Sociotechnical Thesis

Both of my undergraduate thesis projects—my technical capstone on the design of a high-powered sounding rocket, and my STS research on safety culture in aerospace—grapple with the same fundamental question: how do engineers maintain safety in environments of escalating complexity, ambition, and risk? As the field becomes increasingly driven by ambitious goals, rapid innovation, and commercial pressures, safety becomes not merely technical concern but organizational and cultural, and is a problem that should be addressed accordingly. My projects investigate this problem from complementary angles: the technical project examines how experiential learning fosters safer design practices among student engineers, while the STS paper analyzes how institutional cultures historically fail to uphold safety under pressure. Together, they contribute to a broader understanding of how safety must be taught, maintained, and continuously reevaluated in high-risk engineering environments.

In my technical project, I was a team lead on the design of Hoo-Rizon 1, a high-powered subscale sounding rocket developed by aerospace engineering seniors as a capstone project. The goal was to investigate how students react to real-world systems design challenges while simulating the mission-driven framework used by professionals in our field. Our methods incorporated a systems engineering approach with a condensed version of NASA's project lifecycle, iterative aerodynamic and propulsion analysis, and project management tools including risk matrices and Gantt charts. As a student-led effort, the project served two purposes: building technical competency in rocketry and fostering a mindset where engineering decisions are constantly evaluated against performance, feasibility, and safety metrics. One of our key findings was that while students naturally emphasized technical success metrics (e.g., altitude, stability), there was difficulty seeking and interpreting safety guidelines, standards, and protocols. This supports the notion that engineering education must embed safety considerations into all stages of the design process—not as a constraint, but as an essential design parameter. By adopting structured systems engineering processes and accountability tools, our team made significant strides in not only building a technically sound rocket but also instilling habits that reinforce safe engineering practices.

In parallel, my STS research investigates why safety often becomes deprioritized within real-world aerospace organizations, even those with rigorous protocols and high reputational stakes. Using the Challenger and Columbia space shuttle disasters as case studies, I developed a theoretical model called Safety Prioritization Theory to explain how safety shifts from being idealized to normalized, devalued, and ultimately disregarded. Drawing from Diane Vaughan's "Normalization of Deviance," David Collingridge's dilemma of technological control, and distinctions between safety climate and safety culture, I show how institutional behaviors and cognitive pressures contribute to risk becoming embedded in routine decision-making. The disasters were not simply the result of isolated human errors or mechanical failures, but of organizational cultures that incentivized schedule adherence and downplayed deviant practices that had not yet resulted in catastrophe. I concluded that sustainable aerospace safety requires not just post-failure reform, but proactive cultural and procedural interventions—especially during early technological development stages when risk is ambiguous but malleable. This work also highlights the importance of enabling engineers, at all levels, to raise concerns without fear of retribution and to perceive safety as a core professional value rather than an external requirement.

Together, these two projects were successful in offering a dual contribution to the sociotechnical challenge of aerospace safety. The technical project shows how hands-on educational experiences can train future engineers to see safety as integral to engineering rigor, not as a separate consideration. The STS research complements this by revealing how even mature organizations with formal oversight structures can still fall prey to safety erosion if cultural and institutional safeguards are not actively maintained. While our capstone team successfully demonstrated how systems engineering frameworks can be taught and operationalized in an academic setting, my STS research underscores the real-world risks of cultural drift and organizational complacency. Future research should explore how educational programs can more explicitly teach students to identify cultural warning signs of safety breakdowns and how early-career engineers can be empowered to challenge unsafe norms in professional environments. Additionally, further work could focus on developing metrics to assess the strength of safety culture and climate in both academic and professional settings.

Acknowledgments

I would like to extend my heartfelt thanks to my advisors, Professor Caitlin Wylie and Professor Haibo Dong, for their unwavering support, insightful feedback, and encouragement throughout this journey. I also deeply appreciate my capstone team members, whose collaboration and dedication made Hoo-Rizon 1 possible.