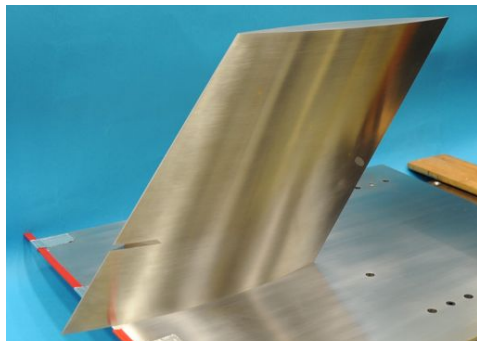
- Significant progress in the prediction of off-body and ground signatures was noted since the 2008 “Boom Workshop.”
- Design methods that reduced perceived noise were demonstrated.
- Determining and modeling the boundary layer state for transitional Reynolds number flow is important to predicting aft portion of acoustic signatures.
- The effect of boundary layer tripping in boom testing was investigated by the use of Euler, Laminar, and RANS with multiple turbulence models.
- First formulation of adjoint-based sensitivities of ground signatures to aircraft mold line changes demonstrated with a preliminary design example.



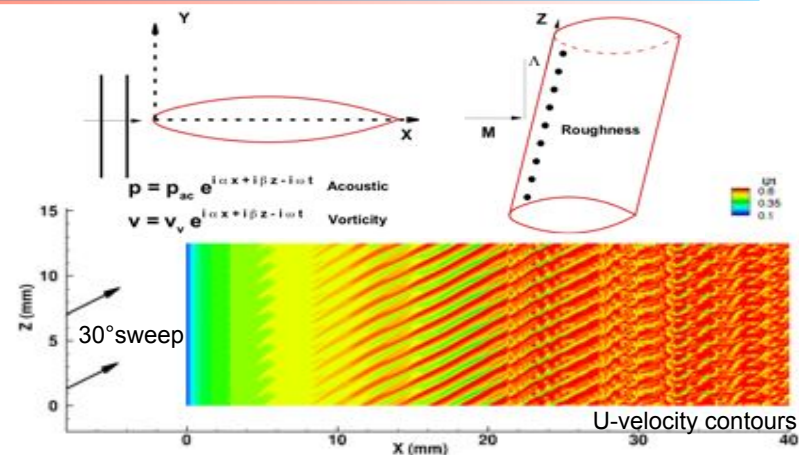
Supersonic Flow Studies / Flow Control



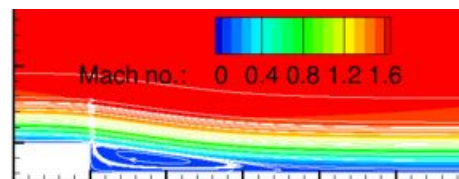
- Accurate mean off-body cone flow measurements demonstrated.
- Continuing to refine dynamic flow measurements to evaluate flow control concepts in a low-disturbance environment.
- Status documented in AIAA-2011-284.



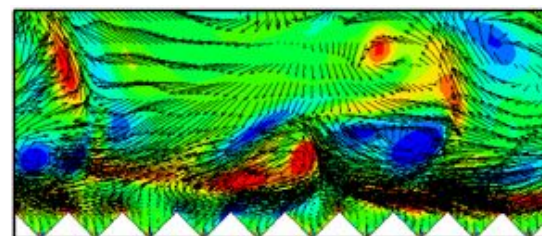
Built model for testing in Langley 20" Supersonic Wind Tunnel. If successful, plan is to build a model with more instrumentation/ interchangeable parts to evaluate cross-flow and attachment-line flow control concepts.



Effects of roughness, acoustic, and vorticity disturbances on cross-flow transition in flows over swept wings modeled. Results documented in AIAA-2010-1454 and AIAA-2011-3880.



Excrescence effects on laminar flow performance modeled and presented at AIAA Fluid Dynamics Conference, June 2011.

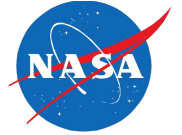


$\Delta C_d = 7\% \pm 2\%$



Drag reduction potential of riblets for supersonic turbulent boundary layers quantified via direct numerical simulations documented in AIAA-2012-1108.

Supersonic Cruise Efficiency - Airframe



Wednesday, March 14

8:00 a.m. – 8:30 a.m. - Boeing N+2 Low-Boom Design and Validation Phase I Summary - Mr. Todd Magee, Boeing

8:30 a.m. – 9:00 a.m. - Lockheed N+2 Low-Boom Design and Validation Summary- Mr. John Morgenstern, Lockheed Martin Aeronautics

9:00 a.m. – 9:30 a.m. - The 9x7 Wind Tunnel Sonic Boom Measurements and Computational-Experimental Comparisons – Ms. Susan Cliff, NASA

