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Corresponding author: MERZ Florian
e-mail of corresponding author: florian.merz@dlr.de
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Title

Green Propulsion Demonstrator "The LÄNDer"

Authors

Florian MERZ [1], Marius Wilhelm [2], Till Hörger [3], Lukas Bischof [4], Fabio Addario[5],*
Dr. Christoph Kirchberger [6], Prof. Dr. Stefan Schlechtriem [7]

** Corresponding author*
[1] Research Associate, DLR, 74239 Lampoldshausen, Germany, florian.merz@dlr.de
[2] Project Lead Green Propulsion Demonstrator, DLR, 74239 Lampoldshausen, Germany, marius.wilhelm@dlr.de
[3] Research Associate (PhD), DLR, 74239 Lampoldshausen, Germany, till.hoerger@dlr.de
[4] Student, DLR, 74239 Lampoldshausen, Germany, lukas.bischof@dlr.de
[5] Student, DLR, 74239 Lampoldshausen, Germany, fabio.addario@dlr.de
[6] Head of Department (RA-SOA), DLR, 74239 Lampoldshausen, Germany, christoph.kirchberger@dlr.de
[7] Head of Department (RA), DLR, 74239 Lampoldshausen, Germany, stefan.schlechtriem@dlr.de

Abstract

For future manned and unmanned space missions, landing systems are required, which are able to initiate and carry out soft autonomous landings on extraterrestrial celestial bodies. Development of rapid and robust guidance and control (GNC) systems as well as efficient, controllable and safe thrusters meeting a high level of autonomy and safety is crucial for successful lander missions. To meet those requirements, both component level view such as physico-chemical behavior of the propellants and the transients of the propulsion system itself as well as the system level view of the behavior of the holistic system are of utmost interest. At the German Aerospace Center (DLR), research is being conducted into new GNC strategies, as well as safer alternative fuels. These "Green Propellants" are intended to replace the proven fuel hydrazine, which requires complex handling due to its toxicity and is becoming increasingly restricted in use [1].

An overview will be given of currently planned space missions that plan propulsive landings, with focus on the propellant and GNC technologies used. Based on existing landers and space vehicles, a selection of control strategies will be presented. In order to further expand test options for landing applications in Europe, DLR is building a test bench that can be used to test GNC strategies and/or thrust-controllable green rocket engines.

In this work, the design and construction of a 1-DoF test bench as well as a 3-DoF test bench for cold and hot gas tests is shown. The test bench is adapted gradually towards enabling free-flight testing (see Figure 1).

Furthermore, simulation models of the test benches are designed and GNC strategies are evaluated regarding their performance and robustness.

The lander is initially limited to translational motion along the vertical axis. Due to its high safety, thrust is generated by pulsed operation of two control valves, with nitrogen being the medium.

In the second stage, an attitude control system is going to be implemented, enabling 3-DoF control. Hot gas tests will be performed after evaluation and selection of promising control strategies.

Simulation of a time and fuel optimal control system reveals, that a soft landing cannot be guaranteed in case of small deviations in the model. Matching results of conventional PID-based control in simulation and reality have been demonstrated [2]. Among the most promising elaborated strategies are model predictive control (MPC) as well as reinforcement learning (RL). Both select control outputs by solving an optimization problem and allow the consideration of constraints. Thrust will be controlled by means of pulseable rocket engines resulting in a nonlinear control problem. Robustness and generalization capabilities of the controller can be influenced in case of RL by variation of the simulation

model through domain randomization and consideration of stochastic disturbances as well as measurement errors during training. RL is chosen over MPC due to its expected capability of overcoming modelling errors.

References

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[2] Merz, Florian. 2022. Master's Thesis. University of Stuttgart. Fundamental Comparison between Different Thrust Throttling Approaches and Implementation of Selected Procedures in a 1-DoF-Coldflow-Demonstrator

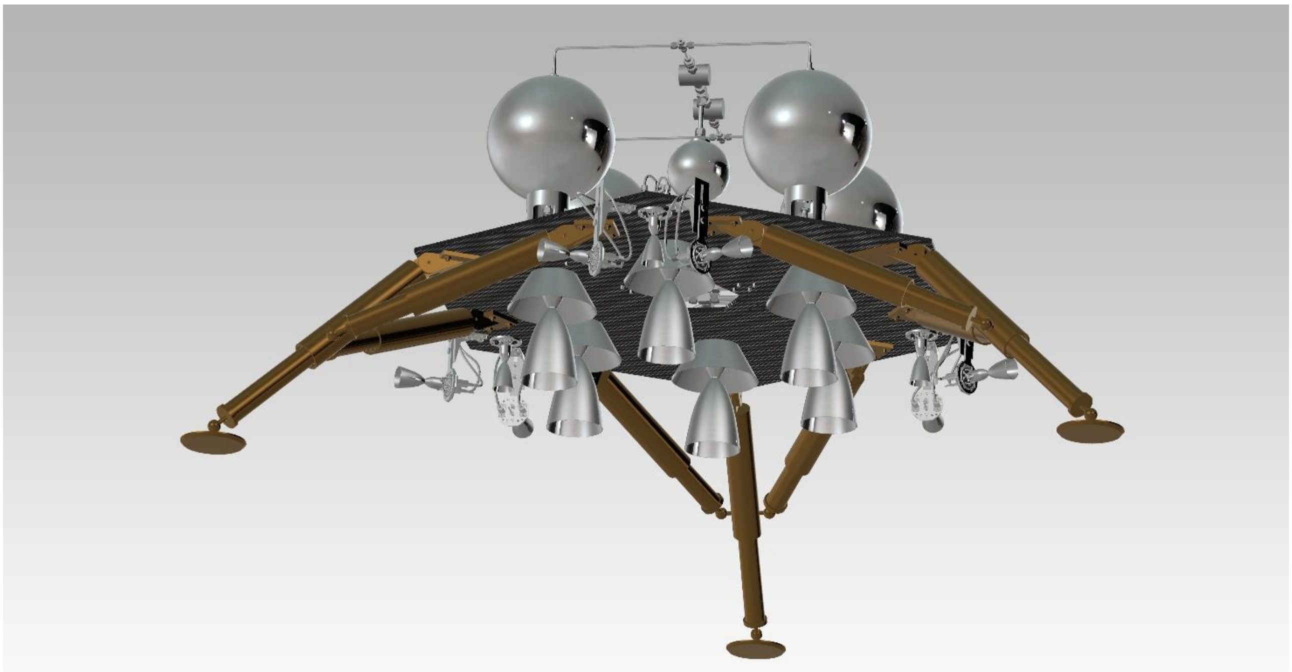

Figure 1: Concept Design "The LÄNDer"