COCKPIT CONTROL AND DISPLAY DESIGN HAZARD ANALYSIS

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1. Does this display or control always operate as advertised?

Principle: Control/Display functions should operate in accordance with documentation provided, and in way that represents an aircrew's "intuitive" understanding.

2. How much is this control/display like others in a pilot's previous experience?

Principle: Standardization of controls facilitates learning and transfer of operational skill between various aircraft types. Possible "negative learning transfer" can result if controls are non-standard (e.g., pilots may confuse flap and gear controls when they are in opposite positions between different aircraft types).

3. Is this display/control within the pilot's visual and reach envelope?

Principle: Controls and displays should be easy to view and operate from a pilot's normal seat position and under high and low illumination levels or high "G" maneuvers.

4. Can controls be distinguished by feel alone?

Principle: If pilot cannot visually verify a switch setting, he/she should be able to identify a control and a particular setting by touching it only(Controls should be shape-coded).

5. Is this display/control likely to be confused for any other?

Principle: Controls and displays that have different functions but similar arrangements are potentially hazardous. Display formats must be distinguishable from one another to clearly assess flight status data. Controls should be different to the touch. Controls with similar movement patterns but functions should be protected from inadvertent activation.

6. Are instruments and controls with related function grouped together in a logical arrangement?

Principle: A logical grouping of controls/displays helps reduce instrument scan time, control operation, and lowers pilot workload.

7. Are warning devices reliable (operate accurately under a variety of expected operational conditions), and are warning signals adequate in gaining attention of crew.

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[1] Adapted from Mason (1989). University of Southern California Class handouts.

Principle: Warning devices must call immediate attention to operators and inform them about the type and severity of failure, and if possible the warning system directs corrective action. A good warning system functions when it should and has a low amount of false alarms.

8. Is information provided by a display in a format that enables a pilot or crewmember to easily assimilate the data and determine equipment mode of operation and meaning of data?

Principle: Display data should be direct and "well-mapped" to the operational condition represented, with minimum problem solving, computing, and input from the crew to read and interpret meaning of displayed data. In today's high technology aircraft, there is a temptation by designers to provide crews with readout of "everything that moves", thereby overloading the crew with sometimes-unnecessary data or making it harder for the crew to extract most important information. Multi-mode controls/displays should always clearly indicate the current mode that the system is in.

9. Are controls/displays adequately labeled (by function) and are they adequately illuminated to find and read?

Principle: When at all possible, it is best to visually verify critical switch actions (as reflected in some checklists). The chances of forgetting a switch action or misidentifying, or mistakenly activating the wrong control are reduced by use of checklists and by own visual verification.

10. Does any equipment or aircraft structure impair reach or visual access to control or display?

Principle: Any equipment that obscures view or puts control out of easy reach poses a potential hazard. Re-design and/or use of crew resources should be considered to reduce risk.

11. Is there possible confusion among operating modes of an onboard-automated system?

Principle: Multimode system designs are notorious traps for aviators who may from time to time become distracted while performing cockpit tasks, or are following "normal" habit patterns. The system should be designed so that the aircrew is clearly advised of the current mode (display) and either warned or guarded against an inadvertent or erroneous mode entry.

12. Are manual backups available if the automatic control/displays fail?

Principle: Murphy's Law # 1, "If anything can go wrong, it will go wrong". A back-up plan for high-risk failures is essential, and crews should be trained for different kinds of failure and what "back-up" steps are required for failure recovery. Pilots need to be prepared to "fly the airplane", and not become overly reliant on automated systems.

Cockpit Automation: Lessons Learned From Commercial Aviation

DC-10 CASE EXAMPLES: AUTOMATION INDUCED ERROR
(Adapted from Wiener, 1988 P. 444)

1. While climbing to altitude, the crew of a DC-10 flying from Paris to Miami programmed the flight guidance system to climb at a constant vertical speed. As altitude increased, the autopilot dutifully attempted to comply by constantly increasing the pitch angle, resulting in a high-altitude stall, a loss of over 10,000 feet of altitude before recovery.

2. A DC-10 landed at Kennedy Airport, touching down about halfway down the runway and about 50 knots over target speed. A faulty auto-throttle was probably responsible. The flight crew, who apparently were not monitoring the airspeed, never detected the over-speed condition.

3. In 1981 a DC-10 crashed into Mt. Erebus in Antarctica. The accident was primarily due to incorrect navigation data that was inserted into a ground-based computer, and then loaded into the on board aircraft navigation system by the flight crew. The inertial navigation system (INS), erroneously programmed flew dutifully into the mountain.

AIR BUS EXAMPLES OF MODE CONFUSION
(*Aviation Week and ST, Jan.30, 1995)*

1. In the China Airlines Airbus A300 accident at Nagaya Japan, the autopilot continued to fly a programmed go-around, while the crew tried to stay on glide slope. The autopilot applied full nose-up trim and aircraft pitched up at a high angle, stalled, and crashed.

2. The engagement of altitude acquire mode at an unexpected point caused a steep pitch up and loss of airspeed during engine failure simulation. The Airbus chief test pilot was distracted by other operating systems. The aircraft went out of control and crashed.

3. Confusion over flight mode was the cause of a fatal Air-320 crash during a non-precision approach into Strasburg-Entzheim Airport in France. The crew inadvertently placed the aircraft into 3300 feet per minute descent when a flight crewmember inserted 3.3 into the flight management computer while the aircraft was in vertical descent mode instead of the proper flight path control mode. Pilots intended to fly a 3.3 glide slope.

4. In another instance, a B757 en route to Cali, Columbia the crew became confused over waypoint designators. The crew entered "R" instead of "Rozo" into the flight management computer, which corresponded, to a non-directional radio beacon that was located 100 miles in the opposite direction from their intended destination. The 180-degree course reversal resulted in a fatal crash into mountainous terrain (Olson, 2001)

All of the of the above, and other incidents/accidents illustrates a considerable lack of attention on the part of the crew. It appears from these examples and others that one effect of automation is to increase the need for close human monitoring of automated systems.

The need and philosophy of "how much automation is desirable" is always a subject of debate. Following the reported incidents of mode errors in advanced cockpits, and prior to Strasbourg and Cali accidents. The NTSB chairman, and former chief scientist at NASA, stated that:

It is apparent that rather than eliminating human error; some of the new technology has simply resulted in creation of entirely new opportunities and entirely new categories of human error to occur (J. Lauber, 1987,p.35).

Research and case examples are continuing to show the considerable impact that advanced technology has on crew performance. Some of the latest research (at this writing), has shown that pilots vary considerably in their views about the benefits and problems that technology introduces. Some feel strongly that they are passing control over to the automated system. This loss of control can have some very real consequences. For example, a few years ago a Fairchild Metro airplane was equipped with an anti-stall device that gave a warning of stall conditions and then "automatically" exerted a 60 lb. downward force on the stick.

The use of this mechanism fell into question, following a crash in which an aircraft impacted the ground in a severe nose down position. On the other hand, many pilots extol the virtues of modern technological innovations in the cockpit. For example, use of Ground Proximity Warning Systems (GPWS), after some of the notorious false alarms were designed out, is credited with a significant drop in controlled flight into terrain airline mishaps (Aviation Week & Space Technology, April 26, 1993).

<u>Summary of Automation Problems</u>

* Requires increased monitoring/watchkeeping
* Requires crew to spend more "head down" time
* Induces complacency and dependency on automated system
* May induce some loss of situation awareness
* May result in an erosion of physical flying skills/proficiency
*Automation Complacency, failure to monitor progress of flight
*Diminishedfailuredetectionprobabilityandpossibleincreaseinresponse
error recovery
* Minor input errors (i.e. mode error) with serious consequences

The question is NOT for or against technology, but given the inevitable advancement in cockpit automation -- ***what are the impacts on the professional pilots performance***, and the consequences for training, safety, etc.

Possible Solutions

1. **Better Designs** -- that put the pilot back in the "control loop" as an active participant in flight, not along for the ride.

2. **Display Data** -- provide advisory displays of system status and warning with low false alarm rate. Display data and design controls that fit pilot's intuitive flying ability/cues used to fly and not copious amounts of alphanumeric data.

3. **Manual Backup** -- give pilot/crew a way out if the system fails, by providing a manual override.

4. **Aircrew Training** -- place increased emphasis on "systems knowledge" and train pilots to use crew resources (work as a team).

RELATED WEB LINKS

Web links for Advanced Cockpit Issues

http://www.maxwell.af.mil/au/aul/aupress/Wright_Flyers/Text/wf14.pdf

http://flightdeckautomation.com/fdai.aspx

http://www.flightsafety.org/hfam_home.html

Web links for US Navy and Marine Corps Advanced Cockpits

1.MH-60S Knighthawk Helicopter

http://www.naval-technology.com/projects/mh_60s/

http://www.news.navy.mil/search/display.asp?story_id=5716

2.F/A-18 Super Hornet

http://pma265.navair.navy.mil/stores/shornet/shornet.html

http://www.military.cz/usa/air/in_service/aircraft/f18e/f18e_en.htm

3. T-45 Goshawk
http://www.naval-technology.com/projects/t45/

4. V-22 Osprey

http://www.naval-technology.com/projects/V22_osprey/

5. E-6 Mercury

http://www.news.navy.mil/search/display.asp?story_id=7311

6. E-2C Hawkeye

http://www.avidyne.com/press/E2C%20Contract%20FINAL.html
7. King Air 200 (C-12 designation)

http://www.janes.com/micro_sites/paris/aircraftdata/raytheon_200_01.shtml

Web links for Human Factors Design Principles

http://www.usernomics.com/human-factors.html

http://www.enre.umd.edu/hfs&h.htm

http://www.enre.umd.edu/hfs&h.htm

Key points of contact for cockpit design and automated systems

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COCKPIT HAZARD ANALYSIS CHECKLIST

Aircraft Model Evaluated: ____________________

[ ] The following control (s), and/or display(s) do <u>not</u> operate as advertised in my aircraft:

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Recommendation:

[ ] The following control (s) and/or display(s) do not match my previous experience:

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Recommendation:

[ ] The following control (s) switch actions cannot be visually verified:

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List here any controls that are not shape coded for tactile verification:

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Recommendation:

[ ] The following control(s) and/or display(s) can possibly be confused:

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Recommendation:

[ ] The following control(s) and/or display(s) is/are not logically grouped according to related functions:

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Recommendation:

[ ] The following display(s) do/does not display proper data or displays information that is likely to be misunderstood or not correctly interpreted:

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Recommendation:

[ ] The following control(s) and/or display(s) cannot be easily identified and/or read because of faulty labeling and/or inadequate illumination:

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Recommendation:

[ ] The aircraft equipment and/or structure obscures view or restricts access to the following control(s) and/or display(s):

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Recommendation:

[ ] No manual backup is available for the following system(s):

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Recommendation: