NASA centers team up to tackle sonic boom

March 18 2014, by Frank Jennings, Jr.

This rendering shows the Lockheed Martin future supersonic advanced concept featuring two engines under the wings and one on top of the fuselage (not visible in this image). Credit: NASA/Lockheed Martin

(Phys.org) —Since the Concorde's final landing at London's Heathrow Airport nearly a decade ago, commercial supersonic air travel has been as elusive as a piece of lost luggage. However, this hasn't stopped NASA from continuing the quest to develop solutions that will help get supersonic passenger travel off the ground once more. And, while aerospace engineers have made significant progress in their understanding of supersonic flight, one significant challenge remains: the loud sonic boom.

"There are three barriers particular to civil supersonic flight; sonic boom , high altitude emissions and airport noise. Of the three, boom is the most significant problem," said Peter Coen, manager of NASA's High Speed Project with the agency's Aeronautics Research Mission Directorate's Fundamental Aeronautics Program.

The level of concern over sonic boom annoyance became so significant that the Federal Aviation Administration prohibited domestic civil supersonic flight over land in 1973. This prohibition helped quiet the skies and reduce potential impacts on the environment. However, it also dashed hopes of introducing supersonic overland passenger service within U.S. airspace during the Concorde era.

Overcoming this sonic boom prohibition has kept engineers busy at the four NASA centers that conduct aeronautics research in California, Ohio and Virginia.

Since the maximum acceptable loudness of a sonic boom is not specifically defined under the current FAA regulation, NASA and its aviation partners have been researching ways to identify a loudness level that is acceptable to both the FAA and the public, and to reduce the noise created by supersonic aircraft. Using cutting-edge testing that builds on previous supersonic research, NASA has been exploring "low-boom" aircraft designs, and other strategies that show promise for reducing sonic boom levels.

Previous research by NASA, the military and the aircraft industry has determined that a variety of factors, from the shape and position of aircraft components to the propulsion system's characteristics, determine the make-up of a supersonic aircraft's sonic boom. Therefore, engineers are able to tune or "shape" a boom signature through design to minimize the loudness of the boom it produces in flight.

The most recent possible supersonic aircraft designs reflect what's needed to meet NASA's low-boom requirements. These requirements specify targets for boom loudness, aerodynamic efficiency, and airport noise for an N+2 —second generation beyond current technology—aircraft design that could be flying by the years 2020 through 2025.

Similar to designs of the past, the current concepts are characterized by a needle-like nose, a sleek fuselage and a delta wing or highly-swept wings. It's the details of how those designs are shaped that result in the reduced sonic boom. One design, proposed by industry partner Lockheed Martin, mounts two engines under the wing in a traditional configuration with one additional centerline engine above the wing. The other industry partner currently working with the NASA High Speed Project, The Boeing Company, proposes two top-mounted engines in a departure from historical aircraft design.

"Engine installation is a critical part of achieving an overall low boom design," said Coen, who is located at NASA's Langley Research Center. "If we mount the engines in a conventional manner, we need to carefully tailor the shape of the wing to diffuse the shock waves. If we mount the engines above the wing, the shock wave can be directed upward and not affect the ground signature. However, such installations may have performance penalties."

NASA's recent focus on supersonic research testing began in November 2010 as part of the project's Experimental Systems Validations for N+2 Supersonic Commercial Transport Aircraft effort. Its goal was to capture boom-relevant data from supersonic scale models built by Boeing and

Lockheed. In preparation for this research, industry engineers first designed full-sized aircraft on their computers, and then scaled down the designs to build wind tunnel models that exhibit the same flight characteristics during testing as do their full-size counterparts in actual flight. The scale models were then sent to NASA wind tunnel facilities at the Ames and Glenn research centers.

This rendering shows The Boeing Company's future supersonic advanced concept featuring two engines above the fuselage. Credit: NASA/Boeing

Once delivered to NASA, the project's engineers focused on obtaining data from two distinct aspects of supersonic design—the measurement of the sonic boom pressure signature at various distances around the aircraft, and the measurement of engine inlet performance for the top-mounted engines. The data from NASA's wind tunnels are being used to validate the computer-based design tools for continued use in future low-boom aircraft design research.

The series of wind tunnel tests began at Ames' 9- by 7-Foot Supersonic Wind Tunnel in late 2010 and continued through mid-2012 with initial tests of Lockheed's and Boeing's Phase I supersonic aircraft concepts. These tests focused on the boom signature measurements and development of test techniques. Testing on the Phase I designs was also performed at Glenn's 8- by 6-Foot Supersonic Wind Tunnel in late 2012.

Both companies then refined their designs for better boom characteristics and improved aerodynamic performance. Tests continued at Ames and Glenn on the Phase II designs through 2012 and 2013, focusing on the engine nacelle integration with the overall vehicle. (Nacelles are the parts of the aircraft that house the engines, and are usually mounted directly on the wings or fuselage of an airplane or on pylons attached to the aircraft.)

One of these Phase II tests was a propulsion integration test at Glenn's 8-by 6-Foot supersonic wind tunnel, conducted in March of 2013. This test of a 43-inch long, 1.79-percent scale model built by Boeing focused on capturing performance data from the engine air inlets—the components through which air enters the aircraft engines. NASA tested this model both with the inlets integrated on the overall aircraft, mounted above the wings, as well as with one of the inlets by itself, measuring the inlet air flow and pressure recovery (the pressure level at the engine face after losses from the flow turning and shock waves in the inlet) each time. The measurements in the inlet were captured by a series of pressure and temperature probes deep inside the inlet, where the first set of blades for the engine would be. A remotely-controlled mass-flow plug assembly (a movable cone that varied the size of the nacelle exit area) was fitted behind the inlet, which gave engineers the capability to vary the rate of air flow through the inlet to capture data throughout the duration of the scale model's test "flight" in the tunnel.

"Capturing this flow rate is important because it directly impacts a supersonic aircraft's thrust performance in flight, as well as cruise efficiency," said Coen.

The part of the test consisting of a stand-alone air inlet, which was mounted on a support cone within the wind tunnel, enabled engineers to capture inlet performance data without the influence of the rest of the aircraft. By comparing the measured data of the two configurations, NASA and Boeing will be able to learn if the shape of the airframe has a big effect – good or bad – on the performance of the inlet.

High levels of inlet performance are desirable to keep the vehicle's engines running smoothly and able to provide thrust," said Raymond Castner, Glenn's Inlet and Nozzle Branch Propulsion Technical Lead for the High Speed Project. "The inlet data collected was used to increase our knowledge and to validate both design and analysis tools. This knowledge was needed across a range of flight conditions at Mach numbers from 0.25 to 1.8, and at various angles occurring between the airflow and the aircraft as it flies."

Once testing was completed at Glenn, a final test was done at Ames Research Center where engineers worked with the 43-inch as well as 16-inch scale models provided by Boeing, similar to a test the year prior with a 19-inch scale model provided by Lockheed Martin. During these tests, researchers sought to capture data that indicated how well the nacelles were integrated with the overall designs, and how they affected the aircraft's boom characteristics and aerodynamic drag.

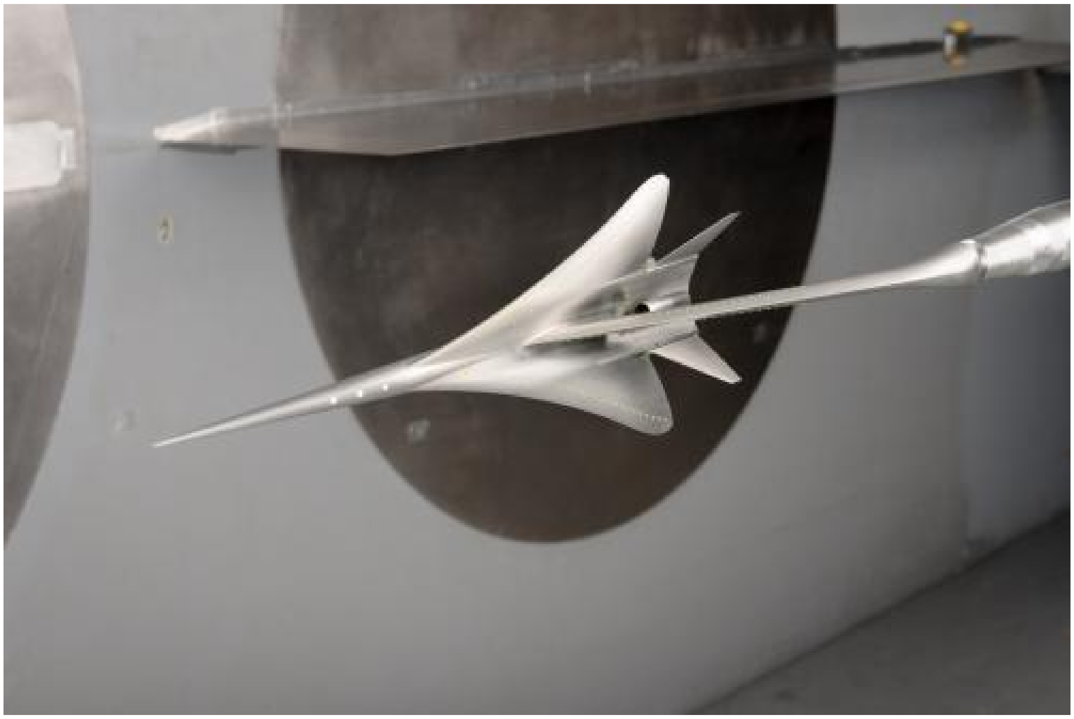
Inside Glenn's 8- by 6-Foot Supersonic Wind Tunnel, technician Dan Pitts inspects Boeing's 1.79% scale model, which shows the two installed flow-through nacelles. Credit: NASA/Quentin Schwinn

The Boeing scale models underwent testing using two different nacelle shapes, and also with the nacelles not installed. Lockheed Martin's scale model underwent one set of tests with nacelles installed and one without. Engineers captured measurement data relating to the influence nacelle configurations had on the models' overall boom signatures and aerodynamic performance.

"The purpose of our testing was to measure the impact of the nacelle configurations on the boom signatures," said Don Durston, a High Speed Project engineer at Ames Research Center. "Preliminary results showed that as expected, with Boeing's nacelles being on top of the wing, any small changes there had negligible effects on the boom, Lockheed's model having the two of the nacelles under the wing, did show a measurable impact on boom; however, that effect was predicted, and could be accounted for in the design process Lockheed used."

Using Ames' 9-by 7-Foot supersonic wind tunnel, engineers subjected each scale model to a series of tests designed to capture the design's overall boom signature, or sound personality.

Over the coming months NASA engineers will pore through the test data with industry partners, in preparation for future research and additional testing, which will also involve NASA's Armstrong Flight Research Center. In the near term, the attention will be on how shock waves in the engine exhaust flow impact the overall boom signature.



The Lockheed concept model undergoes Phase II testing in NASA Ames' supersonic wind tunnel. The small dots are "boundary layer trip dots” used by researchers to "trip" the air flow on the model from laminar (smooth) to turbulent—allowing better predictions of airflow and sonic boom characteristics. Credit: NASA/Dominic Hart

As additional boom research discoveries are made, NASA will add these findings to the growing repository of supersonic data that's available to the civil aviation community to help foster further innovation.

In the meantime, Coen thinks the research over the past year brings engineers one step closer to realizing a viable low-boom, civil supersonic aircraft transport design.

"We've convinced ourselves that we have the design tools and we've validated the level we need to design to," said Coen. "We've reached a point where quiet, low-boom overland supersonic passenger service is achievable."

Provided by NASA

Citation: NASA centers team up to tackle sonic boom (2014, March 18) retrieved 23 April 2024 from https://phys.org/news/2014-03-nasa-centers-team-tackle-sonic.html