IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (2) (9)

Author: Ms. Catherine Massé
McGill University, Canada, catherine.masse2@mail.mcgill.ca

Prof. Inna Sharf
McGill University, Canada, inna.sharf@mcgill.ca
Dr. Florent Deleflie
IMCCE, France, Florent.Deleflie@imcce.fr

ECHO I CASE STUDY OF SRP EFFECT ON ORBITAL MOTION

Abstract

It has been acknowledged for some time by the research community that the secular effect of the solar radiation pressure (SRP) is not always negligible for spacecraft in LEO. Indeed, it was observed that for certain orbits, the long-term behavior of the spacecraft's perigee altitude is greatly affected by the SRP perturbation, whereas it usually averages out for objects in other orbits. This occurs because of the coupling between SRP and the geopotential, specifically, the J_2 perturbations which can lead to a resonance effect. Historically, only a few satellites have been observed to be significantly affected by this phenomenon; NASA's Echo I launched in 1960 is one of them. For Echo I, which was a 9 m^2/kg balloon-type satellite, the resonant oscillations reached an unparalleled amplitude of 500 km, owing to the aforementioned high area-to-mass ratio. This ultimately led to a much faster re-entry of Echo I due to the resulting increase in atmospheric drag.

Through the 60's and 70's, many authors have studied the case of Echo I, using orbit propagation tools available at the time. Since then, more accurate perturbation models have become available, particularly for atmospheric density, thus allowing for more accurate orbit propagation of defunct spacecraft. In the last few years, the ReDSHIFT team conducted an extensive characterization of the resonance phenomenon in LEO, under the cannonball assumption, including amplitude estimation, phase plot analysis, as well as numerical cartography of the resonant orbits in the LEO region. In our prior work, we extended the resonance analysis to plate-like spacecraft and showed that the coupling between rotational motion and SRP could be exploited to generate a resonance that would lead to deorbitation from arbitrary orbital conditions.

In this work, we revisit the orbital motion of Echo I, now considering its complete life span, to validate the resonance theory based on ReDSHIFT's findings, along with carefully selected orbital scenarios. The latter are propagated with D-SPOSE software – a high-fidelity coupled orbital-attitude propagator developed in-house. The results obtained offer several new findings and insights into the resonant behaviour of Echo I. Furthermore, we study the motion of a recently launched spacecraft LightSail 2, a 32 m^2 controllable solar sail, and use it to demonstrate, also with D-SPOSE, the efficiency of a deorbitation solution involving rotational motion.