BID4R
Biologically Inspired Design-for-Resilience Lab

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Summary of BID4R Priorities and Activities

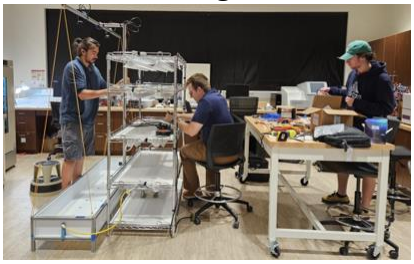
The Biologically Inspired Design-for-Resilience (BID4R) Lab uses a combination of design methodology, systems engineering, and complex system modeling to examine biologically inspired approaches to increase systems, systems of systems, and multi-agent system resilience.

Our mission is to:

1) Develop ERAU graduates as expert engineers, thinkers, and leaders.
2) Develop approaches to increase resilience, thus protecting people, industries, and communities from disruption and harm.
3) Expand the use of biologically inspired design as a paradigm for exploring new, novel engineering challenges.

The BID4R Lab focuses its research on three pillars.

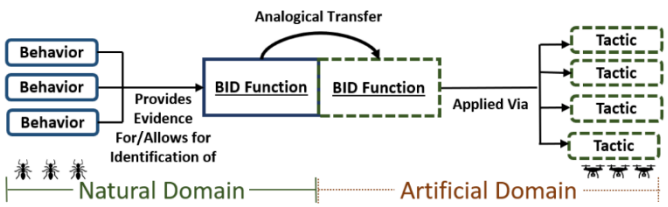
I. Identifying and Applying Biological Inspiration: How can we improve our understanding of biological strategies to increase resilience as well as transfer these strategies to address engineering challenges?



- Ongoing collaboration with ERAU Prescott focuses on measuring bed-bug response to stimuli. Bed-bugs demonstrate distributed collaboration approaches which can be used to inspire UAV and Swarm algorithms.
- Ant colony response to invasive fungi is being modeled and simulated as an approach to minimize the damage from intruders infiltrating swarm operations (2023 ERAU Faculty Innovative Research in Science and Technology (FIRST) Program).
- Applying ecosystem functional roles to system-of-system design has been shown to increase resilience to unexpected faults [1].

II. Design Theory: What are best practices for design-by-analogy and biologically inspired design?

- A recent study presented at the American Society of Mechanical Engineers presented an approach of using functional decomposition to derive design principles to increase multi-agent system resilience through analysis of Eusocial Insects [2].



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- A review of 660 current examples of biologically inspired design provides insight into the uses, purposes, and inspiration for biologically inspired design in academia, practice, and the public perception. Biologically Inspired Design is most often used in the physical domain, inspired by a part of nature that is commonly well-known, uses a structural strategy to solve an issue, improves an innovation's reliability, and impacts the use phase. [3].

III. Resilience Engineering: How can we improve our understanding of resilience as a property of systems as well as support current resilience engineering efforts?

- Work has focused on deriving and developing a new metric to measure resilience for connected systems (or systems of systems) [4].

About the Principal Investigator

Bryan Watson, PE earned his Ph.D. at the Georgia Institute of Technology and his B.S. in Systems Engineering at the United States Naval Academy in 2009. After graduating, Bryan joined the nuclear Navy, serving as a submarine officer onboard the U.S.S Louisville and at the Naval Prototype Training Unit from 2009-2017. Significant milestones include selection as a National Science Foundation Graduate Research Fellow, a Pat Tillman Fellow, earning the Master Training Specialist Certification (the military's highest instructor accreditation), Nuclear Professional Engineer Certification, two Naval Achievement Medals, the Military Outstanding Volunteer Service Medal, and a Naval Commendation Medal for his work troubleshooting and repairing the Moored Training Ship 635's reactor and electrical distribution faults. Following his transition from active duty, Bryan earned his PhD as a member of both the Computation and Advancement of Sustainable Systems Lab, where he developed a new method for distributed system demand estimation, and at the Sustainable Design and Manufacturing lab, where his work focused on increasing System of System resilience. Bryan's work has been published in the Journal of Industrial Ecology, Journal of Mechanical Design, and IEEE's Systems Journal.

Bryan joined Embry-Riddle Aeronautical University in 2022 where he leads the BID4R Lab. The Lab is staffed by 3 graduate students, 7 undergraduate students, and home to the 25 Robot Roving Swarm Test Platform (currently under construction). The Lab's work has been featured in the Conference on Systems Engineering Research, selected for two Summer Undergraduate Research Fellowships, won the Spring 2023 Discovery Day Poster competition, and for attendance at the 2023 Frontiers in Design Representation.

[1] B. C. Watson, S. Malone, M. J. Weissburg, and B. Bras, "Adding a Detrital Actor to Increase System of System Resilience: A Case Study Test of a Biologically Inspired Design Heuristic to Guide Sociotechnical Network Evolution," *J. Mech. Des.*, vol. 142, no. 12, pp. 1–13, 2020, doi: 10.1115/1.4048579.

[2]I. V Hernandez, B. C. Watson, M. Weissburg, and B. Bras, "Learning from Insects to Increase Multi-Agent System Resilience: Functional Decomposition and Transfer to Support Biologically Inspired Design," in *Proceedings of the ASME 2020 IDETC and Computers and Information in Engineering Conference*, 2021, pp. 1–12.

[3]M. G. Jastrzembski, B. C. Watson, M. J. Weissburg, and B. Bras, "Assessing the state of biologically inspired design from three perspectives: academic, public, and practitioners," *Bioinspiration and Biomimetics*, vol. 18, no. 4, 2023, doi: 10.1088/1748-3190/accb31.

[4]B. C. Watson, A. Chowdhry, M. J. Weissburg, and B. Bras, "A New Resilience Metric to Compare System of Systems Architecture," *IEEE Syst. J.*, vol. 16, no. 2, pp. 2056–2067, 2021, doi: 10.1109/JSYST.2021.3062444.