IAF HUMAN SPACEFLIGHT SYMPOSIUM (B3)
Advanced Systems, Technologies, and Innovations for Human Spaceflight (7)

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CLOSED-LOOP DOCKING AND UNDOCKING QUALIFICATION TESTS OF THE EUROPEAN INTERNATIONAL BERTHING AND DOCKING MECHANISM (IBDM) USING AN INDUSTRIAL ROBOT SETUP

Abstract

The International Berthing and Docking Mechanism (IBDM) is the human-rated European docking system developed by Redwire Space in contract with the European Space Agency (ESA). Early 2025, the IBDM qualification model (QM) has successfully passed a major milestone in its qualification test campaign which are the closed-loop tests whereby the in-house built Redwire Robotic Facility (RRF) was used. It emulates the docking and undocking sequences, subjecting the IBDM to a variety of scenarios: different vehicle dynamics, different combinations of approach misalignments/speeds and off-nominal scenarios. In total, over 250 test cases, in line with the International Docking System Standard (IDSS), were applied and captured successfully. This paper will discuss the test setup, results, correlation with simulations and the stabilizing mechanisms required to utilize an industrial robot.

As a world-first, the RRF allowed to perform an end-to-end docking, including hard capture and subsequent undocking, in one run using an industrial robot. The facility, in ISO-5 cleanroom conditions, was specifically designed, built and verified to have an acceptable stiffness while remaining affordable. Off-the-shelf hardware was used to complete the control loop. To increase the hardware safety, a custom signal from the IBDM can halt the RRF in an automated way.

The typical problems during hard capture are the stiff and unpredictable contacts between the Hard Capture System (HCS) elements in a highly constrained area in combination with a low motion bandwidth of such an industrial robot. This can lead to undesired instabilities not representative of any in-orbit vehicle behavior. The RRF allowed to stabilize such events to pass-through every docking and undocking stage: specific mechanisms were developed in the control software of the robot to allow sufficient and relevant movements in highly confined areas to perform automated docking and undocking scenarios. The difficulty lies in defining which robot behavior one needs to allow to accurately mimic the in-orbit interactions between the HCS elements. Therefore, some stabilizing mechanisms were introduced that have the macroscopic effect of adding damping to unrealistic motions of which the tuning values were determined experimentally.

The Redwire Robotic Facility has proven to be capable of performing docking and undocking tests fully in line with the IDSS. Its unique stabilizing mechanisms for hard capture and undocking events

show that an industrial robot setup can be used for such tests which avoids the use of large, heavy and expensive facilities. Further research using in-orbit data and behavior can further improve this approach.