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ATTITUDE DISTURBANCE CAUSED BY PROPELLANT MASS CONTAMINATION AND SUBLIMATION FROM SATELLITE EXTERNAL SURFACES DURING ORBITAL CONTROL OPERATIONS.

Abstract

The geostationary Italian military satellite SICRAL 1 was re-orbited to graveyard orbit in May 2021, after a 20-year operational lifetime. Several longitudinal manoeuvres were executed in order to reach the target altitude and to vent the unified (bipropellant MMH/MON) propulsion system. An unexpected attitude disturbance phenomenon around the pitch axis affected the operations. In particular, during the orbit raising and propellant consumption phases, the event systematically appeared every 24 hours (after each "morning manoeuvre") with a near-constant intensity, direction and duration, influencing both on-board attitude control management and ground operating procedures and planning. AOCS actuators correctly managed the anomalous behaviour and satellite control centre adopted dedicated countermeasures, preventing further escalation and achieving a successful re-orbiting. The paper describes in detail both the outstanding phenomenon through real telemetry data analysis and the ex-post investigation performed by the military spacecraft operators and the satellite manufacturers in order to identify the most likely root cause. The comparison of satellite telemetries (attitude, rates and demanded torque) with the flight dynamics data showed a clear correlation between disturbance timing and specific illumination conditions and a direct proportionality to the quantity of propellant mass consumed for aforementioned firing. These findings brought to conclude that the most likely hypothesis was the delayed ejection of the propellant gases-droplets left on the external surfaces (UHF payload antennas) through the firings. In fact, the propellant exhaust accumulation on the rear of the antenna surfaces, in conjunction with the umbra-light transition during the orbital revolution, caused the sublimation of the residual particles,

resulting in an opposite reaction force and a consequent perturbation torque around pitch axis. The paper demonstrates the thesis with an evaluation of propellant contamination effects on satellite surfaces, taking into account thermal conditions and satellite intrinsic (chemical-physical) and extrinsic (assembly position and direction) properties. The research results, based on real data fostered by a phenomenon modelling and simulation campaign, are very useful to predict the possible disturbance appearance on similar satellite-class and to support the in orbit operations as well as to provide a precious heritage for the next generation geostationary spacecraft design phases.