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PROGRESS IN SOLVING THE "UNSOLVED PROBLEMS IN SATELLITE THEORY"

Abstract

This paper revisits the seminal 1961 paper of G. M. Clemence [1] in light of the advances in the intervening 50 years. We review progress on the unsolved problems identified by Clemence, discuss the supporting technology now available, and conclude with a current list of unsolved problems. We note that the 1961 status still prevails in some current systems, denying those of significant advances over intervening decades. Clemence's concept of a satellite theory ranges from a tabulation of coordinates to a general expression involving time and at least six other parameters. Clemence considered three classes of problems: those that will probably never be solved, those whose solution is computationally unachievable, and those that are unsolved but which can be overcome. A complete solution according to Clemence is precise to within the uncertainty of all the observations. Clemence considered both the natural satellites and the artificial satellites; he concluded that the artificial satellite problem was virtually unsolvable because atmospheric resistance so badly "contaminated" the gravitational effects [1]. Clemence noted the rapid evolution in atmospheric density models. Clemence felt that some of the difficulty could be overcome by frequent, muli-spectral, and widely distributed measurements of solar radiation. He was unduly skeptical about using artificial satellites to investigate the fine structure of the geopotential field. Clemence opined that the Earth's geopotential might never be approximated to any higher orders. Clemence's inferences were probably influenced by publication of Brouwer's algebraically intense expansions of governing equations with low orders of perturbation in terms of eccentricity and other orbit parameters of the Hamiltonian in Delaunay variables [2]. Direct numerical integration of governing equations in native form was far beyond the Pale. He observed that the most appropriate epoch for propagating orbits is neither the time of the first or the last observation. Clemence felt that each satellite and orbit is unique to the extent that there need be as many complete solutions as there are satellites. We will demonstrate that many of Clemence's unsolvable problems have been solved while others that he did not imagine have emerged. Quantifying uncertainty and propagating the resulting covariances appropriately is one of the most vexing. We will demonstrate how amazing computational advances seem to make hard problems easier. But they only seem to since incomplete physical models (process noise) and the foibles of numerical discretization may be more serious than the brute force ability to kill problems with computation.