Dr. Joseph Scott was recently awarded a Young Investigator Program Award (YIP) in the amount of $330,000 from the Air Force Office of Scientific Research (AFOSR). Dr. Scott received this award for his research project entitled, “Rapid and Accurate Uncertainty Propagation for Nonlinear Dynamic Systems by Exploiting Model Redundancy.” The YIP is open to scientists and engineers who have received PhDs or equivalent within the last five years. The purpose of the YIP is to enhance and foster creative research in outstanding young investigators. The AFOSR received over 265 proposals from 41 research institutions, and Dr. Scott’s proposal was one of only 56 that were selected.

Dr. Scott’s project addresses the U.S. Air Force’s goal of engineering more robust systems with enhanced operability in uncertain environments by developing a novel mathematical technique that can rigorously account for the effects of uncertainty in complex computer simulations. The project focuses on computer models in the form of ordinary differential equations, which describe a tremendous variety of physical systems, from (bio)chemical reaction networks to aircraft flight dynamics. Standard computer simulations nearly always provide results with significant uncertainties, both because the computer model is not a perfect representation of reality, and because the real system may need to operate in unanticipated environments. For example, an aircraft flying along a pre-computed path can be knocked off course by unanticipated wind, which makes it difficult to use conventional simulations to safely guide the aircraft through obstacles. Parallels also arise in chemical process control, where unexpected variations in raw materials or environmental conditions can cause a plant to violate important operational constraints. Issues like these are especially problematic for systems that are expected to operate in highly volatile environments, as is often the case in military applications.

To address this issue, Dr. Scott’s research team is developing new simulation techniques capable of accurately and efficiently quantifying the level of uncertainty in the simulation results. Rather than provide a single solution, these methods compute a rigorous enclosure of all possible solutions given a specified level of uncertainty in the model equations. Although this has been possible for decades, existing algorithms are either too slow to aid in real-time decision-making, or provide enclosures that are too conservative to be of practical use. This project aims to develop a novel enclosure strategy based on the key idea of using model redundancy to substantially improve the accuracy of existing methods without sacrificing their efficiency. This work is expected to enable the use of rigorous uncertainty quantification in real-time algorithms for robust control, verification, and fault detection tasks. For example, it will enable rapid and accurate online safety verification of trajectories for autonomous aerial vehicles operating in uncertain, cluttered, and adversarial environments.