Afri-nano³

Leveraging NANOscience, NANOtechnology and NANOsatellites for Africa-Centred Remote Communications Solutions

I. Tadadjeu Sokeng *et al*.

French South African Institute of Technology/Cape Peninsula University of Technology

UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology, College of Graduate Studies, University of South Africa

iThemba LABS-National Research Foundation

Cape Peninsula University of Technology

F'SATI French South African Institute of Technology

UNISA university of south africa

NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

Background

- Problem: In sub-Saharan Africa, there is a dire need for people to be able to request urgent assistance for medical and/or safety reasons.
    - **Having access to such a service will help manage situations like the recent and on-going Ebola crisis in West Africa**

- Proposed solution: A dedicated space mission offering near real time connectivity in sub-Saharan Africa with micro- and/or nanosatellites

Background (cont)

- Further problem: Given the financial limitations of Africa, it is imperative to increase mission functionality per unit mass
- Most used solution today: Nanotechology and nanoscience [1,2]
- Can we do it in Africa? YES! Africa has significant nanoscience and nanotechnology research capabilities which are not yet leveraged for space applications [3,4]

[1] M. Meyyappan, Interview in Physics world. Nanotechweb.org. 6 March (2013)

[2] R.H. Baughmann, A. A. Zakhidov, W. A. de Heer. Carbon nanotubes-the route towards applications. *Science*, 297(5582), 787-792 (2002)

[3] B. W. Mwakikunga, S. Motshekga, L. Sikhwivhilu, M. Moodley. M. Scriba, A. Simo, B. Sone, M. Maaza, S. S. Ray. A classification and ranking system on the H_2 gas sensing capabilities of nanomaterials based on proposed coefficients of sensor performance and sensor efficiency equations. *Sensors and Actuators B: Chemical*, 184(31), 170-178 (2013)

[4] J.B. Kana Kana, J.M. Ndjaka, B.D. Ngoma, A.Y. Fasasid, O. Nemraouia, R. Nemutudi, D. Knoesen, M. Maaza. High substrate temperature induced anomalous phase transition temperature shift in sputtered VO_2 thin films. *Optical Materials*, 32(7), 739-742 (2010)

Background (cont)

- Collaborative concept:

CPUT/F'SATI Designs a communication/connectivity mission with a constellation of micro- and/or nanosatellies. The mission is to be sustainable over a 50 year period of time and have multiple applicability.

Calls are made to universities and research institutions in Africa having space applicable technology to demonstrate. As the constellation is maintained, technology demonstration experiments are included to the satellite designs.

First call answered by iThemba LABS and UNISA

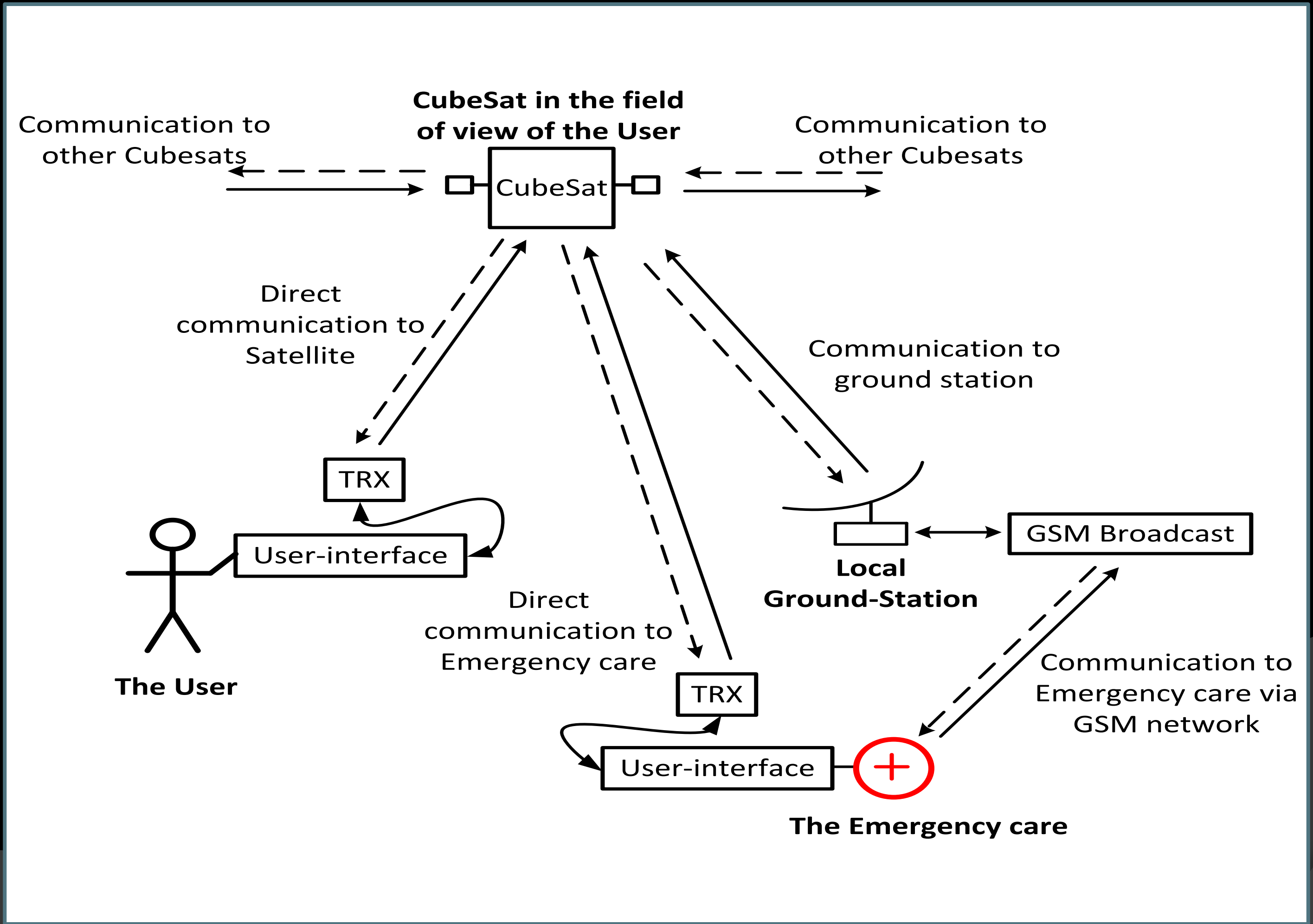
Mission Objectives

- Communications/Connectivity:
  - Ensuring that every point in sub-Saharan Africa is always in view of a satellite.
  - Ensuring that a message can be relayed from one point to any other point in sub-Saharan Africa. The communication links must be scalable to allow for various message content types, and increased number of users (with a variety of cell phone technology generations).
  - The user-interface is text-type messaging with a mobile phone, compatible with 1G onwards.

- Technology Demonstration (first set):
  - Demonstrate Vanadium Dioxide (VO_2) films in space as 0 Watt input power thermal shields ensuring on board temperatures always remain < 70^0C within a VO_2 coated nanosatellite.
  - Demonstrate the use of transparent dielectric resonator antenna arrays in space.

Mission Concept

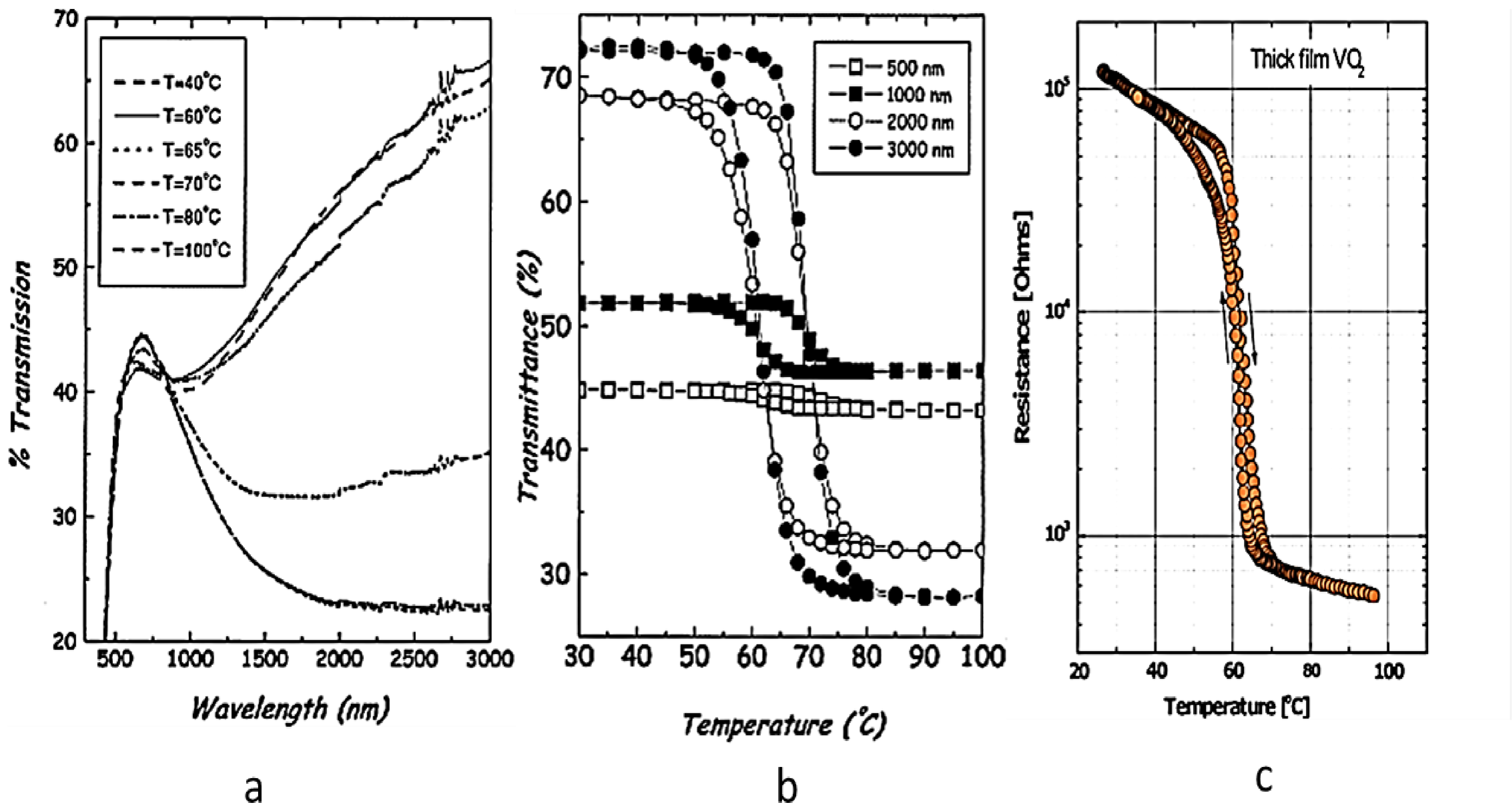
- Cell phones are so prevalent in Africa that they are present even in areas too remote to be part of power grids (and sometimes even out of GSM network range)



Users

- Remote connectivity users:
  - Individuals within sub-Saharan Africa who may find themselves in an emergency situation
  - Emergency care centres
- Technology demonstration users:
  - iThemba LABS and UNISA demonstrate vanadium dioxide coatings in space
  - CPUT/F'SATI demonstrate transparent dielectric resonator antenna arrays in space (principles are not discussed for IP reasons)

Users (cont)

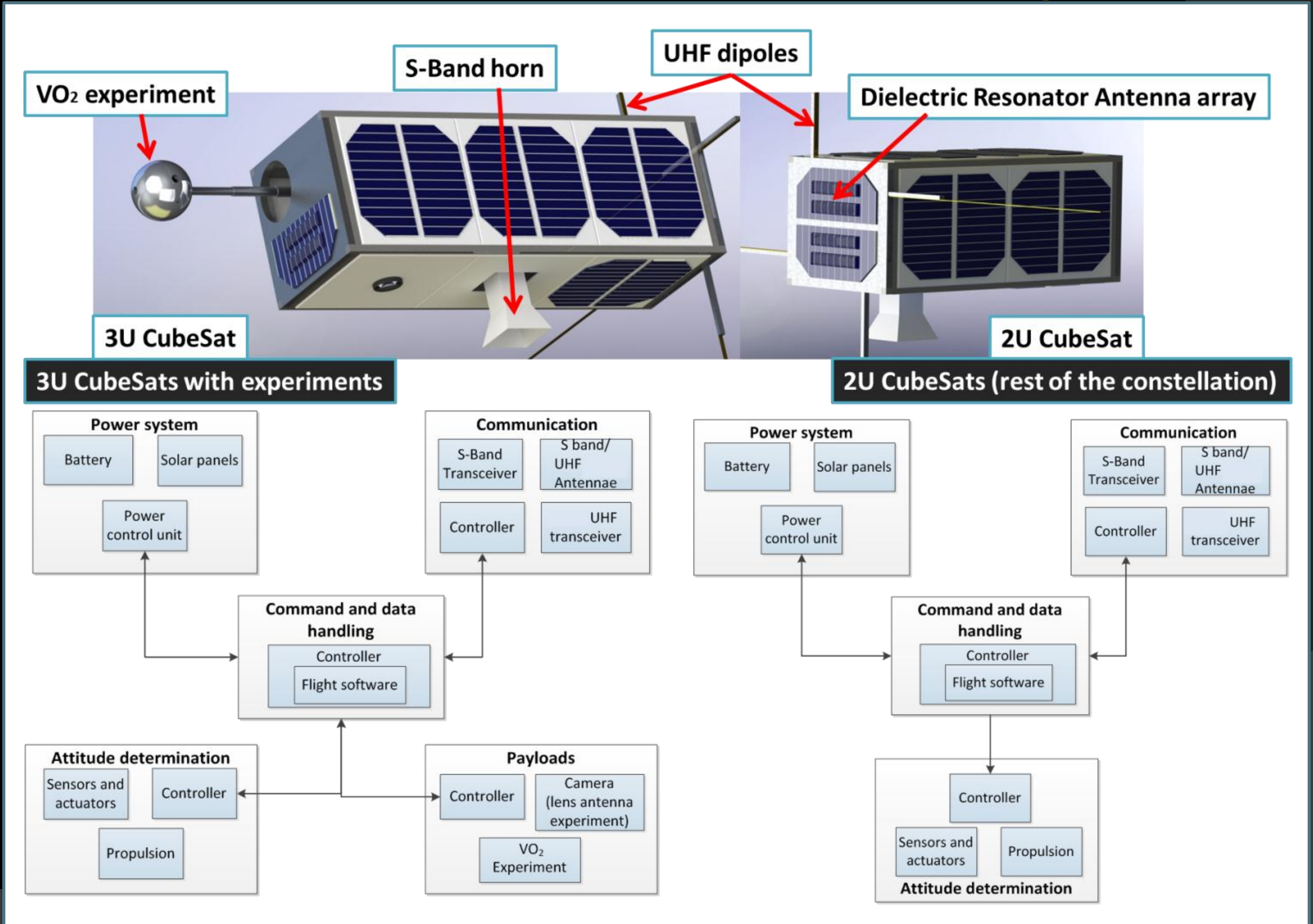


Vanadium Dioxide Experiment

Key performance parameters

- **Antennas:** High gain antennas are required for the highest possible data rates for inter-satellite communications. An isoflux radiation pattern is favoured for a nadir pointing satellite.
- **Inter satellite communications:** This must be achieved between adjacent satellites in the same orbital plane (3 orbital planes with 8 satellites per plane) to ensure near real time temporal resolution.
- **ADCS (ESL):** The satellites should be stabilized nadir pointing with ± 5^0 accuracy in all axes. This is critical for inter-satellite communications.

3U and 2U satellite subsystems



Data link communication

- Cellphone and Satellite Communication Router Interface: Satellite communication router interfaces with cell phone by means of a specialized SIM card. The text message along with GPS data is packed into IPv6 packets and transmitted to the satellite network

- Maximum Node Capacity: The data quantity per node has to take into account the full packet size of 214 Bytes, which is the IPv6 header (40 Bytes), message (Max 150 Bytes) and GPS data (24 Bytes)

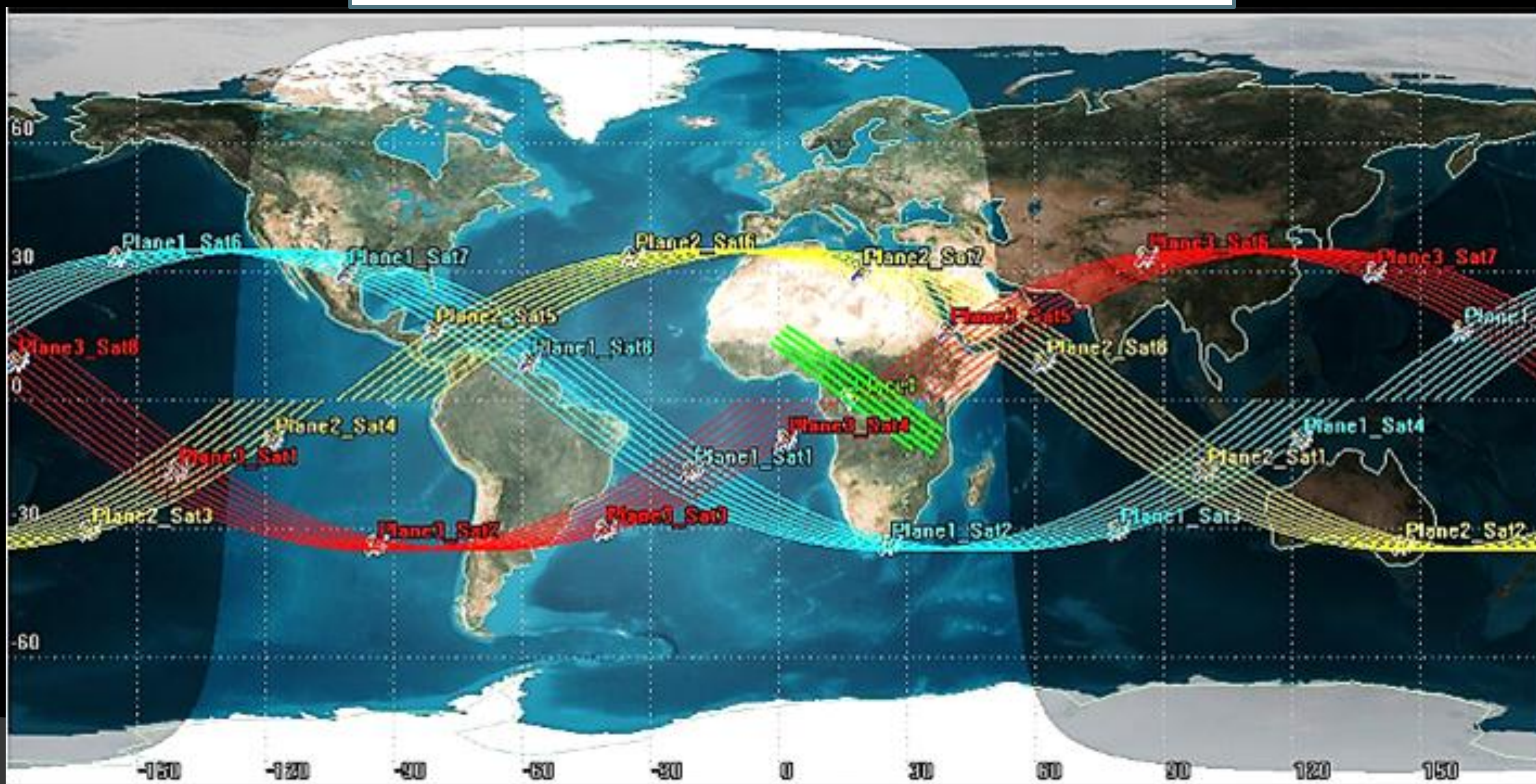
$$\max Nodes = \frac{(Bit\ Rate)(Overpass\ Duration)}{Data\ Quantity} = \frac{(9600)(600)}{1712} = 3364\ Nodes$$

Mission Link Budget

Parameters of the communication system	User to Sat. (UHF UpLink)	Sat. to User (UHF downlink)	GS to Sat. (S-band UpLink)	Sat. to GS (S-band downlink)	Sat. to Sat. (S-band link)
Physical distance between 2 antennas	800 km	800 km	800 km	800 km	5800 km
Transmit power	1 W	1 W	10 W	2 W	2 W
Transmit antenna type	Foldable Dipole	Deployable Diople	Dish	Dual Linear L/S-band Horn Model HCDL14-19-S	Glass antenna arrays
Transmit antenna gain	2 dBi	2 dBi	30 dBi	21 dBi	23 dBi
Transmission frequency	437 MHz	437 MHz	2450 MHz	2450 MHz	2450 MHz
Transmission modulation type	FM + GMSK	FM + GMSK	QPSK	QPSK	QPSK
Transmission data rate	9.6 Kbps	9.6 Kbps	1 Mbps	1 Mbps	1 Mbps
Link margin at 0° elevation	**4.14 dB**	**4.14 dB**	**6.56 dB**	**5.34 dB**	**3.57 dB**
Eb/No	11.67 dB	11.67 dB	10.5 dB	11.40 dB	9.64 dB
Free-space loss	152.73 dB	152.73 dB	167.73 dB	170.57 dB	180.54 dB
Additional loss	5.9 dB	5.9 dB	5.9 dB	5 dB	5 dB

Orbit design
(< 3 minutes maximum revisit time)

Orbital plane	Plane 1	Plane 2	Plane 3
Altitude (km)	800	800	800
Inclination (deg)	35	35	35
RAAN (deg)	0	120	240
Overpass time(min)	15.287	15.287	15.287
Ground track velocity (km/s)	6.623	6.623	6.623



Implementation

- Each launch will place a group of satellites into their respective orbital planes
- Mission concept review, mission and system definition review, mission and system requirements review and critical design review
- System acceptance and flight reviews, after which will be the testing phase
- The deorbit concept is similar to the Terminator Tether deorbit concept [5] where the ADCS unit is separated from the rest of the satellite, leaving a tether between the two parts

[5] R.L. Forward and R.P. Hoyt, Terminator Tether^{TM}: A Spacecraft Deorbit Device,
***Journal of Spacecrafts and Rockets*, Vol 37, Nº2, March-April (2000)**

Business Feasibility

- Emergency centres (private and governmentally owned) will be charged a monthly cost for the service and they can in turn act as a reseller to the end-users
- The communications modules will be built and maintained through a collaboration of universities in sub-Saharan Africa

Year	GSEX & OPEX ($)	Capital repayment ($)	Further development ($)	Yearly Revenue ($)	Yearly Profit ($)
First	1,000,000	0	0	0	-1,000,000
Second	1,250,000	0	624,000	0	-1,874,000
Third	1,500,000	1,560,000	624,000	7,200,000	3,516,000
Fourth	1,500,000	1,560,000	624,000	7,920,000	4,236,000
Fifth	1,500,000	0	624,000	8,640,000	6,516,000
Cumulative	6,750,000	3,120,000	2,496,000	23,760,000	11,394,000

Business Feasibility (Cont)

- Yearly cost per medical centre (including maintenance costs): $ 240 000
- Launch cost: $ 10 000 / kg (approximately $ 30 000 per satellite)
- Satellite cost (including launch cost): $ 130 000 per satellite (due to it being constructed by Universities)
- Ground station expenditure (GSEX) and operational expenditure (OPEX): M$ 1.5 per year
- 24 satellites in the constellation (total cost): M$ 3.12
- Another source of income, not included in the business predictions, is the marketing of the demonstrated developed technology, and the know-how thereof.

The Future

- Extension of the connectivity applications
- More partnerships across the continent
- Ground station agreement in Cameroon (Equatorial plain)
- Growth, growth and more growth

Thank you!!

Acknowledgements to:

UNISEC

French South African Institute of Technology/Cape Peninsula University of Technology

UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology, College of Graduate Studies, University of South Africa

iThemba LABS-National Research Foundation