Design and Integration of Fixed and Separation Couplers for High Powered Rocketry

Analyzing the Disconnect in Risk Analysis in Aerospace from Technical and Nontechnical Perspectives

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In any sufficiently complicated system, there exists the inherent possibility of systemic failure. Nowhere can this be seen better than in the aerospace industry, in which something as insignificant as a faulty gasket can result in systemwide collapse and dysfunction. Everything in the sky from a twin-seater Cessna to a Saturn V rocket relies on interconnected mechanical, electrical, and fluid systems and subsystems, as well as the vast interconnected network of controllers and technicians required to keep them in the sky. With such intricate webs of human and non-human systems, it becomes critical to ensure that any potential risks are assessed, evaluated, and mitigated before they can propagate. As a designer and creator, this responsibility falls in part to the engineer.

My technical project focuses on the design and implementation of coupler systems for our student-led High-Powered Rocketry Capstone, in which we design, integrate, and assemble a high-powered rocket to reach an altitude of 5000 feet in line with regulations of the Intercollegiate Rocket Engineering Competition (IREC). It is my role as an engineer to design and integrate the couplers system in coordination with other teams and subteams, as well as to identify, evaluate, and mitigate risks associated with my components or their integration. As is common in aerospace, lowering risk often comes at the cost of performance, time, and/or expense, resulting in the ‘ideal rocket’ becoming infeasible. It therefore becomes necessary for me to accept certain risks associated with my coupler design while mitigating both their likelihood and consequence. To achieve this, I must approach risk analysis from a technical perspective, as my decisions impact not only me but the safety and success of my fellow engineers and their components as well.

My sociotechnical analysis will focus on the differences in how risk is perceived from the perspective of engineers, airlines, and aerospace 'insiders' in contrast with the perspective of the public, passengers, and aerospace 'outsiders', as well as how this difference impacts decisions made from both groups and their interactions. As individuals, we analyze risk to ourselves from a personal perspective that weighs our values, intuition, and general knowledge. Airlines and aerospace industries in general however represent a vast network of interconnected people and processes responsible for the safety and operation of expansive systems, including the comfort and wellbeing of passengers. It is therefore necessary for airlines to analyze risk from a broad, impersonal perspective based on statistics and regulations. This discrepancy in how the 'insider' airlines and the 'outsider' passengers evaluate risk results in a fundamental disconnect in how risk is treated and communicated between the two groups, and it presents underlying issues in the industry and its practices that I will seek to explore in my sociotechnical analysis.

Through my technical project, I will take on the role of an aerospace 'insider' in the design of couplers by utilizing technical risk assessment methods throughout the design process, so as to gain a deeper insight into the various competing perspectives across the public-aerospace interface. Through my sociotechnical project conversely, I will be able to evaluate the design of couplers from an 'outsider' perspective and thus work towards a holistic understanding of the design process.

Design and Integration of Fixed and Separation Couplers for High Powered Rocketry

The subject of my Technical Capstone Project is the design of fixed and separation couplers and their integration in conjunction with the work of my fellow engineers in the Spacecraft Design course curriculum with the goal of designing and assembling a high-powered rocket in line with IREC regulations. Couplers in the context of rocketry refer to mechanical systems acting as joints between sections of the rocket, lending strength and rigidity to otherwise weak sections of the body structure while minimizing additional weight and design complexity (Nakka, 2022). Couplers are required to withstand all the loads experienced by the rocket throughout its flight path, including the dynamic and extremely disparate loads experienced during launch and throughout separation events, while still being able to be disassembled and reassembled for transportation, testing, and during recovery in the case of separation couplers. I am responsible for the design and implementation of both fixed and separation couplers, both of which present unique challenges and opportunities. The simpler of the two, fixed couplers, act as fixed joints on the rocket, securing and connecting sections of the rocket body throughout its flight path, only being separable in the case of assembly and disassembly on the ground for the purposes of transportation and manufacturing. This form of coupler is required to match the rigidity and strength of the body sections it joins, withstanding bending moments and the large impulses generated during launch while minimizing its size and weight. In contrast, separation couplers are required to perform the same role as fixed couplers during flight until the separation and recovery stages, in which the rocket body detaches at the separation coupler joint and deploys payload and/or parachutes. This design aspect requires the separation couplers to have all the strength and rigidity of the fixed couplers while additionally maintaining the ability to detach in-flight. To achieve this, we will utilize a system of nylon shear screws in combination with a black powder separation charge to facilitate controlled separation event while minimizing loss of prior joint strength. This design, in which the shear screws are intended to fail during the separation event, requires the strength of the screws to be balanced to withstand flight loadings while still being able to be sheared through in separation. Coupler design is characterized by such balances of design requirements due to their nature as integrated systems which interface extensively with other rocket systems, including mechanical and aerodynamic design, as well as mechatronics and separation components. For this reason, it is necessary for decisions to be made in a logical and systematic fashion that seeks an optimal design in accordance with the needs of other subteams, as well as the design requirements of the rocket as a whole. In all aspects of coupler design, it becomes necessary for us to perform technical risk analysis and mitigation strategies that consider the interlinked network of fellow engineers and their components that are required in rocket design, and by doing so, we act beyond the scale of our own coupler design and begin serving the holistic design of a high-powered rocket.

Analyzing the Disconnect in Risk Analysis in Aerospace from Technical and Nontechnical Perspectives

Risk is an inherent aspect of life, and navigating, evaluating, and accepting risk is a daily activity experienced universally, but not necessarily in the same manner. The individual experiences risk on a personal level, having to contend against threats to their person and wellbeing, at times accepting greater risks out of necessity or for increased convenience or reward. However, when a person takes on responsibility for others and acts beyond their role as an individual, the nature of risk and its assessment changes. While individual risk can be evaluated on an intimate level with knowledge of oneself and direct autonomy, at scale it becomes infeasible for the same liberties to be afforded, and it oftentimes becomes necessary to make decisions without the direct approval or informed consent of the people who are directly affected. In this manner, risk assessment becomes detached from metrics based in intuition and personal choice and becomes a system dependent statistics and quantifiable values (Slovic & Peters, 2006), (Gladwell, 2015). Issues arise in the interface between these two forms of fundamentally different risk assessment methods, in which the general public, utilizing personal risk assessment, interacts with aerospace and the aviation industry, which by necessity relies on technical forms of risk assessment. While passengers rely on airlines to convey them safely and comfortably to their destination, airlines are entirely dependent on the continued patronage of passengers to facilitate their business model. It has been repeatedly shown that perception of airline safety is a key factor in passengers selecting a carrier to fly, thus incentivizing airlines to present a public image of safety and low risk (Cho et al., 2018), (Ringle & Zimmerman, 2011). How then should safety be conveyed to passengers? While providing generalized aviation safety education has been demonstrated by Chang et al. (2009) to have a positive impact on passenger safety and behavior, a study by Fleischer et al. (2015) shows that presenting safety metrics to passengers is not necessarily in the best economic interests of airline carriers due to the difference in how individuals evaluate personal risk as compared technical risk analysis. Further accounts from Bikales (2022) and Smith (2011) provide a perspective of reluctance from technicians and flight crews to keep passengers informed of noncritical risks and technical details, explained by Bikales (2009) that “The desire is to avoid confusion, keep things topical, and never, ever insinuate danger.” This atmosphere and de facto policy of noncommunication from aerospace ‘insiders’ result in what Fleischer et al. (2015) describes as “informational asymmetry”, and while it may be nominally beneficial to the aerospace industry under normal operations, it can potentially act as catalyst for communication breakdown and disproportionate public response in the event of failures or nonstandard operating conditions. In my sociotechnical analysis, I will examine the disconnect between aerospace ‘insiders’ and ‘outsiders’ of both information and risk analysis perspectives in the context of systemic disfunction and communication failure. I will utilize the framework of Actor-Network Theory (ANT) to analyze the systems that surround the public-aerospace interface with special regard to evaluating systemic robustness under atypical conditions. To achieve this, I will review existing technical models of risk analysis in aerospace such as the one proposed by Liou et al. (2007), and I will additionally review instances of risk assessment and communication breakdown, as exemplified by 'speed tape' incidents described by Bikales (2022) and Phillips (2002). Following this material review, I will evaluate the current practices of aerospace risk assessment and communication and will seek to determine potential systemic improvements.

Conclusion

My technical project will culminate in fully designed, manufactured, and assembled coupler systems for our student-driven High-Powered Rocketry design, as well as detailed technical assessments of risk and its mitigation throughout the course of the design process. This will be complemented by my sociotechnical analysis of the disconnect in risk analysis and its communication from technical, 'insider' and nontechnical, 'outsider' perspectives. This analysis will utilize an ANT framework to investigate the reality, reasoning, and potential corrections to the current schema of risk analysis and communication within aerospace with a focus on the airline industry and its associated practices. My goal with this project is to investigate and analyze the inherent disconnect between engineers and the public to work towards a more robust and dynamic system of interactions that facilitate a greater mutual understanding and responsibility of technology. Falling short of this high goal, I will still be rewarded by the development of my own understanding of various technical and nontechnical perspectives on risk, aerospace, and engineering at large.

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