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From the Airbus to the Spaceplane: The Future of Commercial Aviation

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As commercial aviation becomes increasingly dependent upon computerized digital technology and less reliant upon hands-on human control, we have to consider the crash of Air France Flight 447 into the Atlantic Ocean, with the loss of all aboard, and other similar disasters in the light of our collective experience and expectations.

The Comet

First flown in 1949 and introduced into passenger service in1951, the Comet was the first pressurized, jet-propelled commercial aircraft. Powered by four "Ghost" turbojet engines, the Comet was found to be fuel efficient above 30,000 feet and flew at almost 500 miles per hour, far faster than the most advanced piston-powered airplanes in service at the time.

England's de Havilland Company rapidly gained a significant advantage in the commercial aircraft market, carrying more than 30,000 passengers and receiving orders for 30 Comets in the first year; however, serious problems with the innovative design quickly developed. Two crashes in the first year in Italy and Pakistan were likely caused by a defective wing profile design that resulted in a loss of lift during steep takeoffs.

A series of catastrophic crashes followed. In 1953, structural failure of the airframe beginning with the stabilizer caused a Comet to crash shortly after takeoff in India. The Comet was equipped with fully powered flight controls that were criticized because they resulted in a loss of "feel" and may have caused excessive stress on the flight control surfaces. Later in 1953, another Comet exploded in midair during a storm over India with the loss of all passengers and crew. The following year, in 1954, two more Comets experienced midair explosive decompression and fell into the Mediterranean killing everyone aboard.

Prime Minister Winston Churchill grounded the fleet saying, "The cost of solving the Comet mystery must be reckoned neither in money nor in manpower." The Comet airframes were subjected to extensive testing that ultimately identified the most likely cause to be metal fatigue caused by stress and strain on the aircraft skin caused by repeated cycles of pressurization.

The first series of Comets were scrapped and modifications were made to the second series; however, the fleet remained grounded until the fourth series was introduced in 1958. Although the plane became the first jet used for transatlantic service, de Havilland had already lost its competitive advantage to Boeing, Douglas and other U.S. manufacturers, who profited from the Comet experience. The last Comet was delivered in 1964, and even the government-owned British Overseas Airways Corporation began to fly American aircraft.

The Airbus

Commencing in the mid-1960, a consortium of European aircraft firms began to collaborate in an attempt to break the lock held by American manufacturers on the commercial aircraft market by agreeing to collectively manufacture a low-cost "airbus" to transport smaller numbers of passengers over shorter distances. Underwritten by the governments of England, France and Germany, the Airbus was intended to be the first mass-produced "fly-by-wire" (FBW) airliner.

Although pilot control of commercial aircraft had progressed beyond the direct use of cables and pulleys to move aircraft control surfaces by relying on hydraulics and electrical assistance, the introduction of electronic control of commercial aircraft increasingly shifted responsibility from human pilots to computers.

First developed by NASA to augment control of the space shuttle and high-performance military combat planes, FBW technology is similar in some respects to the anti-lock braking systems (ABS) on modern motor vehicles that prevents wheels from locking when the brakes are applied and which automatically controls the allocation of braking between the front and rear brakes. Relying upon sensors on each wheel, the hydraulic pressure to each can be increased or decreased up to 20 times per second, far beyond the abilities of any human driver. However, under conditions other than smooth dry pavements, such as deep snow and gravel, ABS can be far less effective than an experienced operator. Additionally, drivers of ABS equipped vehicles tend to overcome the safety benefit by driving more aggressively.

Airplanes that are flown by "wire" still have a stick, rudders, throttles and brake pedals; however, these controls are only connected to sensors that provide "input" to computers that pass along the information to other computers located at or near the control surfaces, engines or wheels to actuate the desired mechanical response. A software program takes the pilot's input into consideration; however, it is the computer that controls the aircraft. Relying upon the entire range of sensors, the computer can make as many as 40 adjustments per second.

FBW control over the aircraft presents a new set of problems that can have an effect on aircraft safety. Since the pilot can no longer "feel" the control surface response through the mechanical system, there is a risk that the surfaces can be over stressed due to excessive movement, or that the computer may erroneously decide that the pilot is wrong and that it knows best what is better for flight safety.

Aircraft designers decide the limits of the planes' performance and program the computers to prevent the pilots from exceeding these limits. The Airbus is designed with very hard limits, while Boeing takes a softer approach. According to the Seattle Post-Intelligencer, John Cashman, Boeing's director of flight-crew operations, said, "It's not a lack of trust in technology. We certainly don't have the feeling that we do not want to rely on technology. But the pilot in control of the aircraft should have the ultimate authority." Cashman also believes that hard limits reduce a plane's absolute capability. For example a Boeing 747 tumbled out of control over the Pacific Ocean in 1985 and the pilots were able to recover by subjecting the plane to four times the force of gravity. The stress caused by emergency maneuvering of an Airbus is limited to 2.5 times the force of gravity.

Both Boeing and Airbus depend upon FBW technology in aircraft design; however, there are fundamental differences. Basically, a pilot can override the computer in a Boeing aircraft, while Airbus pilots are not allowed to second guess the flight control computer. Boeing pilots also receive greater visual feedback from control surfaces by relying upon a conventional control yoke, while Airbus pilots use a small joystick.

A Boeing pilot can turn the airplane upside down, release the controls and the plane will right itself. If an Airbus pilot wants to lose lift and stall to avoid a midair crash and the computer decides that acceleration and a climb is better, the pilot simply hangs on for the ride. Only if all electronic systems fail does the Airbus default into a "manual backup" mode allowing limited use of basic mechanical systems while the pilots attempt to determine the cause of the electrical and computer failure.

Although airplanes equipped with FBW systems are reportedly easier to fly, the very efficiency can conceal defects that might be otherwise discovered by hands-on mechanical operations and may allow a plane to be operated under conditions where a human operator would fail.

The accident rates for Boeing and Airbus are similar: however, there have been some unusual Airbus accidents apparently caused by computer malfunctions. One of the first occurred in 1988 shortly after the Airbus was placed in service. During a flyover at a French air show, the computer assumed that the plane was supposed to land since it was close to the ground and the landing gear was down. Although the pilot attempted to accelerate and climb, the computer ignored his input and landed the plane in an adjacent forest killing three passengers. Airbus attempted to blame the accident on pilot error.

Another incongruous accident more recently occurred during the testing of a brand new 472-passenger Airbus A-340-600 being delivered to Etihad Airlines in 2007 at the Toulouse airport. As the flight crew ramped up the four engines to takeoff power with the brakes on, a takeoff warning horn sounded because the computer sensed that the plane was not properly configured for takeoff. When the crew silenced the alarm, the computer apparently decided the plane was flying and trying to land with its brakes on. The computer released the brakes and the plane accelerated into a crash barrier at full power.

The spectacular televised landing of a JetBlue Airbus at the Los Angeles airport in 2005 with its nosewheel locked in place crosswise to the fuselage brought to light at least 67 earlier "nosewheel failures" on a variety of Airbus aircraft that were usually repaired by the replacement or "reprogramming" of the Brake Steering Control Unit computer.

A rudder design implemented by Airbus in 1988 increased the sensitivity of actual rudder movement to the pilot's movement of the pedals by slightly more than one inch and allowed for a wider degree of rudder travel per pound of force on the pedal. Rudder movement is necessarily restricted at cruising speeds; however, the Airbus computer did not impose a limit at lower speeds, such as during takeoff.

These rudder changes contributed to the crash of American Airlines Flight 587 on November 12, 2001 shortly after takeoff from Kennedy Airport in New York City when the aircraft encountered wake vortices from the preceding aircraft. As the copilot attempted to maintain the Airbus' steady-state left turn, he sought to correct an unexpected, vortex-caused "overbank" by using the rudder attached to the back of the tail fin. The copilot commanded rapid left-right rudder movements that exceeded the design loads of the vertical stabilizer, and the computer was not programmed to limit the command at low speeds. The all-composite stabilizer was ripped from the fuselage and the aircraft became uncontrollable. Its crash killed nine crew members, 251 passengers and five people on the ground. The relatively intact tail fin was found floating in the waters of Jamaica Bay.

Although several catastrophic Airbus crashes into the ocean with major loss of life have been blamed on pilot error, including the 2000 losses of Kenya Airways Flight 431 and Gulf Air Flight 072, the crash of an Airbus belonging to Air New Zealand on November 27, 2008 into the Mediterranean Sea has raised new questions about Airbus safety. Seven crew members engaged in a test maintenance flight died in the crash, and the tail section was found floating where the plane went down. No official cause for the accident has been reported.

One month previously, an accident aboard Qantas Flight 72 on October 7, 2008 that injured 106 of the 313 passengers was apparently caused by a malfunction of the FBW system. While traveling at 37,000 feet, the computer reported an autopilot irregularity and trouble with the inertial reference system.

After the Airbus A330-300's autopilot was disengaged, the computer caused the aircraft to suddenly pitch down and rapidly descend 650 feet in 20 seconds before the pilots could regain control. Three minutes later, the computer again caused the plane to pitch down and descend 400 feet in 16 seconds. The crew declared a Mayday and made an emergency landing at the Learmonth airport.

Preliminarily, the "likely origin of the event" has been blamed on the failure of an Air Data Inertial Reference Unit that supplied incorrect data to other aircraft systems. The Unit may have falsely reported that the airplane angle of attack was very high resulting in the flight control computers commanding the nose-down movements, or the computer may have believed that the plane was going too slow and put it into a dive to increase speed.

On June 1, 2009, Air France Flight 447 operating an Airbus A330 carrying 216 passengers from Rio de Janeiro to Paris was four hours into its flight and was cruising at an altitude of 35,000 feet in excess of 500 mph as it approached an area of thunderstorms that extended upwards to 41,000 feet. Over a four-minute period, Air France received a series of automatic failure and warning messages from the Airbus's Aircraft Communication Addressing and Reporting System, relayed by satellite, indicating there were serious problems aboard the aircraft. The autopilot was disengaged, the electrical and pressurization systems had broken down and the plane's control system was receiving contradictory information about its airspeed.

The final message reported faults with its Air Data Inertial Reference Unit that, among other things, provides speed warnings. In addition, as a result of earlier incidences involving a loss of airspeed data during the cruise phase of Air France A340s and A330 and recent tests, it had been determined that icing of the external speed monitors known as "Pitot tubes" could be a factor in a loss of data. Although Airbus had issued a recommendation in September 2007 to replace the tubes, replacement was not viewed as a

mandatory safety concern. Air France did not commence the replacement of the airspeed indicators with an improved Pitot tube in its fleet of A330s until April 27, 2009. The airline had not gotten around to the aircraft operated by Flight 447 on June 1, 2009.

Irrespective of the cause of the "inconsistency in measured air speeds," the inability of the flight control computers to accurately calculate speed while flying at a high altitude could have caused the disaster. If it was falsely believed that the airplane was going too fast, particularly if the plane had already been slowed down to enter the thunderstorm, the plane could have easily stalled and a recovery in a storm would have been difficult or impossible. Or, if it was falsely believed that the speed was too slow and a stall was imminent, an unnecessary increase in speed could have taken the plane beyond its design capacity.

The plane’s tail fin was found floating in the ocean near where the last transmissions occurred indicating that the aircraft broke up in midair. Otherwise, the plane would have been torn into small pieces and sunk immediately when it struck the ocean surface. In addition, 41 bodies have been recovered thus far from the ocean surface, some of which were separated by 53 miles, also indicating a midair disintegration of the aircraft.

The fact that the stabilizer was relatively intact also provides similarities to the crashes of American Airlines Flight 587 in 2001 and the Air New Zealand crash last year. Although the Airbus A330 is equipped with a “rudder limiter” to restrict the movement of the rudder at high speeds, a failure of the computerized control system and disengagement of the autopilot might have allowed the rudder to exceed its limitations, particularly if the plane erroneously exceeded its design speed in the high turbulence of a thunderstorm.

Aided by a French nuclear submarine, the search for the plane’s flight data and cockpit voice recorders continues, even though such recorders have never been recovered from ocean depths as deep as 12,000 feet where Flight 447 crashed.

Unless the “black boxes” are recovered, we may never know if the crash resulted from a failure of the computerized flight control system, including its sensors, or if the system was unable to assist the human pilots cope with an emergency, such as the catastrophic loss of the stabilizer.

As the world waits, Airbus continues to deliver more and more aircraft each year. It has more than 5,000 planes flying, including its new A380, the largest passenger plane in history. First flown commercially on October 25, 2007, and depending upon its seating configuration, the A380 can carry between 555 and 853 passengers on two decks.

The A380 has 330 miles of electrical wiring involving 100,000 separate wires and 40,300 connectors. Cockpit instrumentation has been simplified and made easier to use, and a new Network Systems Server is the file cabinet for a paperless cockpit that does away with paper manuals and charts. The entire electrical power system is computerized and many electrical components have been replaced by solid-state devices.

As we move into the future of commercial aviation, pilots may find themselves increasingly supplanted by computers and ultimately replaced in the cockpit. The military is increasingly launching aircraft without onboard pilots and the day may come when the “welcome aboard” message from the captain is relayed by satellite.

The Spaceplane

The world caught a glimpse of the future as the United States and the former USSR competed to produce the first aircraft capable of orbiting the Earth and landing on runways. Ultimately, the U.S. was able to launch the Space Shuttle, while Russia emerged as the heavy-lift rocket champion. The Shuttle will be grounded next year, and the West will be dependent upon Russian rockets to service the International Space Station.

The Dyna-Soar X-20. Almost forgotten in the race for space is the Dyna-Soar ("Dynamic Soarer") X-20 project originated during the Eisenhower administration as a demonstration of the President's commitment to the demilitarization of space. Originally envisioned as a winged craft launched into orbit by a large rocket, the program was ultimately cancelled during the Kennedy administration by Secretary of Defense McNamara in favor of the ICBM and Apollo programs.

The Air Force wanted a spaceplane to perform a variety of missions, including the maintenance of U.S. satellites and the destruction of U.S.S.R. satellites. In addition, the Air Force imagined the spaceplane could be used as a nuclear-armed bomber subject to recall. Ultimately, the Nixon administration pressured the Air Force to give up the X-20 and its progeny in favor of the space shuttle program.

The X-30. The spaceplane idea was resurrected during the Reagan administration as a project of the Defense Advanced Research Projects Agency (DARPA) between 1982 and 1985. The program called for a supersonic combustion ramjet (scramjet) aircraft that could achieve Mach 8 speeds. The administration encouraged competition between the major defense contractors to produce a hypersonic, air-breathing Single State to Orbit (SSTO) aircraft known as the X-30.

President Reagan was relying on the X-30 project when, during his 1986 State of the Union address, he called for "a new Orient Express that could, by the end of the next decade, take off from Dulles Airport, accelerate up to 25 times the speed of sound, attaining low earth orbit or flying to Tokyo within two hours." The X-30 program remained under development until 1993, when it was cancelled by the Clinton administration for both technical and budgetary reasons. The program was probably a secret part of the government's Space Defense Initiative and lost favor as its development proved too complicated.

Aerodynamically, the X-30 was a "waverider" that achieved compression lift under a fuselage that looked much like a surfboard with small tail fins. The design relied upon low weight, high temperature surface materials to deal with the heating problems, and was to be equipped with scramjet engines that compressed and heated hypersonic air in a combustion chamber, where it ignited liquid hydrogen and produced thrust.

Details of the X-30 remain classified; however U.S. interest in spaceplane transport of both passengers and freight continues. There are several basic problems that have to be overcome, including the need for wings to provide lift for takeoff and landings, which become a heating and stability problem during reentry. Moreover, jet engines can be used during takeoff and landing when atmospheric oxygen is available; however, an onboard oxidizer is required to fuel rockets in space.

One solution is a two-stage operation combining a large jet-powered lifting body to transport and launch a smaller rocket-powered craft from high altitudes. A single-stage solution combines a turbojet to reach supersonic speed (Mach 1), a ramjet to attain hypersonic speed (Mach 4), a scramjet to achieve Mach 15, and a rocket to achieve escape velocity (Mach 25) and to perform space operations, and adapted for use in the current generation of commercial aircraft.

The X-43. Following cancellation of the X-30, NASA developed a B-52 launched and rocket-accelerated aircraft known as the X-43 to test hypersonic flight and scramjet engines. The aircraft was disposable and was designed to crash into the ocean after flight testing. It was successfully flown several times and set a speed record of 7,546 mph (Mach 9.68) in 2004. The X-43 program was indefinitely suspended in 2004 and replaced by an experimental program operated by the U.S. military.

The X-51. The Air Force Research Laboratory, in cooperation with DARPA, created a scramjet program in 2003, and awarded contracts in 2004 to the Boeing Phantom Works to construct the airframe and to Pratt & Whitney Rocketdyne to construct the engines for a demonstration flight test vehicle designated as the X-51.

The scramjet engine was tested in 2006, and test flights of the airframe from a B-52 at 50,000 feet are tentatively planned for late 2009. The plane will be accelerated by a solid fuel rocket to Mach 4.5, whereupon the scramjet engine will engage and take the plane up to 80,000 feet and Mach 6.

The HTV-3X Blackswift. In association with the X-51 program, DARPA contracted with Lockheed Martin's Skunk Works to build a replacement to the famed SR-71 Blackbird spy plane, which had used gigantic turbojets that morphed into ramjets at speeds in excess of Mach 3. Designated as the HTV-3X and commonly known as the Blackswift, the unmanned plane was to be powered by a turbojet to Mach 3 and then by a ramjet to Mach 6.

The secret program was publicly revealed in March 2008 when DARPA called for bids to manufacture a prototype. The proposed robotic hyperplane had to be reusable, able to take off and land on ordinary runways, and be capable of performing a barrel roll. The program was suddenly cancelled in October 2008.

The Orion Crew Exploration Vehicle (CEV). The U.S. plans to replace the space shuttle with a wingless conical spacecraft launched by the same solid rocket booster and upper stage main engine used to lift the current space shuttle into orbit. The CEV is designed to accommodate six astronauts and to carry a payload of up to 25 metric tons. The vehicles are intended to be reusable for up to ten flights and to be capable of parachuting down over water or land. NASA originally planed to launch the first CEV in 2011; however, the contract was modified in 2007 to extend the period of performance to 2013.

With the last space shuttle flight currently scheduled for September 16, 2010, the U.S. has resurrected the idea of rocket-boosted spaceplanes to transport satellites into orbit and astronauts to the International Space Station. In doing so, it will be building upon the computerized flight control systems originally developed during the X programs.

Russia. The Soviet Union reportedly worked on a spaceplane called the Uragan in the 1980s; however, it was apparently cancelled along with the Soviet's Buran space shuttle. Now, with Russia's emergence as the go-to rocket heavy lifter, it has been hard at work to develop a six-person wingless spaceplane known as the "Clipper," or "Kliper" to replace its aging Soyuz capsule.

In 2006, the European Space Agency (ESA) reached an agreement with Russia to cooperate in the design of the Clipper allowing European astronauts to fly to the International Space Station and perhaps to the Moon. Japan also expressed an interest in participating in the program.

As a part of the collaboration, ESA's Guiana Space Center in French Guiana is being modified to accommodate Russia's Soyuz rocket for the launching of satellites, with manned missions to be flown from Russia's Cosmodrome in Kazakhstan.

Russia completed the design of its Kliper spaceplane in 2006 and announced plans to place it into operation by 2015. It is designed to be operated by two crew members and to transport as many as four passengers, including space tourists to orbit, and ultimately to the Moon.

Japan. A report submitted to Japan's Space Activities Commission in 2000 proposed the development of a space plane using reusable rockets for space tourism and outer space energy production in association with Japan's deployment of its Hope-X space shuttle.

In late 2002, Japan's National Space Development Agency and the National Aerospace Laboratory of Japan flew a robotic test model of the space shuttle to an altitude of 8,200 feet and achieved a speed of 212 mph, before landing on a runway.

In fulfillment of Japan's 20-year dream to achieve a presence in outer space, the U.S. space shuttle Discovery delivered the nation's Exposed Facility and Experiment Logistics Module to the International Space Station in May 2008.

Mitsubishi Heavy Industries, Ltd. has designed a single-stage-to-orbit spaceplane using scramjet engines to lift a crew of 10 into Earth orbit.

China. Japan is not alone in its interest to compete with the U.S., Russia, European and the other space faring nations. A Chinese astronaut walked in space last year, and the year before, China demonstrated its space prowess by shooting down one of their own failed satellites.

A secret photograph posted on the Internet in 2008 reveals that the Chinese may have developed a small spaceplane designated as the "Divine Dragon." Although the posting does not appear to be a hoax, there has been no official confirmation of government involvement in developing a spaceplane; however, China's determination to develop a "space combat weapons platform" is well established.

The Future

It is difficult to image the future of commercial air travel given the worldwide economic depression that has wiped out enormous amounts of wealth from the financial accounts of nations and their individual citizens and corporations; however, there have been substantial gains made in the development of spaceplanes, and the momentum should propel hyperspace travel forward into the future. Undoubtedly, all of these spaceplanes will have to increasingly rely upon computerized flight operations to handle the complexities of space travel. There is no going back.

While Airbus is now in the spotlight as a result of the loss of Flight 447, we must keep in mind that the company has been a technological leader in aircraft design, such as fly-by-wire, automated cockpits and the use of composite materials.

Just days before the crash of Flight 447, Airbus announced the first round of winners in its ?30,000 contest for the best ideas for future aircraft design and engineering. Five entries were chosen from among the proposals submitted by 2,350 students from 82 countries.

Suggestions included the elimination of windows and the use of electric motors to taxi aircraft.

Boeing and Airbus continue to go head to head in seeking to manufacture the current and next generation of commercial aircraft. It currently appears that Airbus is ahead in the number of orders on its books and the quantities of aircraft it is delivering; however, unless and until it solves the hazards of computerized flight operations along with taking advantage of the benefits, it could find its planes buried in the Comet graveyard. Passengers will not continue to board commercial aircraft with fear in their gut, when there is a safer alternative.

The flight crew of US Airways Flight 1549 displayed amazing professional competence after the engines of their Airbus A320 automatically shut down after striking a flock of birds shortly after takeoff on January 15, 2009. The crew was able to maintain control of the aircraft and land in the Hudson River without loss of life. Pilot Chesley B. "Sully" Sullenberger III, has become a national hero; however, there remains a question whether the Airbus flight control system unnecessarily shut down both engines, whereas a Boeing aircraft engines might have chewed up the birds and kept flying. When the copilot, Jeffrey B. Skiles was asked by National Transportation Safety Board investigators how he liked the Airbus, he replied that he liked it "right up until the accident."

Nonetheless, as we jet into a future that will increasingly rely on flight control computers to fly commercial airplanes, I believe it is safe to say that most of us would prefer to have a "Sully" in the captain's seat instead of a robot.

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