Advanced Materials Lessen Bird Damage

Carbon composites and titanium alloys strengthen engine blades and casings

Paul Seidenman and David J. Spanovich San Francisco

JOEPRIESAVIATION.NET

Ingestion of multiple birds damaged this engine on a Delta Air Lines Boeing 757-200 on takeoff from New York's John F. Kennedy International Airport.

When interactions between birds and aircraft, or "bird strikes," happen, the consequences can range from a minor dent on a radome to the loss of an engine.

Bird strikes, as defined by the FAA, are collisions between a bird and an aircraft resulting in the death or injury to the bird, damage to the aircraft or both. Near-misses with birds reported by pilots also are considered strikes.

According to the FAA's National Wildlife Strike Database, there were 177,269 wildlife strike reports on civil aircraft between Jan. 1, 1990, and Dec. 31, 2015. For a more recent comparison, 13,162 strikes were reported for all of 2015, up from 9,540 in 2009—the year that the database was first released to the public. Birds accounted for 97%.

For a more global perspective, the International Civil Aviation Organization (ICAO) reports 65,139 bird strikes for 2011-14, with the U.S. accounting for the Top 10 airports for occurrences. An ICAO spokesman says the agency receives roughly 10,000 reports annually but expects that number to grow as its system is modernized for e-reporting.

Although the windshield, nose, wing/rotor and radome statistically are most at risk for a bird strike, engines sustained the highest percentage of actual damage among major components. FAA statistics show that in 1990-2015, there were 16,636 reports of bird strikes on engines, in which 4,417—or 27% of the total—resulted in damage.

Chris Kmetz, Pratt & Whitney's chief engineer for systems design and component integration, says most bird strikes on engines do no damage. "When damage is found, it tends to be to the plastic flow path panels and wire mesh acoustic panels, which can become cracked, dented or torn in excess of allowable damage," he says. "Higher-impact forces—larger birds struck at higher speeds—can cause bends or cusps in the lead edges of the fan blades, which are the first engine components the bird encounters upon ingestion."

The engine, he notes, will continue to operate after this type of damage, and the hardware can be repaired or replaced easily after landing without removing the powerplant.

Kmetz reports that the introduction of wide-chord fan blades, which eliminated the part span shroud, has reduced bird impact damage. He says that with earlier engine designs, part span shrouds dampened airfoil vibrations due to mechanical and aerodynamic instabilities, although a side effect was that they prevented the fan blades from deflecting easily when hit by birds. The upshot was a tendency for tears in a section of the fan airfoil in the shroud region. With removal of these shrouds, full deflection of the fan blades—without overstressing the airfoil—is allowed.

"Current Pratt engines—including the new PurePower geared turbofan (GTF) family—use these design features," Kmetz says. "In addition, the slower rotational speeds of the GTF engine lower the stress on the fan blades during a bird-strike event, further reducing the chance of significant engine damage."

In fact, Kmetz points out that the fan blades are the first engine components encountered by an ingested bird, and in the case of large birds, the fan rotor can sustain substantial damage. That raises the possibility of fan-blade detachment, although Kmetz stresses that this is rare. "The fan blades are specifically designed and tested to preclude the detachment of a blade during a bird ingestion event," he notes. "However, should that occur, the engine-casing system is designed and tested to ensure the detached blade stays contained within the engine and does not damage the aircraft."

Nick Kray, a GE Aviation consulting engineer, says that as the technology has matured, the engine OEM has used predictive models for bird strikes to

Civil Aircraft Components Reported Struck and Damaged by Wildlife; U.S., 1990–2014

	Birds (25-year total)				Terrestrial mammals (25-year total)			
Aircraft component	Number struck	% of total	Number damaged	% of total	Number struck	% of total	Number damaged	% of total
Windshield	21,937	16	971	6	8	<1	16	1
Nose	19,133	14	984	6	105	4	100	5
Wing/rotor	18,332	14	3,683	24	295	11	307	16
Radome	16,638	12	1,497	10	14	1	15	1
Engine(s)	16,636	12	4,417	29	178	7	175	9
Fuselage	16,107	12	643	4	141	5	148	8
Other	13,574	10	1,227	8	330	12	277	14
Landing gear	5,979	4	508	3	1,151	43	465	24
Propeller	2,953	2	265	2	321	12	298	15
Tail	1,740	1	621	4	61	2	81	4
Light(s)	911	1	656	4	44	2	50	3
TOTAL*	**133,940**	**100**	**15,472**	**100**	**2,648**	**100**	**1,932**	**100**

**In addition, bats struck 598 components, 12 of which were damaged; and reptiles struck 42 components, six of which were damaged.*
Source: FAA: "Wildlife Strikes to Civil Aircraft in the United States—1990-2014"

ensure fan blades are more robust in terms of materials, thickness and overall geometry, to meet bird-ingestion criteria. He adds that the increasing use of carbon composite materials—along with titanium alloys—in the leading edges of the blades, are among the major innovations in materials that strengthen blades to better resist bird-strike damage.

"The combination of carbon composites and titanium leading edges has

INGESTION TESTING STILL DEPENDS ON DEAD BIRDS

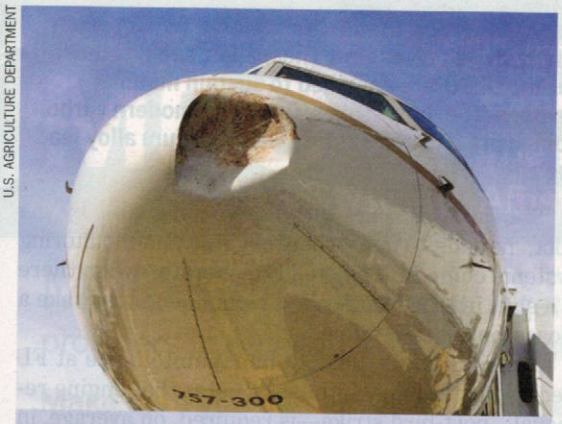
For more than 50 years, FAA bird-strike regulations have continued to evolve. Under the latest version, which was adopted in 2007, engine certification requirements were changed to meet the threats posed by large flocking birds–those weighing more than 4.1 lb.

Pratt & Whitney's Chris Kmetz says testing for compliance with bird-ingestion regulations is conducted at the OEM using euthanized birds. The bird size, he notes, is defined by weight–although the regulations require the use of several categories and differing quantities of birds depending on the engine inlet area, with evaluations on larger engines requiring more and heavier birds. The size categories include small flocking birds (3 oz.) such as killdeer and meadowlarks; medium flocking birds, which are combinations of 1.5- and 2.5-lb. birds, and generally are gulls; and large flocking species (4.1, 4.6 or 5.5 lb.), such as snow geese–because of the 2007 rule change.

All of the flocking-bird rules include a 20-min. engine run-on requirement after ingestion to demonstrate that the powerplant will continue to operate safely following bird ingestion.

In addition to the flocking-bird demonstrations, there is requirement with ingestion of a single 4-, 6- or 8-lb. bird–the weight depends on the size of the engine–that the engine must be shut down safely and not present a hazard to the aircraft.

U.S. AGRICULTURE DEPARTMENT



This Boeing 757 struck a bird during climbout from an airport in the Western U.S. The flight crew detected no abnormalities and continued to their destination, where the large dent in the radome was discovered. The aircraft was out of service for 24 hr., and repair costs totaled $30,000.

The Top 10 U.S. Airports for Reported Bird Strikes, 2011-14

Denver Intl. Airport	1,830
Dallas/Fort Worth Intl. Airport	1,482
Chicago O'Hare Intl. Airport	982
Philadelphia Intl. Airport	844
John F. Kennedy Intl. Airport	829
Salt Lake City Intl. Airport	762
Memphis Intl. Airport	746
Orlando Intl. Airport	666
LaGuardia Airport	616
Total Reported Globally	**65,139**

Note: The ICAO statistics are skewed to the U.S. because it is much more proactive/comprehensive in reporting bird strikes than most other nations.

Source: International Civil Aviation Organization (ICAO)

proven to be very robust in the field," Kray notes. "There have been no reports of extensive damage caused by bird strikes. It's really better materials combined with better predictive tools that enable a higher confidence in our design for any external bird encounter."

Asked about the kind of damage more than likely to result from a bird strike, Kray says a "bulge on a fan blade" is typical. "Also, from time to time, there is some secondary damage, primarily to fairings or acoustic panels within the fan case module, which is where most of the damage is likely to occur. Major damage is extremely rare."

Because of the limited damage involved, Kray says a fan blade or panel can be replaced at the flight-line level within a few hours, because of the modular design of today's engines.

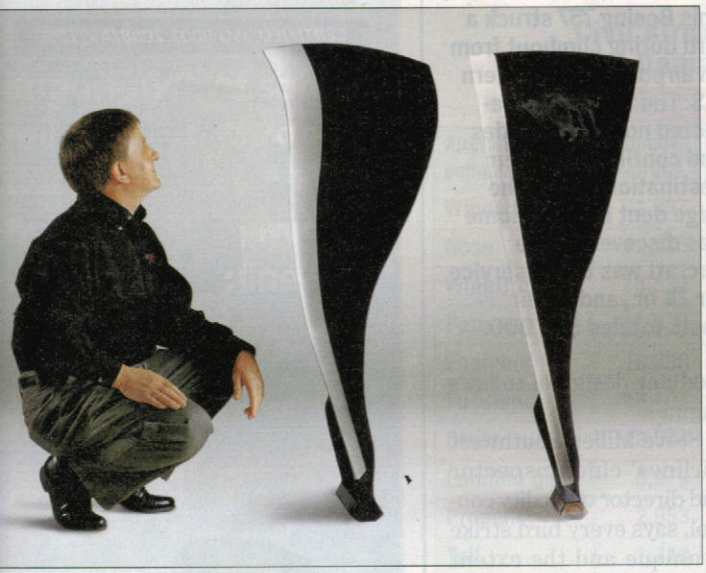
Steve Miller, Southwest Airlines' chief inspector and director of quality control, says every bird strike is unique and the extent of damage varies. "When it comes to engines, we may see blade damage, or clogged pneumatics," he says. "We will conduct an internal borescope inspection to assess the damage."

The repair process for bird-strike damage, Miller notes, is heavily dependent on where the incident occurred within the airline's maintenance network and the extent of the damage. "Often, the logistics of getting the right parts and maintenance personnel to the aircraft can be the most time-consuming part of the repair process, but usually we get the aircraft back into service within 24-48 hr," he says.

Also, Miller stresses that engine removal due to a bird strike is rare: "We might have one incident a year when we have to do that."

The degree of damage depends on where the strike takes place, according to Freidhelm Kappei, head of central performance engineering team at MTU Maintenance Hanover in Germany.

"There are two airflows in a turbofan: the bypass airflow that bypasses the core engine and the airflow that directly enters the core engine," Kappei says. "If a bird goes through the bypass, the damage is likely to be less severe because it is not in the most sensitive part of the engine. However, if it enters the core of the engine, then the strike damage—for instance to the



Fan case blades are the first point of impact where a bird strikes an engine. The blades, such as those for the GE90, are designed to sustain minimal damage from bird strikes, thanks to modern carbon composites in combination with titanium alloy leading edges.

low-pressure compressor/booster and high-pressure compressor—can be greater."

As Kappei notes, impact damage to compressor blades may lead to failures and then "substantial and severe secondary damage" to the entire engine. Bird remains also may enter the turbine and the internal air system, leading to blockages of the engine cooling flow.

"Some bird [strikes] are barely noticeable by the pilot," he adds. "This is where engine trend-monitoring systems come in. They tell the operator when there is a shift in trend values and recommend they take a closer look at the engine."

Karolis Statkus, head of line maintenance at FL Technics in Vilnius, Lithuania, notes that engine removal—post-bird strike—is required, on average, in up to 5% of the cases. "Usually, it's enough just to replace the damaged parts, such as the fan blades, or conduct structural repair on the engine inlet," he says. "Also, engine design allows bird and foreign objects to be directed to the bypass duct, where potentially less damage can be done, given the use of stronger materials and special shapes of fan blades and the inlet cone. Usually, a single bird ingestion doesn't create a major problem, but everything depends on the quantity of birds and their weight."

RADOMES AND COCKPIT WINDOWS MUST WITHSTAND BIRD STRIKES

As with engines, aircraft windshields, cockpit side windows and nose and radome assemblies also must undergo testing for resistance to bird strikes.

National Technical Systems Inc. (NTS)–which specializes in testing, inspection and certification services–conducts bird-strike tests, mainly on radomes and cockpit windows, at its Huntsville, Alabama, and Tinton Falls, New Jersey, facilities.

Using windshields as an example, Brian Cagle, NTS's applications engineer in Huntsville, reports that all cockpit windshields are tested to meet certification requirements under 14 CFR 25.571 (Code of Federal Regulations) and ASTM F330 (American Society for Testing and Materials) using a pneumatic cannon and freshly killed 4-lb. birds. The testing simulates a collision at 350 kt, with the birds fired from 10-20 ft.

Over the past several years, bird-strike testing on windshields, as well as radomes, has trended more toward mitigating damage to cockpit electronics, Cagle points out. "During the testing, we generate acceleration and strain data, which is taken from various cockpit electronics locations, to determine the survivability of that equipment in the event of a bird strike," he says.

The testing is accomplished using an actual cockpit with data taken at representative equipment locations, using sensors such as accelerometers, and strain gauges located throughout the cockpit.