Foreword

I am honored to have been asked to write a foreword for this new *Elsevier Astrodynamics Series*. The word *Astrodynamics* is often attributed to R.M.L. Baker in the late 1950s. So exactly what is Astrodynamics? An aerospace dictionary from the 1960s defines Astrodynamics as "The practical application of celestial mechanics, astroballistics, propulsion theory and allied fields to the problem of planning and directing the trajectories of space vehicles." The aims and scopes of this series states that: Astrodynamics is a well-recognized, stand-alone field of discipline comprising many auxiliary fields including dynamical systems analysis, optimization, control, estimation, numerical analysis, perturbation methods, Lagrangian and Hamiltonian dynamics, geometric mechanics and chaos. The primary difference between these definitions is the list of the allied fields; the list today is much more extensive, and even includes some that did not exist in 1960, such as chaos. These new allied fields being applied to astrodynamics problems along with some exciting new missions, some of the New Horizons missions and satellite formations, are creating excitement in astrodynamics. With this new series we are trying to present to the aerospace community new results and methods that will help fill the gap between the state-of-the-art and existing books.

Let's look at some of the new problems. The problem of swarms of small satellites flying in precise formation and operating autonomously has probably created more excitement than any problem in years. Hundreds of papers have been published and presented at many conferences in different venues, and its interdisciplinary nature has drawn people from numerous disciplines beyond the traditional dynamics, control and navigation. If some of the discussed future NASA formation flying missions occur, there will be some significant challenges for the astrodynamics community. The application of dynamical systems theory to astrodynamics problems has resulted in the identification of new fuel-efficient interplanetary trajectories and has probably enabled some new missions. The GENESIS mission is an example. From this research we now have the *Interplanetary Super Highway* (from Martin Lo). This is an exciting area with many new results still to be discovered. New missions, small satellites and space control are resulting in new demands in orbit determination. We have the precise orbit determination of a few satellites, such as GRACE, and the maintenance of the space object catalog, which is the less precise orbit determination of thousands of satellites with just a few observations per day. The precise orbit determination is requiring more accurate dynamic models and better estimation. A few years ago small space objects were debris; now they may be micro- or pico-satellites. This, coupled with the need to protect the ISS from collision with small objects, means we need to track objects at least as small as 5 cm in diameter, if not 2 cm in diameter. This would increase the size of the space object catalog from its current size of approximately 14,000 objects to 100,000–300,000 objects. While doing this we need to improve the accuracy of their orbits and provide an accurate covariance. Here, again, the problem is multi-disciplinary. The solution will require improved estimation methods, optimum utilization of sensors, improved atmospheric physics, etc. Here I have tried to identify just some of the new problems creating an exciting challenge in astrodynamics. Even though the demands on astrodynamics from NASA's New Space Exploration Initiative are not yet all clear, one thing is certain: There will be demands. An obvious one is the need for real-time trajectory optimization. As with many fields today, astrodynamics is becoming more interdisciplinary and I believe this is where many of the future advances will be made.

Astrodynamics can be viewed from both an engineering and a mathematical-theoretical standpoint. It is a multi-disciplinary science, drawing largely on systems research and multi-disciplinary design, an area that does not fit very well with current journals, and is not covered in any existing book series. With this new series we are presenting some of the new cutting edge research in Astrodynamics. Topics in this first volume '*Modern Astrodynamics*' include orbital dynamics and perturbations, satellite formation flying, dynamical systems theory, trajectory optimization and novel propulsion systems. Details on the contents are provided in the Introduction.

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