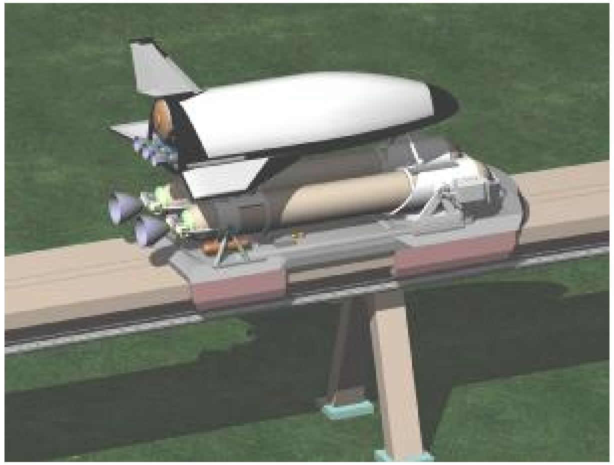
Take-off Assistance Systems Based on Hot Water Propulsion

Hot water propulsion is an attractive choice for applications that require high-thrust propulsion of short duration. It is therefore well suited for horizontal ground-based take-off assistance systems for future reusable launch vehicles. With hot water propulsion, such systems consist of a low friction sled combined with a hot water propulsion unit. In this way, it is off-board energy that is used to achieve the required vehicle acceleration and a separation velocity of up to 200 m/s.



Take-off assistance for future RLVs

This environmentally benign and cost-effective system also reduces the technology requirements on the launch vehicle (e.g. through lighter landing gear, lower fuel consumption, less and hence lighter structures) and allows for a considerable payload increase as the launch vehicle is less strained during its thrust-intensive take-off phase. Ground-based take-off assistance systems that use hot water propulsion are very interesting as alternatives to magnetic systems both during development and operation. Unlike magnetic systems, the power demand of hot water propulsion does not appear only during the acceleration phase of the vehicle, and thus it avoids a high energy demand over a very short period. Therefore hot water propulsion systems are economically attractive for reusable launch vehicles, given the current average launch rate.

Project Description

The AQUARIUS working group has been founded on the 6th of May 1991 on the initiative of students at the Institute of Aeronautics and Astronautics at Berlin University of Technology. It works mainly on the development, manufacturing and testing of hot water propulsion systems. Experience gained in numerous single stage rocket launches led to the development and launch of a two stage hot water rocket for the first time in world history. A dedicated hot water test facility has been built in order to perform firing tests for a deeper understanding of the propulsion efficiency and the influence of various nozzle parameters on exhaust characteristics. For more than five years, ground-based take-off assistance systems for future reusable launch vehicles have now been subject of intensive investigation. In addition, AQUARIUS projects are presented in the university lecture „Space Transportation Systems & Projects“.

Launch of the reusable hot water rocket B4-1

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AQUARIUS

Hot Water Propulsion Systems

Technology demonstrator AQUARIUS X-RATOS II HTV exhibited at the International Astronautical Congress 2003

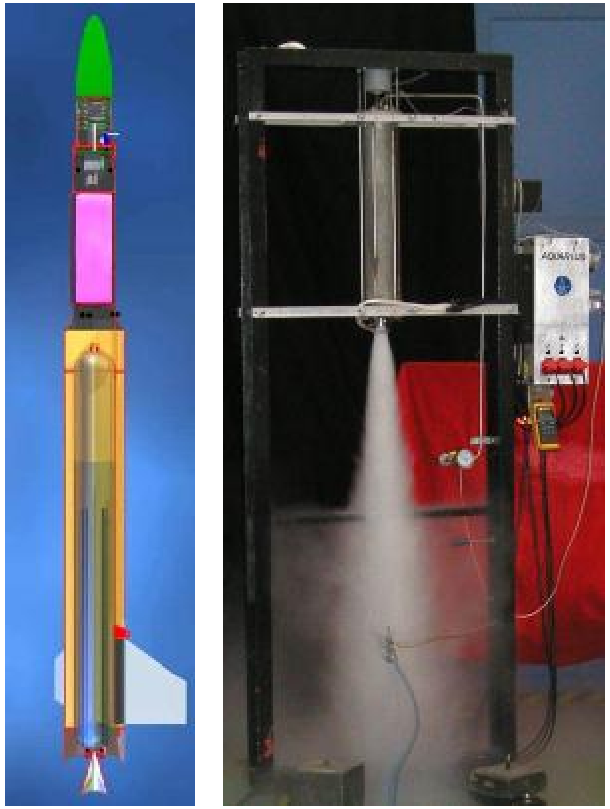
Department of Space Transportation
Institute of Aeronautics and Astronautics
Berlin University of Technology

Supported by:

AI: Aerospace Institute

Advantages of Hot Water Propulsion

Since water serves as the propellant, reusable "green" hot water propulsion produces low production and operational costs. It is environmentally benign and provides maximum safety contrary to conventional chemical rocket propellants. The energy required for water overheating is supplied at the launch site. As a consequence, the transport of the rocket motors filled with cold water is not hazardous at all. Despite the complexity of the thermodynamic processes inside a hot water rocket motor, the design effort remains relatively moderate. Hot water propulsion can be commercially applied in ground-based take-off assistance systems for future reusable space transportation and also in small satellite propulsion systems. Furthermore, it can be used in experimental or sounding rockets for research and educational purposes.



Single stage hot water rocket configuration (left) and test facility (right)

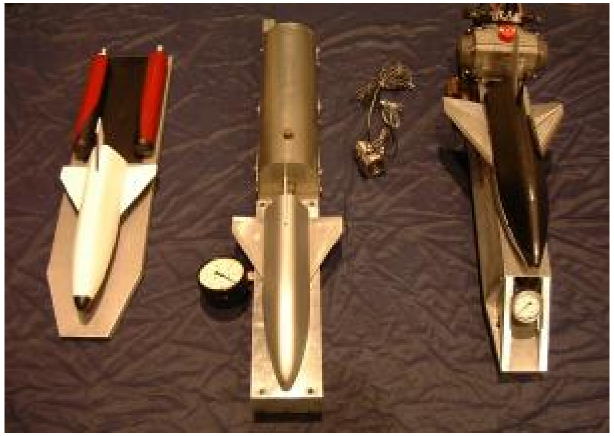
The Principle of Hot Water Propulsion

The energy required for the acceleration of the rocket is provided as thermal energy by electrical resistor heater elements. The water is heated in a hermetically sealed pressure tank until it reaches a vapour pressure of between 50 to 130 atm (735 to 1910 psi) with a corresponding temperature between 260°C (500° F) and 330°C (625° F). During application, right after the tank has been opened, the overheated water is discharged through the nozzle under partial vaporization and thus it accelerates the vehicle.

AQUARIUS X-RATOS

eXperimental Rocket-Assisted Take-Off System

Aiming at future reusable, horizontal take-off space transportation systems, the AQUARIUS working group has since 1998 developed and operated technology demonstrators for ground-based horizontal take-off assistance systems with hot water propulsion.



X-RATOS evolution (1998-2004)

The AQUARIUS X-RATOS vehicle has been gradually improved since the first prototype was completed. AQUARIUS X-RATOS II, which is carried by a pair of low friction bronze skids, is operated on a monorail test track with a length of 25 m and reaches a max. velocity of 100 km/h (62 mph). In addition, the third generation vehicle is equipped with an electro-pneumatic valve assembly in order to open and close the nozzle in a fast and safe way.

AQUARIUS X-RATOS II HTV

Health monitoring Telemetry/telecommand Video data processing system

As an enhancement of the X-RATOS vehicle, a real-time health monitoring telemetry/telecommand video data processing system was developed. Its main focus lies on the characteristics of motion of X-RATOS II, which is analysed by means of redundant acquisition and evaluation of the main vehicle parameters. Tank pressure, tank temperature, velocity and acceleration profiles of the vehicle are measured in real-time while additional video data are recorded and transmitted. The results serve as base for further performance optimisation of the X-RATOS II vehicle.

HTV vehicle with real time data processing and TTC system for AQUARIUS X-RATOS II

During the check-out procedure in the pre-launch phase, after further processing all sensor data received are indicated on a LCD, which is mounted in the HTV case. Throughout the take-off assistance system's operation, sensor and video data are transmitted via radio communication to the tracking station, where they serve health-monitoring in real-time. The HTV system is integrated in an adapted CFRP/Aluminum case with the 1:100 scaled shape of the future reusable horizontal take-off and landing launch vehicle HOPPER, that is currently under investigation by the European space community.