HiSST: 2nd International Conference on High-Speed Vehicle Science & Technology

11–15 September 2022, Bruges, Belgium

Numerical Investigation of the Influence of Nozzle Gimbaling during Reverse Flight of the Reusable Demonstrator Callisto

Moritz Ertl[1], *Tobias Ecker*[1]

Abstract

Different actors in the space trasport sector are moving towards reusable launch vehicles (RLV) for the first stages of launchers, among them Rocket Lab with the Neutron and SpaceX with the Falcon 9. The current European long term strategy is also aiming towards reusability with plans for THEMIS and Ariane Next. In accordance with this strategy the German Aerospace Center (DLR) has entered into a collaboration with the Japan Aerospace Exploration Agency (JAXA) and the French Space Agency (CNES) for the development of RLV relevant technologies in the frame of a vertical take-off and vertical landing (VTVL) reusable subscale launcher first stage demonstrator - the "Cooperative Action Leading to Launcher Innovation in Stage Toss back Operations" (CALLISTO) [1].

Generally a VTVL first stage will return to the launch pad utilising retro-propulsion and deployable landing legs. Callisto uses thrust vector control of a single engine as a method, among others, for guidance and control during reverse flight. The reverse flight leads to new additional aerodynamic and aerothermal design questions compared to traditional launchers as the engine plume is interacting with the vehicle structure due to the air flow. The authors have already analyse some of these aspects in previous articles [2–4].

To aid the development of reusable launch vehicles in the VTVL configuration, in this work we aim to analyse the influence of a gimbaled nozzle on the aerodynamics and aerothermodynamics of a VTVL first stage during reverse flight. The analysis is based on Reynolds averaged Navier-Stokes computational fluid dynamics using the DLR TAU code.

Keywords: *reusable launch vehicle, VTVL, retro-propulsion, aerodynamics, aerothermodynamics, CFD, RANS, nozzle gimbaling, thrust vector control*

References

1. Dumont, E., Ishimoto, S., Tatiossian, P., Klevanski, J., Reimann, B., Ecker, T., Witte, L., Riehmer, J., Sagliano, M., Vincenzino, S. G., Petkov, I., Rotärmel, W., Schwarz, R., Seelbinder, D., Markgraf, M., Sommer, J., Pfau, D. & Martens, H. *CALLISTO: a Demonstrator for Reusable Launcher Key Technologies* in *32nd International Symposium on Space Technology and Science (ISTS)* (Fukui, Japan, June 2019).
2. Ertl, M., Ecker, T., Klevanski, J., Krummen, S. & Dumont, E. *Aerothermal analysis of plume interaction with deployed landing legs of the CALLISTO vehicle* in *9th European Conference for Aeronautics and Space Sciences* (2022).
3. Ecker, T., Ertl, M., Klevanski, J., Dumont, E. & Krummen, S. *Aerothermal characterization of the CALLISTO vehicle during descent* in *9th European Conference for Aeronautics and Space Sciences* (2022).
4. Ecker, T., Karl, S., Dumont, E., Stappert, S. & Krause, D. Numerical Study on the Thermal Loads During a Supersonic Rocket Retropropulsion Maneuver. *Journal of Spacecraft and Rockets* **57,** 1–16 (Jan. 2020).

[1] *German Aerospace Center (DLR), Institute of Aerodynamics and Flow Technology, Department Spacecraft, moritz.ertl@dlr.de, tobias.ecker@dlr.de*