Fly-by-Wire: Getting started on the right foot and staying there…

Imagine yourself getting into the cockpit of an aircraft, finishing your preflight checks, and taxiing out to the runway ready for takeoff. You begin the takeoff roll and start to rotate. As you lift off, you discover your side stick controller is not responding correctly to your commands. Panic sets in, and you feel that you've lost total control of the aircraft. Thanks to quick action from your second in command, he takes over and stabilizes the aircraft so that you both can plan to return to the airport under reversionary mode. This situation could have been a catastrophe. This happened in August of 2001. A Lufthansa Airbus A320 came within less than two feet and a few seconds of crashing during takeoff on a planned flight from Frankfurt to Paris.

Preliminary reports indicated that maintenance was performed on the captain's sidestick controller immediately before the incident. This had inadvertently created a situation in which control inputs were reversed. The case reveals that at least two "filters," or safety defenses, were breached, leading to a near-crash shortly after rotation at Frankfurt's Runway 18. Quick action by the first officer prevented a catastrophe. Lufthansa Technik personnel found a damaged pin on one segment of the four connector segments (with 140 pins on each) at the "rack side," as it were, of the avionics mount. This incident prompted an article to be published in the 2003 November-December issue of the Flight Safety Mechanics Bulletin. The report detailed all that transpired during the maintenance and subsequent release of the aircraft. As you could imagine, there were many issues involved in this incident. Not the least of which improper documentation used for the specific serial number aircraft, improper check out procedures performed by the technicians, followed by the vaguely written maintenance manual procedures and crews not verifying actual movement during preflight. Lack of proper training and good cross check of critical systems on the aircraft were also missing. This event is a real-life demonstration of how human factors affect the outcome of advanced Fly-by-Wire technology.

The purpose of this report is to bring better awareness to FBW technology. There are many factors that can influence the designed operation of this advanced equipment. There are also detailed procedures and inspection requirements that make this system unique, including return-to-service procedures that technicians must perform when maintaining this technology. This is a system that commands good training, operational awareness, and respect.

FBW has taken on a major presence in the Aviation Technology arena. We have gone from simple wire commands to Full Authority Digital Electronic Control (FADEC). This technology has changed the way we operate and maintain these aircraft. What was once considered cutting edge technology in the military sector has become the norm in new aircraft deliveries in business and commercial areas. Properly operating and maintaining this complex technology is critical in reducing failures and increasing reliability. Like all advanced technology, it is only as good as you are in using and maintaining it. Let's talk about both critical issues.

When I think of FBW technology and where we have gone, I think back to my childhood days flying gas-powered string-controlled aircraft in the church parking lot after everyone left. This tethered plane flew around in circles with me pulling or pushing the strings to give control in the right direction. Today, wireless radio-controlled model planes soar through the skies. The advancement in military technology using UAV's demonstrates how far we have come in technology in a short period of time. With this advancement in technology comes greater responsibility. Yet the speed of these advancements has dramatically out-paced the government's ability to make changes to training requirements, much less operations. When you look at the current FAA certified training requirements for technicians, it still centers on mechanical procedures involving the airframe and power plants. Digital technology training is virtually left out. As this technology advances into lighter aircraft, it is going to be imperative that the training requirements for licensing change with it.

FBW technology requires a greater understanding and knowledge for both technicians and flight crews. To be competent in using and maintaining this new technology requires a different set of knowledge and skills. Both technicians and flight crews will require a unique diagnostic and problem-solving skillset. Maintenance training is focused around the basic system and component understanding, preflight requirements, limitations, management of associated malfunctions, and building confidence in the system.

Virtually every business aircraft manufacturer is incorporating FBW technology. Within business aviation, a generational change takes about seven years from inception to full adoption. It takes about three generations for it to go from leading edge to proliferation. We are amid the second generation of digital technology development for business aircraft, which means we are only approximately ten years from FBW becoming the standard. The top-end OEMs are pushing the envelope in incorporating side stick controls in the cockpit now. This is the beginning of what will be the norm in the business aircraft environment.

The technological changes within the Gulfstream G650 is a prime example of FBW incorporation. The Gulfstream 650 cockpit has two traditional looking yokes in the cockpit- it doesn't look like it is FBW. However, under the floor, there are Rotable Variable Differential Transformers (RVDTS) that generate all data for position digitally. These sensors take movement from the yokes, digitally send information to the computers, then directly to the flight controls. Some of the FBW benefits on the Gulfstream aircraft include enhanced flying qualities, enhanced stability, greater protection through entire flight envelope, and continuous monitoring. The system is controlled by two dual channel Flight Control Computers (FCCs) as well as a Backup Flight Control Unit (BFCU), which provides "get home" capability if all four FCC channels are unable to compute a solution. Here's the good news: just one FCC channel can control every flight control surface on the aircraft.

Many of us are concerned about not being able to manually fly the airplane if the black box stops functioning. Not to worry! There are four flight control modes: Normal, Alternate, Direct, and Backup. The probability of losing Normal mode is < 1:1 million per flight hour. Alternate, Direct, and Backup are reversionary modes related to problems with sensors and computers. The probability of reverting all the way to backup (i.e., FCCs unable to compute a solution) is < 1:1 billion per flight hour. The redundancy to assure reliability goes well beyond the computers. There are 16 hydraulically-powered flight control actuators; seven of which can trap hydraulic fluid and operate like a third hydraulic system. If both hydraulic systems fail, the aircraft flies normally. We must keep in mind that this advanced technology does not come without issues. December 2017 data published by Gulfstream reported that out of the top 20 removal components, three were FBW components. This is where continuous improvement plays an important role.

Electro Static Discharge (ESD) is a great risk to FBW technology. Every component installed on the system must be handled very carefully. Gulfstream has dedicated much larger sections of their maintenance manual under ATA Chapter 20 standard practices to address this issue. There is greater emphasis on ESD control, bonding procedures, corrosion control, water egress, and fiber optics maintenance. For instances with ESD control, technicians need to be grounded when handling ESD sensitive components. You must wear a wrist bracelet and attach it by a wire to the airframe to minimize static electricity.

Working on FBW systems today is like opening your laptop and changing out the mother board. Most aircraft have modules that require very delicate handling procedures for proper install and removal. Careful handling of each component is essential. As chairman for the Honeywell Global Customer Committee, one of my responsibilities is to address Rolling Action Items List, or RAILs. RAILs can be generated by both operators as yourself, or internally by Honeywell. One important RAIL generated by the customer base is ESD potential, and how Honeywell needs to address proper handling of components.

Another concern regarding ESD pertains to the handling and shipping of ESD-sensitive components. Custom inspections are becoming an issue. Operators, especially in foreign regions, are discovering notices posted on parts received that the package was inspected by customs and not properly handled. What are you to do? Should the component still get installed? If the agent did not wear an ESD bracelet, is the part airworthy? These concerns are serious. Ongoing training and notification must be done to educate everyone involved on proper handling of ESD-sensitive components. Vendors are considering placing penalties against core returns that are not properly handled.

An additional area of concern from a technician’s point of view is the return-to-service requirements for FBW technology. The CMC display of the G650 reveals how a “Suite A” inspection is performed. Any time you replace a flight control component, you must perform a Suite A check. This requires very specific maintenance procedures that allow the check to be performed successfully. Often, the system will not perform a successful test the first time. Patience and knowledge of the system are imperative. It is important to let the system run at its pace, not yours. Many times, having discussions with engineering is helpful to understand how the system goes through the BITE (Built In Test Equipment) test. The maintenance manual is constantly changing to reflect the conditions that could affect the outcome of the test. During the Suite A test, all systems are run through, and all channels are tested for proper operation. It is important to have knowledge about the system to understand how these tests are performed.

Visual inspection requirements of the components associated with FBW technology is also an area of concern. This design is extremely sensitive to disruptions within the harnesses that send commands from the computers to the flight controls. There is no tolerance for damage to these harnesses. If a wire gets nicked, the entire harness must get replaced. Inspection and proper handling around this equipment is very important. Having knowledge of proper bonding and shielding is essential to inspecting these systems.

Radio Interference (RF) is a common concern when operating digital systems. Paying careful attention to aircraft equipment design and certification as well as quality control in maintenance is essential to reducing risks. Obviously, technicians should maintain due vigilance regarding their existing equipment and systems.

Radio interference could cause the system to shut down if corrupted. Wireless transmitting in the aircraft must not interfere with critical flight control components. That is why such effort is placed on bonding those components. Micro mesh wireless systems are used all through the G650 as well as the new G500/600 aircraft cabin management systems. It works well in those environments. That fact that it is wireless controlled, interference is possible. Other factors like cell phones can interrupt the cabin management system. We need to remember wire transfer of data and proper maintenance of those wires is essential to preventing interference.

The beauty of this design is the fact that if something goes wrong, the system will tell you. Most aircraft that utilize FBW technology require special inspections for a lightning strike. Performing these inspections is critical for proper performance and assured reliability.

FBW technology is Fly-By-Wire, not Fly-By-Wireless! In the end, FBW looks mysterious, but is not. It is no different than the rod and bell crank. Having mechanical back up is unnecessary, increases weight, and defeats much of the value that FBW creates. Human factors play a significant role in operating and maintaining this advanced design. It is only as good as the people who operate and maintain it.

Ref: Flight Safety Foundation Mechanics Bulletin November-December 2003

Gulfstream Aerospace Customer News Letter

Gulfstream Aerospace G650 Maintenance Manual

FlightSafety International G650 operators guide