Cape Peninsula University of Technology

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CPUT's Satellite Programme.

One SMART CPUT

NATIONAL SPACE CONFERENCE

30 August to 01 September 2023

CSIR ICC, Tshwane, Pretoria, South Africa

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African Space Innovation Centre (ASIC) at CPUT “niche area” is the nanosatellite engineering technology

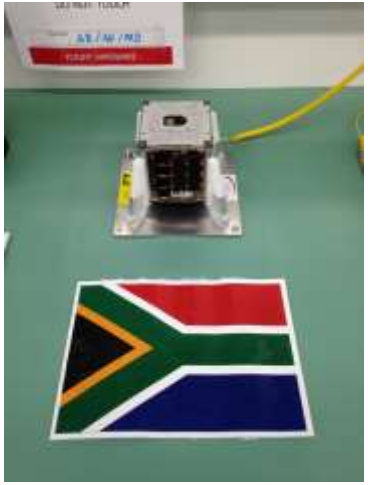
CPUT utilised this centre as post graduate training facility in satellite engineering.

Successfully demonstrated with the first SA’s student nano satellite mission:

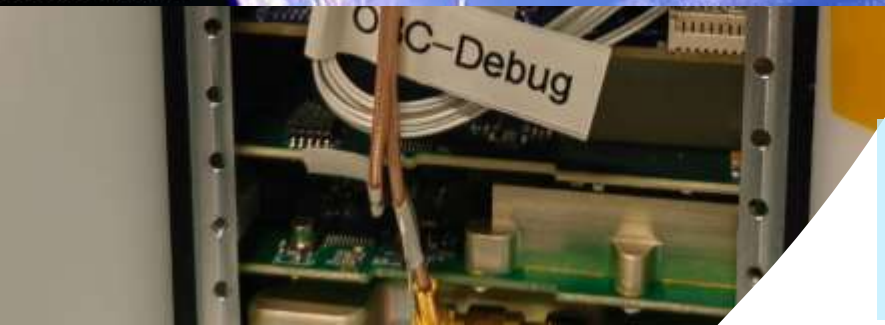
ZaCube 1: Tshepiso Sat

(launched Nov 2013)

- Primary payload: HF Beacon
- Hosted payload: Visible Spectrum Imager



ZaCube-1 payload descriptions.



Zacube-1 – Primary payload.

- SANSA (HMO) operates an HF space weather radar at the SANAE base in Antarctica (Dual Auroral Radar Network).
- 16 element antenna array to transmit signals into the ionosphere.
- Analyse ionospheric density over time
- The whole antenna array is hundreds of meters in size and very difficult to characterise on the ground.
- One solution to characterising the array was to emit a beacon signal from a satellite and measure the signal received by the array.

ZaCube-1 – Secondary payload

- The imaging payload captured images of the earth's surface and stores these images on-board in a digital format for download.

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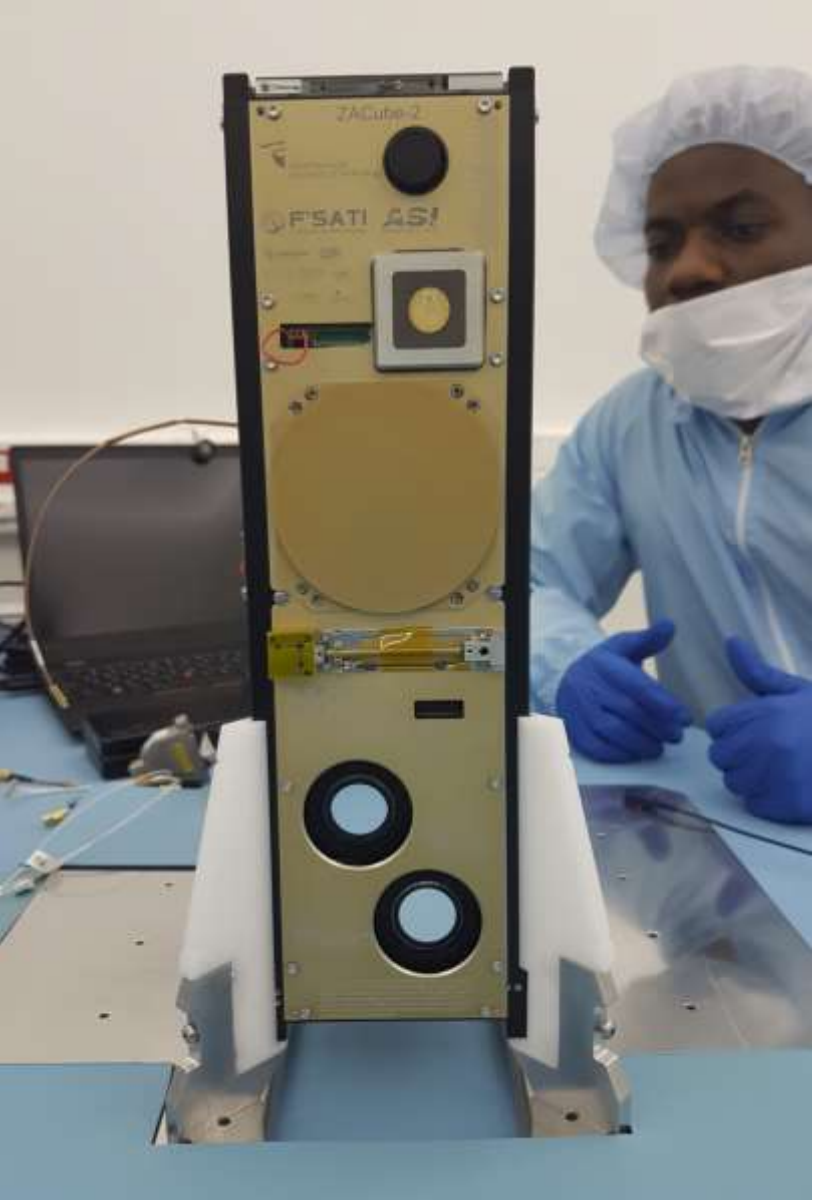
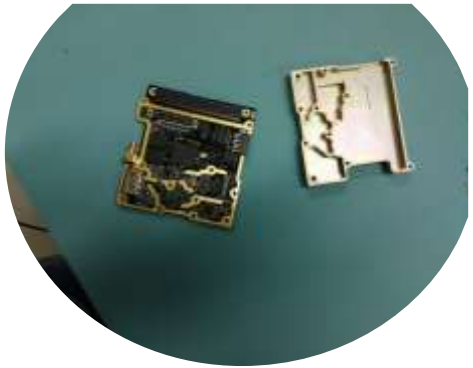


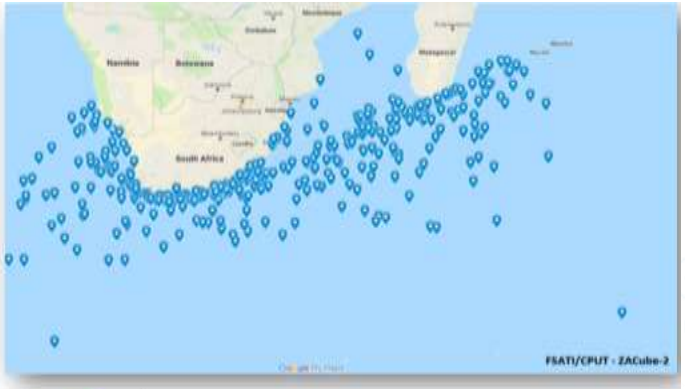
South African Oceans Economy through ZaCube-2 Demo mission

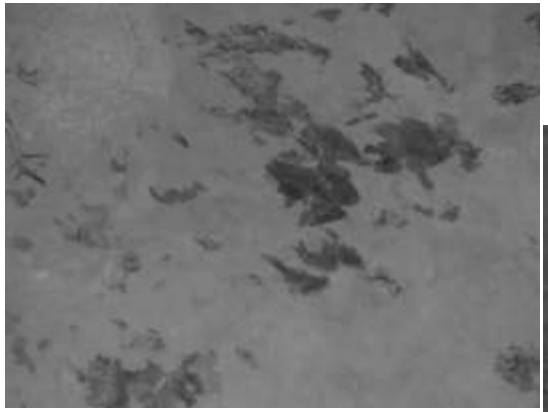
- Operations Phakisa (Maritime Domain Awareness)
  - Operation Phakisa is an initiative of the South African government.
  - It is a fast results delivery programme that was launched in July 2014 to help implement the National Development Plan.
  - It is a cross-sector programme where various stakeholders engage to implement initiatives that would enhance the development of SA's economy.
  - Oceans economy was identified as one of these initiatives.
  - A need was identified under Operation Phakisa's Marine protection services and governance (MPSG) focus area.
  - MPSG Lab developed 10 key initiatives, one of which is the National Ocean and coastal information system (OCIMS) and as the extension of earth observation capacity.

ZaCube-2 Payload Technology Demonstration

ZaCube-2: Launched 27 Dec 2018







ZaCube-2 mission objectives were re-aligned and augmented to allow the satellite to function as a precursor mission for the Operation Phakisa “MDASat” constellation. ZACUBE-2 was utilised as a technology demonstrator for essential subsystems required in operational nanosatellite missions.

- Primary payload - AIS capability utilising an SDR.
  - Software defined radio utilized to receive AIS massages from Ships
  - Over SA’s exclusive economic zone.
- Hosted payload – K-line Near Infra-Red Imager demo.
  - Vegetational fire detection
  - Imager operates in part of the light spectrum where Potassium emissions are found and be detected.

Maritime Domain Awareness Satellites (MDASat-1)

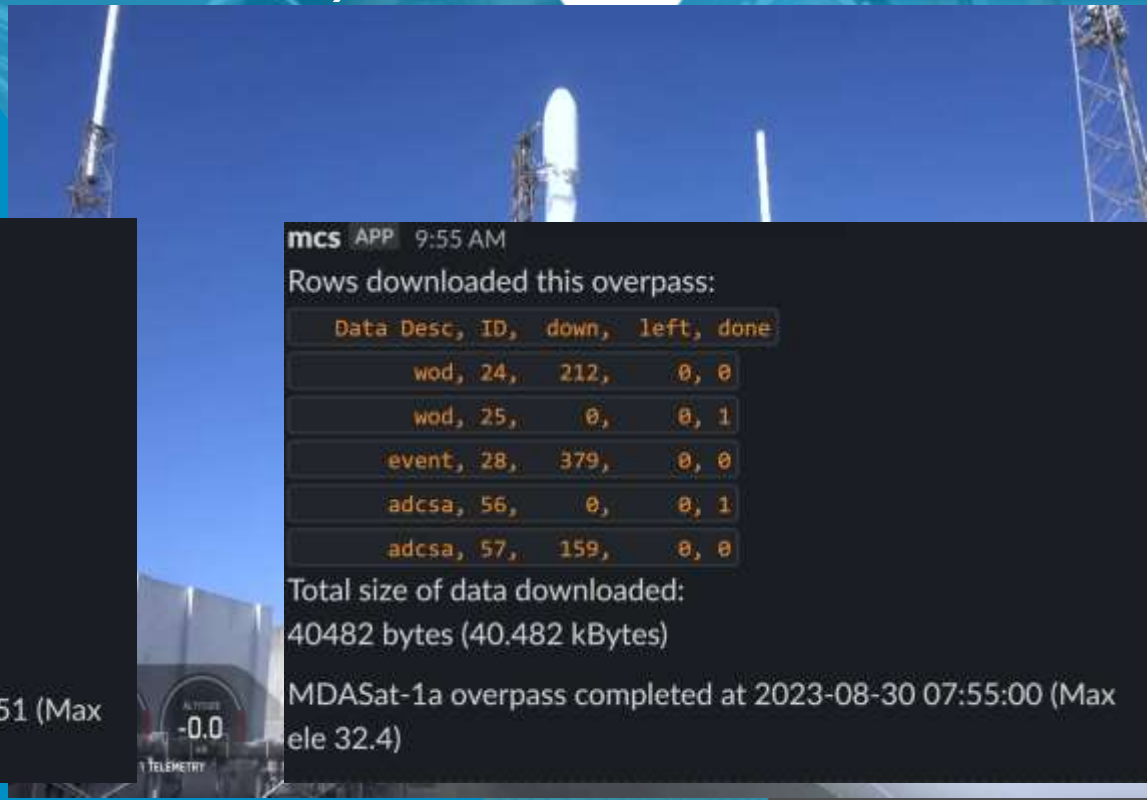
MDASat was built on the heritage of ZACube-2 to demonstrate an expanded capability and data delivery.
- One of the goals of this constellation was to supply data to the OCIMS.
The first 3 satellites of the MDA constellations carried an improved AIS payload compared to ZACube-2, with these additional functionalities and improvements:

- Over-the-air upgrades,
- Capture raw data ,
- Long Range AIS
- Improved efficient messaging scheme.

MDASat-1 (a, b and c) constellation Launched 13 January 2022

Maritime Domain Awareness Satellites (MDASat-1)

Early Operations (Jan and Feb 2022)
Commissioning of MDASAT-1 Complete
Current Operation MDASAT- 1



mcs APP 10:09 AM

Rows downloaded this overpass:

Data Desc, ID,	down,	left, done
wod, 24,	211,	0, 0
wod, 25,	0,	0, 1
event, 28,	5,	0, 0
adcsa, 56,	0,	0, 1
adcsa, 57,	158,	0, 0

Total size of data downloaded:
35807 bytes (35.807 kBytes)

MDASat-1c overpass completed at 2023-08-30 08:09:51 (Max ele 47.8)

mcs APP 9:55 AM

Rows downloaded this overpass:

Data Desc, ID,	down,	left, done
wod, 24,	212,	0, 0
wod, 25,	0,	0, 1
event, 28,	379,	0, 0
adcsa, 56,	0,	0, 1
adcsa, 57,	159,	0, 0

Total size of data downloaded:
40482 bytes (40.482 kBytes)

MDASat-1a overpass completed at 2023-08-30 07:55:00 (Max ele 32.4)

Current study of the constellation and lessons learnt from the deploiment

M2MSat- (VDES) Demonstrator

- Demonstrate machine to machine message transmission (i.e. ship-to-ship).
- Demonstrate machine to hub message transmission (i.e. ship-to-shore).
- Demonstrate hub to machine message transmission (i.e. shore-to-ship).
- Reception of AIS messages in the AIS1, AIS2 and LR-AIS channels.

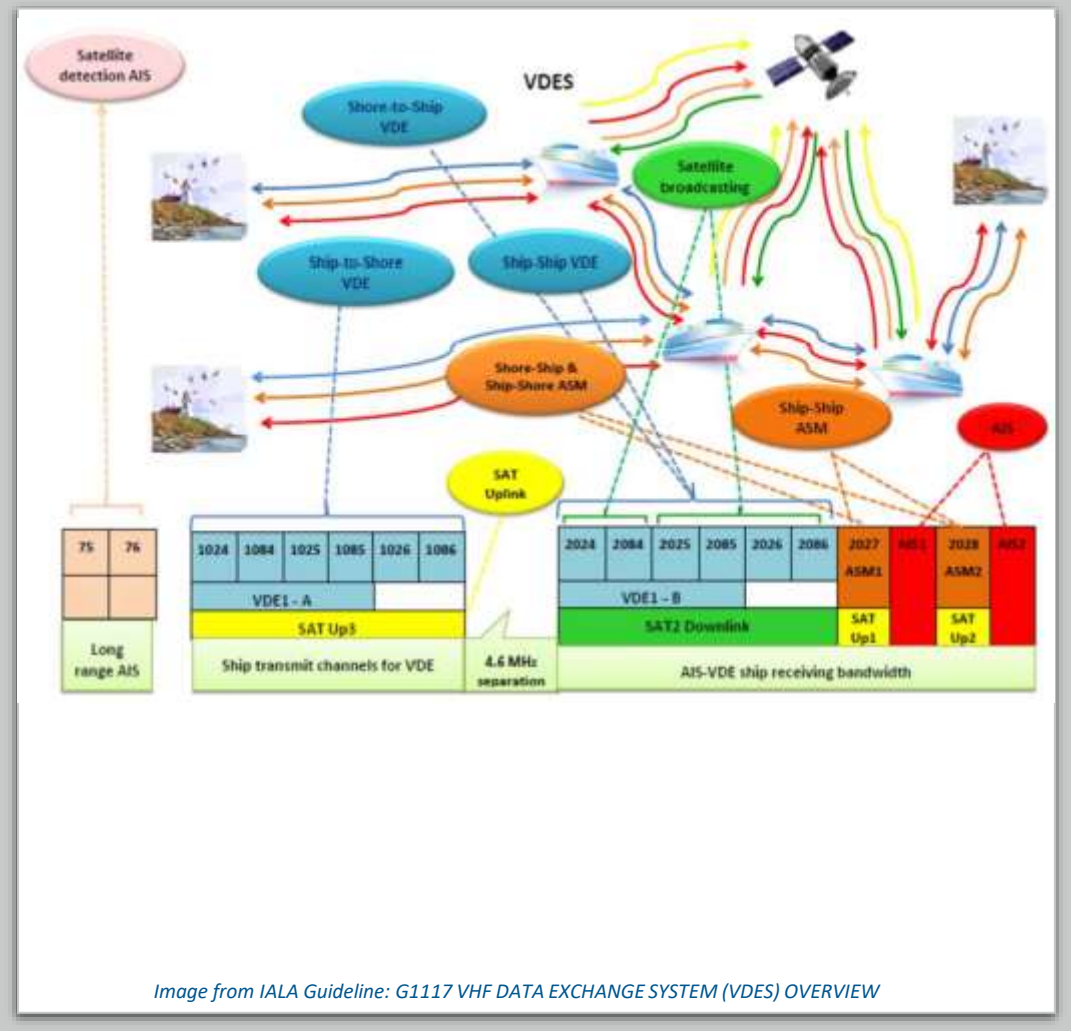
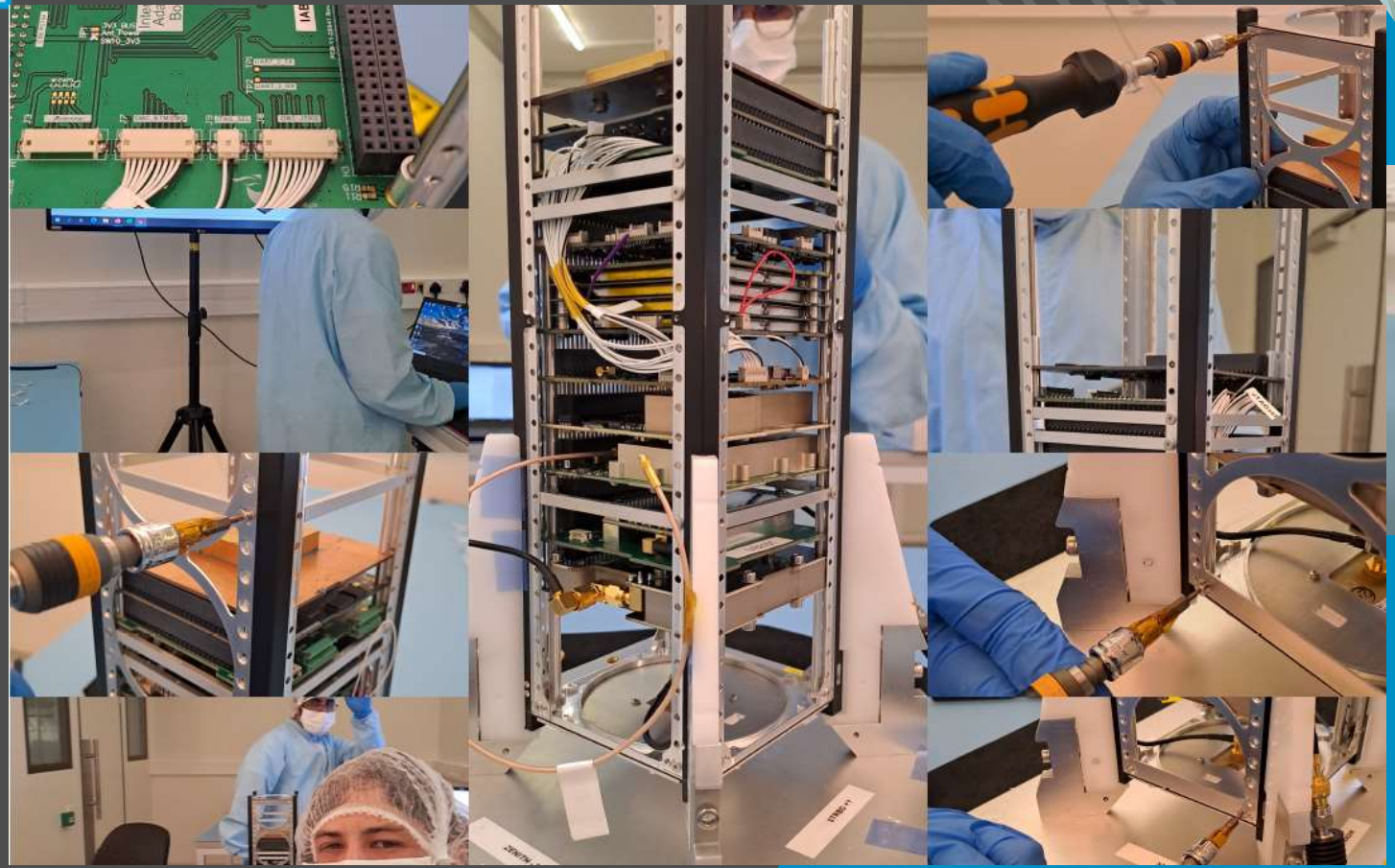


Image from IALA Guideline: G1117 VHF DATA EXCHANGE SYSTEM (VDES) OVERVIEW

M2MSat-1 Development progress
Soft-stack and EQM Integration



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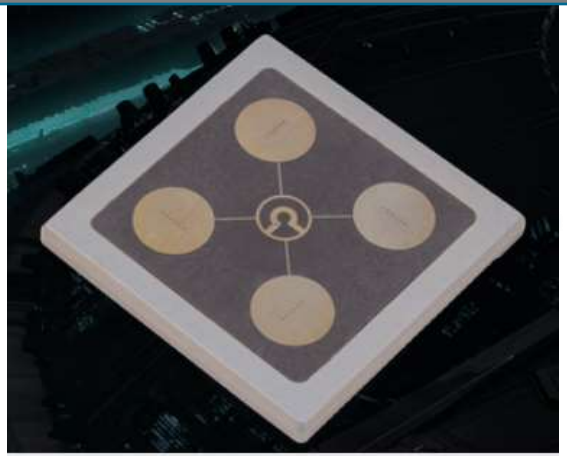
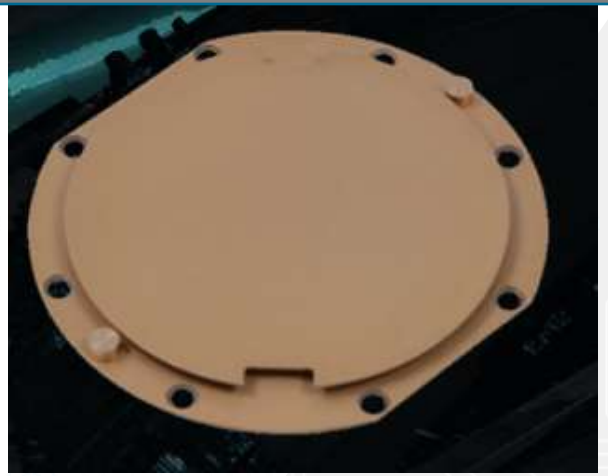
CubeSat Communication Subsystems S-Band and X-Band Antennae

Off-the-shelf nanosatellite products generated from the ASIC programme





General	XANT	XANT-PLUS
Frequency Range	8.025 GHz – 8.45 GHz	8.025 GHz – 8.45 GHz
Bandwidth	200MHz	425MHz
Temperature	-40°C to +85°C	-40°C to +85°C
Mass	< 9 g	< 29 g
Gain	7.75 dBi ± 0.5 dB	11.5 dBi ± 0.5 dB
Axial Ratio	< 3dB across the band	< 2 dB across the band
S^{11}	< -15 dB	< -14 dB
Polarisation	LHCP / RHCP	LHCP / RHCP
Max RF Power	2W (33 dBm)	5W (37 dBm)
Connector Type	Straight SMP	Straight SMP
Design Life	2 years in LEO	2 years in LEO
Width	36 mm	58 mm
Height	4.7 mm	4.7 mm
Length	36 mm	58 mm

General	
Frequency Range	2.2 – 2.3 GHz (SANTCI) 2.4 – 2.45 GHz (SANT)
Beamwidth	60°
Temperature	-40°C to +85°C
Mass	< 50 g
Gain	7 dBi
S^{11}	< -15 dB
Connector	SMA female
Design Life	> 2 years in LEO
Dimensions	1U form factor

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CubeSat Communication Subsystems
VHF/UHF and S-band Radios

General	
Operating Temperature	-25°C to +61°C
Mass	< 100 g
Voltage	3.3 V, 5 V
Frequency	
UHF	400 – 420 MHz (UTRXC) 430 – 440 MHz (UTRX)
Transmit	
DC Power	3 – 5.1 W (27–33 dBm)
RF Power	27 – 33 dBm (3 dB steps)
Channel Spacing	25 kHz
Spurious Responses	< -45 dBc
Frequency Deviation	3 kHz (FM)
Frequency Stability	± 2.5 ppm
Receive	
DC Power	<240 mW
Sensitivity	-115 dB dBm for 12 dB SINAD
Channel Spacing	12.5 kHz
Noise Figure	<2.5 dB
Dynamic Range	-115 to -70 dBm
Frequency Stability	± 2.5 ppm

Performance	
Processing	• Low-power Flash based FPGA • CRC-16-CCITT (AX.25) • Scrambling (DMSK) • Transparent downlink mode • ½ Rate CCSDS convolutional encoding (k=7) available in transparent mode
Interfaces	• I2C Bus – 400 kHz (telemetry, command and user data) • Receive Ready output line • Transmit Ready output line
Modulation & Protocol	• GMSK (9k60 baud) • AFSK (1200 baud) • AX.25 Protocol • Transparent mode

Dimensions	
Length	96 mm
Width	90 mm
Height*	16.51 mm

*Height from top of enclosure to lowest component on bottom.

General	
Temperature	-25°C to +51°C
Power	< 5 W
Voltage	6 V – 12 V (5 V alternative)
Mass	< 100 g
TX SNR	20 dB
Frequency	2.2 GHz – 2.3 GHz (PULSAR-STXC) 2.4 GHz – 2.45 GHz (PULSAR-STX)
RF Power	24 - 30 dBm (1 W RF) in 2 dB steps
Channel Spacing	500 kHz
Spurious Response	< -60 dBc
Design Life	2 years in LEO

Performance	
Processing	• Low-power Flash-based FPGA • V.35 IntelSAT scrambler • ½ rate convolutional encoding (K=7) • Differential encoding • Pulse shaping filter
Interfaces	• Low-speed I2C Bus – 400 kHz (telemetry and control) • High-speed SPI Bus – 4 MHz (payload data) • 50 Ω SMA connector
Modulation	• QPSK or OQPSK • IntelSAT IESS-308

Dimensions	
Length	96 mm
Width	90 mm
Height	16.9 mm

*Height from top PCB to lowest component

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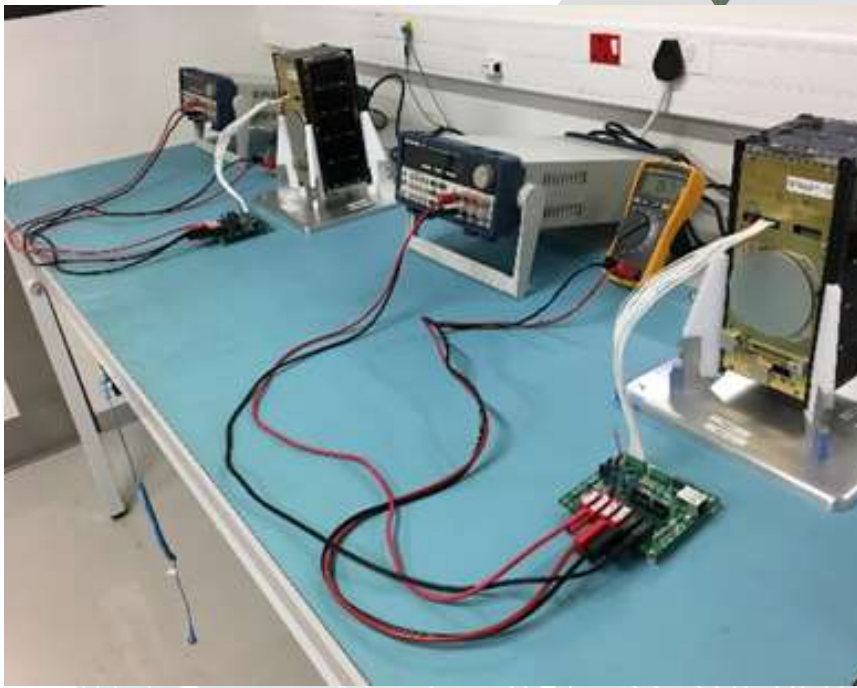
Engineering Research Facilities

(1) Production area



(2) FM area

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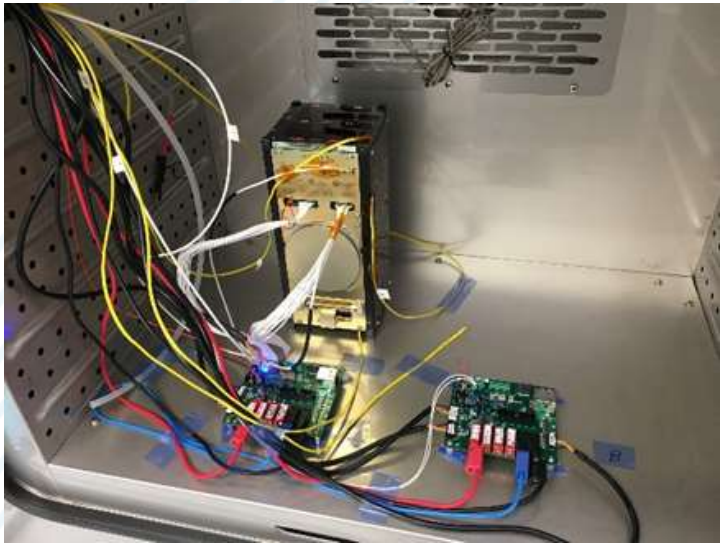
Engineering Research Facilities

(1) Clean room

(2) Ground station
Supports:

- VHF, UHF, and S-band
- 1.2kbps AFSK and 9.6kbps GMSK uplink or downlink.

Engineering Research Facilities



(1) Thermal cycle chamber

(2) Workspaces and classrooms

Conclusion

The satellite missions presented here are displaying progress towards developing a sovereign capability in space technology development and educational training for developing countries like South Africa.

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REPUBLIC OF SOUTH AFRICA

technology innovation AGENCY

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ASTROFICA TECHNOLOGIES

StoneThree
The Future of Work. Now.™

Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

AAC CLYDE SPACE

one SMART CPUT

THANK YOU
BAIE DANKIE
ENKOSI

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