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KEYNOTE: LESSONS LEARNED FROM THE DYNAMICAL BEHAVIOR OF ORBITING SATELLITES

Abstract

This paper presents a few interesting lessons learned by analyzing the dynamical behavior of orbiting satellites. Sometimes, the observed behavior is interpreted as anomalous and it takes considerable detective work to understand them as 'natural' from a dynamical point of view.

The first example happened in May 1979 when ESA's spin-stabilized GEOS-1 had to perform a 45-minute station-keeping maneuver. In order to verify the dynamical behavior of its booms, a detailed dynamical simulation was performed. Contrary to expectations, the simulation predicted a complete despin and loss of satellite due to boom slackness within 5 minutes! After analyzing these predictions it was found that not the booms were responsible for the despin but the rate-coupling in the Euler equations together with the relatively low spin rate. Subsequently, a short trial maneuver on the satellite confirmed the predicted disastrous despin.

After filtering the rough solar aspect angles measured by ESA's Marecs-A satellite in December 1981, unexpected spin-axis attitude changes of 0.05 were observed near the perigee passages. Eventually, it could be shown that these attitude changes were caused by free-molecular drag torques. NASA's CONTOUR spacecraft was lost during the firing of its Solid Rocket Motor (SRM) on 15 August 2002. The SRM extended far into the spacecraft, which produced a short lever jet damping arm. This, coupled with significant changes in the mass properties, lead to concerns about the spacecraft's stability during the SRM burn.

We constructed a representative analytical jet-damping model based on the dynamical condition that the angular momentum flux created by the burning propellant equals the flux carried out by the combustion gases through the SRM nozzle. Explicit results for the jet-damping and misalignment torques and the resulting nutation were established. This allowed us to conclude that jet damping was not responsible for the loss of CONTOUR.

Rendezvous and flyby requirements with planets and comets require accurate targeting and thus accurate non-gravitational models for the accelerations on the spacecraft. ESOC uses high-fidelity spacecraft models for modeling the Solar Radiation Pressure (SRP). Nevertheless, they encountered considerable difficulties during the orbit determination and prediction of Rosetta, Mars Express, and particularly Venus Express. We show that these problems are due to re-emitted thermal radiation off satellite surfaces and depend on the geometry, emissivity and temperatures of the surfaces. Errors in the SRP dynamics were originally mis-modeled by estimating an SRP scale factor imposed on the main component of the SRP acceleration vector.