UWE-4: Integration State of the First Electrically Propelled 1U CubeSat

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2018 NetSat-1 to NetSat-4
Formation Flying Mission
- Distributed Computing Capabilities
- Formation Control
- DTNs, MANets

2018 UWE-4
- Orbit Control

2013 UWE-3
- Attitude Control

2009 UWE-2
- Attitude- and Orbit Determination

2005 UWE-1
- Telecommunication “Internet in Space”
Mission Objectives

• Technical objectives
  – Demonstration of electric propulsion on 1U CubeSat
  – Characterization of the electric propulsion system NanoFEEP
  – Attitude and Orbit control preparations for formation control

• Educational program
  – Hands-on interdisciplinary training of students
Satellite Architecture

- Backplane architecture according to UNISEC Europe Standard
- Subsystems:
  - UHF Communication
  - On-Board Computer
  - AOCS
  - Electrical Power System
  - Power Processing Units
  - Front Access Board
- Multifunctional Side Panels
- NanoFEEP Thruster heads integrated into CubeSat bars
On-Board Computer

• Based on heritage from UWE-3
• Redundant set of low power micro-controllers
  – <15 mW
  – Full JTAG interconnection for repair and restore
  –Latchup-protection and backup power conditioning
• Full debug access to all subsytems
  – JTAG, SBW, SWD
• Improved memory storage (optional)
  – 2x 20Mbit FRAM
  – 2x 4Gbit NAND Flash memory
  – 2x microSD card slots
Attitude and Orbit Control System

- Standard interface
  - Latchup-protection
  - Power monitoring
  - Debug interface: Spy-Bi-Wire
- Isotropic Kalman Filter for attitude determination
  - Gyroscope bias determination
  - Residual magnetic moment estimation
- Low power 9-axis IMUs
  - Primary on AOCS, secondary on panels
- High precision sun-sensors on panels
  - Estimation accuracy approx. 0.1 deg
- Magnetorquers on each panel
  - Magnetic moment: 0.1 Am² per axis
- Hybrid control with torquers and thrusters
Sun-Sensors

• Miniature CMOS camera
  – FOV 130 degree
  – 4.2 mW nominal power
  – Footprint 1.0 x 1.0 x 1.7 mm
  – Accuracy better than 0.1 deg (0.01 deg feasible)

• Embedded on outside panels of CubeSat

• Calibration/identification of lens model ongoing
Electric Propulsion System: NanoFEEP

Development by TU Dresden, each thruster head:

- **Propellent:** 0.25g Gallium
- **ISP:** 1000 – 8000 sec
- **Total Impuls:** ca. 15 Ns
- **Thrust:** 0 – 22 µN
  - **Nominal:** 2 – 3 µN
- **Standby Power:** 50 – 90 mW (for heating)
- **Current:** 0 – 250 µA
- **Voltage:** 3 – 12 kV
- **Δv:** up to $60 \text{ m/s}$ (4 thrusters)
Thruster Heads Integration

• Integration into CubeSat rails
  – Enables attitude control with thrusters (thrust vector pointing)
  – Saves valuable space inside and on the faces of the CubeSat
  – High voltage cables connect PPU and thruster heads

• Each PPU connects to two Thruster heads and one Neutralizer
Thrust Estimation and Attitude Control

- Very low thrust levels of 0.1 – 20 µN make it difficult to detect orbit changes (only long term)
- Procedure based on residual magnetic dipole estimation of UWE-3
- Measure the torque created by thrusters
  \[ M_{th} = r \times F = I\dot{\omega} + \omega \times (I\omega) - \mu \times B \]
- Global optimization algorithm searches for \( F \) and \( \mu \)

- Attitude control for thrust vector pointing
Current Integration State

- AOCS, EPS, OBC prototypes produced and currently being tested
- NanoFEEP
  - assembly completed, fitting test successful
  - testing ongoing, long term tests pending
  - PPU produced and under test
- Launch 2018
- Visit us at booth 167!
Thank you for your attention!