Verification of Miniaturized Reaction Wheels for Pico and Nano Satellites

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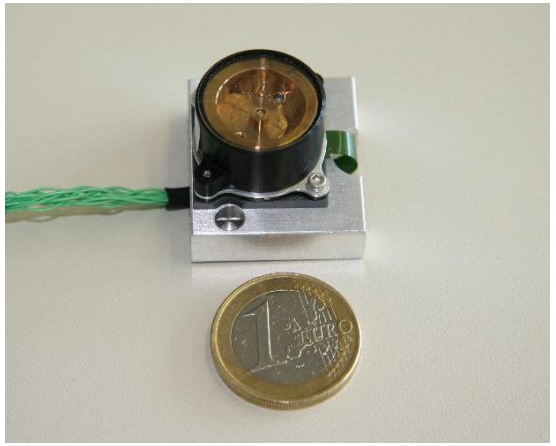
Background

- Launch of 7 CUBESAT's on 17th April 2007 by DNEPR, including 3 companies: Boeing, Aerospace Corporation, Tethers Unlimited
- Most CUBESAT's have no proper attitude control system yet, which is required for many applications such as earth observation or exploration
- Main reason: lack of suitable sensors and actuators (size, mass, power, performance)
- Miniaturization is essential for future constellations and formations of pico and nano satellites

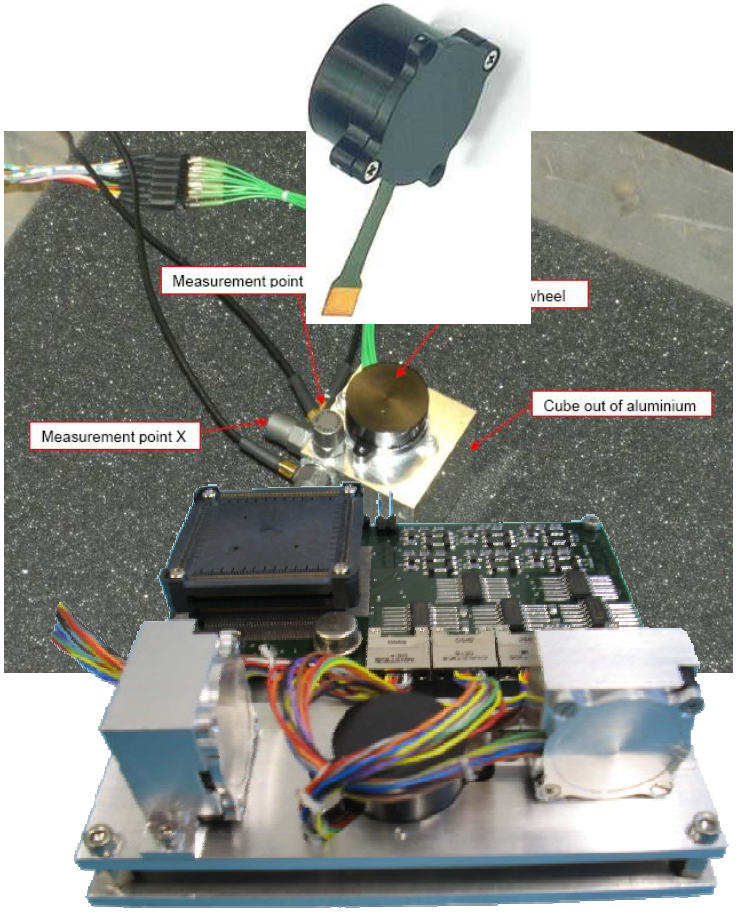


Engineering model
of a micro wheel

Stone wheel
(Source: Foto search Lizenzfreie Fotografie Bildagentur)

Micro Wheels

- TU Berlin developed new micro wheels for pico satellite applications
- First of a series of miniaturization efforts (S-Band transmitter for pico satellites being currently the second one)
- Funded by DLR (FKZ 50JR0552)
- In cooperation with industry and research organizations
- Main parameters of a single wheel:
  - Torque 4 x 10^{-5} Nm
  - Angular Momentum 3.4 x 10^{-5} Nms
  - Moment of inertia 117 gmm²
  - Size (max.) 20x20x15 mm^3
  - Mass 9.2 g



Overall Wheel System Characteristics

- Mass 115 g
- Power 0.3 – 1 W
- Interface CAN 2.0B
- Rotation rate 16000 rpm max.

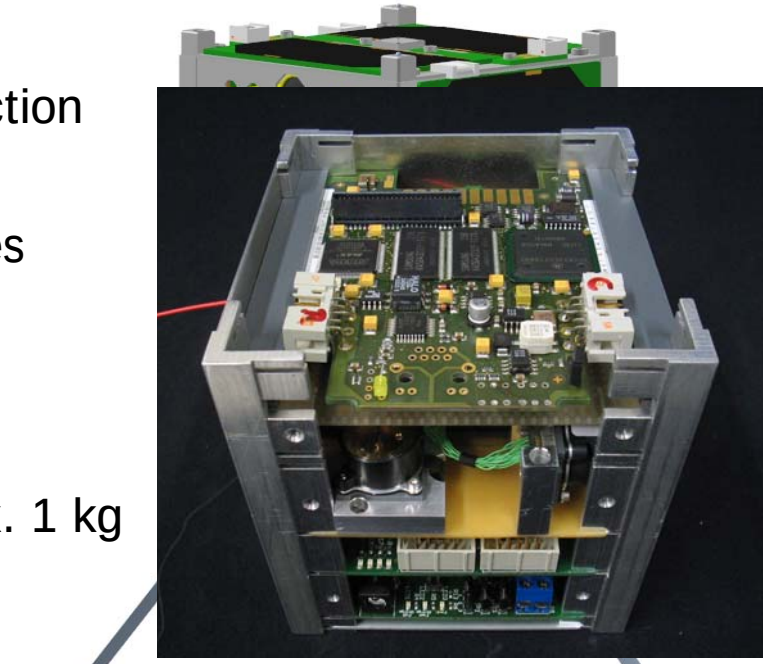
Engineering model of the micro wheel system in vacuum chamber at TU Berlin

BeeSat
(Berlin Experimental and Educational Satellite)

Mission Objectives:

- On-orbit-verification of newly developed reaction wheels for pico satellites
- Verification of other pico satellite technologies
- Education of students

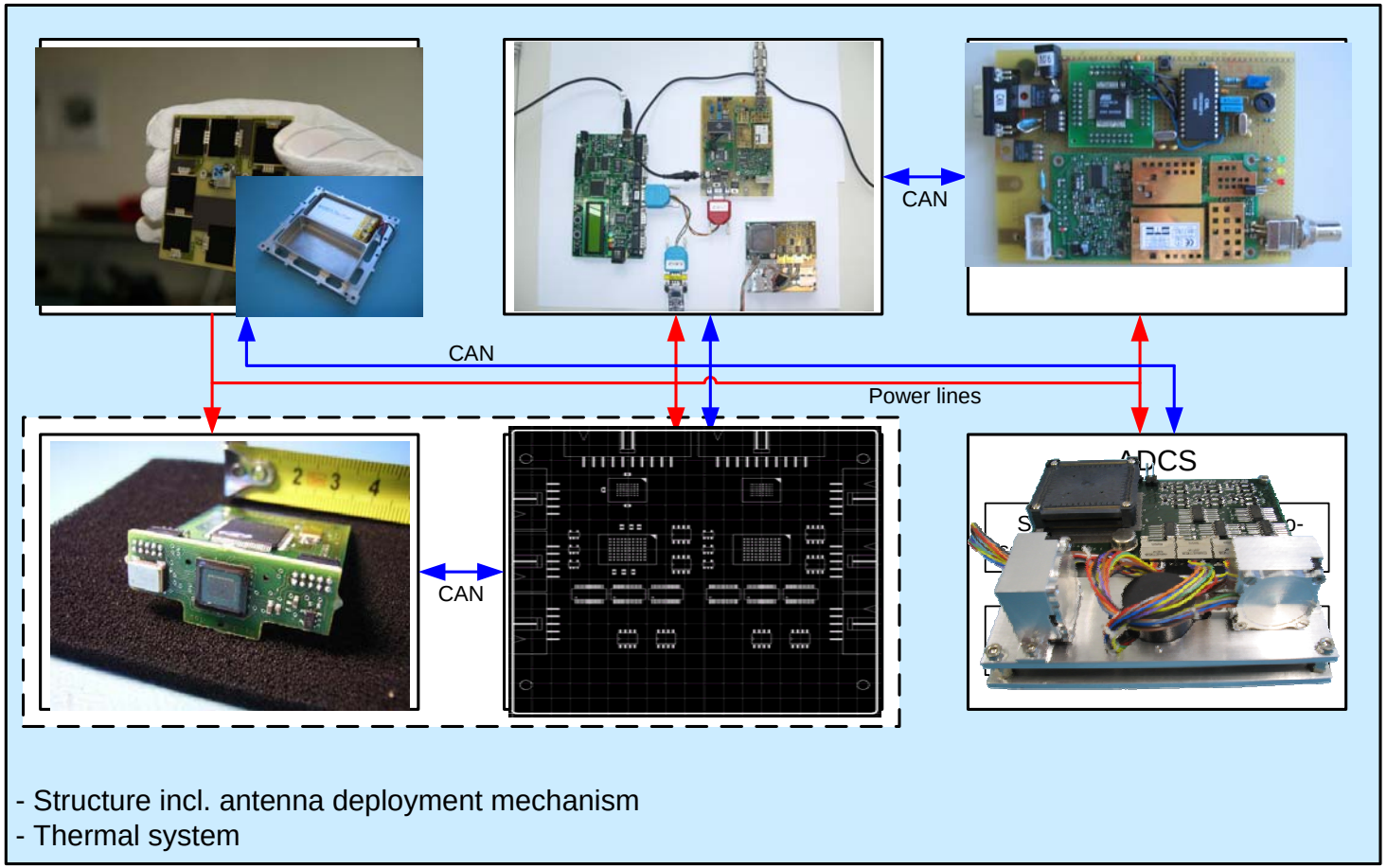
Orbit:	LEO 500–850 km
Dimensions:	10 x 10 x 11.35 cm³, max. 1 kg
Radio frequency:	UHF
Attitude control:	3-axis stabilized
Operation:	TU Berlin
Lifetime:	1 Year
Launch:	2008



Early engineering model of BeeSat

Mission Scenario

Functional Block Diagram



- Structure incl. antenna deployment mechanism
- Thermal system

BeeSat On Board Computer

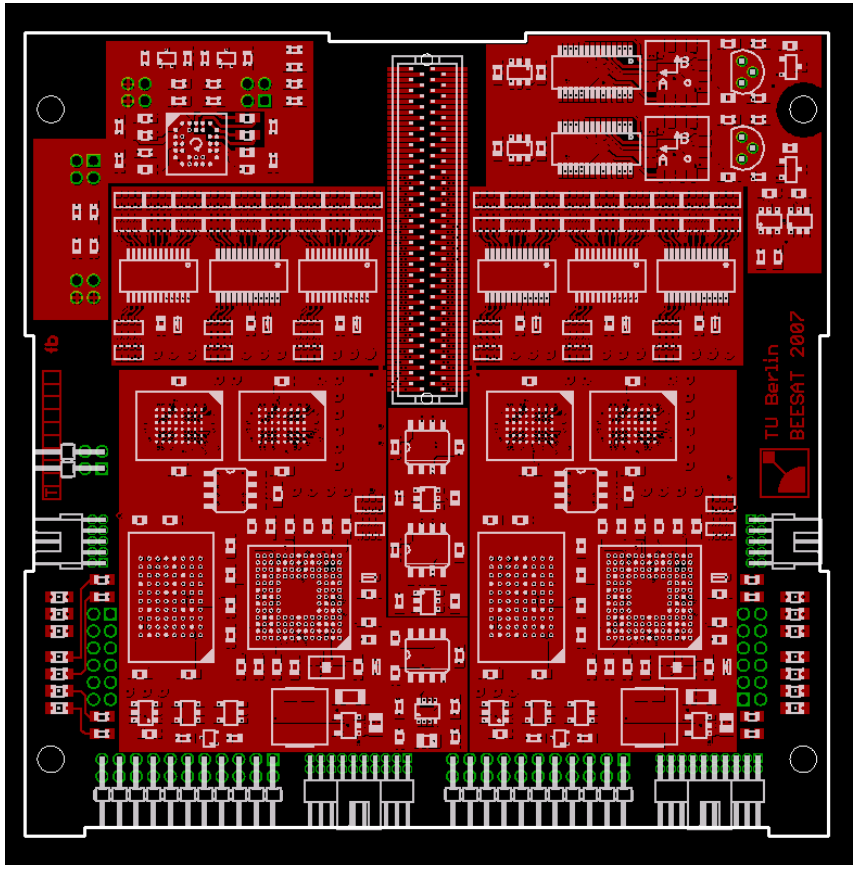
Two cold redundant systems on a single PCB (10 layers, 94 x 94 mm²)

Each board computer has:

- 60 MHz clock rate
- 2 MByte RAM
- 4 MByte flash (Telemetry)
- 16 MByte flash (program)
- 36 Analog channels
- Terminal Node Controller (TNC)
- Redundant CAN 2.0B interface
- TinyBOSS operating system

Additionally integrated:

Watchdog, 2 magnetometers, 3 gyros, temperature sensors



Attitude Determination and Control Subsystem

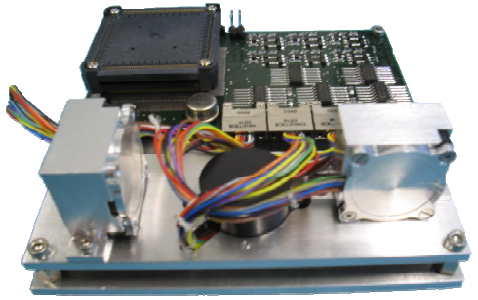
Sensors

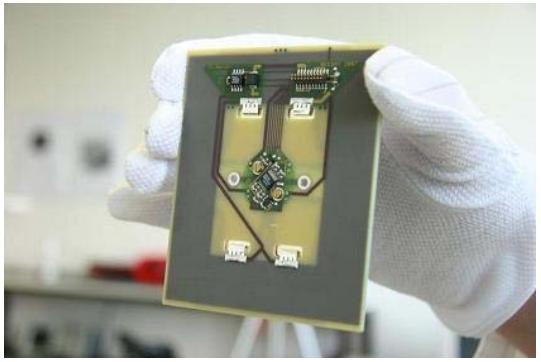
REXUS III, 5. Apr. 06, Kiruna

Software

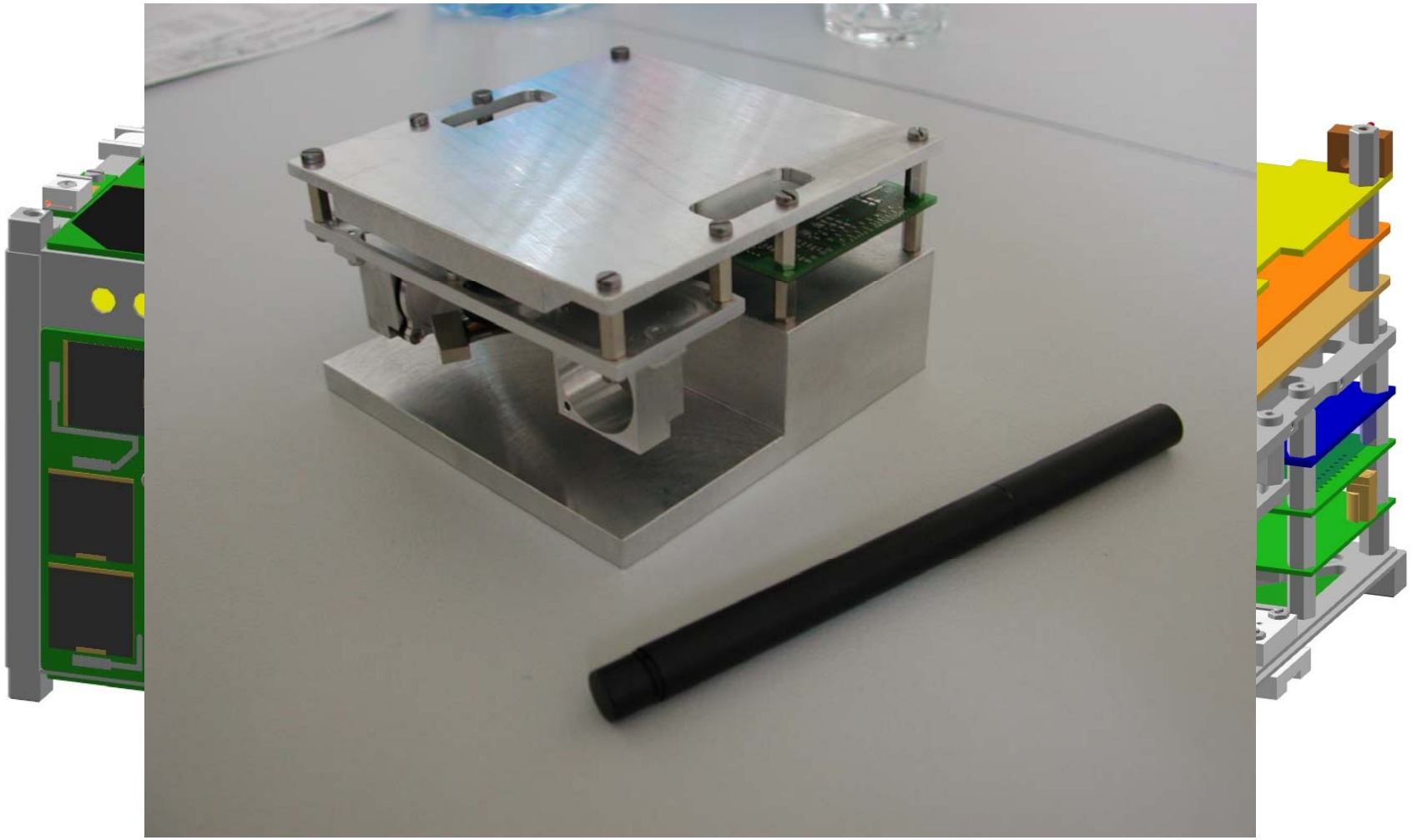
- Command interface
- Attitude determination
  - Orbit propagator
  - Magnetic field model
  - Sensor data interpretation
  - Configuration and calibration
  - Coordinate transformations
- Magnetic coil control
- Wheel control
- Telemetry data generation
- In orbit software update

Actuators



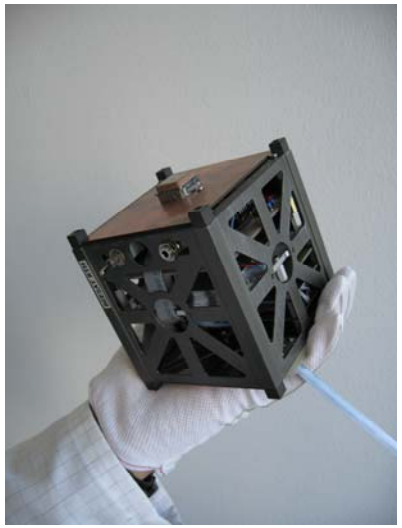


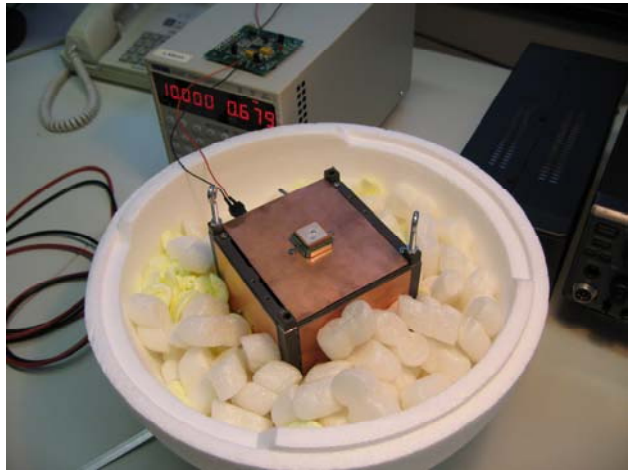
Configuration



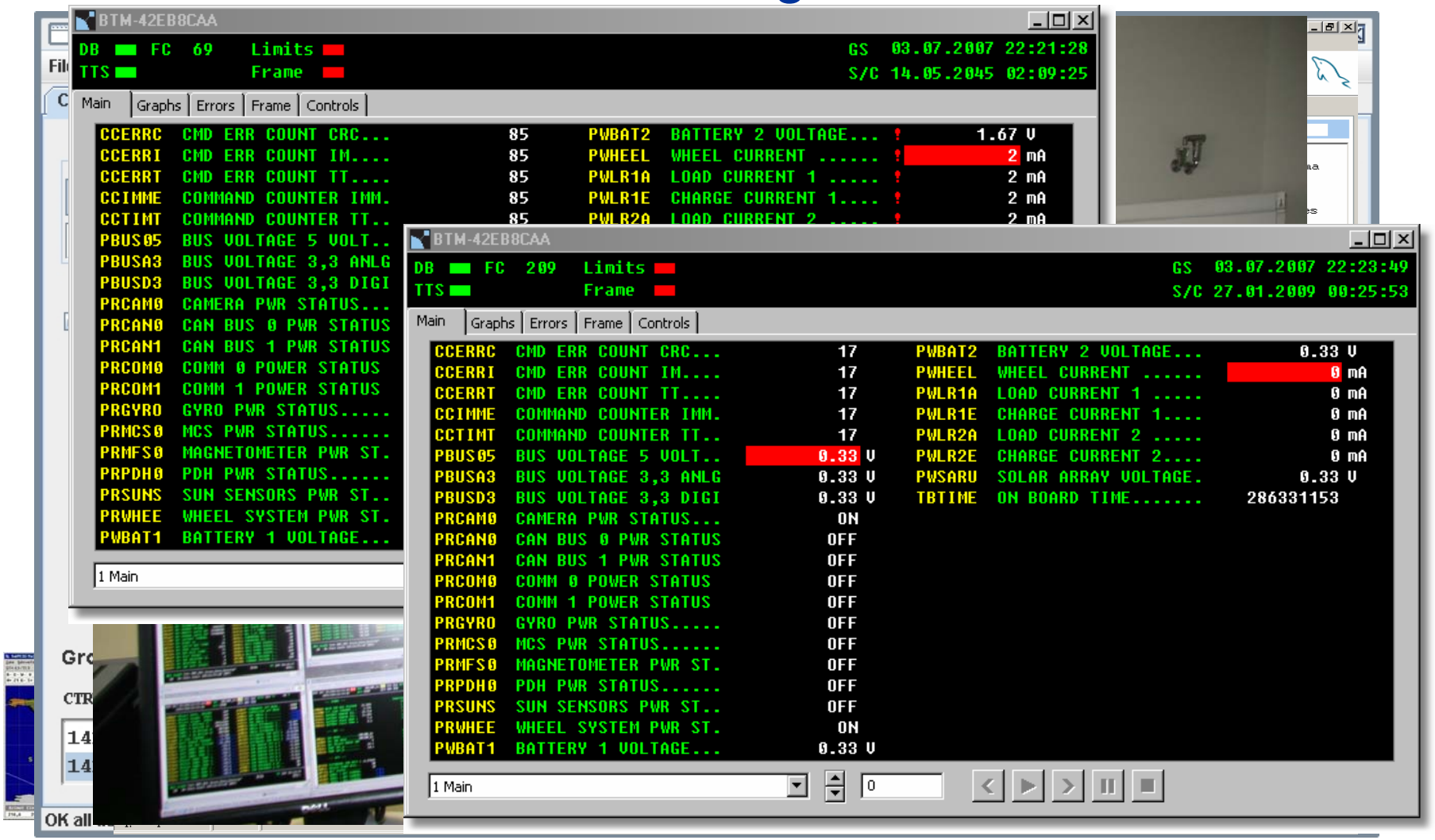
Communications Test

- The Radio Link Test Model of BeeSat has been flown in September on a weather balloon of the German Weather Service (DWD)
- Reached an altitude of 34.8 km in 47 min.
- More then 2800 data sets has been received by two ground stations

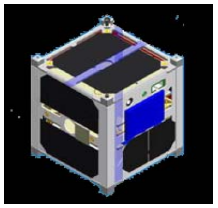


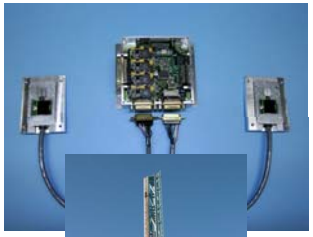


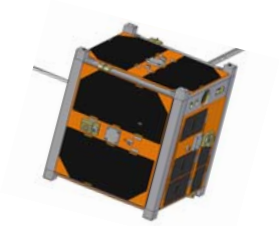
Ground Segment



Roadmap for Pico and Nano Satellites

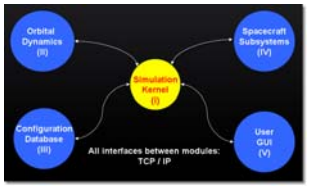






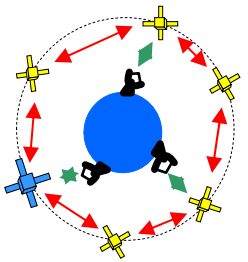
Components

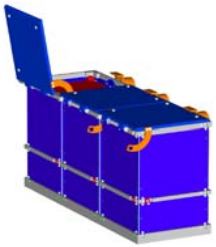
- Wheel √
- Transmitter √
- Star Camera
- Gyro
- GPS
- Instrumentation
- …



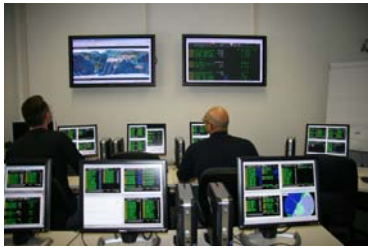
Applications

- Technology Verification
- Earth Observation
- Education
- Exploration





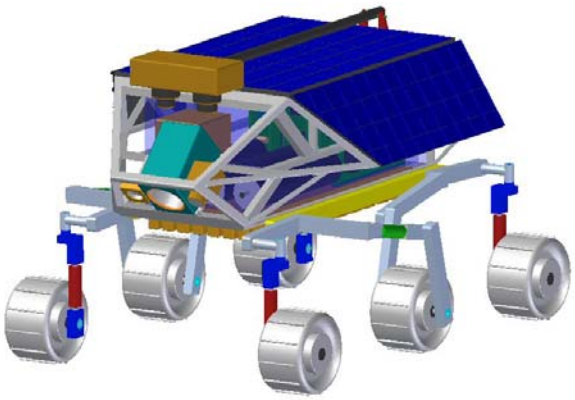
Operations



Semester projects, diploma thesis and practice, own research, external funding

Outlook and Perspectives

- Highly autonomous and operational services, sensor webs
- Use of pico satellite technologies in larger satellites (e.g. nano satellites)
- Synergy between satellite technologies and rovers
- Exploration



Design study of a Micro Mars Rover