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A NEW FREE FLOATING SATELLITE DYNAMICS TEST-BED FOR HARDWARE-IN-THE-LOOP DOCKING EXPERIMENTS

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EXTENDED ABSTRACT

Recently, multiple organizations have started being interested in advancing developments related to the implementation of a first full satellite servicing or de-orbiting mission in space. Multiple related ground facilities have been established in Germany, in the U.S. and at other places. All those facilities have the goal to develop and ground-verify the related robotics and automation technologies related to satellite servicing and debris removal. At ESA, so far, no test-bed has been available that allowed for accurate, hardware-in-the-loop testing of robotic contact operations with objects such as satellites emerged in the weightless space environment.

Hardware-in-the-loop (HIL) testing is an enabling technology for docking experiments, since it is often not possible or at least highly impractical to implement accurate docking and contact simulations in software. This is due to (a) the lack of sufficiently accurate test parameters for materials, object stiffness and other geometric parameters of the objects at hand and (b) due to the difficulty of simulating exact and physically representative contact dynamics at a sufficiently high sampling frequency for implementation in real-time.

This is why, it is interesting to perform robotic satellite contact experiments with the real interface hardware and to rely for the implementation of the general dynamics response of the system in space on the well established capability to on-line simulate the dynamics of objects free-floating in space.

This paper will describe the implementation of the HIL docking test-bed for contact experiments with free-floating objects in space that has been implemented at ESA's Telerobotics & Haptics Laboratory in November 2014 (Figure 1).

The SatSim testbed is based on a lightweight manipulator arm that is implemented in a mixed impedance/position control architecture into the setup to emulate the exact behaviour of any arbitrary free-floating object that can be described in a dynamics software model which is also part of the setup (Figure 2). The robotic system is capable to hold a docking interface hardware interface (the actual hardware relevant for contact experiments, e.g. on a satellite) up to a total mass of 14 kg. As such, it allows holding e.g. the fuel-nozzle interfaces of a standard GEO communication satellite, which could then be used to perform robotic contact experiments in preparation for satellite refuelling operations conducted in space. At the same time, the implementation of the satellite dynamics co-simulation provides no limit on the overall mass of the satellite that can be simulated on the testbed. As such, the HIL testbed allows to perform realistic contact experiments with satellites in the multiple tons of kilogram range, which otherwise would not be possible at this accuracy on a full hardware testbed that would need to support a full satellite mockup. Results will be shown that demonstrate the accuracy of the HIL approach when external forces are applied to set the system in motion.

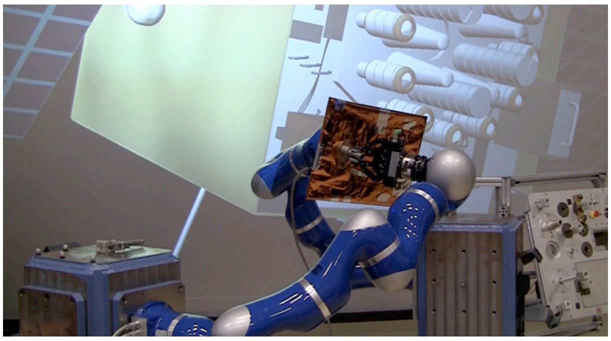

Figure 1: The Hardware-in-the-loop satellite docking simulator during operation at ESA's Telerobotics & Haptics Laboratory.

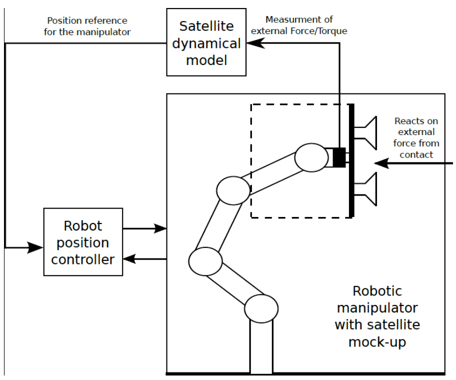

Figure 2: Conceptual control diagramme of the TRH Free-floating Satellite dynamics test-bed for hardware-in-the-loop docking experiments.