If you value your life do not fly Airbus!

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Ground the 'fly-by-wire' Airbus deathtrap

> Since entering service in 1974 with many technological innovations, such as computerized fly-by-wire control systems, user-friendly cockpits, and extended use of composite materials, 5,717 aircraft have been manufactured by Airbus, an European aerospace company. More than 5,100 Airbuses remain in service.

Airbus A330

Not including losses attributable to terrorism, rebellion or military action, Airbuses have been involved in 23 fatal crashes causing the deaths of 2,584 passengers, crew members and people on the ground. In addition, there have been five nonfatal accidents causing 21 serious injuries.

While the overall number of accidents and fatalities are not disproportionate to the crash experience of Boeing aircraft, three of the Airbus crashes involved a separation of the composite vertical stabilizer (tail fin) from the fuselage. Five hundred, or one in five of the Airbus deaths, including 228 from Air France Flight 447, resulted from these three crashes.
In addition, Airbus composite stabilizers, rudders and couplers have also been involved in a number of other emergency in-flight incidents that did not lead to crashes, injuries or deaths.
There is now a question whether all Airbus aircraft equipped with composite stabilizers and rudders should be grounded until the cause of the crash of Flight 447 can be identified *and* it can be determined if the aircraft can be inspected, safely repaired, and returned to service.
Used in law, science and philosophy, a rule known as Occam's Razor requires that the simplest of competing theories be preferred to the more complex, and/or that explanations of unknown phenomena be sought first in terms of known quantities.
We do not know if Air France Flight 447 was brought down by a lightning storm, a failure of speed sensors, rudder problems or pilot error. *What we do know* is that its plastic tail fin fell off and the plane fell almost seven miles into the ocean killing everyone aboard.

What are Composites?

The essential definition of a plastic is the capability of being molded or modeled. Thus, the word can be accurately used to describe the various processes by which "composite" materials are coated, laminated and shaped into the various structures used in the construction of an aircraft.
Basically, a composite "indicates the use of different materials that provide strengths, light weight, or other functional benefits when used in combination that they cannot provide when used

separately. They usually consist of a fibre-reinforced resin matrix. The resin can be a vinyl ester, epoxy, or polyester, while the reinforcement might be any of a variety of fibres, ranging from glass through carbon, boron, and a number of proprietary types.” [1]

There are both advantages and disadvantages to using plastic composites instead of metal. They “have lower density and greater strength and stiffness than aluminum, therefore a smaller lighter structure can carry the same load.” [2]

Composite materials can be shaped and molded far easier than aluminum into compound curves for maximum drag reduction and it is easier to get smooth surfaces for laminar flow designs which allows for increased speeds. [3]

Among the risks of using plastic composites are: (a.) Strengths varies from batch to batch and it’s difficult to detect voids; (b.) lightning protection is very poor since the material does not conduct electricity; c.) materials degrade in the sun due to ultraviolet rays; (d.) delamination problems are caused by moisture; and (e.) *composites tend to break without warning at failure loads, unlike aluminum which can bend and still survive and usually provide some warning prior to failure*. [4]

If plastic composites “are bumped, beaten or excessively shaken, they can develop microscopic cracks that, if allowed to fester, can widen and critically weaken” the material. Delamination is another concern “in which heat, cold, humidity or manufacturing errors cause layers of the composite to separate.” [5]

Use of Composites by Airbus

The first “composite” materials used in aircraft construction consisted of plastic-impregnated wood, such as that used by Howard Hughes in his famous “flying boat” in World War II. [6]

As experience was gained through the use of fiberglass, the aircraft industry began to occasionally use composites for nonstructural applications, such as baggage doors. By the Sixties, at about the time Airbus was being created, the aircraft industry was prepared to consider using plastic materials in more critical structures.

The essence of designing and constructing a heavier-than-air flying machine is to make it as light and strong as possible. Although the initial cost of using plastic is higher than metal, the expense is offset over the long haul by lower fuel costs. Allan McArtor, Chairman of Airbus North America, said “Composites save weight, saving weight saves fuel, and saving fuel is better for the environment and for our customer’s bottom lines.” [7]

Starting in 1974, Airbus used plastic materials in its new A300 series aircraft, but only in secondary areas such as the leading edges of the tail fin. The A310 series introduced in 1978 featured a composite tail fin box, along with a number of additional applications. [8]

Ten years later, in 1988, Airbus began delivery of the A320 with an all composite tail fin, and construction of vertical stabilizers from plastic composites became the standard for all its aircraft. [9]

The vast majority of all commercial aircraft ever manufactured by Airbus remain in service, most of which are equipped with plastic tail fins, rudders and couplers.

Almost 25 percent of the new Airbus A380, which can seat more than 800 passengers on two decks, is constructed of composite materials. For the first time, the wings of the aircraft are stabilized and attached to the fuselage using a composite center wing-box, and the plane is equipped with a plastic vertical stabilizer that is almost 79 feet in length, nearly the height of an eight-story building. [10]

The A380 is already being flown in commercial service by several airlines, including Singapore and Qantas on trans-Pacific trips.

Missed Opportunities to Avoid Air France Flight 447 Disaster

A series of in-flight emergency incidents and fatal crashes extending back 12 years provide a clear record of missed opportunities to correct what increasingly appears to be a basic design error in Airbus commercial aircraft that may have caused the crash of Air France Flight 447.

May 12, 1997 - Aboard American Airlines Flight 903 Over Miami, Florida. Following an uneventful flight from Boston, the pilots of an Airbus A300-600 carrying 156 people were preparing to land at the Miami airport, when they were advised to go into a holding pattern due to an

approaching thunderstorm. [11]
At an altitude of 16,000 feet, the plane suddenly stalled and the “plane rolled to extreme bank angles left and right, and the rudder was moved rapidly back and forth to its in-flight limits. During the event, the airplane was stalled several times and rapidly descended more than 3,000 feet.” [12]
Melanie Joison was sitting with her two children holding her 18-month old daughter in her lap. The child flew from her lap back over three rows of seats where she was caught by another passenger. Ms. Joison suffered five broken ribs. [13]
The pilots declared an emergency, regained control of the aircraft and safely landed. Following a visual inspection in Miami, the plane was flown to New York where a further inspection cleared the plane to be returned to service. [14]
The incident was investigated by the National Transportation Safety Board (NTSB) because a passenger was injured. Although Airbus did not have access to the flight data recorder, it expressed a concern that an urgent inspection was needed because the plane could have reached “ultimate load” the point where force is near the breaking point. [15]
The plane received a more thorough inspection on June 26, 1997 by maintenance crews, who removed the covering over the base of the tail fin and inspected the six lugs that attach the tail to the fuselage. They did not remove the tail and examine the area covered by the fitting attached to the fuselage, and the plane was returned to service. [16]
The NTSB determined that the incident was caused by the flight crew failing to maintain adequate speed to prevent a stall. It did “not mention the rudder reversals or the fact that the tail nearly separated from the plane.” [17]
The plane continued in service for almost five years until after the crash of American Airlines Flight 587 (see below), when an examination of the flight data recorder revealed that the rudder had exceeded its design limit four times in the 1997 incident “during a rapid airspeed change accompanied by rudder inputs.” [18]
Although the Flight 903 pilot made nine rudder reversals during a high rate of speed, which subjected the plane to substantial aerodynamic forces, neither the engines nor tail fin fell off. A subsequent inspection revealed that survival of the craft may have been an engineering miracle. [19]
Between March 4 -11, 2002, the tail was physically removed from the plane and “two marks were found to be visible on the right rear attachment lug, one of six that attaches the fin to the fuselage. During ultrasound inspections, technicians [found] spots where the layers of composite material [had] separated, a condition called delamination.” The right rear lug is in the same area where the tail from Flight 587 first broke away. [20]
Replacement of the tail by American Airlines cost more than $1 million. [21]
November 12, 2001 - Aboard American Airlines Flight 587 Over Queens, New York. Taking off a few minutes behind a Japan Airlines Boeing 747, the pilots of an Airbus A300-650R carrying 251 passengers on a flight from New York City to Santo Domingo quickly experienced air turbulence resulting from a wake vortex caused by the earlier flight.
What the pilots did not know was that, when their plane had been originally delivered in 1988, layers of its plastic tail fin had separated, or delaminated, in the area where it was attached to the fuselage. The defect had been repaired by adding additional layers of plastic and rivets. American Airlines was informed by Airbus that no further inspections of the tail were required. [22]
The pilots did not know that their plane had experienced such severe high altitude air turbulence seven years earlier that 47 people were injured. Nor did they know the extent of any resulting damage was concealed within the plastic tail fin. [23]
Finally, the pilots did not know that their plane was designed with extraordinarily sensitive rudder controls that allowed the rudder to be moved beyond its design limits at low speeds by a movement of approximately one-and-one-half inches on the rudder pedal.
What we do know is that during the next few seconds, a series of right, left, right rudder commands moved the rudder beyond its design limits causing the entire plastic stabilizer to be torn from the fuselage by the force of flowing air. What we still do not know is why. The pilots were killed along

with everyone else aboard the plane and five people on the ground.

With the tail fin and both engines torn from the aircraft, the terror for those aboard, including five infants, was short-lived. The entire flight, from takeoff to impact, only lasted 103 seconds.

Following its investigation, the NTSB "determined that the probable cause of this accident was the in-flight separation of the vertical stabilizer as a result of the loads beyond ultimate design that were created by the first officer's unnecessary and excessive rudder pedal inputs." [24]

Inasmuch as the plane was climbing from takeoff through a steady-state left turn when the turbulence was encountered, there is also the possibility that the first officer either was unintentionally thrown against the rudder pedal, he was unable to exercise such delicate movement of the rudder as to avoid exceeding the limitations of its overly sensitive design, or the rudder's movements were independent of the pilot's actions.

Captain Glenn Schafer, an A300 pilot who had flown with both the pilot and first officer of AA587, stated, "Both were excellent, well-seasoned pilots. Nothing I observed while flying with either of them could possibly lead me to conclude they would even attempt to move the rudder around in the fashion the FDR [flight data recorder] says it was moved." [25]

Schafer argues that, "in a wake turbulence encounter, such as occurred in the accident scenario, a pilot would not normally make a large rudder input and then snap-reverse it at 255 knots, the speed at which the accident airplane was climbing when the tail separated." He suggested, "a simple exercise with a stopwatch to illustrate that the pilots of Flight 587 could not have moved their feet that quickly." [26]

An aircraft control engineer supports Captain Schafer by maintaining "that if the pilots caused the rudder motion, it is doubtful, in a wake turbulence encounter, that they would have achieved virtually the same rudder deflection on each swing. The rudder always stopped at 10 degrees, a pattern that could be 'explained' by the yaw damper oscillating at its mechanical limit." [27]

The only information learned from cockpit voice recorder is a series of "rattling" noises as the plane encountered wake vortices generating a lateral force equal to 0.1 the force of gravity. Then, lateral forces equal to 0.3, 0.4 and 0.3 Gs were experienced coexistent with rudder movements. [28]

Early in the investigation, then NTSB Chairperson Marion Blakey said, "We do not know [if those rudder movements] were caused by the pilots." [29]

In its submission to the NTSB, the Allied Pilots Association pointed out ten previous incidents in which A300 tail fins had been stressed beyond their design limits and stated:

> "Airbus designed and produced the A300B2-1a in 1971. Eleven years later, Airbus designed the rudder control unit in a new model called the A300B4-600. This unique design dramatically changed the handling characteristics of the airplane....
>
> "The pilots operating the accident airplane were highly-skilled, fully-qualified, proficient aviators who were never informed of the unusual limitations of their airplane." [30]

The relatively intact 27-foot-tall stabilizer was found floating in the Jamaica Bay. It was originally connected to the fuselage at six attaching points, each of which had two sets of attachment lugs, one made from plastic, the other of aluminum. They were held together by a titanium bolt. An examination revealed the metal components to be intact and the plastic lugs to be broken. [31]

The NTSB did not find any fault with the composite plastic design of the tail fin; however, it did immediately order a one-time *visual inspection* of all A300-600 and A310 tail fins within 15 days to look for "edge delaminations, cracked paint, surface distortions, other surface damage, and failure of the transverse (side) load fittings. Similarly, indications of failure of the rudder assembly, which could lead to failure of the vertical stabilizer, may be detectable with such an inspection." [32]

Ellen Connors, the former chairperson of the NTSB has stated that the report was delayed because of "inappropriate and intense lobbying by Airbus over its contents" and that "the potential for contaminating the investigation exists." [33]

Following the crash of AA587, United Airlines decided to go beyond the required visual inspection to conduct ultrasound tests on three of its A320 jets, whose plastic tail fins had also been repaired at the factory before delivery. The test found a flaw in a six-year-old A320 on the opposite side of the stabilizer from where the factory defect had been repaired. In spite of the defect, Airbus spokesman David Venz said the defect is in an area that doesn't support the weight of the tail. He said, "We are confident this airplane is fit to fly." [34]

Airbus claimed that damage that couldn't be seen cannot weaken the plastic tail fins and that visual examinations were sufficient. One official said, "Invisible damage cannot produce a significant sub-surface flaw." [35]

Unconvinced, some American Airlines pilots called for more detailed inspections, such as ultrasound to locate hidden flaws. [36]

More than 20 American Airlines pilots asked to be transferred to Boeing aircraft, "although this meant months of retraining and loss of earnings." One pilot wrote that "he had refused to let any of his family take an A300 or A310 and had paid extra to take a circuitous route on holiday purely to avoid them." [37]

Saying there was no way to adequately inspect the plastic tail fins, dozens of American Airlines pilots demanded that the company ground its fleet of Airbus A300 jets until the cause of the crash of AA587 could be determined.

More than 70 pilots signed a statement stating, "Until a definitive cause for the crash of Flight 587 can be determined, along with ways to prevent a similar occurrence, and/or a definitive test can be developed to truly check the structural integrity of the vertical stabilizers of our remaining 34 A300s, I recommend that American Airlines's fleet of A300s be grounded." [38]

Weighing in on the side of the pilots, Professor James H. Williams, Jr., of the Massachusetts Institute of Technology, School of Engineering, stated that the Airbus position regarding the adequacy of visual inspections was "lamentably naive policy. It is analogous to assessing whether a woman has breast cancer by simply looking at her family portrait." [39]

Regarding the repairs performed by Airbus on composite tails with discovered defects prior to deliver, Dr. Williams states, "Such repairs of structural damage in composites are frequently unreliable, especially for joints and attachments involving primary (load-bearing) structures. The rupture of the vertical stabilizer on Flight 587 occurred in the vicinity of repairs, adjacent to an attachment point. Therefore, the FAA must carefully establish and articulate a policy for the repair of primary composite structures." [40]

"Finally," Dr. Williams concludes, "Airbus's extensive design and testing programs for the A300-600 composite vertical stabilizer may be currently deficient if they were based on outmoded or flawed engineering assumptions or an inadequate certification process. No amount of analysis can overcome faulty assumptions or insufficient requirements." [41]

Even in the absence of an overloading or catastrophic event, Dr. Williams believes that, "When subjected to the loading histories of some aircraft, composites will lose both strength and stiffness. Furthermore, studies of the long-term effects of exposure to aircraft environments of moisture, pressure and temperature, as well as fuels, hydraulic fluids, lubricants and deicers remain to be conducted for many composite materials." [42]

His research has shown that, "repeated journeys to and from the sub-zero temperatures found at cruising altitude causes a build-up of condensation inside composites, and separation of the carbon fibre layers as this moisture freezes and thaws." Dr. Williams says it is "like a pothole in a roadway in winter, over time these gaps may grow." [43]

January 2002 - Federal Express Flight. A pilot flying an Airbus A-300 freighter "complained about strange 'uncommanded inputs' – rudder movements which the plane was making without his moving his control pedals. In FedEx's own test on the rudder on the ground, engineers claimed its 'actuators' – the hydraulic system which causes the rudder to move – tore a large hole around its hinges…." [44]

The mechanics "found that hydraulic fluid had caused some of the composite material in the plane's rudder to 'disbond,' or come apart." [45]

The mechanics also "found bent and broken rudder control system components, as well as associated disbonding of the composite tailfin." The mechanics "unearthed a synchronization issue, wherein hydraulic pressure pulses from different sources can get out of phase." The resulting "oscillation was felt as a sustained vibration, and then a loud bang was heard." [46]

The rudder assembly "may represent a telltale of "yaw oscillation." NTSB investigators immediately focused on the implications of the damaged/broken rudder control components found on the FedEx airplane and their possible relevance to the AA587 crash. "It appears that the system damaged the rudder. 'That is not supposed to happen; the system should break out first,' states an NTSB official." [47]

March 2005 - Aboard Air Transat Flight 961 Over the Caribbean Sea. On March 6, 2005, an Airbus A310-300 with 262 passengers was cruising at 35,000 feet when the "flight crew heard a loud bang followed by vibrations that lasted a few seconds. The aircraft entered a repetitive rolling motion, known as a Dutch roll, which decreased as the aircraft descended to a lower altitude." [48] The crew was able to turn the plane around and return to Varadero, Cuba, where they carried out an uneventful landing. Upon arrival, it was discovered that the aircraft rudder had been torn off the plane, except for its "bottom closing rib and the length of spar between the rib and the hydraulic actuators." [49]

"An examination of the vertical tail fin of the aircraft, to which the rudder is attached, determined that the two rearmost fin attachment lugs were delaminated, likely the result of stresses that existed during the rudder separation." [50]

In its report about the occurrence, The Transportation Safety Board of Canada (TSB) observed, "At the time of this occurrence, composite materials in general were from a maintenance perspective, believed to have a no damage growth design philosophy. It was also believed that from a fatigue point of view, more frequent inspections of composite materials would not prove to be more effective." [51]

The TSB report recommended:

> "The separation of the rudder from Air Transat Flight 961 and the damage found during the post-occurrence fleet inspections suggest that the current inspection program for Airbus composite rudders may not be adequate to provide for the timely detection of defects. In addition, the recent discovery that disbonds could grow undetected and the increasing age of the composite rudders suggest that increased attention is warranted to mitigate the risk of additional rudder structural failures. The consequences of a rudder separation include reduced directional control and possible separation of the vertical tail plane." [52]

TSB further recommended that "a detailed inspection of the drainage path of the rudder for blockage be added to the current inspection program to insure that there is adequate drainage." [53]

On March 27, 2006, TSB reported that the required inspections "found examples of disbonds, damage around hoisting points and trailing edge fasteners of the rudder, corrosion and abrasion at hinges, seized hinges, hinges with excessive free play, water ingress, and hydraulic fluid ingress." [54]

TSB commenced "work with the National Research of Canada to identify suitable inspection techniques that will detect failures in composite materials." [55]

November 27, 2005 - Aboard Federal Express Flight. During routine maintenance, the rudder on an Airbus A300-600 was accidently damaged. To access the extent of damage, "the rudder was shipped to the manufacturer's facility and examined. In addition to the damage that occurred during maintenance, the examination found a substantial area of disbonding between the inner skin of the composite rudder surface and the honeycomb core, which is located between two composite skins. [56]

Further examination "of the disbonded area revealed traces of hydraulic fluid. Hydraulic fluid contamination between the honeycomb skin and the fiberglass composite skin can lead to progressive disbonding, which compromises the strength of the rudder. Tests on the damaged

rudder also revealed that disbonding damage could spread during the flight.” [57]
The NTSB determined that existing “tap tests” on the external surfaces of the rudder were unlikely to disclose “the disbonding of an internal surface.” The NTSB recommended a more stringent compliance time for inspections and requested that the FAA make the inspections mandatory. [58]
In December 2007, the European Aviation Safety Agency ordered frequent and extensive testing on the composite rudders of the Airbus A300/310 series due to safety concerns. Only about 20 wide-body A330 and A340 planes were included in the order, which did not include any of the A320 series. The tests had to be completed with six months, and certain airplanes had to be retested every 1,400 flights. [59]
The rudders of approximately 420 older Airbuses “are being subjected to repetitive ultrasonic and other enhanced inspections, the first time airlines and safety regulators have resorted to such recurring, high-tech procedures to determine the integrity of composite parts on airliners already in service” [60]
It is not known whether the inspection order applied to the A330 operated by Air France Flight 447 (see below), or if the aircraft was ever tested.
The order represents a vindication of the American Airlines pilots, who had called for such inspections five years earlier and for Dr. Williams, who had supported their efforts.
The order also represented a repudiation of Airbus’ maintenance standards that “simple visual inspections, combined with a mechanic’s manually tapping on the surface of the composite rudders, were adequate to detect any potentially hazardous internal flaws or structural weaknesses.” [61]
November 18, 2008 - Aboard XL Airways (Air New Zealand) Flight 888T Over Mediterranean Sea Off the French Coast. Two German XL Airways pilots, accompanied by five representatives of Air New Zealand and a member of the Civil Aviation Authority of New Zealand, were operating an A320 in a test flight.
The aircraft had been leased by Air New Zealand to XL Airways and had been serviced and repainted in preparation for a return to Air New Zealand service.
The aircraft disintegrated when it crashed into the water and its tail fin was found floating at the crash site. The flight recorders were recovered, along with several of the bodies.
The cause of the crash is still under investigation by French, German, New Zealand and U.S. regulators; however, the interim findings are that the “crew lost control of the aircraft. While conducting an incompletely-planned test of low-speed flight at low altitude, the aircraft was descending through 3,000 feet on full autopilot for a go-around. Landing gear was just extended when … the speed dropped from 136 to 99 knots in 35 seconds.” [62]
“The stall warning sounded four times during *violent maneuvering to regain control*…. the warning had silenced as the aircraft regained speed in a rapid descent, but six seconds later, at 263 knots, the aircraft had only 340 feet elevation and was 14 degrees nose down. A second later it was in the water.” [63]
For now, it is not known if the floating plastic tail fin or its rudder may have been complicit in the crash.
Airbus has now delivered 3,893 A320s, which have now been involved in 10 fatal accidents, killing 565 people, and at least one famous nonfatal crash – that of US Airways Flight 1549 in the Hudson River on January 15, 2009.
May 31, 2009 - Aboard Air France Flight 447 Over the Atlantic Ocean 400 Miles Off the Coast of Brazil
Two of three pilots aboard an Airbus A330 were monitoring the autopilot controls on a flight carrying 216 passengers from Rio de Janeiro as it cruised at 550 mph at an altitude of 35,000 feet. It was just before midnight and the captain may have been asleep in preparation to landing the plane in Paris the next morning.
The pilot reported that the plane was flying through a towering thunderstorm containing black, electrically charged clouds confirmed by satellite data to be charging upwards to 41,000 feet at 100 mph.

Due to the frequency of equatorial storms in the area, it is likely that the flight crew *and* Air France management were aware of the impending storm before it was encountered, and a decision was made to fly through the storm, rather than to turn back or to navigate around it.

Ten minutes later, the autopilot switched off and a four-minute series of automatic failure and warning messages from the plane's Aircraft Communication Addressing and Reporting System were relayed by satellite to Air France headquarters.

It is difficult to imagine the scene within the cockpit of the plane being thrown about by a raging hail storm in the middle of the night, but the automatic messages provide some clues.

With the autopilot disengaged, the pilots had to manually contend with an ever-escalating series of failures in the flight control systems. All of this had to be done with alarms sounding, in absolute darkness, with no natural horizon to observe and with aerodynamic forces erasing all sense of up or down. The pilots were entirely dependent upon the plane's instruments and the sensors that provided electronic data.

Then, there was a cascading series of failures within the flight control computer and systems to monitor air speed, altitude and direction.

The pilots were flying blind.

The wing spoilers failed, the rudder limiter became inoperative and the rudder may have locked into place. At this point, it is likely that the plastic stabilizer was ripped from the plane. [64]

There is little or no likelihood that we will ever know whether the tail fin was blown off by the storm, as a result of the pilot's attempt to control the plane, or by uncontrolled movements of the rudder.

What then happened, aerodynamically, is that without the vertical stabilizer and engine control, the airplane was like a giant Frisbee spinning through the storm until it fell apart.

The last automatic message confirmed a complete electrical failure and a loss of cabin pressure, as the plane plunged down almost seven miles in less than a minute to the ocean surface. We can try to imagine the scene on the flight deck and in the passenger compartment; however, we cannot possibly feel the terror experienced by everyone aboard, including seven children and one baby.

During the long 14 minutes, as the pilots fought to control the aircraft, everything trusted by those who boarded the aircraft failed – catastrophically. In addition to their terror, they must have felt terribly betrayed.

To date, several large pieces of the aircraft fuselage, and the virtually intact vertical stabilizer, have been recovered from the ocean. All indications are that the plane broke up in midair. There is no evidence of fire.

50 bodies have been recovered, and almost all had multiple fractures, but no burns. Water was not found in the lungs of any victims. They were spread up to 53 miles apart, further confirming that the plane undoubtedly broke apart at high altitude.

A concentrated, multi-national effort, including nuclear submarines, is being made to locate the flight data and voice recorders from ocean depths of more than 15,000 feet and very rugged underwater terrain, before the attached "pingers" become silent after approximately 30 days.

There are early indications that speed sensors may have iced up in the storm and provided inconsistent speed readings, which may have initially caused the cascading failures of flight control systems aboard the plane. We may never know for sure exactly what initiated the collapse of systems unless the "black boxes" are found, which is increasingly unlikely with each passing day.

All we know for sure is that the plastic tail fin separated from the fuselage under conditions that should have been expected to occur at some time during the life of the airplane.

Would metal stabilizers, rudders and couplers have failed under the same or similar circumstances? They never have.

What Are the Lessons Learned and What Questions Do They Give Rise To?

At the cost of 500 lives and millions of dollars in lost aircraft, what can be learned from the crash of Air France Flight 447 and the series of emergency incidents and other similar airplane crashes that led up to it?

Is Composite Structural Design and Manufacturing Technology Sufficiently Mature To Be

Used in Critical Structures on Passenger Aircraft? In cooperation with NASA's Aircraft Energy Efficiency (ACEE) Program to improve the fuel economy of commercial aircraft, Boeing commenced an experimental carbon/epoxy flight service program in the early 1970s and included a limited number of experimental elevators on 727s and horizontal stabilizers and spoilers on 737s. [65]

"The experience gained from the ACEE programs provided the confidence needed by Boeing to select CFRP [carbon fiber reinforced polymer] for the Boeing 757, 767 and 737-300 control surfaces in the late 1970's" [66]

Although some Boeing 737s have experienced rudder problems, including two fatal crashes; none involved aircraft with plastic stabilizers. Rather, the problem with unexpected rudder movements was traced to a faulty hydraulic servo valve, and the metal tail fins did not separate from the fuselage during flight. [67]

While Boeing was still experimenting with the use of composite materials in commercial aircraft, Airbus began to extensively install plastic materials in the construction of its first A300 series as early as 1974, introduced a composite tail fin box in its A310 series in 1978, and began delivery of the A320 series with an all composite tail fin in 1988. [68]

NASA's efforts to explore the effective use of composites in aircraft design and manufacture in the U.S. was transparent, papers were presented, and information and experience was openly shared. European research and experience in the design and use of composites was more closely held, and it is less clear what kind of foundation work Airbus did in developing its use of composites. [69]

In 2001, NASA assessed the state-of-the-art in the design and manufacturing of large composite structures in a paper by Charles E. Harris and Mark J. Shuart, which concluded that:

> "Composite structural design and manufacturing technology is not yet fully mature for all applications. There are 3 key factors that contribute to the lack of maturity of the design and manufacturing technology. These factors are the *lack of a full understanding of damage mechanisms and structural failure modes*, the inability to reliably predict the cost of developing composite structures, and the high costs of fabricating composite structure relative to convention aluminum structure. While the technology required to overcome these uncertainties is under development, *these factors are barriers to expanding the application of composites to heavy loaded, primary structure*." (emphasis added) [70]

Mr. Shuart states that "all of us (at NASA) are proponents of the *effective* use of composites in aerospace," and that the Boeing research and testing experience "makes us feel good." He believes "in the right material for the right application," and the main "question is how do you design and meet loads?" [71]

According to Mr. Shuart, there are places where it may be inappropriate to use composite materials instead of metal such as where there is a "banging around" or "excessive wear," as in joints, hinges, or bearings. [72]

Mr. Shuart believes it may be useful and prudent to do a "hard scrub," or thorough review, of the design loads used by Airbus in the design of critical structures in its aircraft. He is of the opinion that "failures are more likely a design, rather than a composite problem." [73]

Regarding Airbus' use of composites in rudders, couplers and vertical stabilizers, Mr. Shuart said, "What you're asking is a good question." [74]

In the Use of Composite Materials, Should Aircraft Designers Anticipate the Unexpected in Recognizing That Composite Materials Used in All Critical Structures Will Experience Extreme Stress At Some Point? As we have seen, a variety of causes have been found in the various emergency in-flight incidents and crashes involving the damage or loss of composite rudders and tail fins on Airbus aircraft.

In the case of American Airlines Flight 587, the primary cause was attributed to pilot error in the "unnecessary and excessive rudder pedal inputs" that caused the rudder to move beyond "design limitations" and cause the plastic tail fin to be broken off the airplane. However, it must be expected that, at some time during the lifetime of an aircraft that a pilot may accidently push a little too hard on the rudder or that the rudder actuator mechanisms may fail.

If the expectation is that the composite tail fin may be torn off when that happens, then perhaps composites should not be used in that structure. Although aluminum vertical stabilizers may be heavier and accordingly provide less fuel economy, the fact is that there is no history of metal tail fins being torn from fuselages in commercial passenger aircraft in the past half century. This is true even though there has been a history of rudder problems, which necessarily caused the same stress on metal stabilizers as was caused to the composite tail of AA587.

While the crash of Air France Flight 447 is still under investigation, a variety of likely suspects, including lightning, severe thunderstorm, and clogged speed sensors are being advanced as possible causes. However, passenger airplanes have been flying through storms for the past 50 years and there is no history of metal vertical stabilizers being torn off.

In fact, the National Oceanic and Atmospheric Administration makes a practice of flying through the most severe hurricanes to collect forecast data using ordinary Gulfsteam and Orion turboprop aircraft. There is no history of any of them being blown apart.

Critical structures on aircraft, particularly those intended to carry passengers, cannot be constructed of materials that fail to anticipate that they will be exposed to extreme stress at some point during their lifetime. It is true that, ultimately, all materials can be made to fail, why should passenger’s lives be included in the equation or the experiment to determine the breaking point?

Should the Use of Composite Materials Be Prohibited in Critical Structures in Commercial Passenger Aircraft? The use of composite materials in commercial aircraft is for one reason only – to save operating costs. The bottom line in this discussion is not how much money can be saved by composites. The true bottom line is the physical fact that composites fracture when they reach their limit, while metal usually bends before breaking.

Boeing and Airbus are the only two viable commercial manufacturing companies designing and delivering passenger aircraft, and they are competing in every market and with every product line. They are in a race to develop the least heavy aircraft to carry the greatest weight the greatest distance for the least amount of fuel possible.

If the Federal Aviation Administration and the National Transportation Safety Board should decide that, until such time as the composite structural design and manufacturing technology becomes sufficiently mature for all applications, composite materials could be prohibited for a common set of structures, including those most critical to flight operations.

That way, the playing field will be equal, and competition will still favor innovation in all other areas.

Should Commercial Passenger Aircraft Using Composite Materials in Critical Structures Be Regularly Inspected by Technology That Reaches Below the Surface to Identify Hidden Defects? The experience of the Federal Express rudder (see above) illustrates completely why ultrasound and other technologically advanced devices that can look below the surface are essential to the prevention of catastrophic crashes.

The rudder was taken out of service because of visible damage, and upon ultrasound inspection was found to have internal disbonding damage that could spread further during flight. Fortunately, we will never know if or when the rudder would have failed, or if its failure would have brought down the aircraft.

The current European Aviation Safety Agency ordered testing on Airbus composite rudders only applies to the A300/310 series, with only about 20 wide-body A330 and A340 planes included in the order.

The order does not include any of the almost 4,000 A320 series aircraft or the remaining A330, A340 or the new A380 aircraft. Nor does it include the composite vertical stabilizers, or any composite couplers used to connect these structures.

Consideration should also be given to including Boeing aircraft, such as the 777 that operates with a composite tail fin, in the inspection order.

Other than for the time and expense of conducting the test, it is far more likely that opposition from manufacturers and operators *will* be based on the fear that internal defects will be found and that replacement could cost up to a million dollars per plane. What value can be placed upon a baby's life, or the life of any passenger?

Should All Aircraft Manufactured with Composite Materials in Critical Structures Be Grounded Until They Can Be Inspected For Hidden Defects? The most deadly crash in U.S. aviation history occurred on May 25, 1979 when an American Airlines DC10 crashed on takeoff from Chicago's O'Hare Airport, as a wing pylon failed and an engine fell off. All 273 people aboard were killed. The entire DC10 fleet was immediately grounded until it could be determined that the pylon bolts were at fault. [75]

Following the fatal crashes of several Comet airliners in the 1950s, with a total loss of less than 200 lives, the entire fleet was grounded by English Prime Minister, Winston Churchill. He said "The cost of solving the Comet mystery must be reckoned neither in money nor in manpower."

The Airbus is not manufactured in the United States; however, they are being operated by a number of American carriers and U.S. citizens fly on them every day all over the world.

Under the Bush administration, the last FAA administrator, Marion Blakey, "was a fervent free marketeer and opponent of increased government regulation." [76]

President Obama appointed Randy Babbitt to administer the agency, and he was confirmed last month by the Senate. Mr. Babbitt is the former head of the Airline Pilot's Association. What will he decide?

William John Cox *is the author of You're Not Stupid! Get the Truth: A Brief on the Bush Presidency, and he is currently working on a fact-based fictional political philosophy. His writings are collected at http://www.thevoters.org, and he can be contacted at u2cox@msn.com.*

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