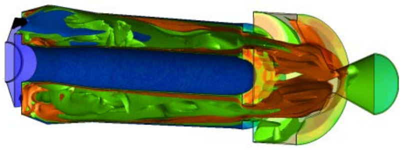
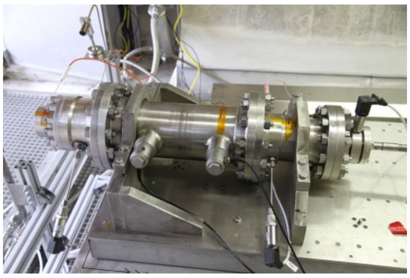
AHRES/ATEK: Software Development for Hybrid Rocket Engine Design

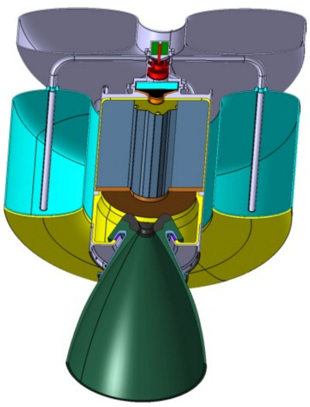
Hybrid rocket engines are a promising and cost-efficient alternative to today's solid and liquid rocket engines for commercial space transportation. As part of the projects AHRES (Advanced Hybrid Rocket Engine Simulation) and ATEK (Antriebs-TEchnologien für Kleinträger) the German Aerospace Center is developing software for the layout of an entire hybrid rocket engine including subsystems within 100 days. In addition, this tool enables the design of solid rocket engines. A designated test bench for these engines is used for validation purposes.



CFD simulation of the engine demonstrator



Combustion chamber process analysis with state-of-the-art measurement technology



Potential application:
Upper stage engine study AHREUS

Cost-efficient and Nonpolluting

Hybrid rocket engines combine the advantages of solid and liquid propulsion systems. The lay-out as well as handling the fuel is simpler and thus less expensive than with liquid rocket engines. The propellant components are non-toxic; the engine is throttable and allows arbitrary reignition. The risk of an explosion is minimal because the fuel components are stored separately and in different aggregate states. The only deficit facing this list of advantages is the low burn rate and the correlating low thrust. Latest studies indicate that this shortcoming can be eliminated through a better understanding of the burning process and the application of new fuel combinations.

Numerical Engine Design

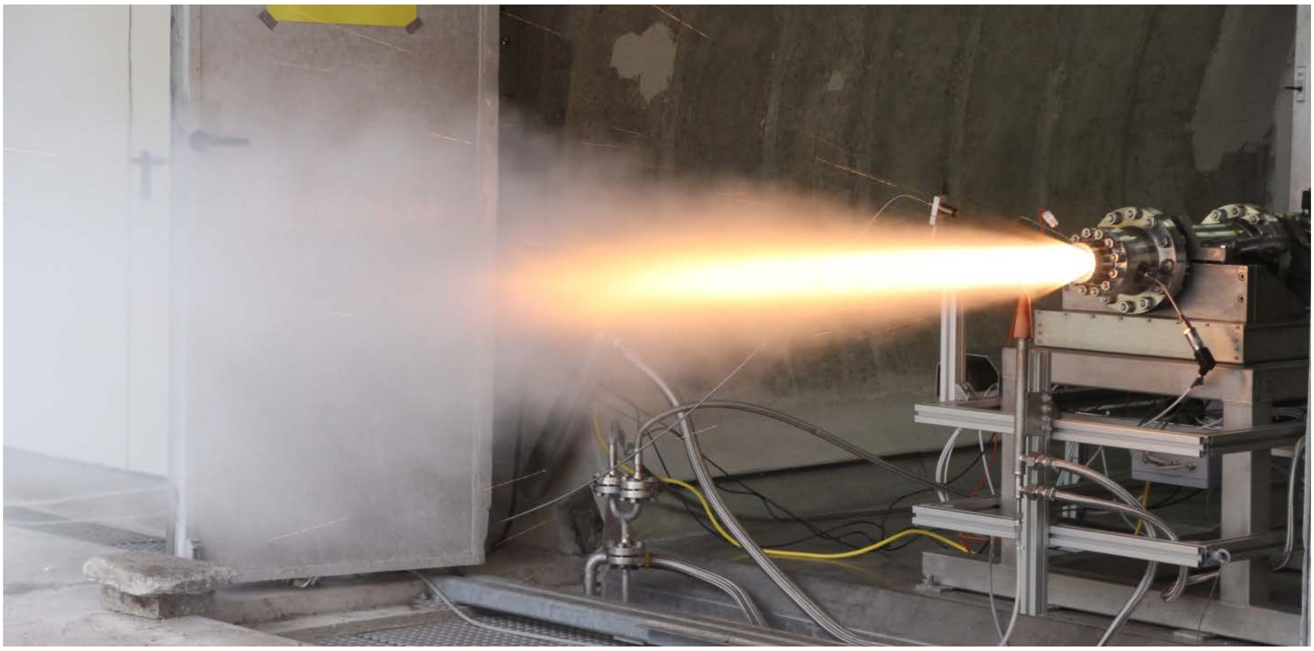
As part of the project AHRES design software for the layout of hybrid rocket engines with the project's name AHRES A was developed from early 2011 to late 2014. It includes the mathematical description of heterogeneous burning processes in a hybrid rocket engine burning chamber and their heat transfer through conduction, convection and radiation. Additionally, the burn-off of the solid fuel grain can be predicted which enables a characterization of the flow from the burning chamber inlet to the nozzle. Furthermore, a routine for process stability calculations is a fundamental part of **AHRES** software. It allows design and process engineering of individual components as well as of entire engines. Two different kinds of problems can be solved:

(a) The geometry and dimensions of rocket engine for a predetermined mission goal and specified fuel components as well as structure materials are calculated (direct mode).

(b) Detailed flow characteristics and burn processes including heat transfer are determined for a preset geometry, fuel combination and structure materials (indirect mode).

Experiments and CFD Simulations for Software Validation

Since early 2015 the modelling, testing and design software development is carried out in the project ATEK. The goal is to enhance the software package AHRES through validation of experiments and coupling of the existing parts with optimizer modules for geometry and burning chamber processes. Optimized configurations can then be inferred by the increased knowledge of the internal processes and enable the application as prototypes for space technology applications. To validate the outcome and to demonstrate the technological development CFD simulations as well as experiments with several engines are conducted.



Experimental firing of the AHRES hybrid rocket engine demonstrator at the test bench at DLR Trauen

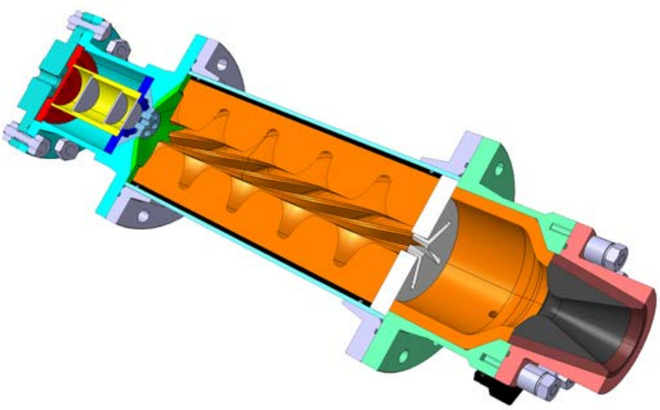
Test Bench at the DLR Facility in Trauen

To execute experiments a team of DLR scientists of the Institute of Aerodynamics and Flow Technology reset a test range that was not used for 30 years. It is equipped with state to the art measurement equipment. The purpose is to prove that the developed hybrid rocket engines using HTPB/aluminum with H_2O_2 (High Test Peroxide) as fuel operates more efficiently than current solid rocket engines. The facility is one of a kind in all Europe and complies with all security standards for future tests with hybrid rocket engines with up to 150 kN thrust. Current testing focusses on the variation of the fuel composition and the analysis of the respective burning process. The test results are used solely to enhance the computer simulations.

Manifold Applications

The goal of the research is to create software with the gathered data enabling both, the design a hybrid rocket engine within 100 days and to optimize existing concepts. The field of potential use of hybrid rocket engines is wide. To name a few, the usage as upper stage engine for small and medium sized rockets is possible. They are promising for research rockets or research aircraft to reach and fly altitudes between 40 to 180 km unachievable with conventional aircraft and satellites.

Due to their ability to throttle and to reignite hybrid rocket motors are attractive for planetary landers. Finally, the high operational safety motivated companies to use hybrids for space tourism.



Current status of the AHRES B hybrid rocket engine demonstrator.

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