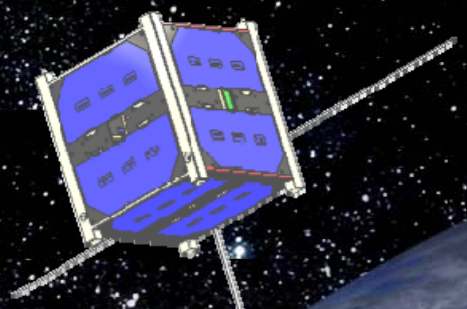
COMPASS-1

The first Pico Satellite Project at the Aachen University of Applied Sciences



Presented by:
Dipl.-Ing. Artur Scholz and Dipl.-Ing. Jens Giesselmann

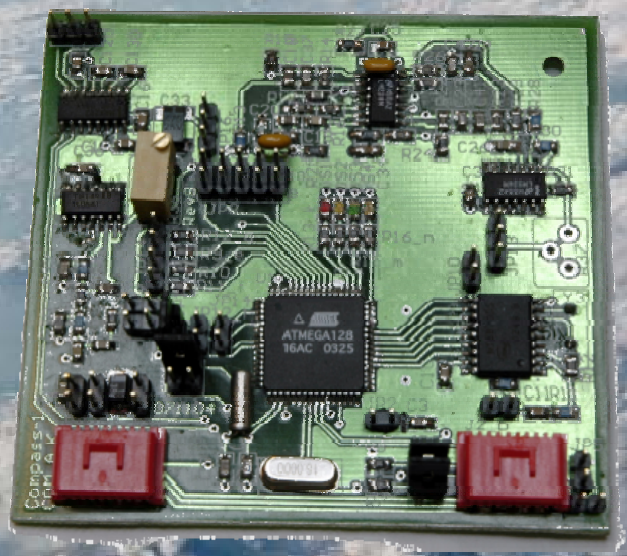
18. Raumfahrtkolloquium der FH Aachen, 10.11.2005

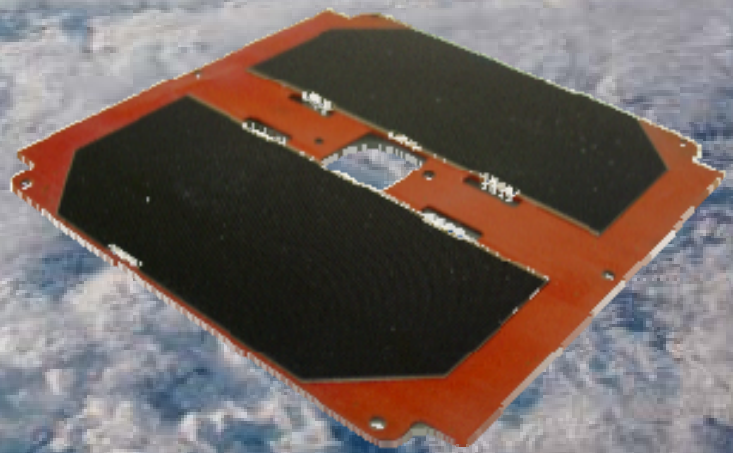
Content

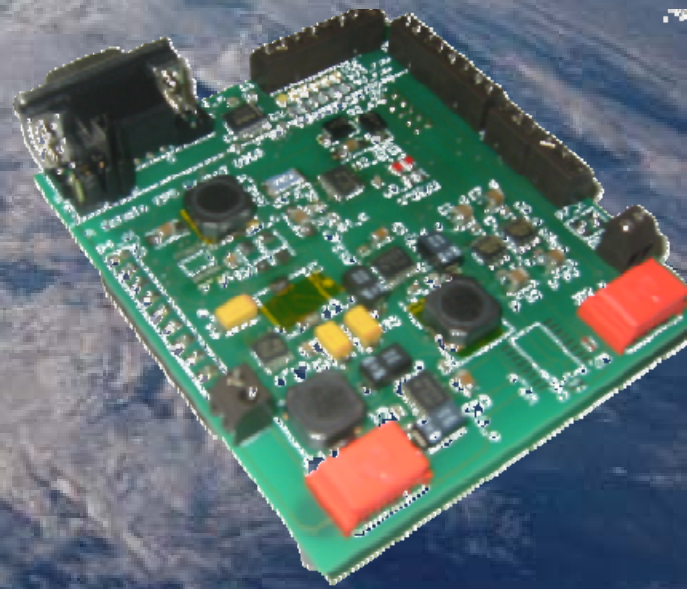
- Mission Overview
- CubeSats
- The COMPASS-1 Spacecraft
- Focus on:
  - Electrical Power System
  - Attitude Determination and Control
- Development Status
- Outlook & Conclusion

Mission Overview

- **The satellite will primarily serve as technology demonstrator:**
  - **to verify novel hardware and software concepts in space,**
  - **to demonstrate practical satellite technology at Aachen,**
  - **and to prepare the way for further advanced missions.**

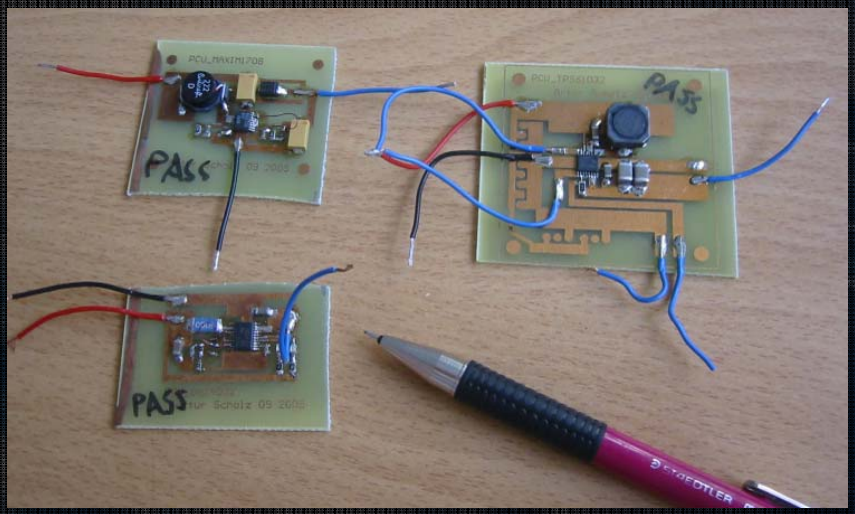




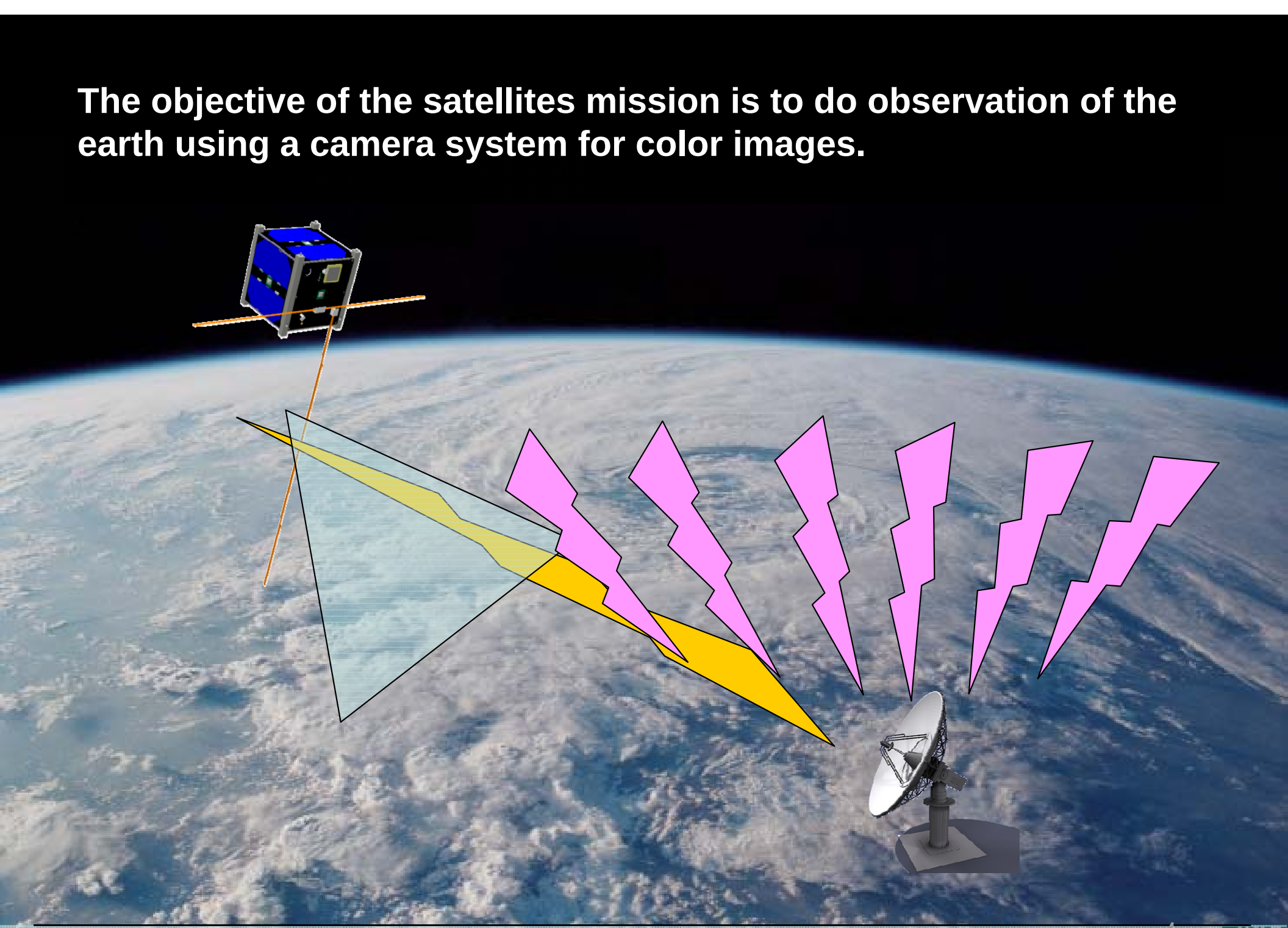


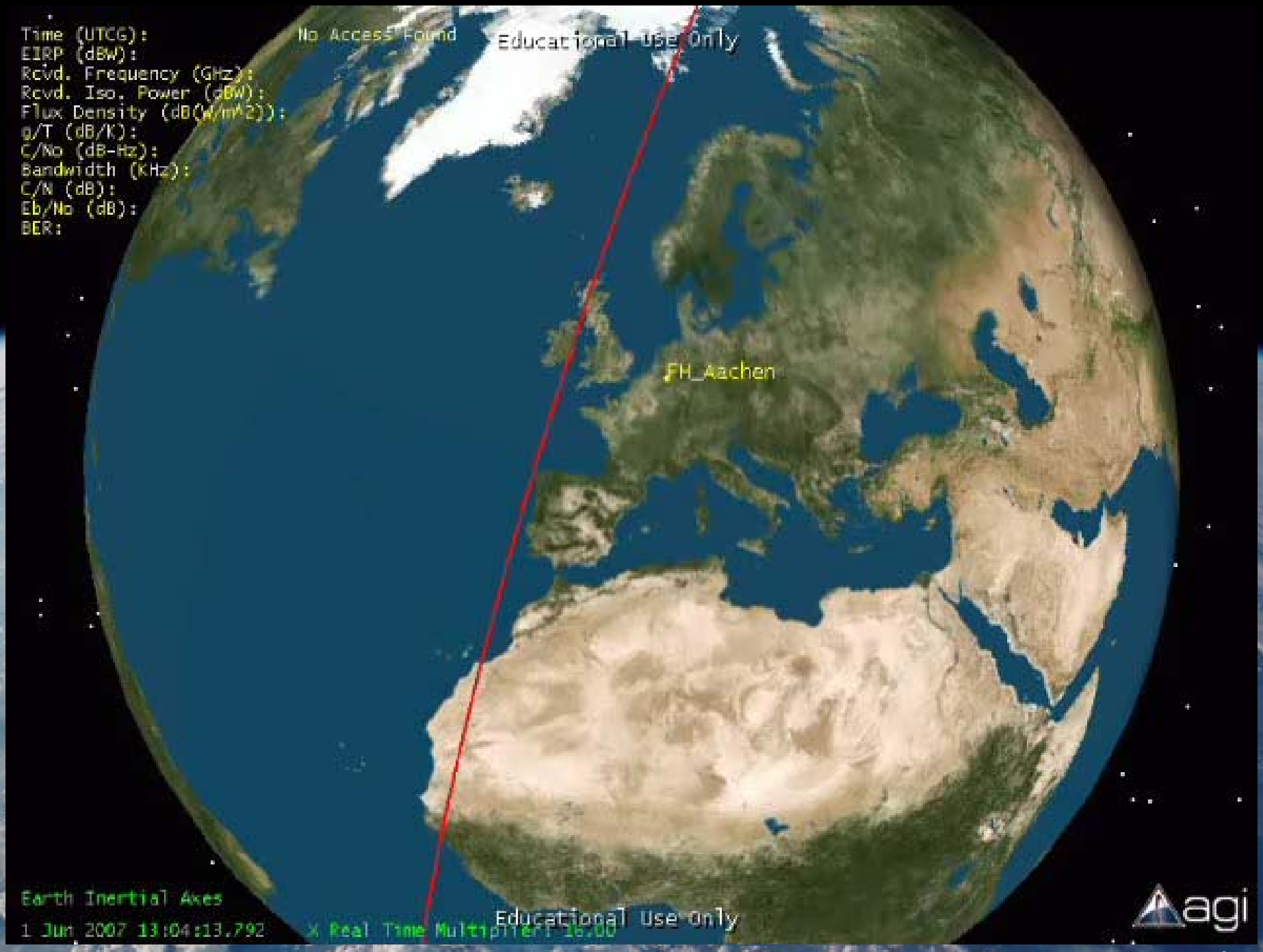
Mission Overview

- **Nearly all building blocks of the satellite are being developed from the scratch in order to:**
  - **meet the stringent power, mass and size limits,**
  - **stimulate the development of up-to-date technologies for very small satellites,**
  - **and because many of the needed solutions were not available yet!**

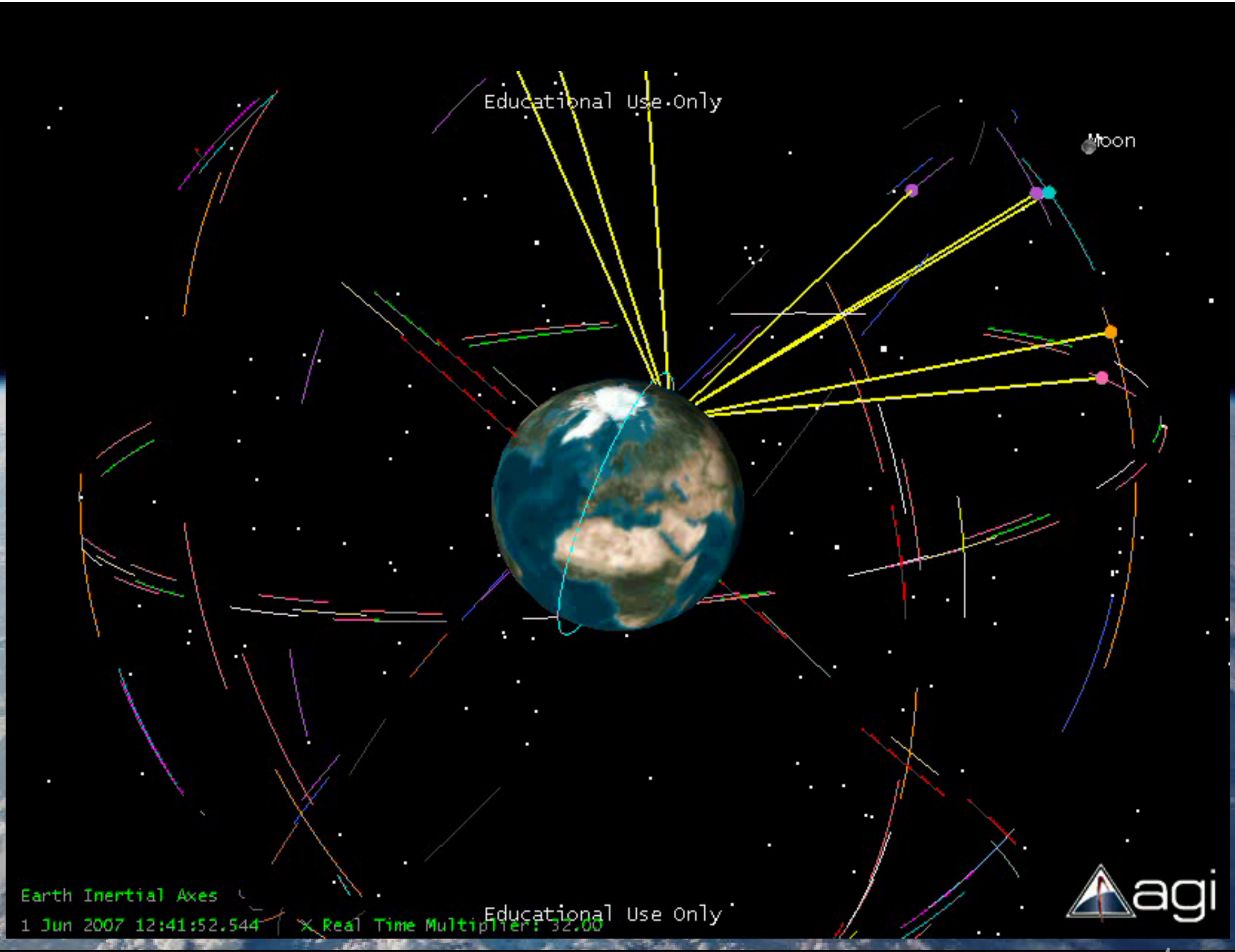


The objective of the satellites mission is to do observation of the earth using a camera system for color images.




Time (UTCG):
EIRP (dBW):
Rcvd. Frequency (GHz):
Rcvd. Iso. Power (dBW):
Flux Density (dB(W/m^2)):
G/T (dB/K):
C/No (dB-Hz):
Bandwidth (KHz):
C/N (dB):
Eb/No (dB):
BER:
No Access Found
Educational Use Only
FH_Aachen
Earth Inertial Axes
1 Jun 2007 13:04:13.792
Real Time Multiplier: 16.00
Educational Use Only
agi

During mission duration, extensive GPS data is collected on regular basis to evaluate the functionality of a commercial off-the-shelf GPS receiver, whose software was modified by the DLR.

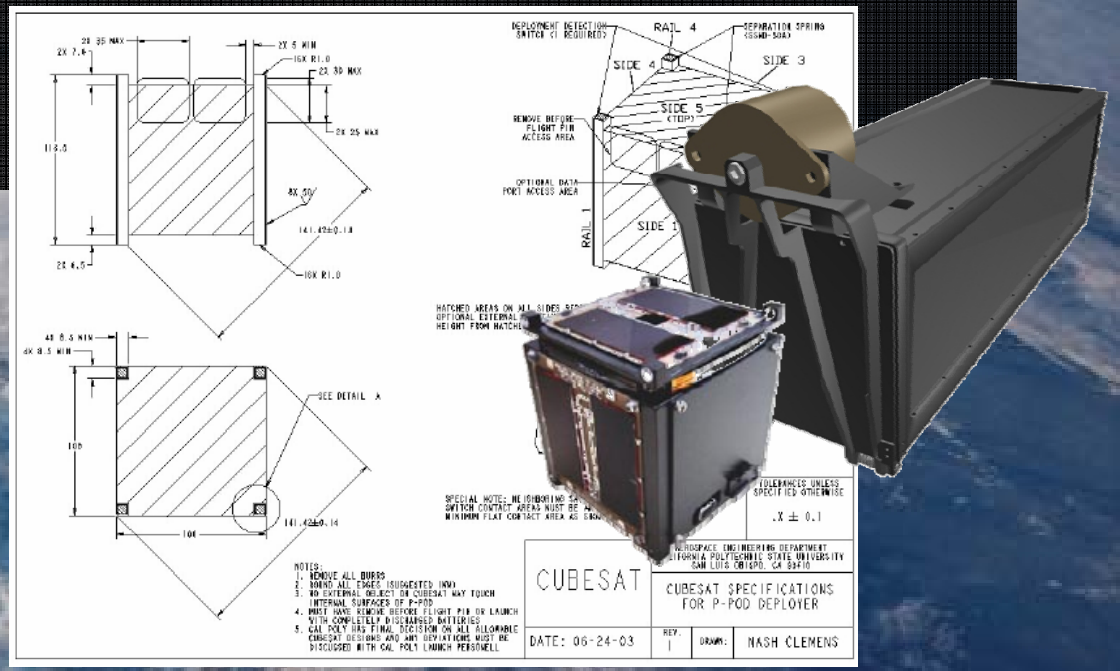

Educational Use Only
Moon
Earth Inertial Axes
1 Jun 2007 12:41:52.544
Real Time Multiplier: 32.00
Educational Use Only
agi

CubeSat Overview

The CubeSat standard has been defined in 1999 by Prof. Twiggs of Stanford University in collaboration with CalPoly University.

The concept was chosen for COMPASS-1 in order to:

- **reduce the launch costs**
- **simplify the design process**



Mass: 1kg

Size: 10cm x 10cm x 10cm

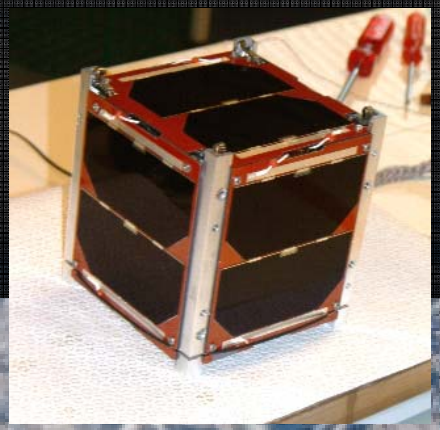
Mission: your choice!

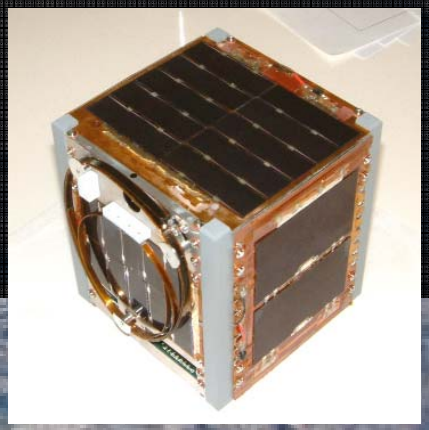
The first launch of CubeSats was in July 2003:

- Canada (1)
- Denmark (2)
- Japan (2)

The second (and latest launch) of CubeSats was in October 2005:

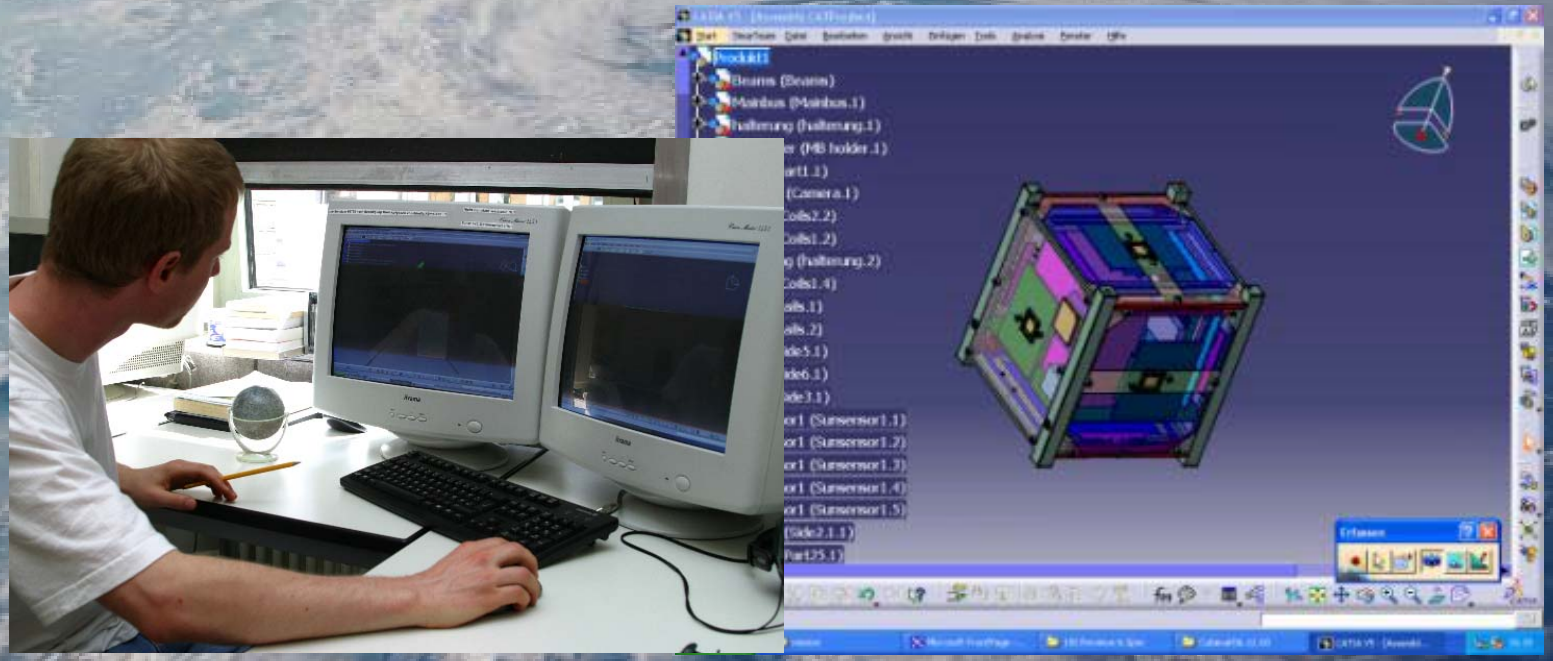
- Norway (1)
- Germany (1)
- Japan (1)

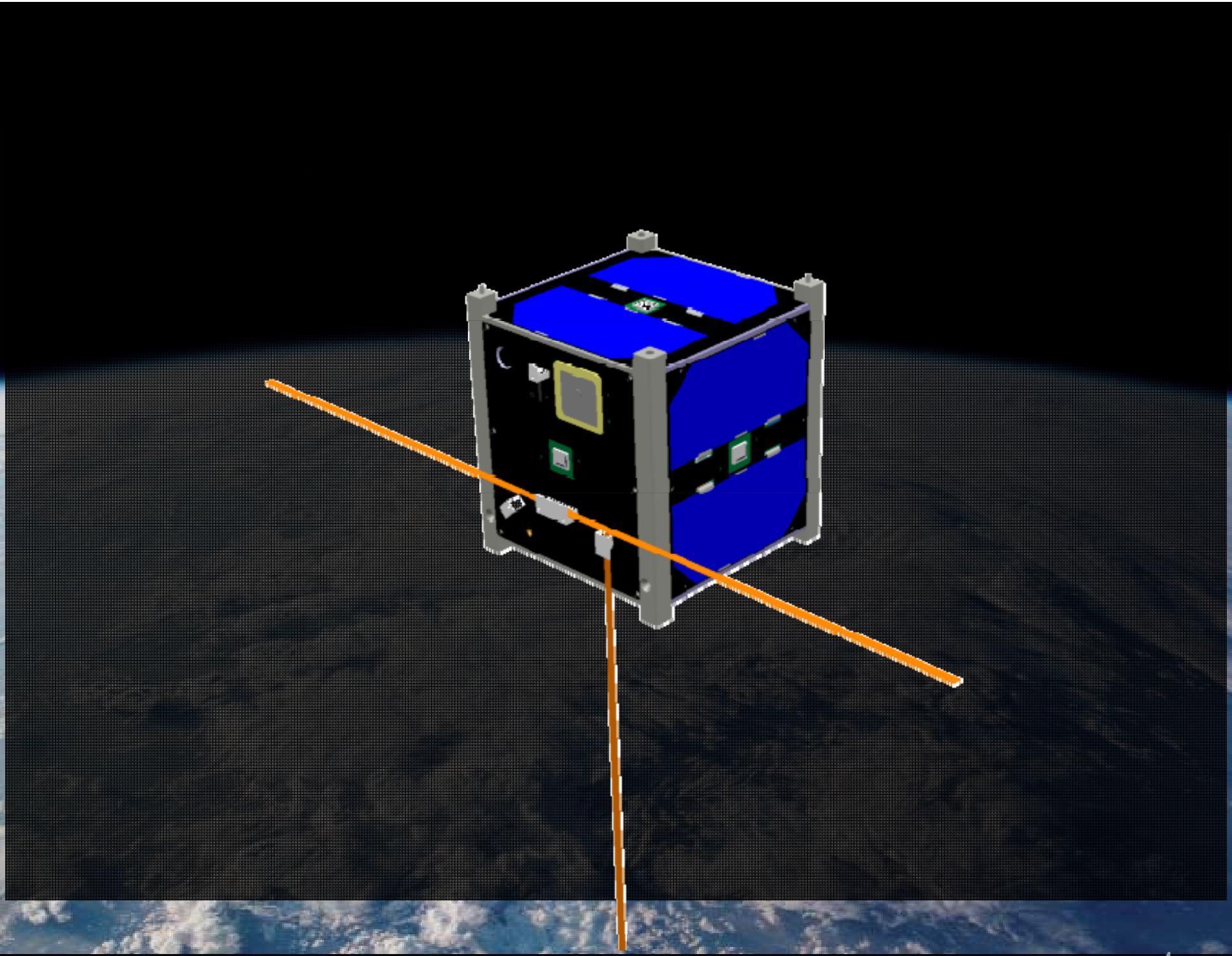


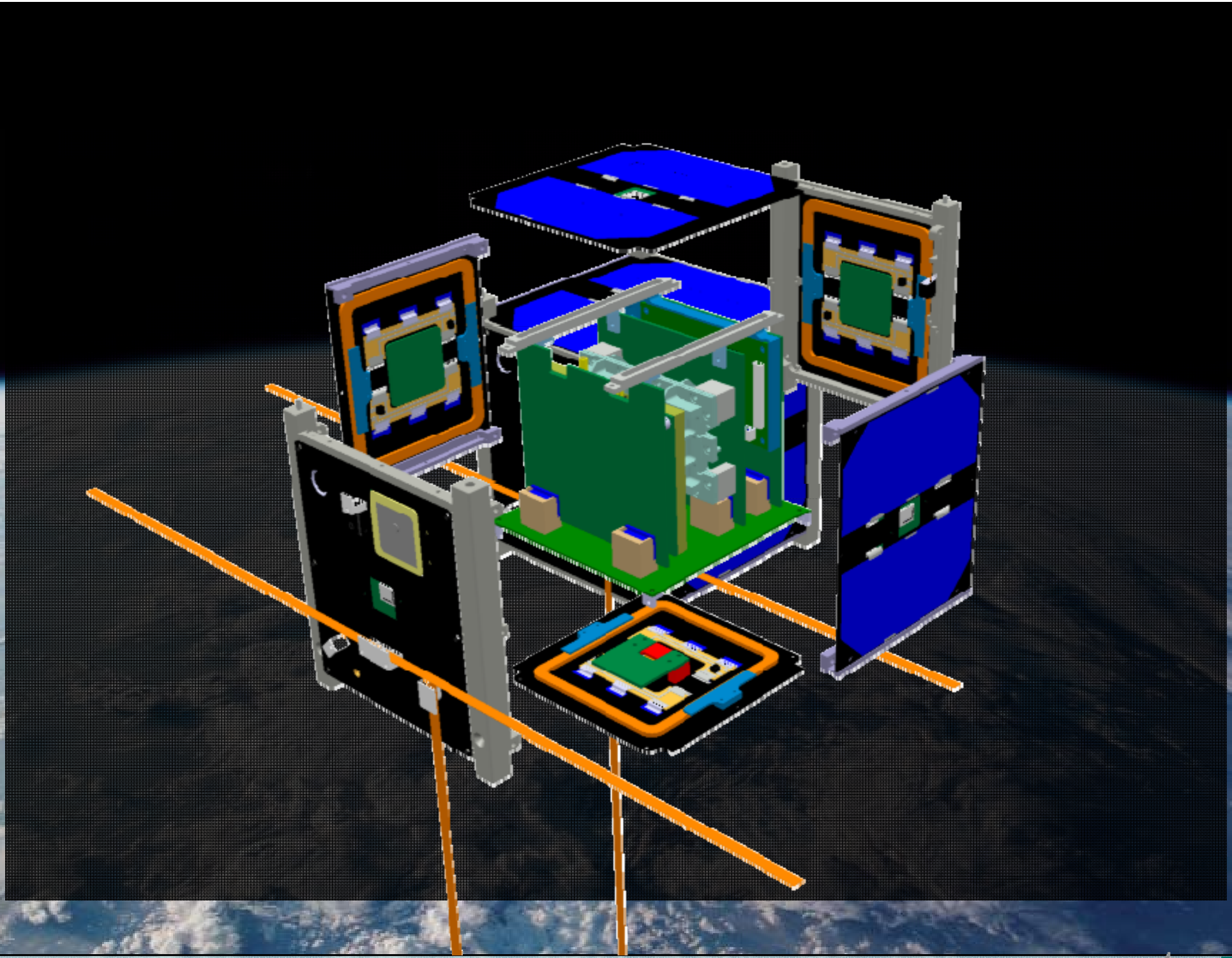


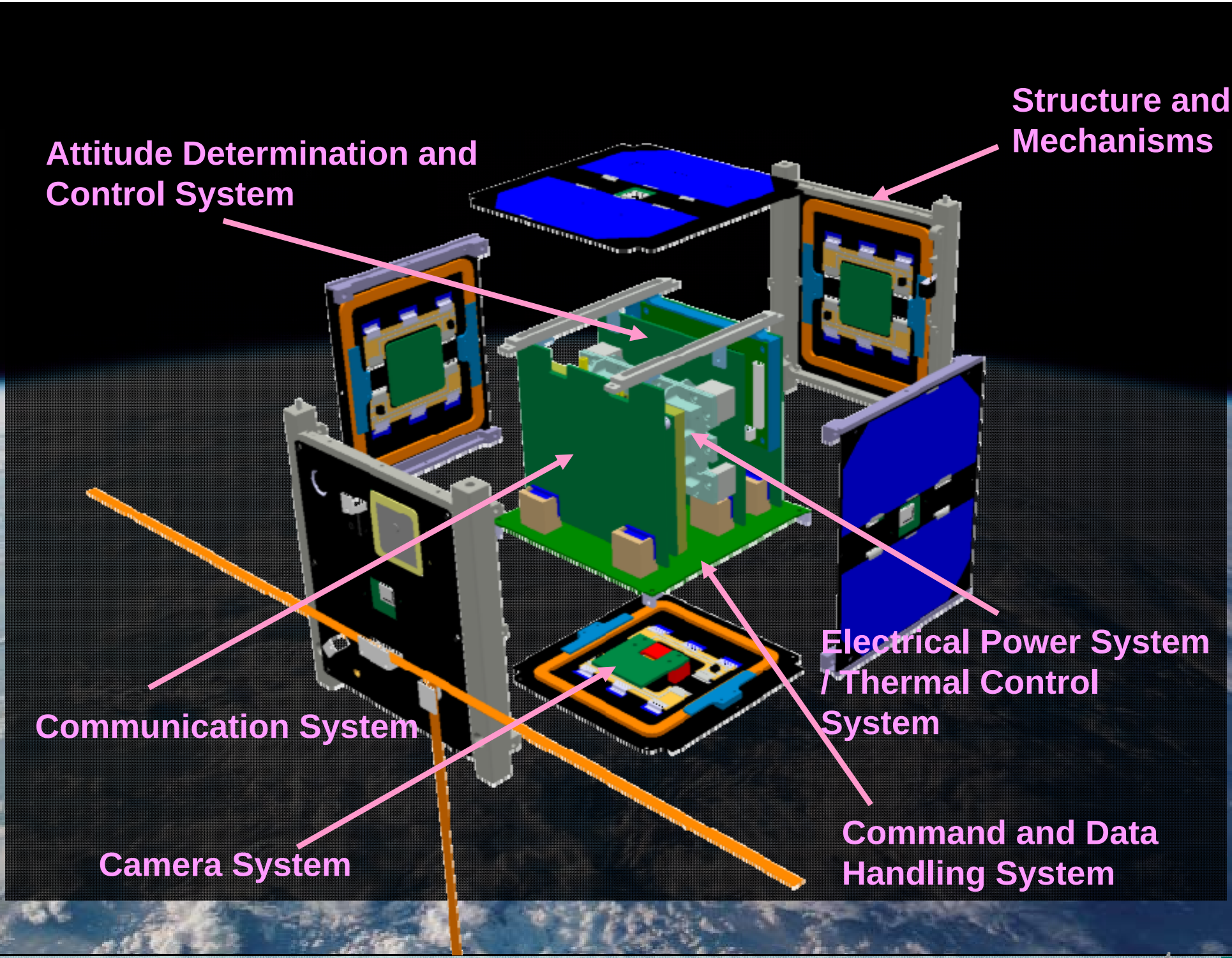
Spacecraft Overview

Following intensive research and design studies, the development of the COMPASS-1 picosatellite commenced in spring of 2005 with the advanced prototype models for the several subsystems.



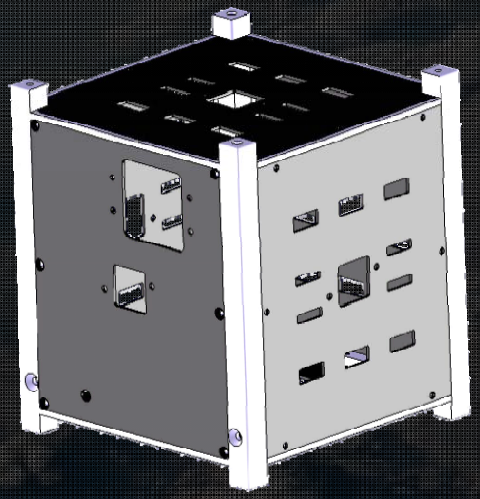


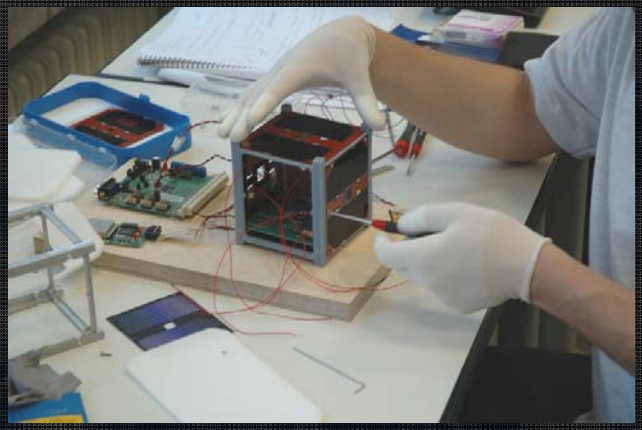


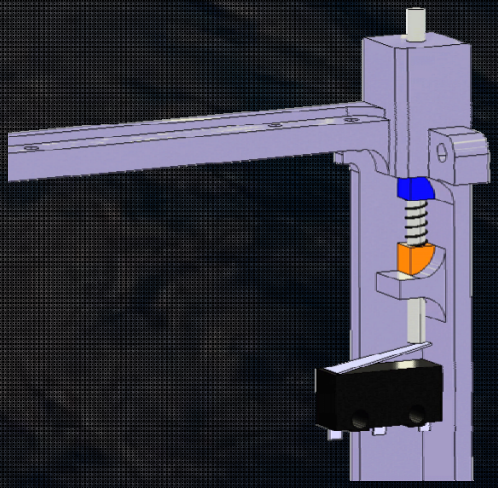

Structure and Mechanisms
Attitude Determination and Control System
Electrical Power System / Thermal Control System
Communication System
Command and Data Handling System
Camera System

Structure & Mechanisms

- Protects the electronics and other parts of the satellite against the launch loads.
- Allows thermal control of the inner components a rigid structure with special surface properties is used.
- Highly modular for easy assembly.
- Mechanisms to deploy the UHF/VHF antennas and to close the power circuit of the satellite.



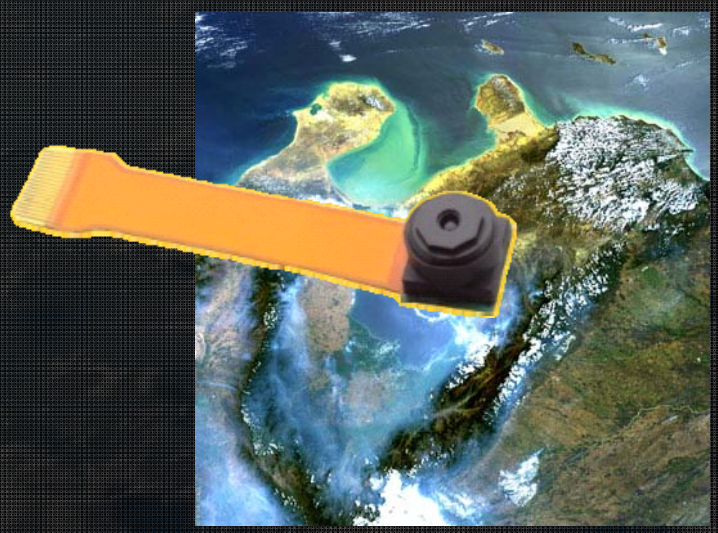




Payload

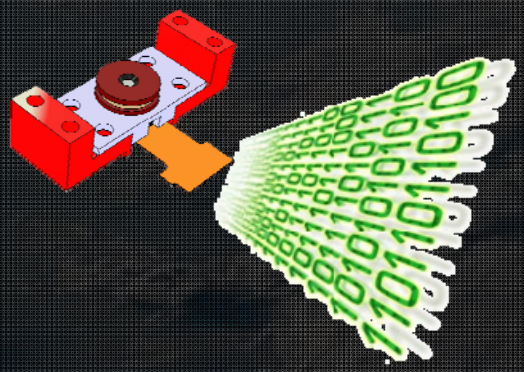
- A color camera module, with very small dimensions and power consumption. It delivers images in VGA format (640x480).

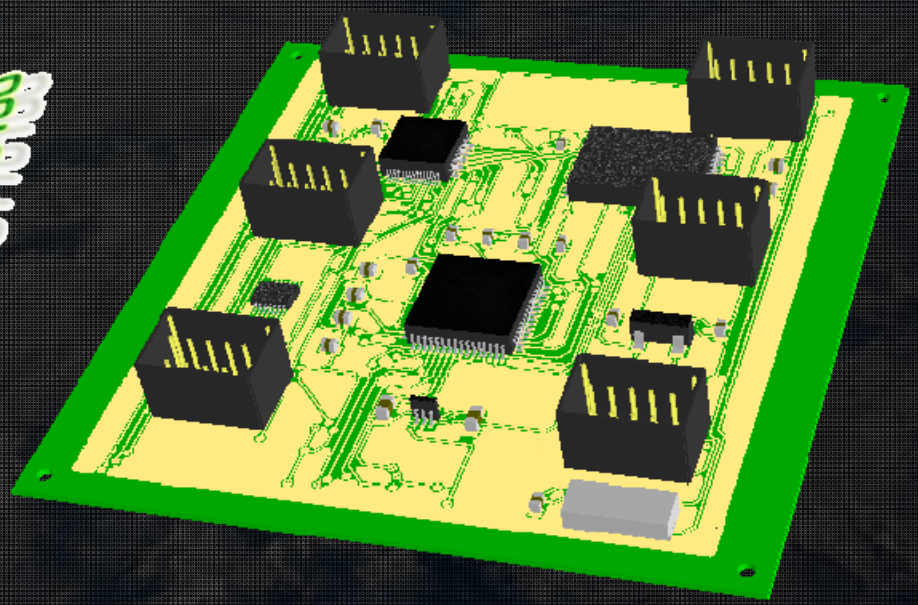
- A GPS receiver. DLR modified software for the use in space.

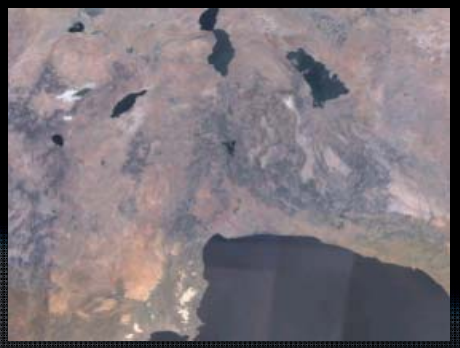


Command and Data Handling System

- Executes commands from ground stations.
- Collects, stores and transmits telemetry and data.
- Interfaces and controls the camera payload.

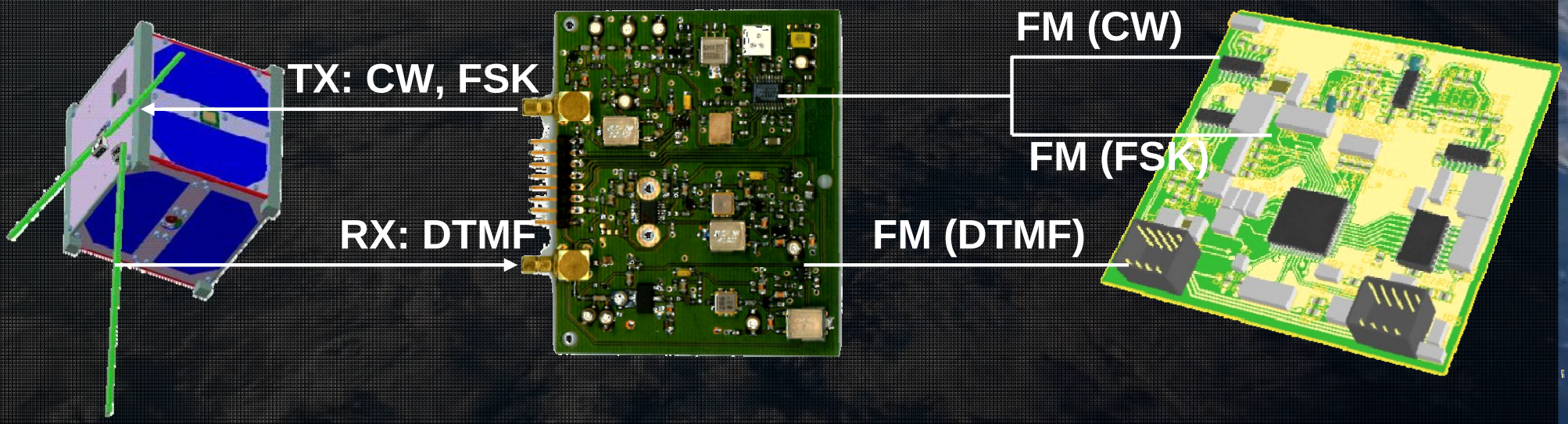






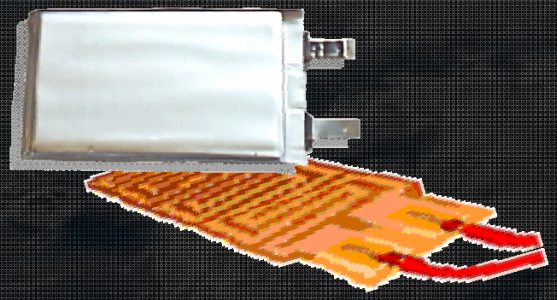
Communication System

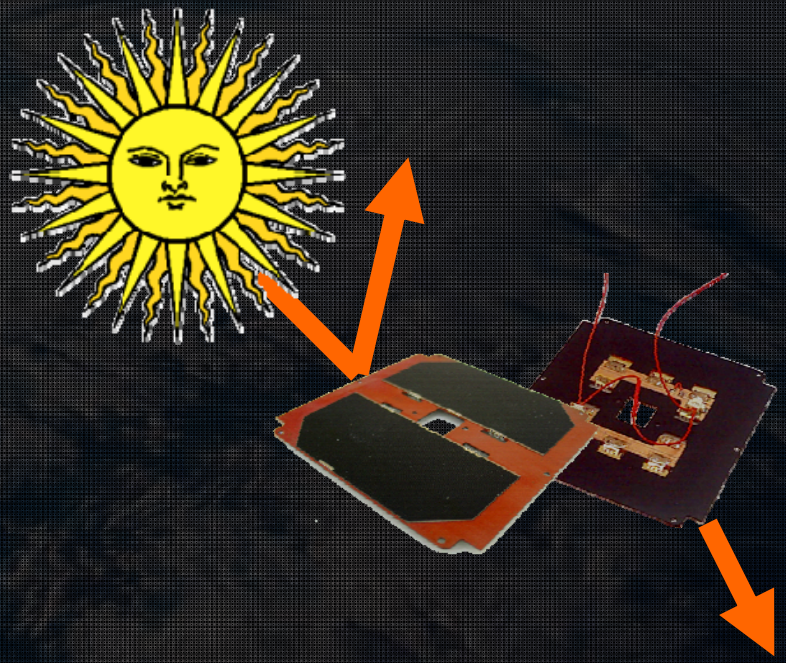
- A monopole antenna is used to receive commands, while data is sent via the dipole antennas.
- The Transceiver amplifies the incoming and outgoing signals.
- The COM board encodes the DTMF commands and sends data in AX.25 format. A beacon signal is sent in CW.



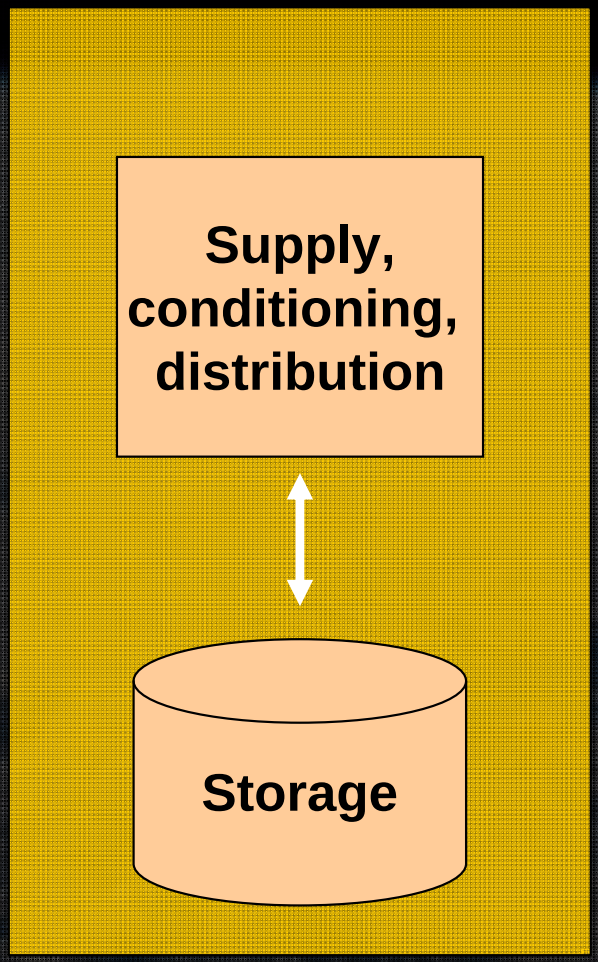
Thermal System

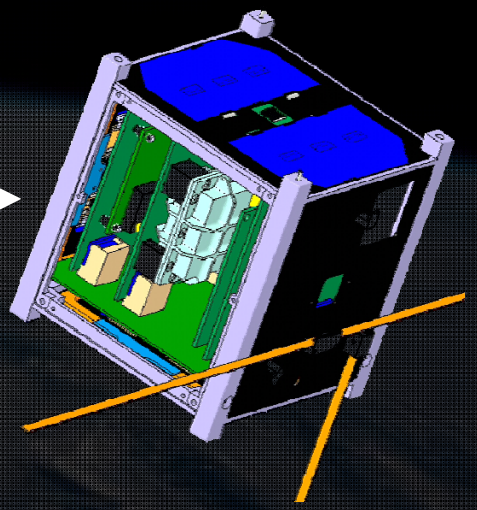
- Active thermal control is realized with a heater placed at the batteries.
- As passive method of thermal housekeeping the panels are anodized in black color.



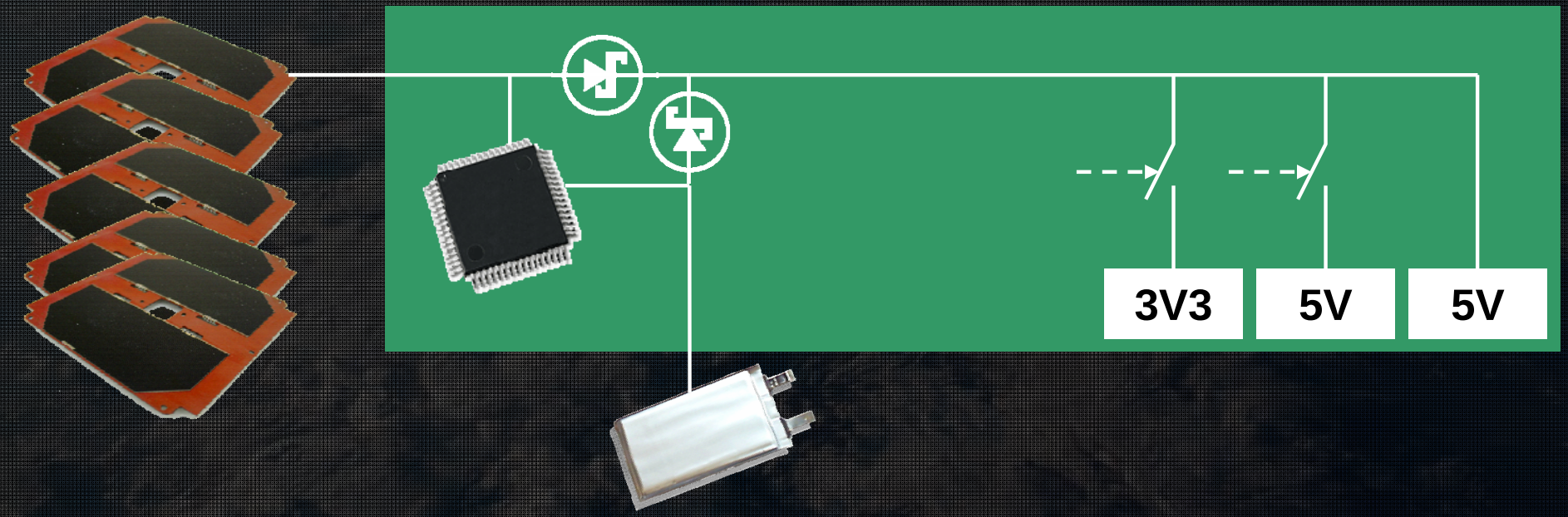


Electrical Power System





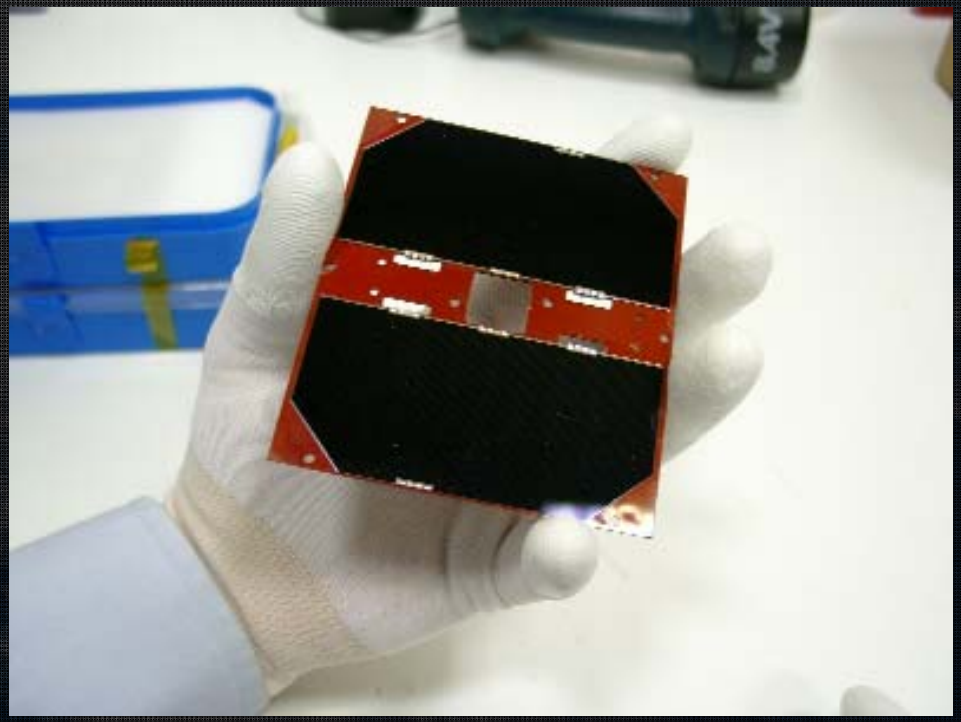
- Triple-Junction solar cells are the power source of the satellite.
- Lithium-Polymer cells are used to store excessive energy during sunlight and to supply the energy consumers during eclipse.
- EPS board carries out power management to maintain batteries within DOD and detects and corrects failures caused by Single-Event Effects.



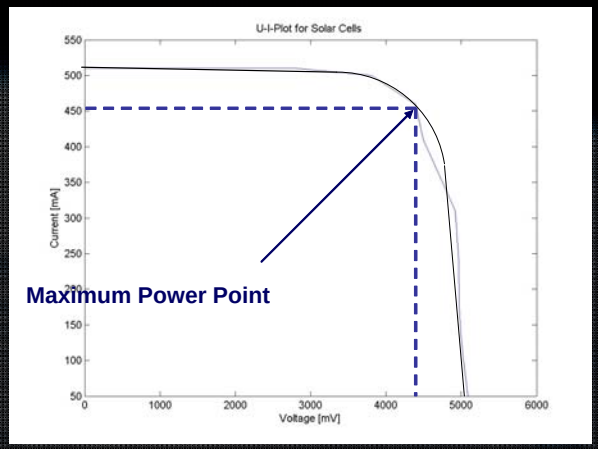
Solar cells:

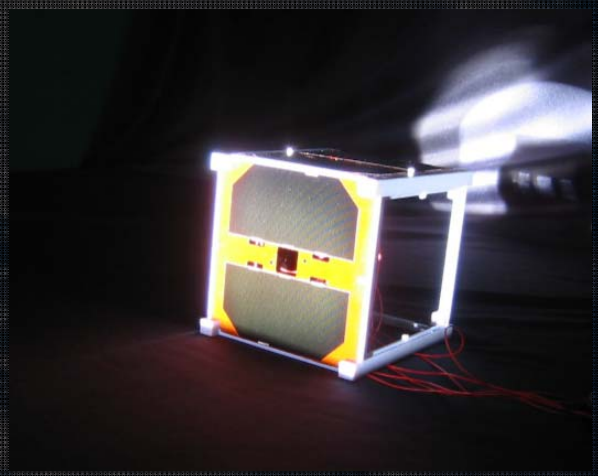
Cell Type:	**Triple-Junction GaAs from RWE Solar GmbH**
Name:	**RWE3G-ID2/150-8040**
Dimensions:	**80mm x 40mm**
Cell Area:	**30,18cm²**
Weight:	**2,6 grams**
Efficiency:	**26,6%**

Voc	**=**	**2,55V**
Isc	**=**	**500mA**
Upmax	**=**	**2,26V**
Ipmax	**=**	**480mA**

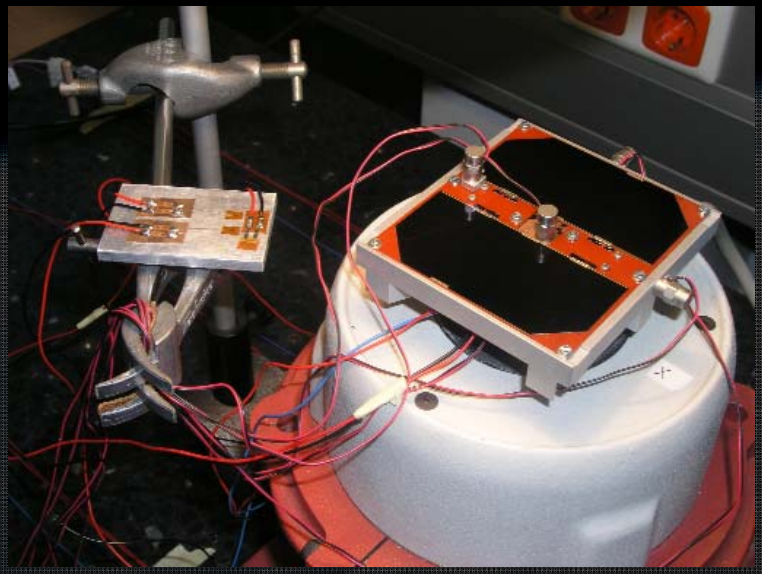


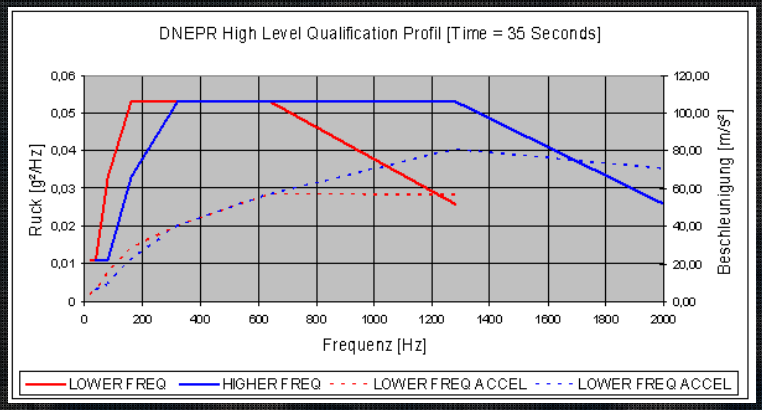
With the AEG sun simulator the characteristics of the cells were measured. The side panels were illuminated with one Solar Constant (1372 W/m²).





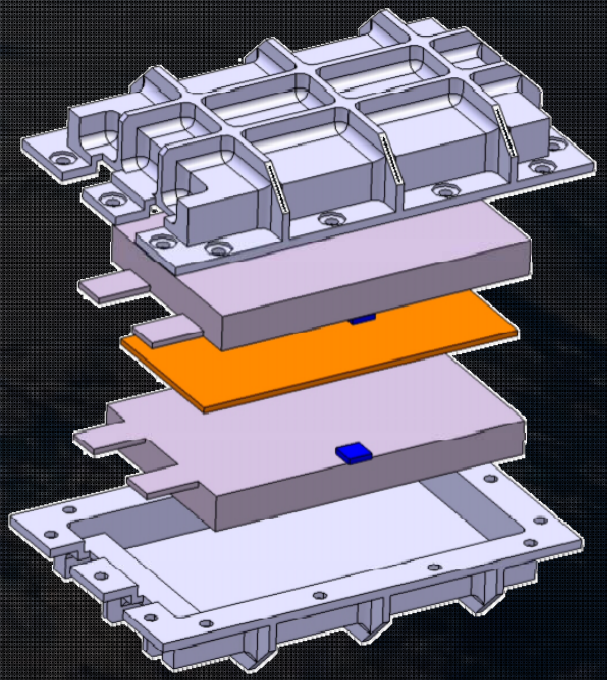
Vibration testing of the side panels verified that the cells are properly fixed to the satellite and that the launch will cause no destruction of the cells.





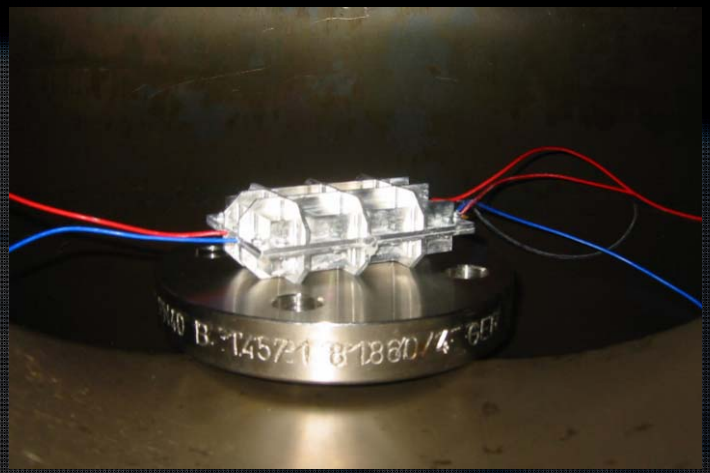
Batteries:

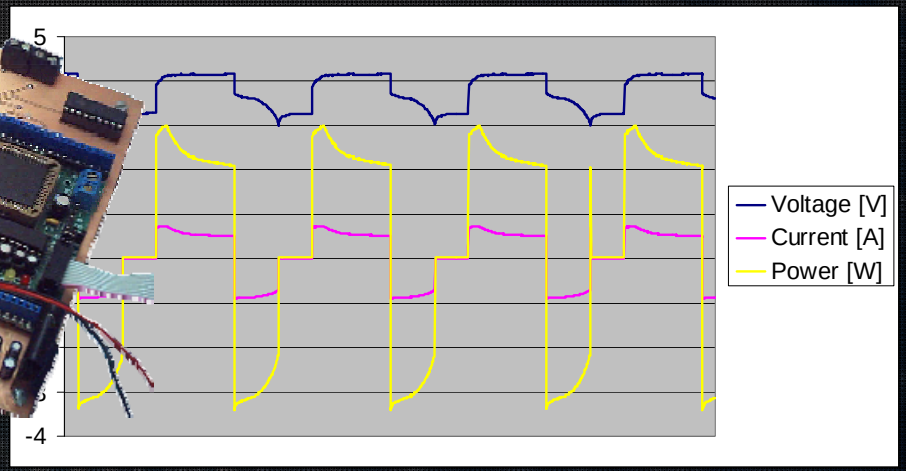
Battery Type:	2x Lithium-Polymer
Product:	Kokam
Dimensions:	39mm x 53mm x 6mm
Capacity:	1200mAh / cell
Weight:	23 grams / cell
Max. discharge:	5-7C
Voltage:	nom. 3,7 Volt



The battery box has endured long-term vacuum exposition without any malfunction.

Charge/Discharge tests were conducted to investigate on the behavior of the battery cells inside the box.





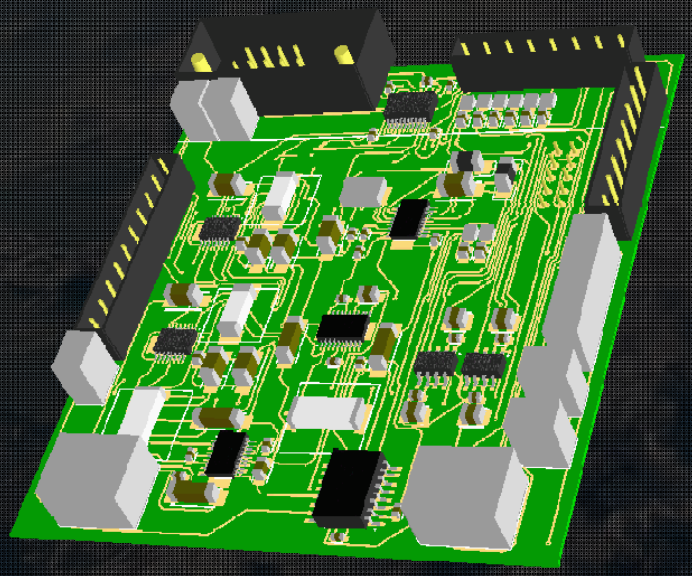
Mainboard:

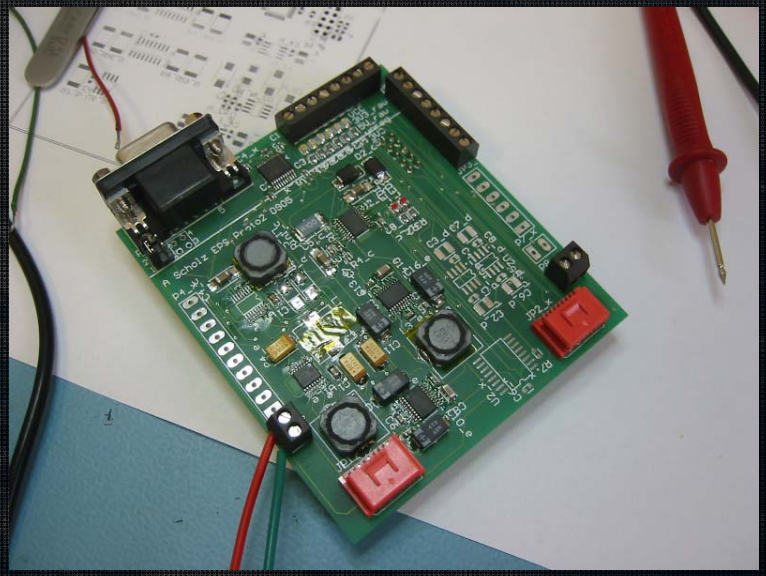
Processor: 8-bit Microcontroller 8051 architecture

Bus Systems: I2C, UART and SPI bus

Units: Peak Power Tracking (PPT), Regulation (5V/3.3V), Li-Poly Charger, Power Distribution

Software: ‘C’ code for Thermal and Power Management



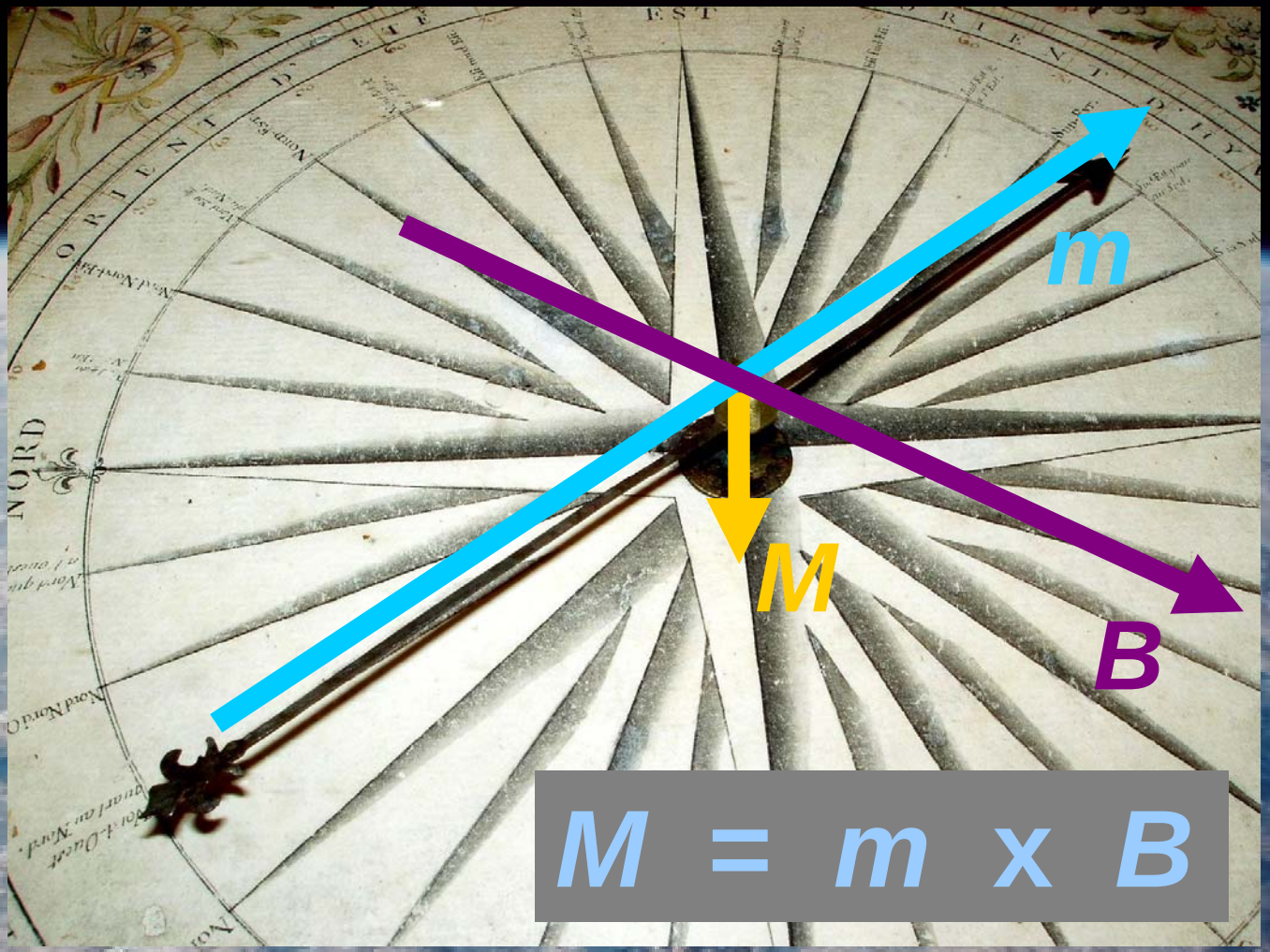


Attitude Determination and Control System (ADCS)

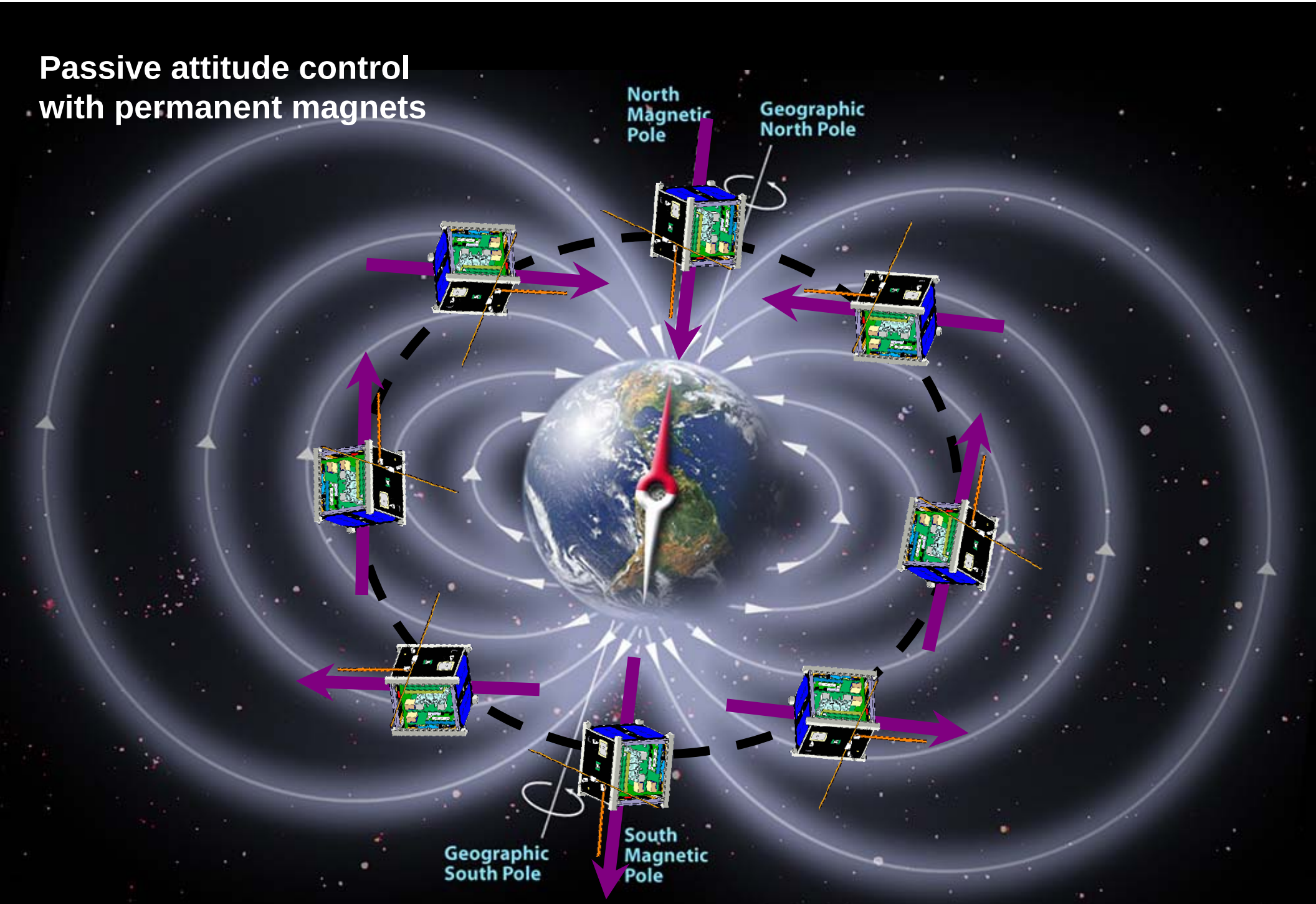
- Detumble the spacecraft after launch interface separation and antenna deployment
- Determine the dynamic state of the spacecraft using on-board sensor measurements
- Maintain nadir-pointing attitude within 8° max. error
- Gather and store housekeeping and engineering data
- Gather GPS telemetry data
- Communicate with CDHS

Compass-1 carries active attitude control

What is a Compass
Concepts of magnetic attitude control
and why does it align itself with the geomagnetic field?

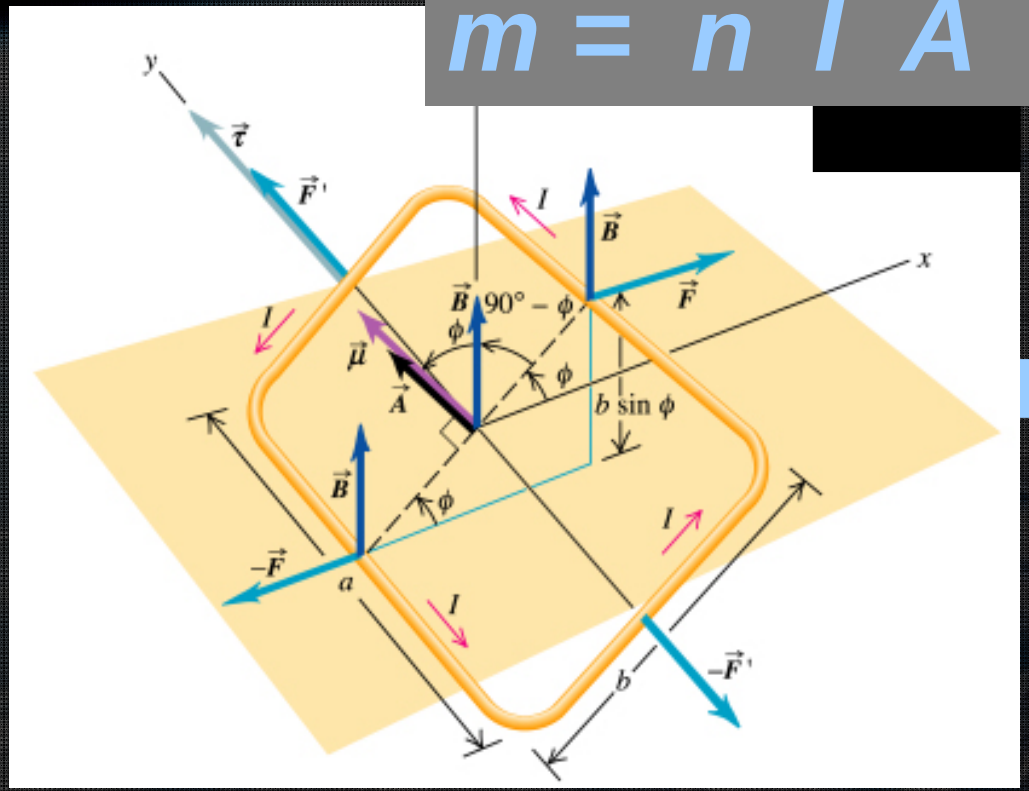


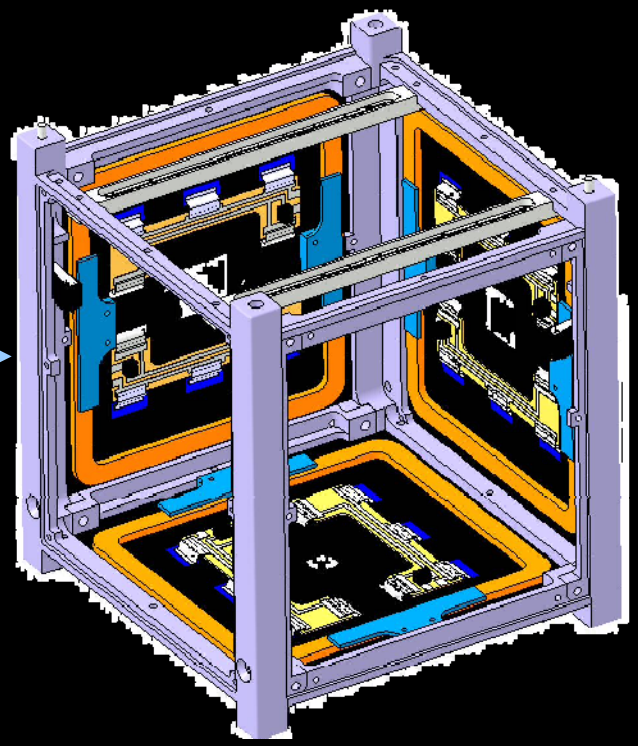
Passive attitude control with permanent magnets



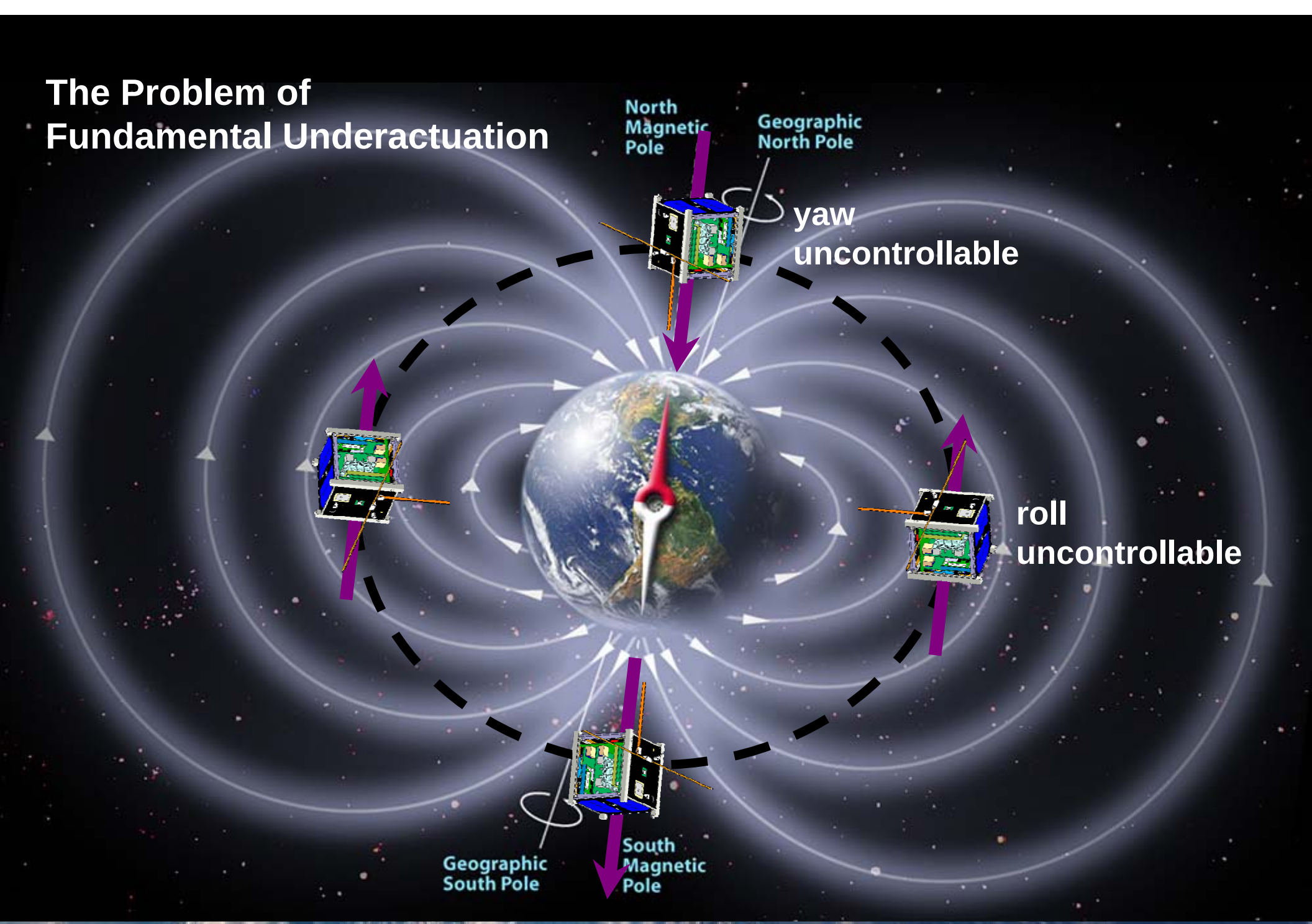
Compass-1 uses electromagnetic coils instead of permanent magnets

$$m = n\ I\ A$$

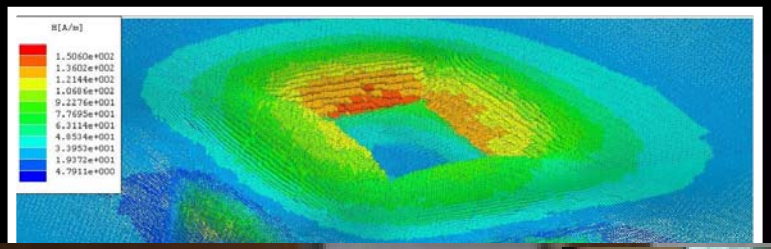


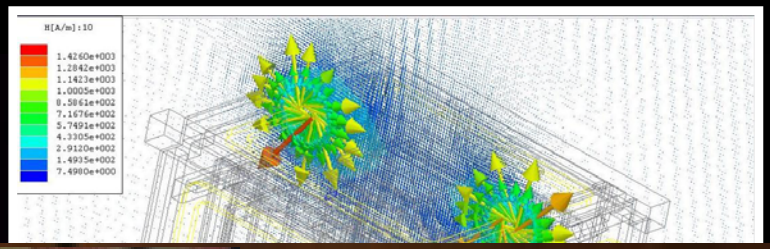


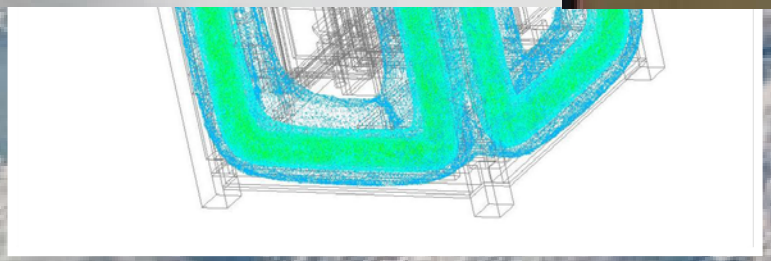
The Problem of Fundamental Underactuation

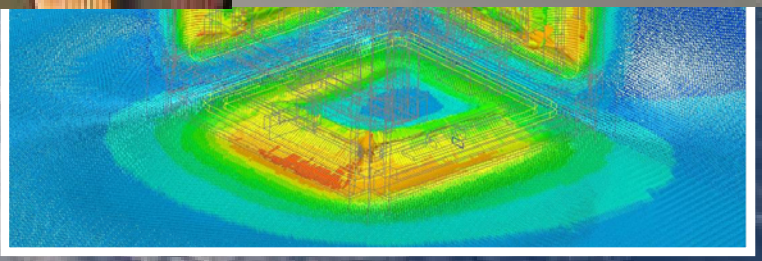


Magnetorquer Design and Validation

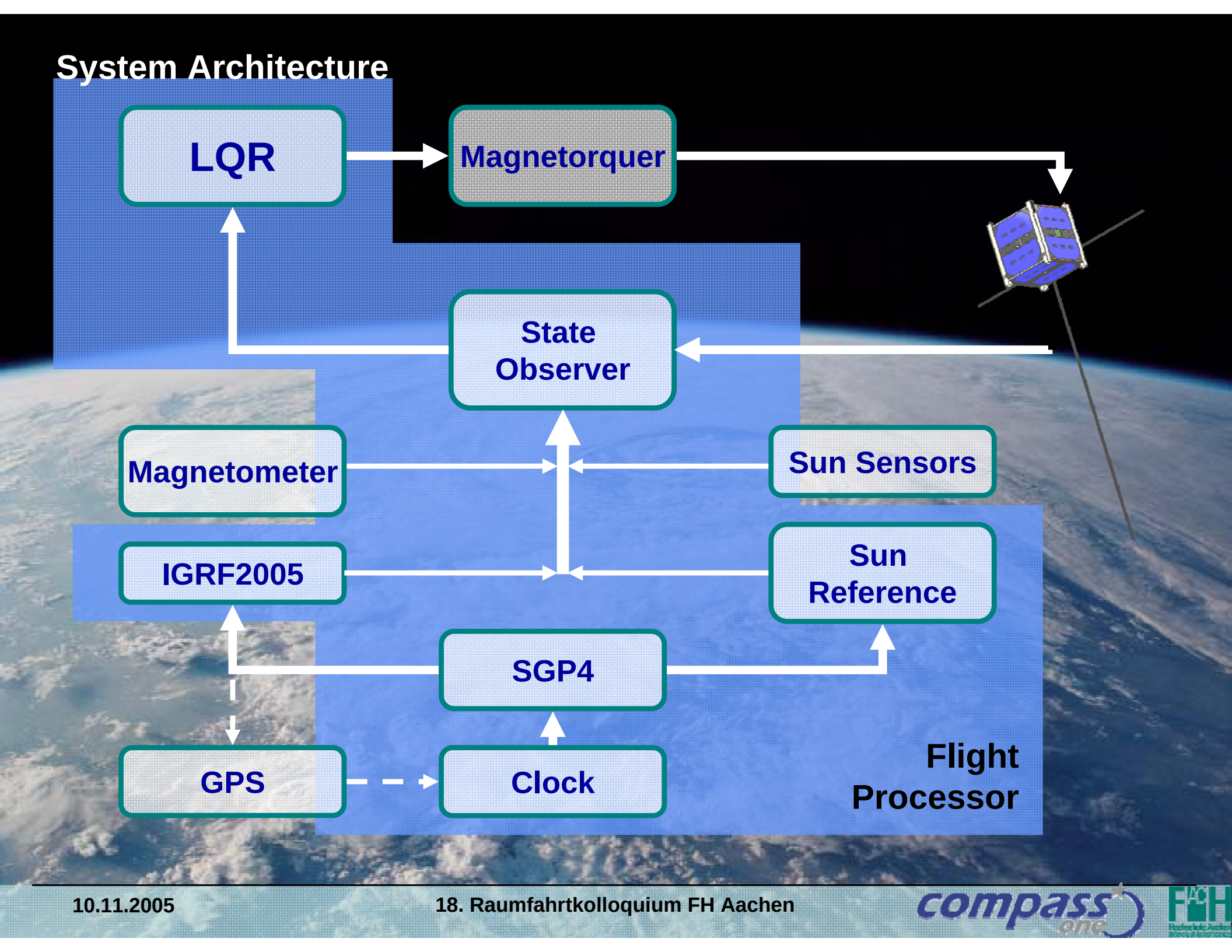


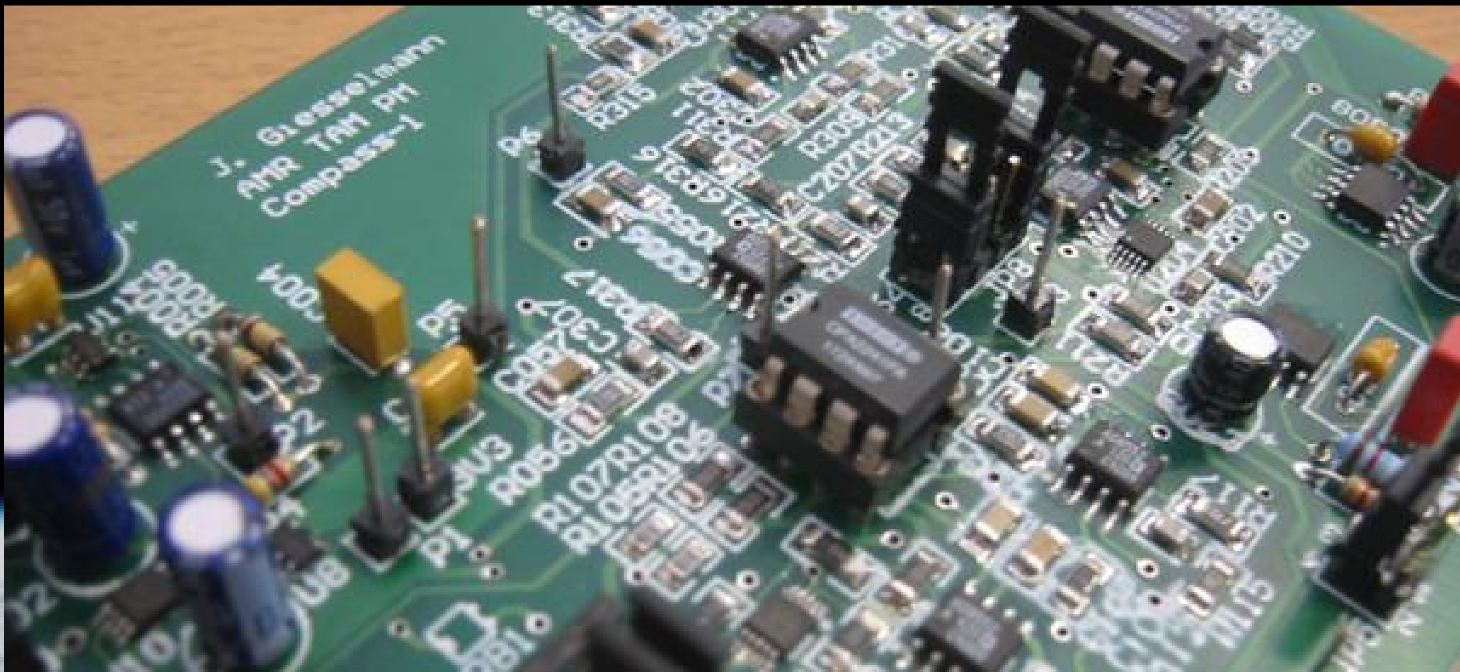


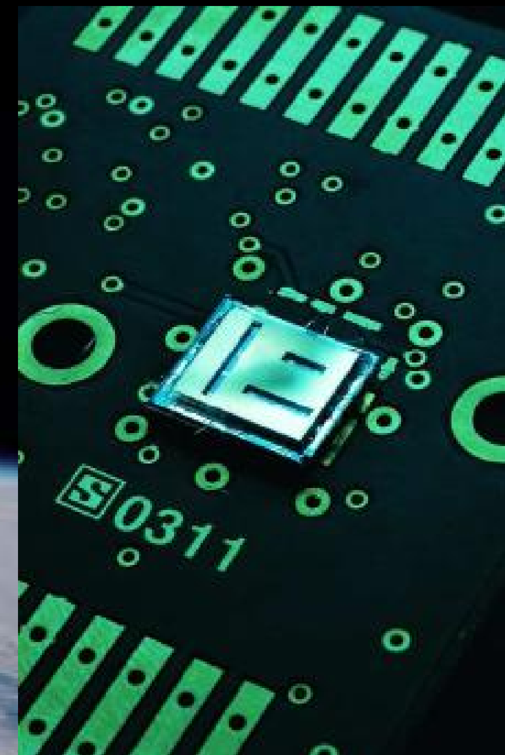




System Architecture







Sun Sensors

2-axis analog sun sensor in MOEMS technology

In cooperation with Denmark Technical University

- Very small footprint, extremely lightweight
- 5 sensors for max. coverage
- Intelligent digital front-end electronics

3-axis Magnetometer

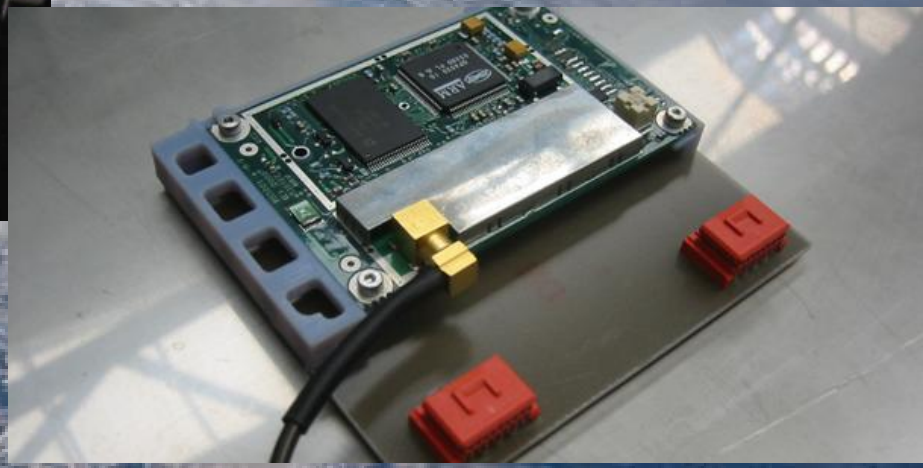
Based on the anisotropic magnetoresistive (AMR) effect

Advantages:

- Good sensitivity, low density fields
- Small package
- Reliable, simple interface

GPS Receiver

- L1 single frequency receiver
- 12 correlator channels
- commercial hardware
- DLR software
- no space heritage
- technology demonstration

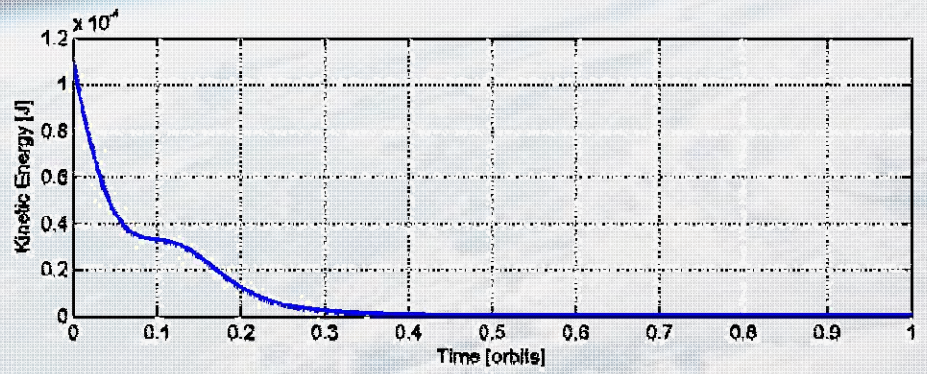


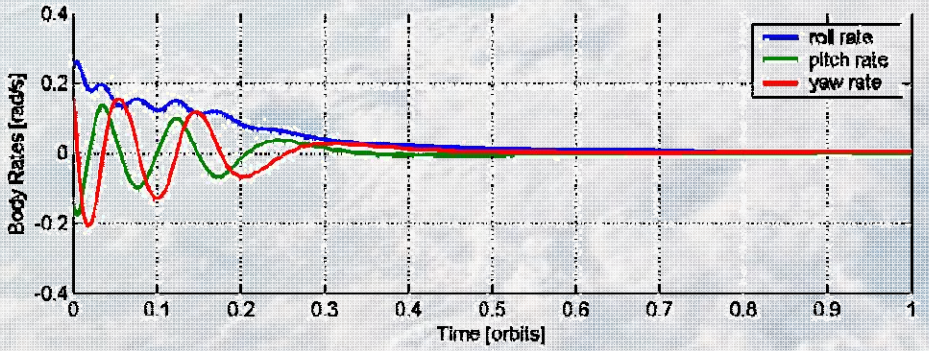
Flight Processor

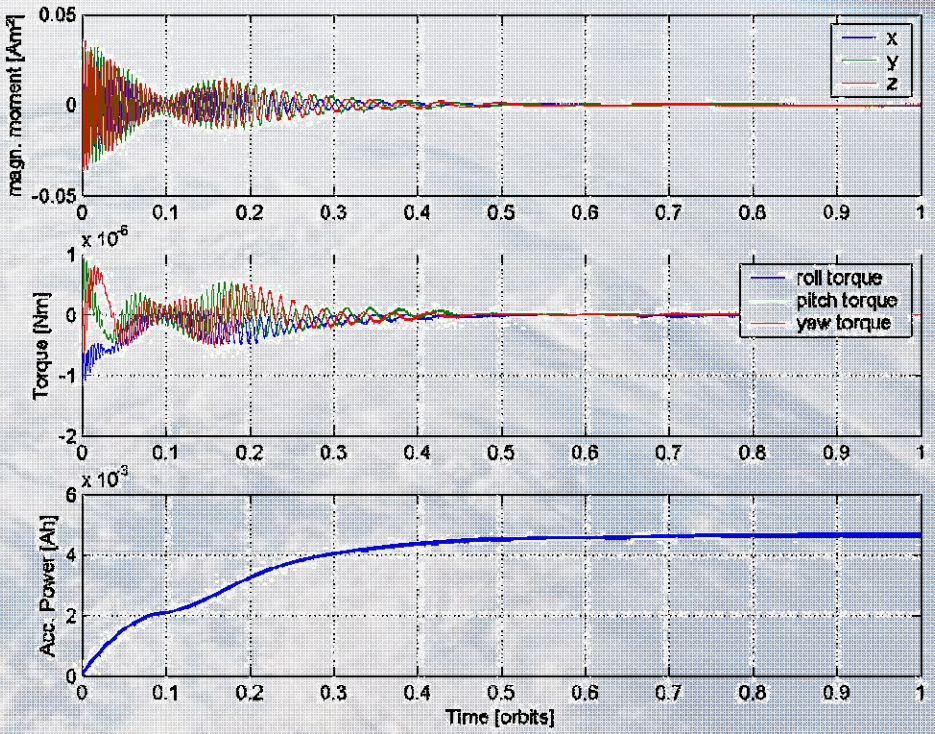
- 16-bit CPU with integrated co-processor
- 32kbyte internal RAM
- 32MHz bus clock
- low voltage
- 2Mbyte external Flash ROM

Detumbling
(Dumping of Angular Momentum during initial Mission Phase)

Magnetometer → state variable filter → B-dot Control Law → Magn. moment Coil currents







Outlook and Conclusion

- With the help of the local amateur radio club (DARC Aachen) a ground station system for satellite communication will be constructed at the FH Aachen in the next months.
- The Engineering Models of the satellite will be finished by end of 2005, with the integration phase commencing in 2006.
- Launch readiness is in June 2006.
- The project work provides excellent hands-on experience in space engineering subjects and team work.
- More than 25 students have participated in this project so far.

Thank you!
…and thanks to our sponsors: