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**Title**

# From Lampoldshausen to Orbit: DLR Spin-off GreenDelta and the Development status of Green Propellant Thrusters based on $H_2O_2$ and $N_2O$

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## Abstract

The German Aerospace Center's Institute of Space Propulsion in Lampoldshausen has more than a decade of experience in green propellant research and green propulsion hardware development. In the frame of internal research projects ( [1–7] as well as ESA [8] and third-party projects DLR employees gained a deep and extensive knowledge of propulsion hardware. Based on this knowledge, in-house thruster and propulsion hardware development was pushed forward. Currently two promising technologies are developed and patented by the Institute: the HyNOx mono- and bipropellant technology, based on nitrous oxide and hydrocarbon fuels, as well as the HIP_11 technology, based on hydrogen peroxide and hypergolic fuels. The commercialization of both propulsion system technologies will take place by the DLR spin-off GreenDelta. The spin-off is currently funded by the German Helmholtz Association and DLR. First thrusters will be available at Q4 2023.

The HyNOx bipropellant offers high $I_{sp}$ (approx. 300 s), non-toxic components, self-pressurized propulsion systems, easy handling and low cost. The overall propulsion system will be available for 25 % of the price of a conventional propulsion system based on toxic and carcinogenic propellants.
HIP_11 is a hypergolic combination based on $H_2O_2$ and ionic liquid fuels, which offers an $I_{sp}$ of approx. 310 s, significantly reduced costs, easy to handle propellants and use of already available hardware for $H_2O_2$.
Both technologies complement each other, as HyNOx is more suitable for lower spacecraft masses and lower delta v requirements, while HIP_11 is suitable for larger spacecrafts and higher delta v.

While for HyNOx a 22 N TRL 5 thruster was successfully develop and tested in more than 2000 hot firings, HIP_11 has currently a TRL of 3 and was tested in more than 500 hot firings in a battleship-thruster.
Demonstrated up to now was vacuum ignition of both propellants at DLR's M11 test facility, Pulse-Mode Operation for 1, 2, 5 Hz with Duty cylces in between 12,5 % to 87,5% and minimum impulse bits below 1 Ns for the 22 N HyNOx and 40 N HIP_11 battleship thruster.
Furthermore, up to 900 s steady state firings with the HyNOx 22 N thruster were conducted while thermal steady state is achieved after approximately 60 s. To the others knowledge this is the first European nitrous oxide thruster capable of thermal steady state firing. The minimum ON-time of the 22 N thruster is 50 ms, offering highly reproducible impulse

bits (+/- 5%) . At the moment, the HyNOx 22 N thruster is tested in the frame of an ESA program (GreenRAIM) under vacuum conditions. Based on the vacuum test results, Ecosim ESPSS modells will be derived. In parallel to the 22 N HyNOx test program, a 1 N battleship-thruster and a 200 N thruster is developed and will be hot fired in Summer 2023. The 40 N HIP_11 thruster is currently undergoing design iterations and improvements in cooperation with an industry partner and an upscaling to 200 N will take place in Summer 2023.

In the final paper test data of campaigns with both propellants in their corresponding thrusters will be presented. A special focus will be on parameters as rise time of the thrusters, reproducibility of the impulse bit, combustion roughness, minim ON-times and combustion efficiency.

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