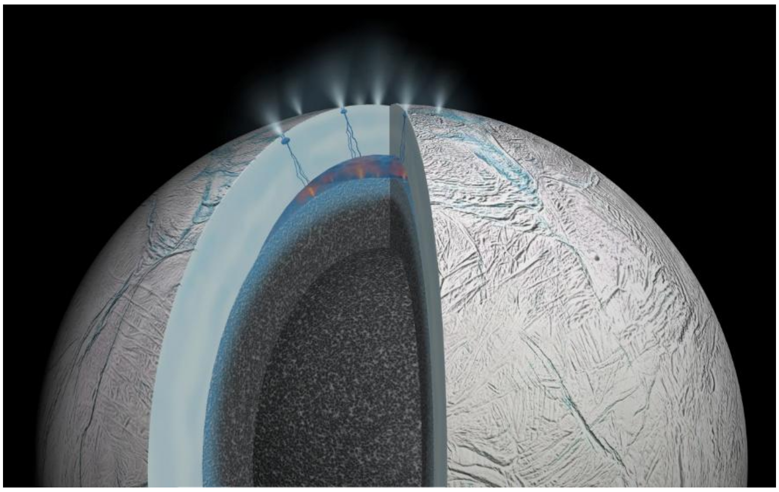
Chair of Space Propulsion and Mobility (Prof. Manfletti)
TUM School of Engineering and Design
Technische Universität München

Master Thesis

Enceladus Plume-Diving Probe

The chair of space mobility and propulsion is seeking **three** highly motivated and talented Master's students to contribute to a critical trade-off analysis for a highly versatile plume-diving probe for the Saturn Moon Enceladus. This interdisciplinary project will assess the feasibility of using a Water-Electrolysis Propulsion (WEP) system to navigate and sample the plumes of Enceladus. Each thesis will run in parallel and contribute a crucial part to the overall mission concept and design.

Background



Illustrated Enceladus with plumes on the pole. Copyright: NASA/JPL-Caltech

The exploration of the solar system is entering a new era, with a strong focus on finding habitable environments and searching for signs of life. The plumes erupting from the south pole of Saturn's moon Enceladus represent one of the most promising targets in this quest. These jets of water vapor and icy particles, containing organic molecules, provide a unique opportunity to sample a subsurface ocean without the need for a complex and expensive lander. A dedicated "plume-diving" probe capable of repeatedly flying through these jets would be a groundbreaking step in planetary science.

To achieve this, the probe requires a highly agile and responsive propulsion system. One of the most promising technologies in the ongoing search for high-performance green propellants is the Water Electrolysis Propulsion technology (WEP). The fundamental concept of such a system is to fill the spacecraft on the ground with pure water instead of highly toxic propellants. Once the spacecraft is in orbit, an electrolyser is used to split the water into gaseous hydrogen and oxygen. The gases can then be used in a chemical or electrical thruster to propel the spacecraft.

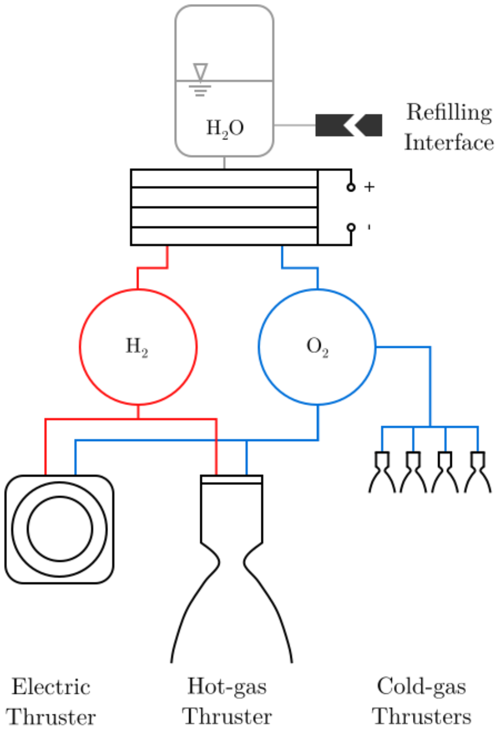
This project will perform a crucial trade-off analysis to determine if WEP is a viable and advantageous propulsion method for such a mission. The work is designed to be undertaken by three master's students, each focusing on a specific, interconnected aspect of the mission design. Collaboration and data exchange between the thesis students will be essential for the success of the overall project.

Thesis 1 of 3: Propulsion & Power Analysis

This thesis will focus on the **technical feasibility and performance of the WEP system**. The core task is to model the propulsion and power aspects of the probe and compare them with conventional propulsion options.

Tasks:

- Familiarization with the WEP and electrolyser technology
- Developing simple performance models for WEP and competing propulsion systems (e.g., steam/resistojet, green monopropellant). This includes modeling key parameters like specific impulse (Isp), thrust, and minimum impulse bit.
- Conducting a deep dive into WEP-specific challenges, such as electrolyzer efficiency, gas storage, and ignition constraints.
- Performing an end-to-end electrical energy analysis, calculating the power required for electrolysis and determining recharge times based on a 120 W RPS power baseline.



Water Electric Propulsion System Schematic

- Developing a preliminary thermal model to address heating needs for water and propellant lines and rough radiator sizing.
- **Output:** Parametric tables of Δv vs. propellant mass, thrust profiles, and a comprehensive power/thermal budget. Documentation and presentation of the work.

Contact
Fabian Riegelsberger, M.Sc.
E-Mail: fabian.riegelsberger@tum.de

Chair of Space Propulsion and Mobility (Prof. Manfletti)
TUM School of Engineering and Design
Technische Universität München

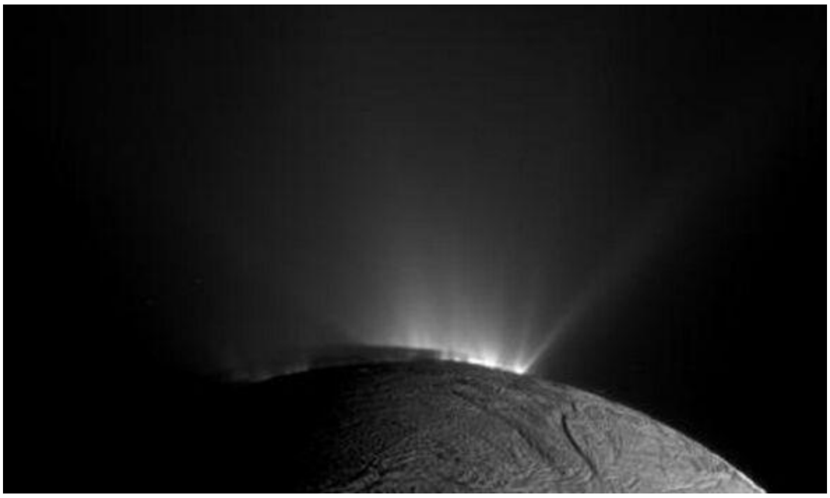
Thesis 2 of 3: Environmental Boundaries & Plume Interaction

This thesis will establish the environmental parameters and constraints for the mission, translating planetary science data into engineering requirements. You will be the primary source of environmental data for the other two theses.

Tasks:

- Analyzing representative data from the ESA Cassini mission to define the plume environment, including density ranges, jet geometry, dust flux, and temperature background (~75-85 K).

- Creating a simplified model to define upper and lower bounds for key disturbances like aerodynamic drag and particulate hazards.



A plume from Enceladus, as seen by Cassini in 2010 Copyright: NASA / JPL-Caltech / Space Science Institute

- Generating data packages and envelope plots (e.g., min/max/nominal values) that will directly inform the GNC and propulsion analyses in the other theses.

- Contribution: Your work will be a critical bridge between scientific data and engineering design, rigorously translating planetary science into tangible boundary conditions for flight.

- **Output:** A detailed boundary condition sheet with tables and plots of the plume environment and thermal background. Documentation and presentation of the work.

Contact
Fabian Riegelsberger, M.Sc.
E-Mail: fabian.riegelsberger@tum.de

Chair of Space Propulsion and Mobility (Prof. Manfletti)
TUM School of Engineering and Design
Technische Universität München

Thesis 3 of 3: GNC & Manoeuvre Effectiveness

This thesis will focus on the Guidance, Navigation, and Control (GNC) aspects of the mission, assessing how effectively the probe can perform its mission-critical maneuvers.

Illustration of probe pass-through the geysers at the south pole of Enceladus to study their composition Copyright: NASA

Tasks:

- Defining the thrust-to-mass ratio and minimum impulse bit required for precise plume-pass guidance and emergency abort maneuvers.
- Utilizing the environmental disturbance data from Thesis 2/3 to conduct envelope simulations and assess the control system's performance under various conditions.
- Comparing the maneuver success margins and agility of a WEP-propelled probe against those of conventional systems.
- **Output:** Success envelopes, a control requirement sheet, and a comparative assessment of the agility and robustness of each propulsion option. Documentation and presentation of the work.

Contact

Fabian Riegelsberger, M.Sc.
E-Mail: fabian.riegelsberger@tum.de