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DISTRIBUTED HARDWARE-IN-THE-LOOP SATELLITE SIMULATION ARCHITECTURE FOR CREATING "DIGITAL SHADOWS" OF SATELLITE CONSTELLATIONS

Abstract

In this paper, we propose a scalable and modular architecture for combining a hardware-in-the-loop approach with several simulated satellites as well as satellites which may be in orbit at the time. This approach aims to create a "digital shadow" of satellite constellations and thereby improve the fidelity and trustworthiness of evaluation of potential constellation evolutions and management of contingency scenarios. Our simulation architecture allows for quick assessment of alternatives and on-the-ground verification of satellites together with hardware-in-the-loop setups, where physical sensor input is impossible due to the different environment.

Utilising software based on the IEEE 1516-2010 *Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)*, we combine several simulations of satellite and satellite subsystems with hardware components. Compared to existing simulation environments, simulations of several domains can be combined easily and run together with hardware components, while placing fewer limits on the number of simulations running together. On that basis we examine the communication chain from simulator to orbit, to present a model for a hardware-in-the-loop simulator architecture that can include systems currently in orbit, similar to pilot-in-the-loop systems which are common in aeronautical simulations. We then compare advantages and disadvantages and discuss the real-time capabilities of the system, considering nanosatellite systems. As a use case, we study the staged deployment of a telecommunications satellite constellation for an uncertain and evolving market demand.

As other authors have shown, staged deployment offers downside protection and opportunity for upside capture in market demand for satellite constellations under uncertain environments. A reconfigurable simulation environment allows to assess this potential in the early project stages by quickly evaluating different scenarios in higher detail than previous research, which is mainly based on simple models (e.g. propulsion and coverage) for each stage. This paper describes the system architecture of our hardware-in-the-loop simulator and illustrates the initial results of our hardware implementation, including a combination of satellite subsystem models and flatsat hardware components.