Experimental investigation on the draining behavior in scaled models of the new A5ME upper stage propellant compartments with respect to different flight conditions

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The maximum possible mass, launched to orbit by a rocket, depends on the launcher performance and the desired target orbit. To provide as much capacity to the payload as possible, the total mass of the launchers upper stage has to be minimized. Intelligent propellant management can contribute significantly to increase the performance of the launcher. To optimize the flight missions the tank outlet design is required, to achieve that a maximum of the propellant is available for the mission and a minimum of propellant loading remains as unused residual.

For a proper function of the spacecraft engine, the propellant has to be supplied in liquid form and free of gas bubbles. By emptying the compartments, therefore the moment is important, when at the tank outlet gas is ingested beside the liquid propellant. Significant is the nature of the free liquid surface. When the engine is in operation, the space craft is under a steady acceleration. Due to this force, the liquid propellant is collected at the tank outlet. Depending on the compartment geometry and the flow velocity at the outlet, deformations of the free surface and vortexes can occur. This may cause ingestion of gas into the outlet flow even before the nominal liquid fill height reaches the outlet point.

To provide predictions of the diphasic propellant residuals for the new A5ME (Ariane 5 “Midlife Evolution”) upper stage, scaled models of the LH_2 (1:5) and LO_X (1:4) compartments were investigated. Several planned flight conditions were simulated. The test liquid was deionized water and the experiment parameters, like flow velocity, rotation rate or inclination angle, were chosen with respect to the Froude- number to assure similarity with the original tanks.
Presented will be the results of the experimental investigation at the German Aerospace Center in Bremen, done under contract of Eurocryospace, Design Authority of the A5ME Upper Stage Tank. The experiments in the laboratory were done with scaled acryl glass models, which enabled specifically observation of the liquid surface and the outlet flow with optical monitoring systems.