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RECONSTRUCTION OF THE EARTH ORBIT PARAMETERS FROM A MINIATURIZED TEMPERATURE SENSOR ONBOARD THE DELFI-C3 CUBESAT

Abstract

This paper reports on the reconstruction of key orbital elements of the Earth's orbit around the Sun from a miniaturized temperature sensor onboard of the Delfi-C3 Cubesat, a novel approach never explored before to the best of our knowledge. Delfi-C3 is a triple-unit CubeSat with a mass of 2.4 kg, developed by Delft University of Technology, which was launched on April 28th in 2008. Despite of its required lifetime of less than four months, Delfi-C3 is still operational and has been beaconing data for 8.6 years, which makes this CubeSat mission unique in terms of a continuous record of telemetry data. Recent inspections of Delfi-C3 telemetry data over five years from different temperature sensors have revealed surprisingly systematic patterns of periodic nature with an amplitude of 3.1 K and a period of one synodic year. First speculations associated this behavior to be correlated to the orbit of the Earth around the Sun. An analytical model of the temperature fluctuations has been established which associates the amplitude, phase and period of the observed temperature to the eccentricity, the argument of periapsis, and the period of the Earth's orbit around the Sun, respectively. This analysis represented the first attempt to reconstruct the Earth's orbit from satellite temperature measurements. To quantitatively estimate the Earth orbit parameters from in-flight telemetry data, a numerical least-squares estimator has been developed and applied to Delfi-C3 temperature data over the period 2008-2015. Preliminary results by using temperature data from the On Board Computer (OBC) Printed Circuit Board already showed that the estimated semi-major axis, eccentricity, and argument of periapsis of the Earth orbit differ from the true values of less than 1%, 3%, and 5%, respectively. An additional filtering of raw data further demonstrated that the achievable accuracy of the estimation can be refined up to better than 0.05%, 2% and 2.5%, respectively. The paper will address the sensitivity of those results to initial conditions, filtering schemes and estimator settings. Furthermore, we expect that a refined analytical thermal model will allow a comparable accuracy also for other instruments that are less sensitive to external temperature fluctuations, in cases where the internal dissipation requires a better representation of the thermal paths in the internal stack. The research provides an exciting demonstration of the opportunities that Small Satellites offer to combine technology demonstration with research in the educational framework of a Master programme.