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Title

DLR project TRANSIENT: Testing reusable cryogenic insulation and thermal protection systems

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Abstract

This paper will summarize the activities done by the DLR within the scope of the TRANSIENT project with regard to combined cryogenic insulation and thermal protection systems for reusable launch vehicles. An overview over the then-current status of the TRANSIENT project has been presented at EUCASS previously [1]. As the project will end in Q2 2023 this paper will contain the final results of the numeric investigations and of the experimental campaigns.

Reusable launch vehicles experience a large range of thermal boundary conditions during their mission. The range of temperatures is extended substantially when using deep cryogenic propellants. This necessitates the use of external thermal protection and cryogenic insulation subsystems in order to keep all elements of the vehicle in their functional temperature range. However, the operational experience with reusable versions of these subsystems is limited, especially for the cryogenic insulation. The total number of operational reusable launch vehicles (RLV) in the history of spaceflight is small. None of them (Space Shuttle, Energia Buran, Falcon 9 booster stage) have made use of a cryogenic tank insulation on their reusable stages. The US Space Shuttle and the Soviet Buran were orbital stages without any large cryogenic tanks. The Falcon 9 is a typical booster stage with integral tanks, however, using the propellant combination LOX-RP-1, which has a heritage of being flown on rockets without cryo-insulation (e.g. Atlas, Saturn V, Soyuz). Therefore, no practical experience with an operational RLV implementing reusable cryogenic tank insulation exists. For future RLV's however, the use of cryogenic fuels has large benefits with regard to vehicle size, mass and environmental impact. For a winged system the cryogenic insulation has to be integrated with the thermal protection system onto the propellant tank surface, imposing new requirements on both.

Within the DLR this topic is being investigated in the TRANSIENT project. The relevant subsystems were first analyzed numerically in order to derive a representative design that fulfills the requirements. Then segments meant to represent a slice of an RLV tank were manufactured and equipped with the selected cryogenic insulation and thermal protection systems. Representative test objects for both metallic as well as CFRP tank structures were manufactured. These test objects were then subjected to mechanical and thermal loads representative of multiple RLV missions. Their initial performance as well as potential changes over the course of multiple load cycles are assessed. A total of three test objects were tested, one in the arc-jet heated wind tunnel L2K, two in the thermo-mechanical test facility THERMEX.

References

[1] Wilken, J. et al: Combined cryogenic insulation and thermal protection systems for reusable stages. 9th European Conference for Aeronautics and Space Sciences (EUCASS), 27. June - 1. July 2022, Lille, France.