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# Aeronautical maintenance system development strategies with flight safety implications

## SUMMARY

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**ABSTRACT**

The aviation industry has come a long way since the early 20th century. The early pioneers of aviation faced many challenges, including limited technology and a lack of understanding of aerodynamics and aviation safety. As the industry has grown, so have the risks and dangers associated with air travel. Today, aviation safety management is a complex and multifaceted process that involves the collaboration and cooperation of aeronautical industry organizations.

One of the key drivers of aviation safety management (MSA) has been the establishment of international regulations and standards. The International Civil Aviation Organization (ICAO) was established in 1944 to promote international cooperation and standardization in the field of aviation safety. Today, ICAO sets standards and recommended practices for all aspects of aviation operations, including aircraft design and maintenance, air traffic control and airport operations.

In recent years, the aviation industry has made significant progress in improving safety management through the use of technology, data analysis, and improved communication and collaboration between stakeholders. One of the most significant advances has been the implementation of safety management systems (SMS) by many aviation organizations.

In addition to SMS, the aviation industry has also benefited from technological advances. Aircraft design and manufacturing have improved significantly in recent decades, resulting in safer and more reliable aircraft. Modern airplanes are equipped with numerous safety features, such as backup systems for critical components and advanced warning systems that alert pilots to potential hazards.

Furthermore, advances in data analytics and predictive analytics have enabled aviation organizations to identify and mitigate risks before they lead to accidents or incidents. For example, remote monitoring systems and predictive analytics tools are used to monitor aircraft systems and detect potential problems before they occur. This proactive approach to maintenance can prevent mechanical breakdowns and reduce the risk of accidents.

Despite these improvements, the aviation industry still faces significant challenges and risks. One of the most significant risks is the emergence of new technologies such as unmanned aerial vehicles (UAVs) and supersonic aircraft. These technologies present new safety concerns that must be addressed, including the potential for collisions with other aircraft and the need for specialized training and certification for pilots and operators.

In addition, the COVID-19 pandemic has introduced new risks and challenges to the aviation industry. The need for social distancing and increased hygiene protocols have led to changes in airport and aircraft operations, and the pandemic has had a significant impact on demand for air travel. Aviation organizations must implement new procedures and protocols to ensure passenger and crew safety while maintaining efficient and cost-effective operations.

To meet these challenges, the aviation industry must continue to invest in safety measures and technology. Implementing new safety systems, such as collision avoidance technology for UAVs and advanced weather forecasting systems, can help mitigate risks and prevent accidents. In addition, industry must work collaboratively and transparently to identify and address emerging risks and hazards.

Aeronautical maintenance systems are designed to ensure that aircraft are maintained in safe and airworthy conditions. This involves a comprehensive program of inspection, repair and maintenance, as well as replacement of components when necessary.

These systems are based on best practices and established standards, such as those developed by the International Civil Aviation Organization (ICAO).

Implementation of aeronautical maintenance systems development strategies has led to significant improvements in flight safety. For example, the number of accidents and incidents related to maintenance errors has been reduced and the overall safety record of the aviation industry has improved.

One of the key factors contributing to the effectiveness of aeronautical maintenance systems development strategies is the use of advanced technologies and tools. For example, remote monitoring systems and predictive analytics tools have been developed to help aviation organizations identify potential problems before they become serious problems. These technologies enable agencies to monitor the performance of their aircraft and identify patterns that may indicate the need for maintenance or repair.

Another important factor is aviation organizations commitment to continuous improvement. Aircraft maintenance systems development strategies are constantly refined and updated based on feedback from industry stakeholders, research and new technologies.

Despite the success of aeronautical maintenance systems development strategies, there is always room for improvement. A challenge facing the aviation industry is the increasing complexity of aircraft systems, which require more sophisticated maintenance techniques and tools. In addition, increasing demand for air travel means that aviation organizations are under pressure to minimize downtime and keep aircraft in service as much as possible, which can create additional risks.

# Contents

# 1. INTRODUCTION

This chapter presents:

❖ The place of maintenance systems in aviation safety management (MSA).

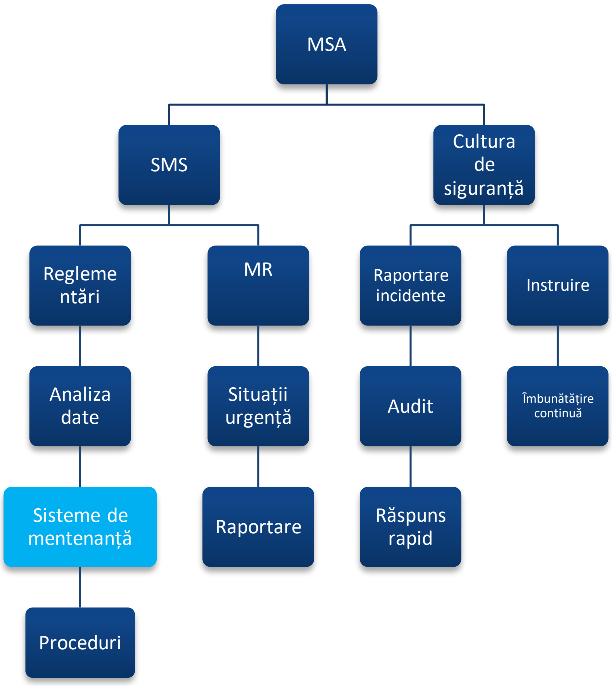



Figure no 1. 1: The relationship of current interdisciplinary fields to MSA

This schematic representation demonstrates the interconnectedness of different areas in aviation safety management. Essentially, safety management systems (SMS) provide the framework for safety management and continuous improvement. Compliance with regulatory requirements is essential, while risk management helps identify and mitigate safety risks. Incident reporting and investigation facilitates learning from safety incidents, while training and competence ensure appropriately qualified personnel. Safety data analysis enables data-driven decision-making, while emergency preparedness and response ensures effective response to emergency situations. Safety auditing and oversight monitors compliance and performance, leading to continuous improvement efforts.

The field of maintenance is included as a separate category. Recognizes the importance of maintenance activities in ensuring the safety of aircraft and aviation operations. Maintenance procedures comprise the specific processes and guidelines followed for the inspection, repair and maintenance of aircraft and related components.

Maintenance is interconnected with other areas of aviation safety management. It relies on the analysis of safety data to identify trends and potential problems in maintenance activities. Maintenance incidents are reported and investigated, like other types of incidents, to identify root causes and prevent future occurrences. Maintenance procedures are subject to audit and safety oversight to ensure compliance with regulations and adherence to safety standards.

This schematic representation is a simplified overview, and the actual interconnections and interactions between these domains are more complex. However, it provides an illustration of how the field of maintenance fits into the wider framework of aviation safety management.

❖ Current stage of MSA development

The current state of MSA is characterized by a proactive and systematic approach to safety management with a focus on continuous improvement and risk reduction. Safety management is an integral part of the

aviation industry and is embedded in all aspects of aviation operations, from aircraft design and manufacture to air traffic control and airport operations.
SMS implementation has been a major driver of aviation safety management, and many aviation organizations have adopted SMS as a standard approach to safety management. The implementation of the SMS has resulted in significant improvements in safety performance, with a decrease in the number of accidents and incidents over the years.

- Regulatory framework for MSA
- Modern architectures in MSA

- **Safety Culture -** Safety culture refers to the values, attitudes and behaviors that are shared by members of an organization regarding safety. A strong safety culture is characterized by a commitment to safety as a top priority, open communication and a willingness to identify and report safety hazards and incidents.
- **MR -** Risk management involves the identification, assessment and mitigation of safety risks in aviation operations. This process involves analyzing data to identify potential hazards, assessing the likelihood and severity of those hazards, and implementing measures to mitigate or eliminate the risks.
- **Safety Performance Monitoring -** Safety performance monitoring involves tracking and analyzing safety-related data to identify trends and patterns and to measure the effectiveness of safety management systems. This includes monitoring safety incidents, analyzing safety data and conducting safety audits and assessments.
- **Human Factors -** Human factors refer to the psychological, social and organizational factors that influence human performance in aviation operations. Understanding human factors is essential to developing effective safety management systems that take into account the limitations and capabilities of human operators.
- **Emergency Response Planning -** Emergency response planning involves the development and implementation of procedures for responding to safety incidents and emergencies in aviation operations. This includes developing emergency plans, training staff on emergency procedures, and conducting regular drills and exercises.

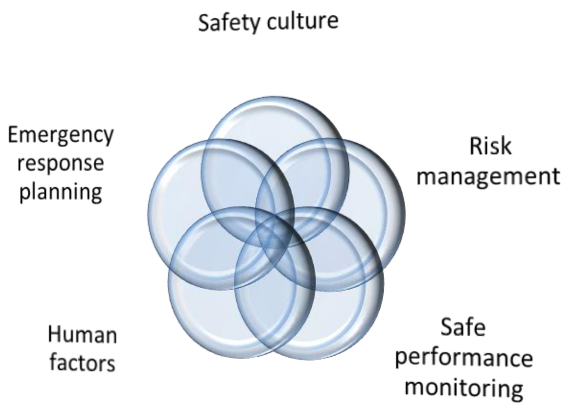



Figure no 1. 2 MSA architecture

- **The role of technological progress in MSA**

Tehnologia joacă un rol din ce în ce mai important în managementul siguranței aeronautice, având potențialul de a spori siguranța prin îmbunătățirea analizei datelor, evaluarea riscurilor și luarea deciziilor. Două tehnologii cheie care sunt utilizate în prezent pentru a îmbunătăți managementul siguranței sunt **inteligența artificială (IA) și analiza datelor mari**.

- **Main current challenges for MSA**

The main identified current challenges facing MSA are developed below as follows:

**Emerging technologies**: unmanned aerial vehicles (UAVs) and autonomous aircraft, the rapid pace of innovation and the ever-changing nature of technology, electric and hybrid-electric aircraft, supersonic transport and vertical take-off and landing vehicles

**Cyber security**: The aviation industry relies heavily on computer systems that control aircraft and support operations. These systems are vulnerable to cyber attacks, which can pose a significant risk to aviation safety.

**Globalization**: The globalization of the aviation industry means that aircraft manufacturers as well as airlines are increasingly operating across borders. This creates challenges for safety management, as different countries may have different safety regulations and standards.

**The human factor** continues to be a significant factor in aviation safety, including issues such as fatigue, stress and training. The human factor is difficult to measure and mitigate.

**Climate change** is a growing concern for the aviation industry as it can lead to extreme weather events and changing weather patterns.

**The COVID-19 pandemic** has highlighted the importance of preparedness and resilience in the aviation industry. The pandemic has created new safety challenges, such as the need to implement new health and safety protocols to protect passengers and crew

❖ **Justification of the choice of title, research hypotheses and formulation of objectives**

Having personal experience of over 15 years in the field of aeronautical maintenance and safety, starting as an airframe engineer in a mixed helicopter and trainer squadron for 2 years and then progressing to the transport aircraft maintenance section (C27J Spartan) for 8 years and then working in the first F16 fighter squadron as a squadron chief engineer, I can confirm and confirm justify the special interest in this topic. Currently, I work within the Aeronautical Safety Section, on the technical analysis and investigation side.

Thus, my active involvement in aircraft maintenance and its safe implementation during the years of activity, the exchange of experience with the Airbus Company, during the internship carried out in France, with Alenia Aeronautica (during the activity in the maintenance section for the C27J Spartan) as well as with the Portuguese Air Force (during the F16 aircraft purchase program), fueled my desire to bring my contribution to finding modern, innovative solutions for the development of strategies of maintenance systems with implications for aeronautical safety.The title of this research focuses on exploring the connections between aircraft maintenance systems and flight safety.

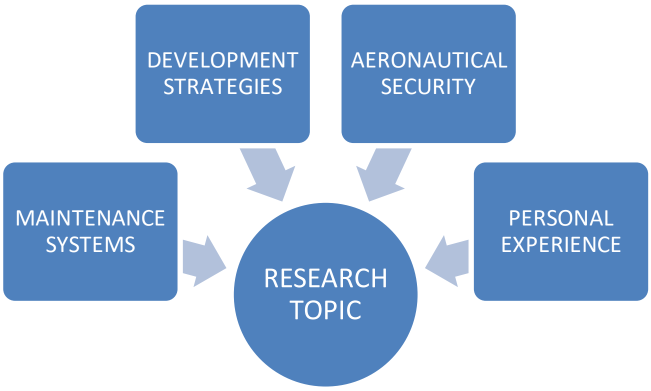



Figure no 1. 3: Harmonization of fields of study and ideas towards the chosen research topic

The establishment of the objectives is based on the assumption that by implementing effective strategies for the development of aeronautical maintenance systems, flight safety results are significantly improved by reducing the occurrence of maintenance-related incidents, improving aircraft reliability and optimizing safety-critical maintenance procedures. This hypothesis suggests that by adopting and implementing appropriate maintenance systems development strategies, the aviation industry can achieve improved flight safety. The research aims to investigate and provide evidence supporting this hypothesis through an in-depth analysis of different approaches to development of maintenance systems, their impact on flight safety indicators and the identification of best practices.

**The main objective** of the thesis refers to the deepening of the aeronautical MS concept, highlighting the implications on flight safety and reducing the number of events, by proposing innovative strategies in MR and MSC and offering innovative tools to improve MS.

In the realization of the framework of the main objective, the architecture of the thesis objectives is configured (Figure 1.4) which rests on several operational objectives. The first objective (OB1.1), with which the theme begins, is to form the overall picture of the MSA and to evaluate its efficiency, in order to further establish the place that the MS occupies within it. Then, the challenges facing MSA are identified and future research directions are proposed, which constitutes the second objective (OB1.2). Starting from the nature of my job, that of a military aviation engineer, I had access to information, both from the civilian field, through the exchange of experience, and implicitly from the military. Thus, in the second chapter, an approach to MSA from both points of view is proposed to provide a more comprehensive picture, pointing out critical elements such as the importance of standardization, effective practices and failures in MR, through the analysis of relevant case studies. Continuing with modern approaches to MR, identifying their challenges and limitations, the MRPD strategy is proposed, thus fulfilling the third (OB2.1) and fourth objective (OB2.2). Having as an idea the statement that the implementation of maintenance systems development strategies cannot be achieved without knowledge of change strategies in the aeronautical organization, based on information from the specialized literature, aspects of the change process in MSA are objectively scored, with the established objective that effective change and development strategies in MSA are essential to ensure that modern aviation maintenance systems can adapt to new and evolving risks and improve safety results, thus defining the fifth objective ( OB3.1). By studying the development strategies of some aviation giants, such as Boeing, Airbus, Lockheed Martin, the improvement areas are identified and predictive maintenance is proposed as an innovative maintenance strategy, which introduces the sixth objective (OB3.2).

To evaluate maintenance in modern aviation systems, to provide a comprehensive picture of maintenance performance and to identify areas for improvement, the indicator system is introduced. Starting from their study, SPM and SDM are developed, as innovative indicators in the evaluation of maintenance systems. Thus, the seventh objective (OB4), to identify and develop new indicators in the evaluation of SM performance, is met.

The eighth objective (OB5) refers to the identification of indicators for the evaluation of human performance. For the development of SM strategies, for the improvement of aeronautical safety, the appropriate selection and evaluation of the human resource, the identification of influencing factors, the detection and prevention of errors are necessary. The use of technology in MS provides a unique opportunity to assess human performance in both an objective and supportive manner. By leveraging AR capabilities, organizations can continuously improve the performance of their maintenance technicians and increase the overall safety, efficiency and effectiveness of their maintenance operations. The ninth objective (OB6.1) focuses on technical performance, thus, the current state of aeronautical maintenance systems and their relationship with flight safety is presented, statistical tools are introduced in MS, as well as new methods for evaluating technical performance. Using the statistical tools, the level of aeronautical safety in the FAR is presented. In the tenth objective (OB6.2) a failure of the Pitot-static system is analyzed, as a critical system in aircraft operation, and MBC is proposed as an optimal maintenance approach strategy. The eleventh objective (OB7.1) proposes to deepen the theoretical safety models for development and implementation in MS, providing an introspection into the SA of FAR, applying the questionnaire technique. The final objective (OB7.2) provides the maintenance image of the F16 aircraft, from the FAR equipment, the representative image for the air force, a model in which I actively participated from the moment of acquisition until operationalization, from the position of chief engineer of the squadron.

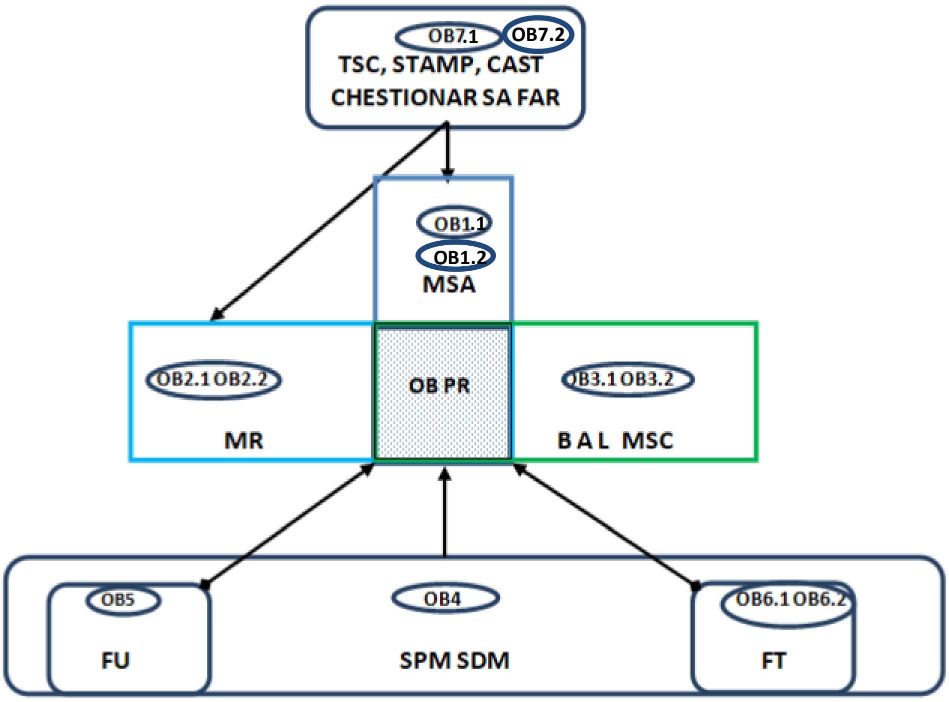



Figure no 1. 4 Convergence of operational objectives to the main objective of the thesis

**Research methodology**

The research was conducted using a literature review, relevant academic journals, government reports and industry publications. The literature review was performed using online databases such as Scopus, Web of Science, IEEE Xplore, ACM Digital Library or Google Scholar, using relevant keywords related to the specific topic and included studies published between 2010 and 2022. The studies selected for inclusion in this paper were based on their relevance to the research topic and the quality of the research methodology used. Studies that had a clear research question, used appropriate research methodology, and had valid and reliable data were selected for inclusion in this paper. Data collected from the literature review were analyzed using a thematic analysis approach. This approach involved identifying common themes and patterns in the literature and using these themes to develop an understanding of the research topic. The themes identified in the literature review were used to develop the recommendations and conclusions presented in this paper. The proposed studies present scientific relevance by addressing specific concepts of MSA, change management, maintenance management. Useful comparative analyzes were used to be integrated into the field of systems maintenance. The information obtained from the case studies, the applications, and the analysis of the questionnaire and the specialized literature, were presented in an easy-to-interpret manner. These results can represent a starting point for future studies, the proposed methods being scalable. The thesis is the result of the years of study in the doctoral school, but also of my professional activity. As I stated, the experience gained as a military engineer in the operation of aircraft, chronologically, IAR316B, IAK52, Alenia Aeronautica C27J SPARTAN, in Portugal F16 and for two years as an engineer in the office of technical investigations in the General Staff of the FAR, formed the basis of my studies and personal contributions. Certainly not all existing publications were found to be discussed or mentioned in this work.

## 2. MSA IN CIVIL AND MILITARY AVIATION ORGANIZATIONS

This chapter presents:

- The role of standardization in improving aviation safety;
- Establishing the importance of standardization through the analysis of case studies.

The importance of international standardization in aviation safety is demonstrated by the following case studies:

Table no 2. 1 ICAO components and elements

| Nr. crt. | Case study | Description | Analysis |
|---|---|---|---|
| 1. | The 1985 crash of Japan Airlines Flight 123 | In August 1985, a Boeing 747 operated by Japan Airlines crashed into a mountain, killing 520 of the 524 people on board. The cause of the accident was a faulty repair of the aircraft's rear pressure wall, which failed in flight, causing rapid decompression and loss of control. | As a result of the accident, the Japanese government initiated a comprehensive review of its aviation safety standards and procedures. The review highlighted the need for stronger safety standards and led to the establishment of the Japan Civil Aviation Bureau (JCAB) in 1986. The JCAB was responsible for overseeing aviation safety standards and ensuring compliance with ICAO standards.<br>The accident also led to changes in international aviation standards. ICAO has developed new regulations for the maintenance and inspection of aircraft structures, including pressure bulkheads, to prevent a similar accident from occurring in the future. |
| 2. | The 2009 crash of Air France Flight 447 | In June 2009, an Airbus A330 operated by Air France crashed into the Atlantic Ocean, killing all 228 people on board. The cause of the disaster was a combination of factors, including pilot error, erroneous airspeed and altitude information through freezing of the pitot tube, and lack of training on how to respond to a high-altitude stall. | The accident prompted ICAO to review its safety standards related to pilot training and aircraft automation. As a result, ICAO has developed new guidance on pilot training, including the use of flight simulators to train pilots on how to respond to unusual flight conditions. ICAO has also recommended that airlines review their flight crew training programs to ensure they meet these new standards. |
| **Official reports** | | | |
| **Report** | | | **Description** |
| 1. | Siguranța aviației globale ICAO:<br>Planul global de siguranță a aviației (GASP) ICAO este un document strategic care subliniază prioritățile și obiectivele organizației în materie de siguranță pentru industria aviației globale. Planul își propune să reducă numărul deceselor din aviație cu 50% până în 2025 și se concentrează pe îmbunătățirea siguranței prin dezvoltarea și implementarea standardelor și practicilor recomandate ICAO. | | GASP recunoaște că standardizarea internațională este crucială pentru îmbunătățirea siguranței în aviație. Ea subliniază necesitatea ca statele membre să i să implementeze standardele OACI și practicile recomandate în sistemele lor de aviație pentru a promova un nivel de siguranță constant la nivel mondial. Planul subliniază, de asemenea, importanța colectării și analizei datelor de siguranță pentru a identifica riscurile de siguranță și pentru a dezvolta măsuri eficiente de siguranță. |
| 2. | European Aviation Safety Agency (EASA) safety promotion campaign:<br>The European Aviation Safety Agency (EASA) launched a safety promotion campaign in 2018 to promote safety culture in the aviation industry. The campaign aimed to raise awareness of safety issues and encourage airlines, airports and other aviation stakeholders to adopt best practices and comply with safety regulations. | | The campaign emphasized the importance of international standardization in aviation safety and emphasized the need for all aviation organizations to work together to improve safety. It also provided guidance on how to implement safety management systems and promote a safety culture within organizations. |

❖ Advantages of standardization in aviation safety. Advantages and limitations of the study method

Standardization in aviation safety offers several advantages that help improve safety in the industry. Some of the key advantages include:

- Consistency and uniformity;
- Clear and well-defined guidelines;
- Collaboration and global cooperation;
- Increased efficiency and effectiveness;
- Improved public confidence;

Some of the limits include:

- Various implementation and application;
- Slow adaptation to emerging risks;
- Cultural and organizational factors;

- Compliance and oversight challenges;
- Innovation and technological advances;

Case studies are effective in illustrating the impact and benefits of standardization in aviation safety.

While case studies can effectively highlight the benefits and impact of standardization, it is important to recognize the limitations of this method. Some limitations include:

Challenges to generalizability: Case studies provide specific examples of the impact of standardization but may not represent the entire aviation industry. Each case study represents a unique context and the results observed may not be universal. Generalizing the case study findings to the entire industry should be done with caution, as there may be variation in safety practices and outcomes.

Lack of long-term analysis: Case studies usually provide insights into short-term outcomes and immediate impact. However, the long-term effectiveness of standardization may require a broader analysis that considers multiple factors, including changes in technology, regulatory environments, and safety culture over a long period of time. Long-term analysis is needed to assess the sustained impact of standardization efforts.

Incomplete understanding of contextual factors: case studies may not always capture the full range of contextual factors that influence the effectiveness of standardization. Factors such as regulatory frameworks, cultural differences, organizational structures, and economic constraints can have a significant impact on the implementation and outcomes of standardized safety practices. It is important to consider these contextual factors when interpreting case study findings.

Limited representation of challenges: Although case studies often highlight successes, they may not adequately represent the challenges and limitations of standardization. Standardization efforts face various obstacles, including compliance issues, resource constraints, and the need to adapt to emerging safety risks. These challenges may not always be fully explored or highlighted in case studies, leading to an incomplete understanding of the limitations of standardization.

- ❖ Types of managerial approaches in aeronautical organizations – the case of MSA
- ❖ Comparative analysis of management types in civil and military aeronautical organizations. Case studies
- ❖ Effective Practices vs. Failures in MSA

To illustrate the differences between safety management in civil and military aviation organizations, the following case studies are examined:

- Flight 371 Tarom
- MiG-21 disasters
- Air France 447 in 2009 and the collision of two Navy F/A-18 fighter jets in 2016.
- Delta Air Lines Flight 191
- Collision of two US Marine Corps CH-53E helicopters

Discussions regarding the management of extreme risk events in Romanian and international aviation

The Tarom Flight 371 incident serves as a case study that highlights the importance of effective safety management in civil aviation. The accident exposed deficiencies in maintenance practices, crew training and safety protocols within Tarom. It emphasized the critical need for robust safety management systems, adequate maintenance procedures and comprehensive training programs to ensure the safety of aviation operations.

The accident prompted significant changes within Tarom, underscoring the importance of continuous improvement in safety management practices. It demonstrated the importance of learning from such incidents and implementing corrective measures to prevent future accidents.

The Romanian case studies provide insights into the differences in safety management practices between civil and military aviation organizations in the country. The civil aviation case study highlighted the need to improve training, decision-making and organizational culture, while the military aviation case study highlighted the importance of maintenance practices and adherence to safety protocols. These cases highlight the importance of effective safety management practices in both the civil and military aviation sectors and the need for continuous improvement of safety standards and procedures. By learning from these incidents and implementing the lessons learned, the aviation industry in Romania can improve safety management practices, reduce the risk of accidents and ensure the safety of passengers, crew and personnel involved in aviation operations.

Safety management is a critical aspect of aviation operations, whether in civilian or military organizations. However, there are significant differences in safety management practices between the two types of organizations, including regulatory frameworks, organizational structures, safety culture and risk management practices. These differences can affect the effectiveness of safety management practices and the likelihood of safety incidents.

To improve safety management in both civil and military aviation organizations, it is essential to prioritize a strong safety culture and effective safety management practices. This includes a commitment to training and continuing education, the implementation of formal risk management processes, and a focus on communication and collaboration within organizations.

Pilot error is one of the most common causes of aviation accidents, whether in civilian or military organizations. However, the specific types of pilot error may differ between the two types of organizations. In civil aviation, pilot error is often related to inadequate training, poor decision making, or failure to follow established procedures. Conversely, pilot error in military aviation can be related to issues such as fatigue, stress, or a culture of risk-taking.

Another significant difference between civil and military aviation safety management is the regulatory framework. In civil aviation, safety standards and regulations are established that govern all aspects of aviation operations. Airlines are required to comply with these regulations and are subject to regular inspections and audits to ensure compliance. Military aviation, on the other hand, operates in a different regulatory framework, with the military responsible for establishing its own safety standards and procedures. While military aviation organizations may adopt some of the safety management practices used in civil aviation, there are significant differences in how safety is managed in these organizations.

One of the key differences between civil and military aviation safety management is the organizational structure. Civil aviation organizations typically have a centralized organizational structure with clear lines of authority and communication between different levels of the organization. This can facilitate the implementation of effective safety management practices as there is a clear chain of command and responsibility.

In contrast, military aviation organizations often have a decentralized organizational structure, with multiple units and individuals operating independently of one another. This can make it more difficult to implement effective safety management practices, as there may be less coordination and communication between different units.

- ❖ Analysis of military aviation safety management - the case of the Romanian Air Force
- ❖ Functions of safety structures
- ❖ Modern strategies for addressing the issue of risk management in aviation
- ❖ Safety vs Security in Aviation
- ❖ Risk, uncertainty, threat in aviation
- ❖ The concept of resilience in MSA

Resilience is a critical concept in MSA. It refers to the ability of an aviation system to anticipate, prepare for, respond to, and recover from disruptions or adverse events. The purpose of developing resilience in aviation is to minimize the impact of incidents and accidents and ensure the continuity of safe and secure operations.

In aviation, resilience is achieved through a combination of proactive risk management and contingency planning.

- ❖ **Modern Risk Management Strategies in Aeronautical Systems: An Innovative Approach**

It has been found that the use of advanced technologies, the human factor and the systematic approach to risk management can lead to better safety outcomes in the aviation industry. The proposed strategy involves using machine learning algorithms to analyze flight data and identify potential safety hazards. Future research directions may include developing a comprehensive framework for integrating the proposed strategy into existing risk management practices.

- Current risk management strategies
- Analysis of modern risk management strategies in aeronautical systems

- Challenges and limitations of current risk management strategies
- Steps in developing a new risk management strategy

The innovative strategy involves using machine learning algorithms to analyze flight data and identify potential safety hazards. The strategy may include the following steps:

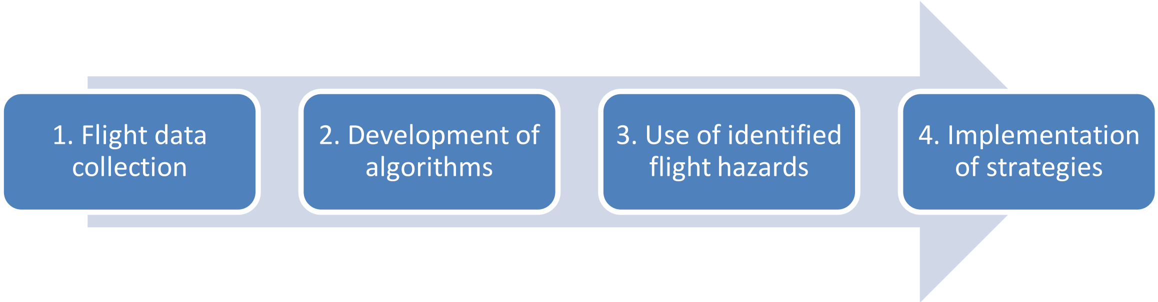



Figure 2. 1: Stages of risk management strategy in complex socio-technical systems.

1. Collection of flight data from various sources, including flight recorders, weather reports and air traffic control data.
2. Development of machine learning algorithms to analyze flight data and identify potential safety hazards.
3. Using identified safety hazards to develop risk mitigation strategies, including changes to flight procedures, aircraft maintenance, and crew training.
4. Implementing risk mitigation strategies and monitoring results to assess the effectiveness of strategies.

**Scientific development of risk management strategy in the aeronautical industry**

Considering the challenges and limitations identified in the current risk management strategies in the aeronautical industry, an innovative risk management strategy is proposed to address the major issues specific to the aeronautical industry. The strategy is based on a proactive approach that involves integrating SMS with risk management practices.

The innovative risk management strategy proposed for the aeronautical industry incorporates the following key elements:

1. Proactive risk management: The strategy emphasizes the importance of proactive risk management to identify potential hazards and risks before they manifest into accidents. This involves the use of various tools and techniques such as hazard identification, risk assessment and risk mitigation strategies.
2. Integrating safety and risk management systems: The strategy integrates SMS with risk management practices. This approach confirms that safety is an integral part of the entire risk management process, from identifying potential hazards to implementing mitigation measures and monitoring their effectiveness.
3. Continuous improvement: The strategy emphasizes the need for continuous improvement by reviewing and updating risk management plans and strategies on a regular basis. This includes analyzing data and feedback from organizations, identifying areas for improvement and implementing corrective actions.
4. Technology: The strategy incorporates the use of technology to improve risk management practices. This includes using data analytics, artificial intelligence and machine learning to identify potential hazards and risks, track safety performance and facilitate decision-making.

**Data Processing Based Risk Management (MRPD)**

Given the emphasis on data and technology in modern aviation, one can consider a MRPD-based strategy version. The focus of this approach is on leveraging data and technology to gain better insight into potential hazards and risks, enabling more effective risk management and mitigation. By collecting and analyzing data on a wide range of factors such as weather patterns, aircraft performance, maintenance history and pilot behavior, MRPD can help identify potential risks and take proactive steps to minimize them.

The use of advanced technologies such as artificial intelligence (AI), machine learning and predictive analytics can increase the effectiveness of MRPD by enabling real-time monitoring and analysis of data, enabling rapid response to potential risks. By combining these technological capabilities with well-defined risk management protocols and procedures, MRPD can help the aviation industry stay ahead of emerging risks and maintain a high level of safety and security for all organizations.

To evaluate the effectiveness of the innovative risk management strategy, it is proposed to develop a case study that tests the approach in a real setting. This would involve selecting a sample group of airlines or airports that would agree to participate in the study and implementing the MRPD approach in their risk management processes.

Case study steps before MRPD implementation:

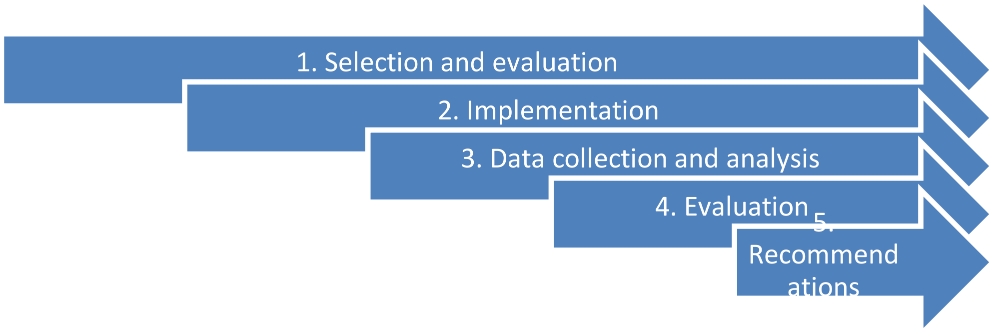



Figure no 2. 2: Stages of the risk management strategy.

1. Selection and Assessment: Prior to the implementation of the MRPD, selected airlines or airports will undergo a comprehensive assessment to identify current gaps and challenges in their risk management processes. This would provide a baseline against which the effectiveness of the MRPD approach could be measured.
2. Implementation: The MRPD approach will be implemented in the risk management processes of selected airlines or airports. This would involve setting up data collection and analysis systems, defining risk management protocols and procedures, and training staff on the new approach.
3. Data collection and analysis: Data will be collected and analyzed using the MRPD approach over a period of time such as 6-12 months. The data collected would include a wide range of factors such as weather patterns, aircraft performance, maintenance history and pilot behavior.
4. Evaluation: Data collected will be evaluated to determine the effectiveness of the MRPD approach in identifying potential risks and taking proactive measures to minimize them. This would involve comparing the baseline assessment with the results of the data analysis.
5. Recommendations: Based on the assessment, recommendations will be made to improve the MRPD approach and address any identified gaps or challenges.

The case study would provide valuable insights into the effectiveness of the proposed innovative risk management strategy and help refine and improve the approach for wider adoption in the aviation industry.

The MRPD approach is a proactive and adaptive approach to risk management that uses real-time data and analytics to identify potential risks and take preventative action before they become critical issues.

The MRPD approach is based on four key components: data collection, data analysis, decision making and risk communication. By collecting real-time data on a wide range of factors that could affect the safety and security of the aviation industry, the MRPD approach can quickly identify potential risks and take proactive steps to mitigate them.

One of the key advantages of the MRPD approach is its ability to adapt to changing conditions and new information. As new data is collected and analyzed, the MRPD approach can adjust risk management strategies to better align with emerging risks and changing conditions.

**Stages of MRPD implementation**

Figure 2.8 shows the steps for implementing an MRPD system in the aeronautical industry:

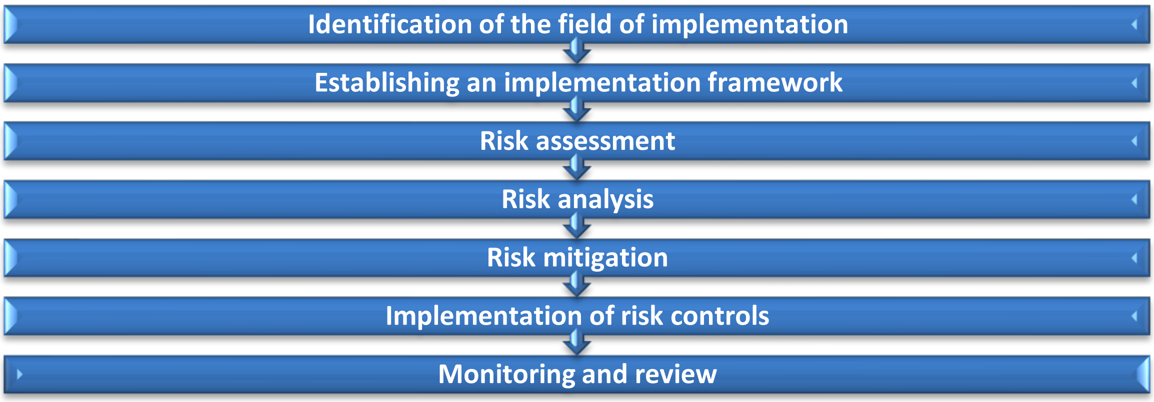



Figure no 2. 3: Stages of MRPD implementation.

**P1. Identifying the scope of implementation**: The first step in implementing the MRPD is to identify the organizations that will be involved in the process. These may include air operators, airport authorities, air traffic controllers, aviation regulators and other relevant parties**.**

**P2. Establish an implementation framework:** A framework must be established that defines the scope of the MRPD system, the risk management process and the tools and techniques that will be used.

**P3. Risk assessment:** A risk assessment should be carried out to identify potential hazards and risks. This may involve reviewing historical data, conducting on-site inspections and analyzing data from other sources.

**P4. Risk analysis:** Identified risks must be analyzed to determine the likelihood and potential consequences of each risk. This can be done using a risk matrix, which shows the probability and consequences of each risk on a diagram.

**P5. Risk Mitigation:** Once the risks have been analyzed, risk mitigation strategies must be developed. This may involve implementing engineering controls, administrative controls or personal protective equipment.

**P6. Implementation of risk controls:** Risk controls must be implemented and monitored to ensure they are effective in reducing or eliminating risks.

**P7. Monitoring and review:** The MRPD system must be monitored and reviewed regularly to ensure that it remains effective. This may involve conducting audits or assessments to identify any gaps or areas for improvement.

• The tools used in the MRPD process:

**1. Risk Assessment Software:** There are a number of software tools available that can be used to support the risk assessment process. These tools enable users to identify and assess hazards, assess risks, and develop risk mitigation strategies.

**2. Incident Reporting System:** An incident reporting system can be used to collect and analyze data on incidents and accidents that occur in the aviation industry. This can help identify trends and areas for improvement.

**3. Safety Management System (SMS):** An SMS is a structured approach to safety management that includes policies, procedures and tools for identifying and managing risks. An SMS can be used to support the MRPD process by providing a framework for managing risk and improving safety culture.

**4. Decision Support Tools:** Decision support tools can be used to help organizations make informed decisions about risk management. These tools may include decision trees, scenario analysis or cost-benefit analysis.

**Modern tools that can be used in MRPD implementation include:**

1. Identification of risks:

- Risk matrix tool (eg Risk Matrix+)
- Checklist for hazard identification (eg HAZID)

2. Risk assessment:

• Fault tree analysis software (eg FaultTree+)
• Event tree analysis software (eg EventTree+)
• Probabilistic risk assessment software (eg RiskSpectrum)

3. Risk reduction:
• Risk Control Action Plan Tool (eg RiskControl+)
• Root cause analysis tool (eg TapRooT)

4. Risk monitoring and control:
• Risk management software (eg RiskLogik)
• Key Performance Indicator (KPI) dashboard (eg KPI Fire)

Implementing MRPD requires a multidisciplinary team of experts, including risk managers, aviation engineers, safety specialists and regulators. The team should work together to develop a comprehensive risk management plan and ensure that the plan is properly implemented and continuously monitored. Overall, MRPD implementation can help aviation organizations proactively manage risk, ensure safety and security, and improve operational efficiency.

❖ **Analyzing the correlations between risk, safety and security in aviation**

The correlation between risk, safety and security in aviation is complex and interdependent. Effective risk management is essential to maintaining a high level of safety and security in aviation operations. Safety and security are closely related, and effective management of both is critical to ensuring the safety and security of aviation operations. By using a comprehensive risk management framework and integrating safety and security management, aviation organizations can effectively manage risk and maintain a high level of safety and security in their operations. The table illustrates some examples of case studies that could be used to analyze the correlation between risk and aviation safety and security.

Tabel 2. 2 Studii de caz pentru analiza corelațiilor dintre risc siguranță și securitate în evenimente extreme de aviație

| No. | Case study | Comments |
|---|---|---|
| 1. | Germanwings Flight 9525: In March 2015, Germanwings Flight 9525 crashed in the French Alps, killing all 150 people on board. | The investigation revealed that the co-pilot intentionally crashed the aircraft, highlighting the security risks associated with insider threats. The incident also raised questions about the effectiveness of mental health screening and support for pilots, demonstrating the relationship between safety and security. |
| 2. | United Airlines Flight 232: In July 1989, United Airlines Flight 232 experienced engine failure, resulting in loss of hydraulic control and a crash landing. | While 111 people died in the incident, the successful evacuation of 185 passengers highlighted the importance of effective safety measures such as training and emergency preparedness. |
| 3. | Malaysia Airlines Flight 370: In March 2014, Malaysia Airlines Flight 370 disappeared en route from Kuala Lumpur to Beijing, resulting in the loss of all 239 passengers and crew. | Although the cause of the disappearance remains unknown, the incident demonstrated the importance of effective risk management processes, including tracking and communication systems, to ensure the safety and security of aviation operations. |
| 4. | Brussels airport bombing: In March 2016, terrorists attacked the Brussels airport, killing 32 people and injuring more than 300. | The attack highlighted the security risks associated with aviation operations and the importance of effective security measures such as screening systems and access control. |
| 5. | Japan Airlines Flight 123: In August 1985, Japan Airlines Flight 123 crashed into a mountain, killing 520 of the 524 passengers and crew on board. | The incident was caused by a failure of the aircraft's rear pressure wall, highlighting the importance of effective maintenance and inspection processes in ensuring the safety of aviation operations. |
| 6. | 9/11 terrorist attacks: In September 2001, terrorists hijacked four commercial airliners and used them as weapons to attack the World Trade Center and the Pentagon, killing nearly 3,000 people. | The attacks demonstrated the security risks associated with aviation operations and led to significant changes in airport security measures and air traffic control procedures. |

| No. | Case study | Comments |
|---|---|---|
| 7. | Tenerife Airport Disaster: In March 1977, two Boeing 747s collided on the runway at Tenerife Airport, killing 583 people. | The incident was caused by a combination of factors, including miscommunication between air traffic control and the aircraft, highlighting the importance of effective communication and coordination in aviation operations. |

By analyzing these and other case studies, key factors contributing to risk, safety and security in aviation can be identified and strategies can be developed to effectively manage these factors.

- ❖ Principles of aviation accident analysis - elements specific to the military aeronautical field
- ❖ Risk and safety in the military aviation system
  - • Characteristics of military aeronautical accidents

A statistical analysis of the accidents in the FAR is carried out.

In this chapter I highlighted the importance of international standardization, civil and military, in MSA, exemplified by means of relevant case studies. Also, through a critical comparative analysis based on case studies, both civil and military, from Romania, other countries in Europe, the USA, we presented the effective practices as well as the failures in MR.

We addressed modern risk management strategies by studying the current strategies, identifying their challenges and limitations and proposed a new data gathering driven risk management (MRPD) strategy with an emphasis on the use of technology.

Having access to information from the field of military aeronautics, by the nature of the job and the positions held over time, we presented what risk and security means in military aviation and we accurately scored features of accidents in the field during critical periods, until 2022.

## 3. CHANGE AND ORGANIZATIONAL DEVELOPMENT STRATEGIES IN AVIATION SECURITY MANAGEMENT

This chapter presents:

- ❖ The concept of organizational change

The concept of change in aviation organizations is defined in the context of the research field, with the stated objective that effective change and development strategies in aviation safety management are essential to ensure that modern aviation maintenance systems can adapt to new and evolving risks and improve safety outcomes.

- ❖ Aspects of the change process in MSA
  - Diagnosing system status
  - Resistance to change
- ❖ Change strategies and organizational development in MSA
- ❖ Defining the change; change as an organizational reality in MSA
- ❖ The model of organizational change in modern aviation systems
  - The foundations of organizational change
- ❖ Managerial methods in aeronautical organizations
- ❖ Analysis of specific problems of change management in modern aviation maintenance systems.

**Case Study**

- **Change management benefits and implementation issues in maintenance processes**
- **Change Management in Modern Aviation Maintenance Systems**

In this subchapter it is proposed to identify the problems associated with the implementation of changes in aeronautical maintenance systems, to create a change management plan based on relevant case studies from the aeronautical industry, as well as to formulate some recommendations. Remote monitoring systems and predictive analysis tools are presented as modern elements to improve maintenance systems. Airbus, Boeing, Lockheed maintenance strategies are explored to identify strengths and weaknesses.

Effective change management in modern aviation maintenance systems leads to increased safety, reliability and efficiency. However, implementing them can be challenging, requiring careful planning, communication and training to ensure successful adoption.

Aviation maintenance systems have come a long way from the paper-based systems of the past to the modern, computerized systems of today. Identifying problems, recommendations, creating a plan based on case studies

To create a plan based on case studies, the problems the aviation industry faces in managing change in their maintenance systems are first identified.

**Case studies:**

Based on the case studies and recommendations presented above, a plan to implement changes in aviation maintenance systems is proposed. The plan would include the following steps:

**1. Change Planning:** A comprehensive plan is developed that outlines all the necessary steps, resources and organizations involved in the change.

**2. Communicating the change:** communicating effectively with employees and the organization to ensure they understand the reasons for the change, the benefits it will bring and the potential impact on their roles and responsibilities.

**3. Involving employees in the planning process:** Involving employees in the planning process to build trust and ensure that their concerns and ideas are taken into account.

**4. Training and support:** Provide adequate training and support to employees to ensure they can adapt to new maintenance systems safely and effectively.

**5. Monitoring and evaluating change:** Regularly monitor and evaluate change to ensure that the desired results are being achieved and to identify any areas where improvements are needed.

Based on these case studies, it is evident that managing change in aircraft maintenance systems is a complex process that requires careful planning, effective communication and the involvement of all organizations. However, the benefits of effective change implementation, such as improved safety standards and increased efficiency, make this a necessary and worthwhile endeavor.

To successfully manage change in aviation maintenance systems, organizations should follow several key principles, including:

1. Involvement in the change process of all organizations, maintenance staff, regulatory authorities and management.
2. Develop a detailed plan for implementing the changes, including timelines and contingency plans.
3. Providing adequate training and resources to support the change process.
4. Communicating effectively with all organizations throughout the process, including providing regular updates on progress and addressing any concerns.
5. Evaluating the effectiveness of changes once implemented, including assessing the impact on safety and efficiency.

By following these principles and learning from the experiences of other organizations, maintenance organizations can effectively manage changes in their systems and ensure the safety and efficiency of their operations.

- **The relationship between aeronautical maintenance systems development strategies and flight safety. Recommendations for their improvement.**

The relationship between aeronautical maintenance systems development strategies and flight safety is essential to ensure safe and reliable operations in the aviation industry. A well-designed and effectively implemented maintenance system can help prevent equipment breakdowns and reduce the risk of accidents and incidents.

One of the main ways to improve aircraft maintenance systems and ensure flight safety is to adopt a proactive approach to maintenance management. This involves developing a comprehensive maintenance program that includes regular inspections, maintenance and repair of aircraft and related equipment. The program should also include a maintenance and repair tracking system to ensure that all equipment is up to date and in compliance with safety regulations.

- **Remote monitoring systems and predictive analytics tools**

Remote monitoring systems and predictive analytics tools are technologies that can be used to improve aircraft maintenance systems and enhance flight safety. These tools can help identify potential problems before they become major issues or problems, allowing maintenance personnel to take corrective action quickly and efficiently.

- **Development strategies of the aeronautical maintenance system - the case of the Boeing, Airbus, Lockheed Martin companies. Benchmarking**

Aeronautical maintenance systems are critical to ensuring the safe and efficient operation of aircraft. Boeing, Airbus, and Lockheed Martin are among the largest aerospace companies in the world, and each has its own unique strategy for developing and maintaining maintenance systems.

**Boeing**

Boeing's approach to developing maintenance systems emphasizes the importance of reliability, maintainability and supportability. This strategy aims to improve the performance and longevity of their aircraft systems while minimizing the costs and downtime associated with maintenance.

**Airbus**

Airbus' maintenance systems development strategy is centered on their digital transformation initiatives. Airbus has developed a number of digital tools and platforms to support maintenance operations, including the Skywise system, which provides real-time monitoring and data analysis for predictive maintenance.

**Lockheed Martin**

Lockheed Martin's approach to developing maintenance systems emphasizes the use of advanced technologies to improve maintenance efficiency and reduce costs. Their F-35 Autonomous Logistics Information System (ALIS) is a key example of this approach, integrating data analytics, predictive maintenance and supply chain management capabilities to optimize maintenance operations.

- **Identify areas for improvement and contribute to the development of safer, more efficient and sustainable maintenance systems**

One area for improvement that all companies could consider is implementing a proactive maintenance strategy, which involves performing regular inspections and preventive maintenance to identify potential problems before they become serious problems. This can help reduce the risk of unscheduled shutdown, improve safety and increase the life of the aircraft.

Another area for improvement is investment in new technologies, such as digitization, which can help improve maintenance efficiency and reduce costs. For example, incorporating artificial intelligence and machine learning algorithms into maintenance operations can help identify patterns and trends in maintenance data that can influence maintenance decisions and improve the accuracy of maintenance predictions.

**Predictive maintenance; innovative maintenance strategy**

A new strategy for the development of aeronautical maintenance systems can be the use of predictive maintenance. Predictive maintenance involves the use of advanced analytics and machine learning algorithms to predict when maintenance is required based on real-time data from the aircraft. By using data to identify potential problems before they become serious problems, companies can reduce the risk of unscheduled shutdowns and improve aircraft reliability.

- **Exemplification of predictive maintenance**

An example of predictive maintenance in the aerospace industry is General Electric's (GE) FlightPulse platform. FlightPulse is a software platform that uses data from aircraft sensors to monitor engine health and predict maintenance needs.

The system uses algorithms and machine learning to analyze real-time data from the aircraft, including engine parameters such as temperature, pressure and vibration. By analyzing this data, FlightPulse can identify potential problems and predict when maintenance is needed.

For example, FlightPulse can detect changes in engine performance that may indicate wear or damage to components such as turbine blades or bearings. This information can then be used to schedule maintenance before the problem becomes critical, reducing the risk of unscheduled downtime and improving aircraft reliability.

In addition to anticipating maintenance needs, FlightPulse also provides pilots with real-time feedback on their flight performance, such as fuel efficiency and emissions. This can help pilots optimize their flight behavior and reduce fuel consumption and emissions.

Overall, FlightPulse represents a promising example of predictive maintenance in the aerospace industry. By using advanced analytics and machine learning, GE is able to monitor engine health in real time and predict maintenance needs, improving aircraft safety and reliability while reducing costs associated with maintenance.

## 4. MODELE DE RISC ȘI SIGURANȚĂ ÎN AERONAUTICĂ

Chapter four presents:

- **The system of indicators used in the evaluation of maintenance**

The system of indicators used for maintenance evaluation in modern aviation systems can be divided into several categories. These categories include process indicators, outcome indicators and safety performance indicators.

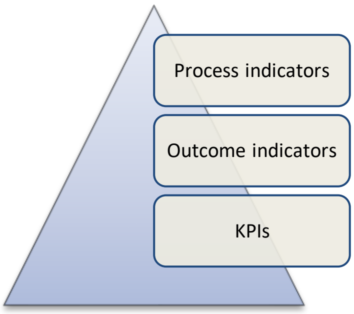



Figure no 4. 1: The system of indicators used in the evaluation of maintenance

Process indicators, outcome indicators and safety performance indicators are important in evaluating maintenance programs. Safety performance indicators are particularly important in identifying potential safety hazards and mitigating risks.

Table 4. 1 Process indicators used in aeronautical maintenance

| No | Indicator | Description |
|---|---|---|
| 1. | Number of maintenance tasks completed on time | This indicator measures the percentage of maintenance tasks that are completed on time. It can help identify areas of inefficiency in the maintenance process and provide guidance for improvement. |
| 2. | Time required to complete maintenance tasks | This indicator measures the average time required to complete maintenance tasks. It can help identify areas of inefficiency in the maintenance process and provide guidance for improvement. |
| 3. | The number of maintenance tasks that require retry | This indicator measures the percentage of maintenance tasks that require rework. It can help identify areas of inefficiency in the maintenance process and provide guidance for improvement. |
| 4. | Compliance with maintenance procedures | This indicator measures the percentage of maintenance tasks that are completed in accordance with maintenance procedures. It can help identify areas of non-compliance and provide guidance for improvement. |
| 5. | Training and qualification of maintenance personnel | This indicator measures the training and qualification of the maintenance staff. It can help identify areas of training and skill gaps and provide guidance for improvement. |
| 6. | Effectiveness of the maintenance program | This indicator measures the overall effectiveness of the maintenance program. It can help identify areas of inefficiency in the maintenance program and provide guidance for improvement. |

There are different types of safety performance indicators that can be used in aviation maintenance programs as shown in Table 4.2.Tabel 4. 1 Indicatori de performanță utilizați în mentenanța aeronautică

| No. | Indicator | Description |
|---|---|---|
| 1. | Incident rate | This indicator measures the number of safety-related incidents that occur in a given period. It can help identify areas of safety risk and provide guidance for improvement. |

| | | |
|---|---|---|
| 2. | Accident rate | This indicator measures the number of accidents that occur in a certain period. It can help identify areas of safety risk and provide guidance for improvement. |
| 3. | Hazard identification rate | This indicator measures the number of hazards identified in a specified period. It can help identify areas of safety risk and provide guidance for improvement. |
| 4. | Risk assessment rate | This indicator measures the number of risk assessments completed in a specified period. It can help identify areas of safety risk and provide guidance for improvement. |
| 5. | Safety audit rate | This indicator measures the number of safety audits completed in a specified period. It can help identify areas of safety risk and provide guidance for improvement. |
| 6. | Safety Culture Survey | This indicator measures employee perceptions and attitudes towards safety. It can help identify weak areas in the safety culture and provide guidance for improvement. |

Safety performance indicators are an important tool for evaluating the safety performance of aviation systems. By regularly monitoring and evaluating SPIs, aviation organizations can identify areas of safety risk and take corrective action to improve safety performance.

❖ **Analysis of maintenance assessment indicators in modern aviation systems. development of new indicators based on emerging technologies.**

The system of indicators that evaluate maintenance in modern aviation systems is crucial to ensure the safety and reliability of aircraft. A variety of indicators are used to evaluate maintenance performance, including:

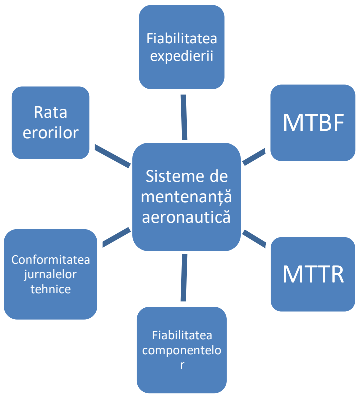



Figure no 4. 2 Indicators used in maintenance performance evaluation

1. Dispatch Reliability: This indicator measures the percentage of flights that depart on schedule and without maintenance delays.
2. Mean Time Between Failure (MTBF): MTBF is the mean time between two failures of a particular component or system. This metric helps identify trends and prioritize maintenance efforts.
3. Mean Time to Repair (MTTR): MTTR measures the average time required to repair a particular component or system once it has failed. A low MTTR is an indication of effective maintenance processes.
4. Component Reliability: This indicator measures the reliability of individual components, such as engines or avionics, and is used to determine the need for replacement or overhaul.
5. Logbook Compliance: This indicator measures the accuracy and completeness of the aircraft's logbooks, which are used to track maintenance and repair activities.
6. Maintenance error rate: This indicator measures the number of maintenance errors that occur, such as incorrect repairs or installations, and is used to identify areas for improvement in maintenance processes.

The system of indicators used to evaluate maintenance in modern aviation systems provides a comprehensive picture of maintenance performance and helps identify areas for improvement. By following these metrics, aviation organizations can ensure aircraft safety and reliability and improve their overall maintenance processes.

- **Maintenance Performance Score (SPM)**

The maintenance performance score (SPM) can be expressed mathematically as follows:

SPM = (W1 x F1 + W2 x F2 + ... + Wn x Fn) / (W1 + W2 + ... + Wn)

Where:

• SPM is the Maintenance Performance Score.

• W1, W2, ..., Wn are the weights assigned to each factor in the SPM calculation.

• F1, F2, ..., Fn are the values of each factor, such as shipment reliability, mean time between failures (MTBF), mean time to repair (MTTR), component reliability, technical log compliance, and maintenance error rate.

Weights should be assigned based on the relative impact each factor has on overall maintenance performance. For example, shipment reliability could be given a higher weight than component reliability because it has a direct impact on flight operations and customer satisfaction.
To calculate SPM, data on various factors such as flight and maintenance records must be collected and analyzed. The SPM can then be calculated by summing the products of each factor and its weight and dividing by the sum of the weights.

- **The score of digitalization of maintenance processes (SDM).**

A potential indicator that could be revolutionary in evaluating maintenance performance in modern aviation systems is the Maintenance Digitization Score. SDM would measure the degree to which an airline uses digital technology and data analytics in its maintenance processes.

SDM can be calculated by considering factors such as:

1. Use of digital maintenance platforms: The extent to which an airline uses digital maintenance platforms, such as computerized maintenance management systems and electronic technical logs, to manage and track maintenance activities.

2. Integration of sensors and data analytics: The extent to which an airline integrates sensors and data analytics into its maintenance processes to improve reliability and safety.

3. Use of predictive maintenance: The extent to which an airline uses predictive maintenance techniques, such as machine learning algorithms and predictive analytics, to anticipate and prevent maintenance problems before they occur.

4. Adoption of digital tools and technologies: The extent to which an airline adopts digital tools and technologies, such as virtual and augmented reality, to improve the efficiency and effectiveness of its maintenance processes.

By considering these factors, SDM would provide a comprehensive assessment of an airline's use of digital technology and data analytics in its maintenance processes and highlight areas for improvement and innovation.

Use of AR/ VR in aeronautical maintenance systems

Augmented reality (AR) and virtual reality (VR) can be used in a variety of situations in aviation maintenance to improve efficiency and accuracy. Some potential scenarios include:

1. Technician training: AR and VR can be used to provide immersive training experiences for maintenance technicians. Technicians can practice performing complex maintenance procedures in a virtual environment, reducing the need for hands-on training on real aircraft.

2. Maintenance inspections: AR can be used to provide technicians with real-time information and guidance during maintenance inspections. For example, technicians can use AR headsets to access maintenance manuals, parts lists, and other critical information while performing inspections.

3. Component Replacement: In this scenario, a maintenance technician is tasked with replacing an aircraft component. Using a VR headset, the technician is able to simulate the component replacement process in a virtual environment, allowing him to practice and fine-tune his procedures before performing the work on the actual aircraft. This helps reduce the risk of human error and increase the speed and accuracy of the component replacement process. Once the component replacement is performed on the actual aircraft, the maintenance technician uses an AR headset to access real-time information and guidance during the procedure. The AR headset displays step-by-step instructions, technical drawings and parts lists, allowing the technician to complete component replacement more efficiently and accurately.

4. Troubleshooting: AR and VR can be used to support technicians during troubleshooting procedures. For example, AR can provide technicians with visual aids and step-by-step guidance, while VR can simulate complex system malfunctions and give technicians experience in solving the problem.

5. Collaboration: VR can be used to support remote collaboration between technicians, engineers and other stakeholders. For example, VR can provide a virtual environment for real-time collaboration during maintenance planning and design reviews, allowing teams to work together from different locations.

Figure no 4. 3: Use of AR/VR in maintenance systems

In each of these scenarios, AR and VR can improve the efficiency and accuracy of aviation maintenance while reducing the risk of human error and increasing the speed of maintenance procedures.

- **Using AR and VR in predictive maintenance.**

In this scenario, airlines use AR and VR to support their predictive maintenance program by viewing and analyzing sensor data from aircraft systems in real time. Using AR, airlines can overlay sensor data on real-world images of aircraft components, allowing maintenance technicians to quickly identify and respond to potential maintenance issues.

VR can be used to create virtual simulations of aircraft systems and components, allowing them to perform predictive maintenance analysis in a safe and controlled environment

Figure 4.4 shows an example of a program using AR and VR in aviation maintenance.

This is just a basic example of how AR and VR can be used in aviation maintenance. Actual implementation may vary depending on each airline's specific requirements and constraints and maintenance scenario.

## 5. HUMAN PERFORMANCE IN MODERN AVIATION SYSTEMS

Chapter 5 presents:

- **Diagnostic criteria**
- **Elaboration of stress diagnostic criteria in the aeronautical environment**

In the diagnosis of stress in the aeronautical environment, the following criteria are taken into account:

1. Self-report surveys: Self-report surveys can provide valuable information about an individual's stress level and the sources of stress they are experiencing. This may include questions about workload, job satisfaction, and physical and emotional symptoms of stress.
2. Performance appraisals: Performance appraisals can provide insights into how stress affects a person's job performance and overall productivity. This may include data on absenteeism, turnover and workplace errors or incidents.
3. Behavioral Observations: Behavioral observations can provide insights into the physical and emotional symptoms of stress. These may include changes in behavior, such as increased irritability or decreased motivation, as well as changes in physical appearance, such as weight loss or changes in sleep patterns.
4. Biomedical Measures: Biomedical measures such as heart rate and cortisol levels can provide objective measures of stress and its impact on an individual's physical and emotional well-being.
5. Interviews and focus groups: Interviews and focus groups can provide in-depth information about the sources of stress and its impact on individuals at work. This may include information about organizational culture, communication and support systems.

Using a combination of these criteria, organizations can gather comprehensive information about the level of stress and its impact on personnel in the aviation environment. This information can then be used to develop and implement effective interventions to support individuals and improve the overall well-being and performance of the workforce.

- **Innovative stress assessment methods in the aeronautical environment**

There are several innovative methods of stress assessment in aeronautical environments, including:

a. Wearable technology: Wearable technology can be used to monitor indicators of physiological stress such as heart rate and sleep patterns. By using wearable technology, organizations can gain real-time insight into an individual's stress levels, buying time to take proactive steps to manage stress and improve performance.

b. Self-report surveys: Self-report surveys are a method of gathering information about an individual's subjective experience of stress. These studies can provide a more complete picture of stress levels in the aviation environment, allowing organizations to understand the impact of stress on their staff.

c. Psychophysiological measures: Psychophysiological measures such as electroencephalography (EEG) and skin conductance can be used to assess physiological responses to stress. These measures provide objective indicators of stress levels, allowing organizations to better understand the impact of stress on their staff.

d. Virtual reality simulations: Virtual reality simulations can be used to recreate high stress situations in a controlled environment. These simulations allow individuals to practice stress management techniques and build resilience, improving their ability to handle stress in real situations.

e. Resilience Training: Resilience training is a method of developing the skills and knowledge needed to effectively manage stress and maintain performance in high-stress environments. This type of training can be beneficial in reducing the impact of stress on performance and improving overall well-being.

f. Biomarkers: Biomarkers, such as cortisol levels, can be used to assess physiological responses to stress. These measures provide objective indicators of stress levels, allowing organizations to better understand the impact of stress on their staff.

g. Cognitive assessment: Cognitive assessments, such as cognitive function tests and reaction time tests, can be used to assess the effects of stress on cognitive performance. By using cognitive assessments, organizations can gain a better understanding of the impact of stress on cognitive function and identify areas for improvement.

h. Mindfulness and relaxation techniques: Mindfulness and relaxation techniques, such as meditation and deep breathing, can be used to help people manage stress in real time. These techniques can reduce the impact of stress on performance and improve overall well-being.

i. Artificial intelligence and machine learning: Artificial intelligence and machine learning algorithms can be used to analyze large amounts of data, providing insights into factors that contribute to stress in aeronautical environments. By using these technologies, organizations can identify areas for improvement and take proactive steps to manage stress.

j. Collaborative stress management: Collaborative stress management programs can be used to promote a supportive, stress-resilient culture. These programs allow individuals to work together to identify and manage stress in the aviation environment, improving overall well-being and performance.

These methods can be used in combination or as specialized solutions, depending on the needs of the organization and the specific requirements of their aeronautical operations. By incorporating these innovative solutions into their assessment process, organizations can gain a better understanding of the stress levels in their aviation environment and take action to improve the well-being and performance of their staff.

These methods can provide organizations with valuable information about the stress levels of their staff, enabling them to take proactive measures to improve the performance of their staff in high-stress aviation environments.

- **Innovative methods for evaluating human performance in maintenance tasks. Use of augmented reality (AR) technology.**

AR technology can provide real-time feedback and support to maintenance technicians during a task. E.g:

1. AR Visual Aids: AR can provide visual aids, such as step-by-step instructions or highlighting important components, to help the technician complete the task more efficiently and accurately.
2. Virtual Mentorship: AR can provide virtual mentorship, allowing experts to remotely observe and provide guidance to technicians in real time.
3. Real-time performance tracking: AR can track and measure the technician's movements and actions during the task, providing objective data about their performance.
4. Safety Checks: AR can perform safety checks during the task and alert the technician to potential hazards in real time.
5. Continuous improvement: AR can provide insight into technician performance over time, allowing for continuous improvement and training opportunities.
6. Skills Assessment: AR can assess the technician's knowledge and proficiency in various maintenance procedures, identifying areas for improvement and helping to create customized training programs.
7. Collaboration: AR can facilitate collaboration between multiple technicians working on a single task, enabling real-time communication and problem solving.
8. Data Analysis: Performance data collected through AR technology can be analyzed to identify patterns, trends and potential improvements to maintenance processes and procedures.
9. Predictive maintenance: AR can be used to support predictive maintenance, using data collected during maintenance tasks to anticipate future failures and proactively address them.
10. Increased efficiency: Using AR technology can increase the efficiency of maintenance tasks, reducing downtime and improving overall productivity.
11. Enhanced Training: AR technology can be used as an effective training tool for maintenance technicians, allowing them to practice and hone their skills in a virtual environment before performing tasks in the real world.
12. Improved morale: Using AR technology can provide a more engaging and rewarding experience for maintenance technicians, improving their motivation and overall morale.
13. Real-time feedback: AR technology can provide technicians with real-time feedback on their performance, allowing them to make immediate adjustments and improve their performance in real-time.
14. Reduced maintenance costs: Using AR technology can help reduce maintenance costs by minimizing errors, increasing efficiency and reducing downtime.

15. Better maintenance management: AR technology can provide valuable insights into the performance and productivity of maintenance technicians, enabling better management of maintenance operations. This method not only provides a more accurate assessment of human performance, but also supports the technician in performing the task more safely, efficiently and effectively.

❖ **Innovative solutions for evaluating human performance in maintenance tasks**

In addition to these wearable technologies, there are other innovative solutions that can be used to assess human performance in maintenance tasks, such as:

a. **Virtual and augmented reality simulations:** These can be used to provide a realistic simulation of maintenance tasks, allowing technicians to practice and improve their skills in a safe and controlled environment.

**b. Predictive analytics**: Active predictive analytics can be used to analyze performance data collected from wearable technology or other sources, providing insights into areas for improvement and identifying patterns that can help predict future performance.

c. **Artificial intelligence and machine learning:** These technologies can be used to analyze performance data and provide recommendations for improvement, helping to improve the performance and safety of maintenance technicians.

d. **Cloud-based solutions:** Cloud-based solutions can provide real-time access to data and performance insights, enabling better collaboration and communication between technicians and management.

These innovative methods can be used in combination or as stand-alone solutions, depending on the needs of the organization and the specific requirements of maintenance operations. By incorporating these innovative solutions into their assessment process, organizations can continuously monitor and improve the performance and safety of their maintenance technicians, leading to improved results and increased overall value.

❖ **Training suggestions to increase resilience**

The following steps are suggested in developing a training program to increase resilience:

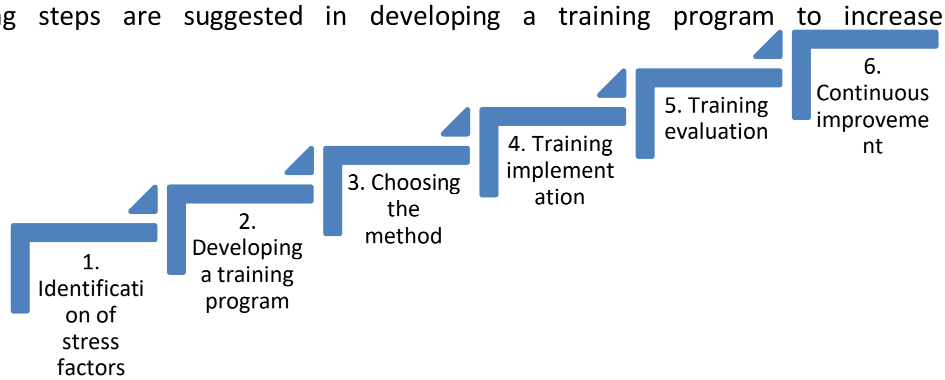



Figure 5. 1 Steps in developing a resilience training program

1. Identifying Stressors: The first step in developing a resilience training program is to identify the stressors that are prevalent in the aviation environment. This information can be gathered through self-report surveys, focus groups, or staff interviews.

2. Develop a training program: Once stressors have been identified, the next step is to develop training content that addresses these stressors and teaches individuals how to effectively manage stress. This content should include a combination of knowledge and skills-based training, such as stress management techniques and cognitive behavioral therapy.

3. Choosing the method: The next step is to choose a delivery method for the training. This could include instructor-led training, e-learning or blended learning. The delivery method should be chosen according to the needs of the organization and the trained personnel.

4. Training Implementation: Once the training content has been developed and the delivery method has been chosen, the next step is to implement the training. This should be done in a supportive and inclusive manner, allowing individuals to learn and practice stress management techniques in a safe and supportive environment.

5. Evaluation of the training: After implementing the training, it is important to evaluate its effectiveness. This can be done through self-report surveys, focus groups or other methods of gathering feedback. This feedback can then be used to refine the training and ensure it meets the needs of the organization and the staff being trained.

6. Continuous improvement: The final step is the continuous improvement of the training program. This should be done based on staff feedback and assessment results, ensuring that training remains relevant and effective in addressing the stressors of the aviation environment.

By following these steps, organizations can develop a comprehensive and effective resilience training program to help their staff reduce stress and maintain performance in high-stress aviation environments.

## 6. TECHNICAL PERFORMANCE IN MODERN AVIATION MAINTENANCE SYSTEMS

This chapter presents:

- **Current aeronautical maintenance systems**

Aircraft maintenance refers to the inspection, repair and overhaul of aircraft components and systems to ensure their safe and efficient operation. It is an essential aspect of the aviation industry as it helps to ensure the reliability and performance of aircraft and reduce the risk of breakdowns or unplanned downtime.

- **Types of maintenance used in FAR**

Depending on the technical condition of the aircraft, the period and time of repair and maintenance work, maintenance can be classified as:

- preventive,
- corrective,
- complex.

- **Codification of maintenance in modern aviation systems**

Maintenance coding is a system used to classify and manage aircraft maintenance information, procedures and tasks. This provides a standardized approach to organizing, storing and retrieving maintenance information and helps ensure that maintenance activities are performed in a consistent and efficient manner.

- **Innovative maintenance coding**

Innovative maintenance coding refers to the development and implementation of new and improved approaches to the organization, storage and retrieval of aircraft maintenance information, procedures and tasks. These innovative approaches aim to increase the efficiency, accuracy and cost-effectiveness of aircraft maintenance activities.

The following approaches are proposed in coding modern maintenance systems:

1. Digital Maintenance Task Cards: Digital maintenance task cards are electronic versions of traditional paper maintenance cards that allow for easier access, updates and sharing of maintenance information.

2. Predictive Maintenance: Predictive maintenance is an approach that uses advanced analytics and data analysis to identify potential maintenance issues before they occur, enabling proactive and preventative maintenance actions to be taken.

3. Augmented Reality (AR) and Virtual Reality (VR) Technology: AR and VR technology can be used to provide interactive and immersive training experiences for maintenance technicians, enabling hands-on, real-world simulations of maintenance tasks.

4. Mobile maintenance applications: Mobile maintenance applications provide access to maintenance information and procedures on mobile devices, allowing maintenance technicians to access and perform maintenance tasks from anywhere at any time.

5. Blockchain Technology: Blockchain technology can be used to securely store and manage maintenance information and data, ensuring the accuracy and integrity of this information.

6. Artificial Intelligence (AI) and Machine Learning: AI and machine learning can be used to analyze large amounts of maintenance data, identify patterns and trends, and make predictions about future maintenance needs. This can help optimize maintenance schedules, reduce maintenance costs and improve aircraft safety and reliability.
7. Cloud-based maintenance management systems: Cloud-based maintenance management systems provide a centralized repository for maintenance information and procedures, allowing real-time access and updates from anywhere in the world.
8. Internet of Things (IoT) technology: IoT technology can be used to collect real-time data from aircraft systems and components, providing valuable information on the health and performance of these systems. This information can be used to support predictive maintenance and improve the overall efficiency of maintenance activities.
9. Remote monitoring and diagnostics: Remote monitoring and diagnostics systems allow maintenance organizations to remotely monitor the performance and health of aircraft systems and components, providing early warning of potential problems and enabling maintenance technicians to take proactive steps to resolve these issues.
10. Collaborative maintenance platforms: Collaborative maintenance platforms provide a collaborative environment for maintenance organizations, suppliers and regulators to work together and share information and resources, helping to improve the efficiency and effectiveness of maintenance activities.
11. Digital Twin Technology: Digital Twin technology creates a virtual replica of an aircraft and its systems, allowing maintenance organizations to simulate and test maintenance procedures and assess the impact of those procedures on the aircraft. his performance.
12. Automatic maintenance planning: automatic maintenance planning systems nants use algorithms and machine learning to generate optimized maintenance schedules, reducing the time and effort needed to plan and execute maintenance activities.
13. Big Data Analytics: Big Data Analytics can be used to collect and analyze large amounts of data from multiple sources, providing valuable insights into maintenance performance, trends and areas for improvement.
14. Predictive Maintenance Analytics: Predictive Maintenance Analytics uses machine learning algorithms to analyze large amounts of maintenance data, making predictions about potential maintenance issues and helping to prevent unplanned maintenance downtime and costs.
15. Autonomous Maintenance: Autonomous maintenance systems use artificial intelligence and machine learning to perform routine maintenance tasks with minimal human intervention, improving the efficiency and cost-effectiveness of maintenance activities.

- **Application of innovative statistical tools in predictive maintenance in aviation**

In predictive maintenance, the goal is often to predict the time to failure (TTF) of a particular component. This can be modeled using a statistical technique called survival analysis, which models the probability of a component failing as a function of time.
A common model used in survival analysis is the Weibull distribution, which models the TTF as a cumulative distribution function:

$$F(t) = 1 - \exp(- (t / \beta)^\alpha),$$

where $F(t)$ is the cumulative distribution function, $t$ is time, $\alpha$ is the shape parameter, and $\beta$ is the scale parameter.
This mathematical relationship can be used to estimate the probability of failure for a given component given its TTF data. This information can then be used to make predictions about the probability of failure for that component in the future and plan maintenance activities accordingly.
It is important to note that this is only one example of a mathematical relationship that can be used in the context of predictive maintenance, and the specific relationship will vary depending on the data and system being analyzed.

Another example in predictive maintenance is the use of regression models. Regression models are used to model the relationship between a dependent variable (such as TTF) and one or more independent variables (such as operational data, environmental data, and maintenance data).
For example, a linear regression model can be used to model the relationship between TTF and operational data such as flight hours, altitude and temperature. The equation for a simple linear regression model is given by:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + ... + \beta kXk + \varepsilon,$$

where Y is the dependent variable (TTF), X1, X2, ... Xk are the independent variables (operational data), β0 is the intercept, β1, β2, ... βk are the coefficients representing the effect of each independent variable on the dependent variable, and ε is the error term.
By fitting the data to a regression model, one can estimate the coefficients and characterize the relationship between the independent variables and the dependent variable. This information can be used to make predictions about a component's FTT based on its operational data, allowing maintenance organizations to plan maintenance activities more effectively.

- **New methods for evaluating technical performance in modern aeronautical systems**

There are several new methods of evaluating technical performance in modern aeronautical systems, some of the most commonly used include:
1. Digital twin technology: This involves creating a virtual replica of the aeronautical system and using it to simulate and evaluate its performance.
2. Big data analysis: By collecting and analyzing large amounts of data from the aeronautical system, it is possible to identify performance trends and patterns.
3. Artificial Intelligence and Machine Learning: AI and AL algorithms can be used to analyze and evaluate performance, detect anomalies and make predictions about future performance.
4. Model-based systems engineering: This approach uses mathematical models and simulations to evaluate aeronautical system performance and identify areas for improvement.
5. Cloud computing: Cloud computing enables the storage and analysis of large amounts of data from multiple sources, making real-time performance evaluation possible.
6. Condition-Based Maintenance (MBC): This approach uses real-time monitoring and data analysis to determine when maintenance is required, rather than relying on a set schedule. This can help reduce downtime and improve overall aeronautical system performance.
7. Human Machine Interface (HMI) Design: Good HMI Design aj helps ensure that the aeronautical system is easy to use and understand, which can improve performance by reducing the risk of human error.
8. Virtual reality (VR) and augmented reality (AR) simulation: VR and AR simulation can be used to train pilots and engineers, allowing them to experience and evaluate different scenarios in a controlled environment.
9. Wireless Sensor Networks: Wireless sensors can be used to collect data from various parts of the aeronautical system and transmit it wirelessly to a central location for analysis.
10. Real-time performance monitoring: By monitoring the performance of the aeronautical system in real-time, it is possible to quickly detect problems and take corrective action, improving the overall performance of the system.
11. Predictive Maintenance: Predictive maintenance uses data and analytics to forecast when maintenance will be needed, allowing maintenance teams to proactively address issues before they lead to system failures or unplanned downtime.
12. Simulation-based design: Simulation-based design allows engineers to test and evaluate the performance of aeronautical systems before they are built, reducing the risk of design defects and increasing the efficiency of the development process.
13. Multidisciplinary Design Optimization (MDO): MDO is a computer-aided engineering process that integrates multiple disciplines, including aerodynamics, structural analysis, and systems engineering, to optimize the design of aeronautical systems.

14. Flight test data analysis: Flight test data analysis provides a wealth of information about the performance of aeronautical systems during actual flight conditions, allowing engineers to identify areas for improvement and make changes to increase performance.
15. Collaborative Engineering: Collaborative engineering involves cross-functional teams working together to evaluate the performance of aeronautical systems, drawing on the expertise of multiple disciplines to identify and solve problems.
16. Internet of Things (IoT) and Edge Computing: The integration of IoT devices and edge computing into aeronautical systems enables real-time monitoring and data analysis, enabling proactive maintenance and reducing the risk of system failures.
17. Cyber Security: With the increasing use of technology in aeronautical systems, it is essential to ensure that these systems are secure and protected against cyber attacks. Cybersecurity assessments and evaluations are an important part of assessing the technical performance of modern aeronautical systems.
18. Autonomous systems: The development of autonomous systems is revolutionizing the aviation industry, and their performance evaluations are essential to ensure their safe and efficient operation. This includes performance evaluations of sensors, algorithms and control systems used in autonomous systems.
19. Green Aviation: As the aviation industry focuses on reducing its environmental impact, performance evaluations of sustainable aviation technologies such as electric and hybrid aircraft are becoming increasingly important.
20. Human Factors Engineering: Human factors engineering evaluates the interaction between aeronautical systems and their operators to ensure that the systems are designed to be easy to use, safe and efficient.
21. Predictive Maintenance Analytics: Predictive maintenance analytics use machine learning algorithms and data to forecast the health of aeronautical systems and anticipate when maintenance is required. This can help reduce downtime and improve overall system performance.
22. Maintenance Performance Monitoring: Maintenance performance monitoring involves tracking the performance of maintenance operations, including the accuracy of maintenance predictions, the effectiveness of maintenance procedures, and the effectiveness of maintenance techniques. This data can be used to improve the overall maintenance process and increase the performance of aeronautical systems.
23. Root Cause Analysis: Root cause analysis is a process used to identify the underlying causes of problems with aircraft systems so that maintenance teams can take corrective action to prevent similar problems from occurring in the future.
24. Spare parts management: Effective spare parts management is essential to ensure that aeronautical systems are maintained and repaired quickly and efficiently. This includes tracking the stock of spare parts, managing the purchase of spare parts and ensuring that spare parts are available c u ease when needed.
25. Maintenance Resource Planning: Maintenance resource planning involves forecasting the maintenance requirements of aeronautical systems, including the personnel, equipment and materials required to perform maintenance, to ensure that maintenance teams are prepared and equipped to perform their work.

These methods demonstrate the importance of using technology and data analysis in evaluating technical performance in modern aeronautical systems. They provide a more comprehensive understanding of system performance and help identify areas for improvement, leading to increased safety, efficiency and reliability in the aviation industry. These new methods lead to the development of state-of-the-art aeronautical systems, providing more accurate and comprehensive performance assessments and enabling improvements in safety, efficiency and reliability.

These new methods and approaches demonstrate the continued evolution of the aeronautical industry as technology and data analysis continue to play a key role in improving the performance and safety of aeronautical systems.

- **The level of air safety in the Romanian military aviation**

From the point of view of technical means, aircraft are the basic means and those which, through their availability and functionality, affect to the greatest extent the level of air safety.

Another element that characterizes the aircraft is the degree of availability and the quality of this availability, evidenced by the number of failures occurring over time.

The determination of the current status of the SA in the FAR was carried out by the statistical analysis of the number of failures in the mentioned periods, by aircraft types, on the ground and in flight, in correlation with the Pearson Coefficient. Following the results, conclusions were drawn to improve the situation.

- **Case study: Analysis of a failure produced by environmental conditions on the static Pitot system**

**Condition Based Maintenance (MBC) - proposals for adopting an optimal maintenance strategy**

MBC has become an increasingly important approach in maintenance and reliability engineering. It aims to optimize maintenance activities by monitoring the actual condition of equipment or systems, rather than relying solely on predetermined maintenance intervals. Research and development of MBC techniques have progressed significantly, with various studies and advances in recent years.

A notable area of research in MBC is the development of sensor technologies and data analysis methods. Sensors play a crucial role in capturing real-time data from equipment or systems, enabling condition monitoring and diagnostics. Advances in sensor technology, such as wireless sensors, have made it easier to collect data from remote or hard-to-reach locations. In addition, research focuses on the development of advanced algorithms and machine learning techniques to analyze large volumes of data and extract meaningful information regarding the status of monitored systems.

Several studies have explored the application of MBC in various industries, including aviation, manufacturing, and transportation. In aviation, research has focused on integrating various sensor data, such as vibration, temperature and pressure, to assess the health and performance of aircraft components, including the pitot-static system. By analyzing data trends and patterns, researchers aim to predict and prevent potential failures, optimize maintenance schedules and reduce downtime.

In recent years, there has been a growing interest in integrating MBC with other emerging technologies such as the Internet of Things (IoT) and big data analytics. IoT enables the connectivity of various devices and sensors, enabling real-time monitoring of equipment status and seamless transfer of data for analysis. This integration opens up new possibilities for MBC as it enables a more comprehensive and accurate assessment of equipment health, facilitates predictive maintenance and enables timely decision making.

The role of MBC in detecting problems in the pitot-static system is crucial for several reasons:

a. **Early detection**: Condition-based maintenance allows potential problems to be detected at an early stage. By continuously monitoring system health and analyzing data, problems can be identified before they become more significant failures. Early detection enables timely corrective action, minimizing the risk of in-flight system failures.

b. **Cost efficiency**: Condition-based maintenance optimizes maintenance efforts by focusing on components or systems that require attention based on their actual condition. This approach eliminates eliminates unnecessary maintenance tasks and reduces associated costs, such as replacement parts and labor hours.

c. **Enhanced Safety**: By proactively detecting and addressing problems in the pitot-static system, MBC contributes to improved safety. It helps provide accurate airspeed and altitude readings, which are essential for proper aircraft control, situational awareness, and avoiding potential hazards.

d. **System Reliability:** Regular condition-based monitoring and maintenance of the pitot-static system increases its overall reliability. Identifying and fixing problems before they lead to system failures or inaccurate readings helps maintain system performance and integrity.

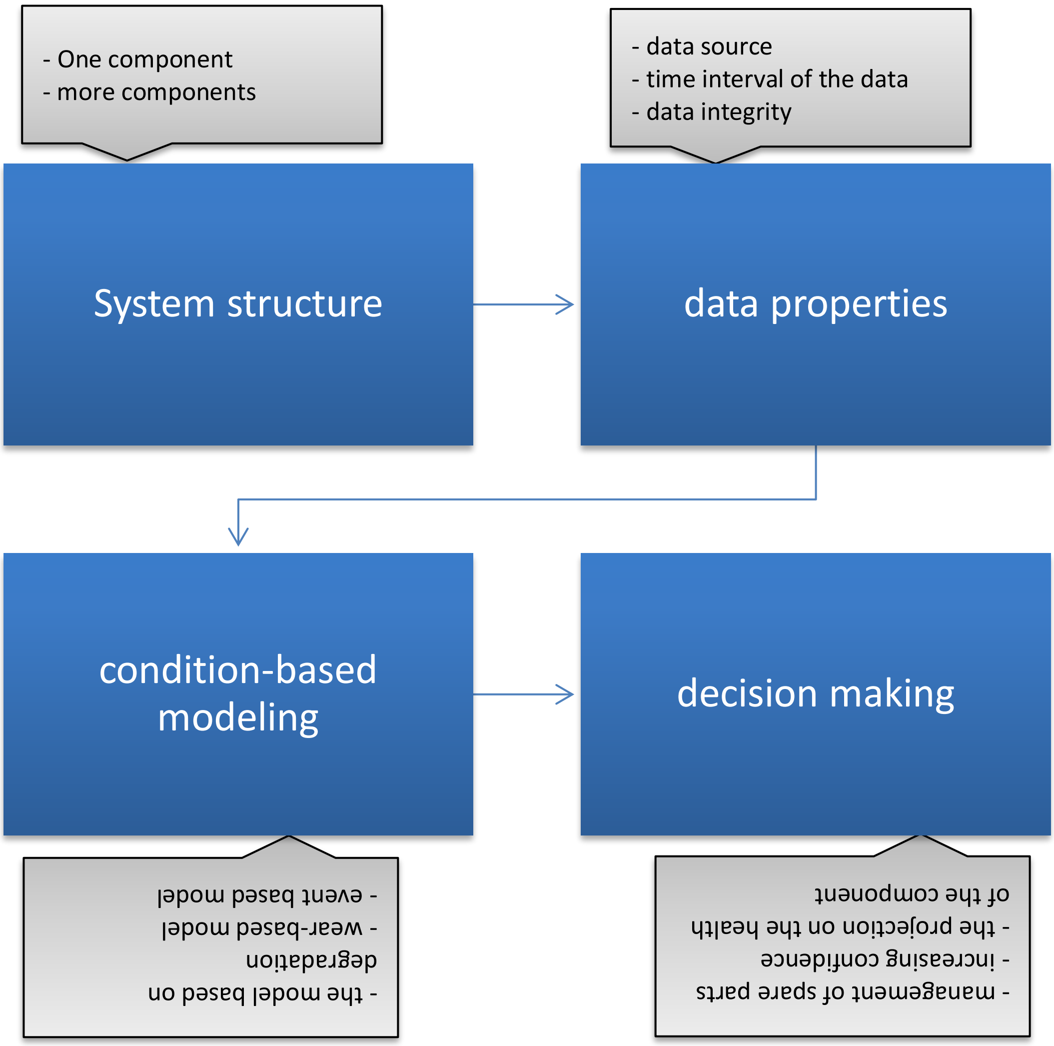



Figure 6. 1 Proposed scheme of MBC

In conclusion, research on condition-based maintenance (MBC) is dynamic and evolving, driven by advances in sensor technologies, data analytics, and the need for more effective maintenance strategies.

- **Operational aspects in pitot-static system analysis**

A "pitot-static" pressure system is a set of instruments on board aircraft that use pressure to provide information about the aircraft's movement in space in the form of speed, altitude, vertical speed. The system consists of one or more pitot tubes, static pressure taps, pressure distribution pipes and indicating instruments. Instruments coupled to the pressure sources are the speedometer, altimeter, variometer, aerodynamic power stations, flight data recorders, altimeters, T-CAS, cabin pressurization controllers and various speed switches. The information provided by these systems has a direct impact on flight safety because they are considered basic elements in aircraft piloting. Several aviation accidents have been associated with errors provided by this complex system.

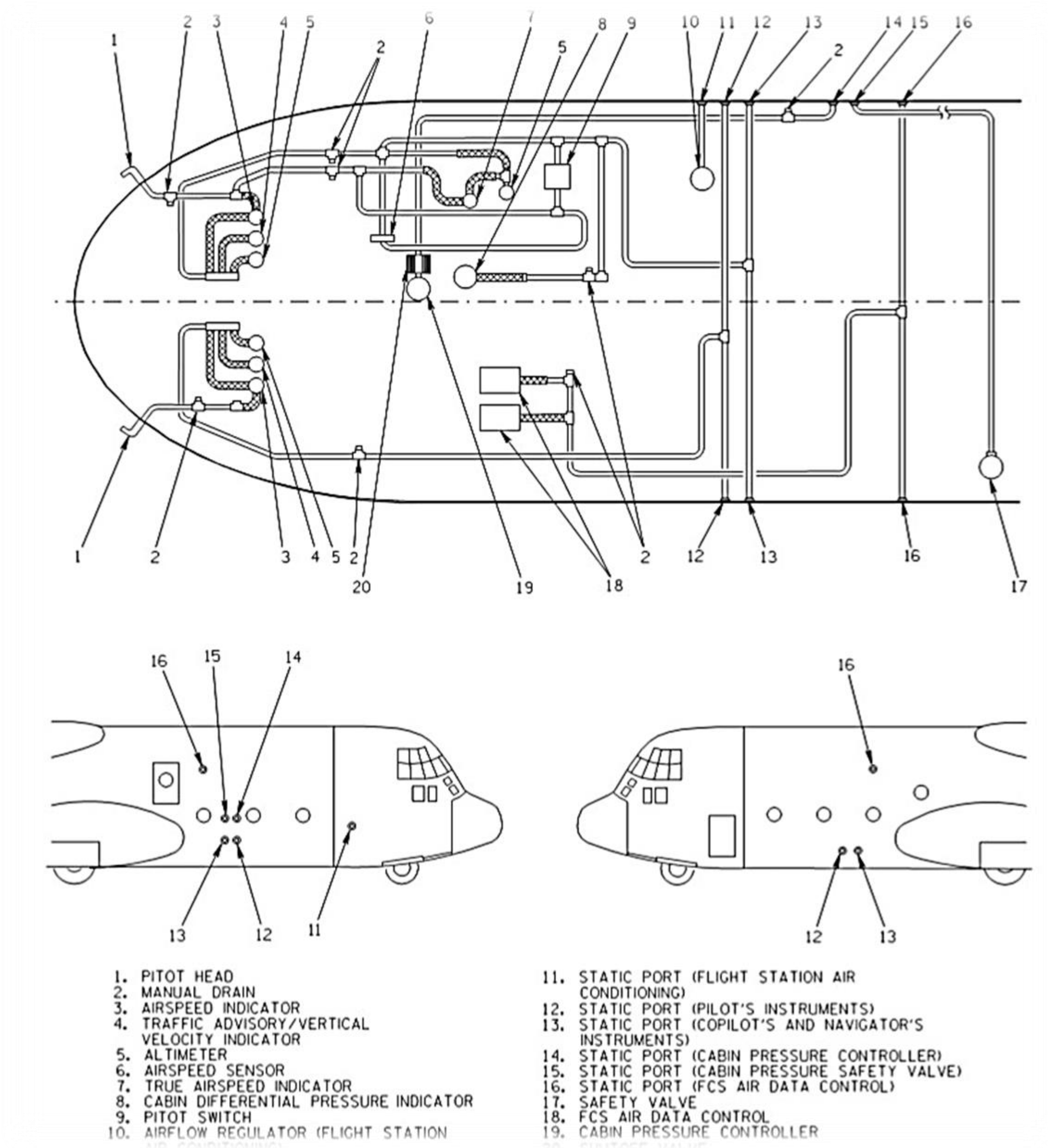



Figure 6. 2 Complex "pitot-static" system on a military transport aircraft(Taken from ROAF FM C130 B/H )

**• Identification of leaks in the static Pitot system. Recommended maintenance for the Pitot-static system:**

Identifying leaks in the pitot-static system is crucial to ensure proper operation and accurate readings. A general approach to leak detection and system testing is presented in the following steps:

**• Visual Inspection:** A thorough visual inspection of pitot tubes, static ports, tubes and connectors is performed. Look for signs of damage, corrosion, loose fittings or any visible leaks such as liquid stains or drips. Check that all components are securely attached and in good condition.

**• System Pressurization Test:** One way to check for leaks is by pitot-static pressurizing the system. This can be done using specialized equipment, such as a hand pump or air source, along with pressure gauges. It begins by closing any valves that connect to other systems, such as the alternate static source. Gradually increase system pressure and monitor gauges for any sudden drops, which may indicate a leak. Pay close attention to pressure readings to ensure they remain stable.

**• Functional check:** a functional check of the pitot-static system is performed by testing the associated instruments. The airspeed indicator, altimeter, and vertical speed indicator are checked to ensure that they provide accurate and consistent readings. Check readings with other trusted sources or tools to verify their accuracy.

• **Barometric Pressure Check:** Regularly compare altimeter readings to a known and accurate barometric pressure source. This can be done by referring to a local weather station or using a calibrated barometric pressure instrument. Any significant discrepancies should be investigated further as they may indicate a problem within the pitot-static system.

**Recommended maintenance for the Pitot-static system:**

• **Regular Inspections:** Perform routine visual inspections of pitot tubes, static ports, tubing, and connectors to ensure they are not damaged, obstructed, or leaking. Inspections should be performed in accordance with manufacturer recommendations or regulatory requirements.

• **Cleaning:** Periodically clean the pitot tubes and static ports to remove any debris, dirt or insects that may interfere with their functionality. Ensure that the cleaning methods and solutions used are compatible with the specific components and follow the manufacturer's instructions.

• **Calibration:** Calibrate the speedometer and altimeter at regular intervals to ensure accurate readings. Calibration must be performed by qualified technicians using specialized equipment and following the manufacturer's specifications.

• **Pitot Heater System Maintenance:** If the aircraft is equipped with a pitot heater system, regular inspection and testing is provided to ensure proper functionality. This includes checking the heating elements, control switches and associated wiring.

• **Record keeping:** Detailed records of inspections, maintenance activities, repairs and any discrepancies related to the pitot-static system are maintained. This documentation helps track system history, facilitates troubleshooting, and ensures compliance with regulatory requirements.

It is important to refer to the aircraft manufacturer's specific documentation, maintenance manuals and regulatory guides for detailed procedures and recommendations regarding pitot-static system maintenance for a specific aircraft type.

**• Specialized equipment to test the Pitot-static system**

Specialized equipment plays a vital role in testing and diagnosing problems in the pitot-static system. Some examples of equipment commonly used for testing are listed:

**Pitot-Static Test Set:** A pitot-static test set is a specialized device designed to simulate air pressure and accurately measure the response of the pitot-static system. It typically includes gauges, valves, and connections to simulate various flight conditions and evaluate system performance. Test sets can be manual or automatic and allow technicians to pressurize the system and verify the accuracy of airspeed, altitude and vertical speed indications.

**Data Test AerSet:** An Air Data Test Set is a comprehensive tool that can simulate various flight parameters and test the entire pitot-static system. It allows the simulation of variations in speed, altitude, temperature and pressure that occur during flight. This equipment is more advanced and can provide detailed information about the perf system performance, including dynamic response and calibration accuracy.

**Leak Detection Equipment**: Leak detection equipment is used to identify and locate leaks in the pitot-static system. It may include devices such as ultrasonic leak detectors, which can detect high-frequency sounds generated by air or fluid escaping the system. Another example is smoke generators that introduce smoke into the system and visually indicate areas where leaks are present.

**• Accidents caused by defects in the Pitot-static system**

Accidents related to the pitot-static system in aviation highlighted the criticality of maintaining the accuracy and reliability of this system. Advances in technology and cockpit automation have been implemented to provide pilots with better situational awareness and tools to address issues with the pitot-static system.

- **Theoretical aspects in the analysis of the pipe from the Pitot-static system.**

**• Griffith analysis regarding the possibility of crack propagation**

Linear elastic fracture mechanics is based on the assumptions: the material is ideally elastic, homogeneous and isotropic. Also, the hypothesis of a continuous medium is valid, the presence of cracks in its volume being admitted. The mechanisms leading to crack propagation are generally very complex on an atomic scale. A relationship can be established between the global propagation resistance and the parameter resulting from the load.

**• Irwin's analysis regarding the state of tension and deformation in the vicinity of a crack**

In the energy balance theory stated by Griffith, Irwin substituted a local approximation based on the stress field existing around a crack. He formulated the problem of calculating the available and necessary energy for a crack of half length a, to advance the infinitely small distance, yes.

Irwin considers at the tip of the crack a region small enough in relation to the respective solid but large enough in relation to the atomic dimensions, in accordance with the theory of linear elasticity, figure 6.24

The origin of the coordinate system is at the tip of the crack, point M, where the stresses are determined, with polar coordinates r and θ, being the center of the infinitesimal element, with r<<a.

The crack is considered to be flat with sharp ends.

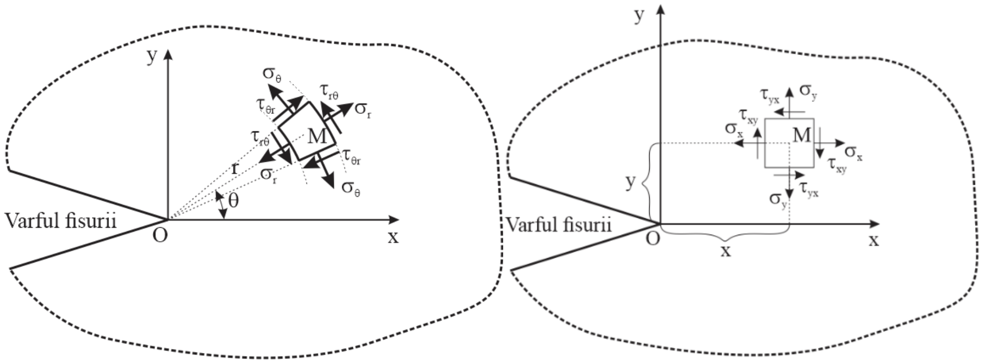



Figure 6. 3: The infinitesimal element in Cartesian and polar coordinates

For brittle materials it is difficult to initiate a crack and control its propagation. One of the more common methods consists of making a very fine notch with the help of diamond cutters. Thicknesses can be variable: from several hundredths of mm to several hundredths of µm. The notch width must take into account the microstructure parameters of the material and must not lead to overestimated values of the cracking resistance.

In the case of vitreous materials or composites containing a ductile phase, a sharp crack must be made to avoid clogging of its tip, which would reflect on the measurement result.

This type of crack can be obtained by several methods:

1- cracking by the wedge method: a metal wedge is inserted into a notch, so as to produce a crack in the extension of the notch.

2. - thermal shock cracking: the crack is obtained by the movement of a hot point, along a certain route established in advance on the sample.

3 - cracking by controlled propagation starting from a mechanical pre-notch;

4 - cracking starting from the marks left by the hardness test (materials with high fragility).

A defect that is due to environmental conditions (high altitude flight conditions), is the case of the Al 2024 T3 pipes used for the pressure intakes. Due to the formation of ice plugs, following the exposure of their aircraft to low temperatures, their local destruction by cracking occurs.

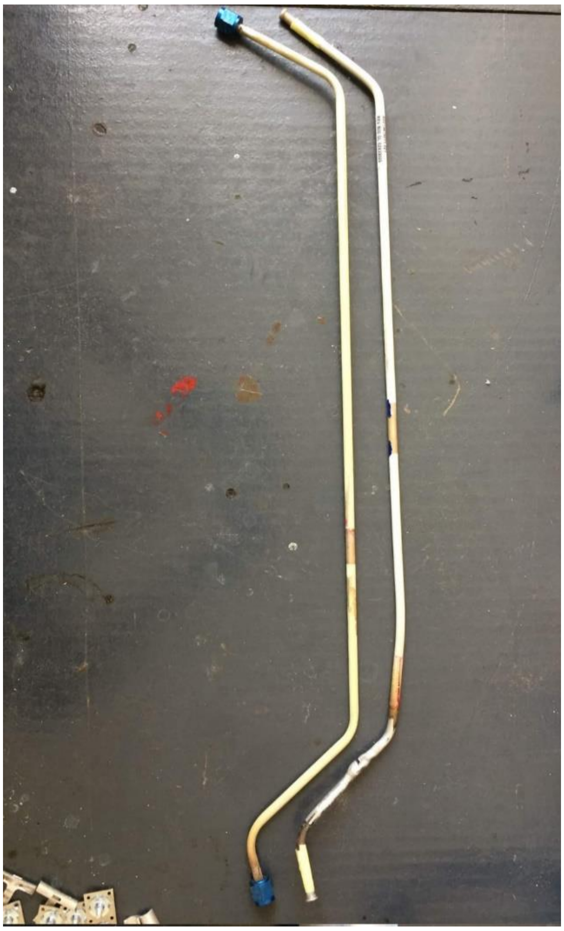


Figure 6. 4: Pipes of the pressure sockets

The cracks that appear are parallel to the pipe axis (along the cylinder generator), Figures 6.28 and 6.29 show the defects that appear in such situations.

Defects occur occasionally, not depending on the flight time of the aircraft, but on the conditions in which it flies. For example, for the pipe in figure 6.25, the defect appeared after 8 years of operation. For this pipe, welding technologies can be applied to remove the defect.

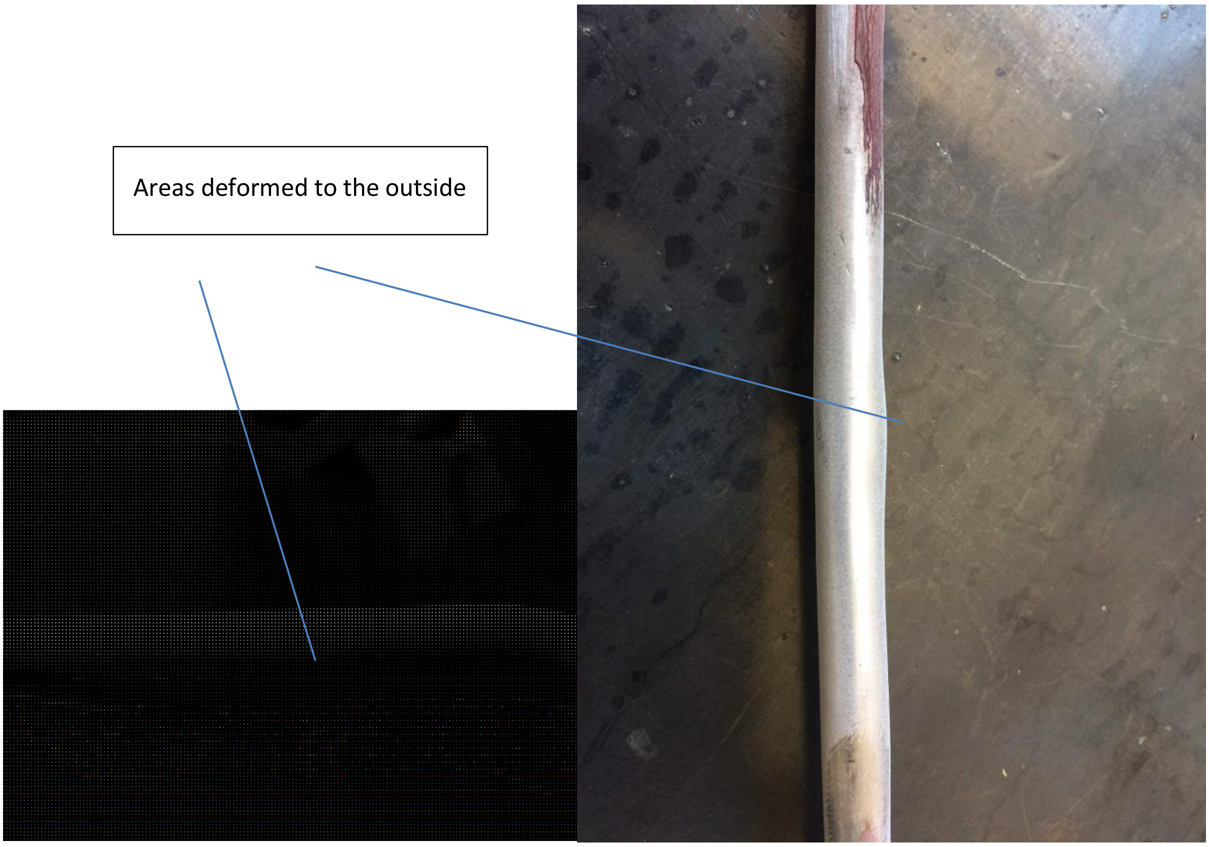



Figure 6. 5: Pipes of the pressure sockets deformed from the inside to the outside

Figure 6. 6: Cracked pipe

For high-strength materials, where breakage is preceded by low values of plastic deformation, associated with brittle-type breakage, the hypothesis of linear-elastic behavior is accepted in the region of the crack tip from which the breakage process initiates and develops. The material characteristic is represented by the mechanical stress intensity factor K, a quantity that is a measure of the increase in mechanical stress in the presence of a crack, compared to the existing stress in its absence.

**The finite element model**

For the geometry, a straight section of pipe 50 mm long, with an inner diameter of 8 mm and an outer diameter of 10 mm, was considered. The inner and outer surfaces were divided into three, the end surfaces 20 mm long and the central surfaces 10 mm long.

The inner central surface was pressure loaded to simulate the action of an ice plug on the pipe wall. The pressure was initially considered to be 5 MPa.

The chemical composition of the Al 2024 T3 alloy is as follows (table 6.11):

Table 6. 1 Chemical composition of Al 2024 T3

| **Compound** | **%** | **Compound** | **%** | **Compound** | **%** |
|---|---|---|---|---|---|
| Al | 90.7 - 94.7 | Mg | 1.2 - 1.8 | Si | Max 0.5 |
| Cr | Max 0.1 | Mn | 0.3 - 0.9 | Ti | Max 0.15 |
| Cu | 3.8 - 4.9 | Altele | Max 0.2 | Zn | Max 0.25 |
| Fe | Max 0.5 | | | | |

General characteristics and uses: good machinability, surface finishing possible. A high strength material with multiple uses.

Alloy uses: aircraft seals and fittings, gears and shafts, screws, watch parts, IT applications, couplings, electrical machine applications, hydraulic valve bodies, missile parts, ammunition, nuts, pistons, worm gears, fasteners, veterinary and orthopedic equipment, metal structures.

Table 6.12 shows the properties of the alloy.

Table 6. 2 Properties of Al 2024 T3 for the temperature of 20 degrees C

| | | |
|---|---|---|
| **Physical properties** | | |
| Density | 2,78 | |
| **Mechanical properties** | | |
| Brinell hardness | 120 | At a load of 500 g, with a ball of diam. 10 mm |
| Breaking stress | 483 MPa | |
| Flow voltage | 345 MPa | |
| Elongation at break | 18% | |
| Longitudinal modulus of elasticity | 73.1 GPa | Average between tensile and compressive modulus (compressive 2% higher) |
| Coef. Poisson | 0,33 | |
| Fatigue resistance | 138 MPa | Determined for 5*108 symmetrical alternating cycles |
| Transverse modulus of elasticity | 28 GPa | |
| Tangential stress at break | 283 MPa | |
| **Thermal properties** | | |
| Specific heat | 0,875 J/g*°C | |
| Thermal conductivity | 121 W/m*K | |

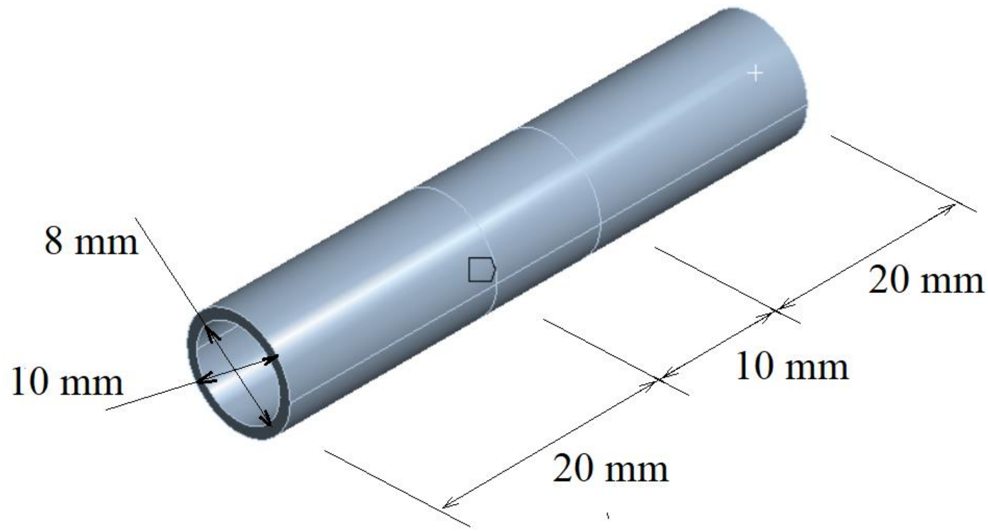



Figure 6. 7: Considered geometry

To estimate the crack propagation conditions in the case of the presented defect, a semi-elliptical, open crack on the outer surface of the pipe is considered. The crack is longitudinal. When an internal pressure is applied to a thick-walled tube, the maximum principal stress is in the angular direction (tangential to the outer circle of the cross-section). In this situation, the request mode is mode 1.

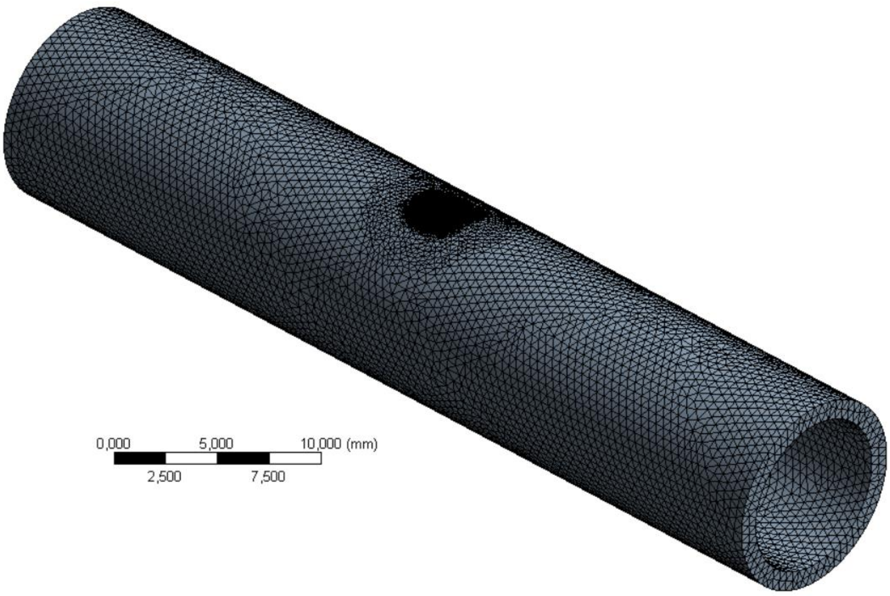



Figure 6. 8: Geometry meshing with tetrahedral finite elements

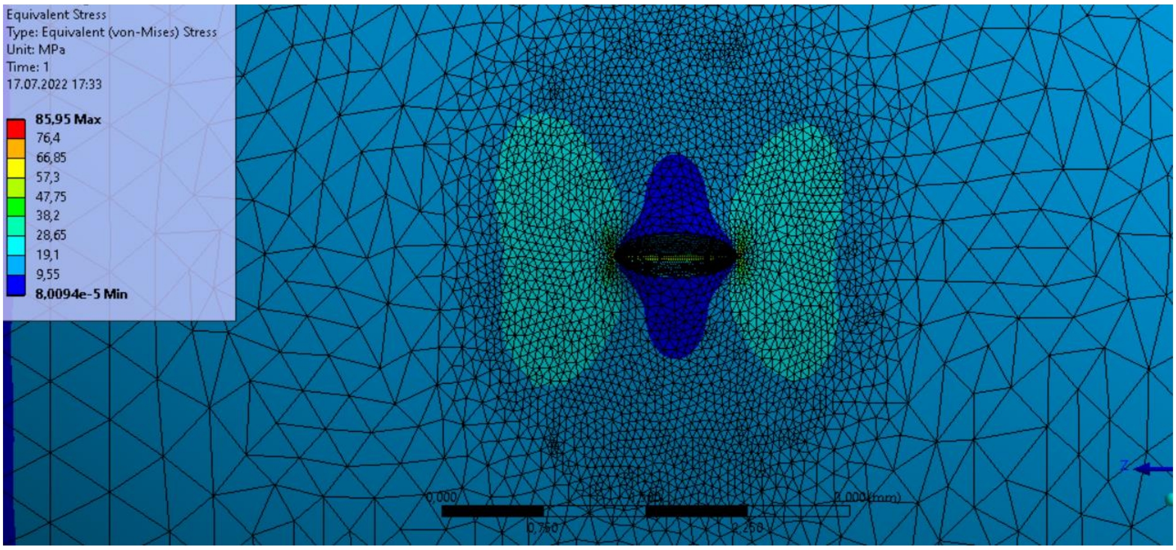



Figure 6. 9: Crack detail, Von Mises equivalent stress field, top view in the radial direction of the pipe

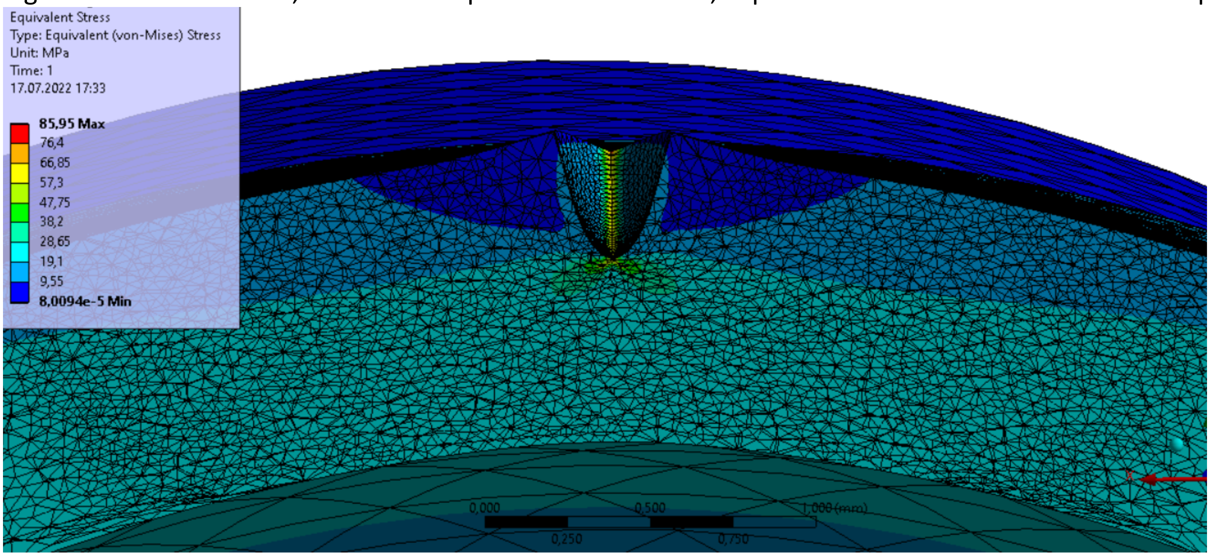



Figure 6. 10: Crack detail, Von Mises equivalent stress field, cross-sectional view

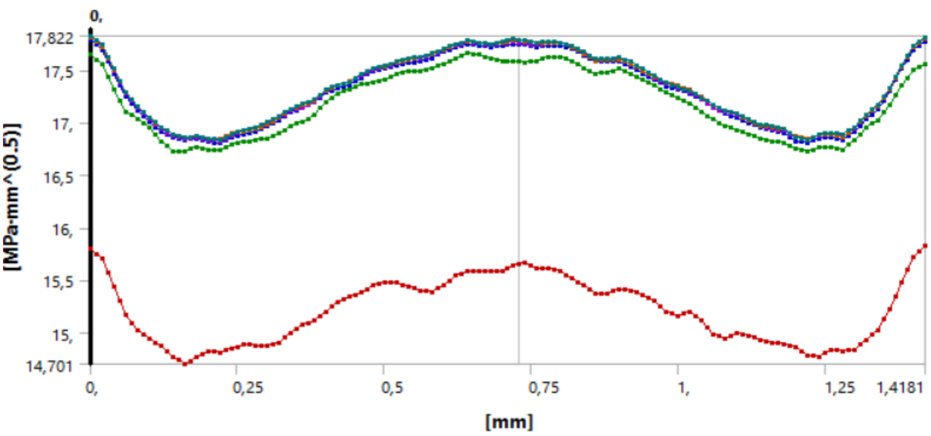



Figure 6. 11: Graph of the stress intensity factor on the crack tip, depending on its length

It is noted that the maximum stresses increase with the increase in the depth of the crack. A similar behavior has the voltage intensity factor. The stress increase at the crack tip is from 45.99 MPa corresponding to the depth of 0.1 mm to 85.95 MPa corresponding to the depth of 0.4 mm (almost a doubling of the stress value). The stress intensity factor at the crack tip increases from 11.4 to 17.8 MPa√mm. A change in the shape of the distribution of the stress intensity factor is also observed, with the depth increasing the value of the factor and towards the lateral surface of the pipe.

We can conclude that for small depths the tendency of crack propagation is towards increasing its depth, as the depth increases, the tendency to increase in length also appears.

If we keep the crack dimensions constant, 1 mm long, 0.1 mm deep, when the internal pressure increases, the results shown in the following figures are obtained.

For internal pressure of 10 Mpa:

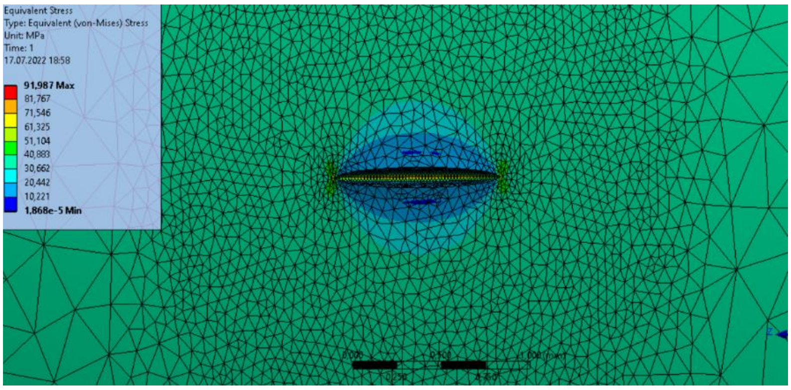



Figure 6. 12: Crack detail, Von Mises equivalent stress field, top view in radial direction of pipe

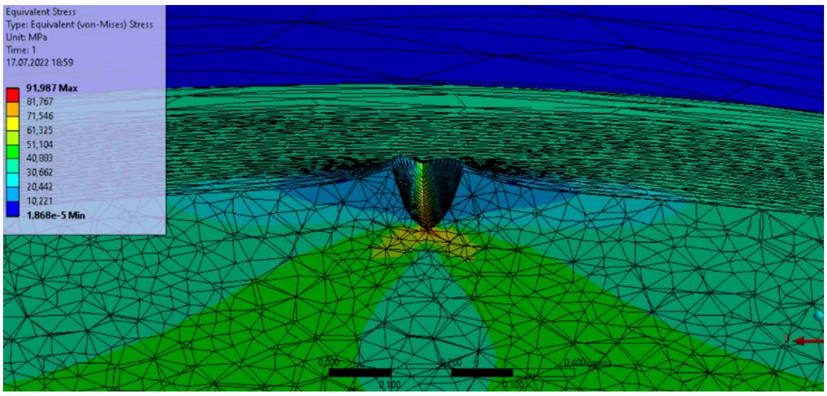



Figure 6. 13: Crack detail, Von Mises equivalent stress field, cross-sectional view

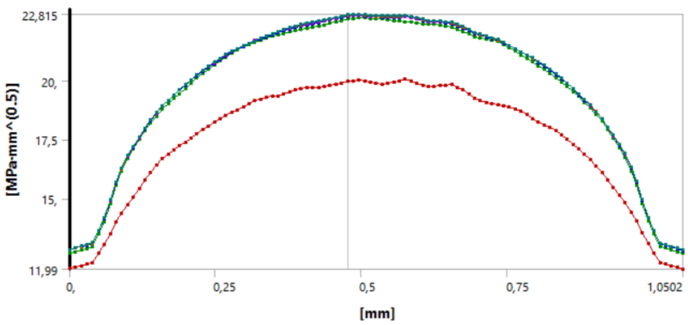



Figure 6. 14: Graph of the stress intensity factor on the crack tip as a function of its length

For internal pressure of 20 Mpa:

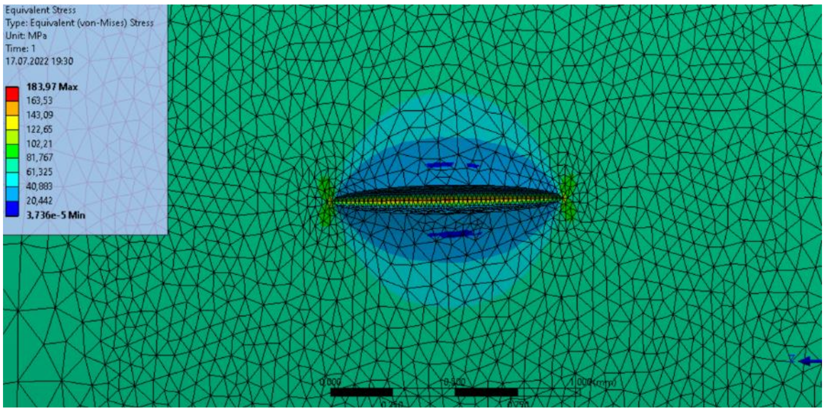



Figure 6. 15: Crack detail, Von Mises equivalent stress field, top view in radial direction of pipe

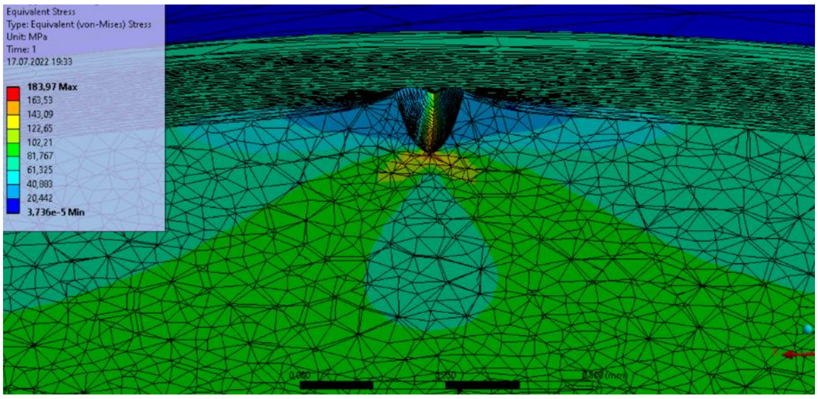



Figure 6. 16: Crack detail, Von Mises equivalent stress field, cross-sectional view

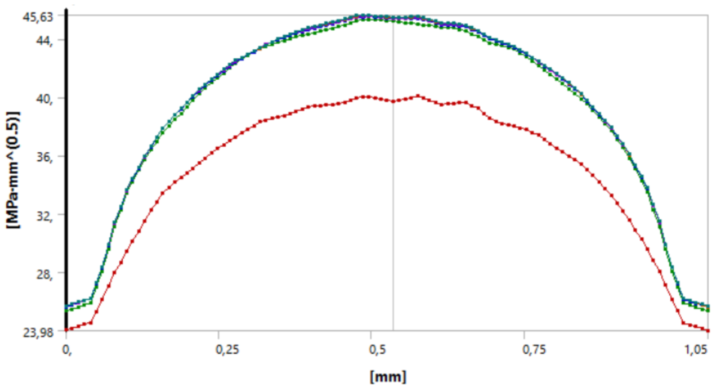



Figure 6. 17 Graph of the stress intensity factor on the crack tip, depending on its length

For the internal pressure of 40 Mpa:

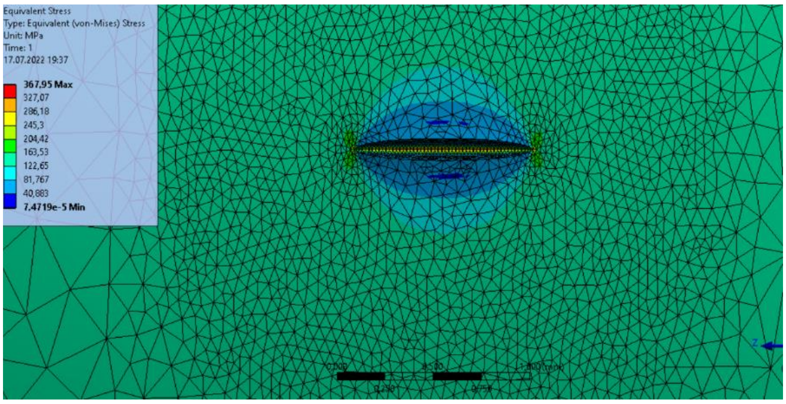



*Figure 6. 18: Detail of the crack, Von Mises equivalent stress field, seen from above in the radial direction of the pipe*

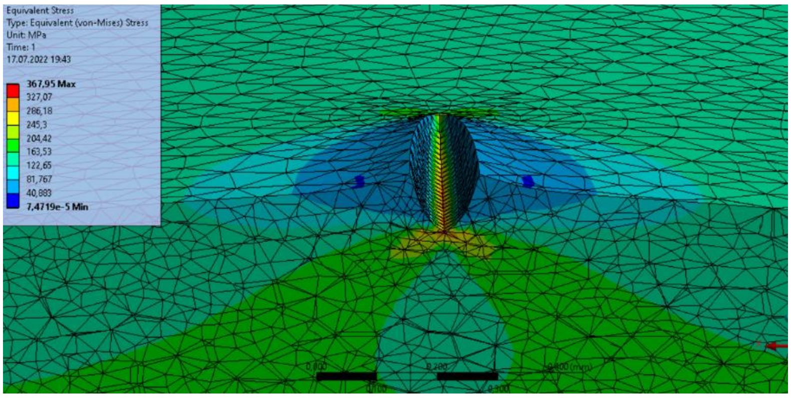



Figure 6. 19: Crack detail, Von Mises equivalent stress field, cross-sectional view

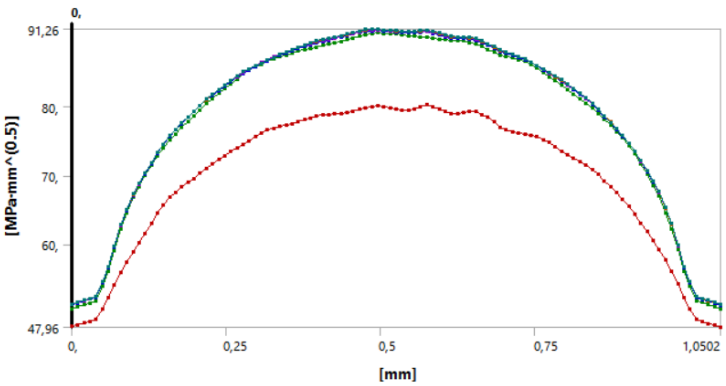



Figure 6. 20: Graph of the stress intensity factor on the crack tip as a function of its length

There is a significant increase in the stress at the crack tip with the increase of the internal pressure, from the value of 45.99 Mpa, corresponding to the internal pressure of 5 Mpa, to 367.95 Mpa, corresponding to the internal pressure of 40 Mpa. The stress intensity factor at the crack tip increases from 11.41 to 91.26 MPa√mm, depending significantly on the loading value. It is noted that the shape of the stress intensity factor distribution does not change along the length of the crack.

Innovative methods of evaluating technical performance are identified. These methods provide a more comprehensive and accurate assessment of technical performance in modern aeronautical systems and help improve the safety, efficiency and reliability of these systems.

Through the statistical analysis of the failures of FAR aircraft over a period of 20 years, we concluded that the number of flight events, caused by technical failures, was reduced in the second half of the period. This fact is due to the creation of databases, having as input parameters the lifetime of the components that failed more frequently.

In the last part of the chapter, we analyzed a defect in some Al 2024 T3 pipes, used for pressure intakes. Due to the formation of ice plugs, following exposure of the aircraft to low temperatures, their local destruction by cracking occurs. Deformation of pipes is caused by the formation of ice plugs inside the pipe, which causes failure of the material.

The possible conditions that led to the occurrence of material failure were analyzed and simulations were made in the Ansys program to see the crack propagation at a given force. The defect can be repaired by welding.

## 7. MULTIDIMENSIONAL MODELS FOR DEVELOPMENT AND IMPLEMENTATION IN MODERN MAINTENANCE SYSTEMS

This chapter presents:
a. Safety management models
b. Accident analysis using complex systems theory
c. Redefining causality starting from TSC
d. The STAMP model
e. Analysis of STAMP application possibilities
f. Application of the questionnaire technique in order to evaluate aeronautical safety

The objective of this technique is to obtain the most relevant points of view of a group of people operating in different positions of the system. This is done through a series of questionnaires or interviews to be answered by the panel of experts. Analysis of the responses reveals the state of the system, indicating problems and allowing the choice of measures to remedy them. Table 7.2 shows the statements from the questionnaire addressed to the flight and technical staff within the FAR, in order to evaluate aeronautical safety.

Table 7. 1 Statements related to aeronautical safety assessment

| | **Statement** | **Category** |
|---|---|---|
| 1 | The training and instruction of the personnel is adequate for the safe aeronautical execution of the flight. | Activities Flight/Technical/ Training/Medical |
| 2 | Conditions for adequate knowledge of aviation safety regulations are ensured. | Management |
| 3 | Aviation safety decisions are made by the best trained people. | Management |
| 4 | Aeronautical safety procedures and regulations are strictly applied | Aplicare proceduri/regulamente |
| 5 | Personalul aeronautic are experiența și abilitatea adecvată pentru calificările obținute. | Staff status |
| 6 | The staff use and apply the principles of operational management in their daily work. | Staff status |
| 7 | There is effective communication between the various categories of aeronautical personnel. | Management |
| 8 | There is effective communication along the hierarchical line. | Management |

| | | |
|---|---|---|
| 9 | The psychological department is effectively involved in aeronautical activities. | Activities Flight/Technical/ Training/Medical |
| 10 | Doctors and psychologists successfully identify and manage high risk takers | Activities Flight/Technical/ Training/Medical |
| 11 | Crew resource management principles are used to improve mission performance and safety. | Management |
| 12 | Violations of flight regulations or discipline are rare. | Application of procedures/regulations |
| 13 | The training flight is proceeding as planned. | The training flight is proceeding as planned. |
| 14 | Staff feel comfortable reporting personal health issues | Staff status |
| 15 | Staff feel comfortable reporting safety violations, unsafe behaviors or hazardous conditions. | Staff status |
| 16 | Decision makers stop unsafe activities when the degree of risk exceeds the aeronautical safety norm. | Management |
| 17 | The aeronautical safety structure enjoys a high degree of confidence. | Staff status |
| 18 | The aeronautical safety rules provided in the current regulations are effective. | Application of procedures/regulations |
| 19 | I know people who intentionally skip work or skim through tasks to accomplish their mission. | Staff status |
| 20 | Rest periods are enforced | Activities Flight/Technical/ Training/Medical |
| 21 | Aeronautical staff work efficiently | Staff status |
| 22 | Morale is high | Staff status |
| 23 | The subunit has adequate material resources to carry out its daily duties and tasks | Activities Flight/Technical/ Training/Medical |
| 24 | The subunit has sufficient staff | Management |
| 25 | It's time for preparation, training and briefing on planned flights, etc. | Activities Flight/Technical/ Training/Medical |
| 26 | The appropriate number of flight hours to maintain/increase the training level is provided. | Activities Flight/Technical/ Training/Medical |
| 27 | Decision-makers put pressure on the availability of aircraft in order to achieve objectives/flight plans. | Management |
| 28 | Decision makers set a good example in terms of following regulations and procedures. | Management |
| 29 | Decision-makers and those who are prone to take unjustified risks in aeronautical activities. | Management |
| 30 | I know cases of alcohol and drug consumption during the execution of aeronautical activities. | Staff status |
| 31 | I trust the aircraft/equipment I operate in flight | Staff status |
| 32 | The procedures in aircraft operation are known. | Activities Flight/Technical/ Training/Medical |

Each statement can be contested, appreciated or viewed neutrally. For each statement there are five possible classifications, coded with numbers from one to five, shown in table 7.3.

## 8. CONCLUSIONS, CONTRIBUTIONS, FUTURE DIRECTIONS, DISSEMINATION OF RESULTS

### CONCLUSIONS

The personal involvement in aircraft maintenance activities as a military aviation engineer, the exchange of experience with the Airbus Company, during the internship carried out in France, with Alenia Aeronautica (during the activity within the maintenance section for the C27J Spartan) and with the Portuguese Air Force (during the F16 aircraft acquisition program), gave me the opportunity to form a vision of what civil and military maintenance systems mean and the close connection between them and aeronautical safety. The thesis gives me the opportunity to contribute to finding modern, innovative solutions for the development of maintenance systems strategies with implications for aeronautical safety.

The topic, **Strategies for the development of aeronautical maintenance systems with implications for flight safety,** is of particular importance for ensuring the operation of aircraft in maximum safety conditions. The aviation industry is strictly regulated to ensure the safety of passengers and crew, and maintenance systems play a critical role in ensuring that aircraft meet the required safety standards. A well-designed maintenance system can help identify and resolve potential safety problems before they become critical.

The development of aeronautical maintenance systems is guided by industry standards such as those set by ICAO, EASA and FAA. These standards ensure that systems are designed to meet specific flight safety and reliability requirements.

A key aspect of developing aeronautical maintenance systems is the integration of MSA principles. This involves considering the potential safety implications of each aspect of the system and incorporating risk management processes to minimize these risks.

An important factor is the use of real-time data and advanced analytics to monitor aircraft performance and detect potential problems before they become critical. This helps ensure that maintenance actions are undertaken in a timely and efficient manner and that aircraft remain safe and operational. Effective communication and collaboration between maintenance and flight crews is essential to ensure this.

Incorporating the latest technologies and innovations in the development of aircraft maintenance systems can also improve the overall effectiveness of the system. This can include incorporating automation and AI (Artificial Intelligence)-based systems for real-time monitoring, predictive maintenance and improved decision-making.

Regular training and professional development of maintenance staff is also crucial to ensure that the maintenance system is implemented correctly and that safety standards are met. This includes training on new technologies, maintenance procedures and safety protocols.

Aeronautical maintenance systems strategies are vital to maintaining aeronautical safety by ensuring aircraft airworthiness, implementing preventive maintenance, using condition monitoring, and complying with regulatory standards. These strategies, when integrated into safety management systems, contribute significantly to the overall safety culture in the aviation industry. By prioritizing the implementation of effective maintenance strategies, aviation organizations can mitigate risks, prevent accidents and protect the lives of passengers and crew members while maintaining high standards of aviation safety.

The field of maintenance strategies in aeronautical systems has evolved significantly in recent years, embracing proactive approaches, data analysis and advanced technologies. The integration of condition monitoring and predictive analytics enabled more efficient maintenance planning, reduced costs and increased safety. As the industry continues to advance, new innovations and refinements in maintenance strategies are expected to lead to ever-increasing operational efficiency and reliability in aeronautical systems.

**The current context** in which maintenance strategies are situated is shaped by several factors influencing the aviation industry. These factors include:

- Technological Advances: The aviation industry is experiencing rapid technological advances, such as increased use of digital systems, advanced materials, and automation. These advances have led to more complex aircraft systems that require sophisticated maintenance strategies to ensure their safe and efficient operation.
- Regulatory Environment: Regulatory authorities such as ICAO, FAA and EASA are continuously updating and refining regulations ntations and maintenance requirements. Adherence to these regulations is essential to maintaining safety standards and driving the adoption of new maintenance strategies and technologies.
- Focus on Safety: Safety remains the primary concern in the aviation industry. The focus on safety leads to the development and implementation of robust maintenance strategies aimed at preventing breakdowns, mitigating risks and ensuring the well-being of passengers and crew. Safety management systems and continuous improvement initiatives play a vital role in maintaining a high level of safety.
- Cost optimization: While safety is essential, there is also an increasing focus on optimizing maintenance costs without compromising safety and reliability. Maintenance strategies that minimize downtime, reduce unscheduled maintenance events, and maximize resource utilization are highly valued in today's economic climate.
- Data-driven decision making: The industry increasingly relies on data analytics and digital technologies to inform maintenance decisions. Real-time monitoring, predictive analytics and machine learning algorithms are used to analyze large amounts of data collected from aircraft systems, sensors and maintenance records. This data-driven information helps optimize maintenance planning, improve reliability and improve safety.
- Sustainability considerations: The aviation industry is actively addressing environmental sustainability concerns. Maintenance strategies are developed to optimize fuel efficiency, reduce emissions and support the adoption of sustainable practices such as aircraft component recycling and life cycle management.
- Industry collaboration: Collaboration between industry stakeholders, including airlines, manufacturers, maintenance providers and regulators, is essential in shaping maintenance strategies. Joint efforts and knowledge sharing facilitate the development and implementation of best practices, standardization and harmonization in the aviation industry.

The ideas presented above are part of the picture that forms the thesis in the eight chapters. The multidisciplinary character of the work is rendered by the method of approaching the proposed objectives, based both on the experience in military aviation and on the critical analysis of the specialized literature. The duality between the civil and military aviation field is present in the entirety of the thesis, giving the thesis originality.

Through the treatment of the research topic, the critical analysis of the specialized literature, through the studies and proposals submitted to the analysis, the scientific character of the work is rendered.

**The main objective** of the thesis refers to the deepening of the aeronautical MS concept, highlighting the implications on flight safety and reducing the number of events, by proposing innovative strategies in MR and MSC and offering innovative tools to improve MS.

In building the main objective architecture (Figure 1.4), we developed the overall framework that rests on several operational objectives developed in the eight chapters.

Thus, in the first chapter, the introduction to the MSA issue was made and the place that SM occupies within it was established (Figure 1.1). The overall picture of MSA was created by presenting the current state of development, the regulatory framework, the challenges it faces and possible future directions were presented. In this chapter the choice of the title was justified, the research hypothesis was proposed and the objectives of the thesis were established. The chapter outlined the architecture of the thesis (Figure A1.1) and presented the research methods and methodology. Objectives OB1.1 and OB1.2 of this thesis are achieved in this chapter. **OB1.1: creating an overview of the MSA and evaluating its effectiveness, to further establish the place that the MS occupies within it;**

**OB1.2: Establish current challenges and future directions for MSA.**

In the second chapter, called **MSA in civil and military aeronautical organizations**, I proposed an approach to MSA from both points of view, civil and military, and made the most comprehensive picture possible. We developed critical elements such as the importance of standardization, effective practices and failures in MR through critical analysis of relevant case studies. The advantages and limitations of case studies are set out, including the challenges of generalizability, short-term analysis, contextual factors and representation of limitations. Continuing with the modern strategies to approach MR, their challenges and limitations were identified, and the MRPD strategy was introduced as an innovative strategy vative in MR, thus fulfilling objectives OB2.1, OB2.2, OB2.3.

**OB2.1: Importance and role of standardization in MSA**

**OB2.2: Identify effective practices and failures in MR**

**OB2.3: Developing modern strategies in MR, identifying challenges, gaps and limitations**

Chapter three, **Change strategies and organizational development in MSA**, opens the statement that the implementation of maintenance systems development strategies cannot be achieved without knowledge of change strategies in the aeronautical organization. Thus, based on the information from the specialized literature, conceptual aspects of the change process in the MSA were reproduced, a change implementation plan was proposed. The challenges of implementing change in modern aviation systems were identified and a change management plan based on relevant case studies in the aeronautical industry was proposed, thus achieving the objective OB3.1. Remote monitoring and predictive analytics tools were presented as a state-of-the-art solution for improving maintenance systems.

A comparative analysis of the development strategies of some aviation giants, such as Boeing, Airbus, Lockheed Martin, was carried out, areas for improvement were identified and predictive maintenance was proposed as an innovative maintenance strategy, which achieves the OB3.2 objective.

**OB3.1 Identify the challenges of implementing change in modern aviation systems**

**OB3.2 development of a development strategy based on the study of current modern strategies.**

Chapter four, **Risk and safety models in aeronautics**, deals with the indicators used in the evaluation of maintenance programs. To assess maintenance in modern aviation systems, to provide a comprehensive picture of maintenance performance and to identify areas for improvement, the indicator system was introduced. Safety performance indicators are particularly important in identifying potential safety hazards and mitigating risks. Process indicators can help identify areas of inefficiency in the maintenance process and provide guidance for improvement. Safety performance indicators are an important tool for evaluating performance in maintenance activities. Performance indicators are quantities that quantify the objectives and reflect the strategic performance of an organization.

Starting from their study, SPM and SDM were developed, as innovative indicators in the evaluation of maintenance systems. Thus, the objective of OB4, to identify and develop new indicators in the evaluation of SM performance, is met. Possible scenarios where AR and VR can be used in maintenance systems to improve efficiency and accuracy as well as predictive maintenance are presented.

Chapter five, **Human performance in modern aeronautical maintenance systems**, presents stress as an element of human factor performance analysis in the aeronautical environment, diagnostic criteria. Innovative stress assessment elements in the aeronautical environment were presented. The elements of analysis and classification of the human factor, of human errors in the specific case of pilots, were highlighted. Modern assessment methods have been proposed in the detection and prevention of human errors. Continuing the objective of chapter four, the indicators used in evaluating human performance were established as well as innovative methods for evaluating human performance by using AR technology, innovative solutions for evaluating performance in maintenance tasks were presented. The objective of chapter OB5, establishing indicators for the evaluation of human performance has been achieved. Identifying influencing factors, detecting and preventing errors. The use of technology in MS provides the unique opportunity to assess human performance in both an objective and supportive manner. By leveraging AR capabilities, organizations can continuously improve the performance of their maintenance technicians and increase the overall safety, efficiency and effectiveness of their maintenance operations.

Chapter Six, **Technical Performance in Modern Aviation Maintenance Systems**, is the defining chapter for the main objective of the thesis. The current aeronautical maintenance systems, the typology of maintenance used in the FAR, as well as their relationship with flight safety were concisely presented. It highlighted the maintenance coding system as an essential element in improving the efficiency and consistency of maintenance processes and supporting regulatory compliance and quality assurance efforts, and proposed an innovative maintenance coding system. The statistical tools used in estimating the correlation between series of events were analyzed, scoring the instrument objectively the innovative entities used in the relationship between events in aeronautical MS and their application in predictive maintenance. Using statistical tools, the current state of air safety in the FAR from 2001 to 2020 was determined, based on the analysis of the failures that occurred during the mentioned period, which is the objective of OB6.1. The defining element treated in this chapter is developed in the case study that analyzes a failure of the Pitot-static system, as a critical system in the operation of aircraft with direct implications on aeronautical safety, and MBC is proposed as an optimal maintenance approach strategy, revealing the OB6.2 objective.

**Multidimensional models for development and implementation in modern maintenance systems**, is the chapter that concludes the thesis and complements the other chapters by deepening the theoretical safety models for development and implementation in MS, identifying hazards and interpreting data to achieve high-performance maintenance, through the analysis of the reliability function and the statistical analysis method. The questionnaire technique was applied in establishing the SA level from FAR OB7.1. Definitive for this chapter is the presentation of the maintenance system proposed and approved for the F16 aircraft in the FAR equipment. As I mentioned in the paper, I actively participated in the FAR endowment program, contributing to the adoption of a high-performance maintenance system adapted to the FAR conditions.

**PERSONAL CONTRIBUTIONS**

**C2.1 Analysis of relevant case studies in establishing the importance of standardization in MSA and determining the limits of the study method.**

The use of safety data collection and analysis is essential for identifying safety risks and developing effective safety measures.

The case studies reviewed provide valuable insights into the impact and benefits of standardization in aviation safety. Examples such as the European SAFA program and the IATA IOSA program illustrate how standardized practices contribute to improved safety outcomes. However, it is important to recognize the limitations of case studies, challenges to generalizability, short-term analysis, contextual factors, and representation of limitations. Understanding the effectiveness and limits of standardization requires a broader perspective that considers multiple cases, long-term analysis, and the complexities of the aviation industry.

**C2.2 Critical analysis of aviation catastrophes in Romania and in the international environment and the formulation of some recommendations**

The Romanian case studies provide insights into the differences in safety management practices between civil and military aviation organizations in the country. Civil aviation case studies highlighted the need to improve training, decision-making and organizational culture, while military aviation case studies highlighted the importance of maintenance practices and adherence to safety protocols. These cases highlight the importance of effective safety management practices in both the civil and military aviation sectors and the need for continuous improvement of safety standards and procedures. To improve safety management in both civil and military aviation organizations, it is essential to prioritize a strong safety culture and effective safety management practices. This includes a commitment to training and continuing education, the implementation of formal risk management processes, and a focus on communication and collaboration within organizations.

**C2.3 Implementation of MRPD**

The MRPD approach is a proactive and adaptive approach to risk management that uses real-time data and analytics to identify potential risks and take preventative action before they become critical issues.

The MRPD approach is based on four key components: data collection, data analysis, decision making and risk communication. By collecting real-time data on a wide range of factors that could affect the safety and security of the aviation industry, the MRPD approach can quickly identify potential risks and take proactive steps to mitigate them.

**C2.4 Statistical analysis of accidents in FAR**

An extensive analysis of accidents during periods with major impact in the development of FAR is carried out. Having access to information from the military aeronautical field, by the nature of the job and the positions held over time, we presented what risk and security means in military aviation and we accurately scored, through statistical analysis, features of accidents in the field, during critical periods, until 2022.

**C3.1 Create an MSC plan based on relevant case studies from the aeronautical industry**

Based on the presented case studies and recommendations, it is proposed a plan for implementing changes in aviation maintenance systems in five steps. By following the principles presented and learning from the experiences of other organizations, changes in MS can be effectively managed for the safety and efficiency of their operations. In addition to the principles, it is essential that organizations proactively identify potential problems that may arise during the change process and take steps to mitigate these risks. This requires a thorough understanding of the existing MS, including its strengths and weaknesses.

**C3.2 Presenting remote monitoring and predictive analytics tools as state-of-the-art solutions in MS improvement, establishing areas for MS improvement by benchmarking Boeing, Airbus, Lockheed Martin**

Remote monitoring systems are typically used to monitor equipment and systems from a remote location. Predictive analytics tools use advanced algorithms and data analysis techniques to identify patterns and trends in maintenance data. By analyzing historical maintenance data, predictive analytics tools can identify potential problems and predict when maintenance is likely to be needed.

Following the comparative analysis, it was established that it is recommended to develop a more collaborative approach to maintenance, invest in automation and robotics, focus on improving the integration of data and maintenance systems

**C4.1 Development of SPM and SDM indicators**

Based on the analysis of the presented indicators, SPM and SDM were developed. SPM provides a comprehensive assessment of maintenance performance and is a valuable tool for airlines in improving aircraft reliability and safety. It is important to note that the SPM should be reviewed and updated regularly to ensure that it accurately reflects maintenance performance and to incorporate new factors that may arise as technology advances and the aviation industry evolves. SDM would measure the degree to which an airline uses digital technology and data analytics in its maintenance processes.

**C4.2 Proposing AR/VR usage scenarios**

By using VR to simulate maintenance procedures, airlines can minimize the need for expensive physical mock-ups and prototypes. By using AR to support maintenance inspections, airlines can reduce the time and resources needed to locate and access technical information, allowing technicians to complete their work faster and more efficiently.

By providing technicians with real-time information and guidance, AR and VR can reduce the risk of human error during inspections and maintenance procedures. Additionally, by allowing technicians to practice and fine-tune their procedures in a virtual environment, AR and VR can improve the overall quality and accuracy of maintenance work.

**C5.1 Use of AR/VR in human performance assessment**

AR technology, the use of wearable technology such as smart watches or smart glasses can provide the technician with real-time monitoring and support as well as feedback during a task.

**C5.2 Innovative solutions for evaluating human performance in maintenance tasks**

Virtual and augmented reality simulations, predictive analytics, artificial intelligence and machine learning, cloud-based solutions are the featured solutions. By incorporating these innovative solutions into their assessment process, organizations can continuously monitor and improve the performance and safety of their maintenance technicians.

**C5.3 Propose a training program to increase resilience**

A six-step program for building resilience is proposed. By following these steps, organizations can develop a comprehensive and effective resilience training program to help their staff reduce stress and maintain performance in high-stress aviation environments.

**C6.1 Proposal of an innovative maintenance coding system**

Innovative maintenance coding is a key driver of change in the aviation industry, enabling maintenance organizations to provide safe, efficient and cost-effective maintenance services to their customers. By embracing innovation and adapting to new technologies and approaches, maintenance organizations can stay ahead of the curve and provide the highest quality maintenance services to their customers.

**C6.2 Identification and application of innovative tools used in the relationship between events in aeronautical MS in predictive maintenance**

We have provided some examples of mathematical relationships that can be used in the context of predictive maintenance, and the specific relationship will depend on the data and system being analyzed. Using mathematical relationships allows maintenance organizations to gain deeper insight into the relationship between events ments and make more informed decisions about maintenance activities.

**C6.3 Determining the current state of aviation safety in the FAR from 2001 to 2021**

The determination of the current status of the SA in the FAR was carried out by the statistical analysis of the number of failures in the mentioned periods, by aircraft types, on the ground and in flight, in correlation with the Pearson Coefficient. Following the results, conclusions were drawn to improve the situation.

**C6.4 Piping Failure Analysis of Pitot-static System**

Operational aspects of the Pitot - static system were analyzed, starting from the description and understanding of the system's operation, the identification of leaks in the system, and the recommended maintenance was proposed. The specialized equipment for testing the system was identified. To establish the criticality of the system in SA, we have presented some relevant cases of accidents caused by system failure. The theoretical aspects were presented using relevant studies from the specialized literature. The simulations and determinations of the cracks that appeared in the static pressure distribution pipe were carried out using the Ansys software, through the finite element method. Repair recommendations were formulated as well as proposals for maintenance strategies, the MBC proposal as the optimal maintenance approach strategy.

**C7.1 Application of the questionnaire technique in order to evaluate SA**

Continuing with the data interpretation methods in chapter seven, we developed and applied the questionnaire in this chapter to assess SA in the FAR, its interpretation and results being described in detail in this chapter.

**FUTURE DIRECTIONS OF RESEARCH**

Despite the significant amount of research conducted on safety management in the aviation industry, there are still several areas that require further investigation. Some of the potential future research directions in this area include:

1. Human Factors: More research is needed on the human factors that contribute to accidents in the aviation industry. This could involve investigating the impact of fatigue, stress and other factors on pilot performance and developing strategies to mitigate these risks.

2. Emerging Technologies: As new technologies such as autonomous aircraft and drones become more prevalent in the aviation industry, there is a need to investigate the safety implications of these technologies and develop appropriate safety management strategies.

3. Safety culture: Further research is needed on the impact of safety culture on safety management in the aviation industry. This could involve investigating the relationship between safety culture and safety performance and identifying strategies to promote a positive safety culture.

4. Collaborative safety management: More research is needed on the effectiveness of collaborative safety management approaches, such as safety management systems and safety partnerships, in improving safety in the aviation industry.

**MRPD implementation**

Future research directions include developing a comprehensive framework for integrating the proposed strategy into existing risk management practices. The framework should include guidelines for data collection, analysis and risk mitigation strategies. The framework should also consider the legal and ethical implications of using machine learning algorithms in risk management practices.

Future research should focus on implementing and evaluating the proposed risk management strategy to determine its effectiveness in increasing safety and reducing the risk of accidents in the aviation industry.

Future research in this area could explore the effectiveness of different change management strategies in aviation safety management and the impact of different technologies and processes on safety outcomes. In addition, research could explore the impact of different organizational structures and cultures on the implementation of change in aviation safety management.

**MSC plan**

First, future research should aim to evaluate the effectiveness of the proposed MSC plan in real environments. This could involve conducting case studies or surveys to assess the implementation of the proposed plan in different organizations and contexts.

Second, future research should explore the factors that contribute to the successful management of change in aviation safety management. This will involve identifying factors that facilitate or hinder successful change management and developing strategies to address these factors. Understanding the factors that contribute to management l of change success, organizations can develop more effective change management plans and achieve better safety outcomes.

Third, future research should explore the role of technology in facilitating change management in aviation safety management. This will require identifying technologies that can support change management, developing methods for integrating technology into change management plans, and evaluating the effectiveness of technology-based change management strategies. By using technology to support change management, organizations can achieve more efficient and effective change management processes.

Recommendations for future research could include exploring the integration of emerging technologies, such as artificial intelligence and machine learning, into MS. Additionally, future research could investigate the impact of collaborative maintenance strategies, where airlines and manufacturers work together to optimize maintenance schedules and improve overall aircraft performance. Finally, research could explore the potential benefits of sustainability-focused maintenance strategies, where maintenance activities are designed to maximize component life and sustainability

Another recommendation for future research could be the implementation of a common maintenance standard in the aerospace industry. Currently, each airline has its own unique maintenance system and standard, which can lead to inconsistencies and inefficiencies when airlines operate a mixed fleet. A common maintenance standard could improve safety and efficiency, reduce costs and improve the overall performance of the aerospace industry.

Research could investigate the impact of maintenance systems development strategies on the sustainability of the aerospace industry. As the industry continues to grow and evolve, it will be important to develop maintenance systems that are environmentally sustainable and minimize the impact on the planet. This could involve exploring new materials and technologies, designing aircraft for durability, and developing new maintenance strategies that prioritize durability.

Another direction of research could explore the use of advanced analytics and machine learning algorithms to optimize maintenance schedules and reduce maintenance costs. By using data-driven insights to inform maintenance decisions, companies can improve efficiency and reduce the risk of unscheduled downtime.

Another area of research could focus on the development of new technologies for maintenance operations. For example, researchers could explore using drones and other unmanned vehicles to perform maintenance tasks in hard-to-reach areas of the aircraft. This could help reduce the risk of injury to people and improve the efficiency of maintenance operations.

There are several areas that could benefit from further study related to predictive maintenance. For example, researchers could explore the use of artificial intelligence and machine learning algorithms to improve the accuracy of predictive maintenance models. In addition, researchers could investigate the impact of predictive maintenance on maintenance costs, aircraft reliability, and overall safety.

## DISSEMINATION OF RESEARCH RESULTS

During the doctoral school, I published the following articles that highlight the interest in the chosen research topic:


[1] **DUMITRU, Iulia Mădălina**; BOȘCOIANU, Mircea. Human Factors contribution to aviation safety. International Scientific Committee, AFASES 2015,49 , ISSN 2247-3173

[2] **DUMITRU, Mădălina**; STOICULETE, Adrian. Risk management in reducing the occurence of aviation events. Scientific research&Education in the Air Force-AFASES, 2021-DOI 10.19062.2247-3173, 2021

[3] **DUMITRU, Mădălina**; Mentenanța în aviație. Concepte și tendințe moderne, STEM EDU lab Journal 4(6)/2021 ISSN 2734-5211

[4] **DUMITRU, Mădălina**. Risk management an example of enforcing it to provide flight safety and operational capabilities. Scientific research&Education in the Air Force-AFASES, 2022-DOI 10.19062.2247-3173

[5] PĂCURARIU, Roxana-Lavinia; BACALI, Laura; SZILAGYI, Andrea; BÎRGOVAN, Andreea-Loredana; MOLDOVAN, Alina; DRUȚĂ, Roxana-Maria; **DUMITRU, Iulia Mădălina** „The circular consumer behavior through industry 4.0 technologies in a post-pandemic reality ”- în revista de Management și Inginerie economică intitulată „ Proceeding of the Review of Management and Economic Engineering 8th International Management Conference”, Editura Todesco Publishing House, 2022

http://conference.rmee.org/wp-content/uploads/2022/10/RMEE2022_Proceedings.pdf

[6] **DUMITRU, Iulia Mădălina; ANDREI, Irina Carmen** „Structural Analysis of Crack Damaged Aircraft Part and Consequent Influences on Adaptative Maintenance Planning"- „20TH International Conference of Numerical Analysis and Aplied Mathematics", 2022 – în curs de publicare

[7] **DUMITRU, Iulia Mădălina**; BUCUR, Florina; STEFAN, Amado „On the Analysis method for pressure tubes failure produced by environmental conditions"-„Proceedings of Fourth International Conference on Material and Structural Mechanics(MSM)", May24-26, 2023- în curs de publicare
https://msm2022.sciencesconf.org/data/pages/Proceedings.pdf

APPENDIX 1 **Thesis architecture - Relationships between chapters, objectives and contributions**

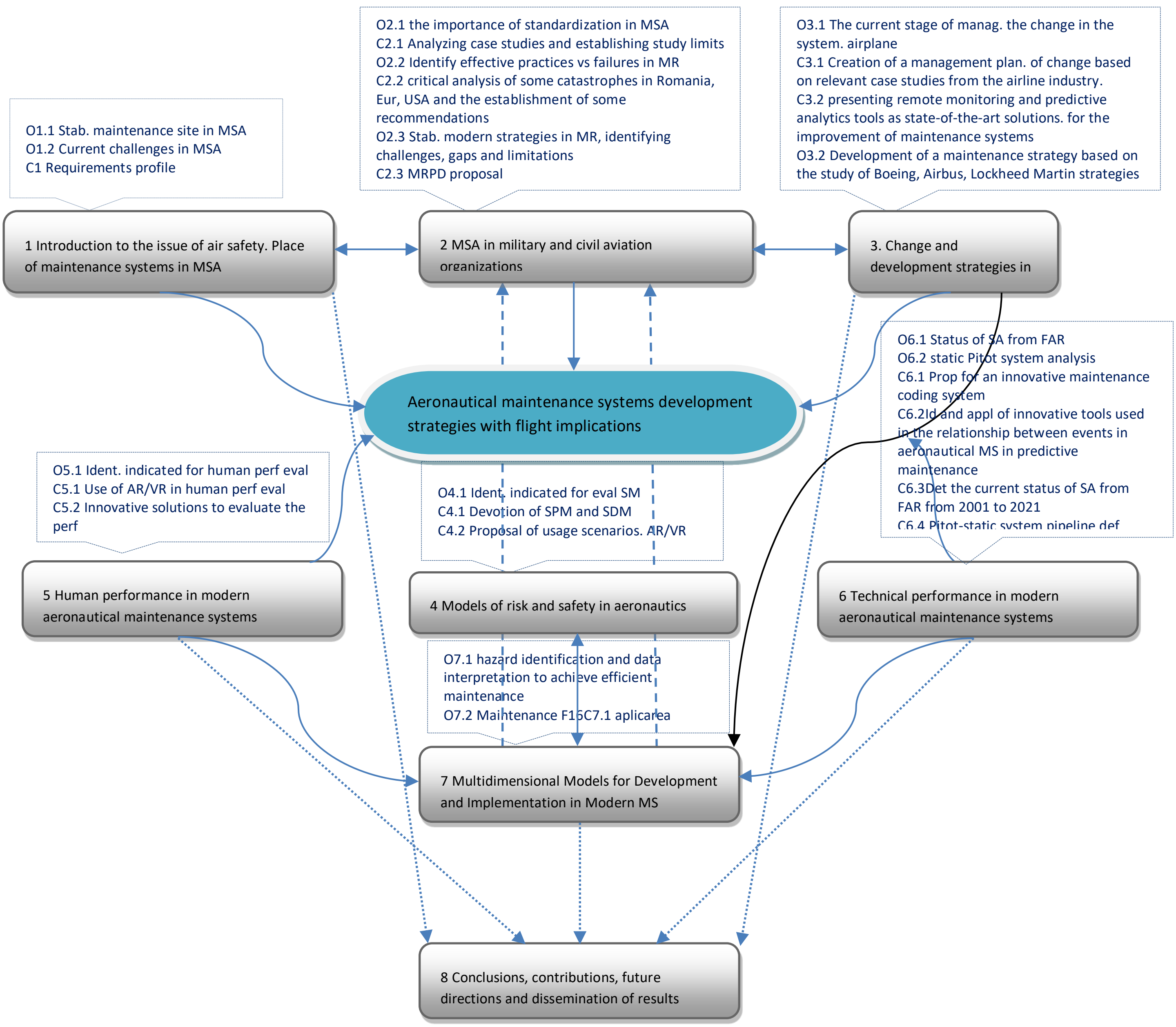



Figure A 1. 1 Thesis architecture – relationships between chapters, objectives, contributions

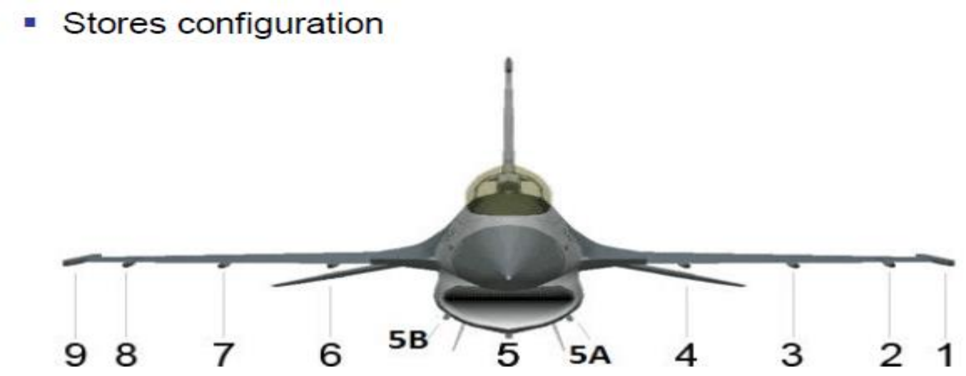
ANNEX 2 Implementation of a new safety management plan in response to changing regulatory requirements and emerging risks in the aviation industry

| Implementation stages | Proposed solutions |
|---|---|
| 1. Establishing a dedicated change management team: | • identifying a project sponsor who has the authority to make decisions and allocate resources.<br>• Establish a project team with representatives from all relevant departments and stakeholder groups.<br>• providing a training and support framework to the project team on change management principles and techniques. |
| 2. Development of a communication plan: | • Identifying the organizations that will be affected by the change and determining their communication needs.<br>• Develop a communication plan outlining key messages, communication channels and timing of communication.<br>• Engaging organizations throughout the change management process to address any concerns or resistance to change. |
| 3. Risk assessment: | • Identify and assess the risks associated with the implementation of the new safety management system and the adoption of new technologies and processes.<br>• Developing risk mitigation strategies to address identified risks. |
| 4. Development and implementation of a training plan: | • Development of a training plan to provide all organizations with the necessary knowledge and skills to operate in the new safety management system and to use new technologies and processes.<br>• Training all organizations in a timely manner and monitoring the effectiveness of the training program. |
| 5. Establishing metrics and measures: | • Develop metrics and measures to evaluate the success of the change management plan.<br>• Monitoring and evaluating, on a regular basis, the effectiveness of the new safety management system and the adoption of new technologies and processes.<br>• Using feedback to continuously improve the safety management system. |

Figure A 1. 2 Change management plan in aeronautical organizations

APPENDIX 3 Technical characteristics F16

| Technical characteristics F16 | |
|---|---|
| Crew | 1 for F-16A si 2 for F-16B |
| Length | 49 ft 5 in (15.06 m) |
| Wingspan | 32 ft 8 in (9.96 m) |
| Height | 16 ft (4.88 m) |
| Wing surface | 300 ft$^2$ (27.87 m$^2$) |
| Empty weight | 18,900 lb (8,570 kg) |
| Full weight | 26,500 lb (12,000 kg) |
| Maximum take-off weight | 42,300 lb (19,200 kg) |
| Internal fuel quantity | 7,000 pounds (3,200 kg) |
| engine | Pratt & Whitney F100-PW-220/220E |
| Full speed | 915 mph, 1,470 km/h |
| Maximum overload | 9g |




**Armament:**

- ➢ 20mm cannon
- ➢ Missile:

• Air-to-air;
• Air-ground;
- ➢ Bombe
- ➢ Razboi electronic

Figure A 1. 3 Features F16 Roaf