The propulsion system of the ZEpHyR - ZARM Experimental Hybrid Rocket: A contribution to the DLR STERN Project by the University of Bremen

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The ZARM experimental hybrid rocket, which is the contribution of the University of Bremen to the DLR-STERN (Studentische Experimentalraketen) national project, is a small sounding rocket with a paraffin-LOX (liquid oxygen) hybrid engine. The goal is a ceiling altitude of about 20km and a maximum velocity in excess of mach 2.

The development of this rocket started in April 2012 and the project has concluded phase B, with the completion of the PDR (preliminary design review) before submission of the final paper. Currently all major systems (propulsion, structure, guidance and power) have been fully designed and are being iterated towards the performance and mass targets necessary for achieving the goals mentioned above. For some systems such as the propulsion system many sub-scale tests have already been conducted, addressing many issues such as fuel grain stability, proper injection of the oxidiser, combustion instability and chamber and nozzle materials just to name a few.

The current paper will focus on the development of the propulsion system only, as an example of the current overall design philosophy. This is in to order not exceed the scope of the paper, while still presenting adequate detail.

ZEpHyR is powered by a hybrid engine using paraffin and LOX as its propellants. The engine is designed to produce about 1,8kN of thrust for thirty seconds resulting in a total impulse of about 54kNs. While the choice of paraffin as the propellant was never in doubt because of its superior regression rate properties, ease of preparation and procurement as well as negligible safety requirements, the choice of a suitable oxidiser was more involved. Three options were considered: GOX (gaseous oxygen), LOX and N_2O. These were then analysed in a trade-off study, with the goal of achieving the maximum apogee.

Following the completion of the trade-off study a small sub scale test engine using GOX (gaseous oxygen) - paraffin was used to gain experience in grain design, regression rate analyses, injector design and additives such as aluminium and titanium hydride. In addition to this, engineering data on start-up procedures for smooth burning and materials subjected to direct combustion chamber gases was gathered. These results will be presented in the following paper.

Using this data and the trade-off study as a basis, a full scale engine EM (engineering model) is currently being manufactured, which will be similar to the flight engine in every way, except thrust to weight ratio. In addition to this the current test-stand is upgraded to support the needed LOX infrastructure. Hence, the paper concludes with the most recent progress in testing the EM and upgraded test-stand.