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# UAV roundup 2011

**Quieter flight: A balancing act**

**China's military space surge**

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AIAA

PART ONE

# Quieter flight: A balancing act

Equipped with an ever-expanding suite of new developmental tools, NASA's aeronautical researchers are exploring innovative concepts in jet engine and airframe technology, all to help achieve specific 'green aviation' goals related to fuel burn efficiency, noxious emissions, and nuisance noise.

Integrating these efforts into the Next Generation Air Transportation System, or NextGen, will follow as ideas are refined, proven, certified, and then adopted into the commercial marketplace during the next 10-30 years.

NASA's direction toward these goals comes from the National Aeronautics Research and Development Plan, a White House Office of Science and Technology Policy document most recently updated in February 2010. It clearly sees the federal government's role as one that "advances aeronautics research to improve aviation safety [and] air transportation, and reduce the environmental impacts of aviation." Another requirement demands that the aviation research community promote "the advancement of fuel efficiency."

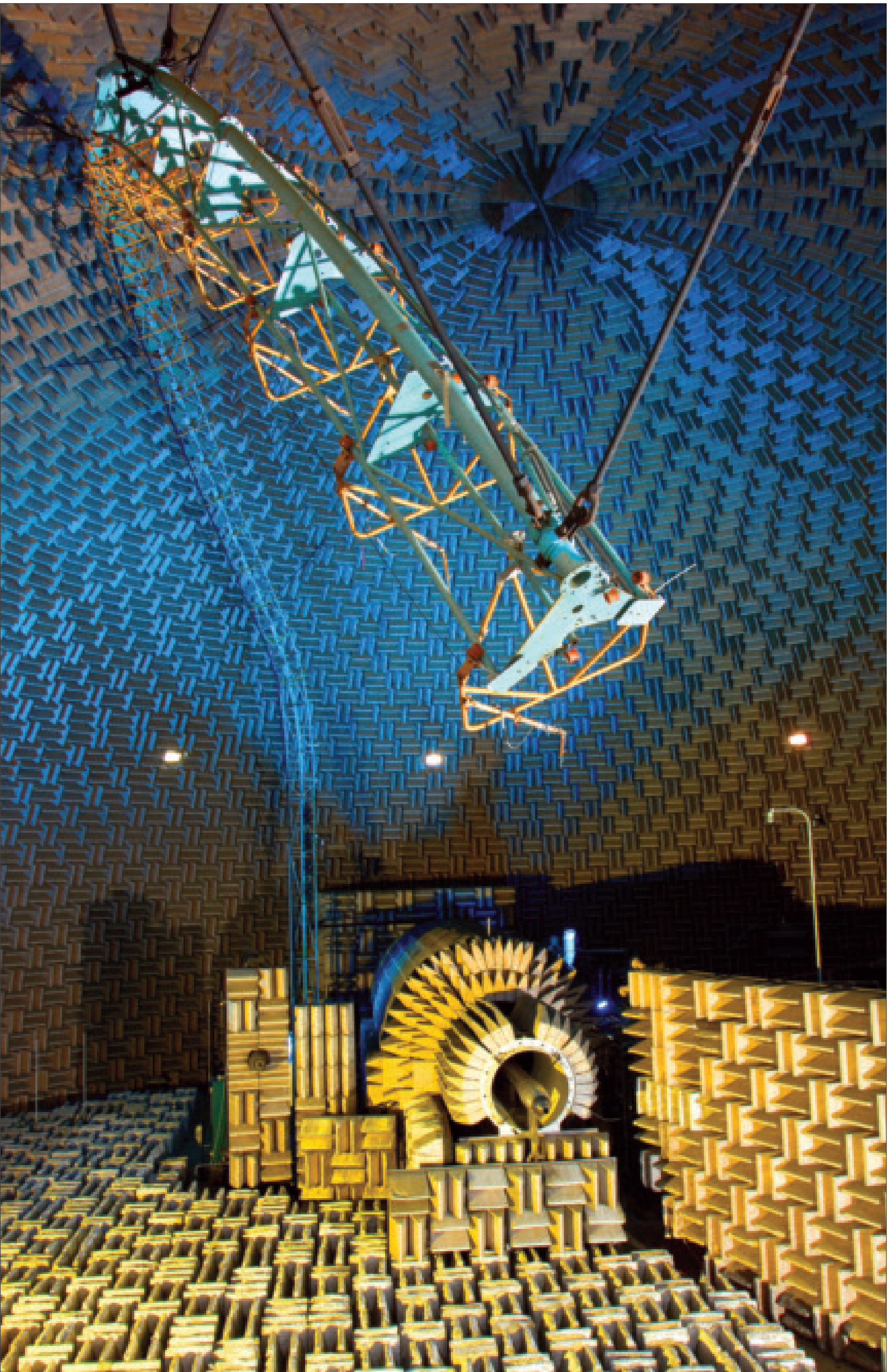
Achieving these national goals will require adequate and sustained funding for NASA's Aeronautics Research Mission Directorate and for other relevant government agencies, including the FAA. In recognition of the need to meet these goals, the Obama administration requested FY11 funding of $580 million, an increase of $83 million from the FY10 request. As of this writing, Congress had not yet approved NASA's funding package.

**NASA is working to achieve aeronautical engineering breakthroughs that will enable development of technologies that make airplanes better for the environment. Among the most challenging problems researchers face is reducing aircraft noise, from both engines and airframes. Design features that successfully lower noise in one area, however, can raise it in another, making the task an extremely delicate balancing act.**

"During these tough economic times, when difficult choices have to be made, it is gratifying to see NASA's aeronautics program will receive more funding this year," says Winston Scott, a former astronaut who is now dean of the College of Aeronautics at the Florida Institute of Technology. "At the same time, when you consider the importance of aviation research to making airplanes safer and more environmentally friendly, you wonder sometimes why aeronautics doesn't receive even more."

### Aircraft should be seen and not heard

It was not until commercial jet operations began in 1958 that complaints about noise really started to become a problem for the aviation community. The combination of urban sprawl and expanding suburbs shrank the distance between residential neighborhoods and airport property. A Boeing 707 on final approach was an impressive sight, but if it flew over your house, even while still a mile high, you would be



*A fisheye view of the anechoic AeroAcoustic Propulsion Lab at NASA Glenn highlights the overhead microphone array that encircles the Nozzle Acoustic Test Rig in the center of the chamber.*

**by Jim Banke**
Public Affairs writer,
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*Gold-colored foam wedges shield test subjects from outside noises during an acoustics test at NASA Langley. NASA researchers study people's perception of aircraft sounds in an indoor setting and investigate the role of rattle noises and vibration. They use this information to help design quieter aircraft. Credit: NASA Langley/Sean Smith.*

subjected to 106 dB of noise—approximately the same level as a jackhammer.

Since then, NASA has worked with other government agencies and industry to significantly reduce the level of nuisance noise made by aircraft, especially during takeoff and landing. Now the bar is set even higher: Confine objectionable noise within the airport perimeter. That means quieting all sources of airframe and engine noise enough that people living or working near an airport in 2035 would not hear any noise they might consider a nuisance.

Eliminating the noise problem is a tall order by itself. But noise, emissions, and fuel-burn reduction technologies are not mutually exclusive. A concept that mitigates one problem might exacerbate another. For instance, one good solution for fuel burn and emissions problems is to equip jet engines with a dual-propeller system known as an open rotor to generate thrust. But then, as Ruben Del Rosario, manager of NASA's Subsonic Fixed Wing Project, notes, "You have the challenge of noise, because these blades are spinning in the open air."

So NASA's biggest hurdle is in developing technologies that can strike the right balance among multiple performance goals and meet them simultaneously. "At the end, the ultimate challenge is to find solutions that significantly reduce the airplane's fuel consumption, thus decreasing carbon dioxide emissions, while minimizing the objectionable noise and mitigating negative effects on air quality around the airports," says Del Rosario.

When it comes to what produces noise on airliners and how to suppress it, NASA researchers are considering everything, not just engines. Landing gear, flaps, the aircraft shape, the kinds of materials used, engine types and placement, the flight paths used during takeoff and landing—even the problems associated with eliminating the nuisance factor of sonic booms from supersonic aircraft—are all on the table. Each noise source could have its own quieting solution, so the trick is to find the best way to balance all of those considerations.

"There's a lot of work to do on all fronts to get the objectionable noise within the airport boundary," says Brian Fite, chief of the Acoustics Branch in the Aeropropulsion Division of NASA Glenn. "We've probably harvested all the low-hanging fruit to quiet a number of noise sources independently. And now we've really started to look at it in an integrated way. We're able to work on a few key areas and make progress, but eventually you have to start addressing interactions between components, including the airframe."

### Testing for the right blend

One of those integrated solution approaches is to consider how best to bring together the airframe and the propulsion system. Will the overall noise be reduced the most by placing the engines on top of the aircraft, under the wings, in the tail, or in some other place that results in an airframe shape very different from the standard tube and wing used today? If a different airframe is the choice, how will the wings and tail be blended into the design? And will the resulting improvements in engine noise now worsen the noise made by the aircraft body itself, or add drag and weight issues that hamper fuel efficiency?

To help determine the ultimate answer, NASA researchers are preparing a series of wind tunnel tests to learn more about acoustic shielding, a design approach that uses parts of the airplane to prevent engine noise from reaching the ground.

Charlotte Whitfield, head of the Aeroacoustics Branch at NASA Langley, says one of these tests will involve Langley's 14x22-ft wind tunnel. This activity is funded by NASA's Environmentally Responsible Aviation Project. A generic hybrid-wing aircraft body, scaled to fit into the test stand, will be outfitted with a pair of propane-powered jet engine simulators. Cameras, sensors, and other instrumentation wired throughout the test area of the wind tunnel will record data about the interaction of the engines and airframe.

Beginning in 2012, several runs will be made with the jet engine simulators moved to different positions, and all the data will be fed into NASA's publicly available Aircraft Noise Prediction Program (ANOPP) software to see how accurately ANOPP can predict the noise of these advanced, highly integrated propulsion and airframe configurations. Validating the accuracy of ANOPP is an important prerequisite for its use in guiding the design of new low-noise aircraft concepts.

"I don't expect we'll wind up with one solution here. We're still going to have to look at our multiple options and try to understand their relative strengths and weaknesses," Whitfield says. "It's very simple to say that we should all go to blended wing bodies, but that's not going to happen. So we need to do more than just look at the effects of shielding from a blended wing body. We need to see what we can do with a conventional tube-and-wing design."

### A look at the airframe

While discussion continues on the best way to bring propulsion and the airframe together, the airframe itself as a source of noise is also being studied. "We've reduced the noise from jet engines so much through the years that now we find airframe noise holds a greater potential for further noise reduction than we have had to think about before," Whitfield says.

Moving a body as large as an airframe though the air sets up any number of air currents that result in turbulence and the creation of noise.

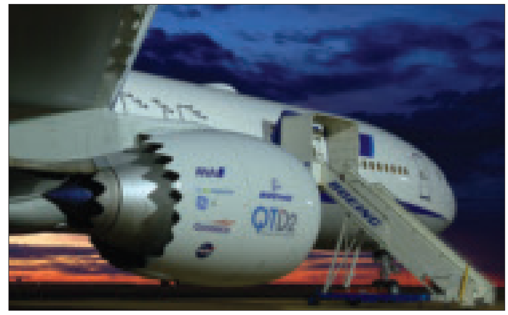
"We understand a great deal, not absolutely everything, but a great deal about how airframe noise is generated. What we end up with is a problem to a certain extent in practicality," says Whitfield. "We know how it is generated, but we also know that it takes a remarkably small amount of energy to create a remarkably large amount of noise. You work on streamlining, especially for landing gear. You have to work on it very carefully, because you can end up with something you think is going to be great flying, but while it reduces one noise source it introduces another."

### Giving teeth to engine efforts

Like airframes, jet engines also are under study for additional noise suppression technology. Further improvements are expected even for one of NASA's more recent noise reduction success stories, chevrons.

Boeing recently introduced chevrons on its 787 and 747-8 aircraft, whose jet engine nozzles sport a distinctive saw-tooth pattern on their trailing edges. The teeth help to enhance the mixing of hot air from the engine core and cooler air blowing through the engine bypass fan, thus reducing turbulence that creates noise.

"Successes like chevrons are the result of a lot of different, hard-working people



*NASA has partnered with industry many times during years of chevron testing, including these tests of nozzles on a specially adapted GE engine mounted on a Boeing 777. Chevron nozzles will be seen on more engines in the coming years. Credit: Boeing/Bob Ferguson.*

and...a lot of very small efforts that all come together, often across many scientific disciplines," says James Bridges, an associate principal investigator responsible for coordinating NASA's aircraft noise research.

One type of propulsion system requiring big advances in noise reduction is that used on airplanes capable of vertical takeoffs and landings. NASA is looking hard at rotorcraft for civil transport, because systems studies have shown this configuration can improve air capacity by 30-60%, says Susan Gorton, manager of NASA's Subsonic Rotary Wing Project at Langley. Improving air capacity is a key feature of NextGen.

Gorton says the type of civil tilt-rotor envisioned would be able to haul 90 passengers at speeds of 300-350 kt with a range of 1,000 n.mi. A rotor wing aircraft would have to hover in the terminal area only a short time, would avoid delays caused by waiting on a taxiway for a runway to be available, and could land directly on the spot where it unloads.

"There's nothing in the industry's current inventory that has that kind of passenger capacity. To make that kind of vehicle a reality, we have to address certain technologies," Gorton explains. Approaches to making the rotor blades quieter include modifying the shape of the blade, employing technologies that would allow it to change shape during flight, or slowing

***NASA and its industry and government partners used a modified F-5E jet to show that changing the shape of an aircraft's nose can reduce the intensity of a sonic boom. The 2003 flight test done was a precursor to current Fundamental Aeronautics supersonics technology low-boom research. Credit: NASA/Northrop Grumman.***

down the blade. Slowing it could be done by simply reducing power, redesigning the blade to provide more lift at slower speeds, or shortening the blade, which would slow the tip speeds. Blade tip speed is a major variable for rotor noise.

"Right now the NASA research is targeting technologies for large civil tilt-rotor development. But at the same time we realize the nation currently has a helicopter fleet that will certainly continue for many years to come," Gorton points out. She notes that NASA's objective is to have any technology advances and breakthroughs apply to both tilt-rotor and helicopter applications.

## Sonic whisper?

NASA is also exploring the fundamentals of how noise is made in the first place, as well as its impacts. "Our research concentrates in the physics of the source of the noise," Gorton says. "How do you model where the noise is generated? How do the blades interact with the wake? How does the noise propagate through the air? What does it sound like when it hits the ground? How do you minimize the footprint of the noise when it hits the ground?"

The rotorcraft story—improving an older technology to better fit an evolving aircraft—is similar to that told by NASA researchers working on technology to enable the FAA to change current policy prohibiting commercial supersonic flight over the U.S. because of worries about sonic booms.

Those laws are left over from the days when the nation first attempted to build its own supersonic transport and then abandoned the project. That left Great Britain and France to field the Concorde, which could fly only to cities along the U.S. coast, and only at subsonic speed when flying overhead. Now U.S. business jet manufacturers are asking for a supersonic option, and NASA may soon come up with a design in which the sonic aftereffect is more whisper than boom.

*A view upstream looks into the NASA/Rolls-Royce variable-cycle nozzle with a lobed mixer, mounted on the jet rig in the Nozzle Acoustic Test Rig during acoustic testing in the AeroAcoustic Propulsion Lab at NASA Glenn.*

"From a technologist's viewpoint, I would say there are a great many of us who have always dreamed of having an economically viable supersonic airplane. And in order to do that we have to be able to fly it over land, which means reducing the sound level of a sonic boom so it is not annoying," says Peter Coen, manager of NASA's supersonics project. "It's a real challenge for us moving forward to clearly identify and explain to the public that the sonic boom we're talking about now is completely different from what has ever been heard in the past."

Whether made by an X-1 rocket plane, an F-22, or the space shuttle, a sonic boom results when supersonic shockwaves are produced by the aircraft's nose, then its canopy, then its tail, and even the handle to open the cargo hatch. Just about any change in the aircraft's geometry will set off a shockwave. Because all of these are produced at different times by different shapes and under minutely different air temperatures and pressures, the shockwaves travel away at different speeds. But within a few thousand feet, those independent shockwaves coalesce, creating two pressure spikes. When these spikes pass over the ground, you hear a sonic boom. (There are always two booms, but usually the aircraft is so small that both booms arrive at the same time. The space shuttle, at 120 ft long, is big enough that the ear can clearly pick up a double boom.)

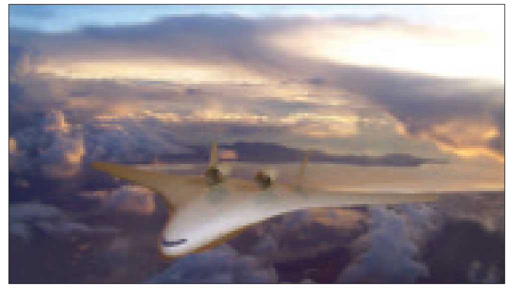
As Coen explains, "the theory of sonic boom reduction says if those waves, those independent shocks, are approximately the same strength, they will not coalesce. They will travel to the ground as separate waves. And all the way through the atmosphere the magnitude of them attenuates. So if you can design an airplane such that the shocks are relatively the same strength, and relatively equally spaced, instead of getting two pressure pulses on the ground, you will get something else." Some have called it a 'sonic puff,' but Coen says he does not like that term and is open to other ideas.

To get an ideal shockwave signature that would not be noticed on the ground, the aircraft would have a long, slender nose and tail. But with the need for control surfaces on the tail, and possibly for a pair of engines hanging on or jutting out somewhere, this design becomes impossible.

"We're coming to the conclusion that

the best thing to do is really not try to get that completely smooth pressure rise on the back end, but break the shock on the back end up into several pieces so you get the attenuation without the coalescing," Coen says. "So we know what needs to be done to shape the airplane to mitigate the boom. But we also need to reduce drag, we need to reduce takeoff noise, so it's really about understanding how to manipulate the shape of the airplane in three dimensions to produce the design that achieves multiple, hard performance goals.

"The real challenge has been integrating all the pieces of the sonic boom with all the components of the aircraft and coming up with a robust approach to reducing the aft signature to acceptable levels. We've made some improvement but we've had to go back and look at other approaches."



*This hybrid wing body concept (N2A HWB) has the engines mounted on top of a body that deflects noise upward instead of toward the ground. The concept was generated by Boeing under a Subsonic Fixed Wing Project study and is planned for testing in 2012 by NASA's Environmentally Responsible Aviation Project. Credit: NASA.*

With nearly 100 years of experience in bringing innovative solutions to the skies, aeronautics is now faced with its biggest engineering challenges ever. The prospect of meeting the goals of simultaneous reductions in noise, fuel burn, and emissions, along with safely integrating the resulting aircraft into an ever-expanding air transportation system, is daunting, to say the least. Some aeronautics researchers have compared this challenge to NASA's 1960s-era effort to land humans on the Moon.

But unlike the historic Apollo goal, this one will not be achievable by the end of the decade—in part because of the time and effort industry must now invest in adopting green technologies and certifying their safety for flight.

*Editor's note: This is the first of four features that will describe the challenges associated with trying to invent a truly 'green' airplane. Future articles will cover work on technology to curb emissions, boost fuel efficiency, and enable the nation's air traffic management system to handle aircraft in a more environmentally responsible manner.*