Fundamental Astrodyanmics Challenges in Orbital Debris Detection, Tracking, Identification, and Characterization

Moriba K. Jah[1]
(1) Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM 87117

The task of tracking resident space objects (RSOs) in and of itself is already a challenging problem given a greatly sparse data set, but assimilating this sparse tracking data into useful and actionable information is an even more perplexing problem that must also be addressed. Current space-tracking sensor detections are subject to finite resolution, noise, and false positives (clutter). Most orbits are propagated forward in time using simplifying dynamics assumptions that are not always valid. When an object is first detected there is a large ambiguity as to its orbit and characteristics (i.e. mass, orientation, size, material properties, etc.). Fundamental elements of estimation theory and the flow of information through and across a dynamically evolving, uncertain population must be accounted for in this problem. In addition, current attempts to automate the estimation process usually treat the stages of detection, identification, and tracking separately which incurs information loss and results in a suboptimal solution. An optimal solution should treat the detection, identification and tracking problem as a joint estimation problem which maximizes some information theoretic cost. Thus, a proper formulation for space objects draws from a more fundamental physics paradigm where RSOs are represented as probability distributions within their state spaces. Moreover, no comprehensive and rigorous physics-based modeling and simulation capability exists. Space Weather subject matter experts tend to work in mutual exclusivity from astrodynamicists, except that space object motion is driven by the local space environment and space weather experts could infer local effects by observing inoperative space object behavior. It is also hypothesized that the population of space objects is as of yet unquantified because there are different classes/species of space objects and that a discriminator amongst these can be found in their temporal and spatial behavior. Therefore, an attempt at defining the first scientifically-based taxonomy for artificial space objects is in order and could greatly assist our understanding of the overall space object population behavior and evolution. The Advanced Sciences and Technology Research Institute for Astronautics (ASTRIA) was created within the Air Force Research Laboratory to be a consortium of world class subject matter experts pulled from government agencies, academia, and private industry, and focused upon making recommendations toward solving these global and critical problems. This briefing will describe these problems in more detail, motivate the drive to finding appropriate solutions, and provide mechanisms for the scientific and engineering community to become more engaged and involved.