Propulsion System for CubeSat Formation Flight

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The University of the Federal Armed Forces (UniBwM) is currently working on an innovative propulsion system for CubeSats based on the so called Vacuum Arc Thruster (VAT). The key features are small size and mass budgets, low energy demand and the use of a solid propellant. UWE-4 of Julius-Maximilians-University Würzburg should be equipped with the VAT to give a first demonstration of its fine positioning capabilities. There are several restrictions for the propulsion system: The mass is limited to 200 g, the power consumption to lower than 2 W and there is very little space aboard UWE-4. The mission goal of the propulsion system is to track another CubeSat deployed by the same launch vehicle in LEO and to maintain a stable constellation arrangement.

According to the mission study performed prior to the project the VAT was selected as the most suitable propulsion system for this task. Since no liquid or gaseous propellants are used there is no risk of leakage or frozen valves. In contrast to the very similar pulsed plasma thruster (PPT) no high voltages are needed. The VAT consists of two electrodes which are electrically separated by a thin insulator. To produce thrust a voltage is applied between anode and cathode. This leads to the formation of a plasma plume from the eroded cathode material which is then ejected in space therefore generating thrust in the range of some µN. By the application of the so called “triggerless” ignition very low brakedown voltages in the range of some hundred volts can be achieved. Thrust and specific Impulse are determined to a large degree by the cathode material used. Ongoing research focuses on the reliability and endurance of the thruster heads together with the improvement of the ignition process and the optimization of the thrust vector. A new feeding mechanism as well as an innovative liquid metal propellant VAT are currently in development.

Since the satellites power budget is strictly limited it is also important to develop a suitable power supply. A maximum of 2 W at an average bus voltage of 4 V is provided by the satellites power system. Together with Apcon AeroSpace and Defense the design of an innovative Power Processing Unit (PPU) is currently in progress. The core of the current approach is an inductive energy storage. It transforms the dc bus voltage in short pulses (some 100 µs). Each pulse starts with a short peak of several hundred volts for some 100 ns. After ignition the voltages drops to around 30 V for the rest of the discharge duration. Together with control and interface elements the whole PPU has to fit on a single standardized printed circuit board in agreement with CubeSat specifications. In addition several diagnostic measures are implemented to allow in-situ analysis of the whole propulsion system. Following first integration tests the PPU is currently under optimization.
NanoFEEP – Highly Miniaturized FEEP Thrusters for Attitude and Orbit Control of Pico-satellites

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Wuerzburg University, Zentrum für Telematik and TU Dresden are planning a cooperation mission to demonstrate formation flying of 1U CubeSats using an electric propulsion system to achieve two axis attitude and orbit control.

To realize a CubeSat formation flight with 1U CubeSats, a highly power efficient, light-weight and space-saving propulsion system is mandatory. In order to satisfy these requirements, TU Dresden is currently developing a highly miniaturized field emission electric propulsion system, called NanoFEEP. These miniaturized field emission thrusters (volume less than 3cm³, weight <6g) are capable of generating continuous thrusts from sub-μN up to 8 μN with peaks up to 22 μN each. Using Gallium as propellant with its low melting temperature of 30 °C in combination with power efficient electronics, a very low power consumption of the whole propulsion system can be achieved. It is planned to place four NanoFEEP thrusters on one side of the UWE (University Wuerzburg Experimental) CubeSat platform to realize two axis attitude and orbit control.

We will present the latest developments of the thrusters, a possible integration into the UWE CubeSat platform and the results of an orbit lowering maneuver simulation to show feasibility and to estimate the performance capabilities of an attitude and orbit control system using miniaturized FEEP thrusters.
The MICROLAS concept: Precise thrust generation in the \( \mu \text{N} \) range by laser ablation

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Microthrusters with high specific impulse promise a very effective solution to achieve precise altitude and attitude control not only for larger scientific satellites but also, due to their low total mass, in particular for pico- and nano-satellite-systems.

Experimental work and hydrodynamic simulations on the MICROLAS concept of a pulsed laser-ablative microthruster are presented. Impulse bit generation in the nNs range is affected by laser parameters like wavelength, pulse duration, beam incidence angle and polarization as well as the optical and thermal properties of the chosen propellant material. A parameter study for the optimum working point is carried out yielding two different operation modes with respect to laser pulse duration. Thrust in \( \mu \text{N} \) range is generated by repetitive laser ablation events under fixed and well-defined process parameters allowing for thrust level control by the laser pulse repetition rate through several orders of magnitude. Thrust noise, e.g., by mechanical motion for continuous propellant supply, can be minimized since the laser beam can access every part of the propellant surface without any mechanical motion. Electro-optical beam-steering constitutes a promising technology for an inertia-free setup enabling high precision thrust generation.