

1995128351

N95-34772

User "Type" Certification for Advanced Flight Control Systems

Richard D. Gilson & David W. Abbott

University of Central Florida

28-08
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Changing Flight Crew Roles

Advanced avionics through flight management systems (FMS) coupled with autopilots can now precisely control aircraft from takeoff to landing. Clearly, this has been the most important improvement in aircraft since the jet engine. Regardless of the eventual capabilities of this technology, it is doubtful that society will soon accept pilotless airliners with the same aplomb they accept driverless passenger trains. Flight crews are still needed to deal with inputting clearances, taxiing, in-flight rerouting, unexpected weather decisions, and emergencies; yet it is well known that the contribution of human errors far exceed those of current hardware or software systems. Thus human errors remain, and are even increasing in percentage as the largest contributor to total system error.

Currently, the flight crew is regulated by a layered system of certification: by operation, e.g., airline transport pilot versus private pilot; by category, e.g., airplane versus helicopter; by class, e.g., single engine land versus multi-engine land; and by type (for larger aircraft and jet powered aircraft), e.g., Boeing 767 or Airbus A320. Nothing in the certification process now requires an in-depth proficiency with specific types of avionics systems despite their prominent role in aircraft control and guidance.

New System Information

New systems now emerging will undoubtedly add safety to aircraft operating in the future airspace system, but the added information processing required to operate in that system will probably increase, not decrease, the crews' overall mental workload. For example, the capabilities of the Global Navigational Satellite System (GNSS) will eventually allow "uplinking" of the positions of individual aircraft via Automatic Dependent Surveillance (ADS), which could include data quantifying weather conditions surrounding each aircraft. The consolidation of specific traffic and weather into a national, even global, information network could be re-transmitted on demand to equipped aircraft. Moreover, air traffic control equipped with comprehensive and real time data about traffic and weather events in the airspace could dynamically manipulate airspace restrictions and uplink new configurations to cockpit electronic maps.

Even individual aircraft flight management systems could be automatically re-programmed from the ground for more efficient routing, then activated by acknowledgement from the crew. All this can provide crews with rich information about traffic, weather, and the airspace surrounding their aircraft, but it also increases monitoring responsibilities.

Monitoring

In the attempt to try to convey all information (without prioritization), the danger may be that there will be less knowledge conveyed (by overloading information). Design philosophy will play a role; some air carrier manufacturers (e.g., Airbus Industrie) prefer to display the status of many ongoing events and data, presumably with the objective to keep the crew better informed and aware. Other manufacturers (e.g., Boeing) choose to display principally abnormal status items, presumably protecting crews from lowering their attention by becoming accustomed to overlooking normal data. The implications of such designs are echoed in the ongoing debate about the effect of datalink cutting off "party line" monitoring of common radio frequencies. One side argues that crews are losing valuable situation awareness information by eliminating broadcasts from surrounding aircraft; the other side contends it is better to filter out all non-essential communications.

Supervision

Flight crews may have an even greater challenge supervising automated flight control systems than by actually performing tasks themselves. As Dr. Earl A. Wiener put it, "... bigger mistakes are made more often while supervising, than when in direct control" (Wiener, 1990). This may be due, in part, to less involvement by the crew; thus the potential for divided attention and larger casual errors. In addition, autopilots in the past were programmed to or from single ground reference points or altitude. These were easily remembered, and flight crews were kept involved as they made simple speed, time, and fuel calculations.

Today's flight management systems (flight-controlled autopilot coupled or not) have the programming and sequencing capabilities for dozens of navigational routes, flight profiles, and hundreds of waypoints far beyond the working memory of the crews. On-board computers (with databases) can process information with ease and precision, leaving manual calculations passé and crews ever more dependent on system processing. Moreover, automatic sequencing is for the most part externally initiated at points of passage or interception, sometimes leaving the crews with the question "How in the world did I ever get into that mode?" (Sarter & Woods, 1994). The problem is that crew members may lose their awareness of the automated mode changes in their role shift from that of a supervisor anticipating future events to that of a monitor of lagging events. Often hardware and software are not designed to allow easy crew surveillance. Worse yet, mindless dependency on computer reliability, without mental supervision checking, produces the three most commonly asked questions on highly automated flight decks – "What is it [the flight management system] doing? Why is it doing it? What will it do next?" (Wiener, 1990).

Since current avionics are more likely to be integrated with aircraft controls, the consequences of errors are greater than even only a few years ago. The potential for errors extends across mistaken inputs (dumb use, i.e., non-checked use), misunderstood algorithms (misuse), and inadequate time for programming changes (rushed use). For example, transposition errors during the entry of latitude/longitude coordinates were implicated in the shoot down of Korean Airline 007 and in the 1977 collision of an Air New Zealand into Mount Erebus, Antarctica. Mode verification was apparently not done in the Airbus (A320) accident at Strasbourg, France, Air Inter Flight 148. The crew misinterpreted a desired flight path angle 3.3° for a vertical speed value of 3.3×1000 ft/min because both are entered into the same display. However, which one is active depends on the current mode (Monnier, 1992). As a final example, the slow response of a China Airlines crew in disengaging the autopilot during an engine failure in a Boeing 747 over the Pacific, resulted in a rollover and near terminal dive.

Thus, regardless of the level of automation, the pilot-in-command (PIC) remains the final authority. The FMS/FGS as an electronic crew member is not yet deemed capable of replacing the PIC's judgment. These systems currently perform exactly as programmed, yet they are not yet equipped with the artificial intelligence to correct PIC errors or suggest alternatives to a proposed PIC course of action. Moreover, in an informal survey we conducted, flight crews in both a Boeing 767 and an Airbus 320 did not know the manufacturer or the model of their "electronic" crew member, the FMS, admitting they were not fully aware of the full range of its capabilities, limitations, idiosyncracies, and underlying strategies.

Proposal

It is proposed that flight crews be certified for attaining mastery of sophisticated control systems. Perhaps the type of aircraft *plus* the type of FMS should become a new integrated type of aircraft/FMS certification, e.g., a B767/A_(FMS) or B767/B_(FMS). (Note, it is recognized that it becomes a judgment call as to when A_(FMS) and B_(FMS) are "significantly different" to require a different type rating.) Extending beyond automated flight control is the possible certification of crews to use software-specific navigational systems (FGS) which provide guidance during instrument flight operations. Given that manual control is often based on the same information displayed through the flight director that drives coupled systems, the argument for certification for use of uncoupled systems is just as compelling in IFR conditions.

An advantage to FMS/FGS certification beyond the demonstration of competency is that it provides hardware, software, and instructional system designers with human performance benchmarks to guide the design or training system process so as to best accommodate the human component. It also begins to insure that the total system (hardware, software, and people) will meet expected standards.

Justification

The basis for this proposal is that the traditional role of the flight crew is swiftly changing. Hands-on flight control is rapidly giving way to semi-automated or fully automated control even for the most routine operations. So much so that some long-haul crews that use

automation for their infrequent takeoffs and landings fear losing their basic flight proficiency. Lower psychomotor effort without the need for constant attention to direct flight control has translated directly to a greater opportunity for monitoring and supervising flight systems, but only for crews who are highly FMS proficient. For low proficiency crews, the “mental” workload may be heavier. While certain mundane tasks such as navigational and altitude tracking are automated, additional capabilities and requirements are being added to the flight deck. This not only serves to supplant the “free time,” but belies the mental effort involved in conducting the safest possible flight.

Testing

Testing should be done with the total system (i.e., the particular flight management system with a particular type of aircraft) to uncover any idiosyncratic aspects of system integration. The type certificate for aircrews should read, “(aircraft type)/FMS”. Note that testing should consider both crew competency with the manufacturer’s standard configuration as well as with their utilization of customized features. Unlike the past, the depth of testing should go well beyond just “how to use the system.” In order to maintain mode awareness, the crew must know “how the system works” at a deeper structure – (based on a mental model) at least at a macro-level – and have the ability to track what the system is doing at any given time. For example, current FAA testing is for type ratings with the FMS fully functional and fully operational. In prior years, examiners turned *off* equipment to increase the difficulty level. A deeper understanding of the system(s) would be demonstrated with partial levels of automation and no automation – e.g., scenario manipulation to infer situation awareness (Sarter & Woods, 1994). Perhaps more importantly, crews should be able to accurately predict what the system will do next, allowing for anticipation of automated programming changes or hardware/software errors in the making; “thinking ahead of the aircraft” (Regal et.al., 1988).

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