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

Small Satellite Conference 2017

Philip Bangert
A. Kramer, K. Schilling
University Würzburg
University Würzburg Experimental Satellites | NetSat

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 microcontrollers
  - <15 mW
  - Full JTAG interconnection for repair and restore
  - Latchup-protection and backup power conditioning
- Full debug access to all subsystems
  - 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:

- **Propellant:** 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!