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Mapping an ideal sociotechnical safety management system for Remotely Piloted Aircraft Systems

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SUMMARY

Remotely Piloted Aircraft Systems (RPAS), also known as drones, are a rapidly emerging technology that is being quickly adopted in many civil and military applications. Although there are several benefits, a number of safety risks also exist. It is essential to take a proactive approach in designing broader sociotechnical safety systems that support the safe and optimal use of this technology. We used the Systems Theoretic Accident Model and Processes (STAMP) method to develop an optimal control structure needed to ensure safe and effective RPAS operations.

KEYWORDS

RPAS, Drones, STAMP, Safety, Systems thinking

Introduction

The rapid growth of Remotely Piloted Aircraft Systems (RPAS) is expected to persist in the coming decades. Integrating this emerging technology into existing managed airspaces remains a challenge worldwide. Key issues include security, regulation and policy gaps, monitoring, and the maturity of technology and safety systems (Aposporis, 2024; Wiedemann et al., 2024). Addressing these major challenges within a highly dynamic and complex aviation system calls for a comprehensive, flexible safety approach grounded in systems thinking principles.

Many traditional approaches to understanding and addressing risk have limitations based on their simplistic and linear view of how complex systems function (Dallat et al., 2019; Leveson & Thomas, 2019). However, approaches such as the Systems Theoretic Accident Model and Processes (STAMP; Leveson, 2004) can assist our understanding of risk management in complex systems, like RPAS. STAMP is underpinned by systems thinking principles, control theory and the idea that safety in complex systems is management via a dynamic control loop (Leveson, 2004; Leveson & Thomas, 2019). A key element of STAMP is the hierarchical control structure, which includes actors (i.e., key stakeholders) at various levels. Between each level exist controls (i.e., constraints imposed by one level on another), and feedback mechanisms (i.e. information about the system's status communicated by one level to another). To date, there have been numerous applications of STAMP to existing systems (Read et al., 2019; Woolley et al., 2020), but the approach has not yet been used to model ideal systems.

Method

This study aimed to develop an optimal control structure for the broader Australian RPAS sociotechnical safety system. It was considered ‘optimal’ because the model was based on a review of key high-level documents outlining safety standards and recommendations, along with input from two Subject Matter Expert (SME) workshops. The analysis presented in this abstract focuses on the System Operations aspect of the control structure.

Using Leveson's (2004) generic STAMP model, the authors began modelling by drafting an optimal STAMP control structure outlining the system's structure and essential elements. The international influences level was added to recognise the impact of outside actors on the Australian system. Relevant publicly available documentation outlining recommendations on system safety, from organisations such as the Australian Civil Aviation Safety Authority (CASA) and the International Civil Aviation Organisation (ICAO), was identified through web searches and by reviewing the reference lists of included documents for additional sources. Each document was reviewed to identify relevant actors, controls, and feedback mechanisms. When identified, they were mapped to the STAMP control structure. An accompanying Data Dictionary defined each item and provided examples to enhance understanding. The STAMP model and Data Dictionary were reviewed and discussed by all authors several times to ensure accuracy. This process continued until all authors agreed that the draft model accurately reflected the documentation.

To refine and validate the draft optimal STAMP model, 14 SMEs participated in one of two 3-hour online workshops. The SMEs had varying experience levels with RPAS (mean = 8.75 years; range 0.5-20 years), with 11 participants having five or more years of experience. Each workshop introduced SMEs to systems thinking and the STAMP method. The draft control structure model was explained in detail. Participants then participated in discussions and exercises to revise and validate the model. The groups reviewed proposed changes and collectively decided whether to incorporate them into the optimal model. Rejections occurred only when the proposed change fell outside the scope of analysis. Following the workshops, participants had two additional opportunities to further refine and validate the model via email.

Results

The final STAMP model comprised 124 actors, 123 control mechanisms and 93 feedback mechanisms. At the top level of the model was a level reflecting International Influences on the national system. Under this was the System Operations control structure. See Figure 1 for an example of actors at each level.

Between each of these levels, numerous controls and feedback mechanisms were identified. Example controls issued by Level 1 Parliament & legislatures include Laws, Agreements and conventions, Strategy, policy and action plans, and Parliamentary committees and inquiries. Example feedback issued by Level 3 Operational delivery and management includes Public consultations on rules and regulations, Accident/safety occurrence reporting, Audit reporting, and Variations to accreditation and certification.

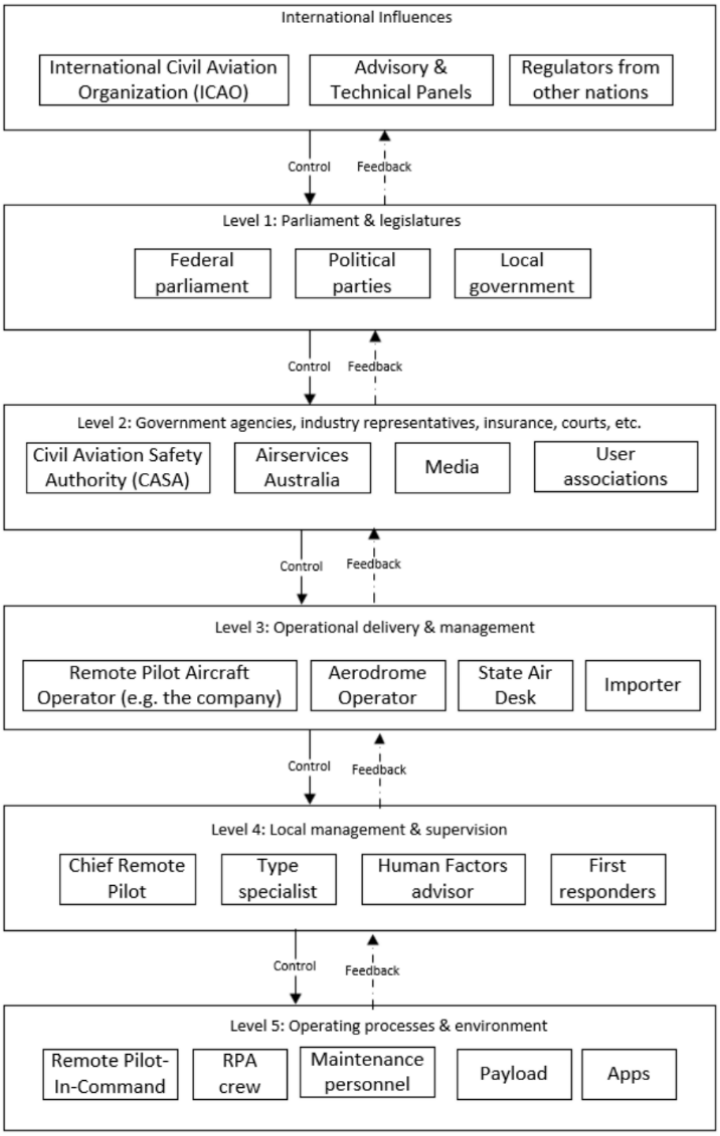

Figure 1: Example hierarchical levels and actors in the STAMP control structure

Discussion

The control structure model provides a comprehensive overview of what an optimised RPAS safety management system should include in terms of agents, controls and feedback mechanisms. This includes control and feedback mechanisms that either do not currently exist or need modification to meet RPAS safety management requirements. A limitation of the STAMP framework, however, is that it cannot observe relationships among agents at the same level, potentially missing critical relationships and limiting our view of system connectedness (Read et al., 2019). Whilst valuable relationships are nevertheless identified across levels, this may increasingly be an important limitation to consider when modelling complex systems of systems, where connections across and within levels are critical. A further consideration when interpreting STAMP is that Systems Operations exist within a larger, more integrated system that includes systems design and construction/manufacturing. If system operations are considered in a siloed approach, significant factors impacting operational capability can be unaccounted for, such as the security and availability of supply lines and safety manufacturing oversight by sovereign safety authorities. Thus, it is recommended that, when designing an optimal system, the entire system comprising both design and construction and operations be considered.

Conclusion

This study demonstrated the utility of STAMP for modelling an ideal system for rapidly evolving, complex emerging technologies with both national and international significance. Applying systems thinking principles, the analysis mapped the key components of an optimal Australian RPAS safety management system. The control structure could be used to evaluate the current system's maturity, promote continuous learning, identify system gaps, and enable improved design and planning towards a preferred future state. In the context of increasing international interest in RPAS and drone applications, mapping systems in this way provides a new approach to management and utilisation. This methodology may also be relevant to other emerging technologies.

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