When Lightning Strikes

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In a blink of an eye, lightning strikes can have deadly consequences. Here's some advice on how to conduct a post-lightning-strike inspection.

On a routine flight to an oil platform in the North Sea, the Eurocopter Super Puma helicopter carrying 16 oil-rig workers from Aberdeen Airport, Scotland, encountered low clouds at an altitude of 3,000 feet above sea level. About six nm from the rig, the crew was preparing for descent when a bright flash accompanied by a loud bang occurred. Moments later, the passengers and crew began to feel a vibration through the aircraft, rapidly getting more intense. The vibration became severe and the crew declared a mayday with a planned diversion to a nearby oil platform. The copilot checked the tail-rotor pedals for controllability, which felt normal, when another loud crack was heard. The helicopter yawed nose left, accompanied by a right roll and the nose pitching down steeply. The pilots prepared the passengers to ditch.

The pilots secured the engines, armed the floatation devices and made a controlled ditching into very rough seas. All of the passengers and crew successfully entered a life raft and were recovered less than an hour later by a rescue boat. Rescue helicopters arrived to winch the passengers and crew from the boat, but three declined, preferring to take the day-long boat ride instead of another helicopter ride. Apparently they had enough excitement for the day. The helicopter was later recovered and examined by accident investigators.

The tail-rotor gearbox was ripped from the aircraft and the investigators believe that one of the tail-rotor blades was struck by lightning, and an outboard section of the composite blade failed, departing the aircraft and causing a severe vibration that tore the gearbox from its mountings. Helicopters are particularly susceptible to lightning damage due to many possible current paths through the dynamic systems. Airplanes are also vulnerable to both the direct and indirect effects of a lightning strike, where the massive voltage and amperage of the bolt overcomes protective measures and leaves critical systems inoperative.
It is estimated that hundreds of aircraft are struck by lightning every year, but few suffer severe damage. Although all modern aircraft are designed to withstand lightning strikes, it is important to understand that lightning protection systems must be maintained properly and the aircraft must be thoroughly inspected after strike. From a maintainer’s perspective, we like to think that the designers have developed robust protection systems, and aircraft are inherently safe, but the more we learn about lightning, the more we should be concerned.

However, with the introduction of advanced composite fuselages, and fly-by-wire flight control systems, the potential for catastrophic failure due to lightning may actually be increasing. To help maintainers and those who perform the maintenance function, we took a look at the science and technology behind lightning protection.

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Unless you have witnessed the power of a lightning strike up close, it is difficult to comprehend the destructive power that it causes. Caused by a discharge of static electricity from a storm, lightning can travel at a speed of over 130,000 miles per hour and surrounding the bolt can reach temperatures of 36,000°F, which is about three times hotter than the sun. Lightning can also occur during volcanic eruptions and severe forest fires that have massive movement of smoke and dust. The typical peak power released by a lightning bolt is about 10 terawatts. As you can imagine, even a near miss by a lightning bolt can ruin your day.

All pilots know to avoid thunderstorms, but lightning often precedes the storm’s advancing path sometimes many miles away from the front and can be very unpredictable. Areas that are prone to fast moving and frequent storms like Florida or the Gulf Coast are often particularly prone to lightning strikes. Often the Space Shuttle has to delay launching when lightning is nearby, or risk the highly explosive rocket fuel ignited by a strike. It is nearly impossible to avoid lightning completely, so that is why it is so important to ensure that the aircraft can survive a strike.

The effects of lightning strikes are divided into direct and indirect effects. Direct effects are when the aircraft is struck by the bolt; where the pressure shock wave, extremely high temperatures, resistive heating and magnetic forces cause the damage. Indirect effects are associated with the electromagnetic fields and structural voltage rises that can damage electronics if they are not properly shielded. Most aircraft are still manufactured from aluminum alloy and are naturally conductive. When the bolt meets an area of high electrical impedance, like an improperly grounded component or bearing journal, you can have the potential for heat and arcing damage.

The indirect effects of lightning strikes are often not as obvious. Insulators and shielding could be damaged and begin a slow process of deterioration that manifests itself months later with unusual electrical or avionics problems. This is why during your normal maintenance activities it is important to maintain wires and grounds so that if lightning strikes, you will be protected. Bonding jumpers, clamps and connectors need to be inspected and repaired in accordance with the manufacturer’s recommendations. When you find problems address them as soon as possible.

Because of the danger of lightning strikes, FAA certification standards require an aircraft to be able to withstand a lightning and to be able continue flying and land safely at a suitable airport. With the introduction of composite airframes, this poses problems for the manufacturers. “With the transition to Carbon Fiber Composite [CFC] fuselages, the conductivity of the airframe material is three orders of magnitude less than that of aluminum, therefore additional protection is required,” said Dr. Yulia Kostogorova-Beller, a research scientist at the National Institute of Aviation Research (NIAR) based at Wichita State University, one of the world’s top centers for aviation research. “This provides a major challenge in CFC aircraft design where one of the driving factors is to achieve the value of electrical resistance from tail-to-nose of no greater than one milliohm. Although intrinsic to aluminum alloys, this high conductivity cannot be provided by carbon fiber composites alone; hence, CFC aircraft require additional conductivity in the structure,” Kostogorova-Beller added.

Presently, to help augment composite structures, a conductive material is added to the airframe to lower its structural resist. The most common method is based on co-curing of thin expanded metal foils and CFC fabrics with interwoven metal wires skin. Typically, copper alloys and aluminum are used as conductive materials; however, aluminum, while offering the advantage of light weight, is prone to galvanic corrosion with carbon, whereas bronze is heavy and expensive. Interwoven wires can also promote arc root dispersion, thus minimizing specific energy of the strike by spreading it over a wider area.

Post-Strike Action

If your aircraft is ever struck by lightning, it is critical that you perform a post-lightning-strike inspection in accordance with your manufacturer’s maintenance manual. Tiny arc weld pits can lead to reduction of material strength and then to premature structural failure. The key to a good post-lightning-strike inspection is to find the entry and exit area, then trace the path through the aircraft looking for damage, especially in areas where joints, bearings and electrical connections take place.

Lightning protection areas on the aircraft are divided into three zones: Zone 1 is the most likely to be struck and includes the radome and wingtips; Zone 2 includes the bottom of the fuselage; and Zone 3 is the area under the wings. Often the radome is the brunt of the strike, and can suffer damage due to the thin radar transparent composite. Improperly bonded diverter strip increase the damage because the impact will be localized and not dispersed. Entry and exit marks can be very small and difficult to detect, so take extra time to locate them. Obvious burn marks may not be the only entrance or exit, as the bolt may be dispersed through the airframe.

Even though lightning strikes can be dramatic, it is difficult to know if the aircraft has been struck or just suffered a near miss flash may temporarily blind the pilots, and unless a system drops offline or you can see the impact you probably will not know if you have been struck. Most flight manuals have an emergency procedure for lightning strikes and a checklist to determine if the crew should make a precautionary landing or can continue on to the destination.

“When we had an aircraft that was struck by lightning while on approach; the pilots did not report anything wrong with the aircraft first they weren’t sure they were hit,” said Kevin Smith, chief of aircraft maintenance for Raleigh, N.C.-based Progress Energy Service Co. and NBAA Maintenance Committee member. “The destination airport has a service center. Close examination ground found that the lightning blew out a hole in the elevator and blew apart one of the static wicks. We had the service center complete the post-lightning-strike inspection and repair the damage. We were very fortunate to land at an airport that had a center, and the damage was minor,” Smith added.

When lightning travels through the aircraft, it can jump across bearings and flight controls, causing small arc weld pits that could cause binding or cracks. If there is evidence of the lightning path heading through the engine, it must be removed and forwarded for detailed inspection to a service center or OEM. The tiny arc weld pits can be difficult to diagnose and can be confused with corrosion pits. Corrosion pits can often be blended out, but arc welds change the molecular structure of the metal and can’t be repaired. It is best to leave the determination of the damage to the experts.

“Pay close attention to suspected lightning-damaged areas; any items that have obvious marks or evidence of a strike should sent to a service center for post-lightning-strike inspection,” said Jason Pry, technical services manager at Greenville, S.C.-Stevens Aviation Jet Center. “Some pilots think that a lightning strike is not a big deal, but flight control rollers can bind or engine bearings can magnetize and this will accelerate wear and cause problems down the road,” Pry added.

Some believe that if an aircraft has been struck by lightning, the potential resale value will diminish. The unscrupulous may disregard the event and not properly record the actions taken. This is both dangerous and a violation of continued airworthiness regulations. The event itself may only reveal minor damage, but if the inspection has not been complied with and a problem later down the road, you can be sure the lawyers will become involved. So be sure to follow the manufacturer’s instructions make the necessary logbook entries.

Even though weather detection and avoidance are helpful, lighting is unpredictable and can have deadly consequences. Hit damage can take months or longer to manifest itself; careful and thorough inspection is necessary even when you are not certain that the aircraft has been struck. During your daily and routine maintenance, make sure that bonding jumpers, strips, diverters and grounds are properly secured.

If you are ever struck, be sure to inspect the aircraft in accordance with manufacturer’s instructions and keep careful record you need help, seek out guidance from the OEM and qualified service centers.

Even though your aircraft may be down for a while as the inspection takes place, it is essential that you ensure that lightning not caused potential catastrophic damage that can appear later on. Though you cannot predict where or when lightning will you can be prepared to act when you are hit by a bolt from the blue.