Chair of Space Mobility and Propulsion (Prof. Manfletti)
TUM School of Engineering and Design
Technische Universität München

Master/Bachelor/Semester's Thesis – Hazard analysis of Autonomous Flight Termination Systems (AFTS)

Context

At the Chair of Space Mobility and Propulsion, we are dedicated to advancing the safety, reliability, and efficiency of space launch operations. In the rapidly evolving field of space exploration, launch vehicles play a critical role in delivering payloads to orbit. Integral to the safe execution of these missions is the Flight Termination System (FTS), a vital safety mechanism designed to abort the flight of a launch vehicle in the event of an anomaly, thereby protecting lives and property on the ground.

Historically, Flight Termination Systems have been operated manually, with decisions made by ground-based controllers who monitor the vehicle's route and performance, aborting the flight if necessary. However, Autonomous Flight Termination Systems (AFTS) are capable of making real-time decisions without human intervention. These systems rely on advanced algorithms, real-time sensor data processing, and fault-tolerant designs to ensure that flight abort decisions are both timely and accurate.

The introduction of autonomy in FTS can increase system complexity, presenting new safety challenges that must be thoroughly understood and managed. AFTS must operate in highly dynamic and unpredictable environments, where any failure could have catastrophic consequences.

This thesis will focus on selecting and applying a traditional hazard analysis method to evaluate the safety and reliability of autonomous flight termination systems in launch vehicles. The goal is to enhance the understanding of potential hazards and failure modes, contributing to the development of safer and more dependable autonomous launch systems.

Traditional hazard analysis methods to consider

- Hazard and Operability Study (HAZOP): This study focuses on identifying hazards and operational issues through a systematic process review. HAZOP is particularly useful for examining how deviations from the system's intended operations, such as sensor malfunctions or algorithmic errors, can lead to hazardous outcomes. This method is beneficial for understanding the operational behavior of the AFTS and ensuring it responds correctly under all scenarios.
- Failure Modes and Effects Analysis (FMEA): Evaluates potential failure modes of the AFTS, their effects on system operations, and their impact on safety and performance. FMEA is useful for identifying failure points and for understanding the consequences of these failures.
- Fault Tree Analysis (FTA): Provides a graphical representation of the logical relationships between failures within the AFTS and their root causes. FTA is particularly useful for tracing fault paths in subsystems, where failures can propagate through interconnected components. Identifying vulnerabilities and understanding how a failure in one part of the system can lead to a catastrophic event.
- Cause-and-Effect Analysis: Examines the relationships between different factors within the AFTS and their contribution to potential hazards. This method helps in understanding how various elements, such as environmental conditions, sensor inputs, and decision-making algorithms, interact to produce hazardous outcomes. By analyzing these interactions, the analysis can inform the development of more robust and resilient systems.
- Bow-Tie Analysis: Combines hazard analysis elements to visualize the pathways from identified hazards to their potential consequences in the AFTS. Bow-Tie Analysis is particularly effective for autonomous systems because it integrates both preventive and mitigative controls, providing a comprehensive view of how hazards can be managed and contained within the system.

Your Tasks

- Familiarization with traditional hazard analysis methods and with Autonomous Flight Termination Systems and their operational aspects.
- Select a traditional hazard analysis method based on its suitability for analyzing the complexities of AFTS of launch vehicles.
- Conduct literature reviews on the selected hazard analysis method and on AFTS.
- Identify safety and mission-critical subsystems in AFTS whose failure could lead to significant risks or operational issues.
- Apply the chosen hazard analysis method to assess potential hazards and failure modes impacting the safety, reliability, and performance of AFTS.
- Investigate causal factors and mechanisms leading to identified hazards and analyze how different system components and conditions contribute to these hazards.
- Develop mitigation strategies and propose design improvements based on the hazard analysis to enhance safety and reliability.
- Formulate safety recommendations, document the hazard analysis process, and present findings to contribute to the development of safer and more reliable Autonomous Flight Termination Systems.

Your Profile

- Mechanical Engineering, Aerospace Engineering or MSE Student.
- Knowledge of space systems/operations and hazard analysis techniques.
- Nice to have: background in systems engineering and/or safety analysis.
- Independent working attitude.
- Motivation to engage with interdisciplinary and highly relevant topics.

We offer

- Collaboration with an experienced and supportive team.
- Access to a broad professional network within the aerospace sector.
- Opportunities for engaging in discussions with space collision avoidance experts.
- The possibility to contribute to advancements in autonomous collision avoidance technology.

Contact

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