RQ16-6

AFRL CALL FOR RESEARCH

1. Research Title: 1) *Formal Methods Analysis of Non-linear Control Systems*
2) *Formal Hazard and Safety Assessment of Control Systems*
3) *Design of Experiments with Analytical Proof Evidence*

2. Individual Sponsor:

Ms. Kerianne H. Gross
AFRL/RQQA Bldg 146, Room 300
2210 Eighth Street
WPAFB, OH 45433-7542
Kerianne.gross@us.af.mil

3. Academic Area/Field and Education Level: Electrical Engineering, Computer Engineering, Computer Science, Aerospace Engineering, Mechanical Engineering, Operation Research, Mathematics and Statistics, Operational Sciences, Systems Engineering (MS and/or Ph.D. level)

4. Objectives: We propose one of the following 3 research topics:

1) Develop methods to conduct formal analysis of non-linear control systems.
2) Develop methods to conduct hazard analysis and mitigation analysis of control systems using a formal methods framework.
3) Develop a modified design of experiments methodology that incorporates analytical proof evidence from early formal methods-based systems analysis to improve test point selection.

5. Description: Current Verification and Validation techniques rely on modeling, simulation, test and evaluation to generate certification evidence. As we seek to provide comprehensive certification evidence for safety critical autonomous systems, it becomes intractable and cost prohibitive to rely exclusively on established Test and Evaluation, Verification and Validation (TEV&V) methods. Additionally, it is also recognized that new, innovative approaches to TEV&V must start at the earliest stages of design [1]. Therefore, the government is interested in innovative approaches to supplement established TEV&V practices by generating certification evidence throughout the design process and or incorporating operational assurances through run time contingency systems. We are seeking research in one of 3 topics:

1) Formal Methods provides a set of mathematically rigorous techniques to exhaustively evaluate a system, however current formal methods toolsets cannot reason about non-linear systems. The proposed thesis topic is intended to address some of these deficiencies in formally analyzing non-linear control systems. The University masters student and/or faculty member will survey current non-linear programming and non-linear controls analysis techniques, select promising approaches that could be applied formally, apply the approach(es) to simulated non-linear control system challenge problems, and evaluate gaps in current methods. The PhD student would develop and implement methods to bridge these gaps, and demonstrate performance of the techniques on to simulated non-linear control system challenge problems.

2) Many techniques exist to identify hazards and mitigation systems for safety-critical systems, however a gap exists between the identification methods and other analysis techniques such as formal methods The proposed thesis topic is intended to address some of these deficiencies in formally analyzing safety-critical control systems. The University masters student and/or faculty member will survey current hazard and fault identification methodologies, select promising approaches that could be applied formally, develop a methodology for formally apply the approach(es) to simulated control system challenge problems, and evaluate gaps in current methods. The PhD student would develop and implement methods to bridge these gaps, and demonstrate performance of the techniques on to simulated control system challenge problems. Approaches should trace hazard analysis to system requirements, provide formal robustness criteria, evaluate completeness of the hazard analysis, and document assumptions.

3) Design of experiments is a mature process used to select efficient test and simulation points. How does the process change if a large amount of analytical proof exists? The proposed thesis topic aims to develop a modified design of experiments methodology that incorporates analytical proof evidence from early formal methods-based systems analysis to test point selection. The university student or faculty member will study formal methods analysis evidence, analyze how this evidence may change the current design of experiments paradigm, develop a modified design of experiment approach informed by analysis results, apply traditional and modified design of experiments approaches to a challenge problem, compare the results, and develop a cost comparison of the two approaches.

[1] Assistant Secretary of Defense / Research and Engineering (ASD/R&E), Autonomy Community of Interest (COI), DoD Autonomy Test and Evaluation, Verification and Validation (TEVV) Investment Strategy, Alexandria, VA (June 2015), http://www.defenseinnovationmarketplace.mil/resources/OSD_ATEVV_STRAT_DIST_A_SIGNED.pdf

6. Research Classification/Restrictions: U.S. Citizens **only**. Most aspects of this research fall under the 6.1 basic research classification.

7. Eligible Research Institutions:

- [■] **DAGSI** (Wright State University, AFIT, Ohio State University, University of Dayton, Miami University, Ohio University, University of Cincinnati). Note: Public Release Pending
- [■] **AFIT** (only)
- [ ] **USAFA** (only)

  If you are submitting a topic for the USAFA, indicate if you are also interested in sponsoring a USAF Cadet in summer 2015 (Average cost for USAF Cadet for 33 days is $5000)

  [ ] Yes [ ] No