Ergonomics and Cognition in Manual and Automated Flight

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ABSTRACT

Advances in technology have enabled increasingly sophisticated automation to be introduced into the flight decks of modern airplanes. Generally, this automation was added to accomplish worthy objectives such as reducing flightcrew workload, adding additional capability, or increasing fuel economy. To a large extent, these objectives have been achieved. Safety also stood to benefit from the increasing amounts of highly reliable automation. Indeed, the current generation of highly automated transport category airplanes has generally demonstrated an improved safety record relative to the previous generation of airplanes. Vulnerabilities do exist, though, and further safety improvements should be made. To provide a safety target to guide the aviation industry, the Secretary of Transportation and others have expressed the view that the aviation industry should strive for the objective of none accidents. Training standards and currency in manual flying skills may well have deteriorated, but are these changes in proportion to the tasks and situations typical of modern operations, or really at the root of handling related safety concerns.

Keywords: Automation, Manual procedures, System procedures

INTRODUCTION

This appears to be what the FAA have done a pandemic in modern aviation; but it's easy to find error as it is a normal aspect of human behavior. However, without evidence that these 'errors' directly contribute to reduced safety (and what are these errors), more of 'this or that' simple solution will not guarantee any improvement. You may only improve the skill in '*flying one-engine ILS (Instrument Landing System)*. The FAA's investigation has used pilot error as a stopping point; the human is at fault, thus train the human – more currency. This simplistic approach may miss underlying problems, and until these and the contributing factors are understood then any meaningful intervention cannot be formulated. What about the organization, economic, and social changes; has the baseline human behavior been affected by these. Modern views of human factors by-pass human error with the concept of variability; this is a performance characteristic necessary to manage daily activities(Eugenio, 2011). No situation is perfect, work activity is a compromise. So one aspect to consider is if pilots are sufficiently trained / skilled in the process of compromise – the judgment that originates from situation assessment and choice of action (aspects of airmanship), and which also involves risk management, and the skills of thought when stressed. This thread talks about manual handling errors. But it's not about "faults". It’s more about lack of being able to fulfill the role the human still has his place in the cockpit: To take over when the electrons go the wrong way. See figure 1.

Figure 1 - The ILS-(Instrument Landing System)

Training standards and currency in manual flying skills may well have deteriorated, but are these changes in proportion to the tasks and situations typical of modern operations, or really at the root of handling related safety concerns. Again, you sound great intellectually and such questions might be worth investigating (Henriqson, 2010). They expect us to be able to take over, fly the airplane out of any danger irrespective to any of the above (and even you are a customer every now and then). Even on newer cars equipped with cruise-controls and distance monitoring/intervening you still need to be able to brake yourself. We know what you mean, but still insist that the underlying problem here, is that the basics are not taught well enough and the acquired is not maintained enough. This might be simple, but then it's just as simple to remedy it (Reason, 2012).

CONTEXTUALIZATION

On April 26, 1994, an Airbus A300-600 operated by China Airlines crashed at Nagoya, Japan, killing 264 passengers and flightcrew members. Contributing to the accident were conflicting actions taken by the flightcrew and the airplane’s autopilot. The crash provided a stark example of how a breakdown in the flightcrew/automation interface can affect flight safety. Although this particular accident involved an A300-600, other accidents, incidents, and safety indicators demonstrate that this problem is not confined to any one airplane type, airplane manufacturer, operator, or geographical region. This point was tragically demonstrated by the crash of a Boeing 757 operated by American Airlines near Cali, Columbia on December 20, 1995, and a November 12, 1995 incident (very nearly a fatal accident) in which a American Airlines Douglas MD-80 descended below the minimum descent altitude on approach to Bradley International Airport, CT, clipped the tops of trees, and landed short of the runway.

As a result of the Nagoya accident as well as other incidents and accidents that appear to highlight difficulties in flightcrews interacting with the increasing flight deck automation, the Federal Aviation Administration’s (FAA) Transport Airplane Directorate, under the approval of the Director, Aircraft Certification Service, launched a study to evaluate the flightcrew/flight deck automation interfaces of current generation transport category airplanes. The following airplane types were included in the evaluation: Boeing: Models 737/757/767/747-400/777, Airbus: Models A300-600/A310/A320/A330/A340, McDonnell Douglas: Models MD-80/MD-90/MD-11, Fokker: Model

F28-0100/-0070. The Federal Aviation A chartered a human factors (HUMAN FACTOR) team to address these human factors issues, with representatives from the FAA Aircraft Certification and Flight Standards Services, the National Aeronautics and Space Administration, and the Joint Aviation Authorities (JAA), assisted by technical advisors from the Ohio State University, the University of Illinois, and the University of Texas.

The HUMAN FACTOR Team was asked to identify specific or generic problems in design, training, flightcrew qualifications, and operations, and to recommend appropriate means to address these problems. In addition, the HUMAN FACTOR Team was specifically directed to identify those concerns that should be the subject of new or revised Federal Aviation Regulations (FAR), Advisory Circulars (AC), or policies. The HUMAN FACTOR Team relied on readily available information sources, including accident/incident reports, Aviation Safety Reporting System reports, research reports, and trade and scientific journals. In addition, meetings were held with operators, manufacturers, pilots' associations, researchers, and industry organizations to solicit their input. Additional inputs to the HUMAN FACTOR Team were received from various individuals and organizations interested in the HUMAN FACTOR Team's efforts. When Examining the evidence, the HUMAN FACTOR Team found that traditional methods of assessing safety are often insufficient to pinpoint vulnerabilities that may lead to an accident. Consequently, the HUMAN FACTOR Team examined accident precursors, such as incidents, errors, and difficulties encountered in operations and training. This Group also examined research studies that were intended to identify issues and improve understanding of difficulties with flightcrew/automation interaction. In examining flightcrew error, the HUMAN FACTOR Team recognized that it was necessary to look beyond the label of flightcrew error to understand why the errors occurred. We looked for contributing factors from design, training and flightcrew qualification, operations, and regulatory processes (Rasmussen,1982). While the HUMAN FACTOR Team was chartered primarily to examine the flightcrew interface to the flight deck systems, we quickly recognized that considering only the interface would be insufficient to address all of the relevant safety concerns. Therefore, we considered issues more broadly, including issues concerning the functionality of the uderlying systems. From the evidence, the HUMAN FACTOR Team identified issues that show vulnerabilities in flightcrew management of automation and situation awareness and include concerns about:

- Pilot understanding of the automation's capabilities, limitations, modes, and operating principles and techniques. The HUMAN FACTOR Team frequently heard about automation "surprises," where the automation behaved in ways the flightcrew did not expect. "Why did it do that?" "What is it doing now?" and "What will it do next?" were common questions expressed by flightcrews from operational experience.

- Differing pilot decisions about the appropriate automation level to use or whether to turn the automation *on* or *off* when they get into unusual or non-normal situations (e.g., attempted engagement of the autopilot during the moments preceding the A310 crash at Bucharest). This may also lead to potential mismatches with the manufacturers' assumptions about how the flightcrew will use the automation.

Flightcrew situation awareness issues included vulnerabilities in, for example:

- Automation/mode awareness. This was an area where we heard a universal message of concern about each of the aircraft in our charter.
- Flight path awareness, including insufficient terrain awareness (sometimes involving loss of control or controlled flight into terrain) and energy awareness (especially low energy state).

These vulnerabilities appear to exist to varying degrees across the current fleet of transport category airplanes in our study, regardless of the manufacturer, the operator, or whether accidents have occurred in a particular airplane type (Sternberg, 2000) . Although the Team found specific issues associated with particular design, operating, and training philosophies, we consider the generic issues and vulnerabilities to be a larger threat to safety, and the most important and most difficult to address. It is this larger pattern that serves as a barrier to needed improvements to the current level of safety, or could threaten the current safety record in the future aviation environment. It is this larger pattern that needs to be characterized, understood, and addressed (Green,1993). In trying to understand this larger pattern, the Team considered it important to examine why these vulnerabilities exist (FAA, 2011). The Team concluded that the vulnerabilities are there because of a number of interrelated deficiencies in the current aviation system:

- Insufficient communication and coordination. Examples include lack of communication about in-service experience within and between organizations; incompatibilities between the air traffic system and airplane capabilities; poor interfaces between organizations; and lack of coordination of research needs and results between the research community, designers, regulators, and operators.

- Processes used for design, training, and regulatory functions inadequately address_human performance issues. As a result, users can be surprised by subtle behavior or overwhelmed by the complexity embedded in current systems operated within the current operating environment. Process improvements are needed to provide the framework for consistent application of principles and methods for eliminating vulnerabilities in design, training, and operations.

- Insufficient criteria, methods, and tools for design, training, and evaluation. Existing methods, data, and tools are inadequate to evaluate and resolve many of the important human performance issues. It is relatively easy to get agreement that automation should be human-centered, or that potentially hazardous situations should be avoided; it is much more difficult to get agreement on how to achieve these objectives.

- Insufficient knowledge and skills. Designers, pilots, operators, regulators, and researchers do not always possess adequate knowledge and skills in certain areas related to human performance. It is of great concern to this team that investments in necessary levels of human expertise are being reduced in response to economic pressures when two-thirds to three-quarters of all accidents have flightcrew error cited as a major factor.
- Insufficient understanding and consideration of cultural differences in design, training,_operations, and evaluation. The aviation community has an inadequate understanding of the influence of culture and language on flightcrew/automation interaction. Cultural differences may reflect differences in the country of origin, philosophy of regulators, organizational philosophy, or other factors. There is a need to improve the aviation community’s understanding and consideration of the implications of cultural influences on human performance.

Human Systems Integration (HSI) is becoming a critical piece of complex systems to help resolve system designs (Dekker, 2003. This proposal has presented a growing body of knowledge for HSI and new technologies that are being developed to capture critical aspects of HIS(Martins, 2010). The development of a framework for Human Systems Integration with Systems Modeling Language (SysML) will enable teams to collaborate better by providing a common language and process to distribute models and share information. The Human Systems Integration component in systems engineering will be able to recognize the human as an integral element of every system by representing behaviors, constraints, states, and goals through-out the entire lifecycle (Martins, 2007).

METHOD

Based on our investigations and examination of the evidence, these concerns represent more than a series of individual problems with individual, independent solutions. These concerns are highly interrelated, and are evidence of aviation *system* problems, not just isolated human or machine errors. Therefore, we need *system* solutions, not just point solutions to individual problems. To treat one issue (or underlying cause) in isolation will ultimately fail to fundamentally increase the safety of airplane operations, and may even decrease safety. The flaws in the commitment of decision-making in emergency situations and the lack of perception related to all elements associated with a given situation in a short space of time indicate, often, lack of situational awareness. Automation always surprises the crews and often prevents them from understanding the extent of this technology that is very common in aircraft units with a high degree of automation (Martins, 2007, 2010). These facts are discussed in a subtle way by aircraft drivers who can not do it openly, as it might create an impression of professional self-worthlessness (self-deprecation). This leads to common questions like: What is happening now? What will be the next step of automated systems? This type of doubt would be inadmissible in older aircraft because the pilot of those machines works as an extension of the plane.

This scenario contributes to emotional disorders and a growing hidden problem in the aeronautical field. These unexpected automation surprises reflect a complete misunderstanding or even the misinformation of the users. It also reveals their inability and limitations to overcome these new situations that were not foreseen by the aircraft designers. Our studies showed a different scenario when the accident is correlated with systemic variables. It has identified the problems or errors that contribute to the fact that drivers are unable to act properly. These vectors, when they come together, may generate eventually a temporary incompetence of the pilot due to limited capacity or lack of training in the appropriateness of automation in aircraft or even, the worst alternative, due to a personal not visible and not detectable non-adaptation to automation. We must also consider in the analysis the inadequate training and many other reasons, so that we can put in right proportion the effective participation or culpability of the pilot in accidents. Our doctoral thesis presents statistical studies that allow us to assert that the emotional and cognitive overload are being increased with automation widely applied in the cockpits of modern aircraft, and also that these new projects do not go hand in hand with the desired cognitive and ergonomic principles (Martins, 2007, 2010).

CONCLUSIONS

As with many airlines it is self-funded by the student and thus is kept to a minimum number of sessions. As with other airlines the type rating is combined with an OPC. A few decades ago, in my early life entering the airlines, we were taught to fly the Authomatic Control in the Throttle Quadrant (TQ) course, with SOP's (***Standard Operating Procedure)*** attached. The line operations were refined during line training. The initial emphasis was knowing how the automated new system worked and how to fly it. The line training refined these skills and expanded how to operate it within the airways system and a multitude of busy airports and small visual airfields (FAA, 1996). Understanding the complexities of the systems came with our 'apprenticeship', which had started. When automation became readily available we used it to reduce workload when we felt like it.

We didn't really trust it but we used it knowing we could easily disconnect it when it didn't do what we wanted. Now some airliners want everything done on autopilot because it can fly better than any pilot. Airlines hire young pilots with little experience and they are shown how you don't need to hand fly any more because of automation. Labor is cheap. Then Air France Flight 447 accident shows the world how wrong that was. All that flight needed was one pilot in the cockpit who knew how to hand fly but they didn't so everybody died for no reason. Nowadays the TQ (Throttle Quadrant - see figure 2)

Figure 2- Throttle Quadrant (http://aeroprado737-800ng.blogspot.com.br/2013/07/tq-conjunto-de-manetes.html)

The course seems to shift the emphasis more towards SOP's (*Standard Operating Procedures)* during the maneuvers, some of which are with normal & non-normal scenarios. Some of the non-normals scenarios are non reported. It was not the complexity of their feelings which did put them into trouble, it was the lack of training, Understanding of those systems. This ignorance created a complex system when in fact with proper training it would have been quite simple. One wonders if the policy of many airlines to use relatively (2 years experience). They have followed the self same course of knowing what to do, but not the how and the why. They then pass on this diluted knowledge to the next generation of cadets who will become the next generation of equipments and so the downward spiral of knowledge continues. SOP's are so intense that the first thought of a pilot in a less than ideal situation is to ask, "what does the book say?" Second, if at all, comes "what is the most sensible airmanship thing to do?" By the time you arrive at the 2nd option it might be too ate as the a/c was still traveling very fast during the first phase of questioning confusion. The oldies do what is best instinctively, and within the book boundaries, but are not afraid to bend the SOP's; the newbie are terrified to even blow at the boundaries and thus delay making some decisions and then have to race to catch up.

All old farts were newbies once, but mostly with a longer and deeper apprenticeship than today. If the industry is gong to continue making captains with relatively low hours then the training of manual skills, and especially systems knowledge and understanding of all their possibilities, needs to be more in depth to compensate for the shorter apprenticeship. Too many commands can be given to those whose professional checks are above average and the knowledge is perfect. So we can not cover all eventualities. Most incidents and accidents started quite subtly and the human intervention, or lack of it, caused a can of worms to develop, when it was preventable. And that's a whole other discussion about a good crew being preventative rather than reactive. Slavishly following this scenery is not always preventative, but that was touched upon in an earlier thread. I guess lack of training never applied to us old guys. We kind of trained ourselves. We couldn't afford a lot of formal training. Our first few thousand hours had no automation so we just took our hands and did what was needed to fly. The HUMAN FACTOR Team developed recommendations to address the vulnerabilities and deficiencies from a system viewpoint. Our consideration of human performance issues, however, was focused primarily on the flightcrew. We did not attempt to address human performance issues associated with other personnel involved in the aviation system, such as flight attendants, ground personnel, air traffic services personnel, or maintenance personnel. Because the system is already very safe, any changes should be made carefully to avoid detracting from existing safety practices. The Team believes we must improve and institutionalize:

- Investments in people (designers, users, evaluators, and researchers). For example, flightcrew training investments should be re-balanced to ensure appropriate coverage of automation issues.

- Processes. It is important to improve how design, training, operations, and certification are accomplished. For example, regulatory authorities should evaluate flight deck designs for human performance problems.

- Tools and methods. New tools and methods need to be developed and existing ones improved to accompany the process improvements.

- Regulatory standards. Current standards for type certification and operations have not kept pace with changes in technology and increased knowledge about human performance. For example, flightcrew workload is the major human performance consideration in existing regulations; other factors should be evaluated as well, including the potential for designs to induce human error and reduce flightcrew situation awareness.

The same factors that are often featured in modern models of accidents are not perceived recursively to reflect how they influence the process of investigation of the accident itself. These vectors are more complexes than the cognitive and political biases that are often emphasized in theory. This deviation occurs because cognition and human performance, eventually, is less than the expected, or the situation demands greater performance than was available or is influenced by vectors that act systemically.

The temporary incompetence of the pilot shows, eventually, where is notorious a limitation of the capacity of piloting a aircraft, could have happened due to a lack of training appropriateness of automation in aircrafts largely automated. We must also consider many other reasons that can alleviate the effective participation or culpability of the pilot in accidents and incidents. Addressing these problems to a systemic view expands the frontiers of research and prevention of aircraft accidents like the correlation with a large number of variables like considering the abandon by pilots of the primary training process of the pilots on basic aviation schools. This cognitive process assures to pilots the ability to control the aircrafts without the automation devices. In this learning phase, the human need to be part of the plane.

REFERENCES

Accidents and Incidents: Analysis Using NASA Aviation," Safety Reporting System Data, Washington DC, press, Sept. 2010, 2011, 2012.

Dekker, S. "Illusions of explanation- A critical essay on error classification," The International Journal of Aviation Psychology, New Jersey, vol. 13, pp. 95-106, Sept. 2003.

Eugenio,C.- Automação no cockpit das aeronaves: um preciosoauxílio à operação aérea ou um fator de aumento de complexidade no ambiente profissional dos pilotos, 1rd ed., vol. 1. São Paulo: Brasil, 2011, pp. 34-35.

FAA- Federal Aviation Administration, "DOT/FAA/AM-10/13, Office of Aerospace Medicine, Causes of General Aviation

Federal Aviation Administration Human Factors Team Report on: The Interfaces Between Flightcrewsand- Modern Flight Deck Systems, June 18, 1996.

Green, R. G. & Frenbard M.- Human Factors for Pilots. Avebury Technical. Aldershot, England, (1993).

Henriqson , E.- A coordenação como um fenômeno cognitivo distribuído e situado em *cockpits* de aeronaves- Coordination as a distributed cognitive phenomena situated in aircraft cockpits Aviation in Focus (PortoAlegre), v. 1, n. 1, p. 58 – 76 (ago/dez. 2010).

Martins, Edgard, "Study of the implications for health and work in the operationalization and the aeronaut embedded in modern aircraft in the man-machines interactive process complex," "Estudo das implicações na saúde e na operacionalização e no trabalho do aeronauta embarcado em modernas aeronaves no processo interativo homemmáquinas complexas," thesis, Centro de Pesquisas Aggeu Magalhães, Fundação Osw Cruz, Perna:Brasil, Aug. 2010, pp. 567-612.

Martins, Edgard.-"Ergonomics in Aviation: A critical study of the causal responsibility of pilots in accidents," "Ergonomia na Aviação: Um estudo crítico da responsabilidade dos pilotos na causalidade dos acidentes," Msc. Monography, Universidade Federal Pernambuco, Pernambuco: Brasil,

Rasmussen, J. Human errors: a taxonomy for describing human malfunction in industrial istallations. Journal of Occupational Accidents, v. 4, p. 311-333, (1982.)

Reason, J. Human Error, Cambridge, Cambridge . .University Press, (1990, 2012).

Sternberg, R. J.) - Cognitive psychology. Porto Alegre: Ed Artmed . (2000)