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A SURVEY OF LONGITUDINAL-SHIFT MANEUVERS PERFORMED BY GEOSYNCHRONOUS (GEO) SATELLITES FROM 2010 TO 2021

Abstract

During their operational lifetimes, Earth-orbiting satellites in the geosynchronous orbital regime (GEO) typically expend on-board propellant at regular intervals to counteract the natural perturbations that disturb a satellite's mission-critical orbital characteristics, including its longitudinal position in the Earth-centered, Earth-fixed (ECEF) geographic coordinate system. Less often, operators command their GEO satellites to perform maneuvers that more drastically adjust their geographic longitudinal positions—that is, change a satellite's sub-satellite point from one place on the Earth's equator to another—in what are known as phase-change or longitudinal-shift maneuvers. Unlike other types of satellite maneuvers, longitudinal-shift maneuvers can be detected by human inspection of time-series geographic position data. Identifying this kind of on-orbit behavior in GEO is critical for measuring compliance with previously agreed-upon guidelines for space debris mitigation, identifying anomalous behavior in the domain, and developing norms of behavior for satellite operators. This paper presents the results of a survey study of historical longitudinal-shift maneuvers in GEO from January 1, 2010, to December 31, 2021, including summary statistics by satellite operator, country of origin, and years on orbit. A shortlist of the most-maneuvered satellites by year is also presented, including the number of maneuvers pursued by each satellite, the time spent in longitudinal drift, and the approximate Δv required to perform the described maneuvers, followed by a discussion of the on-orbit behavior of several outliers that perennially rank at the top of the shortlist. Additionally, this paper describes a methodology for identifying longitudinal shift maneuvers using publicly available two-line element (TLE) data. The primary data source for this work is the space object catalog provided by the United States Space Forces' (USSF) 18th Space Control Squadron (18 SPCS)—the space control unit responsible for managing the U.S. Space Command's (SPACECOM) space situational awareness program—and made available online at Space-Track.org. This paper also describes a methodology for approximating the Δv required for longitudinal-shift maneuvers using only data available in satellites' TLEs as well as the benefits of doing so. Several longitudinal shift maneuver case studies that together describe a variety of common longitudinal-shift maneuver profiles are used to compare this approximation with more traditional methods for calculating Δv that rely on converting the satellite's classical orbital elements before and after a maneuver into state vectors. The paper concludes with a discussion on the challenges of using TLE data for longitudinal shift-maneuver identification and the limitations of doing so for this application.