UWE-4: In-orbit experience of the first 1U CubeSat employing the electric propulsion system NanoFEEP

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Gefördert durch:

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für Wirtschaft
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aufgrund eines Beschlusses
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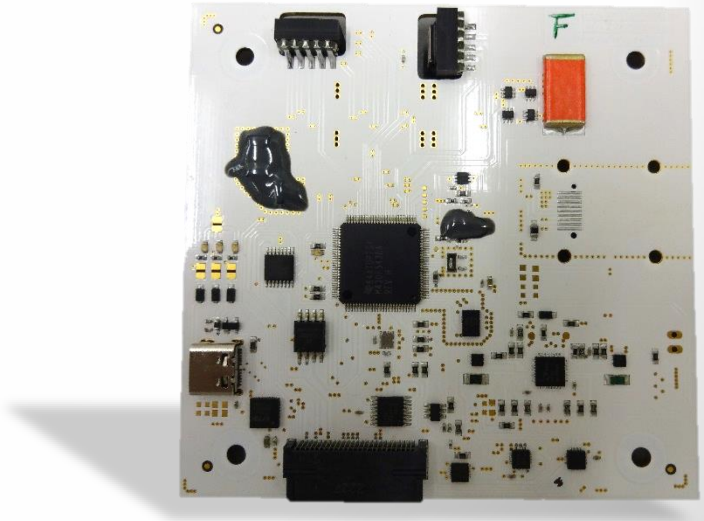
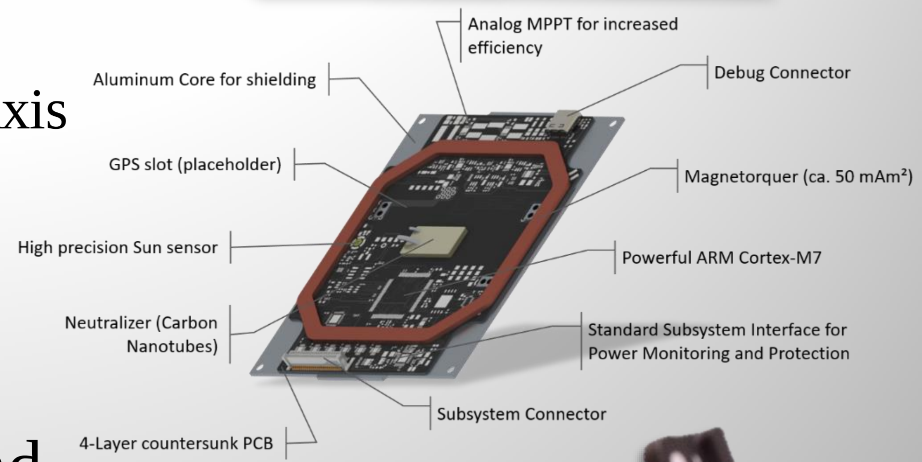
LEOP & Commissioning

- Launch in Vostochny, Russia, December 27th 2018
- ~2h: First signal received in Russia
- ~6h: Two-way communication in Wuerzburg
- 30th January: First detumbling experiment
- 31st January: Calibration of magnetometers
- Afterwards: Thruster experiments

Attitude and Orbit Control System

- Sensors:
  - Low power 9-axis IMUs
  - High precision sun-sensors on panels
- Actuators:
  - Magnetorquers on each panel
    - Magnetic moment: 0.1 Am² per axis
  - NanoFEEP thrusters in each facing the same direction
    - Thrust: Up to 20 µN per thruster head
  - Hybrid control with torquers and thrusters envisioned





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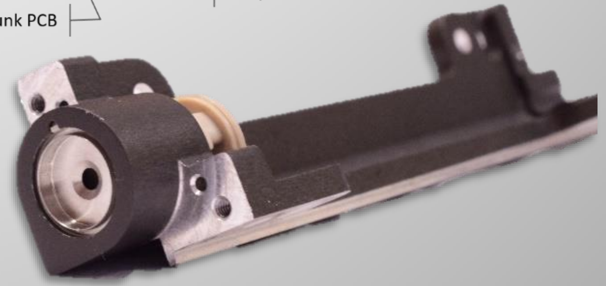
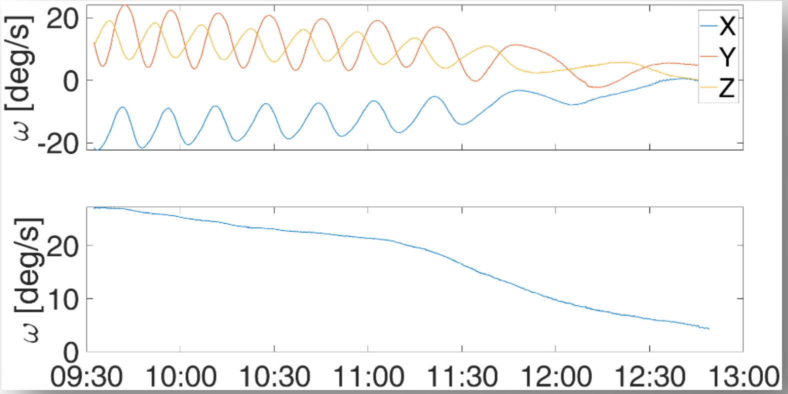
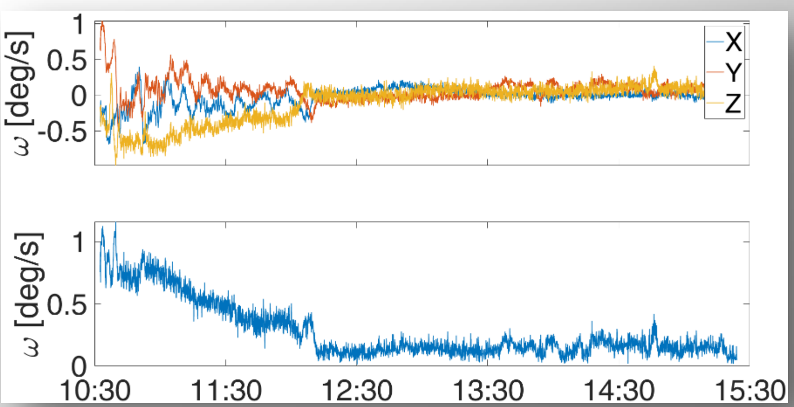


Detumbling using pure magnetic control

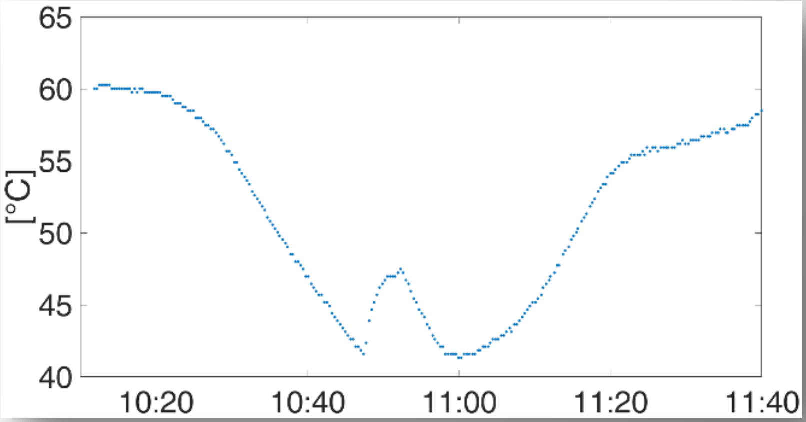
- B-Dot controller activated on 30th January for 3h
- Satellite rotation rate went down from 27deg/s to less than 5deg/s
- Gain **k** in control law $\dot{\omega} = -k\omega$ was increased from 0.05 to 0.15 after 1.5h
- Activated again on 12th February
- At low rotation rates also performes a decline from 1deg/s to < 0.3deg/s within 100min

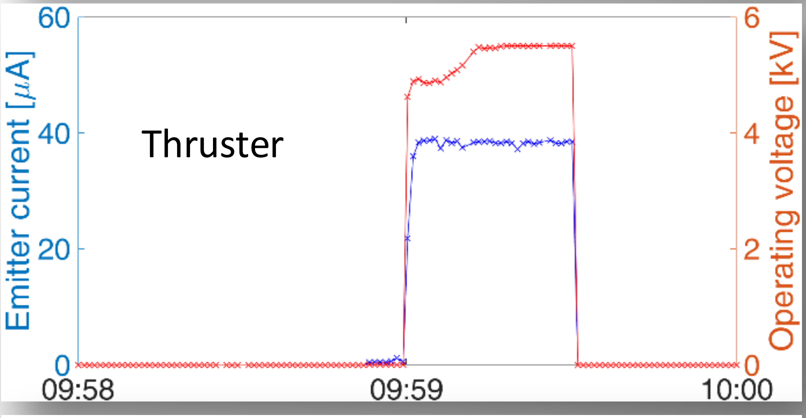


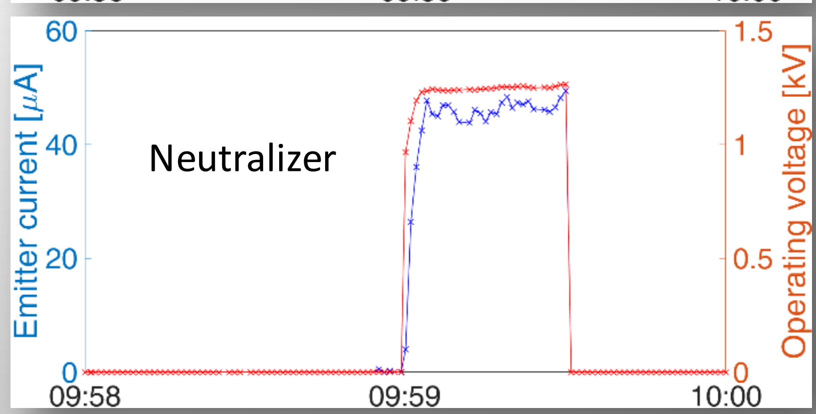


NanoFEEP activation

- Gallium propellant has to be liquefied prior to thruster activation
- Solidification of propellant during eclipse
  → exothermal reaction
  → alteration in heater PI controller & heating for long duration prevented solidification
- Thruster activated @ 40µA emitter current (~ 3.6µN thrust)
  → charge loss balanced by neutralizer instantaneously







Thrust estimation

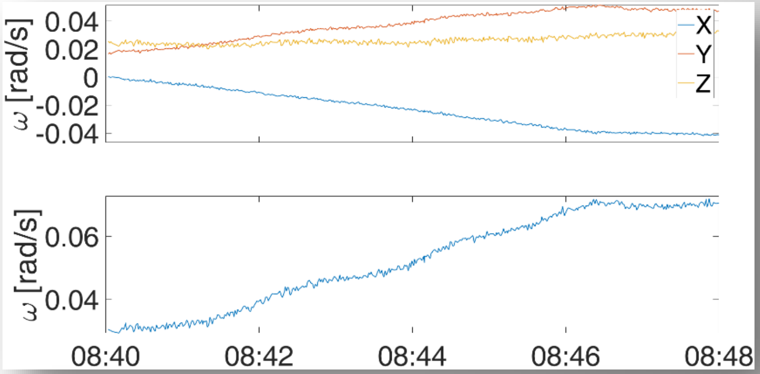
- Satellite detumbled to rotation rate < 0.04 rad/s
- Thruster activated @ 80µA emitter current for ~ 6min
- Thrust can be derived using Euler equation

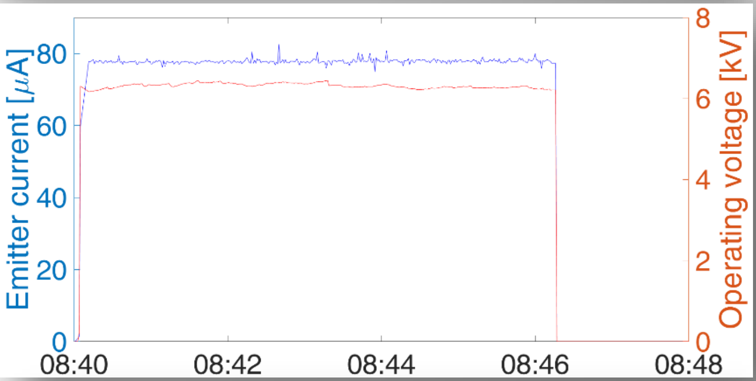
$$M_{ext} = I\dot{\omega} + \omega \times I\omega - \mu_{res} \times B_{Earth}$$

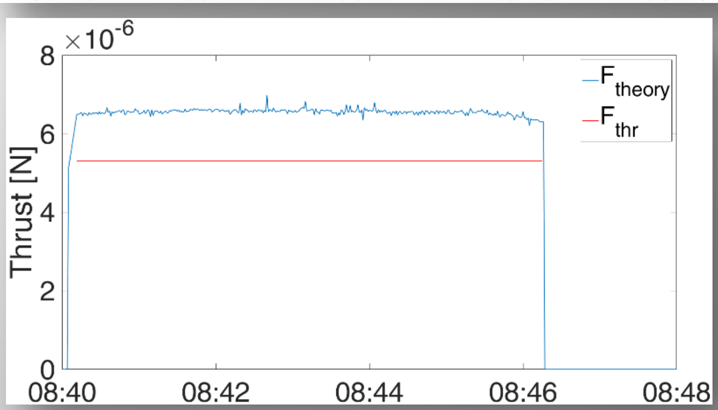
and minimizing

$$E = abs(M_{ext} - r_{Thr} \times F_{Thr})$$

- This leads to an estimated thrust of F = -[0.84, 0.01, 5.23] µN
- Simulations prior to launch have shown that activation for ~ 10min minimizes the error in thrust estimation
→ Future experiments







Thank you for your attention!

Lessons learned

- Check the frequency allocation within the radio amateur band before application **using interference studies**
  - Using jammed frequencies not only takes time for any communication task like e.g. software updates, but also for frequency coordination
- A novel sensor suite consisting several sensors covering only a certain part of the whole value range has to be calibrated and validated **well in time**
  - Calibrating a single sensor is not enough, because the underlying model may only be valid for a single sensor