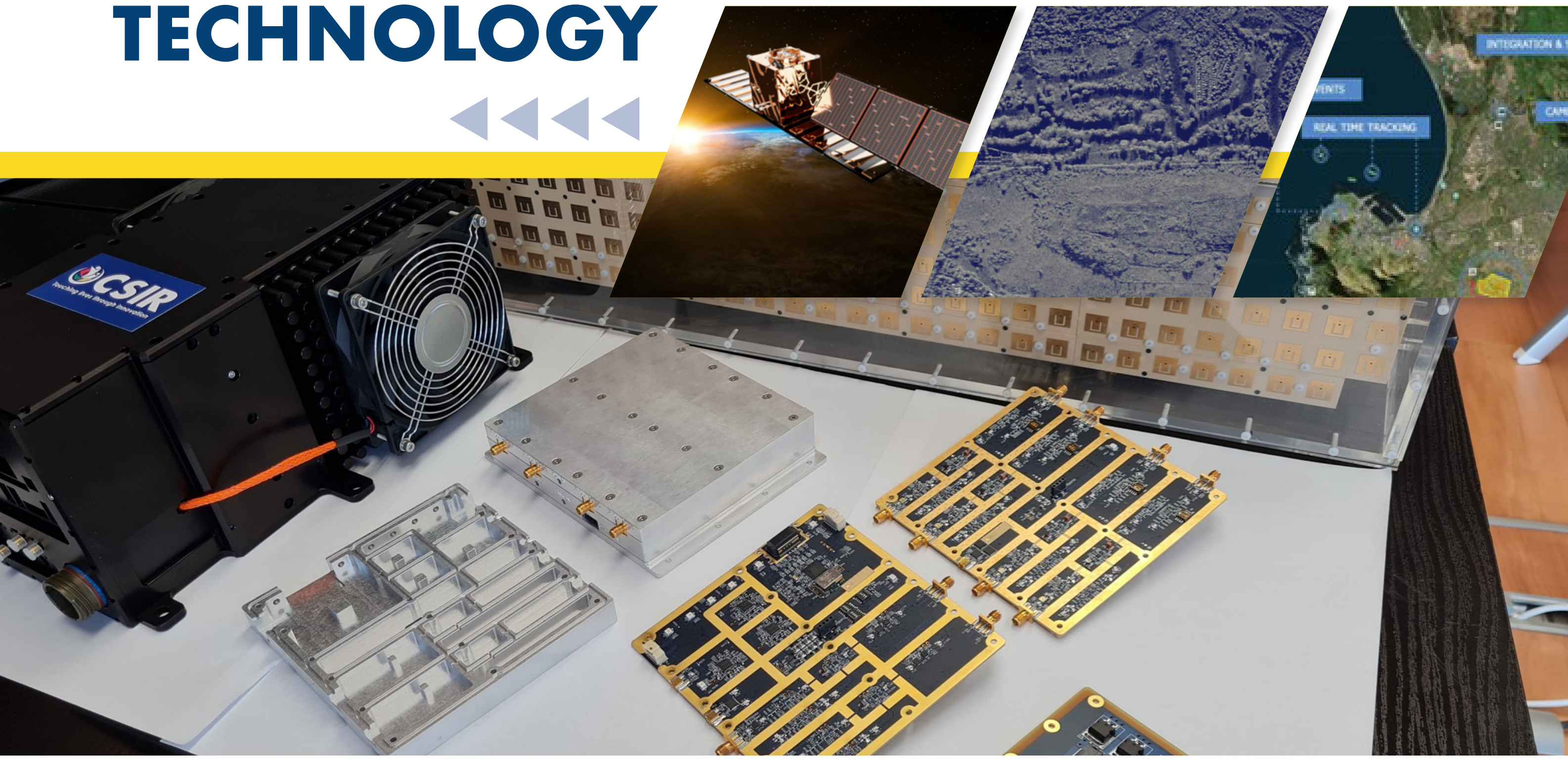
CSIR'S MULTI-DISCIPLINARY CAPABILITIES IN

SPACE SCIENCE AND TECHNOLOGY

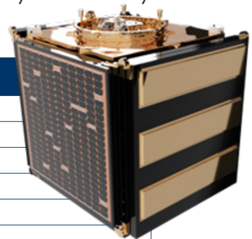


RADAR: SYNTHETIC APERTURE RADAR (SAR)

The CSIR has significant track record in radar system design and development dating back to 1945. Since 2015, the CSIR has been working on SAR payload technology for airborne (manned / unmanned) and spaceborne SAR applications. This R&D included:

- Development of an airborne SAR facility functioning in L-and C-band frequencies for the research and development of SAR image formation algorithms, SAR modes and technology demonstration of hardware prototypes (such as phased array antenna front ends).
- Unmanned Aerial Vehicle (UAV) SAR payload technology and demonstrators ranging from High-Altitude Long-Endurance (HALE), Medium Altitude Long Endurance (MALE) and small UAV platforms with simultaneous SAR/Ground Moving Target Indication (GMTI) modes, Video SAR modes, accurate geo-location, Along Track Interferometry (ATI) SAR modes and more;
- Spaceborne SAR payload designs for payloads at C and X-band. The C-band design has progressed through preliminary designs to engineering models that are now entering the qualification phase for critical elements such as the payload mechanics, RF transceivers, digital control elements and antenna electronics. The C-band payload will be able to image with up to 600 MHz of Instantaneous Bandwidth (IBW) with modes as summarised in the table below.

SAR sensors find application in diverse sectors that include food security and agriculture monitoring, disaster management, military and security operations, maritime domain awareness, cartography, mining, infrastructure management and forestry to name but a few.



SAR-C Satellite Design Specifications as developed in partnership by CSIR and Dragonfly Aerospace						
Operational Lifetime	5 years, payload and avionics fully redundant					
Operating Band	C-band (5.5 GHz)					
Bandwidth	600 MHz (0.25m range resolution)					
Polarisation	First Generation VV, 2nd Generation Quad Pol (VV, VH and HV, HH) switched pulse to pulse					
Peak Transmit Power	Up to 16 kW (up to 18% duty cycle)					
Imaging Time per Orbit	Up to 5 min					
Imaging Modes (Resolution / Swath)	Spotlight	Sliding Spotlight	Stripmap	Stripmap Wide	ScanSAR 100	ScanSAR 300
	0.5 – 1.5 m	1-2 m	3 m	5 m	10 - 15 m	25 -30 m
	10 x 10 km	20x20 km	20 – 44 km	60 - 80 km	100 km	300 km
Extended Imaging Modes to allow further R&D	VideoSAR, Online and Real-time Processing Modes, MTI, MIMO Modes,					
Mass	Satellite Dry Mass			< 350 kg		
Downlink capacity per orbit	Entire imaging session per orbit (full 5min imaging per orbit)					

science, technology & innovation

Department:
Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation

SYSTEMS ENGINEERING

Space programs have driven the development of the systems engineering discipline. It is the core process that is used to manage complexity, risk and outcomes in space programs worldwide.

The CSIR uses a well-established systems engineering process to manage complex technology demonstrators and services. This includes the following:

- » System architecture and concept exploration
- » Requirements definition, decomposition and management
- » Verification and validation processes and events
- » Configuration and quality management
- » Developmental testing and evaluation
- » Integration and re-composition
- » Commissioning, operations and support, and retirement

ELECTRONIC WARFARE: PASSIVE RADAR & SIGNAL INTELLIGENCE (SIGINT)

Passive radar hardware in smaller and ruggedised form factor for mobile deployments:

- » IP67 rated
- » 24/7 covert surveillance
- » Small size, low weight, power and cost (SWaP-C)
- » Typically 3 receiver nodes with 3 FM transmitters
  - AC Power and internet connection;
  - Cutting-edge, locally-developed and manufactured technology to aid with border management;
- » Illuminators: FM/DVB-T with ranges of between 50 to 300 km for various classes of unmanned/manned aircraft;

SIGINT – developing a Radar-SIGINT Payload contributes to:

- » Military missions
  - Maritime security / domain awareness
  - Long-term intelligence gathering
- » Demonstrator missions
  - Improved maritime domain awareness
  - Electronic Intelligence gathering of weapon systems
  - ELINT-based geolocation of weapon systems using radar
  - Technology demonstration and evaluation Electronic Support Measures (ESM) Sensor
  - Performance testing of sensors in space
  - Characterisation of failure modes
- » Functions
  - Operational Frequency Bands: S, C, X Band focus (2-18 GHz)
  - Interception, detection, measurement & geolocation (from space)
  - Signal sorting and emitter/threat classification (on the ground)
  - Target position accuracy of ~2 km
  - In-mission reprogrammable

MODELLING AND SIMULATION-BASED TRADE-OFF STUDIES

It is important in early designs to explore a wide range of alternative architectures to facilitate innovation and justify selection of optimal design alternatives. This entails the following:

- » Capturing and synthesis of the requirements;
- » Exploring design space for architecture concepts;
- » Performing assessments and sensitivities against weighted system attributes, and
- » Defining candidate architecture concepts for refinement and gap assessment.

The CSIR has powerful mission simulation tools and experience in applying these to architectural selection of complex systems. These allow for well justified starting points for solution architectures, configurations and layouts, as well as concepts of operations for given sets of scenarios.

LOCALISATION OF KEY TECHNOLOGIES

The CSIR is at the forefront of developing and testing technology demonstrators to rapidly escalate technology readiness levels of core technologies and prove integration and operation of previously unprecedented capabilities – an essential approach required for localising space capabilities.

SPACE LAUNCHER TECHNOLOGIES

The development of a space launcher requires a range of advanced technologies across propulsion, materials, manufacturing, guidance, and support systems. Across CSIR divisions and in collaboration with partners, we can contribute to several of these technologies. This includes:

- » Propulsion Systems
- » Structural and Materials Engineering
- » Guidance, Navigation, and Control (GNC)
- » Avionics and Electronics
- » Aerodynamics and Flight Dynamics
- » Aeroelasticity
- » Advanced Manufacturing and Assembly
- » Ground Support and Launch Infrastructure
- » Payload Integration
- » Testing and Validation
- » Software and Simulation
- » Reusability Technologies (Optional for Reusable Launchers)
- » Regulatory and Safety Compliance

OPTRONICS PAYLOAD DEVELOPMENT

The CSIR has played a pivotal role in advancing space sensor technologies, sensor development and has undertaken several projects in areas such as:

- R&D of novel optical sensors for micro and nano satellites;
- R&D of image processing techniques for on-satellite data;
- Hyperspectral image processing;
- Marine oil spill and pollution monitoring research; and
- Test and evaluation of optical payloads for satellites.

Some of the cameras and calibration capabilities developed by the CSIR's Optronic Sensor Systems group were used on:

- SUNSAT
- KITSAT-3,
- Sumbandila-SAT
- ZACUBE-2 satellite, and
- ZACUBE-3 satellite, to be launched in 2027.

One of the optical sensors developed by the CSIR is the K-line sensor. The K-line satellite payload detects and reports on fires in real-time based on potassium light emitted from the vegetation combustion, from a nano-sat at low earth orbit in space.

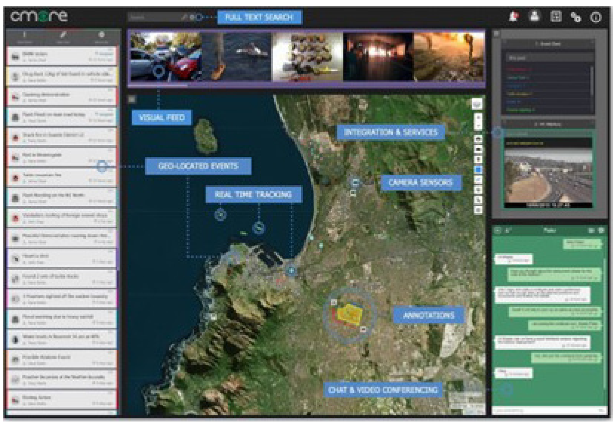
COMMAND, CONTROL, COMMUNICATIONS AND COMPUTERS (C4)

The CSIR has a long track record of providing C4 support, and specialises in the following:

- Automation (data and information collection, automatic data consolidation, automated reporting),
- Visual analytics (trend detection and predictive modelling, machine learning and AI, pattern and behaviour analysis),
- Collaboration (information and intelligence gathering, early warning, controlled and secured information sharing, interagency operations), and
- Defence and security (planning, tasking, and monitoring of C4 operations, real-time situation awareness, resource and asset tracking, and incident management).

C4 can be applied in space operations including:

1. Satellite operations - such as ground control stations (monitoring and tracking of satellite health and status, sending commands, receiving data).
2. Space traffic management (collision avoidance, debris monitoring).
3. Military and defence applications (strategic communications, surveillance and reconnaissance, missile warning systems).
4. Commercial applications (fleet management, service provisioning).



TESTING INFRASTRUCTURE

WIND TUNNELS

The CSIR provides world-class wind tunnel testing solutions based on almost 60 years of wind tunnel testing experience. The six wind tunnels are operated for the production of wind tunnel data for both local and international clients. The four main wind tunnels, in order of test speed, are:

» Seven Metre Wind Tunnel (7mWT),
» Low Speed Wind Tunnel (LSWT).
» Medium Speed Wind Tunnel (MSWT), and
» High Speed Wind Tunnel (HSWT)

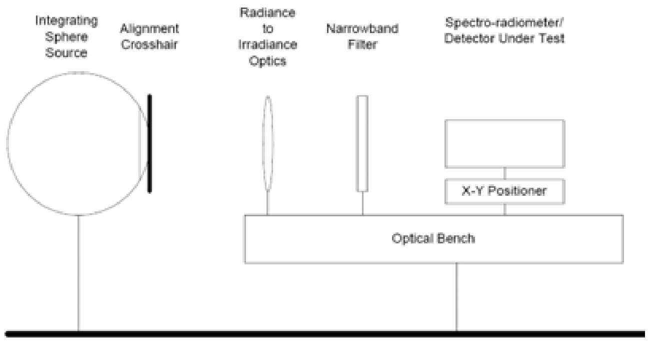
ANECHOIC CHAMBER

The CSIR's anechoic chamber was established in 2018. The CSIR and its clients utilise this specific facility for commercially or military sensitive projects, to measure antenna performance, including antenna patterns. The CSIR's Radar and Electronic Warfare group uses these antenna measurements and patterns to develop advanced radar sensors and effective countermeasures against modern radar systems.

OPTICAL TESTING AND EVALUATION LABORATORY (OTEL)

The CSIR has Optical Testing and Evaluation laboratories used for testing optical imaging systems for satellites and ground-based surveillance systems; these are inclusive of the Integrating Sphere Source (ISS) used for development of optical sensors. The system can also be used for general radiometric calibration requirements for various other applications.

Depending on the focal length and mission specifications of the satellite payload, the Optical Testing and Evaluation Laboratory (OTEL) can be utilised to test the sensor resolution and conduct day and night evaluation tests. The laboratory has also been employed in developing testing protocols to verify the performance and reliability of optical payloads under laboratory and simulated orbital conditions, ensuring mission readiness and compliance with operational standards.



The CSIR also utilises vicarious calibration techniques, which employ ground-based targets and reference measurements to optimise sensor performance for on-orbit calibration. The artificial target at its test range is used for post-launch calibration, eliminating the need to rely on onboard sensors in the satellite. These practices help link laboratory calibration with real-world operational conditions, ensuring the long-term integrity of data and mission success.

CONTACT:
Biko Managa
Impact Area Manager: Aerospace Systems
Email: tmanaga@csir.co.za
Tel: +27 12 841 2407

PHYSICAL ADDRESS:
CSIR Scientia Campus
Meiring Naudé Road
Brummeria
Pretoria
South Africa

www.csir.co.za

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