James Hand 2026 INCOSE Foundation/ Stevens Doctoral Award application

1) Why the INCOSE Foundation/ Stevens Ph.D. Award should be given to me.

My dissertation research will address multi-agent system (MAS) resilience to faulty or malicious agents, a critical and increasingly common issue within MAS. With the rise of interconnected sensing systems, robotic warehouse and distribution systems, and expansive multi-layer computing networks, these types of faults can lead to multi-million-dollar losses or even loss of life. To address this issue, I look at the unique intersection of biology and engineering, which is not widely pursued in systems engineering. Specifically, my work addresses two different gaps in the current literature: 1) Lack of research on how to handle contagious faults in multi-agent systems, especially in relation to robotics and autonomous systems that do not rely upon complex interconnectivity and communication within the system; and 2) the solution space for biologically inspired behavioral faulted agent resilience is underexplored.

These gaps are also echoed broadly in the Systems Engineering Vision 2035 document, which highlights the need for resiliency research. From these gaps I created the following research hypothesis: ***If*** **insect inspired resilience behaviors are implemented in MASs,** ***then*** **overall system resilience to contagious faults will improve,** ***because*** **insects have unique natural resistances to infectious vectors in the wild due to their behaviors and strategies.** This research is thus broken down into several stages: biological strategy identification, computer simulation of biological strategy implementation, hardware implementation of biological strategies, and analysis of strategy resilience effects.

The first stage, biological strategy identification, has already been completed and is currently published in a peer-reviewed biologically inspired design journal1. This work reviewed a wide range of biological research studies to identify the ways colony insects deal with diseases, invasive parasites, and rival colonies and relate them to multi-agent system resilience strategies. The results were 144 diverse ways that colony insect species with these issues, recorded in a multilayered functional decomposition diagram. This work, during its development, also received the Best Graduate Student Poster award at Embry-Riddle Aeronautical University's (ERAU) Student Research Symposium 2023.

The second stage focuses on taking the 144 different observed biological strategies, condensing them down into multi-agent system functional rules, and applying them to a computer simulated swarm use case. For this stage, four specific strategies from the 144 observed were taken and made into actionable agent behaviors. Specifically, this work is focused on using rules and behaviors that are implemented on the agent layer, to avoid centralized system control. This was done to focus on solutions that are more easily scalable. The resulting resilience of two of these four strategies provided were presented at the INCOSE International Symposium 20252, where it received the ***Brian Mar Best Student Paper Award***.

The third, and final, stage plans to take the four computer simulated strategies and implement them on a physical testing platform. The platform is a custom robotic testing platform that I helped design and build to evaluate research like this in swarm environments. This step is done with the goal of additional verification of computer simulation findings, and to promote real world application of these identified behaviors. Preliminary findings from stage two show that this work has practical resilience improvements, so I hope that showing the strategies work outside computer simulation will lead to meaningful application in real world systems.

In addition, this work has received prestigious recognition in a variety of ways. Since 2024 I have been a Department of Defense SMART Scholar, a highly sought-after fellowship, due in part to my research on this subject. Additionally, this work is supported by the ERAU FIRST grant, an award that funds "highly impactful" research. This shows just how far-reaching and impactful this research can be, with my work being presented at events such as the ERAU Cyber Rodeo and Industry Advisory Board visit. My long-term goal is to see the findings of this research implemented in integral systems such as emergency response, energy grids, and defense applications.

[1] Bioinspiration and Biomimetics, Hand and Watson, "A guide to eusocial…", 2025
[2] INCOSE IS, Hand and Watson, "Faulted Agent Resilience…", 2025

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2) What my research will contribute to Systems Engineering and Integration.

The research I do has an impact upon a wide range of systems, from the smallest robot swarm to the largest national energy grid. Biologically inspired strategies identified and assessed from my dissertation work could be used in industries ranging from mobile cellular networks to warehouse management or public services. Each of these systems can use the strategies from my work to improve their resilience to faulted agents and malicious interference, saving time, money, and in some cases lives. Already these insect-inspired strategies have already been shown to improve resilience in preliminary testing, with up to 85% improvement in terms of a system's ability to resist a spreading/infectious fault. As part of this my dissertation work has two primary expected research outcomes:

- A quantitative understanding of the impact insect inspired strategies have on resilience in multi-agent systems.
- An analysis of the identified and tested strategies effectiveness when compared to current state of the art strategies.

While attending INCOSE IS 2025 this research, alongside other biologically inspired projects I presented, was of great interest to many attendees from a variety of institutions and companies like MIT Lincoln Labs and John Hopkins University Applied Research Labs. To illustrate the impact this work could have I present the following summaries of both the current State of Knowledge and Sate of Practice, alongside the changes to both I expect to see as part of my research.

State of Knowledge

Current research has a wide range of approaches to multi-agent resilience when focusing on malicious faults. One of these methods is multi-agent reinforcement learning1 (MARL), which can be intensive to set up as well as intolerant of unexpected or chaotic inputs to a system. Another common method for resilience is to assign observer agents to watch the system to detect and isolate faults within the system, requiring some levels of centralization and wasted effort2.

Many of the current systems require some level of centralization, high level encryption, or responsive systems, all of which can be some mixture of expensive, difficult to implement, or degrading upon system performance. My contributions focus entirely on individual agent rules and actions, which promote decentralization and require no identification of malicious agents. These reduce the complexity of implementation, the cost of operation, and risk of cascading effects of a single agent taking down the entire system, a risk of more centralized systems.

State of Practice

The increase of autonomous driving vehicle software exploits, cyber-attacks on public services, and single point of failure collapses of energy grids3 shows that the current practice is insufficient to protect systems from growing threats. Many of these critical systems rely on simple redundancy and centralized consensus approaches to reduce the impact of faults, both of which are limited in their ability to provide fault tolerance. Furthermore, with recent conflicts in Ukraine and along the Cambodia/Thailand border we have seen the rise of small low-cost drone swarms in combat, which are extremely vulnerable to spoofing and malicious control.

In addition to the exploration of additional avenues of knowledge mentioned previously, my work includes a physical hardware implementation step specifically to encourage the use of these strategies in real world systems. This is meant to give a push to the current State of Practice which is already lagging in many key industries. Personally, real world utilization of my findings is one of the primary reasons I do research.

[1] IEEE Transactions on Automation Science and Engineering, Shi et al., "Towards Fault Tolerance in…", 2025
[2] IEEE Access, Maldonado et al. "Multi-Agent Systems: A Survey About…", 2025
[3] Reuters, Muvija and James, "'Preventable' National Grid failures led to Heathrow fire…", 2025