Paper ID: 63854
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IAF SYMPOSIUM ON COMMERCIAL SPACEFLIGHT SAFETY ISSUES (D6)
Commercial Spaceflight Safety and Emerging Issues (1)

Author: Mr. Jacob Keller
The Ohio State University, United States, keller.974@osu.edu

A CRITICAL EXAMINATION OF AUTONOMOUS FLIGHT SAFETY SYSTEMS FROM A COGNITIVE SYSTEMS ENGINEERING PERSPECTIVE: CHALLENGES, THEMES, AND OUTLYING RISKS

Abstract

Flight safety systems (FSS) act as a method to terminate off-nominal rocket launches which threaten public safety. Traditional FSS delegate decision authority to an experienced Mission Flight Controller tasked with flight termination decisions, observing multiple points of telemetry data in real time to ensure nominal flight status. Autonomous flight safety systems (AFSS) are an emerging flight termination technology boasting reduced range infrastructure costs and more rapid decision-making capabilities than traditional FSS. AFSS shifts the human-in-the-loop system architecture surrounding flight termination decision-making, localizing the process to automated software onboard the rocket. This change significantly reduces range infrastructure requirements but necessitates extensive pre-flight analysis to compensate. Reduced range costs coupled with improved decision-making times have driven the development and subsequent adoption of AFSS in the commercial space industry, where it is gradually becoming standard practice. Yet, these systems have an unproven capacity to respond effectively to challenging or contextually rich off-nominal flight conditions and establishing software safety requirements for the automation of critical decisions remains a significant challenge for regulators and commercial entities alike.

This study examines the engineering tradeoffs, complexities, and pitfalls introduced by automating this key safety task. We approach this problem from a Cognitive Systems Engineering (CSE) perspective. CSE is an interdisciplinary field that draws upon elements of systems engineering, computer science, and cognitive psychology to provide an innovative framework for examining work in complex domains. We performed semi-structured interviews with various stakeholders (mission controllers, regulators, engineers, amongst others) to better understand the technical and organizational implications of AFSS. The general method of the interviews drew from knowledge elicitation methods in CSE and ethnography, probing the expertise of interviewees and actively searching for systemic breakdowns, goal conflicts, and tradeoffs (made implicitly or explicitly) within work. Based on these interviews, we elicit a unique mapping of perspectives within the expert community and identify how the adoption of new AFSS capabilities causes fundamental shifts in work system architecture, prompting changes in the nature of work and the re-delegation of responsibilities. Our findings highlight that, while the benefits of AFSS hold great promise for increasing the viability of commercial space operations, the automation of an irreversible, instantaneous, and complex decision-making task brings with it significant challenges and risks. We propose directions for further research to minimize the likelihood of errant, expensive, and dangerous flight terminations by an automated agent.