

## AIRBORNE RISKS: THE INTERPLAY OF COMPATIBILITY AND RISK ASSESSMENT IN AVIONICS COMPONENTS

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**Abstract:** We explore the vital interplay between compatibility assessments and risk evaluation for avionics components. This symbiotic relationship underpins safety and operational excellence. Our journey encompasses foundational insights into avionics components, the significance of compatibility, risk assessment methodologies, their synergy, key risk factors, effective risk mitigation, and practical applications.

## РИСКОВЕТЕ В НЕБЕТО: ВЗАИМОДЕЙСТВИЕТО МЕЖДУ ОЦЕНКАТА НА СЪВМЕСТИМОСТ И ОЦЕНКАТА НА РИСКА В КОМПОНЕНТИТЕ НА АВИОНИКАТА

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**Резюме:** Разглеждаме важната връзка между оценките за съвместимост и оценката на риска за авионични компоненти. Тази симбиотична връзка подчертава безопасността и оперативното съвършенство. В доклада е включена основна информация за компоненти на авиониката, значението на съвместимостта, методологии за оценка на риска, тяхната синергия, ключови фактори на риска, ефективни стратегии за намаляване на риска и практически приложения.

### Introduction

Avionics components are the backbone of aviation, ensuring aircraft safety and efficiency. This current article explores the critical interplay between compatibility and risk assessment in avionics components. Compatibility means seamless interaction between these components to prevent system malfunctions and safety hazards. Risk assessment methods evaluate potential risks. This article also delves into how these factors guarantee aviation safety and reliability.

### Avionics Components: An Overview

Avionics components are the electronic systems and software at the heart of aviation, serving as the backbone of aircraft functionality. These components are categorized into hardware (e.g., sensors, processors, communication modules) and software (including embedded software, communication protocols, and data analysis algorithms). Hardware sensors provide critical data for navigation, control, and safety. Processors serve as the computational center, making real-time

decisions, while communication modules enable data exchange. Displays relay essential information, and electronic subsystems manage various aircraft functions. In parallel, software components control the operation of hardware, encompassing real-time operating systems, navigation software, and communication protocols. Data analysis algorithms process sensor information, and user interfaces allow interaction. This harmony between hardware and software is fundamental to aircraft functionality. Understanding avionics components is key to exploring their interplay with compatibility and risk assessment in aviation, critical for ensuring aviation safety and reliability [8].

**S (Software)** – non-physical resources such as organizational policies, rules, procedures, symbols, etc.;

**H (Hardware)** – equipment, tools, apparatus, workplace, buildings and other physical resources;

**E (Environment)** – climate, temperature, vibration and noise;

**L<sub>L</sub> (Liveware)** – human interaction factors;

**L<sub>c</sub> (Central Liveware)** – knowledge, attitudes, culture, stress, etc.

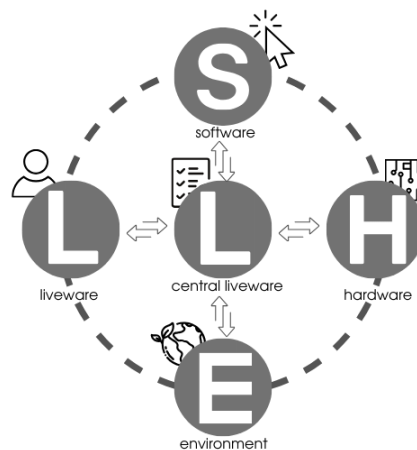


Fig. 1. Main Avionics Components

### Compatibility in Avionics Components

Compatibility within avionics components is the bedrock upon which aviation safety and operational efficiency are built. This multi-dimensional concept extends beyond physical connectivity, encompassing electrical, data, environmental, and software dimensions.

In the electrical realm, compatibility ensures that voltage, current, and power requirements of avionics components align seamlessly with the aircraft's electrical infrastructure. This guarantees electrical stability and prevents disruptions that could compromise safety. Data compatibility governs the standardized communication protocols, ensuring information flows harmoniously between systems. Environmental compatibility addresses the challenges of fluctuating temperatures, varying pressures, and the omnipresent electromagnetic interference, demanding avionics components to function optimally under these conditions. Software compatibility involves the interaction of various software components, ensuring that codes, interfaces, and architectures work in concert, mitigating the risk of software bugs or crashes [4, 9].

### Risk Assessment

The seamless operation of avionics components in the aviation industry hinges on an essential process known as risk assessment. In this section, the article delves into the core concepts of risk assessment in avionics and the methodologies, and tools employed to ensure the safety, and reliability of these critical systems. In the world of aviation, risk assessment is a meticulous and systematic process, which goes beyond mere compliance. It is the proactive examination of an array of factors, which could compromise the functionality and safety of aircraft systems. This methodical evaluation encompasses potential threats, from electromagnetic interference (EMI) to software anomalies, aiming to identify vulnerabilities before they escalate into operational challenges [10].

To execute comprehensive risk assessment, the aviation industry utilizes a spectrum of methodologies and tools. These include Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA), and Probabilistic Risk Assessment (PRA). These techniques empower experts to dissect complex systems, identifying potential failures, their causes, and their associated risks [2].

## Failure mode and effects analysis

A successful Failure Mode and Effects Analysis (FMEA) activity helps identify potential failure modes based on experience with similar products and processes – or based on common physics of failure logic. Effects analysis refers to studying the consequences of those failures on different system levels. Functional analyses are needed as an input to determine correct failure modes, at all system levels, both for functional FMEA or piece-part (hardware) FMEA. An FMEA is used to structure mitigation for risk reduction based on either failure (mode) effect severity reduction or based on lowering the probability of failure or both. The FMEA is in principle a full inductive analysis, however the failure probability can only be estimated or reduced by understanding the failure mechanism [4].



Fig. 2. Failure Mode and Effects Analysis

## Fault Tree Analysis

Fault tree analysis (FTA) is a type of failure analysis, in which, an undesired state of a system is examined. This analysis method is mainly used in safety engineering and reliability engineering to understand how systems can fail, to identify the best ways to reduce risk and to determine or get a feeling for event rates of a safety accident or a particular system level functional failure. FTA is used in fields as diverse as risk factor identification relating to social service system failure. When fault trees are labeled with actual numbers for failure probabilities, computer programs can calculate failure probabilities from fault trees. When a specific event is found to have more than one effect event, i.e. it has impact on several subsystems, it is called a common cause or common mode. Graphically speaking, it means this event will appear at several locations in the tree. Common causes introduce dependency relations between events. The probability computations of a tree, which contains some common causes, are much more complicated than regular trees where all events are considered as independent. Not all software tools available on the market provide such capability. The tree is usually written out using conventional logic gate symbols. A cut set is a combination of events, typically component failures, causing the top event. If no event can be removed from a cut set without failing to cause the top event, then it is called a minimal cut set [5, 7].

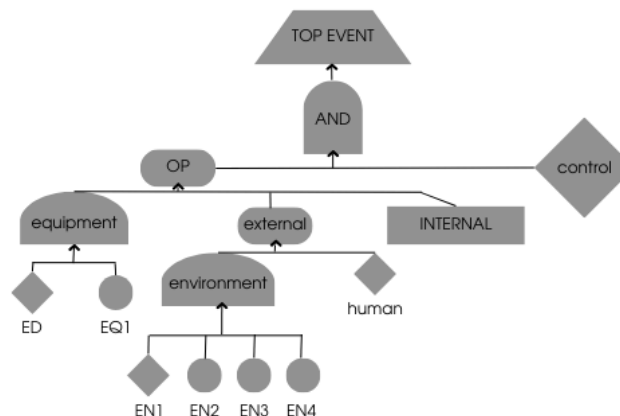


Fig. 3. Fault Tree Analysis

## Probabilistic risk assessment

Probabilistic Risk Assessment (PRA) is a comprehensive, structured, and logical analysis method aimed at identifying and assessing risks in complex technological systems for the purpose of cost-effectively improving their safety and performance. Objective is to better understand and effectively manage risk, and thus more effectively ensure mission and programmatic success, and to achieve and maintain high safety standards. Intends to use risk assessment in its programs and projects to support optimal management decision making for the improvement of safety and program performance.

The central objective of risk assessment in avionics is to ensure unwavering safety and reliability. By identifying potential issues across all phases, from design to operation, aviation professionals can proactively implement measures to prevent, mitigate, or rectify risks. This proactive approach is the cornerstone of maintaining aviation's rigorous safety standards, ultimately contributing to the industry's commitment to the well-being of passengers and the integrity of aircraft systems [1, 13].

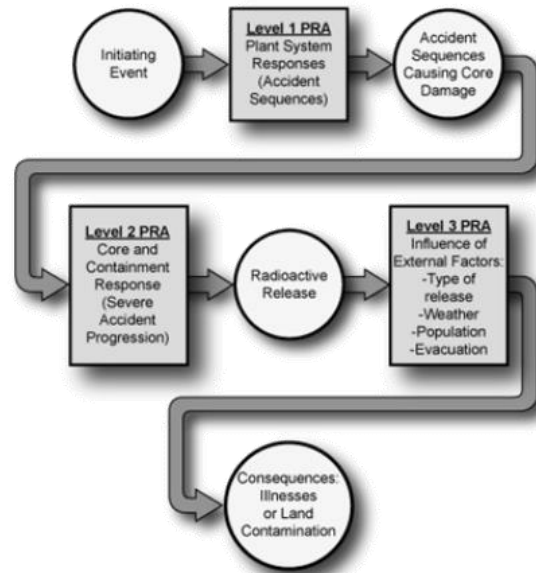


Fig. 4. Probabilistic Risk Assessment

## Interplay Between Compatibility and Risk Assessment

In the intricate world of aviation, where the safety of passengers and the integrity of aircraft systems are paramount, the interplay between compatibility and risk assessment is of profound significance. In this section, we explore the symbiotic relationship between these two crucial aspects, demonstrating how compatibility assessments inform risk assessments.

Compatibility and risk assessment are not standalone processes but are intricately intertwined. Compatibility assessments serve as the initial filter, through which avionics components must pass. This assessment not only ensures that various systems can work harmoniously but also significantly reduces the likelihood of incompatibility-related risks. Compatibility assessments consider factors such as EMI, system integration, and software compatibility, among others. By addressing these factors, the aviation industry can preemptively identify potential risks associated with incompatibility.

Compatibility assessments provide valuable input for the subsequent risk assessment phase. When components are deemed incompatible, it not only raises operational concerns, but also elevates the potential for safety risks. This incompatibility is a red flag, which alerts professionals to areas that require a deeper dive in risk assessment. Risk assessments can then focus on the specific elements, which have been identified as high-risk due to incompatibility issues. This targeted approach streamlines the risk assessment process, ensuring that resources are allocated efficiently to address the most critical concerns.

By recognizing the interplay between compatibility and risk assessment, the aviation industry embraces a proactive approach to risk management. Rather than waiting for issues to manifest, aviation professionals can identify and address potential risks at an earlier stage, reducing the likelihood of incidents and enhancing safety. This synergistic relationship between compatibility and risk assessment underscores the aviation industry's commitment to ensuring the highest standards of safety and reliability. In an environment where precision and reliability are non-negotiable, understanding how these processes complement each other is a vital step towards safer skies [9].

## Key Factors in Avionics Component Risk Assessment

In the ever-evolving landscape of aviation, ensuring the safety and reliability of avionics components is a multifaceted endeavor. This section delves into the critical factors considered in avionics component risk assessment. It emphasizes the holistic approach required to address potential vulnerabilities, encompassing design, environmental factors, software integrity, compatibility, and human factors.

The design of avionics components is fundamental to their performance and safety. During risk assessment, design aspects are meticulously scrutinized. This includes evaluating the robustness of the design, redundancy measures, and fail-safes. Comprehensive design considerations help mitigate the risk of component failure and enhance overall system reliability. The aviation environment can be harsh, subjecting avionics components to extreme conditions. Risk assessment involves assessing how components will perform under these conditions. Factors, like temperature fluctuations, pressure variations, and exposure to EMI are all considered. Understanding how components interact with their surroundings is critical to risk mitigation. Modern avionics rely heavily on software systems. Ensuring the integrity and reliability of software components is a vital part of risk assessment. This involves evaluating the code for potential bugs, vulnerabilities, and compatibility issues. Rigorous testing and quality assurance are essential to minimize software-related risks.

The Swiss cheese model has become the dominant paradigm for analyzing human errors and aviation accidents and incidents. It illustrates that accidents involve successive breaches of multiple defenses. These breaches are triggered by many enabling factors such as equipment failures or operational errors. The Model contends that complex systems – such as Avionics – are well defended by layers of defenses (otherwise known as barriers). A single-point failure is rarely consequential.

Breaches in safety defenses can be a delayed consequence of decisions made at the higher levels of the organization, which may remain dormant until their effects or damaging potential is activated by certain operating conditions. However, under such specific circumstances, human failures – or Active Failures – at the operational level act to breach the final layers of safety defense. The Model proposes that all accidents include a combination of both active failures and latent conditions – Latent failures.

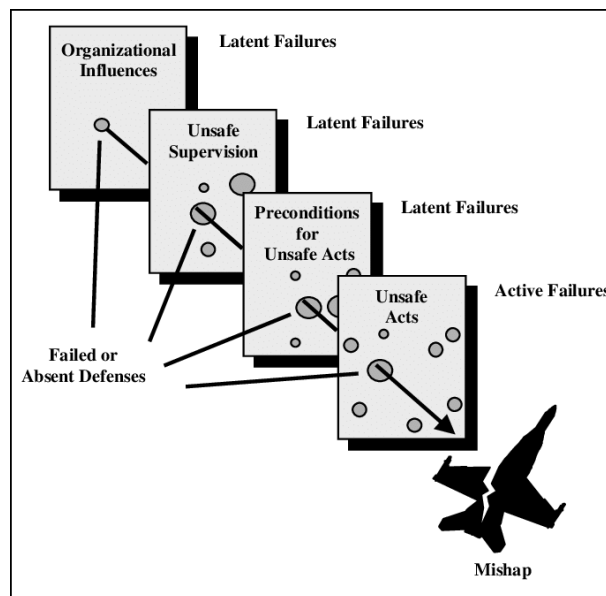


Fig. 5. The Swiss cheese model [11]

As discussed in previous sections, compatibility is a key element in risk assessment. Compatibility assessments help identify potential risks associated with component integration. These assessments play a vital role in determining the safe coexistence of avionics systems. Human error remains a significant source of risk in aviation. Risk assessment also considers the human element, including factors such as training, procedures, and maintenance practices. Addressing human factors through training and clear operational procedures can substantially reduce the risk of accidents. The holistic approach to avionics component risk assessment recognizes that safety and reliability are the results of a combination of these factors working in harmony. By addressing design, environmental, software, compatibility, and human factors, the aviation industry proactively manages risks and strengthens its commitment to passenger safety and operational integrity [12].

## Mitigation Strategies

Mitigating risks in avionics components is a paramount concern in aviation safety. This section delves into the strategies employed to address identified risks and ensure the continued reliability of avionics systems. By understanding and implementing effective mitigation measures, the aviation industry demonstrates its commitment to passenger safety and operational excellence.

Mitigation strategies encompass a wide range of measures aimed at reducing the potential hazards identified during the risk assessment process. These strategies are not only proactive but also reactive, designed to respond swiftly to emerging risks and challenges in the dynamic aviation landscape. One key aspect of risk mitigation involves design modifications and the incorporation of redundancy in critical systems. By improving the design of avionics components and introducing backup systems, the aviation industry enhances its capacity to withstand failures, ensuring that a single point of failure does not compromise safety.

Electromagnetic interference can cause avionic equipment performance to degrade or even malfunction. EMI can affect cockpit radios and radar signals, interfering with communication between pilot and control tower. Airborne devices, which can cause interference, include laptop computers, electronic games, cell phones, and electronic toys, and all have been suspected of causing events such as autopilot disconnects erratic flight deck indications, and airplanes turning off course. EMI effects from lightning, solar flares, electrostatic discharge, and high-intensity radiated fields (HIRF) from radar and various kinds of transmitters or communications equipment – have all resulted in numerous aviation incidents throughout the years. As a result, EMI effects are now considered in all aspects of avionics design and certification. New digital flight control systems need to be hardened to all of these EMI effects. One major way to combat EMI is to provide shielding of various line replaceable units (LRUs) and harnesses. Shielding a device or system not only reduces EMI emissions, it improves susceptibility performance. With advances in wireless technology and increased device signal sensitivity, shielding becomes even more important to maintain the functionality and safety of avionic equipment [6].

Mitigation strategies extend beyond design and engineering to encompass proactive maintenance and monitoring. Regular inspections, maintenance protocols, and condition-based monitoring of avionics components help identify and rectify potential issues before they escalate into operational challenges. Real-world examples of successful mitigation efforts underscore the effectiveness of these strategies. Incidents averted and safety maintained due to robust mitigation measures serve as compelling evidence of the aviation industry's commitment to passenger safety and operational continuity.

## Conclusion

Our exploration of compatibility and risk assessment in avionics components underscores their pivotal roles in ensuring aviation safety. We have highlighted the importance of compatibility assessments, serving as gatekeepers to harmonious systems and as informants for more focused risk evaluations.

Risk assessment methodologies, such as FMEA, FTA, and PRA, are essential tools for identifying and mitigating potential vulnerabilities. The interplay between compatibility and risk assessments enhances aviation's resilience. Key factors considered in avionics component risk assessments encompass design, environmental considerations, software integrity, compatibility, and human factors. Each factor contributes to safety and reliability. Mitigation strategies, from design enhancements to proactive maintenance, fortify aviation against identified risks, exemplifying the industry's commitment to safety.

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