MISSILE DEFENSE New Requirements, New Opportunities

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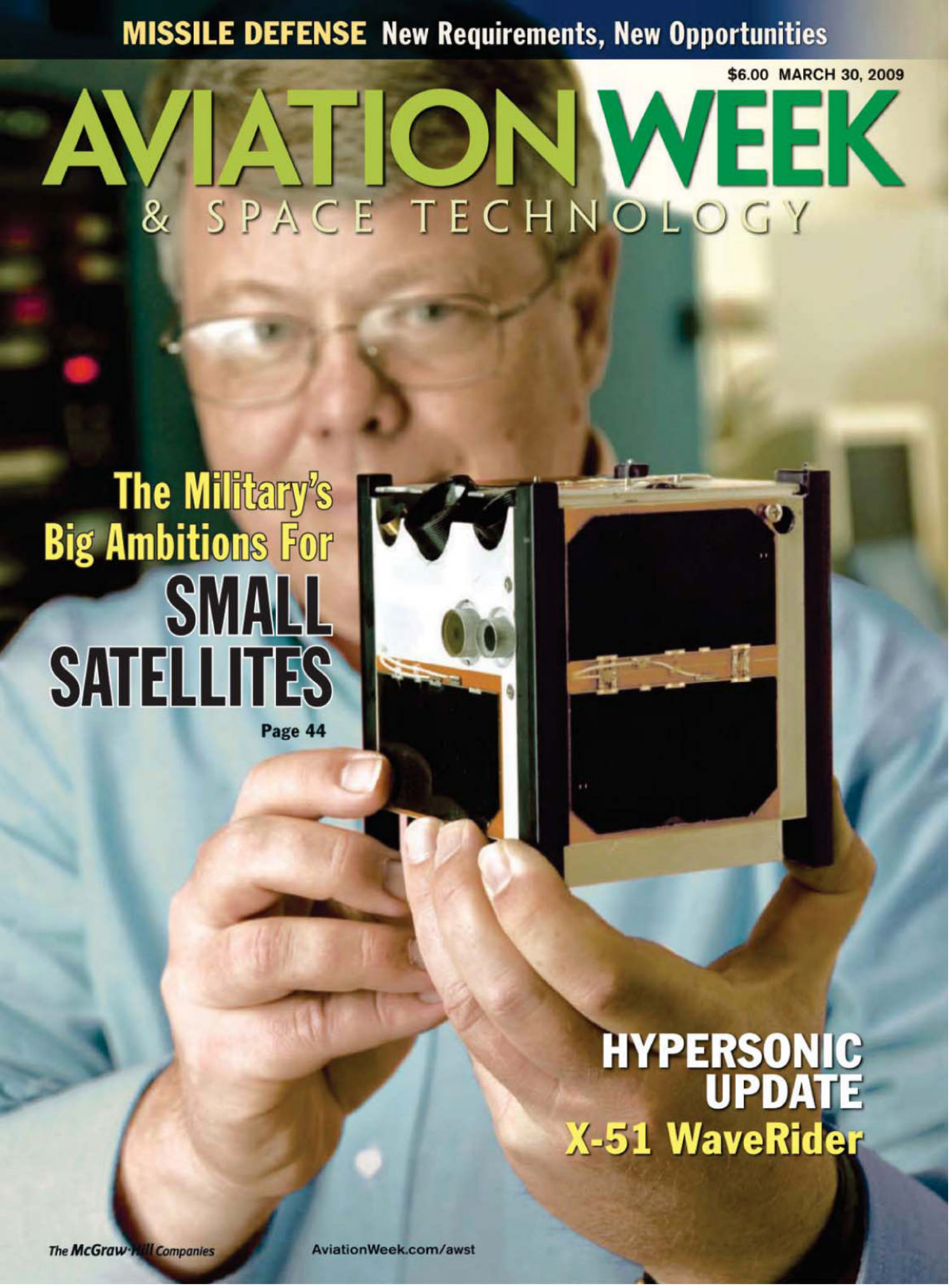

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Rotor Revolution

Research to couple retractable rotor blades, swept wing and ducted props gets a boost

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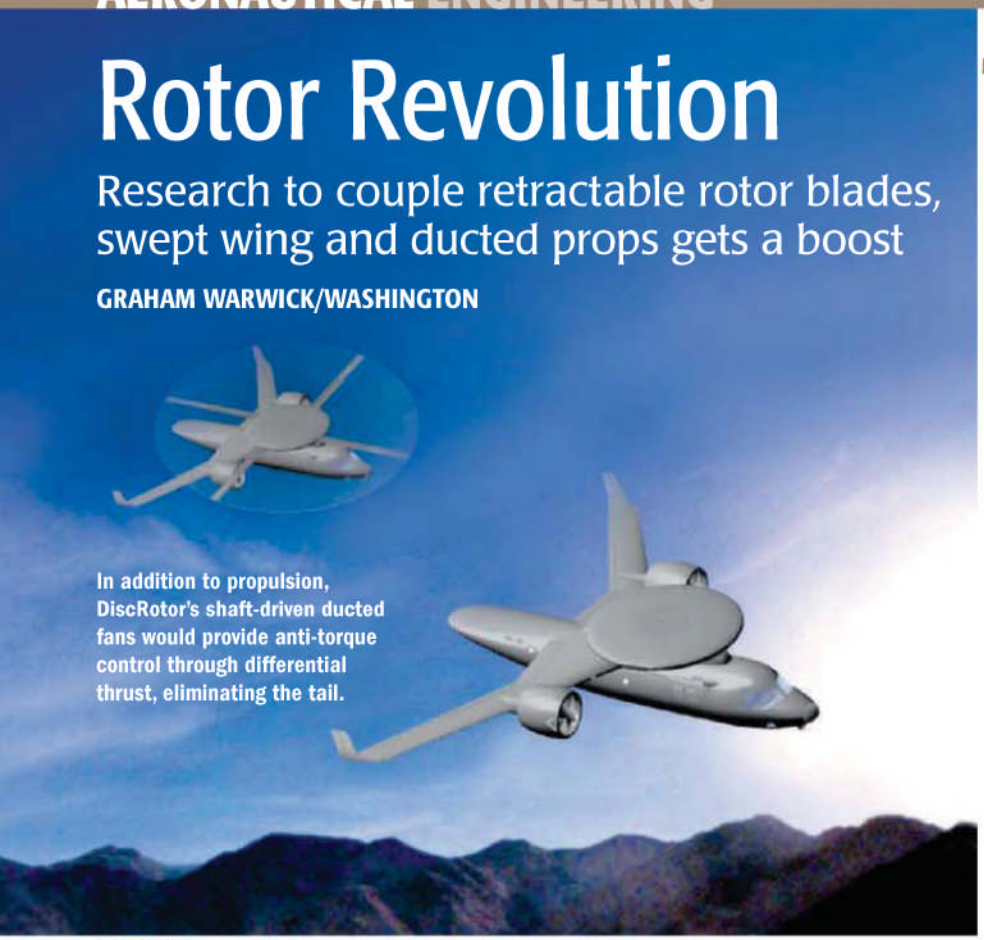


In addition to propulsion, DiscRotor's shaft-driven ducted fans would provide anti-torque control through differential thrust, eliminating the tail.

DARPA CONCEPT

The challenge of combining rotary-wing flexibility with fixed-wing efficiency continues to fascinate designers, tempting the U.S. Defense Advanced Research Projects Agency into funding yet another approach to the perennial problem.

Darpa has awarded Boeing a contract to study the DiscRotor, which would take off vertically like a helicopter, slowing the rotor and retracting the blades into the disc as it accelerates, until it morphs into a swept-wing aircraft powered by ducted fans.

The concept promises helicopter-like hover efficiency, but a speed in excess of 350 kt. in fixed-wing mode. "It would have high speed for ingress and good high-altitude hover, so it would fit the combat search-and-rescue role," says Phil Hunt, Darpa program manager.

The idea of increasing helicopter speed by stopping or stowing the rotor is not new, but success has been elusive. The Sikorsky X-Wing never became airborne and both Boeing X-50 Canard Rotor/Wing (CRW) demonstrators crashed while still in hover testing.

Darpa is trying to avoid past mistakes with DiscRotor, says Hunt. "Other pro-

Transformer

Roadable aircraft might improve safety and utility of general aviation

GRAHAM WARWICK/WASHINGTON

As if designing a vehicle to meet aviation safety regulations was not hard enough, Terrafugia must ensure its new Transition also complies with highway safety rules to qualify as a "roadable aircraft." But the result, the U.S. startup company believes, will be a safer light aircraft.

Flown for the first time on Mar. 10, the two-seat Transition is being hailed as the first true flying car, as the vehicle converts between aircraft and automobile mode at the touch of a button. The flight created a sensation on the Internet, fueled by aviation and motoring enthusiasts who have waited decades for a practical flying car.

Since the 1930s attempts have been made to produce a flying car, but these required the wing, tail and sometimes the propeller to be removed and either left at the airport or towed behind the vehicle. None made it into production.

Woburn, Mass.-based Terrafugia says it has more than 40 nonrefundable deposits on the $194,000 Transition, with deliveries planned to begin in 2011. The privately financed startup company will need to raise additional capital to get the Transition into production—and demonstrate compliance with both aviation and highway safety regulations.

The Transition is built to light sport aircraft (LSA) airworthiness rules, which strictly limit gross weight and performance, but which allow the manufacturer to self-certificate the aircraft by demonstrating compliance with industry consensus standards. It will also meet all applicable federal motor vehicle safety standards, says Andrew Heafitz, vice president of product development.

"There are many trade-offs when building a dual-purpose vehicle, but the flexibility we have from following the LSA rules, as opposed to those for a Part 23 certified aircraft, has allowed us to work through many regulatory conflicts," he says, adding that the FAA, National Highway Transportation Safety Agency, Environmental Protection Agency and others "have been very supportive."

A light sport aircraft is limited to two seats, 1,320-lb. gross weight, 120-kt. maximum speed and 45-kt. stall speed. An LSA is restricted to flying in day visual flight rules conditions, but a sport pilot's certificate needs only a driver's license and 20 hr. of flight instruction.

The Transition is designed to take off in 1,700 ft., cruise at 100 kt., and fly 400 naut. mi. On the road, the vehicle is expected to achieve up to 65 mph. and 30 mpg. Power comes from a 100-hp. Rotax 912S burning unleaded gasoline and driving either a fixed-pitch pusher propeller via a shaft or the front wheels via a continuously variable transmission.

A lightweight carbonfiber composite structure offsets some of the added weight from designing the Transition to meet highway safety standards, requir-

grams aimed from the outset at flight demonstration," he says. "CRW paid the price of going straight to a demonstrator when those early design decisions came back and bit us."

As a result, the agency is funding a 30-month program with Boeing "to see if DiscRotor is feasible" before taking a decision on designing and building a demonstrator, says Hunt. "We will take it to a good decision point, then think about recompeting the program."

Instead of a firm idea for the DiscRotor configuration, Boeing has a "conceptual approach," he says. In addition to a 350-kt. cruise speed, Darpa is aiming for a disc loading that is less than the CH-53's 14 lb. per sq. ft., a hover out of ground effect at 15,000 ft. and a significant maneuver capability. "But we don't know where the trades will end up."

The initial concept has a UH-60 Black Hawk-size fuselage and telescoping blades that retract into a disc that's roughly a third of the rotor's diameter. The original idea was to use the stationary disc as the wing, but the lift-to-drag ratio was not good enough, so now most of the lift in forward flight comes from the swept wing. The disc is angled for minimum drag, similar to radar rotodomes on airborne early warning E-2s and E-3s.

The DiscRotor will convert between rotary- and fixed-wing modes in a flat attitude, avoiding the complex transition of the CRW, which required the aircraft to pitch nose-down to accelerate like a helicopter, then unload lift from the rotor to the canard and wing, stop and lock the blades and then shift lift back to the rotor, now acting as a wing.

In the DiscRotor, propulsion for forward flight comes from ducted props on the wing, with differential thrust providing anti-torque control. "We get rid of the tail, which saves weight," says Hunt. The cross-shafting required to drive the props from the rotor transmission makes weight one of the design challenges.

"Can we do this at a weight where there remains military utility? We will only find out through more refined analysis," Hunt says. The Black Hawk's transmission is about 25% of the aircraft's total weight. "We will not get that close—35% may be the price we pay for the shafting." Research into lightweight structures and transmissions are a key part of the program.

Other challenges include retracting and extending the rotor blades in flight. The exact mechanism has not been decided, but needs to be precisely controlled. "A few millimeters mismatch in deployment could cause out-of-balance forces," Hunt says, adding that active blade control will likely be required to manage the response.

The DiscRotor program consists of two phases. In the year-long first part, the Boeing-led team will "rescrub" the design trades performed during the previous "Phase 0" study. A small-scale model of the aircraft will be built for wind tunnel testing to determine lift-to-drag ratio and stability, and a small model of the rotor system built to investigate transition. A larger retractable rotor test rig will be put through its paces in a 20-ft. wind tunnel later in the program.

Although based at Boeing's rotorcraft plant in Philadelphia, the DiscRotor team will include people from the company's Mesa, Ariz., and Irvine, Calif., locations that have had experience with the stopped-rotor X-50 CRW and the A160—a Darpa unmanned helicopter program that included advances in lightweight, low-drag airframe technology. "I'm keen to embed lessons from the X-50 and draw on work on the A160," says Hunt.

ing a crash cage and crumple zones. But the result is "one of the safest planes out there," he says. "The crash test speed is right around our stall speed." The ability to land and drive under weather is another safety enhancement, one that "has the FAA excited," according to Heafitz.

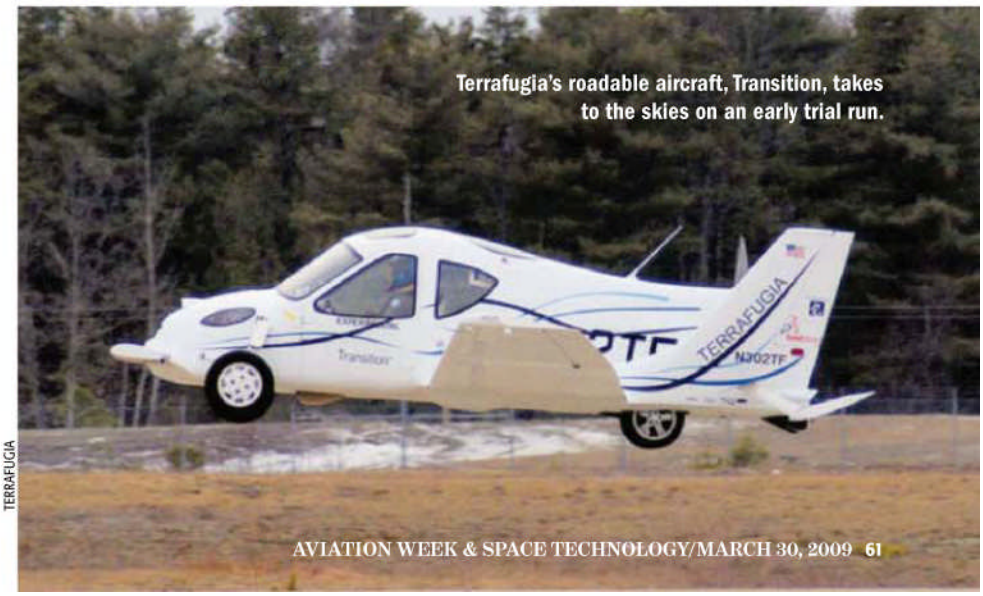
The Transition has standard driving and flying controls, kept completely separate for simplicity. Flight controls are stick and rudder pedals, which flank brake and gas pedals. The stick folds away under the seat, but the steering wheel remains in place and can be used during taxiing. Terrafugia is in talks with a manufacturer on developing a dual-mode airbag system. The two-screen glass cockpit switches between flight displays and car instruments.

On landing, a single button-push folds the wings against the rear fuselage and converts the aircraft into a car. Interlocks prevent the wings folding unless the engine is off and weight is on the wheels. To convert back to an airplane, the pilot has to enter a PIN number for security and conduct a pre-flight walkaround inspection.

The Transition has four-wheel independent suspension, which makes for a smooth landing, but does not have some automotive features such as an anti-skid braking system. "This is primarily an aircraft, with an added functionality of being able to drive on the road, and with standard aircraft features," Heafitz says.

"Some things will be better than your average aircraft, such as four-wheel disc brakes, and we have automotive-style doors, which our 40+ customers like because it makes it easy to get in and out," he says. "However, the light sport aircraft rules are very strict about weight, so we cannot have extra features that are not absolutely necessary for operation as a plane or a car."

The proof-of-concept Transition is being used as a flying (and driving) testbed, and will be followed by a prototype to demonstrate compliance with LSA standards. There are no plans for crash testing as highway safety rules also allow self-certification, Heafitz says. Production is slated for the Boston area, but ramp-up plans are not finalized.



Terrafugia's roadable aircraft, Transition, takes to the skies on an early trial run.

TERRAFUGIA