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BUILDING BLOCKS

NASA makes headway on tough goals for efficient narrow and widebody designs

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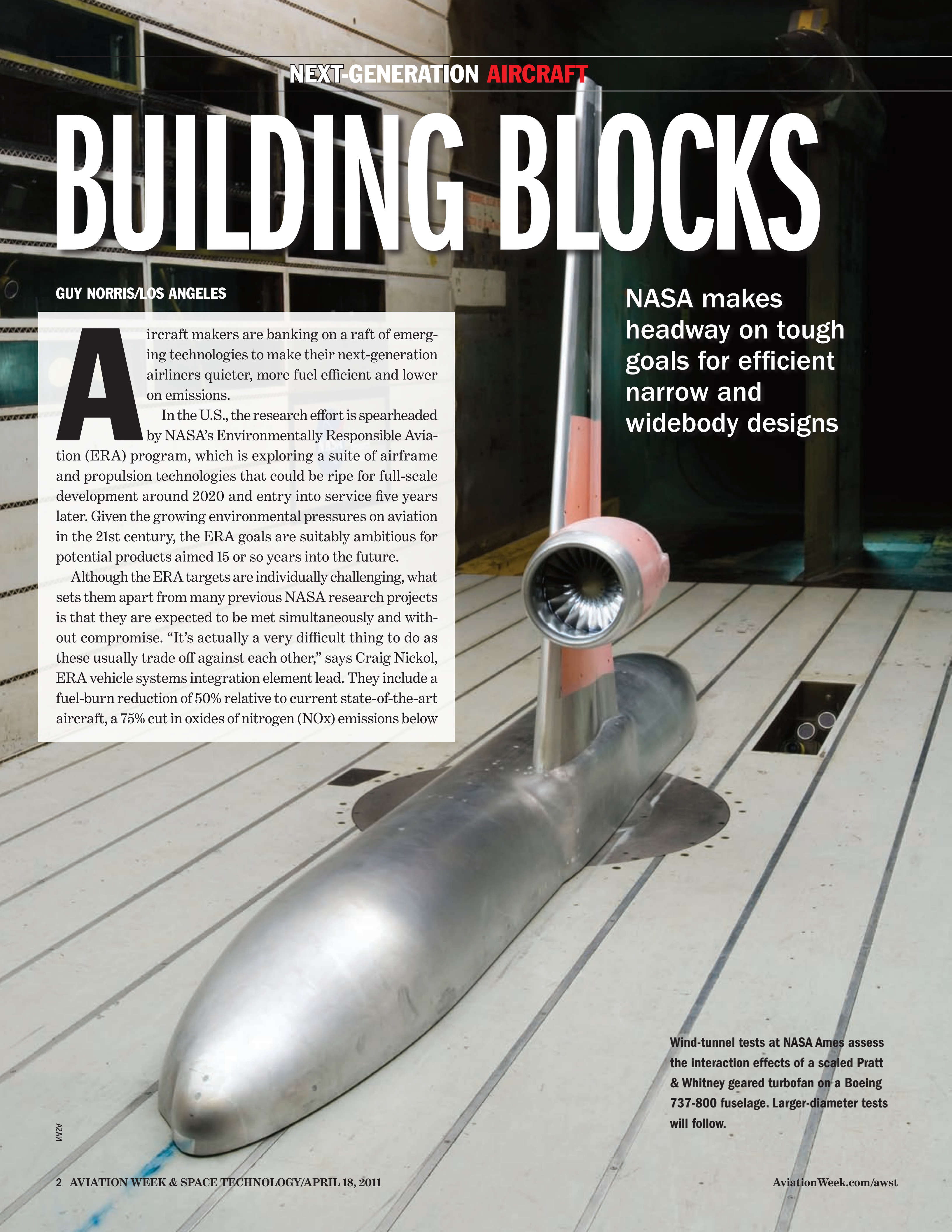


Aircraft makers are banking on a raft of emerging technologies to make their next-generation airliners quieter, more fuel efficient and lower on emissions.

In the U.S., the research effort is spearheaded by NASA's Environmentally Responsible Aviation (ERA) program, which is exploring a suite of airframe and propulsion technologies that could be ripe for full-scale development around 2020 and entry into service five years later. Given the growing environmental pressures on aviation in the 21st century, the ERA goals are suitably ambitious for potential products aimed 15 or so years into the future.

Although the ERA targets are individually challenging, what sets them apart from many previous NASA research projects is that they are expected to be met simultaneously and without compromise. "It's actually a very difficult thing to do as these usually trade off against each other," says Craig Nickol, ERA vehicle systems integration element lead. They include a fuel-burn reduction of 50% relative to current state-of-the-art aircraft, a 75% cut in oxides of nitrogen (NOx) emissions below

Wind-tunnel tests at NASA Ames assess the interaction effects of a scaled Pratt & Whitney geared turbofan on a Boeing 737-800 fuselage. Larger-diameter tests will follow.

NASA

the current standard, and aircraft noise 42 db below the FAA's Stage 4 certification level.

"It's quite a challenge, and people are asking how we are going to do this," says ERA Project Manager Fayette Collier. "We've done some experiments that lead us to believe that although this is difficult, we think it is achievable."

The targets are tough because, NASA believes, without major improvements the growth of air transport will be actively impeded by environmental and related cost concerns. From a cost perspective, cutting the fuel burden makes better business sense with each jump in oil price. U.S. commercial carriers alone spent $59 billion on fuel in 2008 when oil was at roughly $3 per gallon. Together with the Defense Department burning 4.6 billion gal., this usage also pumped 250 million tons of carbon dioxide (CO_2) into the atmosphere, while noise continued to be seen as a restraining factor on growth of the U.S. National Airspace System.

Formulated in 2009, and kicked off in fiscal 2010, ERA is approaching the midpoint of Phase 1 and managers are sketching out plans for a second phase that will take the program through fiscal 2015. Coming at a time when fuel prices and environmental concerns are combining to accelerate new commercial engine and airframe projects, the ERA initiative appears to be well timed for maximum impact. "We're trying to look at those technologies that have a high payoff and, no matter whether the platform is a [Boeing] 737, [Airbus] A320, [Boeing] 777 or regional jet replacement, we believe the portfolio covers it," explains Collier.

The ERA targets are individually challenging, and they are expected to be met simultaneously and without compromise

"The program has a significant impact on the 737/A320 replacement market as well as the next widebody replacement, irrespective of whether they are conventional tube-and-wing or more advanced configurations. It also depends on the timing; but if the market opportunity moves to 2025-30, it gives us a chance to [include] more advanced configurations where we can bring in more significant gains in terms of environmental metrics," says Collier.

For drag reduction, NASA and Boeing will test an advanced fluidic control system that could increase rudder effectiveness, allowing vertical tail size, and therefore drag, to be decreased. Under ERA, the active flow control (AFC) study will evaluate the use of pressurized jets in place of a conventional mechanical actuator to help control the rudder. The concept—which works by using the jets to alter local airflow and pressure gradients to control surface movement—has previously been tested on experimental aircraft such as the Bell XV-15.

The AFC study comes as Boeing starts development of a drag-reducing hybrid laminar flow-control system for the stretched 787-9, and could eventually become a complementary feature should it prove effective. Active and laminar flow control are NASA's two main areas of investigation for reducing skin friction, which accounts for an estimated 48% of the drag on current airliner designs.

"The intent is to increase its technology readiness level [TRL] so that it could be applied to any generic widebody or single-aisle hinged rudder," says Tony Washburn, NASA's ERA chief technologist. The AFC, in the form of fluidic oscillating jets or synthetic jets, will be located near the rudder hinge line and operated only during takeoff and landing, or in the event of an engine out. Applied to operations in the most critical conditions, it would be sized for airspeeds of 100-150 kt., ±15 deg. of sideslip and ±30 deg. of rudder. "Part of what the study will do will determine the limits of the vertical rudder size reduction," Washburn adds.

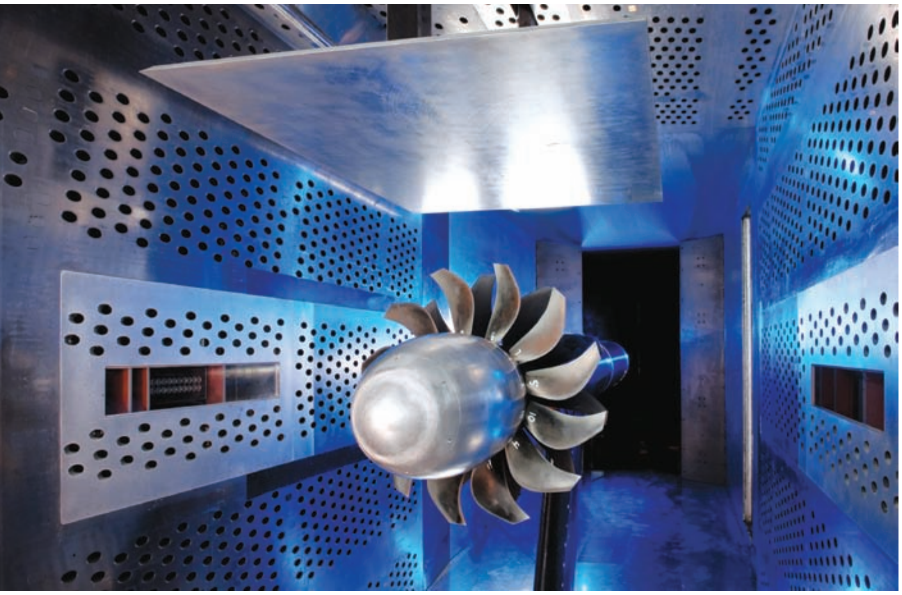
Noise reduction is being tackled across three fronts: airframe, propulsion and combined propulsion-airframe aeroacoustics. Under ERA, NASA is working with Gulfstream to test methods for mitigating airframe noise, particularly from flaps and slats on the wing and from the landing gear. Mehdi Khorrami, lead project investigator at NASA Langley Research Center and ERA noise-reduction element lead, says flight tests are being conducted using a specially instrumented G550 to gather detailed noise-source data.

Noise mitigation technologies being tested include a continuous mold-line flap and a faired main landing gear, both of which will be tested on an 18% scale half-model at Langley. Further flight tests of the G550 will gather steady-state surface pressures on the wing and flaps, as well as unsteady pressures on the flap edges, nose and main landing gear. Acoustic tests of the "most promising noise-reduction technologies" will be undertaken on the 18% model; follow-on flyover noise tests of the selected devices will be conducted at NASA's Wallops Flight Facility, says Khorrami.

Fuel-burn reduction is being addressed via laminar flow control, improved engine performance and weight reduction. NASA's ERA program is funding flight tests of a wing glove with a natural laminar airflow airfoil on a modified Dryden Flight Research Center-based Gulfstream III. Micron-size discrete roughness elements, pioneered by William Saric of Texas A&M University, will be placed on the glove for passive laminar cross-flow control during flight trials starting around 2013.

Dramatic weight savings are expected from the Boeing-developed PRSEUS (pultruded rod-stitched efficient unitized structure) lightweight composite concept. This consists of carbon-epoxy panels infused using high temperature and vacuum pressure, with no autoclave required. Under the manufacturing process, the composite frames and stringers are stitched to the skin to produce a fail-safe structure. After stitching, pre-cured carbon-fiber rods are fitted through pockets in the stringers, locking the structure together and creating a self-supporting preform.

Because no autoclave is required, larger parts can be produced, which increases the attractiveness of the concept, says Collier. "It could be a game changer, and that's what we want to prove—whether it is or is not." PRSEUS is "broadly applicable to fuselages of any



NASA

NASA hopes upcoming tests of a set of second-generation GE open rotor blades will continue the lower noise trend discovered with trials of baseline versions.

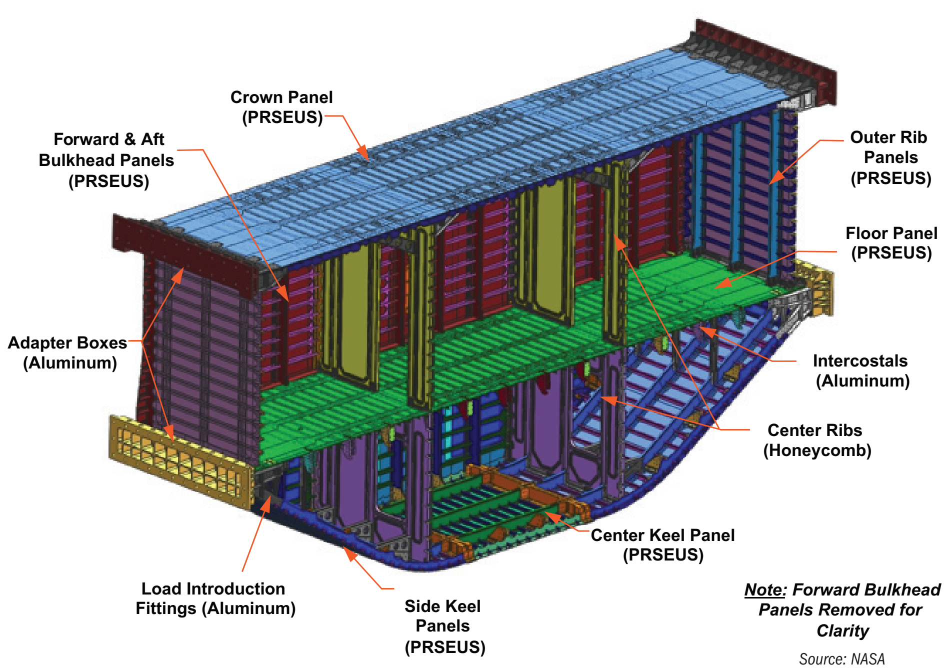
shape and wings. It is lightweight, damage tolerant and built with fewer parts," he adds. The frames and stringers provide continuous load paths and the nylon stitching stops cracks.

The process has been used in limited areas so far for Boeing C-17 gear doors and other fairings; but "so far, everything has been done in terms of unidirectional loading," says Dawn Jegley, NASA ERA structures lead. "Now we're going to look at combined loads." Testing of a 127 X 75 X 90-in. curved panel is set for mid-2011. The biggest test for the material comes later this year when a 30-ft.-wide section of double-deck hybrid wing-body (HWB) airframe, incorporating a PRSEUS shell and floor structure, will be tested in the combined-loads facility at Langley.

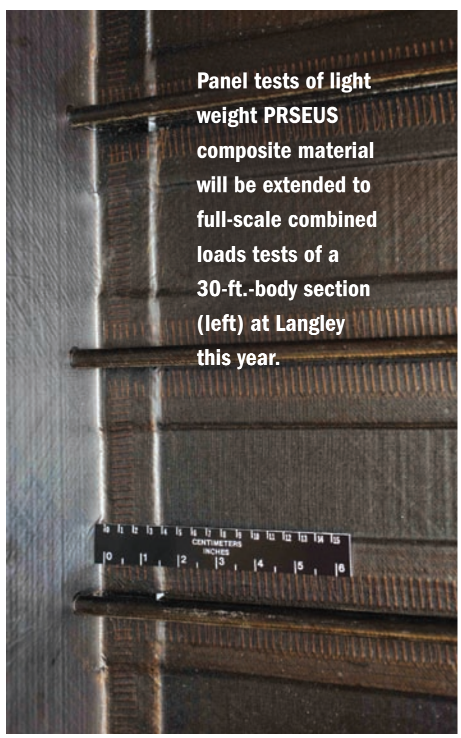
Chi Lee, ERA combustor task lead, is studying fuel-flexible combustor technology aimed at cutting NOx by 25% below CAEP6 international levels. "Emissions during landing and takeoff affect local air quality, and above 3,000 ft. they account for 92% of total ozone. We think that improvements here [at higher altitudes] could result in as much as a 60% reduction in cruise emissions. The problem is that the NOx emissions increase as overall pressure ratio increases, particularly above 50:1, so it is a tremendous challenge for us."

Lee's team is studying balanced combustor designs with General Electric and Pratt & Whitney, as well as a NASA configuration with an improved fuel-air mixer and a lean direct-injection combustion system. "Every time we improve fuel mixing, the NOx drops," he observes. The plan is to progress from tests of a single injector flame tube to multi-injector sector combustor trials in 2012-13, with a full annular combustor test aimed at substantial NOx reductions of up to 80% by 2015.

The combustor group is focused on injector design, active combustion and advanced liners to improve emissions. Further refinement of existing air blast or atomizer injectors may be possible, they believe, with further characterization of combustion processes using alternate and regular jet fuel planned over the next two years. For example, fuel produced through the Fischer-Tropsch process "provides more opportunities for emissions reductions because it



Source: NASA



Panel tests of light weight PRSEUS composite material will be extended to full-scale combined loads tests of a 30-ft.-body section (left) at Langley this year.

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has no aromatics, no sulfur and its distillation profile is different. That means it can vaporize quicker than jet fuel, and the viscosity is smaller; this, in turn, means droplet size is 10-20% smaller," says Lee.

Active combustor concepts under study are aimed at devices that will carefully control combustion instability and incorporate an intelligent fuel/air management system, he adds. Work on advanced liners is focused on silicon carbide fiber-reinforced silicon carbide matrix ceramic composites (Sic/Sic CMCs). "We need 80% of air in front of the combustor to get fuel/air mixing going and that's going to come from the combustor liner," says Lee. "CMC liners will reduce combustor cooling air requirements."

Other engine efficiency improvements, meanwhile, are being tackled through core and propulsor studies aimed at a 50% reduction in fuel burn. Described as "very aggressive" targets by James Heidmann, ERA propulsion technology project engineer, the core research effort is challenged with the age-old conundrum of how to improve thermal and propulsive efficiency without adversely affecting emissions. The key, says Heidmann, is the combined use of improved materials and cooling methods, such as film cooling, to boost turbine performance without generating more NOx.

The turbine film-cooling experiment looks at the fundamental heat transfer and flow field. "The small size of features makes it very difficult to get data, so we've scaled it up and tested various hole shapes using a plexiglass model for much more detailed results. Now we're transitioning to direct measurements with an infrared camera," Heidmann says. Testing is also underway of an "anti-vortex" film-cooling concept in which a series of auxiliary holes produce counter-vorticity to promote jet attachment and reduce its velocity.

The ERA project includes studies with General Electric of a highly loaded three-stage axial compressor with swept rotors and stators at NASA Glenn Research Center's W7 turbine test site. The trials are aimed at building up a database of transonic performance as part of efforts to improve matching of highly loaded compressor blade rows to increase overall pressure ratios. Work is also under way with GE on a highly loaded high- and low-pressure turbine in the nearby W6 single-spool turbine facility. The HP turbine is a reduced shock design, while the LP turbine features a flow-controlled stator and a contoured endwall.

NASA is also experimenting with active-control plasma actuators as a potential way of improving the efficiency of LP turbines. The solid-state dielectric barrier discharge electrodes are mounted perpendicular to the flow and impart control via an oscillating wall jet, while others mounted parallel to the flow provide control by generating vortices. "We place them upstream or on a separation point on a blade. It produces velocity and forces close to the wall that give you more control authority than you'd expect," says Heidmann.


NASA

Noise-reduction tests of a G550 model in Langley's 14 X 22-ft. aeroacoustic tunnel will be followed by flight tests with Gulfstream.

There are also two CMC-related experiments in ERA, one of which is an uncooled high-pressure turbine vane. Heidmann says the approach is to demonstrate different manufacturing techniques and explore design issues. A pre-preg lay-up of a CMC turbine vane made from a high-temperature resistant material called Hi-Nicalon SiC/SiC, and another using a hybrid approach involving chemical vapor-infiltration and melt-infiltration is planned in 2011. "Right now we're looking at a temperature capability of 2,400F for this generation, but next year we're looking at raising that to 2,700F."

NASA's ERA effort includes follow-on research into the next steps for ultra-high-bypass (UHB) ratio engines, including potential derivatives of Pratt & Whitney's PW1000G geared turbofan (GTF), now in development for service entry in 2013. "The GTF pushes the state of the art; but for the 2020 timeframe we need to push the state of the art even further," says Chris Hughes, UHB engine technology sub-element lead. A 22-in.-dia. scaled second-generation GTF is being investigated collaboratively by NASA and Pratt in Glenn's 9 X 15-ft. wind tunnel, and the two are expected to join with the FAA for an engine demonstration as part of the administration's Cleen (continuous lower energy, emissions and noise) program in 2014.

Work to integrate larger-diameter UHB engines on single-aisle aircraft such as the 737 successor has involved tests of a powered half-span model in the 11-ft. NASA Ames wind tunnel. The tests will help explore the performance tradeoffs of various engine-airframe combinations, allowing optimization of transonic wing-body shapes.

These include nacelles beneath a high wing or over the wing nacelles, as well as designs incorporating boundary-layer ingestion. "As there are more issues the larger the nacelle gets, the wind-tunnel tests will be used to validate the shape we will come up with," says Steve Smith, vehicle systems integration element lead.

The baseline test model is based on a 737-800 with an 88-in.-dia. fan, versus the 61-in. diameter of the current CFM56-7B engine, with the pylon located at 34% span. The test assesses 161 design variables, including seven wing sections, says Smith. "Initial optimization eliminated a double shock on the inboard leading edge, and a shock in the large 'trench' between the engine and fuselage," he adds. Although lift is transferring to the nacelle and offloading the wing, "[overall] for now it looks like it's going to work pretty well, and we're starting to build a semi-span model that will have a new 15-18 bypass ratio [powered] test engine," says Smith. "We will validate cruise performance in tests around November-December 2011," he adds.

Beyond GTF, the efficiency benefits of a direct-drive open rotor are being actively pursued under a cooperative research effort involving NASA, GE and CFM International. Testing is focused on validating blade designs that minimize noise from a set of counter-rotating unshrouded rotors while retaining the 25-27% fuel-burn advantage of the UHB ratio concept.

Baseline aerodynamic and acoustic testing has been completed in the 9 X 15-ft. low-speed wind tunnel at Glenn Research Center. This involved the blade design from GE's Unducted Fan engine to provide a database for evaluation of improved blades intended to reduce noise. Follow-on tests were conducted on a further set of five different GE blades (12 forward, 10 aft), all modified from the baseline "historic" design of the 1980s. The research effort is past the halfway point and is now testing at cruise Mach numbers in Glenn's 8 X 6-ft. high-speed tunnel, and will include both aerodynamic performance and near-field unsteady pressure measurements.

From May to October, a further phase will focus on a second-generation GE blade design.

Undertaken jointly by NASA, GE and the FAA as part of the Cleen program, the tests will use both Glenn's 8 X 6-ft. and 9 X 15-ft. tunnels. An intense phase will see aerodynamic and acoustic evaluation of the next-generation design at both high- and low-speed tunnels at takeoff, approach and cruise conditions. NASA says tests to date have demonstrated a 8–10% noise reduction relative to the 1980s design; confirmation of predicted cruise efficiency improvements is still pending.

As early conclusions from ERA and other studies point to integrated airframe-propulsion concepts as being the only way to meet NASA's performance targets, an element of the program is focused on combined airframe-propulsion aeroacoustics. The goal of the effort is to reduce interaction effects directly, or to actively use integration of the engine and airframe to reduce net radiated noise.

System noise assessments have been made with an HWB and a 7:1 bypass ratio turbofan, as well as with an open rotor, with plans to complete the latter assessment by the end of 2011. Tests evaluated the effect of turbofan engines mounted from above on 777-like pylons versus ones mounted from below on "keel" pylons on an HWB. Different acoustic liner and chevron nozzle configurations were also evaluated. "We see a strong technical path to meeting the -42-dB goal," says Russ Thomas, HWB community noise team leader. "It's the last 10 dB that's really tough," he says, noting that the target can only be achieved by applying acoustic liners to crown pylons, adding "quiet" landing-gear technology and having a reduced approach speed. Open rotor tests will take place later this year in Boeing's 9 X 12-ft. low-speed aeroacoustic facility.

The highest profile element of ERA is the preferred system concepts competition in which the winners will identify advanced integrated vehicle and component technology concepts that could ultimately be flight tested as a demonstrator. Boeing, Lockheed Martin and Northrop Grumman won contracts, and up to two finalists will be selected by year-end.

Boeing is proposing a blended wing-body powered either by two GTFs or optionally by three General Electric/CFM Leap-X-based open rotors. Lockheed Martin's more radical-looking option is configured with a laminar flow, modified box-wing and tail-mounted engines. Northrop Grumman proposed a notional double-fuselage concept and says its final concept will "fall out of the study."

The coming year will focus on five main tasks, says ERA chief engineer Mark Mangelsdorf. The first will be to evaluate a full-scale concept, starting with studies of how the contenders could best fit into the FAA's NextGen airspace plan. Task 2 will focus on meeting the preferred performance requirements, which include a 50,000-lb. payload and an 8,000-nm range for the passenger version. The freighter is required to carry a 100,000-lb. payload over a range of 6,500 nm.

Task 3 will sketch out a detailed 15-year technology maturation road map, while Task 4 will focus on the "long poles," or the critical technology demonstrations for the second half of the ERA program in 2013-15. "We're also interested in technologies that apply to N+1—[these are] nearer term single-aisle concepts or retrofitable to current 737/regional jet-class models," Mangelsdorf says. Task 5 covers the conceptual design of a subscale test vehicle that, if built, will be large enough "to demonstrate noise, emissions and fuel-burn goals," he adds.

"In June we'll start seeing some refinement of the vehicle concept, and around September we'll have to get more maturity and start seeing the technology road maps that go with them," says Collier. Up to two concepts may be downselected in December.

Next Steps

Boeing studies 'art of the possible' for 737 successor versus re-engine decision

GUY NORRIS/LOS ANGELES

Despite reports to the contrary, Boeing says it has no plans to announce in June the launch of an all-new model to replace the 737 or a decision to re-engine its best-selling twinjet.

Instead, the company says those expecting a dramatic new program unveiling at this year's Paris air show will have to make do with "more clarity on which direction we are leaning." However, if the signs of the last nine months are anything to go by, the trend continues remorselessly toward an all-new 737 replacement aimed at entering service in 2019-20.

Two major factors continue to influence Boeing's thinking. The Airbus A320NEO (New Engine Option) has galvanized the market since its launch last December, attracting more than 330 commitments to date. Secondly, Boeing has publicly described the market response to last year's 737 re-engining survey as "underwhelming," strongly indicating an all-new design as airlines' preferred alternative.

Yet, for all that, Boeing is being very careful not to be viewed as neglecting its 737 cash cow, unfilled orders for which currently stand at 2,162 or around two-thirds of Boeing's entire undelivered backlog. Mike Bair, Advanced 737 product development vice president, declares: "We have the ability to continue to improve and develop the [737] Next Generation and to consider the development of an additional plane that would complement the NG fleet." Describing the "what if" new-airplane product as "an additional opportunity," he adds that this "would not come at the expense of continued development and improvement of the [737NG], which remains our highest priority."

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Business aviation EVS/SVS technology could be ripe for air transport use by 2020.

From Bair's perspective, the re-engine option with Pratt & Whitney's PW1000G geared turbofans, CFM International's Leap-X or Rolls-Royce's Advance2 two-shaft design, "is a real, technically viable option. This option features in several of our product scenarios under investigation," he adds.

Pratt Engineering Senior Vice President Paul Adams says, "We've been working the installation with Boeing on both re-engine and Y1." Yellowstone 1 is Boeing Product Development's code for the broad umbrella studies under which the 737 replacement falls.

"The decision on a new airplane is based on whether there is real value to be offered to the industry, with a possible entry-into-service toward the back end of the decade. We are focused on understanding where the market [airlines and passengers] is going and when key technology matures—determining the art of the possible," says Adams.

But with this timing, what can Boeing offer with confidence from its technology toolkit?

Much of this, in turn, depends on how aggressive the performance targets are. Boeing will not confirm reported goals for the new airplane of a 10% and 20% improvement in cash operating costs and fuel burn, respectively, over today's 737, but these are thought to be in the ballpark based on the goals set for the former 737RS (replacement study). Whatever array Boeing chooses will compete not so much with the A320NEO but rather the all-new A30X, which Airbus now says will likely follow in 2030 rather than 2025 as originally planned.

Starting with the baseline aircraft layout, Boeing remains unwilling to stray from the conventional tube-and-wing configuration. Recent revelations about small dual-aisle "semi-widebody" designs are dismissed by some industry observers as "Sonic Cruiser-like smoke and mirrors." However, ongoing research at NASA indicates such alternate, highly integrated configurations hold great promise for more efficient designs in the 2030s and beyond.

One possible glimpse into Boeing's thinking on Y1 may be taken from configurations developed by the company's Research and Technology branch for its 2010 subsonic ultra-green aircraft research (Sugar) study with NASA. Although aimed at meeting stringent noise, emissions and fuel-burn targets by a 2030 timeline, the reference "Sugar Free" and "Refined Sugar" Model 765 concepts (against which more advanced models are compared) may come close to showing how a clean-sheet, next-generation tube-and-wing configuration might appear.

A more radical "Super Refined Sugar" configuration with a 160-ft. span, high-aspect-ratio wing (16 versus 11.6 on the more conventional design and 9.45 on the current 737) indicates how even standard designs can be optimized for better fuel burn. In the case of the extended wing, Boeing designers also came up with a wing-fold option, similar to that originally offered on the 777, to reduce span by 42 ft. at narrow gates.

Y1 also gives Boeing the first opportunity since 1964, when the 737 fuselage was derived from that of the 707, to adopt a slightly wider, circular or ovoid cross section, with associated increases to the lower deck volume and increased capacity for containerized pallets. One key ground-handling advantage frequently cited for the 13-ft.-dia. cross section of the A320 is the capacity to take LD3-46-size containers in its lower hold.

Boeing says larger new twin-aisle concepts, such as the Light Twin study that emerged in early 2009, will likely not provide the basis for the cross section. Although much larger than the baseline 150-seat market needs of the 737RS, Boeing confirmed the Light Twin at the time was part of its single-aisle replacement work that broadened following the formal disbanding of the original 737RS project in April 2008.

Part of the reason the study was abandoned was because the product development team could not meet the 20%-plus operating cost improvement targets. Now, three years on, with the launch of A320NEO, and Boeing "over the hump" on 787 development, the story seems to be different.

From the perspective of propulsion for Y1, Pratt is offering its "Gen 2" GTF, which will have a targeted overall pressure ratio of 50-55:1 against the 47-48:1 in development for A320NEO and on offer for the 737. Bypass ratio will also be in the 15–18:1 range versus 12:1 for the NEO engine. "We feel it will be achievable when we work it at a systems level," says Adams, who adds that goals include a lighter hybrid fan and nacelle, with a shorter inlet. "We may also [modify the] gear ratio to a point where it could change from a star to a planetary system, but my expectation is we'll probably stay with the current configuration and look at both."

Aerodynamic advances—particularly in potentially high-payoff areas such as passive, natural and active laminar flow control for drag reduction—are progressing toward practical application. NASA is planning to flight test a method of laminar flow

Technology studies range from active side stick and human-machine interface issues with advanced displays (above) to engines such as Gen 2 versions of Pratt & Whitney's geared turbofan (right) .

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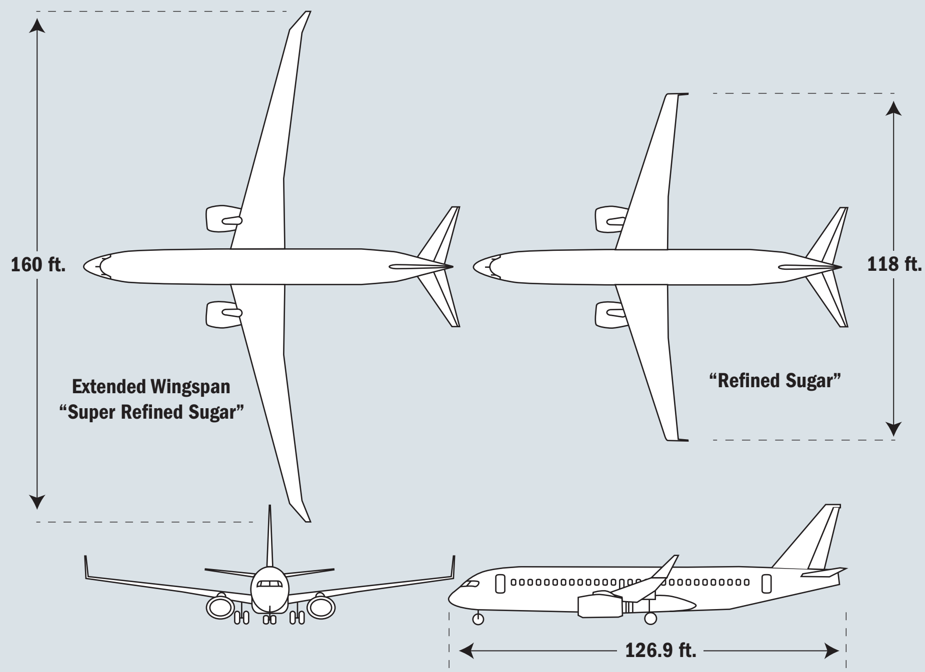
Boeing Advanced Concept Model 765



BOEING

control on swept wings with micron-size protuberances called discrete roughness elements around 2013, while Boeing is developing hybrid laminar flow control for the empennage of the stretched 787-9. Active and laminar flow control are NASA's two main areas of investigation for reducing skin friction, which accounts for an estimated 48% of the drag on current airliner designs. Fewer fasteners, smaller and fewer flap fairings, and multi-function structures will also cut excrescence drag.

One of the key unknowns concerns the proportion of composite materials that will be used in the primary structure, either in the wing or fuselage. Despite Boeing's pioneering experience on the 787, the company continues to warn that scaling factors do not always justify their use at the smaller single-aisle size. However, ongoing materials research suggests that lightweight ceramic matrix composites (CMC) may be sufficiently mature for wider application by 2020, and that out-of-autoclave composites could be used for secondary control surfaces.

Other structural technology advances that might be brought to bear could include adaptive structures for spanwise load control, lighter interiors and an integrated structural health management system with embedded sensors. Y1 could use future versions of the trailing-edge variable-camber (TEVC) system developed to boost 787 cruise performance, as well as a maneuver-load-alleviation system similar to that used to reduce stress and enable a lighter wing structure on the 747-8.

The TEVC is a rudimentary morphing wing and uses slight adjustments of the moving surfaces on the trailing edge to optimize wing camber for better lift/drag ratios under changing flight conditions. A future version adds a dynamic adjustment-control module to the TEVC to provide command signals for optimum positioning of flaps, ailerons, and flaperons.

Although key suppliers such as Honeywell and Rockwell Collins decline to identify specific systems under review, they can discuss concepts applicable to the Y1 timescale. “We really look at the whole aircraft because of the portfolio we have,” says Carl Esposito, Honeywell product management vice president, who cites human factors, optimized “more-electric” hydraulic and pneumatic energy usage across the aircraft, and advanced predictive maintenance/health- and usage-monitoring systems as focus areas.

Y1 concepts may build on Boeing/NASA efficient airliner studies.

Following the lead taken by the 787 with dual head-up displays as standard, Esposito believes advanced flight-deck features such as enhanced and synthetic vision systems (EVS/SVS) will ultimately find air transport applications. New-generation flight-deck features such as Automatic Dependent Surveillance-Broadcast and controller-pilot data link communications “will become a baseline configuration for entry-into-service in the 2020 timeframe,” says Bob Ellis, Rockwell Collins product systems marketing director.

From a controls perspective, Ellis believes development of active, jam-resistant side-stick controllers could give the flight deck a new look, while backup safety modes, such as the ability to fly with degraded or damaged control surfaces, could appear. The transition to electrical stabilizer actuation with the 787, A380 and A350, is also likely to continue onto future single-aisle designs, he says.

Far Horizon

NASA looks further ahead in its quest to make aircraft cleaner and quieter

GRAHAM WARWICK/WASHINGTON

In its drive to identify technologies that could be pursued to make aircraft cleaner and quieter, NASA has extended the horizon of its search to 2040-45. Europe has already extended its vision for aviation in 2050 to help guide long-term research goals.

NASA had previously set its horizon at 2030-35, when aircraft three generations more advanced than today's airliners could enter service. Four teams developed concepts for these so-called N+3 aircraft in studies completed last year. Now the agency has awarded follow-on contracts to advance some of those ideas and identify new technologies that could become available within the extended horizon.

The decision to look further ahead came out of the Phase 1 studies conducted between October 2008 and April 2010 by teams led by Boeing, General Electric, the Massachusetts Institute of Technology (MIT) and Northrop Grumman. "Under Phase 1, many technologies were not considered because they would not be mature within the 2030-35 timeframe," says Ruben Del Rosario, NASA's subsonic fixed-wing program manager.

"We wondered, if we gave them another 15 years, what other technologies would mature," he says. "So we opened up a "mini-N+4" and gave them until 2040-45." Identifying technologies that will become available within the extended horizon is one of 10 tasks covered by $16.5 million in contracts awarded to Boeing, Cessna, MIT and Northrop Grumman under Phase 2 of the N+3 program.

Envisioning 2040-45 is one of several tasks awarded to Boeing and will be a focused effort limited to a year and leveraging the investment in Phase 1 studies, says Rich Wahls, subsonic fixed-wing project scientist. Other tasks under Boeing's three-year, $8.8 million Phase 2 contract include closer looks at two technologies evaluated in Phase 1 under the company's Subsonic Ultra-Green Aircraft Research (Sugar) concept. These are the truss-braced wing and hybrid-electric propulsion.

A truss-braced wing allows substantially longer span for significantly higher lift-to-drag ratio, but Boeing's Phase 1 study identified uncertainty in estimating wing weight as the biggest risk. Under Phase 2, the company will perform higher-fidelity analysis, develop a detailed finite-element structural model and test a flutter model in NASA Langley Research Center's transonic dynamics tunnel.

Boeing will also investigate special high lift-coefficient airfoil designs for the low-sweep, narrow-chord wing and conduct two-dimensional airfoil tests in Langley's 0.3-meter transonic cryogenic tunnel. Airfoil tests are expected to begin late in 2012, with testing of the flutter model planned for 2013, says Wahls.

Two of the Phase 2 tasks relate to hybrid-electric propulsion, which in Phase 1 was identified by Boeing and its team-member General Electric as a promising but risky technology. The Sugar study developed the "hFan" concept for a fuel-efficient, low-emissions turbofan that combined an ultra-high-pressure-ratio gas-turbine core with an advanced electric motor powered by batteries.

Under Phase 2, Boeing will refine the concept and its understanding of how to integrate hybrid-electric propulsion with a truss-braced wing (its Sugar Volt concept developed under the Phase 1 study). "They will also study how to integrate the hFan with other platforms, not just Sugar Volt, including hybrid wing-body and advanced conventional configurations, and run analyses to see what benefits they get," says Del Rosario.

Boeing will also work to gain a better understanding of the total energy used with hybrid-electric propulsion, and not just the fuel consumed. Another Phase 2 task is to model the hFan in NASA's numerical propulsion system simulator, a software tool widely used by industry. This will allow side-by-side comparisons of hybrid-electric and other, more conventional propulsion systems such as geared turbofans and open rotors.

Under a three-year, $4.6 million Phase 2 contract, MIT and partner Pratt & Whitney will conduct further studies of the D8 "double-bubble" configuration developed in Phase 1. This has a lifting-body fuselage, its cross section comprising two cylinders side-by-side, and a low-sweep, high-aspect-ratio, laminar-flow wing. The engines are mounted on the tail so that they ingest the boundary layer over the fuselage, reducing drag.

Computational fluid-dynamics analysis and wind-tunnel testing of the D8 configuration will focus on propulsion-airframe integration, says Del Rosario. Tests will focus on boundary-layer ingestion (BLI), a technique used by other advanced aircraft concepts. "We will use the D8 as a testbed, but other BLI concepts will benefit," he says.

A final tunnel entry will assess the acoustic design of the D8, which has the engines mounted atop the aft fuselage and between twin vertical fins that provide shielding, but under a high-set horizontal tail that could reflect noise downward to the ground.

The MIT/Pratt team will also study high-efficiency, small-core engines, another key feature of the D8 configuration. Reducing core size is a way to increase bypass ratio and propulsive efficiency without increasing overall engine size, but creates challenges with blade-tip clearances and losses. Under Phase 2, the team will explore the limits of core size and technologies to make the engine cycle work at smaller scales.

Under a 27-month, $1.9 million contract, Cessna will design a protective skin that could enable lighter structures by protecting composite materials from impact damage, humidity, high temperatures and lightning strikes. The skin would combine foam or honeycomb layers for impact absorption and acoustic insulation with an outer film providing a smooth surface for drag-reducing natural laminar flow.

MIT

Model testing of the D8 "double-bubble" configuration has been conducted in the Wright Brothers Wind Tunnel at the Massachusetts Institute of Technology.

"Traditionally we over-design a composite structure to cope with heat, humidity and damage. The idea was to come up with a protective skin that would enable us to design a structure without the knock-downs that add weight," says Vicki Johnson, lead investigator at Cessna. In Phase 2, the company will develop initial concepts, select potential materials and build test panels.

"We will limit ourselves to commercial off-the-shelf materials to demonstrate feasibility," she says. Cessna plans to test up to 180 panels, evaluate the results, modify the concept, then build a final set of panels that will be tested against all the requirements from damage prevention to drag reduction. "We will weigh them, to see if we are adding or subtracting weight," Johnson says. Manufacture and repair will be analyzed.

For the final Phase 2 task, Northrop Grumman will study a multi-function wing leading edge that will enable cruise laminar flow while reducing airport noise by eliminating the slat. Under a 14-month, $1.2 million contract, the company will build and test models of several leading-edge concepts.