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Boeing 787 Could Lose All Power

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The 787 Dreamliner is The Boeing Company's newest addition to its fleet. Unfortunately, it has been plagued with problems. The latest is a software bug, discovered by Boeing, that could cause loss of all electrical power, potentially shutting down both engines.

The Boeing 787 Dreamliner

The Boeing 787 Dreamliner is a mid-size, wide-body replacement for the Boeing 767 and seats up to 335 passengers. The plane entered service in October, 2011, with All Nippon Airways. So far, Boeing has delivered 264 787s, including 28 to U.S. airlines.

A major goal of Boeing in the development of the 787 was to improve fuel efficiency. Boeing intended the 787 to be 20% more fuel-efficient than the 767 airliner it was replacing. To achieve this objective, Boeing used carbon composite materials as the primary material in the construction of the 787's airframe, significantly reducing the weight of the plane.

In addition, many mechanical components were replaced with electrical systems to save weight. As a result, all major systems in the plane are now electrically operated. For instance, control services such as the ailerons, elevator, and tail that previously were pneumatically operated are now electrically operated.

The Plane's Electrical Generation System

With the 787's heavy dependence on its electrical system, Boeing went to extraordinary measures to add redundancy so that the continuous availability of electrical power was assured. The plane uses six electrical generators. Two 250-kilowatt generators are mounted on each of its two engines, and two others serve as backups. These generators provide control for avionics, pressurization, de-icing, and all of the other important functions required for the safety of flight.

Even if all of these generators failed, a lithium-ion battery supplies power for about six seconds. It is enough time to deploy an air-operated ram turbine that can deliver the minimum electrical power needed to keep the engines running and the avionics operating so that the airliner can fly safely to the nearest airport and land.

Each generator is linked to a control unit. However, all the redundancy in the world is useless if the design includes a single point of failure. In the case of the 787, the single point of failure is the software in the control unit.

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A Software Error Could Shut Down the Engines

In lab testing years after its first delivery of 787s, Boeing discovered a software error in the generator control unit. The error could result in a total loss of electrical power to the aircraft, even in flight. The condition occurred if electrical power were left on for about eight months without being turned off. More specifically, the problem became existent on the 248th day of continuous electrical power.

With its extended dependence on electrical systems, the 787 could experience a loss of control if it lost all electrical power. Loss of control of the airplane could occur during any phase of flight, including takeoff, landing, or while maneuvering in the air. Control loss during takeoff or landing could be particularly catastrophic.

Why would any airline keep its airplanes powered up for such a long period of time? When the 787 was first delivered, customers discovered that the airliner issued a series of erroneous nuisance messages when it was first powered up. Boeing recommended that the airlines power up the 787 earlier for a flight than they otherwise might to avoid this condition. As a result, many airlines simply kept their Dreamliners powered up continuously until their next maintenance intervals.

Fortunately, according to Boeing's records, the electrical power for all 787s currently in service has been turned off as part of routine maintenance approximately every four months. The maintenance intervals for the airliner have been much shorter than the eight-month trigger point, so the problem of electrical power loss has never been experienced by an airline.

The FAA's Airworthiness Directive

In response to Boeing's discovery, the U.S. Federal Aviation Administration (FAA) has published an Airworthiness Directive (AD) ordering 787 operators to periodically shut down the plane's electrical power. The AD requires that 787 electrical power must be recycled at least every 120 days.

According to an FAA statement,

> "We are issuing this AD to prevent loss of all AC electrical power, which could result in loss of control of the airplane. If the four main generator control units (associated with the engine-mounted generators) were powered up at the same time, after 248 days of continuous power, all four GCUs will go into failsafe mode at the same time, resulting in loss of all AC electrical power regardless of flight phase."

A Boeing spokesperson stated that:

> "The airworthiness directive action addresses a condition that only occurred in the lab. Simulated testing determined that this condition is possible in cases where an airplane's power is left on for more than eight continuous months. No airplane in the fleet experienced that condition."

The Fix

Boeing's only comment related to the cause of the problem was that:

> "This condition is caused by a software counter internal to the GCUs that will overflow after 248 days of continuous power."

Speculation is that the software bug is a signed 32-bit integer overflow that is triggered after 2^{31} centiseconds, or 248.55 days.

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Boeing is working on a software upgrade for the generator control units, and the upgrade should rectify the bug. The fix is expected to be available during the fourth quarter of 2015.

Other Problems Have Plagued the 787

The lithium-ion battery used as part of the 787's generator backup system has also presented a problem for the 787. The entire fleet of 787s was grounded for more than three months in 2013 after two fires and several smoke incidents were associated with the batteries. One incident was a fire that occurred in a Japan Airlines 787 parked at Boston's Logan International Airport. Boeing had to redesign the internal fuel cells for the battery as well as the battery casing.

The heavily burned battery from JA829J after it suffered thermal runaway

Lithium batteries can be a fire hazard since, unlike other rechargeable batteries, they contain a flammable electrolyte and are also kept pressurized.

Summary

Despite its problems, the 787 Dreamliner remains a mainstay of the Boeing fleet. Although teething problems are common within the first year of a new aircraft design's life, the three-month grounding of the 787 fleet was the first such grounding since that of the McDonnell Douglas DC-10 in 1979.

The problems faced by the 787 were generally the result of a major shift in airliner design away from mechanical controls to electrical controls in order to save weight. This is a trend that is sure to continue in airliner design, aided now by the experience of the 787's shift in design philosophy.

The Availability Digest reported a similar problem associated with the use of an internal intranet for interconnecting the plane's avionics controls and the passenger cabin controls.[1] Some claim that the intranet can be hacked by passengers to take over control of the plane. The 787 is one of the main suspects in this threat.

Acknowledgements

Material for this article was taken from the following sources:

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