A Technical Background of the ZACUBE-i Satellite Mission Series

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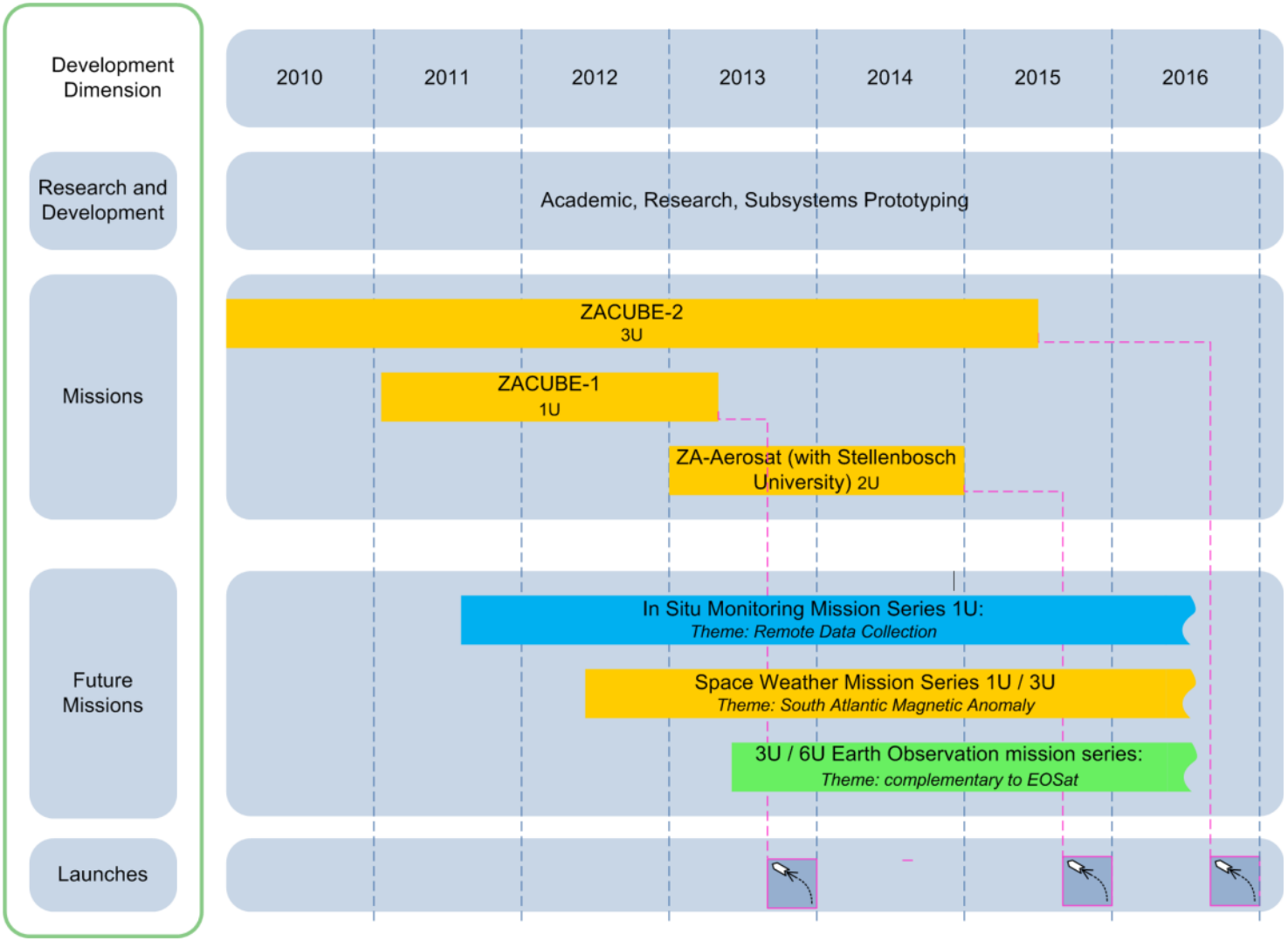
Agenda

- Roadmap
  - In situ monitoring
  - Remote sensing
  - Space weather
- Enabling Infrastructure
  - Ground station
  - AIT
  - Mission assurance
- CubeSat missions
  - ZACUBE-1
  - ZACUBE-2
- Enabling technologies
  - Comms
  - ADCS
  - Propulsion
  - Radiation testing and hardening techniques

ZACUBE-i Roadmap



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Faculty of Engineering

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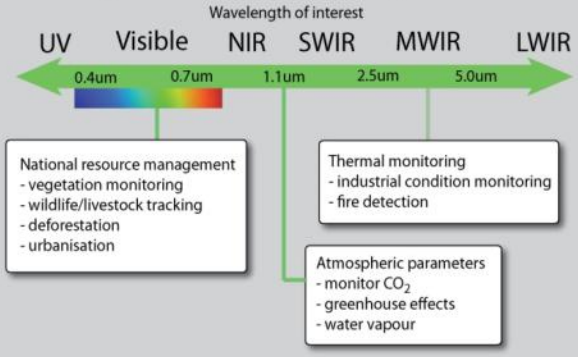
Nano-Satellite Constellations for Monitoring Climate Change Impact on Africa

Multi-Spectral Remote Sensing

Monitoring temperature, CO_2 levels, precipitation and ocean levels is important as it indicates a change in the Earth's climate.



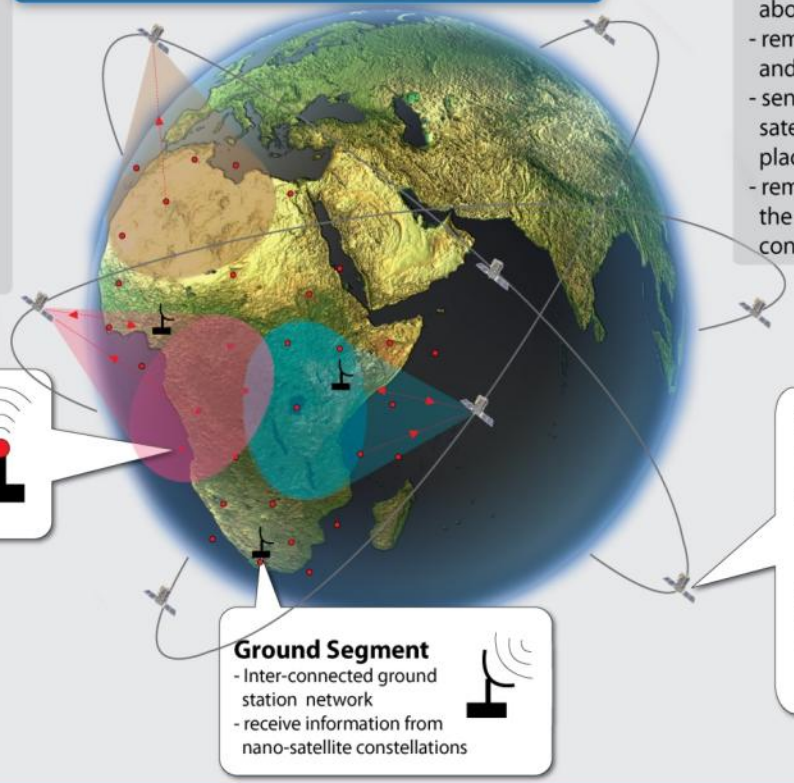
CHALLENGES

- agricultural and land management
- human and economic development
- disaster monitoring (flooding, fire)
- natural resource management
- climate change monitoring
- environmental protection
- food security

What is different to existing solutions?

- comparatively low cost solution
- high temporal resolution (≈ 1 hour revisit time)
- medium spatial resolution (≈ 25m)
- developed in Africa as a technology driver
- distributed ground support (continent wide)

Africa is one of the world's fastest developing continents. This impacts the climate through increased carbon dioxide emissions, deforestation and pollution. Monitoring climate change and its impact on the environment can help manage these challenges while keeping Africa's carbon footprint to a minimum.



Sensor Node
- monitor atmospheric and environmental conditions
- transmit sensor data to nano-satellite constellations

Ground Segment
- Inter-connected ground station network
- receive information from nano-satellite constellations

In-situ sensor network connectivity

- Earth-based sensor nodes distributed throughout Africa
- sensor networks provide information about the environment
- remote monitoring of desert, ocean, and forest regions
- sensor data is captured with nano-satellite constellations allowing for remote placement of sensor nodes
- remote sensing is possible without the need for existing terrestrial connectivity

Space Segment
- LEO constellations with 9 satellites (3 per orbital plane)

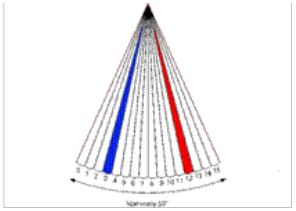
Multi-Spectral Remote Sensing:
- space-based multi-spectral image capture (25m ground sampling distance, 1 hour revisit time)

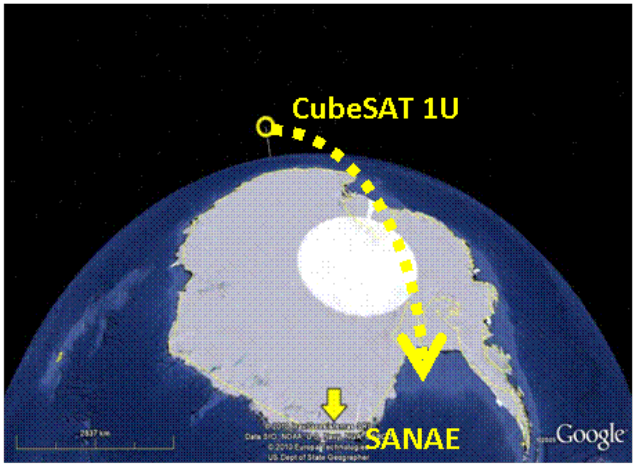
In-situ sensor network
- information is collected from Earth-based sensor nodes and relayed to geographically distributed ground stations

FUNDING BY:
science & technology Department: Science and Technology REPUBLIC OF SOUTH AFRICA
NRF

ZACUBE-i Space Weather Experiments

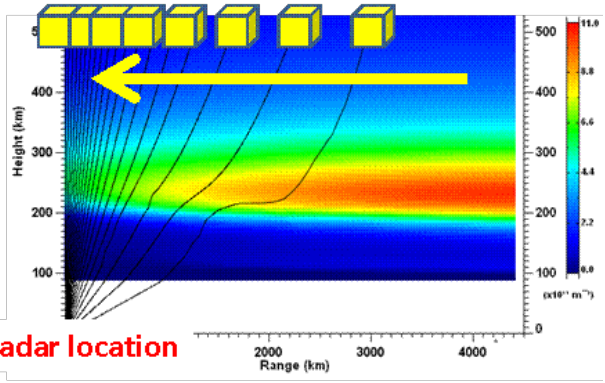
Characterizing the SuperDARN Field-of-View





As the Cube passes through the FoV of the radar it will emit a 14MHz signal that will be received by the radar.

This signal will allow an accurate characterization of the angle of arrival capabilities of the radar



SuperDARN

SuperDARN is an international collaboration of HF radars in the polar regions that measure interactions between the solar wind and the Earth's magnetic field

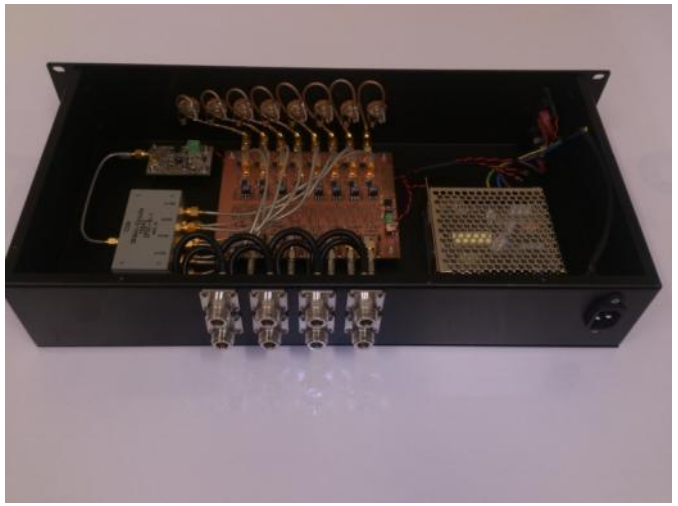
SANSA Space Science, Hermanus

SANAE Base Antarctica

ZACUBE-i Space Weather Experiments

HF Antenna at SANAE-4
Part of the SuperDARN radar network

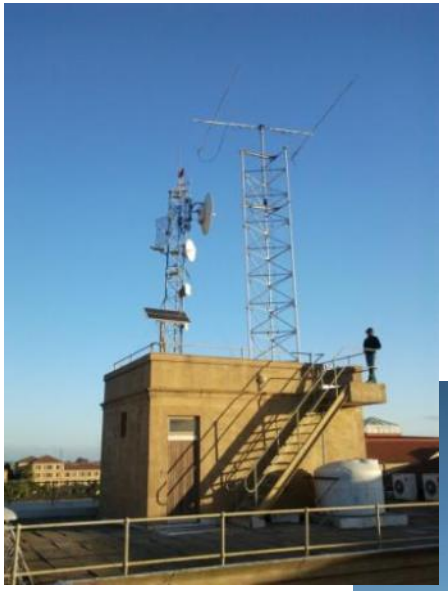
ZACUBE-i Space Weather Experiments



HF Ground Station Antenna Array
Constructed at SANSA, Hermanus
Designed and developed internally

Infrastructure: Ground station

- Typical amateur satellite tracking installation
- VHF / UHF Amateur bands
- Next phase: 2.4 m dish for S-band, C-band dish



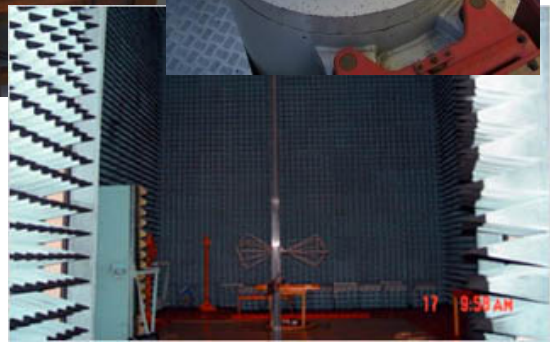
Infrastructure: AIT

- Flight model integration and testing facilities
- Clean room
- New Electrical Engineering building
  - 1000 m² satellite development and production facilities

Infrastructure: Mission Assurance

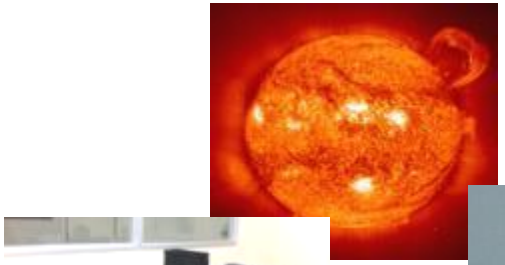
- Access to other facilities in the region
  - Hot vacuum and bakeout
    - iThemba Labs
  - Vibration testing
    - Tellumat
  - EMC testing
    - Anechoic chamber, Houwteq
- To be acquired
  - Thermal chamber
  - Thermal vacuum chamber
- Hardware-in-the-loop testing
  - To be established by newly appointed research chair as a national facility



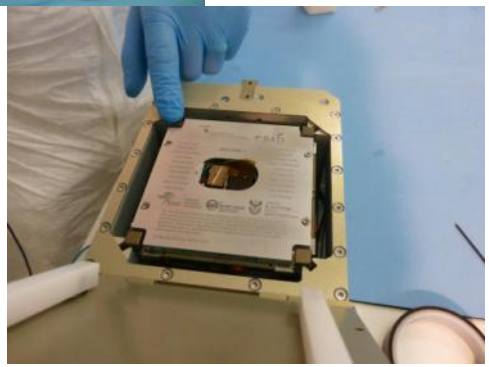



ZACUBE-1 mission objectives

- Space weather mission
  - Initiate HF ionospheric propagation studies of ZACUBE-i series
  - SuperDARN characterisation
- Skills development
  - Postgraduate students
  - Establish infrastructure
  - Professional development
  - Building legacy
- Technology demonstrator
  - Deployable HF antenna
  - UHF/VHF transceiver
- Camera
  - Awareness
- Research output
  - Conferences, journals, patents



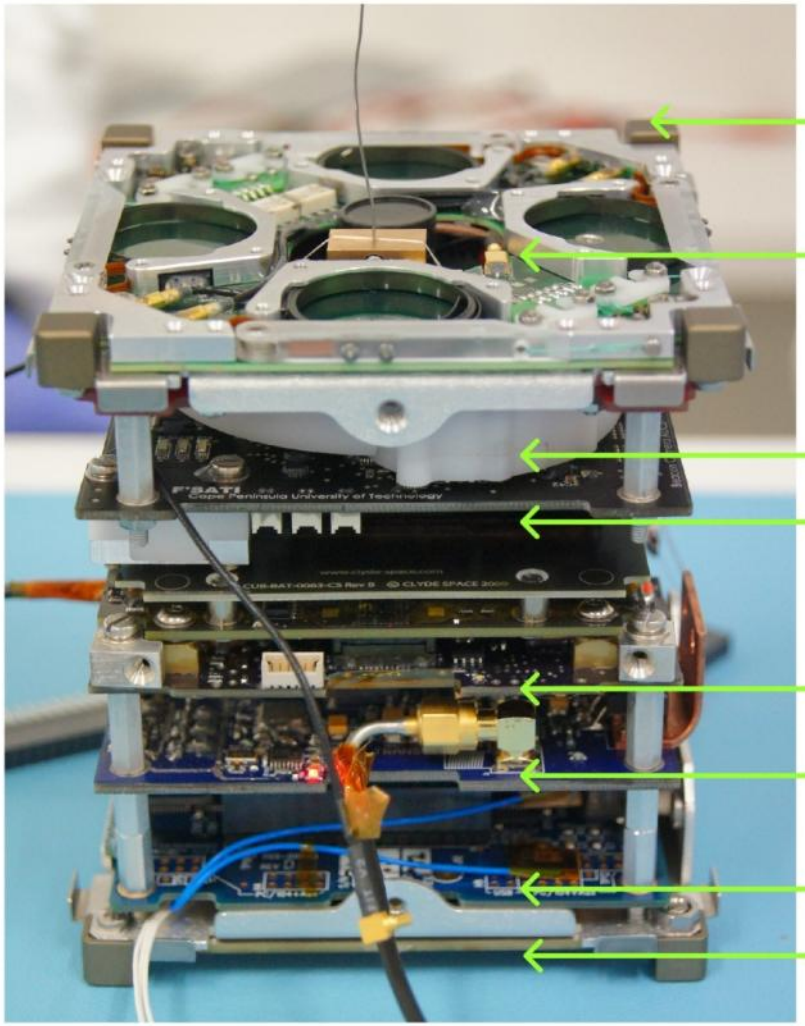


Time line

- ZACUBE-1
  - 2011/12
  - 30 000 man/hrs

ZACUBE-1 layout



Deployable magnetometer

ISIS deployable VHF/ UHF antenna

Deployable HF antenna, beacon transmitter electronics and VGA camera

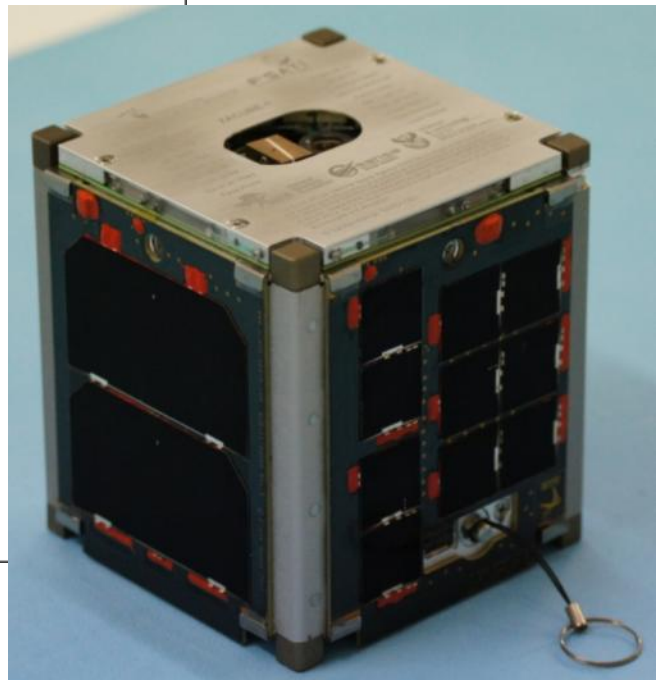
Magnetic ADCS with torquer coils

Clyde Electronic Power Supply (EPS)

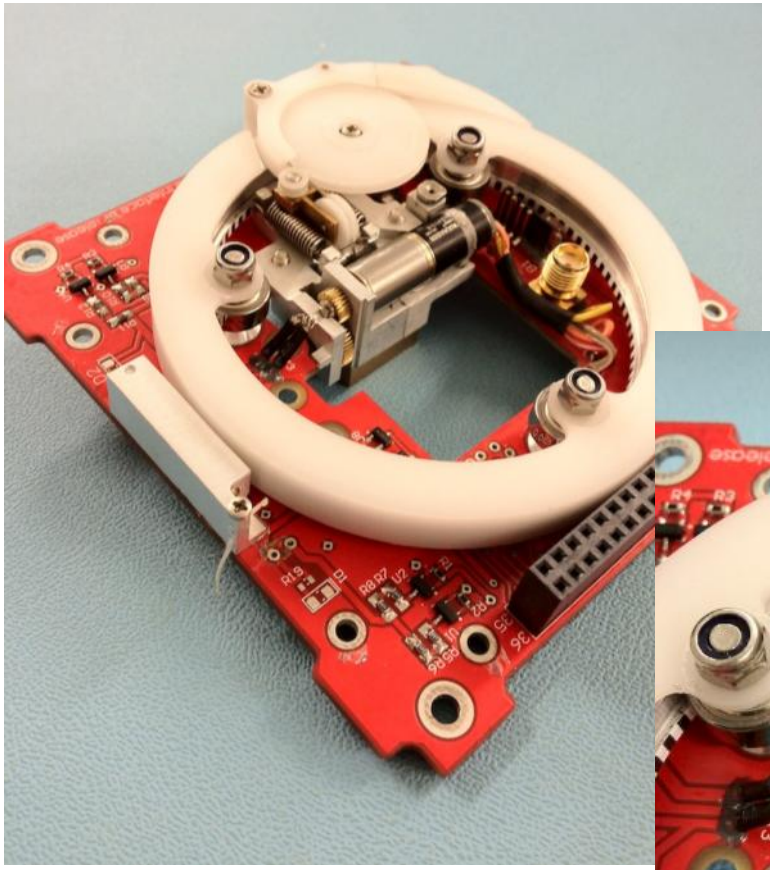
VHF/UHF communications module

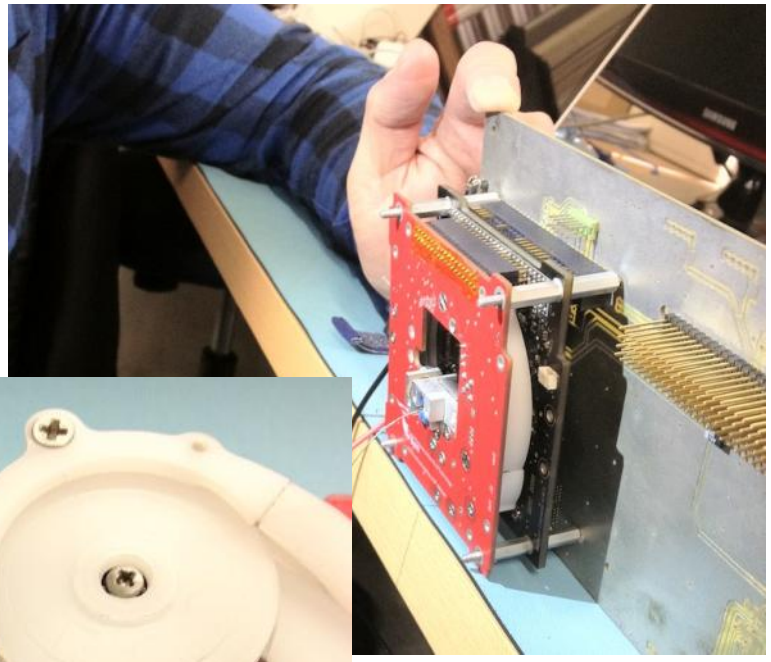
Pumpkin On-Board Computer (OBC)

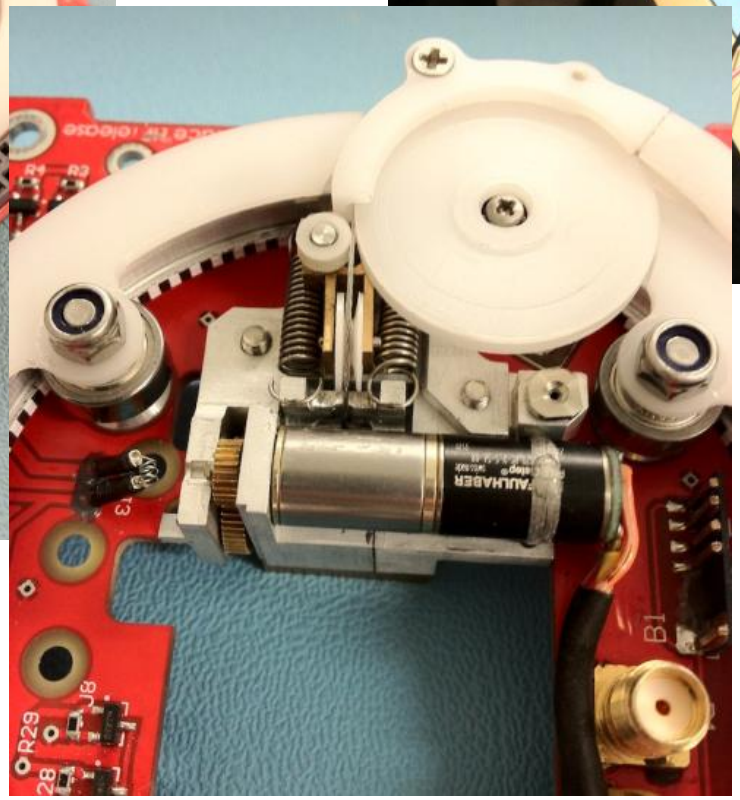
Pumpkin structure



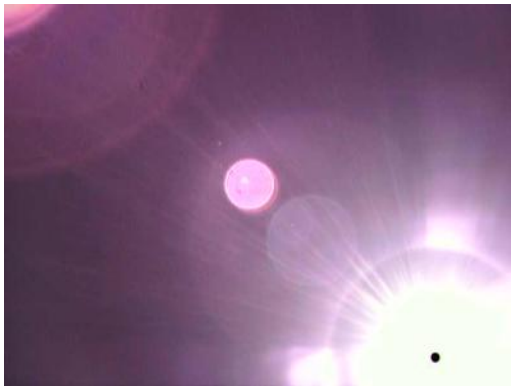
ZACUBE-1 HF beacon

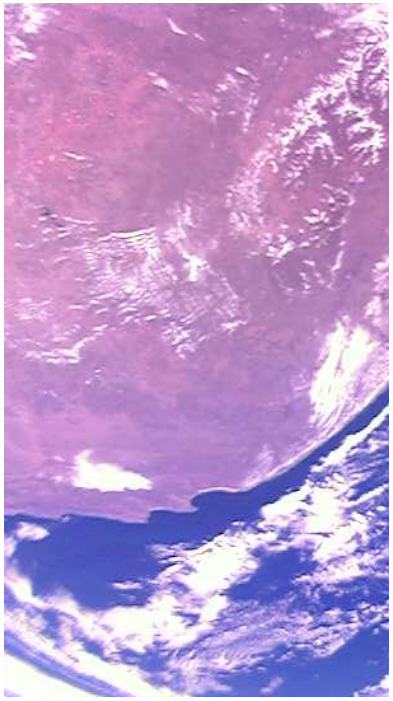


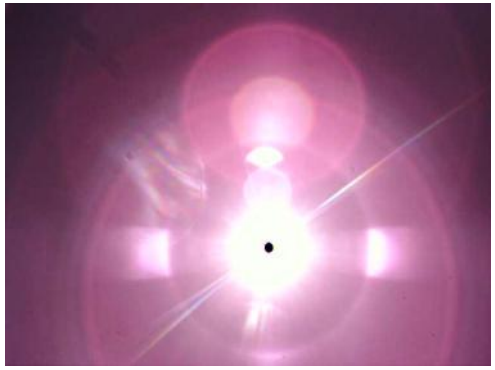




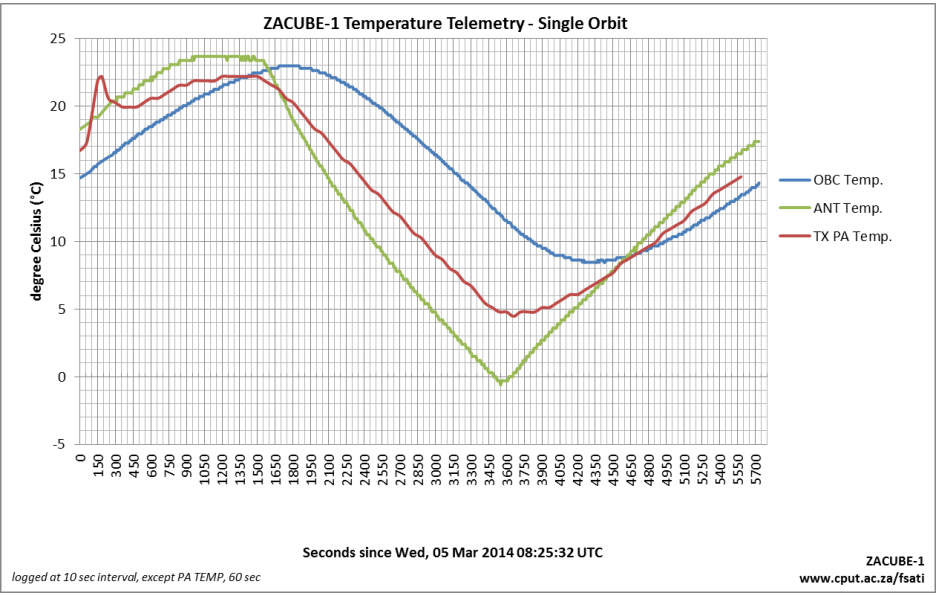
ZACUBE-1 Images

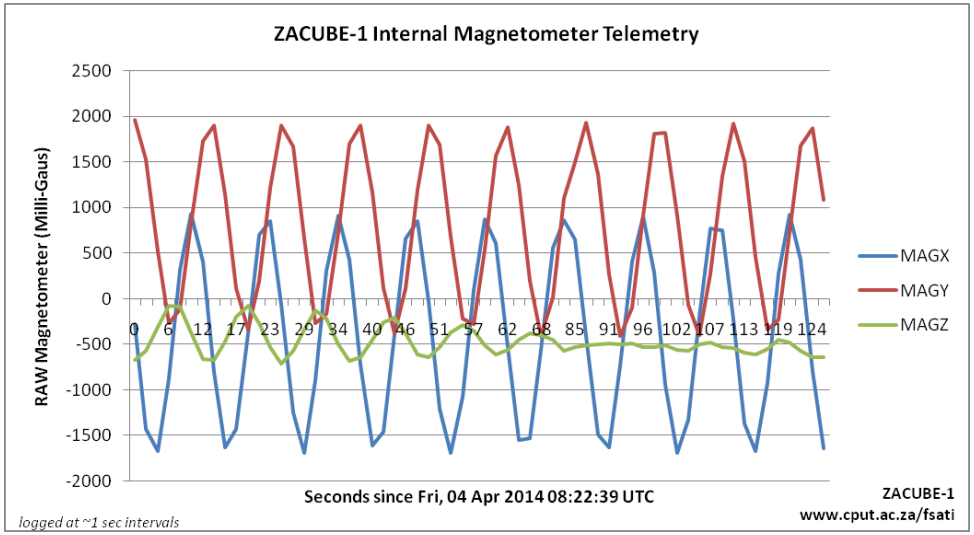


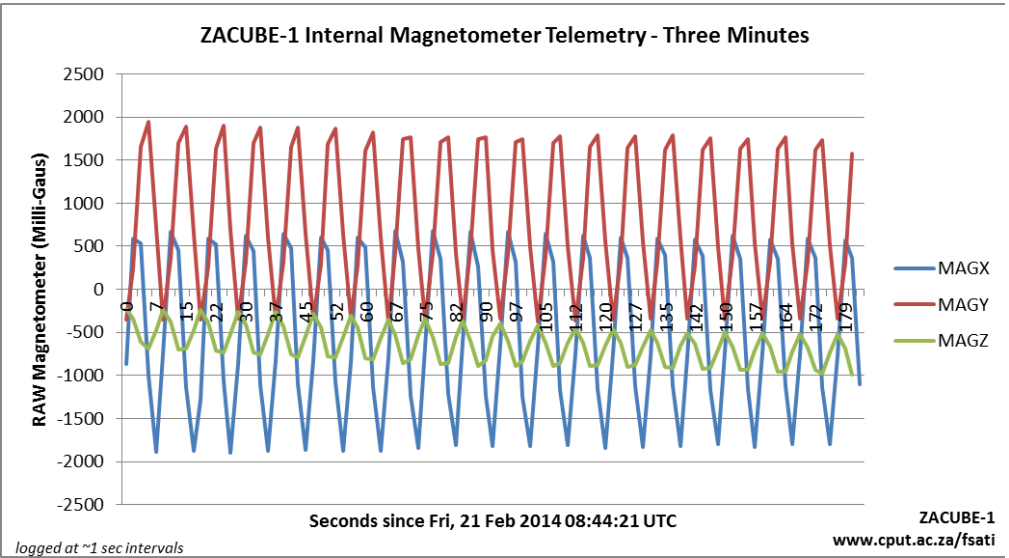


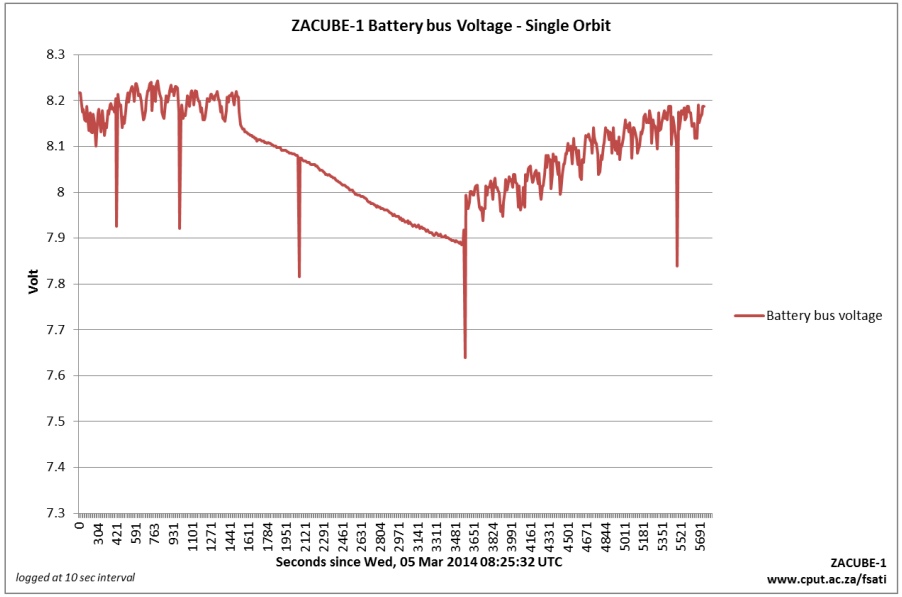


ZACUBE-1 Telemetry



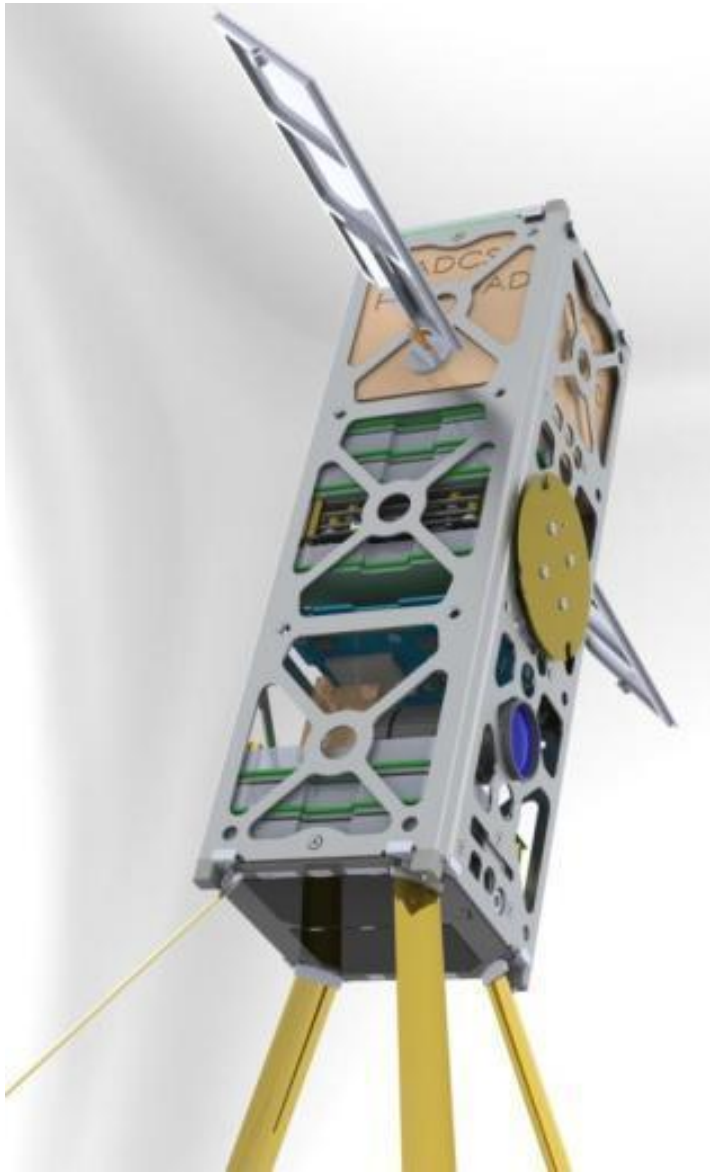




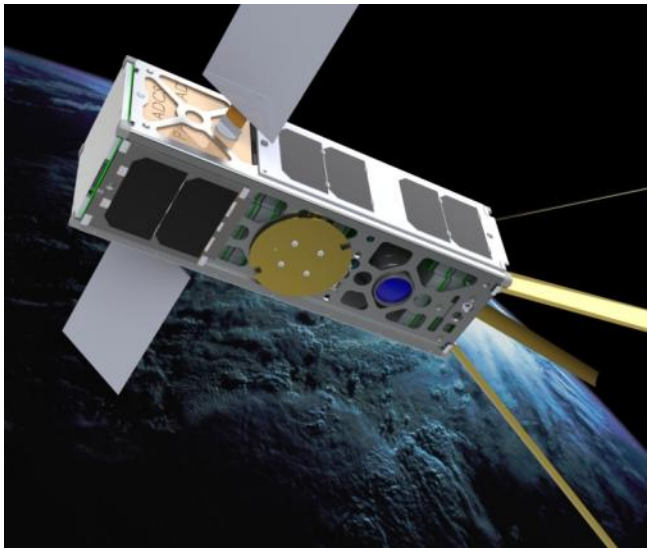


ZACUBE-2

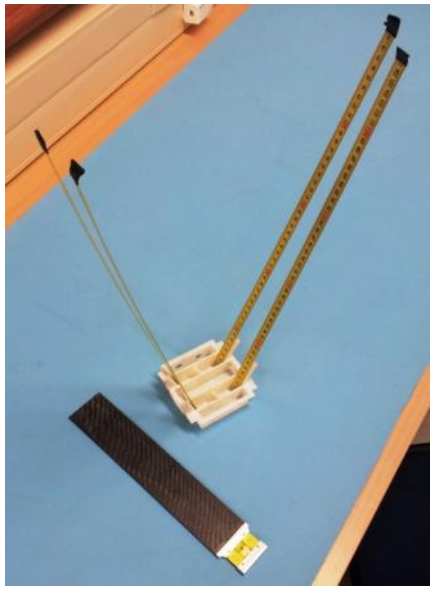
- 3U CubeSat
- S-Band Transmitter
- ADCS System Developed by ESL at Stellenbosch University
- L-Band Receiver
- VHF/UHF Communication System
- HF Beacon Payload
- On-Board Computer (OBC)
- 5 MP Camera Payload

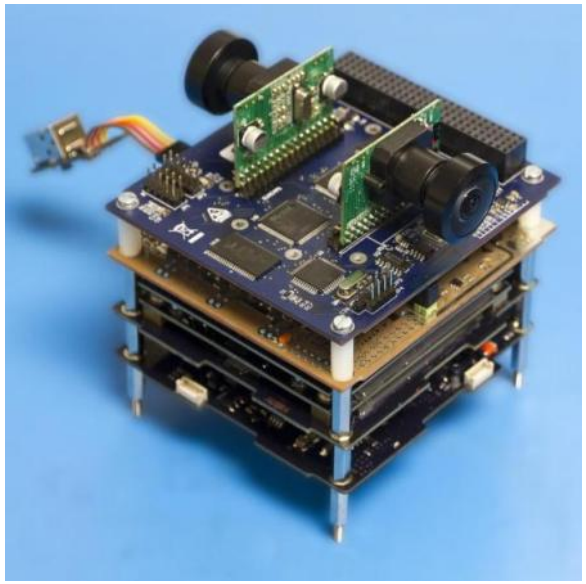


ZACUBE-2



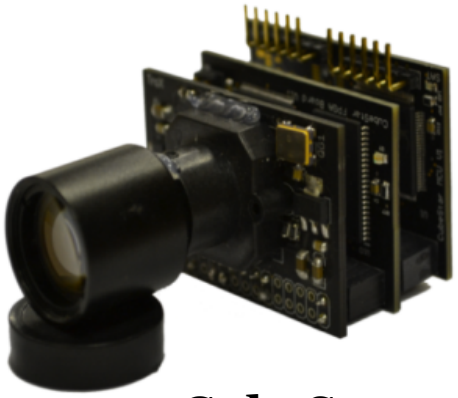
- ADCS
  - Unique control method using aerodynamic drag
  - Deployable UHF / L-band antennas also serve as stabilising tail feathers
  - Deployable side panels control roll angle
  - Full redundant backup with magnetorquers and reaction wheels.
  - CubeSense ADCS sensor module
- Space weather sensors to be determined
- Collaboration with other institutions/universities in SA, Europe and America
- Government approved funding for development

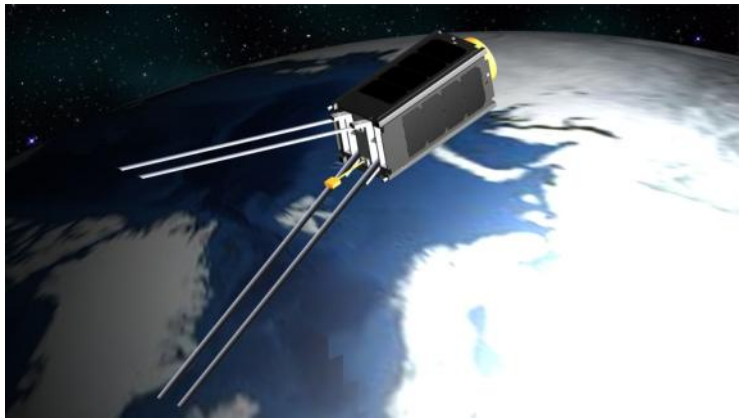




QB50 Participation

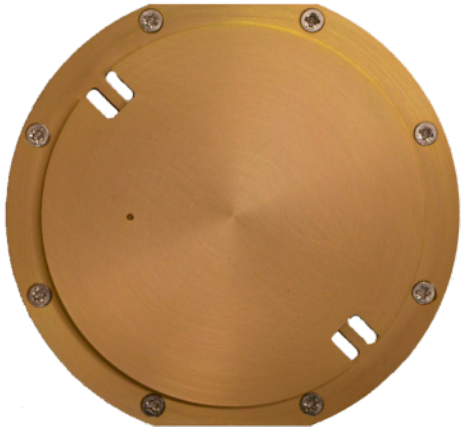
- QB50 mission
  - 50 International CubeSats with science payloads to model the upper layers of the thermosphere
  - Launch January 2016
- ZA-AeroSat (Africa's only contribution to QB50)
  - SU project to design and manufacture 2U CubeSat
  - F'SATI supplies comms payload – TT&C transceiver (CMC) and deployable antenna system
  - Demonstrate passive aerodynamic stabilisation (antennae used like plumes on a shuttlecock)
  - Fipex science sensor and new CubeStar star tracker

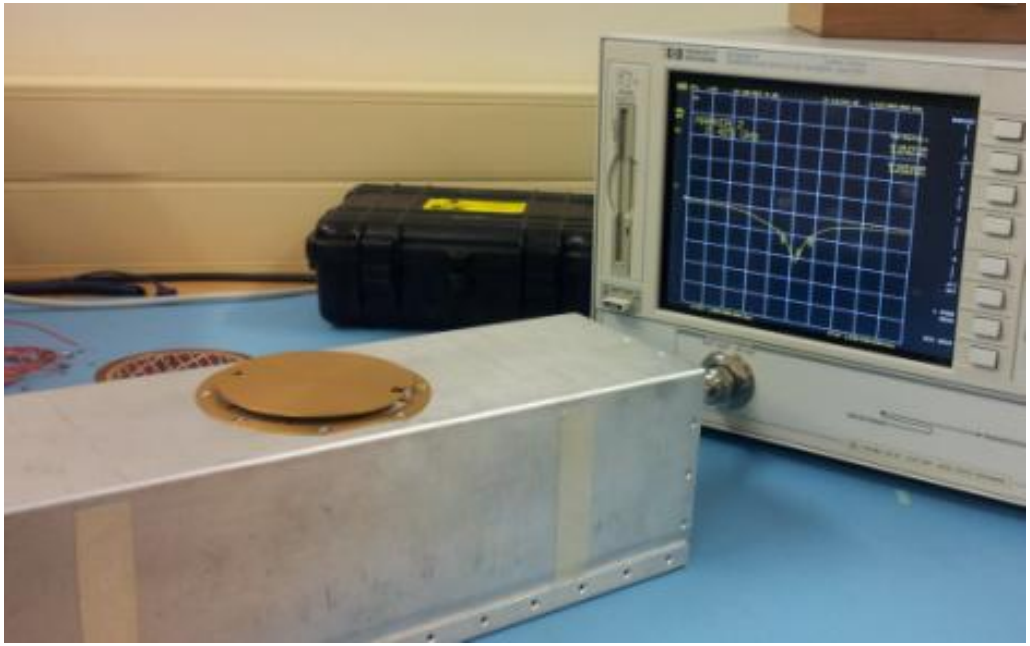




Enabling Technology: Communications

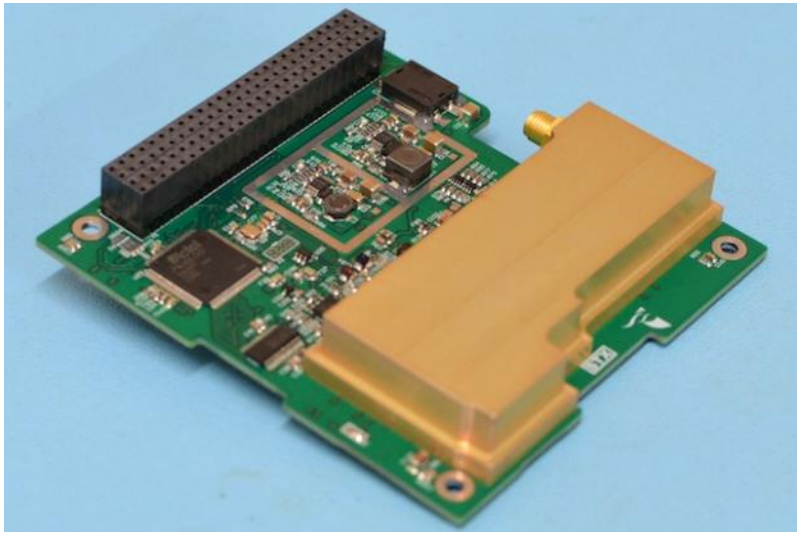
- S-band shorted annular ring patch antenna
- 7 dBi gain
- Circularly polarised
- Light weight: 17.2 g without screws
- 89 x 83 x 4.3 mm

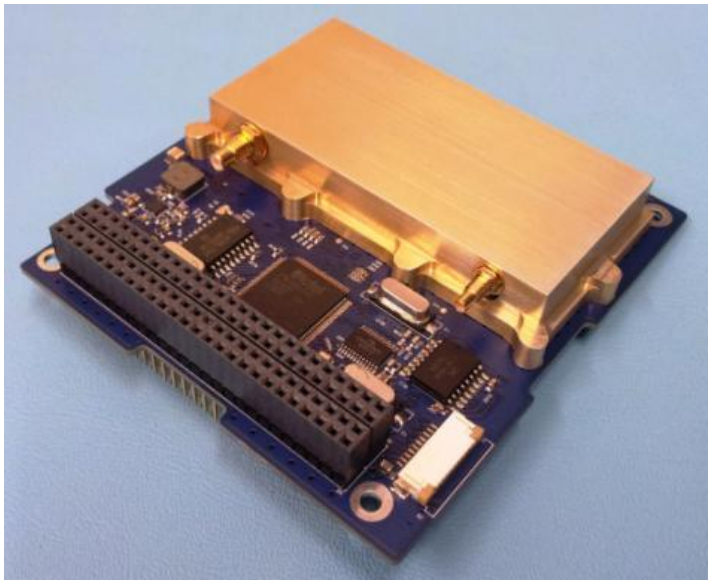




Enabling Technology: Communications

- S-band transmitter for large amounts of payload data
  - 2 Mbps / 1 W RF transmit power
  - QPSK modulation
  - FEC
  - Future improvements
    - 50 Mbps downlink
    - SDR
    - Transceiver: 10 Mbps uplink
- UHF / VHF transceiver for telecommand / telemetry
  - 1.2 kbps AFSK or 9.6 kbps GMSK amateur radio transceiver





Enabling Technology

- Nanosatellite propulsion, debris mitigation
  - Wits University
- ADCS
  - ESL, Stellenbosch University
- Radiation testing and hardening
  - iThemba Labs
  - University of Pretoria
- Advanced manufacturing and nano-tech
  - NLC, ALC

Future nano-sat missions

- Nano-satellite ***constellations*** provides a ***paradigm shift*** from existing platforms:
  - High temporal resolution / medium ground sampling resolution
    - 30 min / 20 m vs. 8 hours / 10 m
  - Shift in applications
  - Technology threshold low
  - Can be done by Africa, for Africa, in collaboration with our international partners


The End