

Spaceflight Dynamics

Research Title: Libration Point Orbit Utilization for Tactical Advantage in Communications, Surveillance and Risk Mitigation

Principal Investigator: [Eric Butcher](#), (575) 646-6179, eab@nmsu.edu

Sponsor: U.S. Department of Defense

Summary: While military satellites typically do not venture beyond geosynchronous orbits, there are several reasons to investigate the use of alternative locations for our space assets. These include risks associated with collision with space debris, susceptibility to purposeful interference and of being easily tracked, and to increase global coverage. It has been known since the time of Euler and Lagrange that there are five special locations in the Earth-Moon system (libration or Lagrange points L1-L5) where a spacecraft may remain motionless in the rotating frame. In the past 50 years various orbits near L1 and L2 have been discovered, and low-cost transfers to these locations have been found which utilize the nonlinear and chaotic dynamics associated with the restricted three- and four-body problems. While several scientific spacecraft have ventured to the Sun-Earth libration points, the first one (the NASA Artemis mission) to reach the Earth-Moon L1 and L2 points recently arrived in 2010. In this research a group at NMSU works with other researchers in the Aerospace Engineering Sciences Department at the University of Colorado at Boulder and at the Air Force Research Laboratory in Albuquerque to investigate the use of libration point orbits for military satellites, study the coverage characteristics from these locations, and find new low-cost transfers, especially for the L1 and L3 locations. Data from the NASA Artemis mission will be utilized to investigate strategies for station keeping and the required fuel usage.



http://engr.nmsu.edu/research_2011/research_funded_11_5_butcher.shtml

Research Title: Proximity Operations for Near Earth Asteroid Exploration

Principal Investigator: Eric Butcher, (575) 646-6179, eab@nmsu.edu

Sponsor: National Aerospace and Space and Administration (NASA)

Summary: This is a multi-disciplinary effort, leveraging the engineering and scientific talent within New Mexico to develop new methods and technologies needed to conduct proximity operations at Near Earth Asteroids (NEAs). Both robotic and human exploration missions are targeted in the proposed research. Recently, there has been much interest in sending robotic precursor missions to NEAs for scientific study and to prepare for a possible manned mission. Increased understanding of these small irregularly-shaped bodies is essential to any NEA deflection strategy implemented for planetary protection.

In the future, NEAs could serve as fueling stations, mining sites, or remote observatories. Interest in asteroid exploration is demonstrated by recent, current, and proposed missions such as NEAR Shoemaker, Hayabusa, DAWN, OSIRIS REx, and BASiX. Other objectives of this proposal are to build the infrastructure needed for New Mexico to become nationally competitive for funding in the fields of astrodynamics, Guidance, Navigation, and Control (GNC), telemetry and space communications, orbital mechanics and orbit determination, spacecraft attitude dynamics and estimation, and asteroid observation and modeling; to develop partnerships with NASA research assets, federal laboratories, and industry; to contribute to the state's research infrastructure, science and technology capabilities, and economic development; and to improve the environment for STEM education in New Mexico.

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Research Title: Robust State and Uncertainty Estimation for Unmanned Systems in the Presence of External Uncertainties

Principal Investigator: Eric Butcher, (575) 646-6179, eab@nmsu.edu

Sponsor: National Science Foundation

Summary: Three sweeping generalizations can be made about most unmanned vehicles, spacecraft, and vehicle formations. The first is that they have un-modeled dynamics due to operating in unknown or poorly known environments; the second is that they operate with noisy sensor measurements; and the third is that there is some time delay in the measurement, communication, estimation and control process. Moreover, the state space on which the dynamics evolves is nonlinear, and therefore global motion cannot be represented by generalized coordinates. This research examines state and uncertainty estimation for feedback control of unmanned systems. Research objectives are to: (1) characterize uncertain inputs affecting the motion of unmanned vehicles in uncertain dynamic environments; (2) augment motion estimation schemes with a disturbance estimator to learn the uncertain inputs acting on the system based only on sensed motion states; and (3) characterize and exploit the effect of time-delay on the combined estimator/controller. In addition, the transformative investigations are applied to three important applications of unmanned systems where understanding the interplay between un-modeled dynamics, stochastic inputs, and time delay will advance the current state of knowledge. Unmanned systems, which include unmanned vehicles and robotic spacecraft, are often subjected to forces and moments arising from poorly known or poorly modeled external effects. For feedback control of such systems, it is necessary to obtain accurate estimates of motion states for feedback. However, little is understood about the interplay between uncertain dynamic environments, stochastic inputs, and time delay, and how to enable accurate estimation for feedback control of the motion of unmanned systems while taking these effects into account. Given the fact that these circumstances can arise in many applications of unmanned systems including air, space, and underwater vehicles, the work of this research is to pursue fundamentally new insights. In addition, the currently available techniques for state and uncertainty



estimation of such systems are either few or nonexistent. The goal of this research is to obtain robust unscented motion and uncertainty estimation schemes that can accurately estimate the motion states as well as un-modeled forces and torques acting on the system through motion sensing only. Such robust estimation schemes can then be used in conjunction with feedback control schemes by providing motion state estimates for feedback. The deterministic unscented state and uncertainty estimation schemes that will be obtained will be robust to sensor and process noise characteristics as well as unknown time delays and will not require re-tuning when sensors are changed.