International Conference on Space Optics—ICSO 2022

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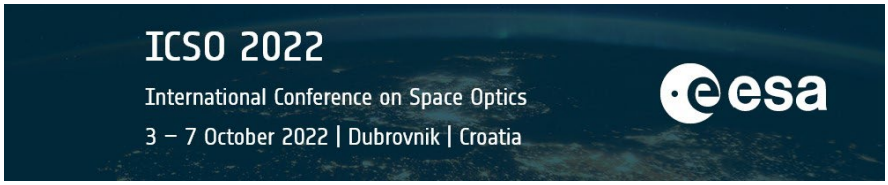
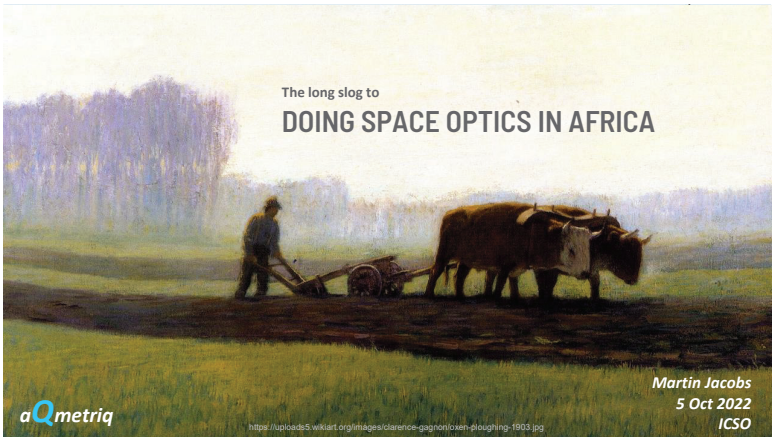
3–7 October 2022

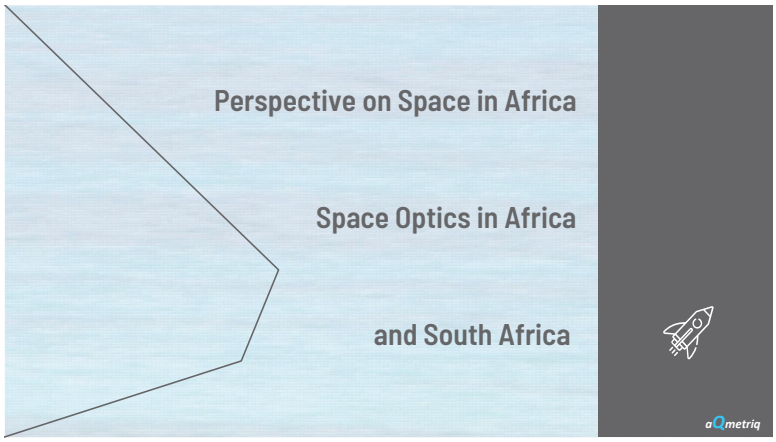
Edited by Kyriaki Minoglou, Nikos Karafolas, and Bruno Cugny,



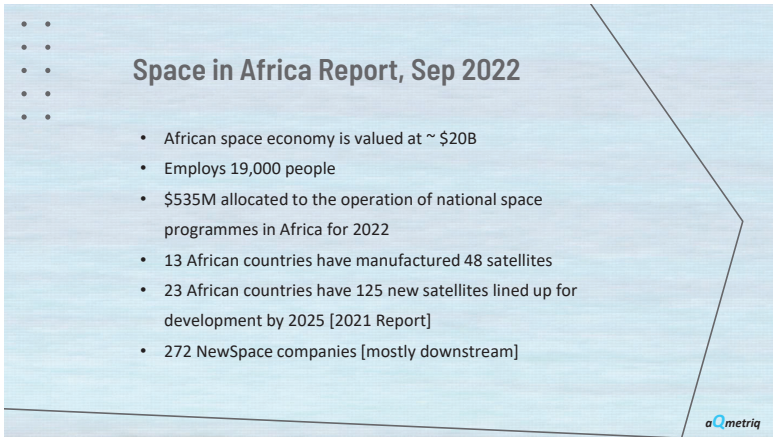
The long slog to doing space optics in Africa

International Conference on Space Optics — ICSO 2022, edited by Kyriaki Minoglou, Nikos Karafolas, Bruno Cugny, Proc. of SPIE Vol. 12777, 127777P · © 2023 ESA and CNES · 0277-786X · doi: 10.1117/12.3011179


The long slog to
DOING SPACE OPTICS IN AFRICA
aQmetriq
https://uploads5.wikiart.org/images/clarence-gagnon/oxen-ploughing-1903.jpg
Martin Jacobs
5 Oct 2022
ICSO


Perspective on Space in Africa
Space Optics in Africa
and South Africa
aQmetriq


Perspective on
Space in Africa
aQmetriq


Space in Africa Report, Sep 2022
African space economy is valued at ~ $20B
Employs 19,000 people
$535M allocated to the operation of national space programmes in Africa for 2022
13 African countries have manufactured 48 satellites
23 African countries have 125 new satellites lined up for development by 2025 [2021 Report]
272 NewSpace companies [mostly downstream]
aQmetriq

21 African countries with space agencies

Space in Africa's list of African countries with Space Agencies – in some cases these are research centres that coordinate space activities in the country.

Source: https://africanews.space/list-of-space-agencies-in-africa/

last updated 25 July 22

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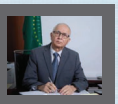
An African Space Agency ?



- African Union passed the African Space Agency Act in 2017
- This establishes the African Space Agency (AfSA)
- To lead, promote and unify work in African space policy and strategy
- AfSA to be based in Egypt
- Expected to become operational in Q1 2023
- AfSA is an organ of the AU Commission, rather than a specialized agency with full political and financial autonomy ⟹ some limitations

Source: SpaceTV https://www.youtube.com/watch?v=LIOPUUp8Bac https://africanews.space/towards-an-independent-african-space-program/

African Satellites

- Adapted from Prof Woldai's 2020 list:

The status of Earth Observation (EO) and Geo-information in Africa Woldai 2020

ALGERIA	ALSAT-1	2002
	ALSAT-2A	2010
	ALSAT-1b	2016
	ALSAT-2B	2016
	ALSAT-1N	2016
	ALCOMSAT-1	2017
ANGOLA	AngoSat-1	2017
EGYPT	NILESAT-101	1998
	NILESAT-102	2000
	EGYPTSAT-1	2007
	MisrSat-1	2013
	EGYPTSAT-2	2014
	EGYPTSAT-A	2019
	NARSSCube-1	2019
ETHIOPIA	ETRSS-1	2019
GHANA	GhanaSat-1	2017
KENYA	1 KUNS-PF	2018
MOROCCO	Maroc-TUBSAT	2001
	MOHAMMED VI-A	2017
	MOHAMMED VI-B	2018
NIGERIA	NigeriaSat-1	2003
	NIGCOMSAT-1	2007
	NigeriaSat-2	2011
	NigeriaSat-X	2011
	NIGCOMSAT-1R	2011
RWANDA		2019
	RWASAT-1	2019
South Africa	Grewsat (QM)	
	SUNSAT	1999
	ZACUBE-1	2013
	SUMBANDILA	2009
	KONDOR-E (SAR)	2014
	nSight-1	2017
	ZA-AeroSat	2017
	ZACUBE-2	2018
SUDAN	SRSS1	2019

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Indigenous space optics development in Africa ?

- Algeria
- Egypt
- Morocco ?
- Nigeria ?
- South Africa

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AFRICA's indigenous development of SPACE OPTICS

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Algerian Space Agency (ASAL)

- Design and implement an earth observation satellite
- Centre for Satellite Development (CDS) houses mechanical & thermal, electrical, electronic and optics research and development laboratories
- Facilities:
  - optics integration / alignment, ISO5, on a seismic block
  - anechoic chamber for EMC tests
  - thermal vacuum chamber
  - vibration test chamber
  - acoustic test chamber

https://en.wikipedia.org/wiki/National_Space_Program_(Algeria)

Space Optics Lab. of the Egyptian Space Agency

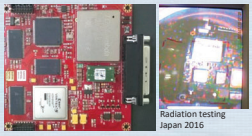
Dr. Ayman Ahmed

The Space Optics Lab. specializes in design and implementation of space cameras as part of the satellite's payload system mission

EgSA
وكالة الفضاء المصرية
Egyptian Space Agency

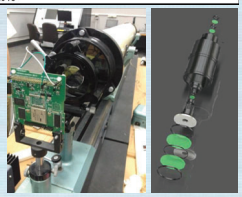
- Five projects presented
- Facilities
- Roadmap

First Project First Space Qualified Egyptian product (Satellite's Camera computer Board) 2013-2015
Funded by Science and Technology Development fund-STDF



Radiation testing
Japan 2016

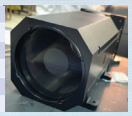
Second Project Space Qualified Visible Imaging System
Funded by Science and Technology Development fund-STDF
2016-2018



Third Project Design and implementation of NEXsat-2 Satellite Imager
2017-1018

Fourth Project Design and implementation Hyperspectral camera
Funded by Science and Technology Development fund-STDF 2021-2023

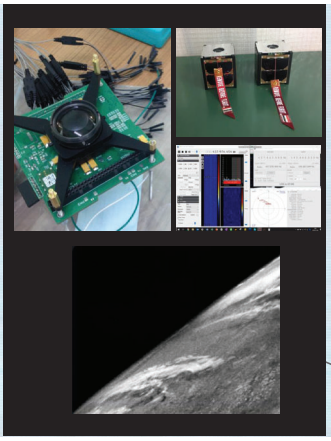
Camera specs	
Spatial resolution	30 m
Orbit altitude	500 Km
Image dimension	60 Km
Spectral range	470 – 900nm (NIR)
Radiometric resolution	10 bit
Spectral bands	150



Fifth Project ClimCam :International Space Station's Camera to be delivered to Air Bus 2022-2024

Egypt
Kenya
Uganda

PrimObj-1: **Take color images for East Africa**
PrimObj-2: **Determination and allocation of climate change effects at East Africa region**

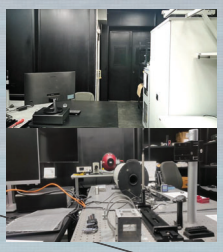


In-orbit Heritage

- NARSSCube-1 : 7-2019
- NARSSCube-2 : 11-2019

with cameras developed by the Space Optics Lab

Facilities



Roadmap for future development of satellite cameras

- High resolution - submeter camera 2025
- Infrared camera

Indigenous development of SPACE OPTICS in South Africa

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The GREENSAT Programme: 1985 - 1994

- Should be viewed in the context of the cold war era and a heavily sanctioned and isolated South Africa
- Denel state-owned defence contractor
- A military programme and tandem civilian Greensat programme
- **Over $2.5 B spent** (about **$6 B** today)
- 50 - 70 South African companies were involved, employing 1,300 -1,500 people ~ 1992
- By 1994 funding dried up and the programme was effectively terminated

Source: The South African Space Programme - Past and Present Alden 2007

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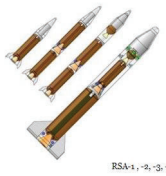
RSA Rockets

- RSA-1 & 2 were followed by RSA-3:
- orbital launch vehicle
- could carry small nuclear weapons and put a surveillance satellite in LEO
- 3 successful test launches during late 80's and early 1990
- RSA-4 was under development at time of termination

Source: The South African Space Programme - Past and Present Alden 2007



RSA-1, -2, -3, -4

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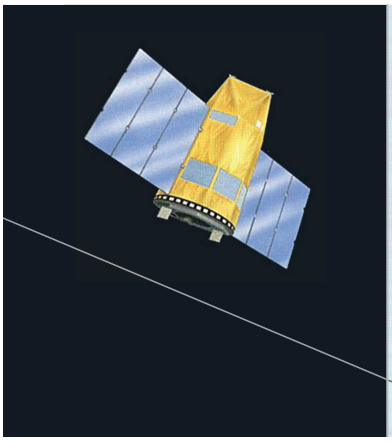

GREENSAT Satellite

- 2.3m tall
- 330kg
- 2.5m GSD
- Progressed to QM

Source: SANSA

aQmetriq

Greensat hubs of activity

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The SUNSAT Programme: 1991 - 2005

- Developed by Masters' students at the Electronic Systems Laboratory of Stellenbosch University
- Virtually everything was designed, developed, built, assembled and tested in-house by students, with exception of the solar panels and EO imager's optics (lens).
- Approximately 30 students at peak ~ 1995 and total of 88 postgrad degrees earned
- Shoestring budget
- Environmental test facilities at Houwteq were a key enabler
- Free launch by NASA in 1999

⟹ Africa's first indigenously developed satellite in-orbit

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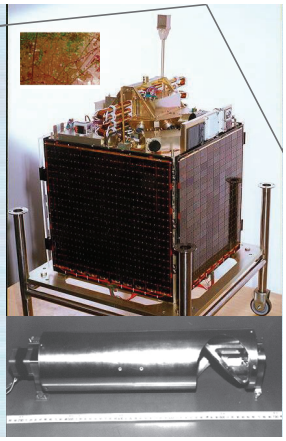
SUNSAT Satellite

- 64kg
- Multispectral pushbroom stereo imager
- Imager could rotate for stereo or off-nadir imaging
- The refractive optics were developed by the South African Council for Scientific and Industrial Research (CSIR)
- 3 bands: red, green, NIR
- 15m GSD x 52km swath
- Horizon sensors, sun sensors and two star trackers developed in-house
- Operational for 2 years



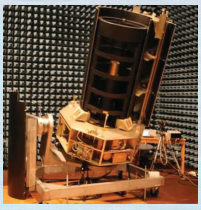
SunSpace : 2000 - 2012

SunSpace INNOVATIVE SATELLITE SOLUTIONS

- Stellenbosch University spin-off to commercialize SUNSAT technology
- Similar business model to SSTL (Surrey Satellite Technology Ltd) at the time
- Initially funded by know-how and technology transfer (KHTT) EO projects delivered abroad
- About 80 employees at peak ~ 2006
- Technopark, Stellenbosch
- In severe financial distress by 2012
- Four EO satellites

Export Sat 1

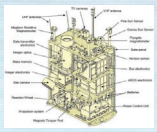
Export Sat 2



Source: www.spaceteq.co.za/

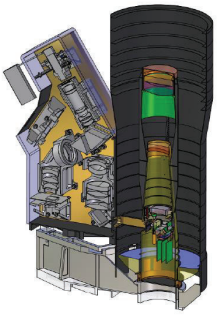
Sumbandilasat: 2006

- Contracted by SA Dept of Science & Tech
- 80kg satellite
- 6.25m GSD x 45km swath x 6 bands
- Ø 80mm aperture
- Minimum budget and < 1 year delivery
- Launched 3 years later in 2009 on Soyuz



MSMI Hyperspectral Imager: 2004-2005

- Collaborative SA/Belgian project
- Belgium supplied hyperspectral bench
- SA supplied remainder of the imager
- Ø 200mm aperture
- 2.6m video GSD
- 2.7m pan-sharpened GSD x 23km swath
- Hyperspectral:
  - 15m GSD x 14km swath
  - > 200 bands in 400 – 2350nm @ 10nm
- Progressed to QM before SA funding dried up



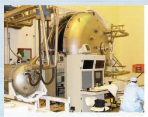
SPACETEQ: since 2012

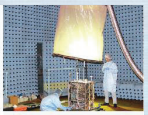
- Denel acquired and rebranded SUNSPACE in 2012
- Relocated from Stellenbosch to Denel's facility at Houwteq
- At its peak Spaceteq may have employed about 80 people
- SA Government's EOSat-1:
  - 1.8m GSD x 22km swath x 10 bands
  - Teledyne Dalsa contracted for imaging detectors in 2015
  - progressed to PDR and "currently in the design development phase" after 7 years

  ⟹ implies funding dried up

Source:
www.spaceteq.co.za/eo-sat1
www.photonics.com/Buyers_Guide/Teledyne_DALSA_Machine_Vision_OEM_Components/c33747AID=57792

SPACETEQ Facilities


Thermal Vacuum Chambers


EMC Test Facility


Vibration Facility


OTF 600

https://www.spaceteq.co.za/facilities

- 8m x 7m x 8m anechoic chamber
- Vibration testing of items up to 1 ton
- TVACs: 3.8m x Ø 3.4m and 0.7m x Ø 0.9m
- 480m² ISO8 main cleanroom
- Various space application test laboratories accessible directly from main AIT clean room
- Optical Test Facility 600 (OTF600):
  - payloads up to Ø 600mm
  - 9m tall decoupled structure
  - seismic base – 200 ton decoupled
  - anti-static 5m x 7m working floor area
  - interferometric test bench, λ/10
  - collimator test bench, 6 DOF focal plane
  - assembly and alignment bench
  - liquid mirror autocollimator
- Available for use by local and international clients

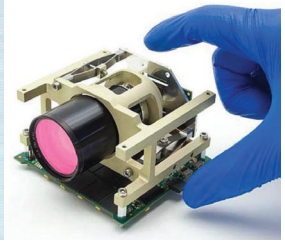
https://www.spaceteq.co.za/eo-sat1

AEROSPACE GROUP: since 2009

- Founded by Sias Mostert and Ferdi Herbst
- Technopark, Stellenbosch / Somerset West
- Consulting and KHTT programmes for international clients
- Also in-house developed products:
- Very high-speed COTS matrix detectors for pushbroom / linescan / TDI imaging created a new market segment in the local industry
- First very compact high-resolution (< 10m GSD) hyperspectral (> 100 bands) cubesat cameras
- nSight-1 2U cubesat, launched 2017 as part of QB50
- Group unbundled and restructured in 2020, positioning SCS-Space to focus on missions

SCS space SPACE advisory company

https://africanews.space/scs-group-is-restructuring-leaving-a-future-space-heritage/

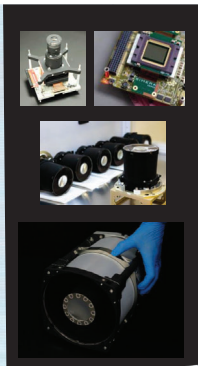


SIMERA SENSE: since 2010

- Simera founded by Johann du Toit and Terry Terblanche
- "More resolution, smaller satellite"

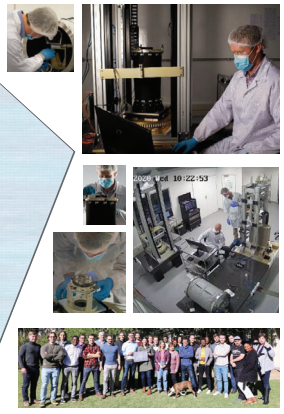
	GSD x swath @ 500km	Bands	Size	Heritage
xScape50	30m x 119km	8x MS, or 32x HS or Bayer	1U	First launch Q2 2023
xScape100	4.75m x 19km	8x MS, or 32x HS, or RGB/Video	1.5U	5 versions in orbit to date
xScape200	1.5m x 14km	8x MS, or RGB/Video	12U	Since 2021

- > 25 payloads delivered in the last 2 years
- 100% success rate



SIMERA SENSE Facilities

- Somerset West
- AS9001D Management System
- 1kg to 100kg payloads supported
- Two ISO7 production cleanrooms ~ 100m²
- Vacuum chamber with optical window
- On-site surface preparation and coating capabilities
- Vertical integration stages
- 5m focal length collimator
- High precision interferometric alignment and performance measurement equipment
- In-house and external calibration facilities

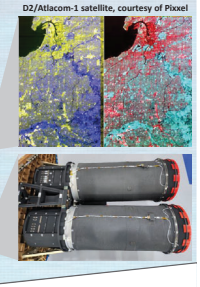


DRAGONFLY aerospace: since 2019

- In-house conceptualization, design, manufacture and testing of optical payloads

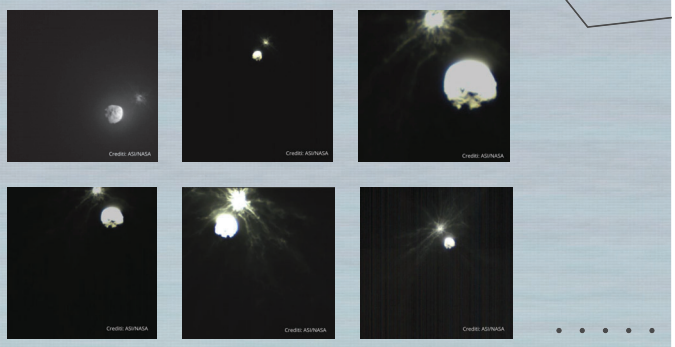
	GSD x swath @ 500km	Bands	Size	Heritage
Gecko	39m x 80km	MS or Bayer	1U	> 15 delivered > 15 on order One used on LICIACube of DART
Mantis	16m x 32km	PAN + 6x MS or >100x HS	1U	Since 2021
Chameleon	10m x 40km	PAN + 7x MS or >100x HS	2U	Since 2021
Caiman	3m x 12km	PAN + 7x MS	2.5U	First FM to be delivered Oct 2022
Dragon Eye	1.4m x 22km	PAN + 6x MS	45 x 90cm	First 2 FMs completed Sep 2022, for launch Dec 2022
Raptor	0.7m x 11km	PAN + 6x MS		Under development

D2/Atlacom-1 satellite, courtesy of Pixxel



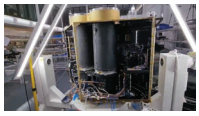
Gecko images taken from LICIACube

Credit: ASI/NASA



DRAGONFLY Facilities

- Technopark, Stellenbosch
- Preparing for ISO9001
- 1,000m² of ISO8 cleanroom areas for microsatellite constellation production
- 140m² dedicated ISO7 optical cleanroom area, with ISO6 flow cabinets
- Vertical integration stages for up to Ø 450mm optics
- Interferometer and wavefront sensors
- Integration sphere
- Small vacuum chamber with optical window for imager testing
- Large vacuum chamber for testing up to 400kg satellites
- Brüel & Kjaer LDS V8900 electrodynamic shaker



CHROMAR TECHNOLOGY

- Founded by Tymen Nagel
- Develops specialised optical systems with application in military, airborne, space, naval, medical, industrial, security, mining and forestry
- > 200 original optical designs of which many concepts are unique

Space Heritage

Chromar has designed, built and supplied various optical lens systems for space applications, including South-Africa's first micro Earth observation satellite, the Sumbandila.

NEWSPACE SYSTEMS : since 2013

- Founded by James-Barrington Brown as a joint venture with local and international shareholders
- Customizable, space-proven ADCS solutions
- Including optical sensors:
  - Coarse sun sensor
  - Fine sun sensor
  - Stellar gyro
- > 3,000 products in-orbit, including sun sensors on the moon and destined for the planets

NEWSPACE SYSTEMS Facilities

- Somerset West
- ISO9001:2015 and ESA/ECSS qualified technicians
- 350m² ISO7 cleanroom area
- Clean darkroom with 'artificial Sun' two-axis programable gimbal for sensor calibration
- 3 thermal chambers and 65kN vibration
- Clean manufacturing capability with paste screen printer, pick n place, vapour-phase reflow, cleaning machine and contamination testing

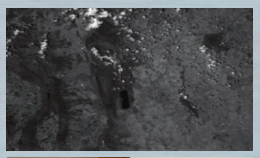
CUBESPACE : since 2014

- Stellenbosch University spin-off by Prof WH Steyn and his students, lead by Mike-Alec Kearney as CEO
- Small satellite turn-key attitude control systems, ADCS sensors, actuators, algorithms and simulations
- > 200 full ADCS systems for satellites and > 2,000 components delivered and currently in-orbit or awaiting launch
- All sensors designed, developed, integrated and tested in-house
  - CubeSense Sun and Nadir visible sensors for sun and earth direction
  - CubeIR infrared Earth horizon sensor
  - CubeStar star tracker for nanosatellites

www.cubespace.co.za/products/gen-2

CUBESPACE Facilities

- Stellenbosch University / Launchlab Campus
- Adhering to various ESA small satellite standards
- Dark room for optical sensor calibration with various motorized rotation stages
- Thermal vacuum chamber
- Climatic chamber
- Vibration table
- Class 6 cleanroom



QM alignment

FM focus check

CPUT
F'SATI
CSIR

- ZACube-2 launched 2018
- 3U satellite and mission, by CPUT
- K-line camera for fire detection, by CSIR
  - Reference band: 25nm at 750nm
  - K-line band: 1nm at 770nm
  - 53m GSD @ 500km

Source:
The Emerging Role of Cubesats for Earth Observation Applications in South Africa Mhangara 2020
Flight hardware verification and validation of the K-line fire sensor payload on ZACube-2 Griffith 2019

Other

- Dedicated calibration labs
  - Dept of Science and Technology's satellite calibration lab at Houwteq
  - CSIR calibration labs
  - NMISA (National Metrology Institute of South Africa)
- Companies pursuing satellite EO missions include:
  - SCS-Space – satellite missions
  - ASTROFICA – satellite consulting, GIS and mission company
  - aQmetriq – EO consulting and mission company

aQmetriq

Challenges faced in South Africa ?

- **FUNDING, FUNDING, FUNDING !!**
  - Discontinuity in funding
  - Lack of government funding, grants and projects
  - Access to venture capital, especially for early stage tech development
- Tertiary education and new talent in the space sector
- Poor infrastructure: "DAY 0 for Cape Town's water supply" and rolling blackouts for up to 8 hours a day
- National and continental branding
- Isolation from the rest of the "space fairing world"

See also: Challenges and the conquering thereof in the space industry in South Africa, AM Louw, IAC, 2019

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Do you feel isolated in Africa?

- Resounding "**YES**" from all respondents
- Issues with venture capital funding, supply chain, shipping of products, participation in conferences, meeting suppliers and clients
- *"We face many challenges that are sometimes felt as 'facing it alone', there is no easy way to find assistance or just talk to peers to discuss problems, successes and challenges."*

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Its been a long slog getting here ..

- In the last 20 years SA's private space optics sector evolved from consulting and KHHT services to include four commercially funded, fast-growing niche manufacturing companies
- Have developed a world-class range of 'basic' space technology – we're not building Copernicus or the JWST here, but
- Can achieve sub-metre resolution
- SA companies are supplying key building blocks for today's EO [and comms] constellations
- We are set up to and have mastered the development of products from the ground up, while
- Our playing field is constrained by resources, facilities and expertise to less sophisticated optical technologies, for example excluding off-axis systems / TMAs

⟹ As African space optics engineers, our passion, dedication, resourcefulness and resilience are no less than a NASA engineer working on JWST

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THANK YOU

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