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Author: Ms. Francesca Cirillo
Airbus Defence & Space, Germany, francesca.cirillo@airbus.com

Dr. Philipp Behruzi
Astrium, an EADS Company, Germany, Philipp.Behruzi@airbus.com
Mr. Francesco De Rose
Germany, francesco.derose@airbus.com

IMPROVEMENT AND VALIDATION OF MICROGRAVITY PROPELLANT SLOSHING MODELS FOR HIGH-ACCURACY POINTING MISSIONS

Abstract

Liquid-propellant sloshing constitutes nowadays an important mission, system and AOCS design and performance driver for space vehicles. In fact, space missions are becoming increasingly demanding in terms of high-pointing performance and stability, or tight Center-Of-Mass (COM) control. This is often in combination with competing requirements for fast re-pointing slew maneuvers and fast tranquillization times to achieve high mission availability. Additionally, de-orbiting requirements have been recently introduced, implying that nearly all future missions will carry large-scale liquid tanks for their entire operational life. In all these cases, the disturbances produced by the large amount of fuel, excited e.g. by a re-pointing maneuver, interact with the solid body dynamics and its control system, potentially leading to increased actuators commands and associated fuel consumption, degraded satellite pointing performances, increased tranquillization times and reduced mission availability, undesired COM displacements, and therefore representing a major driver in the system design. For these reasons, accurate and validated models and tools are needed to predict and mitigate the impact of microgravity propellant sloshing for a large number of mission scenarios. In this framework, a study to evaluate the state-of-the-art and the improvements required by current sloshing modelling methodologies in low-gravity environment to support high-fidelity simulation for high-performance missions has been conducted by Airbus DS under ESA contract. Two benchmark case-studies have been defined: one based on the AS400 Functional Avionics Platform developed by Airbus DS and representative of a wide range of applications in the framework of highly-stable system; the second is a scaled test-case for an experiment on-board the International Space Station (ISS). The analysis is founded on state-of-the-art analytical models and numerical simulations, making use of the CFD tool Flow3D and the in-house CFD-in-the-loop FiPS®, which couples liquid sloshing, rigid body motion and thruster activations driven by the flight controller. The present paper discusses approaches and results achieved in the study, focusing on the improvement required w.r.t. modelling, accuracy and computational costs to cope with high-performance missions. As the lack of long-duration microgravity experimental data is considered crucial to improve the understanding of the fluid-mechanics in microgravity and therefore to enhance the mathematical formulation and modelling of the sloshing problem, as well as to benchmark and validate sloshing models and tools uncoupled or coupled to the spacecraft dynamics and its AOCS, DLR and Airbus DS teamed-up to build the MICROSLOSH experimental platform, whose flight is foreseen for 2017 and whose design is herein outlined.