# The Fault Tree in Aviation-Always Ends in Humans

*Edgard Thomas Martins [a], Isnard Thomas Martins[b] and Marcelo Márcio Soares[c]*

[a,c] *Department of Design*
*Universidade Federal de Pernambuco*
*Recife,21267173, Brazil*

[b] *Institute for Universidade Estácio de Sá*
*Advanced Systems Engineering*
*Rio de Janeiro, 98714888, Brasil*

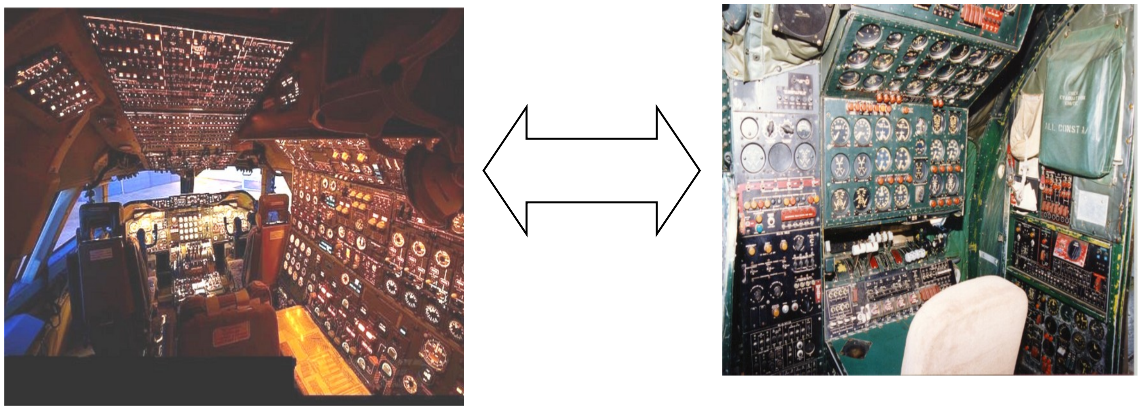
## ABSTRACT

Guilt! : A word which disrupts accident investigations. In the scenario of aircraft with high degree of automation control which resembles computer consoles, point to the need for further research focused on possible conflicts between the "human logic" and "logical automation" checked in control systems for aircraft.
It is very important to consider that the logic of automation was also drafted by pilots, so that this assumption is difficult to validate. A pilot in command of the Airbus blurted that "modern technology was withdrawing men of cockpits. This happened with the radio-telegraph when they got the new communication systems called SSB and VHF. But from there, the pilots were more burdened with the task of transmitting operational information and logistics companies, diluting attention at critical moments of the flight, in congested terminal areas. Also happened with the navigator when new systems arise like Omega and Doppler Radar. Over a sequence of operations adjustments and manipulations more equipment were transferred to the pilots on this occasion, adding to the known and the complex and overloaded duties of these professionals. This also happened with the mechanics of flight (the third man in the cockpit), when computers arrived. Until the 70s there was a work station flight engineer.

**Keywords**: Guilt, Automation, Manual Procedures, Human Factor

## INTRODUCTION

Today there are only the pilot and co-pilot in the cockpit and modern automated. Only two men just to control a Boeing 777.  This is a large modern aircraft carrying hundreds of passengers and so much faster. Now a days, the tasks of the pilots were multiplied and increased the weights of aircraft, and the number of passengers, speeds takeoffs and landings were more significant, decreasing the number of men in the cockpit. However, the biological machine called human being is not structurally changed in the last thousands of years to support the increased cognitive and emotional overload. How to know your limits? The professional called Mechanics of Flight (the third man in the cockpit),  was extinguished when computers arrived as shown in figures 2 and 3. Until the 70s there was a work station flight engineer. The Figure 3 shows a modern station with only the pilot and co-pilot - Two men just to control a Boeing 777 - A huge and modern aircraft that carries hundreds of passengers much more quickly.



Figures 1 and 2 - Old workplace of the third man in the control booth (cockpit) - withdrawn on behalf of Automation

Several procedures were loaded to the pilots that were executed by the Flight Engineer (Mechanic of Flight). Figure 3 shows a modern station with only the pilot and co-pilot - Two men just to control a Boeing 777 - A huge and modern aircraft that carries hundreds of passengers and on faster way. Several procedures were loaded to the pilots that were executed by the Flight Engineer (Mechanic of Flight).


Figure 3 - Modern Cockpit Boeing 777 with only the pilot and co-pilot in the cockpit (Photo courtesy Cmte Rock, Singapore Airlines.).

# FUNDAMENTATION

The following factors are an integral part of cognitive activity in the pilot: fatigue, body rhythm and rest, sleep and its disorders, the circadian cycle and its changes, the G-force and acceleration of gravity, the physiological demands in high-altitude, night-time take-offs and the problem of false illusion of climbing. But, other physiological demands are placed by the aviators. It is suggested that specific studies must be made for each type of aircraft and workplace, with the aim of contributing to the reduction of incidents arising from causes so predictable, yet so little studied. We must also give priority to airmen scientists that have produced these studies in physiology and occupational medicine, since the literature is scarce about indicating the need for further work in this direction. Human cognition refers to mental processes involved in thinking and their use. It is a multidisciplinary area of interest includes cognitive psychology, psychobiology, philosophy, anthropology, linguistics and artificial intelligence as a means to better understand how people perceive, learn, remember and how people think, because will lead to a much broader understanding of human behavior. Cognition is not presented as an isolated entity, being composed of a number of other components, such as mental imagery, attention, consciousness, perception, memory, language, problem solving, creativity, decision making, reasoning, cognitive changes during development throughout life, human intelligence, artificial intelligence and various other aspects of human thought (Henriqson, 2010).

The procedures of flying an aircraft involve observation and reaction to events that take place inside the cabin of flight and the environment outside the aircraft (Dekker,2003). The pilot is required to use information that is perceived in order to take decisions and actions to ensure the safe path of the aircraft all the time. Thus, full use of the cognitive processes becomes dominant so that a pilot can achieve full success with the task of flying the "heavier than air."

With the advent of automated inclusion of artifacts in the cabin of flight that assist the pilot in charge of controlling the aircraft, provide a great load of information that must be processed in a very short space of time, when we consider the rapidity with which changes occur, an approach that cover the human being as an individual is strongly need. Rather, the approach should include their cognition in relation to all these artifacts and other workers who share that workspace (FAA, 2010).

## THE DEPLOYMENT OF THE ACCIDENTS GENERATED BY BAD-PLANNED-TASKS ACCIDENTS

A strong component that creates stress and fatigue of pilots, referred to the design of protection, detection and effective handling of fire coming from electrical short circuit on board, is sometimes encountered as tragically happened on the Swissair Airlines flight 111, near Nova Scotia on September 2, 1998. The staff of the Federal Aviation Administration (FAA), responsible for human factors research and modern automated interfaces, reports a situation exacerbated by the widespread use an electrical product and a potentially dangerous wire on aircrafts, called "Kapton" (Dekker, 2010).

If a person has to deal with an outbreak of fire, coming from an electrical source at home, the first thing he would do is disconnect the electrical power switch for the fuses. But this option is not available on aircraft like the Boeing B777 and new Airbus. The aviation industry is not adequately addressing the problem of electrical fire in flight and is trying to deal recklessly (Reason, 1990). The high rate of procedural error associated with cognitive errors, in the automation age, suggests that the projects in aviation have ergonomic flaws. In addiction, is has been related that the current generation of jet transport aircraft, used on airlines, like the Airbus A320, A330, A340, Boeing B777, MD11 and the new A380, that are virtually "not flyable" without electricity. We can mention an older generation, such as the Douglas DC9 and the Boeing 737.

Another factor in pushing the pilots that causes emotional fatigue and stress is the reduction of the cockpit crew to just two. The next generation of large transport planes four engines (600 passengers) shows a relatively complex operation and has only two humans in the cockpit. The flight operation is performed by these two pilots, including emergency procedures, which should be monitored or re-checked. This is only possible in a three-crew cockpit or cockpit of a very simple operation. According to the FAA, the only cockpit with two pilots that meets these criteria is the cabin of the old DC9-30 and the MD11 series. The current generation of aircraft from Boeing and Airbus do not fit these criteria, particularly with respect to engine fire during the flight and in-flight electrical fire.
The science of combining humans with machines requires close attention to the interfaces that will put these components (human-machine) working properly.

The deep study of humans shows their ability to instinctively assess and treat a situation in a dynamic scenario. A good ergonomic design project recognizes that humans are fallible and not very suitable for monitoring tasks. A properly designed machine (such as a computer) can be excellent in monitoring tasks. This work of monitoring and the increasing the amount of information invariably creates a cognitive and emotional overload and can result in fatigue and stress.

According to a group of ergonomic studies from FAA (2000) in the United States this scenario is hardly considered by the management of aviation companies and, more seriously the manufacturers, gradually, introduce further informations on the displays of Glass cockpits. These new projects always determine some physiological, emotional and cognitive impact on the pilots.

The accident records of official institutes such as the NTSB (National Transportation Safety Bureau, USA) and CENIPA (Central Research and Prevention of Accidents, Brazil) show that some difficulties in the operation, maintenance or training aircraft, which could affect flight safety are not being rapidly and systematically passed on to crews worldwide. These professionals of aviation may also not be unaware of the particular circumstances involved in relevant accidents and incidents, which makes the dissemination of experiences very precarious.

One of the myths about the impact of automation on human performance: “while investment in automation increases, less investment is needed in human skill”. In fact, many experiments showed that the progressive automation creates new demands for knowledge, and greater, skills in humans. Investigations of the FAA (2010), announced that aviation companies have reported institutional problems existing in the nature and the complexity of automated flight platforms. This results in additional knowledge requirements for pilots on how to work subsystems and automated methods differently. Studies showed the industry of aviation introduced the complexities of automated platforms flight inducing pilots to develop mental models about overly simplified or erroneous system operation. This applies, particularly, on the logic of the transition from manual operation mode to operation in automatic mode (FAA apud NTSB, 2011). The process of performing normal training teaches only how to control the automated systems in normal but do not teach entirely how to manage different situations that the pilots will eventually be able to find.
This is a very serious situation that can proved through many aviation investigation reports that registered the pilots not knowing what to do, after some computers decisions taken, in emergences situations (Steremberg, 2000). VARIG (Brazilian Air lines), for example, until recently, had no Boeing 777 simulators where pilots could simulate the emergence loss of automated systems what should be done, at list, twice a month, following the example of Singapore Airlines. According to FAA (2005), investigations showed incidents where pilots have had trouble to perform, successfully, a particular level of automation. The pilots, in some of these situations, took long delays in trying to accomplish the task through automation, rather than trying to, alternatively, find other means to accomplish their flight management objectives. Under these circumstances, that the new system is more vulnerable to sustaining the performance and the confidence. This is shaking the binomial Human-Automation compounded with a progression of confusion and misunderstanding. The qualification program presumes it is important for crews to be prepared to deal with normal situations, to deal with success and with the probable. The history of aviation shows and teaches that a specific emergency situation, if it has not happen, will certainly happen.

## FUTURE WORK TO MAKE AN ASSESSMENT IN SYSTEMIC PERFORMANCE ON PILOTS

Evaluating performance errors, and crew training qualifications, procedures, operations, and regulations, allows them to understand the components that contribute to errors. At first sight, the errors of the pilots can easily be identified, and it can be postulated that many of these errors are predictable and are induced by one or more factors related to the project, training, procedures, policies, or the job. The most difficult task is centered on these errors and promoting a corrective action before the occurrence of a potentially dangerous situation. The FAA team, which deals with human factors (Green, 1993), believes it is necessary to improve the ability of aircraft manufacturers and aviation companies in detecting and eliminating the features of a project, that create predictable errors. The regulations and criteria for approval today do not include the detailed project evaluation from a flight deck in order to contribute in reducing pilot errors and performance problems that lead to human errors and accidents. Neither the appropriate criteria nor the methods or tools exist for designers or for those responsible for regulations to use them to conduct such assessments. Changes must be made in the criteria, standards, methods, processes and tools used in the design and certification. Accidents like the crash of the Airbus A320 of the AirInter (a France aviation company) near Strasbourg provide evidence of deficiencies in the project.

This accident highlights the weaknesses in several areas, particularly when the potential for seemingly minor features has a significant role in an accident. In this example, inadvertently setting an improper vertical speed may have been an important factor in the accident because of the similarities in the flight path angle and the vertical speed in the way as are registered in the FCU (Flight Control Unit).

This issue was raised during the approval process of certification and it was believed that the warnings of the flight mode and the PFD (Primary Flight Display-display basic flight information) would compensate for any confusion caused by exposure of the FCU, and that pilots would use appropriate procedures to monitor the path of the vertical plane, away from land, and energy state. This assessment was incorrect. Under current standards, assessments of cognitive load of pilots to develop potential errors and their consequences are not evaluated. Besides, the FAA seeks to analyze the errors of pilots, a means of identifying and removing preventively future design errors that lead to problems and their consequences. This posture is essential for future evaluations of jobs in aircraft crews. Identify projects that could lead to pilot error, prematurely, in the stages of manufacture and certification process will allow corrective actions in stages that have viable cost to correct or modify with lower impact on the production schedule. Additionally, looking at the human side, this reduces unnecessary loss of life.

# CONCLUSION

We developed a study focusing on the guilt of pilots in accidents when preparing our thesis. In fact, the official records of aircraft accidents blame the participation of the pilots like a large contributive factor in these events. Modifying this scenario is very difficult in the short term, but we can see as the results of our study, which the root causes of human participation, the possibility of changing this situation. The cognitive factor has high participation in the origins of the problems (42% of all accidents found on our search). If we consider other factors, such as lack of usability applied to the ergonomics products, the choise of inappropriate materials and poor design, for example, this percentage is even higher.

Time is a factor to consider. This generates a substantial change in the statistical findings of contributive factors and culpability on accidents. The last consideration on this process, as relevant and true, somewhat later, must be visible solutions. In aviation, these processes came very slowly, because everything is wildly tested and involves many people and institutions. The criteria adopted by the official organizations responsible for investigation in aviation accidents do not provide alternatives that allow a clearer view of the problems that are consequence of cognitive or other problems that have originate from ergonomic factors. We must also consider that some of these criteria cause the possibility of bringing impotence of the pilot to act on certain circumstances. The immediate result is a streamlining of the culpability in the accident that invariably falls on the human factor as a single cause or a contributing factor. Many errors are classified as only "pilot incapacitation" or "navigational error". Our research shows that there is a misunderstanding and a need to distinguish disability and pilot incapacitation (because of inadequate training) or even navigational error.

Our thesis has produced a comprehensive list of accidents and a database that allows extracting the ergonomic, systemic and emotional factors that contribute to aircraft accidents. These records do not correlate nor fall into stereotypes or patterns. These patterns are structured by the system itself as the accident records are being deployed. We developed a computer system to build a way for managing a database called the Aviation Accident Database. The data collected for implementing the database were from the main international entities for registration and prevention of aircraft accidents as the NTSB (USA), CAA (Canada), ZAA (New Zealand) and CENIPA (Brazil). This system analyses each accident and determines the direction and the convergence of its group focused, instantly deployed according to their characteristics, assigning it as a default, if the conditions already exist prior to grouping. Otherwise, the system starts formatting a new profile of an accident (Dekker, 2003).

This feature allows the system to determine a second type of group, reporting details of the accident, which could help point to evidence of origin of the errors. Especially for those accidents that have relation with a cognitive vector. Our study showed different scenarios when the accidents are correlated with multiple variables. This possibility, of course, is due to the ability of Aviation DataBase System (Martins, 2007, 2010), which allows the referred type of analysis. It is necessary to identify accurately the problems or errors that contribute to the pilots making it impossible to act properly. These problems could point, eventually, to an temporary incompetence of the pilot due to limited capacity or lack of training appropriateness of automation in aircraft. We must also consider many other reasons that can alleviate the effective participation or culpability of the pilot. Addressing these problems to a systemic view expands the frontiers of research and prevention of aircraft accidents.

This system has the purpose of correlating a large number of variables. In this case, the data collected converges to the casualties of accidents involving aircraft, and so, can greatly aid the realization of scientific cognitive studies or applications on training aviation schools or even in aviation companies (Martins, 2010). This large database could be used in the prevention of aircraft accidents allowing reaching other conclusions that would result in equally important ways to improve air safety and save lives.

## REFERENCES


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.

FAA- Federal Aviation Administration, “DOT/FAA/AM-10/13, Office of Aerospace Medicine, Causes of General Aviation Accidents and Incidents: Analysis Using NASA Aviation,” Safety Reporting System Data, Washington DC, U.S. Department of Transportation press, Sept. 2010.

FAA- Federal Aviation Administration- FAA, “The Interface Between Flightcrews and Modern Flight Deck Systems,” Federal Aviation, Administration Human Factors Team Report, May 2005. pp-34-35.

FAA- Federal Aviation Administration, “Human Error Analysis of Asrts Reports: Altitude Deviations in Advanced Technology Aircraft,” Federal Aviation Administration, Human Factors Team Report, 1992, 1996, 2002.

FAA- Federal Aviation Administration- FAA, “Human Error Analysis of Accidents Report,” Federal Aviation Administration- Human Factors Team Report, 2010, pp. 201-206.

Green R.G., and Frenbard, M. Human Factors for Pilots. Avebury: England, Technical Aldershot, 1993.

Henriqson, E“Coordination as a Distributed Cognitive Phenomena Situated in Aircraft Cockpits- Aviation in Focus,” *A Coordenação Como Um Fenômeno Cognitivo Distribuído e Situado em Cockpits de Aeronaves,”* UFRGS edit., Porto Alegre, vol. 12, pp. 58 –76, Dez. 2010.

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, Mar. 2007, pp. 285-298

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 homem-máquinas complexas,”* thesis, Centro de Pesquisas Aggeu Magalhães, Fundação Oswaldo Cruz, Pernambuco:Brasil, Aug. 2010, pp. 567-612

NTSB- National Transportation Safety Board, “Airline Service Quality Performance- User Manual- ASQP,” Washington, DC, Bureau of Transportation Statistics, U.S. Department of Transportation press, Oct. 2011, pp. 75-77.

NTSB-National Transportation Safety Board, “C.F.R.- 234 Airline Service Quality Performance Reports,” Washington, DC, Bureau of Transportation Statistics, Research and Innovative Technology Administration (RITA), U.S. Department of Transportation press, Oct. 2011, pp. 45-61

Reason, J. Human Error, 2nd ed., Cambridge: U.K., University Press, 1990, pp.92-93.

Reason, J. Human Error, 2nd ed., Cambridge: U.K., University Press, 1990, pp.103-107.

Sternberg, R. Cognitive psychology, Porto Alegre: Brasil, Ed Artmed, 2000rrtrr