The emerging role of nanosatellites in developing South African space infrastructure

Stewart Bernard, Imraan Saloojee, Justin Witten and others
AIR Centre: Networking Friday Thematic Special Session on Nanosatellites
January 2021
Objective 1: The development of a suite of space application products and services that directly respond to user needs

Objective 2: The building of core space infrastructure, both ground and space based, that will enable the delivery of essential space services

Figure 1: Space Data Value Chain
Space Infrastructure Hub

The Space Infrastructure Hub represents the largest strategic investment to date in mission-focused space-service provision in South Africa at ZAR4.5B.

It seeks to fundamentally change the nature of national space-based business, and to significantly grow and transform space-based services, nationally and regionally. Directed by SANSA, the Hub is outward & community facing, seeking to engage & benefit the broadest range of stakeholders, not limited to the upstream and downstream space industries; science councils & tertiary institutes; application-relevant industries & community groupings; and of course government at all levels.

Through collaborative development, it seeks to provide new South African satellite missions and downstream ecosystems, with opportunities and enabling mechanisms to sustainably develop the national space industry, and encourage new actors and innovative forms of distributed digital ownership across all of South African society.
New industry Value

Data Cubes and Access Services

Domain Specific Downstream Product Systems

Domain Specific R&D

Sensor Portfolio

Stakeholder Advisory Groups

R&D Initiatives

New industry Sectors

Upstream Missions

Interlinking downstream, upstream, R&D, enablers & Public/market Value

Upstream Industry

SANSA

Requirements

International Missions & Collaboration

National, Provincial & Municipal Government

Public Service Platforms

Domain Specific Downstream ECOSYSTEMS

Industry Start-up, Incubator & Accelerator Platforms

Downstream Industry

New industry Value

Tertiary & R&D Community

Domain & Application-Specific

Interlinking downstream, upstream, R&D, enablers & Public/market Value
Domain Specific Downstream Product Systems

Domain-Facing Data Access and Exploitation Services

FREE: RESEARCH & LOW volume

Start UP & Enabling Mechanisms

Masters
Hackathons
Accelerators
Incubators

B2b: Value Added resellers

B2C: Diverse Consumer Facing Markets

Downstream R & D

Co-Designed VALUE ADDED DECISION SUPPORT TOOLS

Public Service Platforms

Downstream Public Service, Industry Enablers & Revenue Generators

Domain & Application-Specific Downstream ECOSYSTEMS
An Example of Value Chain Creation
Agriculture: Delivering Value & Enabling Smart Farming Capabilities

New SIH Upstream Missions
- Sentinel 1
- Sentinel 2
- SPOT Series
- Landsat 8
- Etc...

Available & Emerging missions

Data Access & Exploitation system
- Analysis Ready Data Cubes
- Analysis Ready Data Cubes
- Analysis Ready Data Cubes
- Analysis Ready Data Cubes
- Analysis Ready Data Cubes

Agricultural Downstream Ecosystem

Revenue Generation for Co-operatives, Extension Services & Services Industry
- Farm Boundaries
- Crop Yields
- Crop Type Mapping
- Water Management
- Crop Condition
- Rangeland Condition
- Drought & Flood Risk
- Crop Anomalies
- Market Synthesis

National, Regional & District Food Security Planning

Farm Level Management & Business Efficiency

Downstream Industry & Value Added resellers

CO-DESIGNED, VALUE ADDED, DECISION-SUPPORT TOOLS
Earth observation based products and services providing values across sectors: banks, insurance, farmers, agricultural service industry, SMMEs providing support & supply chain disruption - all around lowering the entry point to smart farming…

Courtesy Africultures
There is a very strong national interest both in domestic nano- and micro-satellite development and collaborative constellations. These are obviously for many of the same reasons as the global interest in small sats:

Low platform, launch & life cycle costs; modular structure; rapid development & evolution cycles; ability to assimilate technological advances; constellation scaling & risk distribution; passive de-orbiting; ownership & greater independence; development of national mission & engineering capabilities….

South Africa also has a strong nano- and micro-satellite heritage and significant domestic industry capability – more on this shortly…

New South African nanosatellite candidate missions that fall under the Space Infrastructure Hub will be determined through an emerging, hierarchical set of programme, domain and mission user requirements, in consultation with national stakeholders and industry….
Process for South African Nanosatellite Development

**Upstream Requirements**
- Downstream economic value
- Catalytic upstream economic benefit: market attractiveness
- Industry feasibility & level of maturity through TRL & SRL
- Timeliness
- Uniqueness and complementarity
- Programmatics
- ...

**Economic Studies**
- sector values & potential EO service values across development scenarios

**International EO Landscape Assessment**

**National Capabilities Landscape Assessment**

**Informing Studies**

**Programme Requirements**
- Economic sector returns spread across direct, catalytic and public good
- Catalytic industry impact from upstream & downstream missions & systems
- Inclusive & transformative economics - distributed downstream ownership
- Non-monetized societal challenges e.g. security, land issues, climate change
- ...

**R&D Requirements**

**Downstream Requirements**

**SANSA Candidate MISSIONS**

**Hybrid Venture Capital MISSIONS**

**Iterative Industry Engagement**

**User Requirements**

**Examples:**
- Economic sector returns spread across direct, catalytic and public good
- Catalytic industry impact from upstream & downstream missions & systems
- Inclusive & transformative economics - distributed downstream ownership
- Non-monetized societal challenges e.g. security, land issues, climate change
- ...

**Examples:**
- Downstream economic value
- Catalytic upstream economic benefit: market attractiveness
- Industry feasibility & level of maturity through TRL & SRL
- Timeliness
- Uniqueness and complementarity
- Programmatics
- ...
New Infrastructure for South African satellite Development

SANSA’s CONCURRENT ENGINEERING & DESIGN FACILITY (CDEF)

Planned Completion Date – end of 2021
New Infrastructure for South African satellite Development

PLANNED UPGRADE FOR NATIONAL AIT FACILITIES

- ANECHOIC CHAMBER
  - Size (l x w x h): 11.5 x 7.5 x 8.5 m
  - Class 100 000 facility

- Control room
  - Frequency range: 10 kHz to 18 GHz (For immunity and emission tests)
  - Field-strength: up to 200 V/m (Unique capability in RSA)

- THERMAL VACUUM CHAMBER
  - Temperature: +140 to -170 °C
  - Working diameter: 3.4 m
  - Vacuum: 10^-9 Bar
  - Working length: 3.8 m
  - Facility: Class 100 000

- VIBRATION TEST FACILITY
  - Force: 160 kN
  - Frequency: 5 Hz to 2 kHz
  - Facility: Class 100 000

Other facilities to be upgraded include:
- 3D measurement & Mass Property facility
- Optical Payload AIT Facilities
- Integration Chamber

Completion Date – end of 2023
Examples of South African Nanosatellite Capabilities
Phakisa Phase 1 | ZACube-2

Mission objectives

• Phakisa Initiative 6: National Oceans & Coastal Information Management System (OCIMS) and extend Earth observation capabilities.
• OCIMS IVT uses AIS data to track ocean vessels and SAR data to detect vessels that are not transmitting AIS (dark targets)
• Directly supports Initiative 6 by providing South Africa with sovereign capability to independently obtain AIS data that can be used in OCIMS
• Automated Information Service (AIS) standard – ocean vessel tracking
• Future VHF Data Exchange Service (VDES) standard.
• Demonstrate technology that will be used in MDASat
  – In-flight testing of software defined radio (SDR) payload developed by Stone Three.
  – Reduce cost and risk of technology development and accelerate development timelines
• Builds on ZACube-2 heritage, constellation of 9 satellites to be launched in 3 phases
• First phase, MDASat-1 will consist of 3 satellites, to be launched Q2-3 2021
• Software defined radio (SDR) payload to receive AIS messages from ocean vessels
• Provide VDES services to maritime users
• Collection of statistical data in the South African maritime zone, with a special focus on vessel detection.
ZACube-2 mission results

OCIMS ingestion of data and comparison with commercial data

- ZACube-2 (red arrows) performs well in low traffic areas
- Commercial data (blue) performs better in high traffic areas.
  - Possibly augmented with data from coastal AIS stations
ZACube-2 mission results

AIS PAYLOAD: STATS

- SDR payload activated 23 times
- 24 400 AIS messages downloaded
- 4617 different MMSI (ship IDs) detected
- 10862 messages originated within SA EEZ
- Activations performed with satellite out of view (Australia and central Africa)
- Almost equal spread between AIS channel 1 and 2 messages
- 86% of messages are scheduled position reports

Distribution of AIS messages types received

- 1: Position report (scheduled)
- 3: Position report (When interrogated)
- 4: Base station report
- 18: Standard Class B equipment position report
- Other
nSight Satellites

nSIGHT 1
Gecko Imager
40m RGB
3 band 80 km

nSIGHT 2
Mantis Imager
20m MS or 30m Hyperspectral
8 bands 40 km
50 bands 30 km

nSIGHT 3
Chameleon Imager
30m Hyperspectral
148 bands 20 km
The specific areas of **innovative applied research, funded through public/private partnership** are:

a. **Digital imaging technique and sensor optimization** of hyperspectral, super-spectral and thermal infrared sensors for very small satellite platforms. Small platforms suffer from instability properties that need the application of novel techniques.

b. **Digital control system optimization** and implementation to enhance a spacecraft platform’s ability to keep imaging payloads **more stable** during imaging sessions.

c. **Manufacturing process research** into the design and production of **high performance renewable satellite power systems** (solar panels and power control units). The successful implementation of this research will result in South Africa being able to locally manufacture and supply one of the 3 most **high value components** of any satellite.

d. **Radiation hardening of compact electronic systems** for use in radiation prone environments like space and nuclear based power plants using coding and physical shielding techniques.
• All mission objectives achieved in first 6 months
• Practically the only CubeSat to deliver useful FIPEX data to QB50 project
• First Gecko image downloaded 22 June 2017
• 40+ good quality images captured and downloaded with Gecko camera
More Resolution. Smaller Satellites.

Simera Sense is pushing the limits for the Newspace market with its **xScape product range** of optical payloads.

- Designed for a Cubesat Bus
- 1.5 m to 30 m GSD
- Optimized cost vs accuracy
- Stretched aperture for performance
ATROFICA
TECHNOLOGIES

- Founded in Cape Town with 50+ years Space Sector Experience
- Core skills in satellite program management, satellite system assembly integration and testing, Groundstation networks, commissioning, operations and training across the Space Value Chain.
- Network of partners across the Space and ICT sectors.
- Our vision is to be a Pioneering African Space Solutions company providing spaceborne services and access to reliable, real-time and actionable information to our clients and stakeholders.
- The Service Provider of service providers.

Satellite Integration Experience : 50+ years
Successfully delivered satellites by our team : 21
(Local and International , total mass range > 5000 tons)

We are currently on a mission to build, launch, operate and commercialize information from our constellation of satellites. Our first in-orbit satellites are expected in 2022!

www.astrofica.com
WORLD-LEADING, TIER TWO SUPPLIER OF HIGH-RELIABILITY ATTITUDE DETERMINATION AND CONTROL SYSTEMS

- Currently supplying into 5 constellations including the French Kinéis IoT nanosatellite constellation
- Clients include: 14 National Space Agencies such as NASA and international recognised primes such as Airbus
- State of the art facilities (ISO9001 certification, ESA accreditation)

WWW.NEWSPACESYSTEMS.COM
Our mission is to continuously improve our system so that all satellite builders can benefit from an ADCS product with unmatched maturity, at an affordable price.

We aim to be the integrated ADCS system supplier for all satellites.

20 full-time staff, of which 9 have post-grad degrees in Control Systems.

7 trained technicians to IPC class 3 soldering standards

250 m² facility with 80 m² cleanroom, including:
- 8m-long dark optics calibration clean room
- Thermal chamber
- Helmholtz coil
- 1.5m diameter thermal vacuum chamber
- High accuracy 3-Axis rotation stages

Plan to open an environmental test facility hub to the rest of the industry early 2021

Visit our website and find us on social media:

www.cubespace.co.za
SANSA has a very strong industry capability and interest in collaborative nanosatellite constellations:

- SANSA needs to go through a requirements process to determine candidate domestic missions. These are likely to be variants on high resolution optical, hyper/multi-spectral optical and M2m (AIS/VDES).

- Subsequent to that process, strong interest in constellation collaboration around downstream integration of multi-national assets through a minimum constellation requirement.

- Good immediate potential for collaboration around radiometric science missions e.g. Hyperspectral Modelling, signal analysis and algorithm development.
## Starting a collaborative discussion on Cubesat Trade-offs

<table>
<thead>
<tr>
<th>Cubesat Advantages</th>
<th>Cubesat Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shorter development times &amp; shorter evolution cycles</td>
<td>High failure rate e.g. 20%</td>
</tr>
<tr>
<td>Smaller mass and size</td>
<td>Less functionality</td>
</tr>
<tr>
<td>Lower overall Life Cycle Cost</td>
<td>Shorter design life = shorter mission</td>
</tr>
<tr>
<td>Miniature technology driver/rapid technology adapter</td>
<td>Increase the speed/rate of obsolescence</td>
</tr>
<tr>
<td>Risk distribution (in a constellation)</td>
<td>Lower reliability per unit</td>
</tr>
<tr>
<td>Passive deorbiting at ca. 500km allows for reduction of space debris</td>
<td>Becomes &quot;space junk&quot; at higher altitudes</td>
</tr>
<tr>
<td>More accessible to private sector</td>
<td>Risk of cubesat technologies losing credibility through too rapid a transition to operational</td>
</tr>
<tr>
<td>Greater independence and control</td>
<td></td>
</tr>
</tbody>
</table>
Primary Mission: typical target albedos, e.g. vegetation albedo >> water albedo
Bus Stability & Suitability: mass & AOCS (optimized bus design), data transmission & balance (on board processing, downlink etc), data throughput
SNR: mission targets, atmospheric correction, precision (<10% possible?), sensor stability
Spectral Resolution: hyper vs multi, mission dependency & sensor pay offs
GSD: primary mission aims & sensor/bus/constellation payoffs
SANSA is entering an intensive development stage for nanosatellite-relevant infrastructure, capabilities and missions, based on a strong nanosatellite heritage and significant domestic industry capability.

SANSA is currently undertaking a process to determine candidate domestic missions, based on a hierarchical set of programme through to sectoral user requirements. Candidate missions are likely to be variants on high resolution optical, hyper/multi-spectral optical and M2M (AIS/VDES).

Subsequent to that process, there is strong interest in constellation collaboration around downstream integration of multi-national assets through (for example) a minimum constellation requirement.

SANSA will be launching a series of relevant research calls in the coming years, including studies into massive hyperspectral synthetic data sets, signal characterisation & algorithm development etc - designed to lead to more quantitatively informed sensor & mission design/exploitation. These are designed to open studies, with outputs in public space, and there is good potential for collaboration around these actions, e.g. active collaboration with NASA is currently being discussed.