REDUCING SONIC BOOM - A COLLECTIVE EFFORT STATUS REPORT

BY CHARLES ETTER (GULFSTREAM)
AND PETER G. COEN (NASA)

Several members of the Aviation Industry believe that a new market segment, and possibly a new era of aviation, could be within reach in the next 15 years or less. This new era will reintroduce civil air travel at supersonic speeds. The technical challenges are significant, and progress is being made on many fronts. The economic impact of a new market segment is global, creating new jobs and new technologies.

Industry views the development of a socially responsible enroute supersonic noise standard as a parallel effort to technology development. This new noise standard, in conjunction with relevant environmental standards is beginning to take shape within the ICAO CAEP (Committee for Aviation Environmental Protection) process.

The new era of supersonic civil flight could be reintroduced in one of two ways. One way would be to operate at supersonic speed over both water and land, utilizing a low boom aircraft design (unrestricted supersonic flight). The other operational scenario would be to fly at design speeds above Mach 1 over water and unrestricted areas, while slowing down to subsonic speeds, or just over Mach 1, in restricted areas. Flying just over Mach 1.0, between Mach 1.0 and 1.15, is referred to as Mach cut-off. Flying below the Mach cut-off speed will result in the sonic boom waveform not reaching the ground. The actual Mach cut-off speed depends on the prevailing atmospheric conditions.

The achievement of commercial supersonic flight will be accomplished via technology breakthroughs developed for smaller aircraft such as business jet aircraft. To date, no purpose-built low boom aircraft has ever been manufactured. The general public has never been exposed to the “softer” overpressure sounds of such a uniquely shaped aircraft.

This article addresses the efforts of Industry and national research organizations to mitigate sonic boom and mature enabling technologies to support the introduction of a low boom aircraft capable of supersonic operation over land. Additionally, the article highlights the accomplishments of CAEP Working Group 1 (Noise) over the last three years, and the interdependence of these efforts.

National Research Organizations

Recently, national research organizations such as National Aeronautics and Space Administration (NASA) in the USA, and the Japanese Aerospace Exploration Agency (JAXA), have increased their investments in supersonic research and development and have plans to continue this effort into the future. Their focus is on developing modern design tools for supersonic aircraft, as well as understanding public response to sonic boom exposure.

National Aeronautics and Space Administration, USA

NASA is a leader in research and technology development for supersonic flight. Recently, NASA published a new strategic plan that includes six thrust areas outlining its investment strategy in the coming years. Strategic Thrust 2 focuses on innovation in commercial supersonic aircraft and near term efforts (2015-25) to support the establishment of a standard for acceptable overland supersonic flight in cooperation with international standards organizations.

NASA will continue validation of analytical tools and technologies to enable the design and development of supersonic aircraft that create minimal sonic boom noise. In the longer term (2025-35), NASA will continue research on technologies required to meet the desired boom level in larger aircraft, in addition to other technical challenges for successful supersonic transports. This research will include reducing propulsion emissions and noise affecting the airport community. NASA will conduct this research in partnership with universities, industry and regulatory organizations.

Low Boom Flight Demonstration

NASA continues to seek support from the U.S. government to design, build, and fly a Low-Boom supersonic Flight Demonstration (LBFD) aircraft (**Figure 1**). NASA has initiated concept studies and project planning to inform the decision-makers regarding a future LBFD. The objectives of LBFD were defined as flight validation of low boom design tools and technologies and creation of community response data to support the development of the above-mentioned supersonic en route noise standard.

The LBFD aircraft is envisioned as a subscale research aircraft that creates a shaped sonic boom signature with a loudness level of 75 PLdB (Stevens Mark VII Perceived Level) or less during supersonic cruise (Mach ≥ 1.4). The LBFD project is envisioned to range from five to seven years in duration.

The LBFD research aircraft, though smaller than future supersonic jets, will serve as a test bed to evaluate the effectiveness of the low-boom design process and accuracy of acoustic propagation codes. Also, by flying LBFD over preapproved populated areas, the reaction of communities can be assessed systematically, providing validation for community response models under development.[1]

Figure 1. Low Boom Flight Demonstrator Concept

Sonic Boom Prediction and Community Response

NASA's work includes the utilization of a unique laboratory that mimics a typical residential living space. This facility, called the Interior Effects Room (IER), provides a controllable environment for subjective testing of indoor effects from sonic booms. Recent results, including the effects of rattle on sonic boom annoyance, were published in 2015.[2]

In 2015, NASA launched two new studies designed to: (1) improve atmospheric turbulence modelling for sonic boom propagation and, (2) develop strategies for future community response testing using an LBFD aircraft. These efforts are expected to continue for two to three years, with results and data publicly available at the conclusion of the work.

Japan Aerospace Exploration Agency

JAXA has been promoting the Silent SuperSonic (S-cube) technology research program for future economical and sustainable supersonic airliners since 2005.

In the S-cube program, a sonic boom test named D-SEND (Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom) was conducted to demonstrate advanced low-boom design concepts. One recent completed phase of this program, included dropping an unmanned and non-powered scaled airplane from a stratospheric balloon to demonstrate front and aft shaping of the sonic-boom signatures (**Figure 2**). During that flight test, several sonic-boom signatures at design conditions were measured by airborne and ground microphones.

The Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) released its "Next Generation Aircraft Research and Development Vision" in August 2014. A roadmap of this vision established goals to validate new technology for supersonic airplane engines through ground testing and flight tests by 2030. JAXA is expected to play a key role in this program through a close partnership with aerospace companies and academia.

Following this vision, JAXA is considering a new supersonic research program starting in fiscal year 2016 as a successor to its S-cube program. Its main focus will be aircraft noise reduction technologies to accommodate the recent ICAO Chapter 14 noise standard. This program will also include sonic-boom mitigation technology and evaluation research for the ICAO sonic-boom standard development process.

Figure 2. JAXA's Scaled Airplane – Used During Drop Test

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Office National d'Etudes et de Recherches Aérospatiales (ONERA), France

The European Commission 2016-2017 work program, officially released on the 15th of October 2015, has retained a Research and Innovation Action item to contribute to the evolution of the regulation allowing supersonic overland flights, by actively giving support to the ICAO Sonic Boom regulation roadmap.

The RUMBLE (RegUlation and norM for low sonic Boom LEvels) contribution, initiated jointly by Airbus Group Innovation, ONERA and Dassault Aviation, will involve both European and International academic and industrial partners.

The RUMBLE objective is to actively contribute to the ICAO roadmap by bringing complementary scientific knowledge and support to the regulation authorities to prepare for the smooth introduction of low-boom supersonic overland flights with the highest level of worldwide acceptability.[3]

Industry Activity

Several aerospace companies are involved in civil supersonic research. In some cases, this work is funded by, or in partnership with, their respective national research centers; others are funded internally.

Engine and airframe manufacturers have engaged in aircraft and propulsion conceptual design studies for several years, including the NASA Quiet Supersonic Vehicle study of 2003/4 and the EU Framework 5 HISAC program.More recently, some engine and airframe manufacturers have been exploring a wide range of propulsion cycles. (**Figures 3 and 4**) These studies include the relevant requirements for payload, range, and community noise (such as ICAO, Annex 16, Volume I, Chapter 4 or 14).

Some aircraft manufacturers continue to invest in supersonic technology that mitigates the effects of traditional sonic booms. Their approach includes design requirements for unrestricted supersonic flight over land to enable the same operational flexibility of existing subsonic fleets. Sonic boom minimization is the largest technical barrier to achieving this objective.

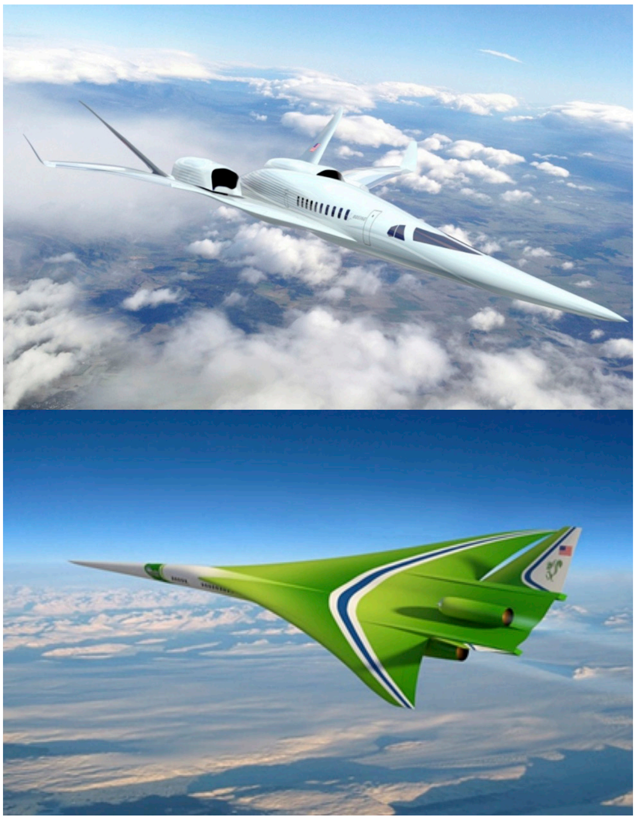

Figure 3 & 4. Examples of Boeing and Lockheed Martin Entry Level Supersonic Commercial Concepts.

Additionally, industry is engaged with NASA on its Commercial Supersonic Technology program.

Aerion Corporation, based in Reno, Nevada, anticipates program launch of its AS2 business jet in 2016, first flight in 2021, and certification in 2023 (Figure 5). Aerion intends for the AS2 to cruise at Mach 1.4 over oceans and uninhabited areas, and operate at "Mach Cut-off" over populated areas (see Mach Cut-off in introduction). In areas prohibiting cruise above Mach 1, the AS2 can cruise at Mach 0.95 with full range capability. Aerion is considering a family of aircraft, including small supersonic airliners, and has secured firm orders for twenty AS2 aircraft from Flexjet with deliveries as early as 2023.

Figure 5. Aerion AS2 Supersonic Aeroplane.

CAEP Related Activities

Since 2004, ICAO's Committee on Aviation for Environmental Protection (CAEP), Working Group 1 (WG1) has monitored the scientific progress toward supersonic flight of low boom aircraft and has worked to develop the framework for a new boom noise standard.

The primary focus since 2013 has been defining applicable noise metrics for sonic boom and developing certification test procedures for a future supersonic aircraft noise certification standard. These aspects of a new noise standard were considered by the group to be the most reasonable elements of a standard that could be addressed prior to the availability of a LBFD.

The efforts to develop an appropriate metric for a future en route sonic boom standard started with assembling all noise metrics that might be a good candidate for sonic boom measurement. A group of technical specialists from around the globe then began the selection process. As a result of their efforts, the list has been narrowed to a few options that provide a good, but generally similar measure of response to sonic boom. A better understanding of some of the more subtle aspects of community response, such as rattle, vibration, and indoor noise, will likely be needed to shorten the list further.

Additionally, the group has been working on the development of flight test procedures for supersonic noise certification. Three initial priority tasks were identified to: 1) determine measurement locations for assessing sonic boom noise, 2) evaluate the benefits of using sonic boom predictions in supersonic noise certification, and, 3) define instrumentation system requirements. A typical ground exposure is illustrated in **Figure 6**.

It is envisioned that a future low boom noise standard will need to cover more than just the cruise condition, so WG1 is also considering flight conditions such as climb. Additionally, certain unique challenges will exist during noise testing an aircraft that is passing overhead at very high altitudes, where both the noise and the atmospheric conditions need to be measured. The group will be evaluating possible technical solution to address these new challenges.

Research and Future Plans

Due to advancements in high performance computing tools, aerodynamic drag is being significantly reduced using the improved capability to analyze complex flows and aircraft configurations.

Engine manufacturers are working to improve fuel burn, NOx, and jet noise. There may be interdependent and viable trades on environmental design objectives as technologies mature. Avionics and cockpit systems already provide the capabilities needed for civil supersonic operations. Additional work continues to enhance these systems.

Enabling supersonic technologies are converging to produce viable and efficient aircraft configurations, but civil supersonic operations may come in two main phases – supersonic operations over water, followed by supersonic operations over land.

Industry sees the development of both noise and emissions standards by CAEP over the course of the next few years as a vital step in reintroducing the public to civil supersonic flight.

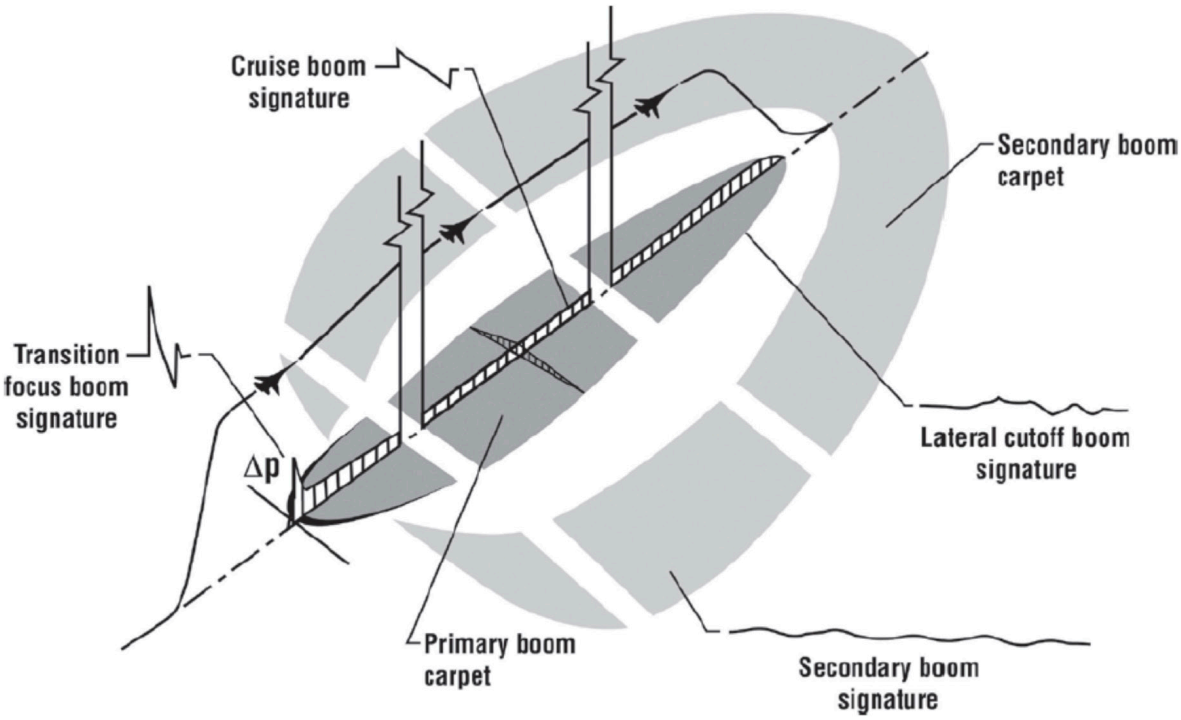

Figure 6. Schematic of Sonic Boom Ground Exposures.[4]

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