The Evolution of the CubeSat Program MOVE

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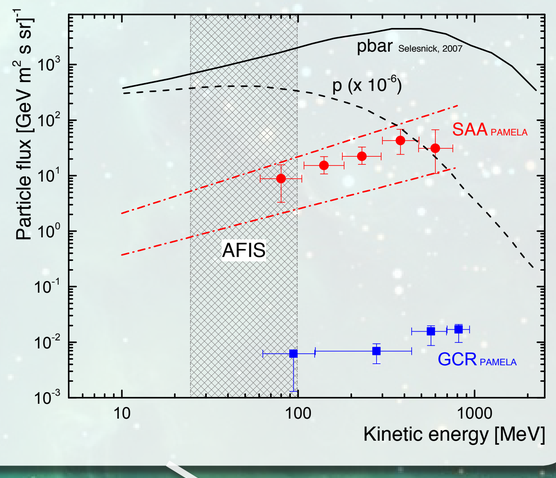
Abstract The CubeSat program MOVE, for "Munich Orbital Verification Experiment", was initiated in 2006 at the Institute of Astronautics (LRT) of the Technische Universität München (TUM), Germany. The primary objective of the program is the hands-on education of students. The first CubeSat of the program, called First-MOVE, was launched on November 21st, 2013.
The programs' second CubeSat, MOVE-II, is currently under development and shall be a 2U satellite, thus enabling the scientific use of nanosatellites beyond the 1U satellite bus of First-MOVE. MOVE-II will evolve the subsystems that were developed in-house. In terms of the scientific payload for the MOVE-II mission, the 1U Multi-purpose Active-target Particle Telescope (MAPT), developed by the Physics Department E18 of TUM, aims to measure the flux of antiprotons trapped in the Earth's magnetic field at very low energies. The 1U-sized bus of MOVE-II with its flexible interfaces is designed to accommodate a multitude of payloads. MOVE-II is due to be launched into space late 2017.

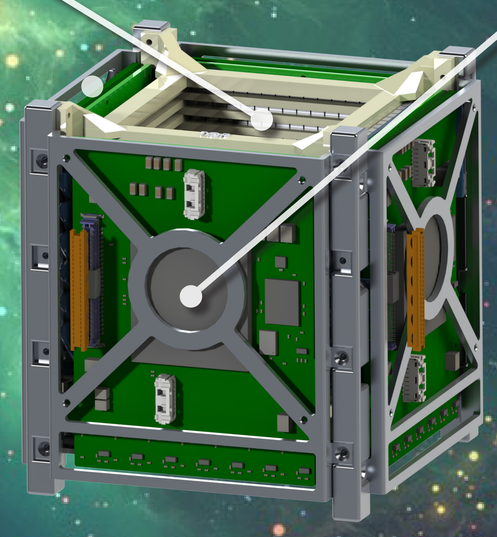
Scientific Objective

- Measure the flux of antiprotons trapped in the inner Van Allen belt in the 25 to 100 MeV energy range (**A**ntiproton **F**lux **i**n **S**pace mission)
- Complementary to measurement of PAMELA experiment
- Understanding interaction of high-energy cosmic rays with Earth's atmosphere and magnetosphere (trapping, transport mechanisms)



The Multi-purpose Active-target Particle Telescope (MAPT)

- 900 channel active-target tracking particle detector
- active volume: scintillating plastic fibers
- photodetectors: KETEK silicon photomultipliers
- custom FPGA-based data acquistion electronics
- sensitive to ions in 10 MeV/n to 500 MeV/n range
- identification of ion species using Bragg curve spectroscopy technique

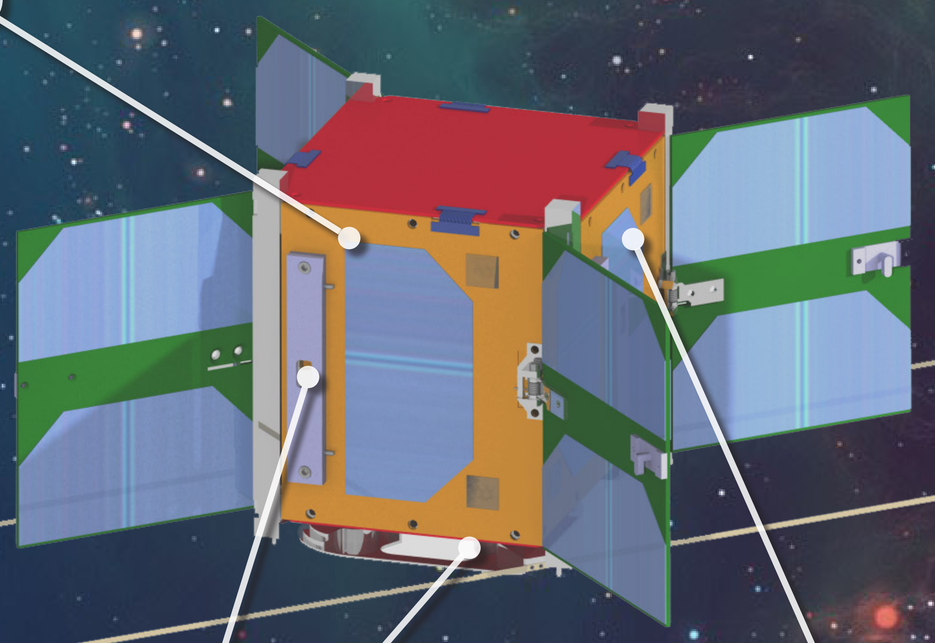


Attitude Determination & Control

- Attitude determination with magnetometers and sun sensors
- Attitude control based on magnetic coils, etched into PCBs

Electrical Power Supply

- Average power 4W at 600km/60°
- Optimization algorithms for solar cell wiring to multiple battery charge regulators
- Active overcurrent and overvoltage protection for each subsystem



Communications

- Full-duplex UHF/VHF transceiver
- Experimental S-Band transceiver (half-duplex, up to 1 Mbit/s)
- Student-designed data-link layer protocol (Nanolink)
- Stainless steel half-dipole UHF/VHF antennas
- S-band patch antenna

Command and Data Handling

- Full functionality of MOVE-II's on-board computer required at all times to enable scientific measurement within in South Atlantic Anomaly
- High degree of failure tolerance, assuring dependability while using COTS hardware
- Following centralized philosophy, software-side error protection
- Based on application processor core and the Linux operating system
- Enabling high degree of software reuse
- Error sources minimized and increased testability without relying on expensive special puspose hardware

Deployable Structures

SMARD

- Non-destructive hold-down and release mechanism based on shape memory alloy technology
- Reset by mechanical spring, facilitating quick and easy testing
- Successfully tested on REXUS 18

Redundant Antenna Deployment Mechanism

- Antennas folded into deployment structure
- Nominal deployment via solar panels
- Back-up deployment via +Z-movement of structure

[1] Adriani, O. et al. (2011). The Discovery of Geomagnetically Trapped Cosmic-Ray Antiprotons. The Astrophysical Journal, 737(2):L29.
[2] M. Losekamm et al., "AFIS: A New Instrument for Cosmic Radiation Studies on Bexus 18 and Future Nanosatellite Missions", Proc. '22nd ESA Symposium European Rocket & Balloon Programmes and Related Research', 7–12 June 2015, Tromsø, Norway (ESA SP-730, September 2015).
[3] M. Grulich et al. "SMARD-REXUS-18: Development and Verification of an SMA Based CubeSat Solar Panel Deployment Mechanism", Proc. '22nd ESA Symposium European Rocket & Balloon Programmes and Related Research', 7–12 June 2015, Tromsø, Norway (ESA SP-730, September 2015).

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