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Author: Mrs. Christine Hill
University of Stuttgart, Germany, Christine.Hill@gmx.net

Dr. Juergen Hill
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, juergen.hill@dlr.de
Mr. Andreas Fink
University of Stuttgart, Germany, andreas@explore-rexus.de
Mr. Johannes Weppler
University of Stuttgart, Germany, johannes@explore-rexus.de
Mr. Emil Nathanson
University of Stuttgart, Germany, emil@explore-rexus.de
Mr. Robert Schelling
University of Stuttgart, Germany, robert@explore-rexus.de
Mr. Daniel Stoerk
University of Applied Sciences Offenburg, Germany, daniel@explore-rexus.de
Mr. Thorben Heinrichs
Aalen University of Applied Sciences, Germany, thorben@explore-rexus.de

EXPLORE: AN EXPERIMENT FOR ON-ORBIT REFUELING ON A SOUNDING ROCKET

Abstract

Space exploration missions, in particular human and large cargo flights, will require considerable transportation efforts to future destinations such as Moon and Mars. A possible solution for enabling far destination flights is the refueling of orbital transportation stages in orbit. The "EXPeriment for Liquid On-orbit REfueling" (EXPLORE) aims at informing the investigation of technologies and processes for these orbital refueling activities under microgravity conditions. EXPLORE was launched on the REXUS 9 sounding rocket in February 2011. Although storable propellants are already transferred in orbit (e.g. at ISS), the handling of more efficient cryogenic propellants pose specific challenges. The usage of those typically requires a pressurized gas, which then remains in the fuel tank after depletion. By refueling the fuel tank again a mixture of the liquid and gaseous phases has to be avoided, while the imposed pressure has to be kept to avoid propellant boil off. This refueling process was reproduced in the EXPLORE experiment to investigate the influence of the filling flow velocity on the propellant flow and final fill level. Numerical simulations have identified several promising flow velocity profiles to avoid gas cavities in the refuelled volume. The experiment was installed in a payload compartment of the REXUS sounding rocket. It comprised the refueling system, the control and measurement electronics, and the structural mounting. In the refueling system, a central gas pressure tank pressurized two identical liquid tanks, which again distributed the liquid fuel to the test chambers through mass flow controllers and adequate valves and tubing. EXPLORE used six transparent test chambers, where relative geometric properties resemble typical propellant tanks. To avoid mixture of gaseous and liquid phase, the filling was supported by a customized internal structure in the test chambers. The structure directed the fluid surface under microgravity and ensured proper extrusion of the pressurizing gas. The flow velocity profile was varied for each chamber in the experiment according to the numerical simulations. The fuel transfer process was observed visually by a camera and through the recording of pressure and temperature data. While

detailed evaluation of the flight data is ongoing, preliminary analysis showed successful filling of all test chambers without perceptible mixture of the gaseous and liquid phases. At least one of the test chambers achieved a fill level of more than 90 percent. The results of the EXPLORE experiment will be used to inform large scale refueling simulations and demonstrations in the future.