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PHD THESIS

-summary-

Considerations regarding management methods for system’s safety in air transport

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CONTENTS

CHAPTER 1 - Introduction

1.1. Abstract

Transport aviation is a major contributor to economic development by providing fast global connections, being essential for business and tourism. The aviation industry plays a critical role in modern society as it influences the global, regional and local economy, facilitating long-distance transport for both business and leisure travel – improves world trade by increasing access to international markets and thereby ensuring globalization. Aviation is indispensable for tourism and developing economies. Connectivity helps increase productivity by encouraging investment and innovation, improves operating environments and efficiency, giving companies the opportunity to attract quality employees from around the world.

The aeronautical industry is in direct connection with technology. The advanced development of aircraft, including from an ecological point of view by improving fuel consumption or recycling issues, requires that everyone involved, from aircrafts production company to operators, must adopt the appropriate technological level from the early stages of system design to be able to evolve operationally and organizationally. Despite stringent regulatory standards, advanced technologies and complex manufacturing and maintenance processes, evolution and progress are quite rapid in the aeronautical industry.

At the same time, new challenges arise. The structure of the latest generation aircraft consists of composite materials, which require different procedures in the maintenance and inspection processes than those used in previous generations; the development of large and long-range aircraft implies new requirements in terms of reliability and performance.

Emerging technologies, the ever-changing scale and dynamics of armed conflict, different global actors, and increasing cyber trust are changing the nature of threats and put pressure on the industry to maintain a high level of safety in the context where, before the pandemic caused by the SARS-COV-2 virus, the number of passengers was expected to double in the next 20 years.

One of the best-selling and most reliable transport aircraft is the Boeing 737 aircraft. Each variant of the aircraft represented an improvement over the previous model, thus ensuring not only better conditions for passengers, but also new elements that optimized the control functions of the aircraft, thus improving human-machine interaction and increasing operational safety. Improving aircraft performance enables airlines to develop their flight operations by ensuring the connectivity of different regions globally over short, medium and long distances safely. The safety level of the aircraft is demonstrated in particular by the small number of accidents that the Boeing 737 aircraft had in the companies that opted for this type of aircraft, predominantly in the United States of America. The way in which these new technological elements are implemented often represents the premises of possible functional vulnerabilities, when the level and way of understanding of the pilots is not adequate, and the two catastrophes with the Boeing 737 MAX 8 aircraft demonstrate this aspect. The relationship between the human factor and technological evolution is becoming more and more dynamic and requires the permanent adaptation of aeronautical organizations and, implicitly, of pilots in order for them to acquire the necessary skills to act appropriately in unforeseen flight situations and maximize air safety. Inadequate training of personnel can be a prerequisite leading to the transfer from a state of safety to a state of risk. Certain aspects intentionally or unintentionally omitted in the preparation can affect this relationship and the result can lead to catastrophes.

Lessons learned from the operational phases demonstrated the need to develop training and training processes. Improving these processes through development of flight scenarios within simulator represents major operational advantages, but the cost and time aspects involved are an unattractive feature for organizations given commercial interests; the use of standard preparation processes, for example standard scenarios, is the common approach in the air transport industry. But the technological and organizational development, the particularities of the human factor and the resulting implications as a result of interactions between these and the other collateral systems (the environment, air traffic management systems, the maintenance system, etc.) offers a much more complex set of risks that require both a high volume of knowledge and well-defined and different approaches from the previous ones. A first step in trying to gain control over potential hazards and risks generated by the new systems, processes and concepts can be achieved by means of improving information management from a qualitative point of view both through structuring information in flight manuals and the existing procedures, as well as through creating much more complex scenarios in the flight simulator, or in other words, a new skills and abilities management system.

Challenges in pilot training include the need to adapt to an industry with a totally unpredictable environment technologically, economically or exposed to unforeseen situations, such as the 2020 SARS-COV-2 virus-induced COVID-19 pandemic. Even if pilot training suffers, they must carry out their work with high professionalism and perform consistently given the increasing demands for operational efficiency. One form of response by organizations in terms of operational readiness is to increase the levels of simulation – that is, more complex scenarios in flight simulators. The simulator has a fundamental role in supporting the pilot (of the human factor) in obtaining and perfecting the skills and abilities required in the flight activity imposed by technological progress. The state-of-the-art technology currently used in construction of flight simulators is not enough. Adequate preparation of particular and complex flight scenarios must cover a wide spectrum of potential hazards due to interaction between the various systems in aviation - technology, environment, human factor - and contribute to recognition and clear understanding of hazards by pilots in critical situations of flight to avoid air catastrophes through an adequate response to the situation encountered.

In aviation, the foundation of management and operational efficiency is safety. The complexity of the organization-technology-human factor relationship can give rise to a chain of events difficult to manage during operational phases, but the lessons learned, most of them being the result of incidents and accidents produced over time, have imposed the need to develop standardization both at the organizational level, as well as at a technological level. The human-machine relationship is in turn standardized, but the absence of information, deficiencies in training or various external variables (e.g. weather conditions or fatigue) can constitute premises for aviation events. Air safety is the basis of all air operations, therefore it represents not only the essence of the present thesis research, but also of the undergraduate and dissertation works that I have carried out. In this thesis I approached the issues related to air safety in order to highlight the elements that can affect the organization-technology relationship and whose impact can be maximized or minimized by the influence of the human factor.

Too much conformity can be a negative in some situations. There is a tendency to focus aviation safety efforts on compliance with existing regulations. Identifying vulnerabilities takes a long time due to application of aviation regulations, and this aspect can lead to a situation where new threats can be ignored, thus affecting the training of flight and maintenance personnel.

By giving computers more prerogatives, human abilities are diminished. Automated systems are becoming capable of managing more and more situations, and this means that human factor only needs to intervene when something abnormal and unexpected occurs in operation. But when people have fewer and fewer opportunities to practice and improve their skills, they diminish their ability to react quickly and effectively in crisis situations. Even though the airline industry is extremely safe today, identifying ways to continuously promote aviation safety is an ongoing obligation for those with safety prerogatives.

The continuous evolution of the aeronautical field requires the development of new methods and models to provide the possibility of a better understanding of operational processes. I identified this aspect in the scientific research carried out and through the resulting model, which I applied in the case study presented in this thesis.

The understanding of all the aspects presented above is based on the information, which in the situation of the two catastrophes with the Boeing 737 MAX 8 aircraft was insufficient from the point of view of the organization-man-machine relationship. Informational problems can affect preparation and planning processes, so they can represent operational vulnerabilities. That is why we studied the need for the operation and development of the information process in aviation and briefly presented the principles of the process in the organization-man-machine context.

The model we created in the case study represents an original approach aimed at identifying the probability of operational risk based on the theory of system reliability as a mathematical basis. A simple and logical reasoning regarding the need and importance of both theoretical and practical training can provide an organizational management perspective through which the probability of risk can be diminished, which means improving the level of safety and streamlining operational processes in transport aviation.

1.2. Thesis objective

The purpose of this paper is both the brief presentation of the systems that interact in aviation (organizational, technological and human), as well as the identification of elements that keep the relationships and interactions between them in balance, in the context of the complexity of aeronautical systems, with the aim of identifying the probability of risk in operational processes.

The continued development of the air transport system has given rise to a much more complex risk. Risk cannot be eliminated in aviation, but only managed through specific management processes, and system development mitigates conventional risks. As a result, new risks of a different nature are generated, unknown, but which must be identified and shared by operators in order to make operational processes more efficient and ensure a high level of safety. Having as a starting point the modern theories that underlie the functional understanding of the subsystems in air transport system, as well as the specific elements of the safety management systems in aviation, this paper aims to present and provide a new approach to identifying the probability of risk at the moment of interaction between systems starting from their individual reliability as a system in the operational spectrum (organizational, technological and human factor); each value used in calculations and attributed to the previously mentioned systems are obtained following in-depth research and studies by specialists within specialized and accredited institutions to obtain data on organizations, technological level and human factor in aviation.

Based on the values calculated and obtained as a result of the reasoning and the mathematical model proposed by me in this work, conclusions can be drawn for ways to reduce operational risk through efficient adn thorough training (DROP – reducing operational risk through training) thus offering a possibility to address the issue of safety for air operators in order to maintain a safe and high efficiency operational level.

The analysis carried out aims to help air operators to understand how the probability of risk occurrence changes due to the interaction between systems and, at the same time, the possibility to decrease the probability of the risk identified, regardless of its initial level, through a very well-made theoretical and practical training system covering the entire informational spectrum necessary to ensure efficiency and safety in the comercial air transport system.

1.3. Thesis structure

Chapter 1 – ***Introduction***. In this first chapter, an overview of the necessity for systems is made (organizational, technological, maintenance system and human factor) in aviation and their importance in operational processes; both the objective and structure of the thesis, as well as its research methodology, are presented.

Chapter 2 – ***Systems interaction in aviation and its probability of producing adverse events in the air transport system.***

In the second chapter I presented different models, particularities and theoretical approaches currently used in commercial aviation which are the result of analysis and understanding of risk evolution following the conduct of aeronautical operations. At the same time, different management approaches are presented and the functional characteristics that must be understood to support the optimization, development and operational efficiency in the air transport system.

Chapter 3 – ***Elements of mathematical modeling of safety in air transport system.***

The content of this chapter is a continuation of the topic covered in Chapter 2; in this chapter I presented mathematical models and methods developed to improve risk management currently used in risk analysis both in aeronautical system and in other high risk areas that must be controlled to ensure the functionality of organizational and operational processes.

Chapter 4 – ***Comparative study of technological systems in the air transport system to understand and identify particularities of risks affecting operational safety.***

In this chapter, the current state of technological development in the air transport system is presented, with the main research and analysis element being one of the most reliable aircraft in the history of commercial aviation, the Boeing 737 aircraft. I motivated the decision to choose the Boeing 737 MAX 8 aircraft; I briefly presented the evolution of Boeing 737 aircraft models, the philosophy of Boeing aircraft control systems, in contrast to Airbus aircraft, and the catastrophes occured with Boeing 737 MAX 8 aircraft in order to exemplify how the interaction between systems can affect aviation safety through the emergence of new risks due to technological development.

Chapter 5 – ***Organizational management systems in the airline industry. Systems theory and organizational control.*** In this chapter, an overview of the systems is made to understand their functionality, dynamics and interaction in operational processes. Also, this chapter presents the aeronautical organization from a systemic perspective to understand the complexity of managerial implications, organizational development strategies and risk management in aviation systems. These identified elements and characteristics must be understood in order to gain organizational control in order to manage organizational processes effectively.

Chapter 6 – ***System safety in operational processes in the air transport industry.*** In this chapter I addressed the issue of air safety in air transport systems. Several elements that influence aviation safety are presented, many of which can be controlled by organization and which are the strengths of safety culture or which can become weaknesses in the case of poor management.

Chapter 7 - ***The impact and implications of the human factor in flight operational processes***. This chapter reviews and presents current studies, in a succinct manner, of the human factor in aviation due to its importance and direct implication on flight safety in the air transport system; in this chapter the main focus is on situational awareness due to its importance in identifying, analyzing, assessing and managing risk during flight operations, regardless of the level of complexity of the technological systems operated.

Chapter 8 – ***Model for identifying risk probability in total systems in transport aviation.*** Based on the scientific research carried out in the previous chapters and identifying the need to study the interaction between systems following my professional experience, in this chapter I developed a model for identifying the probability of operational risk in the total systems of transport aviation and demonstrated the possibility of reducing it by improving knowledge, implicitly by developing theoretical and practical training programs for pilots.

Chapter 9 – ***Conclusions. The need to develop training programs in the organizational environment.*** In this chapter the conclusions of this thesis are presented as a result of application of the model proposed by me and the results obtained regarding the probability of operational risk and the possibility of reducing this risk with the help of an appropriate training program.

1.4. Research methodology

The research topic of this thesis represents a continuation of the research activity begun with my undergraduate thesis entitled „Aeronautical safety in Romanian Air Force, integrated part of NATO's and EU's safety culture" and followed by the research and development of the dissertation entitled „ Developing organizational culture for improving air efficiency and safety within modern aeronautical systems" for the completion of master's studies within the Faculty of Aerospace Engineering, in the domain of aeronautical engineering and management.

The research methodology is based on an extensive research of the specialized literature in order to identify the factors that influence the relationship between the interacting systems in the modern air transport system. The need to address this issue has been identified in the previous research mentioned above and in the professional activity carried out to date.

For the development of this thesis, I had as a starting point the study of air accidents and catastrophes in order to understand the functional and dysfunctional elements that interacted and produced flight events in the last decade; I studied safety related elements from the system complexity standpoint and modern control methods which resulted in development of many risk management theories. The literature review was conducted to document organizational, technological and human factor aspects that influence operational process safety in air transport aviation. The elements identified in the scientific research do not represent aspects related to the standards and practices recommended at international level. To obtain relevant information in this regard, I studied scientific articles, specialized books on aeronautical management and other specialized works that analyzed technological, organizational and human nature problems in the modern aeronautical system. Given my professional training, I had discussions and interviews with pilots and engineers of Boeing 737 and Airbus A320 aircraft to understand both how the technology implemented on the aircraft supports the conduct of aeronautical operations, as well as the level of reliability of the human-machine interface in commercial transport aviation in order to gain a better perception of the importance and risk level that a technological element such as the angle of attack sensors and on-board computers in the case of Boeing 737 MAX 8 and Airbus aicrafts, can influence a commercial flight both positively and negatively.

CHAPTER 2 – Systems interaction in aviation and its probability of producing adverse events in the air transport system

Civil aviation is worldwide fast, safe and efficient means of transport over long distances. In the second half of the 20th century, reliance on air transport increased, safety was greatly improved and costs reduced; the volume of civil aviation has increased steadily and today the demands are still increasing. The social and economic benefits of aviation are substantial, but the associated costs are significant and, at the same time, increasing exponentially.

Technological development has brought major benefits to air transport, but it must be understood that this is a long-term process, based on lessons learned, which is primarily aimed at reducing risk. Even if the conclusions drawn from aviation incidents, accidents and catastrophes that have occurred over time have been pertinent, they have not been sufficient to eliminate the risk entirely. Lessons learned have helped, among other things, to improve operational processes, efficiency, human-machine interface both from the point of view of the pilot-aircraft relationship, as well as the engineer-aircraft relationship and in parallel contributed to the development of new, innovative solutions that respond to the characteristic elements of the modern "green aviation" concept.

2.1. Types of probabilities currently used for operational process development

Probability is a statistical method obtained by assigning a numerical value to the likelihood of an event occurring. The probability value is always between zero and one, and the sum of the probabilities must equal one. Probabilities can be used to assess risk being methods that support aviation safety by assessing the likelihood of an undesirable event occurring. Probabilities, at the same time, can be used to analyze the number of passengers in certain regional areas or the sales of aircrafts according to the needs of airlines and their desire for development and expansion; also, probabilities can be used in aviation and for weather forecasting. Probabilities can be expressed verbally, through numbers or through tables, graphs or models. The understanding of probabilities has many uses in understanding the probabilities of occurrence of events.

2.2. Systems safety in the context of interdependencies and cascading effects

Modern socio-technical systems are characterized by high level of inter-dependencies. While these interdependencies make systems more efficient during normal operations, they contribute to cascading effects in times of crisis. Thus, the processes of preparing to administer and respond to the crisis become extremely complex. An incident involving modern socio-technical systems can have severe cascading effects and can quickly become very difficult for responders to manage. The more complex the environment in which an incident evolves, or the more vulnerable the system due to the environment, the greater the risk of cascading effects. From management standpoint, the response to such situations must be as efficient as possible and built on the basis of recent information - this information supports the decision-making process. New strategies, structures and methodologies are required to withstand and manage evolving challenges, including inter-institutional or inter-organizational cooperation in conducting operations and providing or receiving support regardless of the operational environment. [1]

An incident has the potential to amplify in its aftermath and through the cascading effect develop into something much larger than the initial event. Understanding the amplification process requires knowledge, understanding of event triggers and inter-system dependencies, physical phenomena and key decision points in crisis situations.

By studying the chain of events in recent air catastrophes, one can identify the links and nature of these connections – between the initiating elements of events and dependencies. Cascading effects can be defined as the impact of initiating events where system dependencies lead to the propagation of impacts from one system to another - from an organizational point of view, in this situation, several people and events are involved and feel the effects of the event. Figure 2.1. shows the initiating event, system dependencies and propagation order for cascading incidents.

Cascading events can have different reasons and connections and dependencies can vary. Initiating events can be natural, accidental, and intentional. Also, the characteristics of dependencies and how systems can suffer may be different.

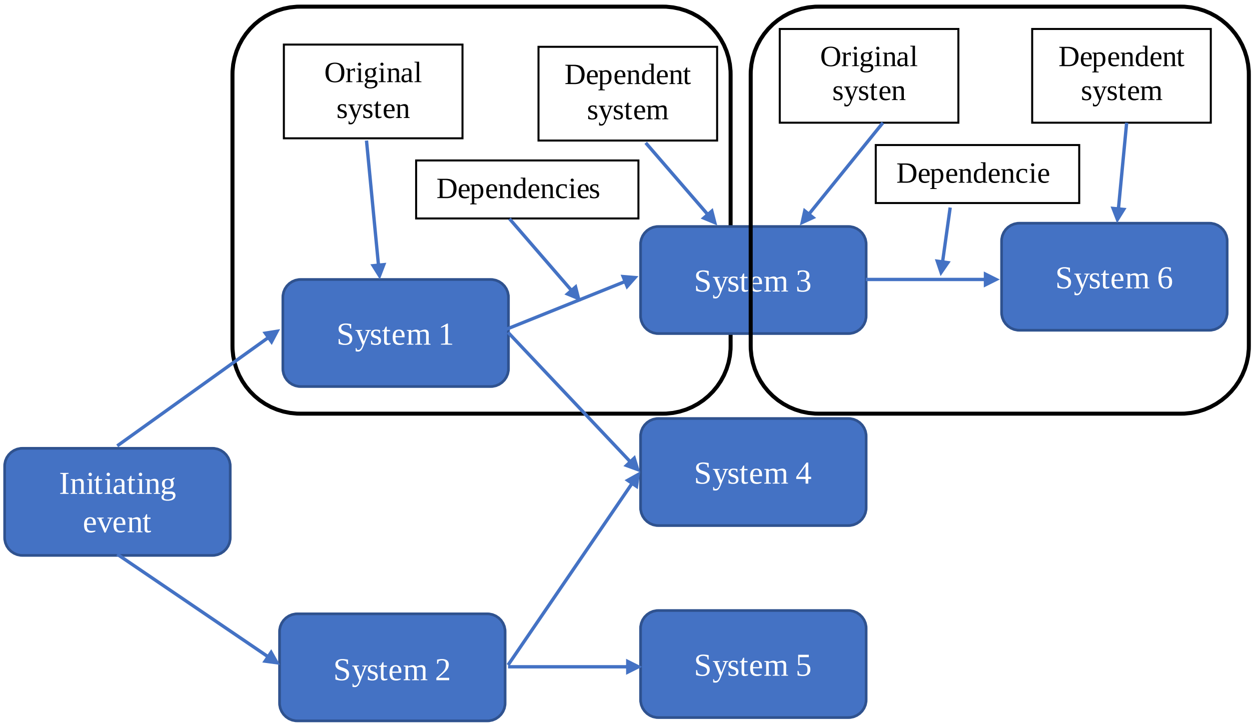

Figure 2.1. Representation of an initiating event and system dependencies in a cascading incident situation [2]

In order to identify and characterize these initiating events, the connections, dependencies between different systems and previous incidents with cascading effects must be studied and understood – knowing and understanding them is the basis for making appropriate response algorithms. In the context of incidents with (or at risk of) cascading effects, human decisions and activities can play a significant role in the production and development of events and their effects.

An important aspect is to identify the effects of different decisions and key decision points, such as, for example, opportunities to influence the connections between the initiating system and the dependent system when an external intervention can prevent the cascading effects of an event. The goal is not to fully analyze how decisions are made, as it can be very difficult to determine this aspect, but to find the decisions that affect the development of processes during an event with the risk of cascading effects. The degree to which an event is perceived as complex, stressful or difficult to understand depends on both the experience of the receiver and his ability to understand the information received. From the point of view of the decision-making factor and possible success, the influencing factors can be considered as follows: system's capacity and ability, interface, stress, workload, motivation, complexity, training, experience, culture, social dynamics such as group effects, the performance of processes and organizationsIt must be recognized that decision-making is a collaborative effort that brings together multiple groups with different views of situations, things, decisions and actions [3]. Acest lucru creează necesitatea unei baze comune și a unor modele mentale puse la comun în vederea luării deciziei. Posibilitatea de a obține acest lucru, pe timpul unui eveniment care implică efecte în cascadă, crește cu înțelegerea modului de funcționare, cunoaștere ale echipamentelor și ale instrumentelor disponibile și înțelegerea caracteristicilor membrilor/echipei/organizației, inclusiv cunoașterea acestora despre competențe, convingeri și eforturile celorlalți. [1]

Nevertheless, cascading effects are focused on how systems in their vicinity can be influenced. To limit the consequences, the most effective means may be to have appropriate organizations and structures, common technologies and procedures with other organizations, and the information is also made available to other persons or institutions involved. Strategic decisions must be made long before a cascading incident occurs.

2.5. Conclusions regarding the interaction of systems in air transport systems

Considering the high level of complexity existing in air transport system, an ideal model must identify and evaluate the risk arising from the manifestation of operational hazards combinations.

The presented methods allow a methodical, structured and rigorous approach, being easy to learn, apply and follow. These methods combine elements of structure, software, environment and human interactions, offering the possibility of making approximations that can be an excellent provider of information for the decision-making process. But they have a number of disadvantages, such as: they can become a waste of time if used independently, or they can become the goal and not the tool to improve safety. Not including the human factor in the analysis, during the analysis process, not understanding the system structure and operation or omitting certain logical steps, among others, are some of the most common mistakes encountered.

Given the total systems concept that currently exists in transport aviation, the inability to track and identify problems due to combinations of factors, to identify hazards unrelated to failure modes, provides limited analysis both from the point of view of the human factor, as well as from the point of view of external influences and interfaces. The absence of a reference value for the probability of risk due to the interaction of systems makes any theoretical model of safety difficult and interpretable.

CHAPTER 3 – Elements of mathematical modeling of safety in the air transport system

The methods and techniques required for risk assessment were originally developed in the nuclear field and have a wide range of uses today. There are several methods for assessing risk and the probability of its occurrence in many fields and industries, including aviation. Quantitative and qualitative assessments coexist, and in the case of organizations' risk mitigation approaches, the timing of risk management strategy analysis is an important consideration. From the regulatory point of view, risks are analyzed starting from two components of the danger, namely: the time of risk occurrence and danger's intensity (its severity or magnitude) resulting from the existence of the risk. A high level of risk is due to exposure to hazardous conditions. [4]

The existing methods and models for identifying the risk and its probability of occurrence demonstrate the continuous efforts made over the years to improve the operational safety status in aviation. But, at the same time, demonstrates low versatility and reduced unpredictability for implementing technical, procedural and operational elements for risk and safety assessment. The aim of these existing models is to increase the operational capability of the aeronautical system while reducing risk and operational limitations to have a permanent state of safety. The need to develop "specialized" and "dedicated" methods and models for certain management processes in an aeronautical system has been identified in many situations, especially following air disasters that have demonstrated that traditional approaches to risk identification and mitigation are limited. Taking lessons learned as a starting point, systemic research is needed to improve existing models in line with recommendations that generally involve risk and safety assessment both in the development phase of new technologies, as well as in the implementation phases and in the operational one's. These new models and methods must be simple to understand, have a modular form for the system structure and provide an element of predictability for air operators. [4]

3.1. Risk and probability from the perspective of aviation organizations

Most aviation organizations are required to implement a systems safety management program. ICAO has published a framework called Safety Management Systems (SMS) program based on risk management. Risk management processes in order to improve safety can be divided into three main elements [4]:

1) Identifying the hazards;
2) Risk assessment; and
3) Risk mitigation.

The way organizations define risk is similar. ICAO and FAA define risk as [4] the product of the probability of its occurrence and the severity itself:

$$Risk = Probability\ x\ Severity \quad \text{(ec. 3.1.)}$$

A limitation of the classic risk formula ($Probability\ x\ Severity$) is that it doesn't take into account the different risk barriers specific to a given situation (those elements that control the risk). Usually, when the risk analysis is done, it is necessary to analyze the risk considering the current barriers, without there being a specific way in which they are quantifiable, and then another assessment is made, considering control barriers, implicitly risk control elements. [4]

ARMS (*Aviation Risk Management Solutions*) is a working group made up of people working in various organizations in the aeronautical industry. This group is not politically affiliated and is non-profit with a mission to develop a clear methodology for aviation risk assessment. Their results are available to both the aeronautical industry and others interested in the subject. Unlike other organizations, ARMS members include commercial transport pilots, so their risk perception is based on their operational experience. [5]

ARMS' risk methodology has some elements in common with ICAO's proposed SMS framework, namely risk assessment (and mitigation) and safety performance measurement and monitoring and change management. ARMS methodology can be seen as a continuation of the development of the principles underlying the ICAO SMS and also found in the safety management manual (*Safety Management Manual* - SMM). To identify the risk and the probability of its occurrence during flight operations, they use two methods: the ERC method (*Event Risk Classification*) and SIRA method (*Safety Issue Risk Assessment*). [5]

ARMS presents the risk as a summation of four components, which are [4]

$$Risk = (Probabillity * \ Frequency\ of\ situational\ avoidance) * (Frequency\ of\ return\ to\ safe\ state) * \ Severity \quad \text{(ec. 3.2.)}$$

The importance of a decision and action without considering risk exposure, the effectiveness of barriers and limitations, and the effectiveness of the feature to return to the initial safe state without the need for specific actions for "worst case scenario" cannot be assessed correct. These factors require a high level of subjectivity, and it is quite difficult to include them in a formula that defines the risk or danger. [4]

3.2. Sequence of events, probabilities and consequences

The concepts used for accident scenarios and accident quantification are introduced by means of logic trees (or event trees, Event Tree – ET) and event sequence diagrams (Event Sequence Diagram – ESD). An event tree is represented in the figura 3.1. Initiating event – IE it is A, probability is q, the adjacent events that influence the final state are the actions of the pilot (*pilot intervention*) and are written as *PI*, and the return to the state of equilibrium following the emergency (*emergency recovery*) is *ER*. The conditional probabilities of the event tree representation for success are denoted by B_i and for failure $\overline{B_\iota}$. [6]

These notations are explained by means of two examples: *Event X* - wind shear phenomenon and *Event U* - loss of control of the aircraft in flight. The following notations for probabilities will be used for these situations [6]:

- Unconditional probabilities $P(X)\ and\ P(Y)$ for that event X or Y to happen.
- Conditional probability $P(X|Y)$ for that event Y to happen because of Event X.
- Joint probability $P(X,Y)$ so that Event X, and also Event Y to happen.

For the tree of events in the figure 3.1. and exemple from figure 3.2. the notations used mean the following [6]:

- $q = P(A)$ *– unconditional probability of the initiation event A.*
- $B_1 = P(PI|A)$ *– conditional probability on pilot intervention (PI) if state A exists.*
- $\overline{B_1} = P(\overline{PI}|A)$ *– conditional probability on pilot intervention* (PI) *(actions without succes) if state A exists.*
- $B_2 = P(ER|\overline{PI})$ *– conditional probability of recovery applying the specific emergency procedures if the pilot's intervention was not adequate.*
- $\overline{B_2} = P(\overline{ER}|\overline{PI})$ *– conditional probability of unsuccessful emergency recovery if pilot intervention was not appropriate.*

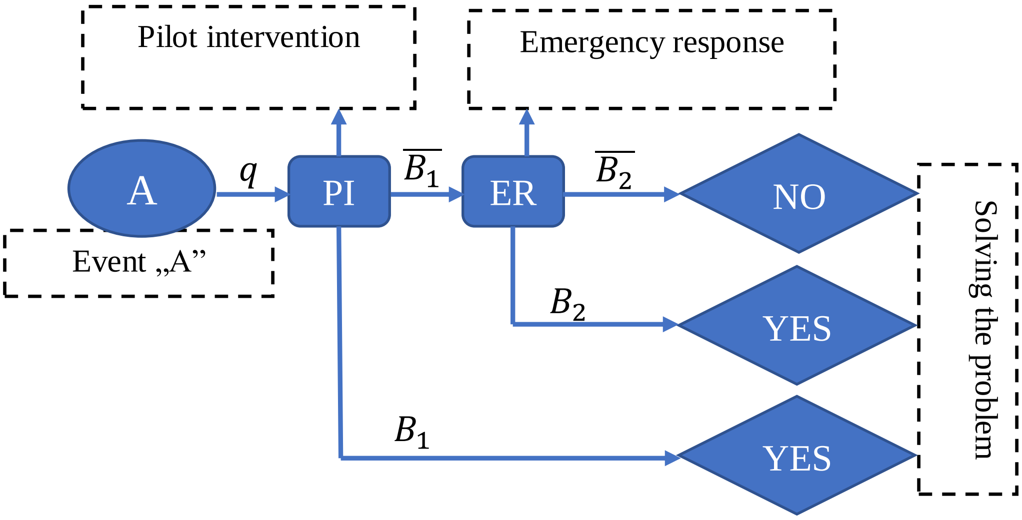

Figura 3.1. Aviation event occurence diagram (adapted after Georgiev 2021 [6])

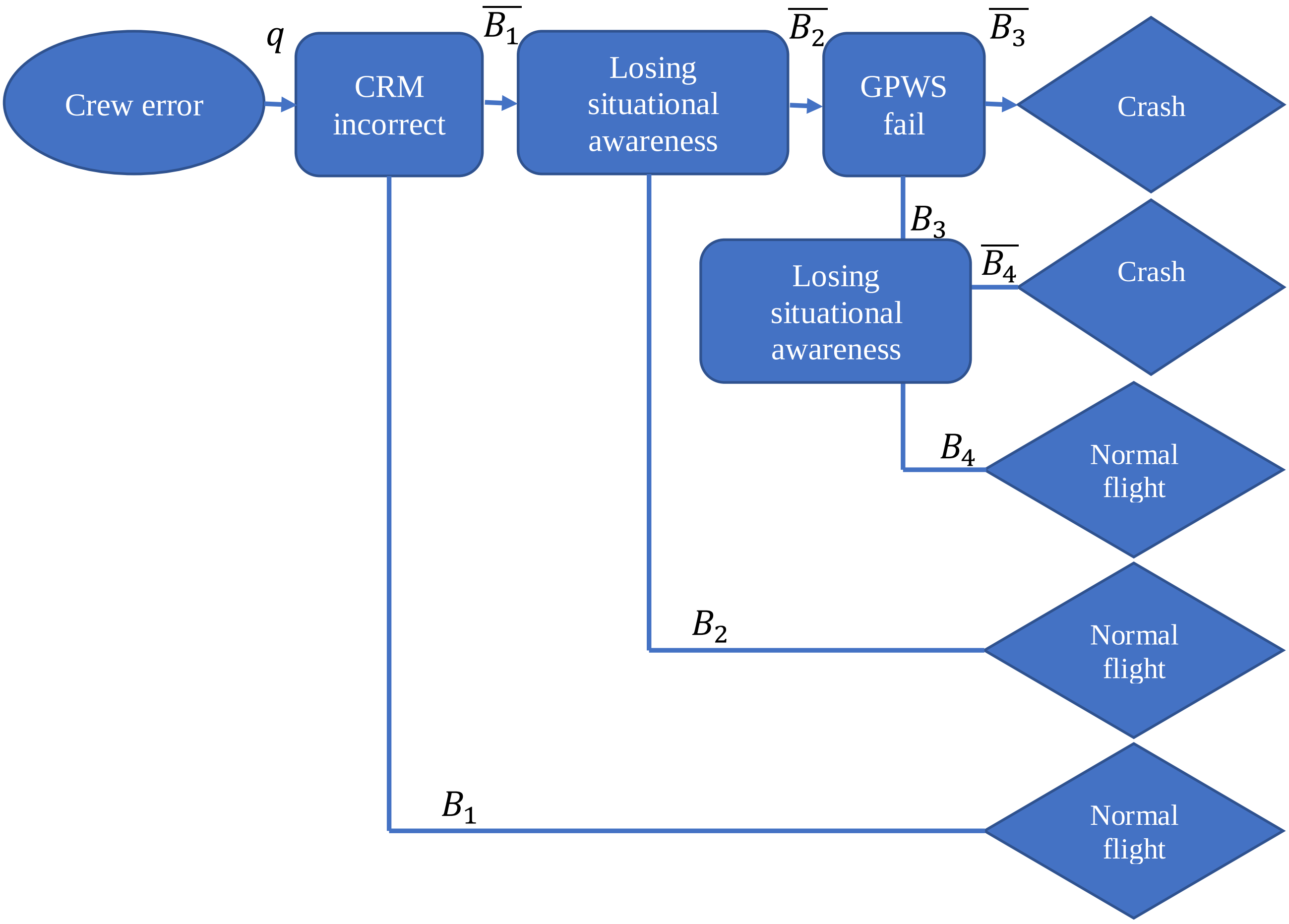

Figura 3.2**.** Scenarios for the occurrence of accidents in controlled flight in terrain (CFIT – Controlled flight into terrain) (adapted after - Georgiev 2021 [6])

3.3. Characteristics of an effective control system

An effective control system must report deviations from the standard performance level as quickly as possible. It is preferable that possible deviations are identified before they occur. It is important that deviations from the original plan are reported in a timely manner so that corrective actions can remedy the situation in a prompt and compliant manner. For example, information that the budget may be exceeded, or not reached, must reach managers in a timely manner to enable them to take proactive decisions in this regard, avoiding last-minute situations/drastic actions/limits. [7,8]

The process of creating a control system generally involves several stages. An example of this is the following [8] (figura 3.3.):

1. Studying the system to be controlled and deciding which types of sensors and actuators will be used and positioned.
2. Modeling the resulting system that requires control.
3. Simplifying the model, if necessary, to be flexible.
4. Analyzing the resulting model; determining properties.
5. Establishing performance specifications.
6. Establishing the necessary control methods.
7. Making a control mode that meets the specifications, if possible; otherwise, the specification or generalization of the desired control type must be modified.
8. Simulation of the resulting controlled system, using a computer or reference.
9. Repeating the algorithm from step 1 if necessary.
10. Choosing hardware and software platforms and implementing control.
11. Adjusting the control in dynamics, if necessary.

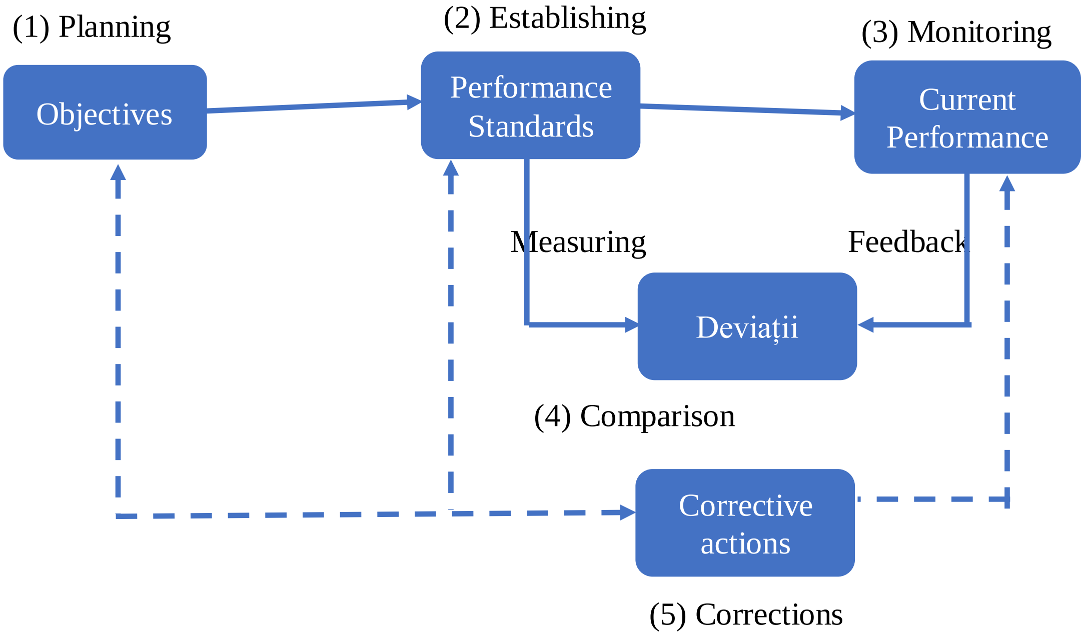

Figure 3.3. The five stages of organizational control (adaptated after Mullins 2011 [8])

3.3. Risk analysis and strategies for risk mitigation

The essence of risk management is the continuity of the process, as this can ensure a continuously improved risk management process that helps organization to meet its stated objectives. The process must not be limited to an operational structure, but must be a component part of a much larger process - organizational management (decisions taken at organizational level, with a preponderance of strategic ones). [7]

Risk is a concept used that has several meanings and definitions in the literature. The concept of risk includes both the dangers and the probabilities of their occurrence.

A hazard is defined as a situation that may cause harm to people or technical systems. This means that risk includes an assessment of undesirable events, their consequences and probabilities of occurrence. Mathematically, the risk can be written as follows [9]:

$$Risk = F(A, C(A), P(A)), \qquad \text{(ec. 3.3.)}$$

were A – unwanted event; $C(A)$ – the consequences of event; $P(A)$ – the probability of events occurring; F – unknown function (the state at a given moment).

The function F can be defined as follows:

$$Risk = \sum_{i=1}^{n} C_i * P_i, \qquad \text{(ec. 3.4.)}$$

were n – the total number of accidents or situations that are considered; C_i – the consequences of the accident or the situation from the initial moment i; P_i – the probability of occurrence of an accident or situation from the initial moment „i".

This is a simple method to define function „F", whose limitations and application areas are under discussion due to the complexity and dynamics within the aeronautical systems, and not only, from the present days.

Reliability of a system or component is the probability that it will function adequately in the system component for which it was designed for a specific period of time under the operating conditions encountered.

Carrying out the risk analysis, defining the performance levels in relation to the existing risk and the tolerance limits are proportional to the complexity and the investment desire of the organization. The problem in large organizations is the ability to understand the full spectrum of risk and distinguish individual risk, manage the risk, proportion the impact, ideally before it escalates to accident level. [10]

A reliable series system is extremely difficult and expensive to achieve; for example, if such a system would have 5 components in its structure and each component has a reliability of 0,9 (90%), then the system's reliability is:

$$0{,}9^2 = 0{,}81;$$
$$0{,}9^3 = 0{,}73;$$
$$0{,}9^4 = 0{,}66;$$
$$0{,}9^5 = 0{,}59.$$

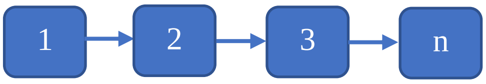

Figure 3.4. General diagram of series reliability in a system

When we talk about reliability in parallel the problem is different; basically the components complement each other, thus having the following mathematical relationships:

In the case of the reliability of a system with several parallel components (figure 3.5.) each components having a reliability of 0,9, then:

- for 2 components: $1 - [(1-0{,}9)(1-0{,}9)] = 1 - 0{,}01 = 0{,}99$.
- for 3 components: $1 - [(1-0{,}9)(1-0{,}9)(1-0{,}9)] = 1 - 0{,}001 = 0{,}999$.
- for 4 components: $1 - [(1-0{,}9)(1-0{,}9)(1-0{,}9)(1-0{,}9)] = 1 - 0{,}0001 = 0{,}9999$.
- for 5 components: $1 - [(1-0{,}9)(1-0{,}9)(1-0{,}9)(1-0{,}9)(1-0{,}9)] = 1 - 0{,}00001 = 0{,}99999$.

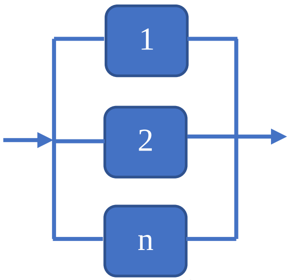

Figure 3.5. General diagram of parallel reliability in a system

The above example demonstrates that redundancy improves the reliability of systems.

3.4. Risk and reliability analysis for understanding risks and developing the operational level

Uncertainties are also conditioned by the short life cycle of the system/subsystem because only their short-term behavior is visible. This aspect is only useful for a short time in order to learn about the product and its behavior in the operational phase - when it works in the real conditions for which it was made. During this phase it is necessary to analyze the failure modes and the causes for which they occurred in a detailed, fast, but very careful way.

The reliability of a technical system is characterized by the working capacity of the system functions, in a particular time interval. Functional safety is synonymous with reliability; thus, the term refers to the proper functioning of a system/subsystem. A reliable system is one in which all specific functions are permanently ensured, regardless of conditions. For example, nowadays, software-ul is used in automotive industry, aerospace engineering and in medical technology. These areas are considered safety critical; in the event of a malfunction, people's lives and the environment are at risk; therefore, the reliability of software plays an important role in the safety of the domains in which it is implemented. The situation becomes critical when the price of a software failure, and the incorrect management of the situation, leads to the loss of human life, as happened in the cases of the two aircraft accidents Boeing 737 MAX 8.

Reliability analysis focuses on the probability that a system or component will perform its intended function within a specified period of time under specified conditions. [11]

In certain situations, reliability must be taken into account from the design phase when there is no statistical record of the number of possible failures. If there are human safety concerns, record keeping is not an option; there may be situations where previous product or system design experience is non-existent or limited. This implies that reliability must be assessed following material testing and computer simulations of various elements that are exposed to failure during the life cycle. Mechanisms and other structural elements that can suffer damage depend on the materials and how they are used during the operational phase.

3.4. Conclusions on Mathematical Modeling Elements of Safety in Aviation Systems

The methods and mathematical models presented represent a small part of those existing in the specialized literature, but they have a simple and effective approach for identifying, evaluating and understanding the risk in the air transport system.

A mathematical model for identifying the probability of risk must not only be efficient, but also simple to understand, both from the point of view of the calculation algorithm and from the perspective of interpreting the obtained values.

Considering the operational dynamics and the different philosophy of the managers, technical staff or flight staff the simplest and most effective model whose principles can be successfully applied in the air transport system, and which does not require specialized training in the field of safety, is series reliability (figure 3.4.) and parallel reliability (figure 3.5.). I believe that it represents the ideal approach by which to model the systems/subsystems that interact within the air transport system; through this approach the need for redundancy in the interaction between certain systems can be understood, and by assigning existing values to the subsystems a reference value for operational processes can be determined.

For this reason we have selected and used series and parallel reliability models and principles to develop the model for the interaction of total systems in aviation by assigning values from specialized statistical studies, on minor, major and catastrophic flight events, and representative scientific research from the air system.

CHAPTER 4 – Comparative study of technological systems in the air transport system to understand and identify the particularities of risks affecting operational safety

4.1. The technological system in the modern air transport system. The motivation for choosing the technological system used in development of the risk probability identification model

Commercial transport aviation is one of the most developed and complex industries globally. Even though there have been several companies that have produced commercial transport aircraft over time, only two companies have been able to continuously develop and improve their internal aircraft construction processes to meet the demands of the world market; these companies are Boeing and Airbus.

The rivalry between Boeing and Airbus is well-known in the aviation world. Both companies have been on the market for several decades, developing during this time many aircraft that have been the basis for improving the efficiency and safety of air transport. Both companies are true titans in the aviation world, successfully surviving in the commercial air transport system.

In 2011, Boeing announced project Boeing 737 MAX, which was to be sold in three variants (Boeing 737-7, Boeing 737-8, Boeing 737-9 ang Boeing 737-10) and which was considered as a replacement for the Boeing models 737-700 New Generation, Boeing 737-800 New Generation, respectively Boeing 737-900ER. Boeing 737 MAX aircraft is a forth generation of Boeing 737, who succeeds Boeing 737 Next Generation and competes in the commercial transport aviation market with Airbus series A320neo aircraft. In the wake of two air disasters (one in Indonesia and the other in Ethiopia), Boeing 737 MAX model was grounded on March 13th 2019. [12-15]

The operational efficiency of the Boeing 737 aircraft in the history of commercial transport aviation is impressive. Improving aircraft systems both to meet the needs of airlines in compliance with ICAO or FAA aviation safety standards and to improve aircraft control systems and instruments to provide pilots with a more efficient interface has been shown to be a foundation for the confidence of airlines, especially those in the United States of America, in the Boeing 737 aircraft, which is also demonstrated by the number of orders that are constantly increasing with each new series. Datas from tabel 4.1 have the role of briefly presenting the operational history of the Boeing 737 aircraft models presented above; it can be seen that the technological improvement has resulted in the increase in the number of aircraft delivered. At the same time, this aspect is an indicator of the development of the world air transport system, which is becoming much safer and more efficient. Even though the number of aircraft delivered has been increasing with each new model of the Boeing 737 aircraft, the accident rate has decreased, as can be seen in tabel 4.1, which proves an increase in safety level.

Tabel 4.1. Aircraft operational safety statistics Boeing 737 (values until february 2020) [13]

Model	**-100/200**	**-300/400/500**	**NG**	**MAX**
First commercial flight	10 Feb 1968	24 Nov 1984	17 Dec 1997	22 Mai 2017
Total number of aircrafts deliveries (Feb 2020)	1144	1990	7056	387
Number of accidents (W/O)	109	49	16	2
Percentage Aircrafts destroyed/ Aircrafts delivered	9,53%	2,46%	0,22%	0,52%
Primul accident (W/O)	19 Jul 1970	18 Ian 1988	30 Sep 2006	29 Oct 2018
Ultimul accident	18 Mai 2018	31 Mai 2017	05 Feb 2020	10 Mar 2019

Time frame from the first accident until the last one (in months)	574 months	351 months	160 months	4 months
Perioada de la primul zbor comercial până la primul accident	29 months	38 months	106 months	17 months

note: W/O – *Written Off* = aircraft destroyed.

Taking as a starting point the information provided by boeing.com and listed in table 4.1, conclusions can be drawn about the impact that the development of new models of the Boeing 737 aircraft, implicitly the technological development, had on operational efficiency and safety the commercial air transportation system.

4.2. The first air disaster of the Boeing 737 MAX 8 aircraft; flight Lion Air 610, 29th October 2018.

On October 29th 2018 a Boeing 737-8 MAX aircraft (with registration PK-LQP) operated by the Indonesian airliney Lion Air had to perform a flight from Jakarta Soekarno-Hatt la Pangkal Pinang with callsign LNI610; 11 minutes after take-off the aircraft crashed into the sea, north-east of Jakarta.

It was determined that on the previous flight, which preceded the accident, the pilots had an incorrect IAS indication on the left airspeed and a problem with the elevator trim, which operated uncommanded. Both issues were resolved by appropriate use of existing procedures, so the flight was completed safely – the pilots declared an emergency to ATC (*Pan-Pan*). After landing, the commander of the aircraft entered erroneous information in the technical forms, due to the failure to recognize the situation he encountered in flight, and following the maintenance processes, in response to the reported defects, the engineer who took care of the aircraft cleaned ADM (air data module) for left side pitot tube and ADM static to correct for IAS and ALT differences (altimetry) and then successfully carried out the ground test of the system. Corrected the control differential pressure problem by cleaning the electrical connectors and performed another satisfactory ground test. According to the company's electronic reporting system, the aircraft was flown the next day, after 7 hours on the ground. [16]

On the next flight, immediately after the aircraft detached, the data from the DFDR (digital flight data recorder) shows that there was a 20^{o} difference in the left and right angles of attack, a difference which was maintained until the end of the recording. Also in the same data it can be observed that only the controls on the left side were operated, apart from a 20 second interval, until the end of the recording; at no time was the autopilot engaged and the starboard controls were not actuated. [16]

In figure 4.1. the significant parameters during the flight are represented Lion Air 610 from the moment of take-off to the moment of impact with the ground. As can be seen in the graphic representing the trimers actuation, each time the pilot actuated the trimers (shown graphically in blue), there was an immediate response from the system that automatically actuated the trims (shown in orange) to bring them back to their original position. It can also be seen that the pilots only had to operate the trims after the flaps were retracted, which meant that when the flaps were retracted, the effort on the controls was not as great, so the aircraft could be kept in horizontal stable flight. The pilots' actions to control the aircraft via the trims, due to the high effort on the flight controls, resulted in altitude variations, while the indicated airspeed remained relatively the same. The flight control, specifically the control yoke, was operated limited time from takeoff to ground impact. After analyzing figure 4.1 it can be concluded that there was a constant struggle between man (pilots) and the technological system (aircraft), because of the different information they had at their disposal. Even though the technological system must support the pilot's actions for air safety and efficiency, in this case, the technological system did not allow manual control of the aircraft and caused an air catastrophe. At the same time, the pilots had difficulty understanding what was happening and how they could control the aircraft. If they had identified in time that removing the flaps helps control the aircraft, due to the way the technological system was designed, then the catastrophe could have been avoided.

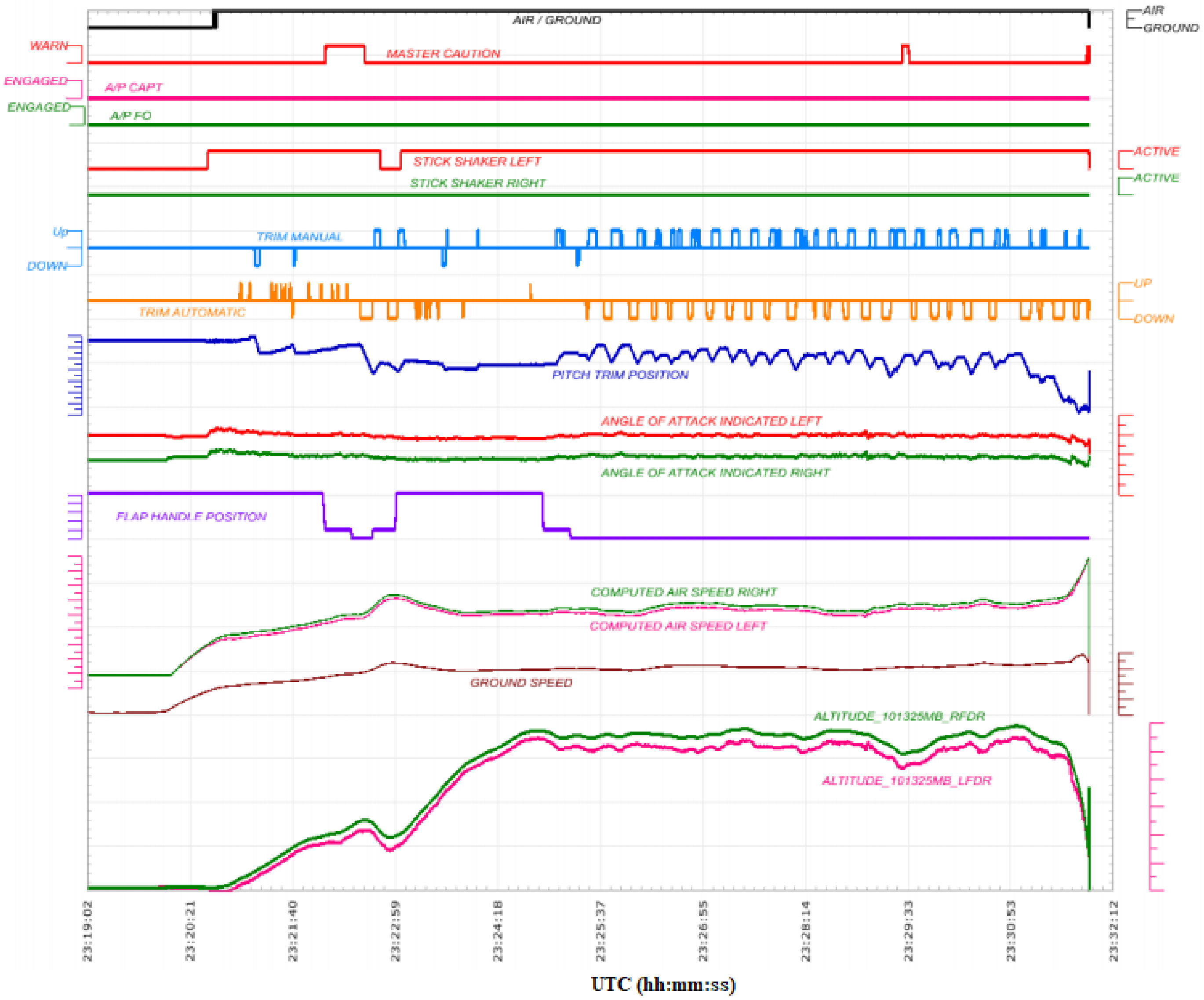

Figure 4.1. Significant parameters during the flight Lion Air 610 – information from DFDR (graphic taken from the investigation report of the catastrophe) [16]

4.3. The second air disaster with Boeing 737 MAX 8 aircraft: flight Ethiopian Airlines 302 – 10th March 2019

On March 10th 2019 a Boeing 737 MAX 8 aircraft (with registation ET-AVJ) operated by Ethiopian Airlines had scheduled a flight from the international airport Addis Ababa Bole, Etiopia to international airport Jomo Kenyatta din Nairobi, Kenya witch callsign ETH302; 6 minutes after take-off the aircraft crashed 28 nautical miles (51,86 km) from Addis Ababa area, near Ejere town. All 157 of persons, passengers and crew, on board the aircraft have died.

Immediately after takeoff, the angle of attack (AOA) sensors recorded different values. Left side AOA decreased to 11,1° then increased to 35,7 ° while the AOA value from right side indicated 14,94°. AOA value from left side reached 74,5° in ¾ seconds while AOA from right side indicated a maximum value of 15,3°. From this point, the flight controls on the left side were operated until the end of the recording. The flight speed, altitude and pitch indication value of the flight director from the commander's station were different from those of the co-pilot. The values on the left side were much lower than the values on the right until the end of the recording. [17]

Six seconds after the autopilot was engaged, slight roll oscillations accompanied by lateral accelerations, yaw oscillations and slight changes in flight heading were recorded. These oscillations continued until the autopilot was disengaged.

After receiving clearance to board the FL340 – the altitude set being 32000ft (8754m) - and were vectored by air traffic control, the pilot-in-command called for the flaps to be retracted, and the co-pilot operated the control lever from 5° la 0° - consequently the flap changed its position. The flight course has been changed from 072° la 197° and the commander told the co-pilot to request air traffic control to maintain the flight course related to the runway direction; 5 seconds later the autopilot has been disengaged. Shortly after disengagement of the autopilot, according to DFDR, the aircraft automatically went into descent (nose down) and remained so for 9 seconds, the trimmer changing its position from 4,6 la 2,1 units – GPWS system (Ground Proximity Warning System) alerted the pilots about altitude loss – „*Don't sink*". The flaps, both on the left and right wing, remained at the value of 0,019°. [17]

The co-pilot said twice „*stab trim cut-out*" – procedure in the flight manual to disengage the system MCAS. The pilot-in-command agreed to the execution of this procedure, and the co-pilot confirmed the execution of the procedure. At approximately 5 seconds from stopping aircraft's descent attitude – of the automatic elevator movement – automatically the trimmer commanded the aircraft in descent flight without the elevator changing its position. Three times the pilot-in-command told the co-pilot „*Pull-up*" to right the aircraft, the co-pilot acting accordingly – the two operated the flight controls simultaneously. [17]

With 32 seconds before the end of recording, at approximately 13.400ft (4084m), DFDR recorded two manual electrical inputs of the trimmer to pitch the aircraft. Elevator*'s* trimmer changed it's position from 2,1 units to 2,3 units. at approximately 5 seconds after last electrical input recorded, automatically the elevator trimmer was engaged for descent flight, and the elevator changed its position from 2,3 units to 1,0 units in approximately 5 seconds. The aircraft entered into descending flight; the pilots tried to level the aircraft, with constant effort being recorded on control yoke, but the aircraft continued its descent - the descent slope was increasingly accentuated, reaching up to 40º. Elevators position varied between 1,1 și 0,8 units for the entire recording. The last airspeed recorded by the left side airspeed indicator was approx 458kt (846km/h), and the right side airspeed indicator registered 500kt (926km/h) until the end of recording, that is, until the moment of impact with the ground. [17]

In the case of this air catastrophe it can be observed that following the manual operation of the trimers, the on-board computer reacted and tried to correct their position. Again, there was a problem between the inputs of the human factor, due to the information available and how he perceived the situation at the time, and the inputs of the technological system, i.e. the on-board computer, which received erroneous information from other systems and acted erroneously by attempting to correct a problem that did not exist.

In contrast to figure 4.1. for air catastrophe I which Boeing 737 MAX 8 aircraft operated by Lion Air was involved, in figure 4.2. there is also a parameter that indicates heating of the angle of attack sensor, a system that transmitted erroneous information to the on-board computer regarding the aircraft's attitude. This increase in temperature is due, according to specialists in the field, to the fact that during takeoff, a bird hit the respective sensor, and it blocked and heated up a lot, being covered by the remains of the bird.

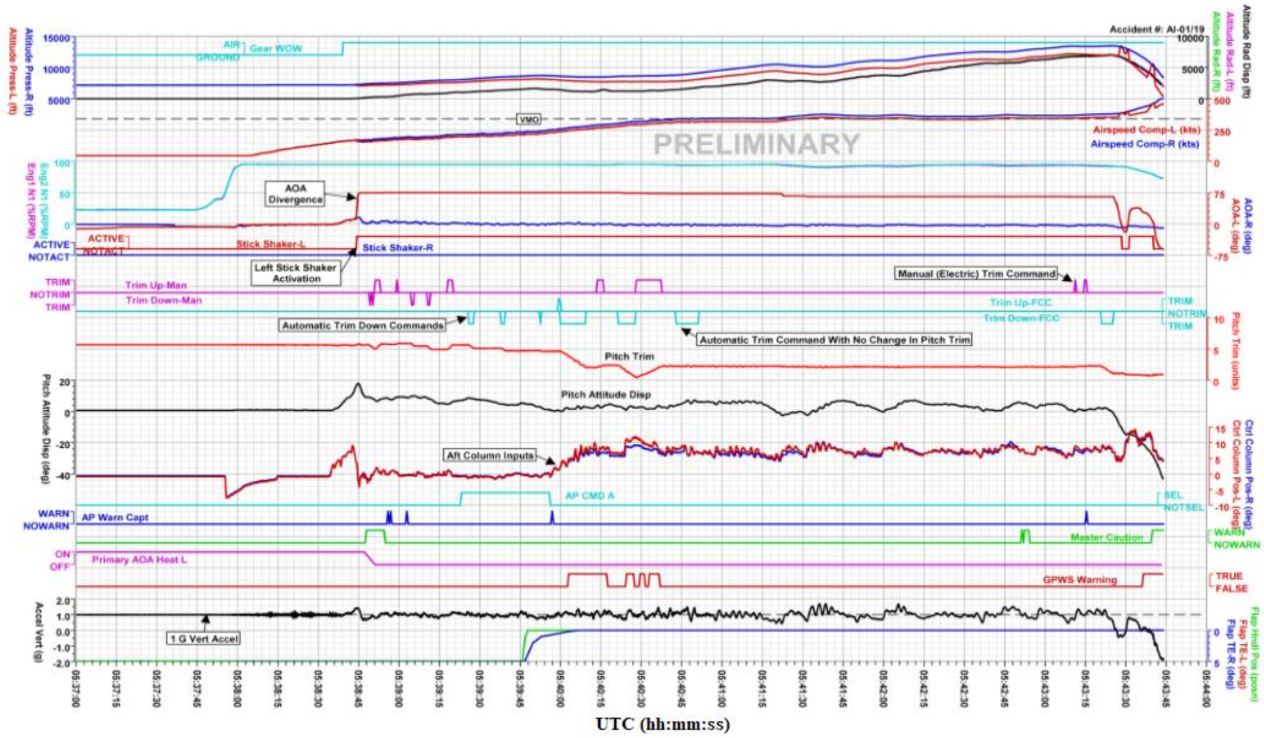

Figure 4.2. Significant parameters during the flight Ethiopian Airlines 302 – informations from DFDR (graphic taken from the disaster investigation report) [17]

CHAPTER 5 - Organizational management systems in the airline industry. Systems theory and organizational control.

5.1. Types of systems. General considerations on the evolution of systems and organizational control

By system, we understand an integrated set of elements (or components) that interact and whose purpose is to ensure a predetermined function [18]. Prin această definiție, în mod intenționat, se dorește acoperirea unui număr vast și diferit de sisteme. In organizational context this involves a large number of people, processes, technologies and materials that together perform an important function to achieve a well-defined goal - service or product development.

Systems in which life exists, such as organizations, exist in space and are composed of matter and energies (which are organized as information) [19]. Systems can be described through structures and processes. If a process is to be studied, a structure must be defined in a way that includes even the smallest units to be used. In other words, a process is always observed through the changes that take place in its structure.

The organization represents an element consisting of several sub-elements in interdependent interaction. The flow of inputs is the starting point when describing the organization. Each organization is a small part of a particular industry (a larger system), a society (another larger system), and the global economy (probably the largest system there is). Systems theory can describe the behavior of individuals and groups within an organization. An input (cause) can be processed by an individual both mentally and through psychological processes to produce a specific output (result). [20] Systems theory allows the description of internal and external behavior of organizations. Internally, it observes how and why people in the organization act individually and as a group. Externally, the relationships between organizations and institutions can be evaluated. All organizations obtain resources from a larger environment, the one they are a part of, and in return provide products and various services required by the environment they belong to. [20]

A complex system consists of a subsystem, which is a concrete construction, a technical system, without life, and another subsystem represented by humans, which is a living system [19]. The goal of the organization is to maintain the supersystem, which includes the technical and organizational system, and their subsystems, within the limits of the equilibrium state considering the multitude of existing variables. If this does not occur, the system structures and processes change and the system moves towards another equilibrium state. Depending on the change, the system may have difficulty surviving, but it is ideal to adapt to the new environmental requirements.

Systems theory allows us a better perception and understanding of the existing problem and at the same time helps in identifying the causes of the problem. By analogy, if doctors were only able to treat people's symptoms and never the disease itself, we would never be able to fully recover from an illness. Identifying not only the problem, but also the elements that cause the problem helps us to communicate much more effectively.

Organizational model from figure 5.1 represents the organization as a system consisting of a management subsystem and a transformation subsystem. The entire system is involved in multiple relationships, transactional and interactive, with different elements. For an aeronautical organization these elements can be: distributors, competitors, customers, governmental or non-governmental organizations, etc. [21]

The management subsystem deals with the management processes that include: decisions, planning, improvisations, checks, evaluations and control. The management subsystem makes decisions based on internal and external information. In addition to these elements, other important criteria for decision-making for management system are: organization values, organization standards, organization principles and business culture. Decisions are made to define the organization's strategy, initiate investments and control the operational and safety processes of the transformation system. The profit that the organization obtains can be perceived as a direct result of the decisions taken by the management subsystem and therefore can be considered as a feedback for management processes. At the same time, another feedback for management processes can be considered the level of safety and organizational efficiency. [21]

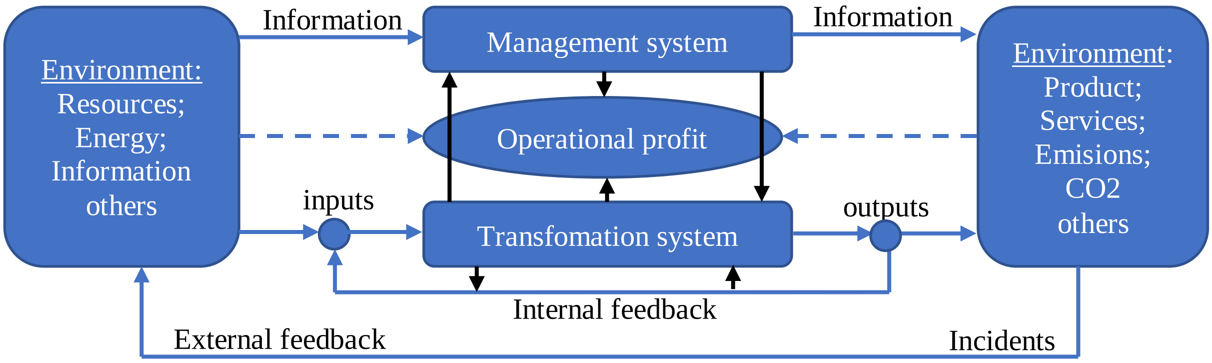

Figure 5.1. Theoretical model of organization in systems theory [21]

The primary goal of systems control management is to achieve congruence of objectives. Systems function as a means of distributing resources and responsibilities according to clear criteria through planning, monitoring, evaluation and reward. Complementary to this main goal of achieving goal congruence is the principle of using systems control management to reduce uncertainty [7]. Congruence of objectives as the primary objective of systems control management is not contradictory with the use of controls to reduce uncertainty because, even if a system is used for this purpose, it must achieve a certain level of coordination between people's interests who operate/use that system and organizational interests, thus allowing for "alignment of interests" [22]. The authors define alignment of organizational interests as "the extent to which organizational members are motivated to behave and act in accordance with organizational goals" [22]. The purpose of systems control management is to shape people's behavior so that it contributes to the achievement of organizational goals.

The literature on organizational fairness has investigated the objectivity of informal rules that create strong perceptions about it, therefore ensuring the best reactions, thus helping to achieve established organizational objectives. [23-25]

5.2. Conclusions on systems theory in transport aviation

The air transport system cannot be seen as a single element. The aircrafts, therefore the technological system, are not the only ones that have the characteristic of complexity, the organizations being also quite well developed and dynamic. Starting from the general definition of systems theory, I noticed that transport aviation fits perfectly into this definition: "interdisciplinary study of systems that can be groups, interconnected, natural interdependent or man-made. Every system is limited in time and space, being influenced by its environment, defined by a structure and a purpose, expressed by the mode of operation". [26]

The relationships between organizational systems give rise to risks whose severity depends on how operational elements are managed both at technological level and those related to human factor. Even if several organizations use the same technological system, it does not mean that the level of safety and efficiency is the same. For example, organizational policies and procedures, or their violation, have a major impact on air operations; In particular, as I presented in Chapter 4, the organizational relationship between Boeing and the FAA can have an impact on the work carried out by other airlines. This relationship together with technological and human particularities can lead to catastrophes, as it happened with the two air catastrophes with the Boeing 737 MAX 8 aircraft. Therefore, considering the situation in the air transport system where, as I stated before, complexity exists and is constantly expanding and developing, the understanding of systems theory is, from my point of view, very important because it allows a clear perception of how systems influence each other.

5.2. Conclusions on the importance of organizational control in transport aviation

Organizational control is a key function of management that tries to maintain balance in the organizational system. The existing complexity in the air transport industry, especially if we look at aviation from the "system-within-system" perspective, requires the development of this managerial function; the integration of a set of practices to regulate the activities carried out by people, such as theoretical training and institutionalized practice, becomes a very important process in an aeronautical organization. From my point of view, taking into account the organizational specifics and the particularities that an airline has, organizational control can be the source of strength to have stability, balance and organizational development, but at the same time it can be an element of vulnerability. The continuous development of systems in aviation and the need to maintain a high operational level even in moments of transition is a challenge, therefore I consider it very important that this characteristic of management - organizational control - is developed in parallel with the development of systems and their implementation in operational dynamics. Organizational control is fundamental to any aeronautical organization and can be considered the sum of the control elements of all other interacting systems in aviation.

CHAPTER 6 - System safety in operational processes in the air transport industry

6.1. The evolution of aviation safety

The transport aviation safety system has had different notable periods of evolution, these being (figura 6.1.): the technological era, the human factor era, the organizational era, and the total systems era that we are in today.

The technological era refers to the period between the early twentieth century and the 1970s, when aviation emerged and developed as an element of international transport, and identified safety deficiencies were associated with failures of a technical nature. Therefore, the investigation of technical problems and technological development represented the main element of research for aviation safety specialists of that period. Until the 1950s, with the technological improvement and the reduction of the accident rate, the development of the main objectives were focused on the area of regulations and compliances. [27,28]

The human factor era refers to the period between the early 1970s and the mid-1990s. In the early 1970s, the accident rate was considerably reduced due to technological improvements and imposed regulations. Aviation has become a safer means of transportation and the development of safety objectives has also developed the human-machine interface. Even though considerable resources have been invested in reducing human error, it is still a cause of many air disasters. [27,28]

The organizational era refers to the period between 2001 and 2010 when people began to perceive safety from a systemic perspective. In addition to technological and human factors, organizational factors were also included. Considering the impact of organizational culture and policies on risk safety management, the concept of structural organization was adopted. Traditional data research methods, and their analysis, have been limited by data collection in serious accident investigations and accidents. To address the issue, a new proactive approach to aviation safety has been introduced. During this period, civil aviation safety management focused on standardization and systematization by creating a structured work framework, building a safety system, establishing procedures and establishing operational standards. [27,28]

The modernization of commercial transport aviation and the increase in the spectrum of operations required the outsourcing of various services and cooperation with various companies in the aeronautical industry and beyond. That is why the aviation industry can be perceived as a system, with all other companies that support the services and flight operations of a company being perceived as sub-systems. This is how the concept of Safety Management System (SMS) was born. [27,28]

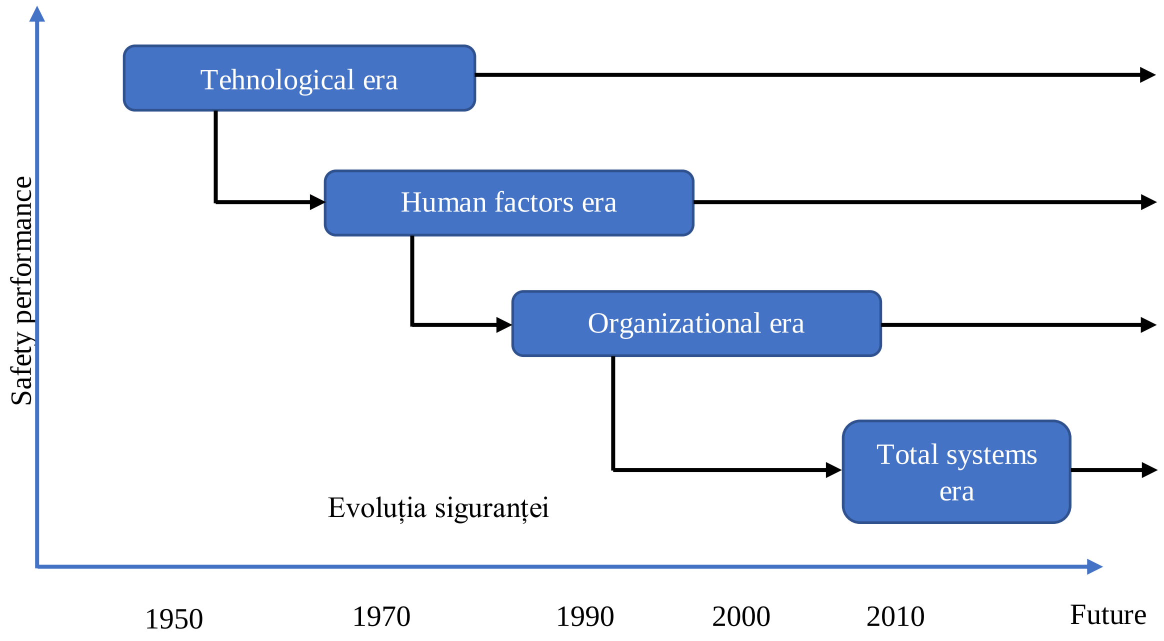

Figure 6.1. Evolution of aeronautical safety (adaptated after China GA Report 2021 and SMM 2013 [27,28]

6.2. Safety of the aeronautical air transport system

About aviation it can be said that it is a *'"system-of-systems"*. Maier (1998) [29] stated that "system-of-systems" are characterized by the following five elements: operational independence of elements, managerial independence of elements, continuous evolution, emergent behavior and a specific distribution of elements in the systems structure. In the context of aviation, these systems have a distinct operational independence (aircraft operation, maintenance, air traffic management/control) and each of these in turn have managerial independence (they are provided by independent companies or state structures); however, they are based on a common set of operating principles and international regulations regarding their structure and operationalization. All aspects of the aviation environment include technical, human and organizational aspects. Aviation is a socio-technical "system-of-systems" that encompasses critical human factor considerations such as attrition, readiness, projection, maintenance, safety, procedures, communications, workload, and automation.

6.3. The safety system in the modern era of transport aviation – *Safety Management Systems* (SMS)

Safety Management Systems emerged as a conglomerate of safety-related activities that enable an organization to meet its responsibilities under the spectrum of self-regulation. The role of the regulator has evolved to the extent that it seeks to support the organization and assess strengths and weaknesses SMS-ului. This change also brought many challenges for organizations that from this moment had to impose their own operational regulations and have positive results; at the same time, the regulatory authority no longer evaluates the compliance with the prescriptive regulations, but the efficiency of the entire system.

The transition from the prescriptive approach to the modern SMS involved a gradual evolution in that regulations sought to ensure the safety of systems operation. Certainly the period between 1970 and 1990 was that of "safety programs" characterized by new elements, and many of these elements are part of what we now call systems safety management - SMS. The initial formulation of the SMS was a vast collection of activities needed to ensure comfort and safety for organizations in the new era of regulatory requirements.

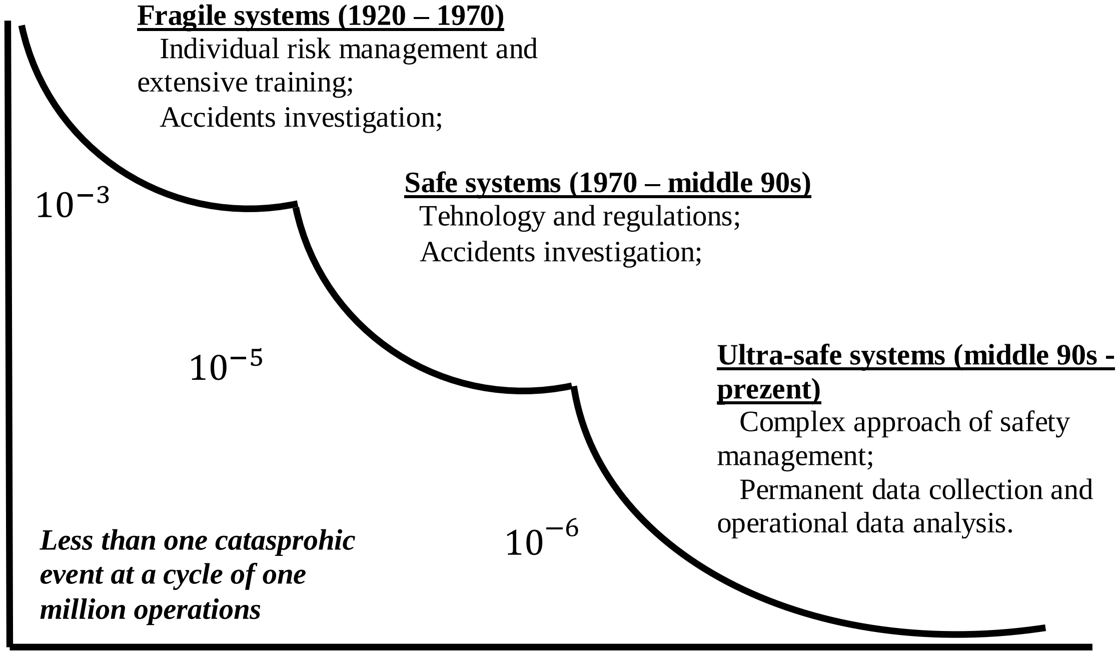

Figura 6.2. Evolution of ultra-safe systems (adapted after Amalberti [30])

Systems safety management (SMS – Safety Management System) can be defined as a method of planning, documenting and verifying the management of hazards and associated risks [31]. ICAO define this concept in more detail; systems safety management involves a systematic approach to risk management and includes organizational structures, responsibilities, policies and procedures. [28]

6.4. Safety of aeronautical organizational systems

Systems safety has two primary features; first of all, it represents a doctrine of management practices that obliges the identification of dangers and the permanent control of risk, being a collection of analytical approaches with which different doctrines can be put into practice. Systems are analyzed to identify hazards, and these hazards are risk-assessed to assist the decision maker. Management must decide whether the risk is acceptable or not; if unacceptable, then it will be decided what must be done, by whom, when and at what cost.

CHAPTER 7 - The impact and implications of the human factor in flight operational processes

7.1. Human factor considerations

Human error is a contributing factor of 70% of air accidents according to studies and statistics carried out in recent years. Usually, human error is associated with flight operations, but it has become a problem in maintenance and air traffic management processes. The term "human factors" became popular with the global development of the commercial air transportation system, as it was found that not only mechanical problems are at the root of aviation incidents and accidents, but also human factors problems. In narrow terms, human factors are considered synonymous with crew resource management (CRM) or with maintenance resource management (MRM). The study of human factors in aviation involves the collection of information about human abilities, limitations, and other characteristics that are then applied to instruments, machines, systems, or the environment, within operational tasks to achieve effective use of human resources. In aviation the study of human factors aims to help understand how people can integrate effectively and safely with technology, and this is achieved through ergonomic design, training, procedures and regulations. The outcome of this understanding must support processes that lead to improved human performance and help maintain a high level of human-pilot performance. [15]

Regardless of the speed of technological development, the human is responsible for ensuring success and safety in the aeronautical industry. Therefore, the person must be flexible, dedicated, efficient and constantly improve his knowledge while making the right decisions. At the same time, the aerospace industry continues to make major long-term investments in training, equipment, and systems. Because technology evolves faster than the ability to appreciate how humans will interact with it, the aerospace industry cannot depend on experience and intuition to make decisions about human performance. But scientific research is needed to evaluate human performance and its design, training and procedural implications, just as the development of a new type of wing requires in-depth studies in the field of aerodynamics. [15]

The human factor is a complex issue; interaction between pilots/crew members, implicitly crew resource management procedures are part of a wide field, difficult to quantify in a numerical value; but this is an aspect from the field of psychology, and in the model that I have created in this thesis, in chapter 8, it does not seek to emphasize the human factor, although its importance in aeronautical operations is inexhaustible, that is why I studied the issue regarding the human factor, emphasizing aeronautical circumspection, an element that was essential in the catastrophes presented in chapter 4.

For the calculations made in chapter 8 of this paper, I used as a starting point the study published in the International Journal of Aviation, Aeronautics and Space and entitled *Validating the Knowledge, Skills, and Abilities Composite Measure: An Aviation Industry pilot Study* din anul 2015 [32]. It refers to the importance of experience, certifications and qualifications for pilots, managing to quantify these results following psychometric studies carried out in the aeronautical field; the basic idea of the study and the values obtained by the authors were also used in the intersystem risk model carried out in the case study of the present thesis to implement and capitalize on the human factor.

Following the study regarding the paradigm of educational change in aviation, Earnhardt, Newcomer, Watkins și Marion (2014) [33] highlighted that education, certification and experience (ECE) are important aspects in the aeronautical industry; the importance of each element varies according to the organization and its culture. The authors made a connection between education, certification, experience and the (potential) knowledge, aptitude, ability (KAA) aspect that greatly influences the decision to hire or promote someone in the aeronautical field. Understanding the relationship between ECE and KAA is extremely important to identify the ideal combination of KAA in the aerospace industry because KAA also influences the decision-making factor. [34]

7.2. Situational awareness – fundamental element in aeronautical operations

In aviation, maintaining a high level of situational awareness is one of the most difficult characteristics of a crew. Situational awareness can be learned, thus developed as a skill, in the form of an internalized mental model of the aeronautical environment at a given time.

Situational awarness in aviation is formally defined as the perception of all elements in the environment in a certain volume of time and space, the comprehensive understanding of the meanings and the anticipation of the status in the near future [35]. Briefly, it refers to the perception of critical factors in the environment (Level 1), the understanding of those factors, especially as they relate to the objectives of the crew members (Level 2), and at the highest level, the understanding of what might happen to the system in the near future (Level 3). These higher levels of aeronautical circumspection allow the pilot to act in a timely and efficient manner.

CHAPTER 8 – Model for identifying risk probability in total systems in transport aviation transport

The model I developed is based on the concept of total systems presented in chapter 6 (figure 6.1.); even though aviation safety has evolved over time from technological, to human, and then organizational elements, the complexity of the systems currently in place in transport aviation requires the development of models that emphasize the interaction between the three main systems (organizational system, technological system and human system (human factor) (figure 8.1) to understand the risk register in the air transport system. A relationship must exist and be developed between the three main systems in transport aviation; the organization must develop an institutional plan adapted according to the technology used and the particularities of the human factor identified following specialized training.

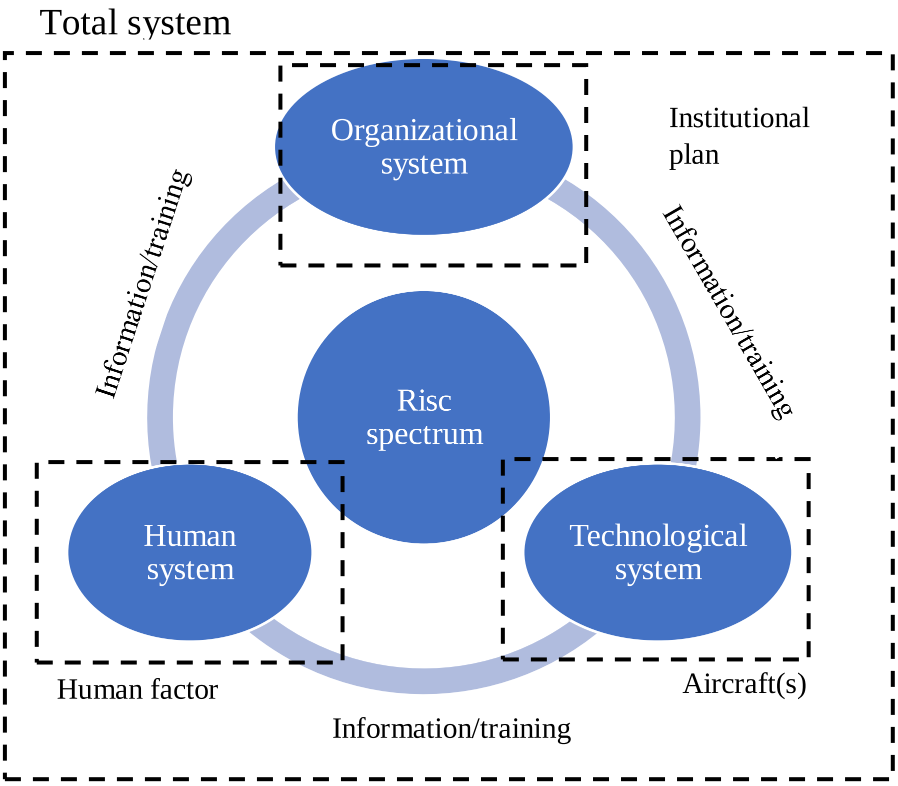

Figure 8.1. The general scheme of the model proposed in the thesis

To improve aircraft reliability and safety, components within these systems are periodically checked and repaired at well-defined time or operational intervals. Depending on the criticality and functionality of these components, some are checked before flight, others after a certain period of time, flight hours or after a number of operating cycles, according to the company's maintenance program or the one imposed by the company that built the aircraft.

The organizational environment encompasses all factors or forces that can potentially impact organizational performance or operations. There are two types of definitions for the organizational environment - in general or narrow context. In general, it refers to the entire environment both outside and inside the organizational boundaries. For a given organization, the external environment can be divided into the specific and the general environment. The specific environment directly influences the manager's action decision and is relevant in achieving organizational goals – environmental tasks. [37]

8.1. Elements used to develop the proposed model – theoretical considerations

Both the study and scientific research carried out for this paper as well as professional experience helped me to develop in the early stages the model for identifying risk probability in total systems in transport aviation.

To obtain the numerical value of the organizational system, several variables were taken into account; a value rigorously obtained following a complex algorithm and comprising many variables, listed below, according to the information provided by the authors, is the JACDEC safety risk index [38]. The higher the percentage value, the safer the airline in question is considered; in the ranking made by JACDEC there is no airline that holds the index of 100%, which means that there is still a residual value of the risk - value that was used in the calculations.

Accorfind with www.jacdec.de [38], the methodology and definitions underlying the risk index are quite broad. JACDEC specialists take into account only the companies that had over one million passengers per year in four consecutive years. The way in which safety has been quantified has become much more complex and better understood, so that it is now possible to compare the level of safety of airlines around the world through it. JACDEC safety-risc index it is based on many components, the most important being the following [38]:

1. *Accident/incident history*

- *Revenue Passengers Kilometers – RPKs.*
- *Fatalities.*
- *Total number of injuries.*
- *Total number of losses.*
- *Number of incidents.* .

2. *Environment factors*

- *IASA audit.*
- *Transparency.*
- *Universal Safety Oversight Audit Programme*
- *Country risk factors 1.*
- *Country risk factors 2.*

3. *Organization - the airline and the operator's risk factors.*

- *IOSA audit*. IATA.
- *Age of fleet in use.*

- *Operational Routes Profile*.
- *European Union list of airlines banned from European airspace for safety reasons*.
- *Operational risks*.

Even though this index includes a lot of elements, any airline safety index must be considered imperfect due to the complexity of all methods of managing/reducing/eliminating risk in aviation - denying this aspect is a big mistake. Certain key sectors in aviation such as crew member fitness or maintenance issues are covered in a superficial manner, and this is mainly due to the lack of a global supranational audit system covering these issues. However, the JACDEC risk index can be regarded as an estimate and as an ideal reference for understanding the level of risk of air operators. At the same time, it can be an ideal tool to compare major airlines globally by combining the main safety parameters.

Within the proposed model, in addition to the JACDEC safety index, I considered for calculations the human factor as a system that manages risks and operational modes, the environment as a system that influences through external variables the operational state and that can generate risks (for example weather conditions or birds), which must be managed by the flight crew, and the technological system another system, the central system, which is operationally influenced by both environmental variables (*inputs*), but also by the response (output data) of the flight crew to these variables; also, maintenance processes can influence the operation of the technological system, so new operational variables (input data) appear.

Considering the technological complexity of a modern aircraft, for the proposed model I took into account the technological element of the flight control system architecture of the Boeing 737 MAX 8 aircraft, namely the MCAS system that I explained in chapter 4. This component was taken as a reference because it was directly affected by maintenance and environment during the two catastrophes, and the risk due to these variables increased considerably due to elements that would not have affected the flight of aircrafts from past generations, under the given conditions; a new aircraft is designed to reduce operational risk, and software systems are meant to improve flight efficiency and safety, but an incorrectly implemented system demonstrates, in this situation, that the risk appears in a different form – the risk is rescaled. The difficulty of managing these risks and the lack of information were the premise for the occurrence of air disasters, according to scientific research carried out in chapter 4.

For the errors of the MCAS system, implicitly of the technological system, I used the value of „10^{-5}" for both Lion Air and Ethiopian Airlines flights; this value represents the probability of a major in-flight hazard used by the FAA, EASA, or ICAO for the possibility of a major flight event due to associated hazards. In this document and the ICAO Safety Management Systems manual, also mentioned in Chapter 6, risk levels for software systems are classified, and a major risk can occur at a probability of $1*10^{-5}$. In the case of the two Boeing 737 MAX 8 air disasters, both poor maintenance and environmental factors contributed to the development of a latent risk of the MCAS system, a risk that did not exist in previous generations of the Boeing 737 aircraft.

70:20:10 leaning model was developed by Morgan McCall, Robert Eichinger și Michael Lombardo at *Center for Creative Leadership* during 1990s. Following a study on the philosophy of learning carried out on almost 200 people with management positions, they reached certain conclusions and created a new paradigm of learning [39], which states the following:

- 70% learning is the result of challenging tasks – experiential learning is the result of the tasks and challenges people face at work;
- 20% from developing relationships – this aspect is achieved through mentoring, feedback and peer relationships;
- 10% from courses and training – formal learning.

Even though many years have passed since this model was presented, it remains a reference even today, being used to achieve an organizational balance in terms of employee training. The model is flexible; it can be used to gain productivity from employees or it can have a strategic role, such as continuing professional development. At the same time, the model is an informal training method that proves effective; 70:20:10 model assumes that both managers and all staff are involved in training, and this factor is extremely important because staff can be motivated to stay in the organization. [39]

8.2. Calculating reliability between systems. The relationship between technology and human factor – mathematical exemplification

The model proposed in this thesis is divided into two stages. In the first stage, the value of the probability of the interaction risk between the systems (technology and human factor) is identified, and in the second stage, the importance of theoretical and practical training is demonstrated in the context of the operational risk probability. Organizational risk is considered to be the residual value of the JACDEC safety risk index, this residual value of the safety risk index is obtained by subtracting the percentage value of the JACDEC risk index from the maximum possible value, by default 100%.

In the second stage, the reduction of probability of existing risk is calculated by means of accumulated information and knowledge. For these reasons I added the variable $DROP$ – variable for reducing the probability of operational risk through training (Figura 8.2.) – which is different according to operator's strategy, having, among other things, economic implications due to the processes involved. It is implemented according to the needs of theoretical and practical training of human operators, pilots, based on the information and knowledge acquired; the variable represents the practical stage – the simulator, and the values it can have are from 70% la 100%, depending on the level of training, thus passing rate of the simulator, obtained by pilots after completing this practical evaluation stage; lower values than those mentioned are not considered because in aviation the value of 70% is generally accepted as the minimum grade for which a pilot is declared admitted to fly.

The values obtained as a result of completing the practical flight stages are multiplied by 10% (formal learning according to the model 70:20:10) for each stage finalized and promoted, being related to the knowledge previously acquired following experimental learning; the values of the passed practical phases are summed and then multiplied by the value of 0,7 which represents the weight that practice has in the learning process according to the model 70:20:10 mentioned above. The variable for reducing the probability of operational risk through training (figura 8.2.) it can have multiple different forms, in the paper I used it for mathematical exemplification only 5.

In the proposed model, calculations are made for multiple and varied situations to cover the different possibilities of the operator's strategy, i.e. of the airlines. The variable for reducing the probability of operational risk through preparation can have several mathematical forms, which are as follows:

- $\boldsymbol{DROP_1} = \mathbf{0,7} * \textbf{value practical phase} = \mathbf{0,7} * 0{,}7;\ \mathbf{0,7} * 0{,}8;\ \mathbf{0,7} * 0{,}9;\ \mathbf{0,7} * 1.$
- $\boldsymbol{DROP_2} = \mathbf{0,7}\ (\boldsymbol{value\ simulator}\ \mathbf{1} + \boldsymbol{value\ simulator}\ \mathbf{2} * \mathbf{1,1})$ - $\mathbf{0,7}(0{,}7 + 0{,}7 * 1{,}1);\ \mathbf{0,7}(0{,}7 + 0{,}8 * 1{,}1) \ldots.;\ \mathbf{0,7}(1 + 1 * 1{,}1).$
- $\boldsymbol{DROP_3} = \mathbf{0,7}\ (\boldsymbol{value\ sim}\ \mathbf{1} + \boldsymbol{value\ sim}\ \mathbf{2} * 1{,}1 + \boldsymbol{value\ sim}\ \mathbf{3} * 1{,}2)$ - $\mathbf{0,7}(0{,}7 + 0{,}7 * 1{,}1 + 0{,}7 * 1{,}2); \ldots.;\ \mathbf{0,7}(1 + 1 * 1{,}1 + 1 * 1{,}2).$
- $\boldsymbol{DROP_4} = \mathbf{0,7}\ (\boldsymbol{value\ sim}\ \mathbf{1} + \cdots + \boldsymbol{value\ sim}\ \mathbf{4} * 1{,}3).$ - $\mathbf{0,7}(0{,}7 + 0{,}7 * 1{,}1 + 0{,}7 * 1{,}2 + 0{,}7 * 1{,}3); \ldots.;\ \mathbf{0,7}(1 + 1 * 1{,}1 + 1 * 1{,}2 + 1 * 1{,}3).$
- $\boldsymbol{DROP_5} = \mathbf{0,7}\ \boldsymbol{value\ sim}\ \mathbf{1} + \cdots + \boldsymbol{value\ sim}\ \mathbf{5} * 1{,}4)$ - $\mathbf{0,7}(0{,}7 + 0{,}7 * 1{,}1 + 0{,}7 * 1{,}2 + 0{,}7 * 1{,}3 + 0{,}7 * 1{,}4); \ldots.;\ \mathbf{0,7}(1 + 1 * 1{,}1 + 1 * 1{,}2 + 1 * 1{,}3 + 1 * 1{,}4)$

  or
- $\boldsymbol{DROP_{\mathrm{n}}} = \mathbf{0,7}\ \big(\boldsymbol{value\ sim}\ \mathbf{1} + \cdots + \boldsymbol{value\ sim}\ \mathbf{n} * \mathbf{1}, (\mathbf{n} - \mathbf{1})\big).$

where,

- $\mathbf{0,7}$ – represents the experimental learning according to the model 70:20:10, being the value by which the practical phase (simulator) is multiplied in the case of the present model;
- *the value* of the practical simulation stages varies according to the scoring done in simulator, and each additional stage is multiplied by 10%, this value representing previously acquired knowledge; considering that a grading has been achieved from 70% (0,7) la 100% (1), depending on the level reached, during the process of learning the specific situations according with the training program on the simulator. The values obtained in the simulator are summed, and then the obtained sum is multiplied by the experimental learning weight according to the model 70:20:10.

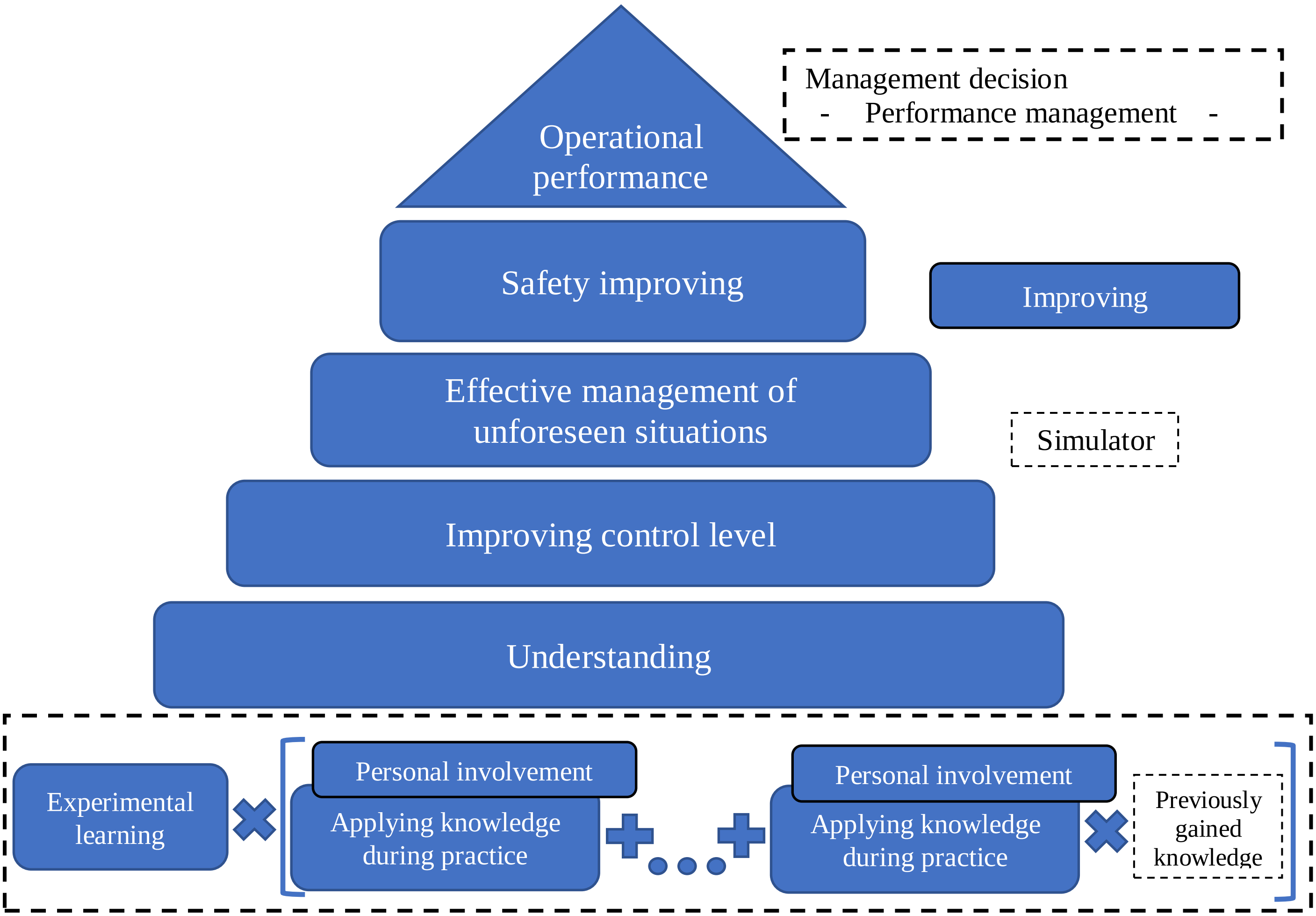

Figura 8.2. The general scheme of temporal-applicative variable proposed in the present model for reducing probability of operational risk through training (DROP) (author's contribution) [40]

The mathematical form of the model explained above for identifying risk probability (P_{RiscOp}) following the interaction between systems in operational context is as follows:

$\frac{1}{\boldsymbol{DROP}}[(\mathbf{100} - \boldsymbol{JACDEC}) + (\mathbf{100} - \boldsymbol{rel.sys.int.})]/\mathbf{2}$ **= the probability of operational risk**

(ec. 8.1.)

unde,

- $\boldsymbol{DROP}$ – variable for reducing operational risk through preparation;
- $\boldsymbol{JACDEC}$ - safety level index, according to specialists from Aviation Safety Center (jacdec.de) ***Airline Safety Information***;
- $\boldsymbol{rel.sys.int.}$ - reliability of system interaction (technological and human system (human factor) resulted from calculations.

I analyzed the accidents involving the Boeing 737 MAX 8 aircraft from the point of view of system reliability. For the human factor I have always used reliability in parallel, explaines in chapter 3 and values from Earnhardt et al. study (2015) [33], because the tasks are divided during the flight, the crew members having very well established roles, but which at any moment can change, and at the same time the role of the crew members is to support each other - as stated before and exemplified in the figure 8.3, which represents the general scheme of the interaction between the systems in the case of the two catastrophes with the Boeing 737 MAX 8 aircraft.

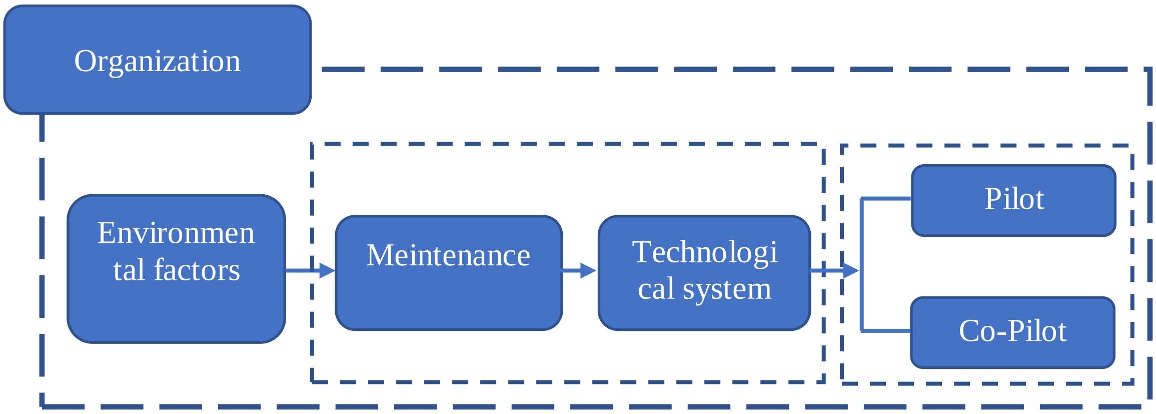

Figure 8.3. The general scheme of the interaction between the systems in the case of the two catastrophes with the Boeing 737 MAX 8 aircraft

In case of series reliability and parallel reliability for human factors in the situation of an incident-free commercial transport flight with the Boeing 737 MAX 8 aircraft, we have the following equations, according with chapter 3, subchapter 3.7:

$R_{MAX8}(t) = 1 * (1 * 1) * [1 - (1 - 0{,}85)(1 - 0{,}75)] = 0{,}963.$ – this value represents the reliability of interaction between systems for the incident-free flight of the Boeing 737 MAX 8 aircraft. (ec. 8.2.)

The values used (neutral value, „1”) in this calculation have the role of highlighting that in a flying situation in which the environment and software system of the aircraft, or other variables, do not influence the flight of the Boeing 737 MAX 8 aircraft, then the only system that influences the flight operations is the human factor. So it can be concluded that pilot training is the one that influences safety and efficiency the most during flight operations in commercial transport aviation, implicitly, the reliability of the system and of human-machine interactions during flight.

If the elements that caused the catastrophes were independent of the MCAS system implemented on aircraft and did not have the ability to influence air safety and efficiency, then we will obtain the following values, using the calculation formula for parallel reliability and values for human system (human factor) also used in the previous example for the series reliability of the system:

$R_{MAX8}(t) = 1 - [(1 - 1)(1 - 1)(1 - 0{,}963)] = 1$ - in this situation, the reliability between systems interaction between the flight of the Boeing 737 MAX 8 aircraft is higher. (ec. 8.3.)

This rearrangement of elements that caused the air catastrophes demonstrates that an initial design that minimized the impact of improper maintenance, software errors, and environmental elements on MCAS operational system (technological system), would have provided a much higher reliability to Boeing 737 MAX 8 aircraft, and the risk of an air catastrophe that this system could have produced was a low one.

CHAPTER 9 - The thesis conclusions. The need to develop training programs in the organizational environment

9.1. Conclusions

The model presented in chapter 8 was made to demonstrate the interactions between organizational system, technological system and human factor and to provide the possibility of obtaining a numerical reference of probability of occurrence of an aviation event with major consequences in order to understand the complexity and importance of control elements in total system existing in commercial transport aviation. Thanks to technological development, high level of automation and standardization at global level, the interacting elements in the aeronautical field can be quantified; but these values must be understood as a reference for application of procedures and algorithms necessary to manage risk in the dynamic spectrum of aeronautical operations. I developed this topic in personal scientific works entitled ***„Considerations regarding process control in aeronautical organizations in the context of improving safety and efficiency”*** [7] and **„*Risk Management and Organizational Considerations for Enhancing Safety State Given the Continuous Technological Development Processes*”** [41]. In transport aviation, safety has become a multidisciplinary problem considering the multitude fields and systems involved that must work in a coordinated and conjugate manner, being necessary features of flexibility and adaptability for the requirements of commercial air transport market, regardless of their nature – economic, technological or due to transformations imposed by new regulations at regional or global level.

The model I created is based on the principles of serial and parallel reliability that was presented in the present thesis and also that I developed in the scientific paper entitled ***Assessment of the Impact of Technological Development and Organizational Complexity in Air Transport*** [40] and which was presented during the international conference ZIRP 2021. Existing operational safety models and approaches that discuss risk within aviation systems do not currently provide a clear insight into how risks may arise during interaction with other systems and whether risk is rescaled within these interactions if other variables arise. From a mathematical point of view, the existing models that have been presented in this thesis require specialized mathematical modeling of elements or subsystems from their structure, providing a perception of risk at a micro, not a macro level.

After obtaining the values from reliability calculation between the systems for flights with Boeing 737 MAX 8 aircraft of Lion Air and Ethiopian Airlines companies in chapter 8, the importance of theoretical and practical training for improving the level of safety and aeronautical efficiency in modern air transport is highlighted.

Concluding the results obtained for the two airlines that have the Boeing 737 MAX 8 aircraft in their fleet and that faced aeronautical catastrophes due to resizing the risk through implementation of new technological elements, it can be seen that the probability of risk decreases with the increase in the levels of theoretical and practical training; practical training – flight simulator – it has a large contribution to decreasing the level of risk, which is a normal aspect. The simulation of critical emergency situations, complex events due to the influence of environment or different situations affecting the human factor, starting from lessons learned from incidents, accidents and air catastrophes produced over time, are extremely important in the context of air transport development and increase in system's complexity. Computer systems are built to support the human factor and aircraft mechanical systems are designed to simplify maintenance processes, improve reliability, streamline air operations; a reliable system, allows managers a globally standardized approach to aircraft operation, giving them the opportunity to focus on other organizational aspects in order to develop the airline.

Given the multitude of resources available to improve operational safety and efficiency in transport aviation, accessing them is an organizational decision directly related to financial aspects. But a model that identifies probability of operational risk in total systems supports the organizational decision and contributes to obtaining the characteristic of organizational control, thus being able to use available resources efficiently.

The obtained values represent the probability of occurrence of a flight event due to risk levels, and through theoretical and practical training it can be observed that risk decreases considerably; obviously these values are dependent on organizational decisions, on theim plication and organizational commitment for safety, on managerial approach to reduce risk that involves resources, material and financial, necessary to improve understanding of emergency situations, of operational algorithms specific to geographical region – in the context of specific risk characteristics to the respective region and resulting from the regional/national culture, so the one that has direct implications on organizational culture of airlines.

9.2. Personal contributions

The architecture and mathematical modeling that I used in order to demonstrate the level of risk during the systems' interaction in operational phases of transport aviation and the reducing method represent for aeronautical operators, therefore for aeronautical companies, a possibility to evaluate the level of aeronautical safety when aviation systems interact and a method of self-evaluation of personal training level for pilots. The model I proposed can also be commonly used by aviation safety departments within airlines to assess operational safety level in organization and to propose different training strategies for aviation personnel with the aim of improving level of operational safety.

Unlike other models and specific approaches to risk management, this model developed in current thesis is multidisciplinary, having in its structure different probability values from multiple specific fields of study (technological, organizational, human factor, informational and environment) commercial air transport system, thus encompassing a broad spectrum of risks specific to aeronautical operations. The simplicity of model, unlike other predictive models presented in thesis, does not require specialized computer software programs to identify probability of a major aeronautical event; this feature makes it very useful and easy to use by transport aircraft crews.

Based on results obtained from calculations made through the model proposed in chapter 8, conclusions can be drawn regarding the need to improve the trainig level in air transport aviation in order to increase safety and efficiency. These obtained values should be understood as references for the operational activity in context of interaction between systems in transport aviation and can be used to improve programs and organizational processes of airlines.

9.3. Further development prospects

The scientific study and research started with my undergraduate thesis, continued with dissertation thesis and completed with this thesis, as well as professional experience helped me to develop in early stages the model for identifying risk probability in total systems in transport aviation. The model can be modified; simultaneously with development of aviation systems, any model and method can be improved, and in present case the DROP variable can be reformulated to obtain much more accurate data. Also, the model can be implemented and adapted on several types of aircraft and may also have applications in military air transport system, even though the risks are different.

The human factor is a complex issue; the interaction between pilots/crew members, implicitly *Crew Resource Management,* are part of a broad field, difficult to quantify in a numerical value; but this is an aspect of psychology field. That is why the values can be modified along with the development of other specialized studies for human factor in aviation, and the present thesis addresses the issue of human factors from the perspective of aeronautical circumspection, an element that was essential in the catastrophes presented in chapter 4. As values may be used for other aeronautical organizations or aircraft types (Airbus, Bombardier, Gulfstream and others) so the human factor can have much more precise values that take into account more cognitive and motor elements specific to pilots.

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