High Assurance Life and Death
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Today’s airspace environment is congested and complex. The enroute environment is a tangled web of victor airways and jet routes connecting the multitude of radio navigation aids sprinkled all over the world and especially the US. The terminal area environments are highly congested with air traffic and requires precise aircraft control by pilots and ground controllers. This situation is even more critical in adverse weather conditions.

The cockpit environment is also complex and unforgiving. There are four fundamental functions that must be executed by aircrews to safely fly an aircraft. The primary function is to aviate. Someone or something (like an autopilot) must constantly maintain aircraft control to at least keep the shiny side up and the greasy side down. The second function is to operate the aircraft systems. Someone or something (like onboard computers) must constantly monitor and operate the electrics, hydraulics, pneumatics, engines, flight controls, and fuel system along with all their related subsystems. Third is navigation. Someone or something (like navigation computers) must always have a finger on the map to know where the aircraft is and where it is going. An airplane can’t stop on the side of an airway to pull out a map or to ask directions. Finally, the aircrew must be able to communicate with the outside world to ensure safe aircraft separation, receive weather updates, and coordinate for other activities after landing.

The basic tools aircrews use to execute these functions are fairly standard. They have a stick and rudder for aircraft control, radios for communication and navigation, and switches and dials for systems operations. But the details of the human interface vary widely in complexity and usability. High assurance in the systems engineering of these tools is absolutely critical for the long term safety of flight operations. In general, high assurance systems should be reliable, convenient, and provide proper feedback to the operator. To illustrate these concepts I will describe a flight director (FD) system and explain what a pilot expects a good FD to do.

A flight director is a cockpit system that allows a pilot to input a flight profile to include route and altitudes. Using this information, the FD interfaces with navigation systems, attitude reference gyros, and other flight instruments to provide visual steering commands back to the pilot in order to execute the programmed flight profile. Once programmed, the pilot merely follows the FD steering commands almost like a video game. Of course, the pilot must occasionally update the programmed flight profile as changes occur. A good FD provides some relief to the pilot from the urgent details of the aviating and navigating functions. He can focus his concentration on more effectively managing cockpit resources, anticipating changes, reacting to new information, and handling malfunctions.

The Flight Director should be able to provide appropriate guidance for each and every phase of flight and not be cluttered with information that may only be important for another phase of flight. For takeoff, the FD should direct an efficient, repeatable, wings level, initial climbout. Thereafter, the pilot should be able to program his choice of rate of climb, angle of climb, constant airspeed climb, or constant Mach climb. A heading
hold mode should operate while the FD is armed to capture a navigational course (eg TACAN, INS, ILS, etc). Course intercepts should be smooth and expeditious but overshoots should be minimized. For TACAN course tracking an "overstation mode" should be incorporated to provide smooth steering through the cone of confusion. Steering through INS or GPS changeover points should be smooth and automatic. The FD should direct a smooth level off at a pilot programmed altitude from either a climb or descent and thereafter provide commands to hold that altitude. As in climbout, the pilot should be able to program his choice of a constant Mach descent, constant airspeed descent, descent angle or descent rate. A heading hold and/or altitude hold mode should be available when the FD is armed to capture a final approach course and glide path. The pilot may wish to fly the aircraft using raw data only, so he should always have the option of completely removing the steering commands from view.

Overall, a pilot expects a FD to direct the flight. It should be convenient to program and the steering commands should be reliable and easy to follow. Pilots will not use an expensive FD if it is inconvenient or unreliable. The FD should have an adequate self monitoring system to inform the pilot of system errors and to provide feedback on what the pilot believes he has programmed and what kind of guidance the FD is providing. If the pilot fails to adequately follow the guidance he has programmed, the FD should warn him of that, too. If the aircraft has an autopilot, the FD should have a smooth interface so the pilot can elect to fly the FD steering commands manually or have the autopilot fly the steering commands automatically. FD steering, autopilot steering, and radio navigation steering should always be in harmony and NEVER conflict. A low time pilot flying at night, in the weather, with an emergency, should be helped by his flight guidance systems, not confused by them.

The concepts of reliability, convenience, and feedback apply to most systems that require high assurance. The bottom line is this: A relatively inexperienced operator, working in suboptimal conditions and confronted with a high stress, even life threatening, situation should be helped by his or her systems, not confused by them.
Norman Johnson obtained his Private Pilot License as a teenager and later joined the US Air Force to feed his habit. Since then he has achieved the status of Command Test Pilot and has acquired over 5000 hours of flight time in more than 60 different kinds of aircraft. This includes 250 hours of combat flight time during Desert Storm. On the low and slow end of the spectrum, he has a Commercial Glider Pilot Rating but he has also flown hang gliders, hot air balloons, and the Goodyear blimp. He has quite a number of hours in numerous general aviation and business class aircraft. In fact, he and his wife have their own airplane that they flew to the workshop. He also holds an Airline Transport Pilot Rating and has extensive experience in jet trainers, fighters, bombers, and heavy transports. In addition, he was at one time an Air Force nominee to the NASA space shuttle program.

He holds a BS in Aerospace Physics from the University of Colorado, an MBA in Aviation Management from Embry-Riddle Aeronautical University, and an MS in National Resource Strategy from the National Defense University.

Lt Col Johnson currently works at the Pentagon in the office of the Secretary of Defense. He oversees the testing of all major fixed wing aircraft and electronic warfare programs throughout the Department of Defense.

He is a member of the Society of Experimental Test Pilots, the International Test and Evaluation Association, the American Institute of Aeronautics and Astronautics, the American Defense Preparedness Association, the Aircraft Owners and Pilots Association, the Air Force Association, and the Order of Daedalians.