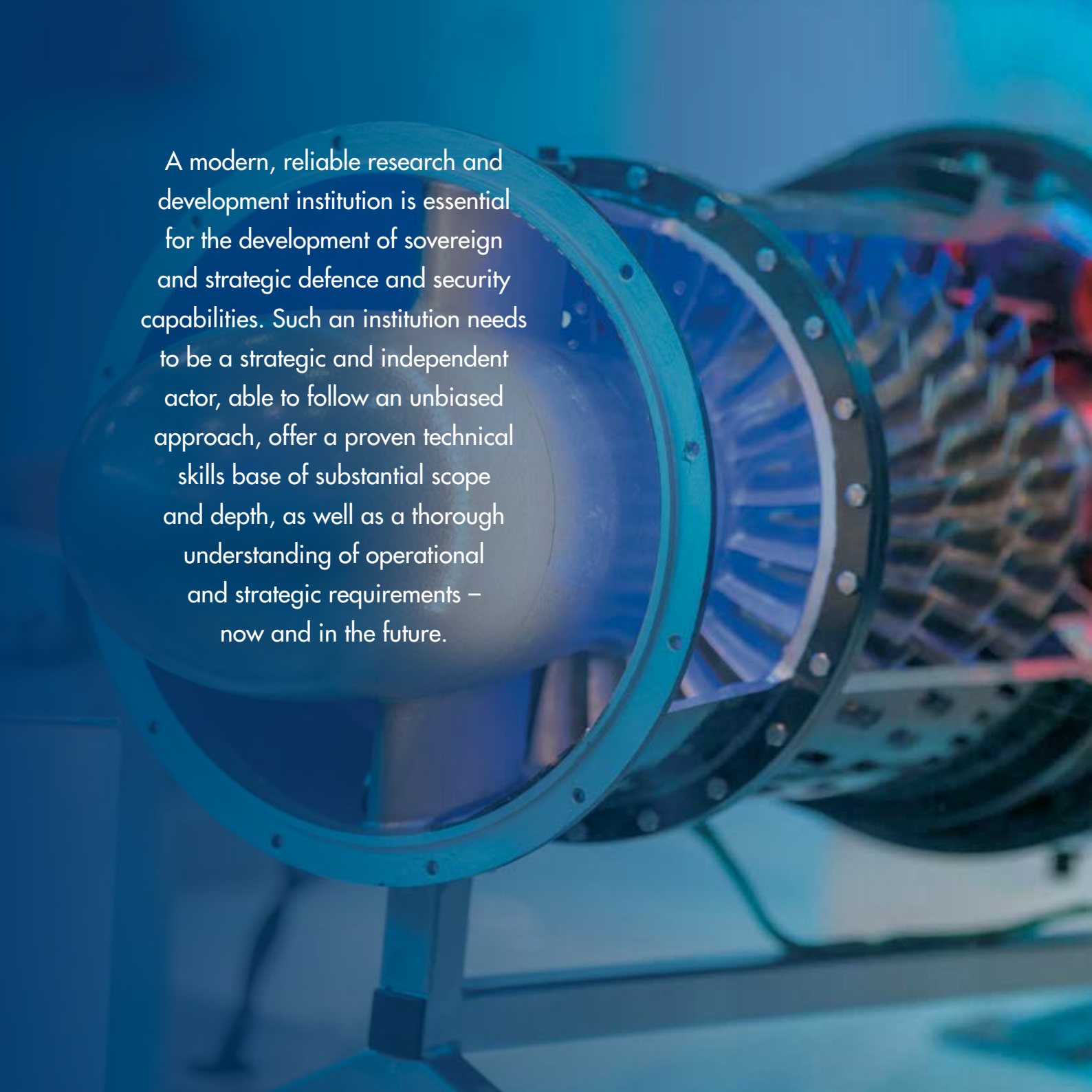
CSIR DEFENCE AND SECURITY

Strategic sovereign technologies and capabilities for air, land, sea and cyber defence. Delivering integrated security solutions for private, public and civil sectors, and technology innovation to foster a robust local defence and security industry.

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation



A modern, reliable research and development institution is essential for the development of sovereign and strategic defence and security capabilities. Such an institution needs to be a strategic and independent actor, able to follow an unbiased approach, offer a proven technical skills base of substantial scope and depth, as well as a thorough understanding of operational and strategic requirements – now and in the future.

ABOUT THE CSIR

The Council for Scientific and Industrial Research (CSIR) is a leading scientific and technology research organisation that researches and develops transformative technologies to accelerate socioeconomic prosperity in South Africa.

The organisation's work contributes to industrial development and supports a capable state. The CSIR is an entity of the Department of Science and Innovation.

The organisation plays a key role in supporting the public and private sectors through directed research that is aligned with the country's priorities, the organisation's mandate and its science, engineering and technology competences.

The nine high-impact sectors identified by the CSIR to achieve its aims are:

Industry advancement clusters

- Advanced Agriculture and Food
- NextGen Health
- Future Production: Chemicals
- Future Production: Mining
- Future Production: Manufacturing
- Defence and Security

Industry and society enabling clusters

- Smart Places
- Smart Mobility
- NextGen Enterprises and Institutions

ABOUT CSIR DEFENCE AND SECURITY

The CSIR Defence and Security cluster develops strategic sovereign technologies and capabilities for air, land, sea and cyber defence. It delivers integrated security solutions for private, public and civil sectors, and technology innovation to foster a robust local defence and security industry.

These domains are supported with associated tools, processes, facilities and the skills and expertise of researchers and engineers employed at the CSIR.

Key objectives

- Conduct research and development (R&D), localise transformative technologies and accelerate their diffusion within the defence and security sector.
- Collaboratively improve the competitiveness of high-impact defence industries to support South Africa's re-industrialisation, notably through the commercialisation of CSIR-developed defence and security technologies with local industry.
- Drive the socioeconomic transformation through research, development and innovation that supports the development of a capable state by ensuring that defence and security agencies such as the South African National Defence Force, South African Police Service and the State Security Agency can successfully deliver on their mandates.

AREAS OF WORK

The CSIR focuses its **defence R&D** on integrated security solutions and technologies that can be commercialised to ensure industry competitiveness. This includes product development opportunities with industry and the broader National System of Innovation (NSI) and demonstrating local product engineering capabilities. A particular focus is on integrated large-scale intelligence, surveillance and reconnaissance platforms; technology solutions that are interoperable; advanced manufacturing; and complete original equipment manufacturer solutions.

The CSIR's **cybersecurity capabilities** are closely aligned to the National Cybersecurity Framework and associated programmes. The CSIR typically serves as decision-support partner to those with complex crime problems. Interventions include countering cybercrime such as identity theft; providing non-visual and visual crime-sensing systems; performing big-data crime analysis; and undertaking enhancement and/or integration of network communication systems.

The **civil security** platform offers command and control capabilities for crowd management; sensor systems for homes, businesses and critical infrastructure that enable authorities to identify and rapidly react to criminal activities; integrated security solutions for infrastructure security; and security solutions for the cash-in-transit industry. These interventions draw on numerous security cluster capabilities and decision-support tools.

The CSIR has a track record of more than seven decades in innovation and technology advances that contribute to the quality and robustness of South Africa's air, land, maritime and cyber defences. It operates seamlessly with defence and law enforcement agencies on the design, testing, evaluation and measurement of capabilities, integrated system performance, doctrine development, training and force preparation.

The aim is to provide these agencies with the ability to be smart buyers, users and managers of technology. Three other important factors driving the CSIR's contribution are technical skills development, cementing R&D partnerships locally and internationally and seeking ways of sparking technology-based enterprises.

AERONAUTICS SYSTEMS

Conducting research, development and innovation (RD&I) in new aerodynamic analysis, test and evaluation technologies; and developing new tools, processes and technologies to deliver validated, cost effective services that support industry.

RD&I in new and niche fields such as autonomous systems, propulsion and control platforms, and localisation of emerging technologies.

The CSIR has a strong track record of technological advances and achievements in support of force development and air power. The CSIR is recognised as a preferred service provider and technology partner in the areas of aeroelasticity weapons integration, aircraft development and gas turbine engine development. These areas are underpinned by modelling and simulation tools, and a suite of wind tunnels with associated measurement and evaluation capabilities such as test rigs and strain gauge balances. The CSIR provides its services to an expanded range of local and international clients.

Focus areas

- Unmanned aerial vehicles (UAV) design, evaluation.
- Gas turbine engine development.
- Aircraft store integration.
- Wind tunnel testing (across a Mach range of 0.1 to 4.0).
- Aeroelasticity design and testing.
- Product demonstrators (including rocket systems, airborne test and evaluation pods, aerostat systems.)

CSIR aeronautics test and evaluation facilities include:

- Wind tunnels.
- Ground vibration test facilities.
- Test rigs for UAVs, engines, propellers, low-speed turbines, atmospheric combustors.
- Strain gauge balances.
- Flutter excitation systems plus associated hardware and software.
- Advanced computational clusters for aerodynamic simulations.
- Simulation-based acquisition and operational support facilities.
- Cascade and turbine test facilities.

THE CSIR'S SUITE OF WIND TUNNELS provides a scientific research and experimental foundation to local and international aeronautics players. Established in the mid-1960s, it is a popular test capability in the southern hemisphere.

Airframes tested in the tunnel include subsonic types such as gyrocopters, helicopters, unmanned aerial systems and military trainers, as well as transonic airframes, (such as bombs and combat aircraft), and supersonic airframes of high-speed missiles and projectiles flying at more than four times the speed of sound. Data collected at the facilities are used for airframe characterisation, aerodynamic design and to populate complex modelling and simulation environments for mission simulation, doctrine development and training.

The seven-metre wind tunnel is a continuous, open-circuit tunnel powered by 28 axial flow fans of 30kW each. Fans run in one of 13 different symmetrical patterns to ensure uniform flow distribution across the speed range of the tunnel.

The medium-speed wind tunnel is one of the best equipped and most sophisticated tunnels of its kind in the southern hemisphere. A 20MW electric motor drives a three-stage axial compressor with variable guide vanes and stator blade angles for accurate Mach number control. This variable density transonic tunnel operates continuously for optimum productivity and accuracy. The square test section is slotted, with a porosity of 5% for the best possible flow at transonic Mach numbers.

The high-speed wind tunnel is a trisonic, blowdown wind tunnel equipped with a colour Schlieren system for flow visualisation. Subsonic and supersonic Mach numbers are tested using the standard wind tunnel setup, while tests in the transonic regime employ an extra cart which is fitted with a plenum evacuation system and porous walls.

The low-speed wind tunnel is a continuous, single-return wind tunnel with a closed test section. Strut mounted models are suspended from an overhead six-component virtual-centre balance. An auxiliary pitch sector allows sting-supported models to be mounted on a variety of internal strain gauge balances.

AERONAUTICS SYSTEMS continued

EXAMPLES OF WORK IN AERONAUTICS SYSTEMS

CSIR-DESIGNED INSTRUMENT FOR FLUTTER EXCITATION

The system imparts a vibration to excite all the natural modes of a structure. These structural vibrations are measured by accelerometers and the responses are used to determine if flutter onset is likely or not. A flutter excitation system provides the signal-to-noise ratio of the accelerometer responses and provides higher fidelity structural data.

The CSIR exciter is based on an annular-wing concept that provides excitation over a programmable frequency range and duration. It is most often used on civilian and high-speed military aircraft.

GAS TURBINE TECHNOLOGY

The CSIR has significantly expanded its activities in gas turbine technology, building on developments over the past years. These include the development of a 200 N micro gas turbine engine for the hobby market, UAVs and potential small diameter precision-guided weapons, as well as a 1000 N turbojet engine capable of vastly extending the range of large guided missile systems.

THE LONG ENDURANCE MODULAR UAV (LEMU)

LEMU is a research platform designed to provide the capability for validating novel technology components and basic sub-systems in a relevant flight environment.

Three variants of LEMU are currently in development at the CSIR: The LEMU internal combustion variant, which is powered by two fuel- injected internal combustion engines providing up to eight hours of endurance; secondly the LEMU electric variant, which is powered by two brushless electric motors and providing up to one hour endurance; as well as a LEMU variant, which is powered by hydrogen fuel cell technology.

SIMULATED TRAINING PLATFORM

The CSIR and Cybicom Atlas Defence developed a simulation and training platform for South African Navy operations. The distributed, integrated simulation system assists in the training of deck-landing officers or controllers on frigates and marine helicopter pilots on frigates. The newly developed helicopter flight deck trainer is designed to provide joint training for flight deck controllers and marine helicopter pilots. It provides a safe, cost-effective solution to train personnel in a realistic and controlled environment.

OPTRONIC SENSOR SYSTEMS

The CSIR develops innovative, cutting-edge optical observation systems and countermeasures for use in surveillance and electronic warfare. The research is conducted in specialist facilities such as a test and evaluation laboratory, flight motion simulators, a ship-motion simulator and missile exploitation laboratories.

The CSIR's research in the field of optronic sensor systems focuses on the development of new and novel electro-optic sensors/imagers and image processing techniques, through the modelling, simulation, engineering, testing and evaluation of advanced electro-optical sensor systems for day, night and multispectral surveillance. In addition, researchers evaluate and design countermeasures for electronic warfare in the visual and infrared wavelengths. The CSIR technology demonstrators and prototypes are designed to provide decision support for operational missions in various application domains including, at sea, on land, in the air and in space.

Focus areas

- **Aircraft self-protection services:** Test and evaluation; measurement; modelling and simulation; missile exploitation; infrared counter measures; directed infrared counter measures; and jam code development.
- **Advanced optical surveillance systems:** Forest fire detection camera for space and terrestrial applications; long-range border safeguarding camera; wide-area surveillance systems using real-time photogrammetry stitching.
- **Surveillance applications:** Advanced CCTV image processing solutions for physical security applications using cutting-edge deep-learning neural networks; forest fire disaster management; land border safeguarding; small-target detection, recognition and tracking; vehicle-based situational awareness systems.
- **Information applications:** Automatic extraction of relevant information from videos and images for decision support; satellite optical radiometric calibration and validation; management of large amounts of image data; interface data streams to other sensor nodes; exploitation/utilisation of satellite image data.

OPTRONIC SENSOR SYSTEMS continued

PROJECT EXAMPLES

TARGET DETECTION AND TRACKING

The CSIR has a strong capability in real-time image processing which has led to the development of applications for target detection and tracking. Computer graphics processing units are used to accelerate image segmentation, object detection and target tracking.

The tracking software is integrated with hardware platforms such as the directed optical countermeasure (DOCM) platform to form a fast, precise and accurate pointing system for tracking small-fast-manoeuvering targets. DOCM is a configurable system which can be integrated with various lasers and long-range cameras for experimentation purposes towards the development of directed infrared counter measures.

DOCM can be integrated on land and naval platforms for detecting and tracking air targets such as drones, in cooperation with an early warning system such as a radar system for target designation.

CUBESAT FOR FOREST FIRE DETECTION

The CSIR developed a camera for forest fire detection from space. It was successfully integrated into ZA-CUBE-2 as a secondary mission, with the main aim of testing and evaluating the camera in space for its ability to detect forest fires from 600km low earth orbit. Since the launch in 2018, the camera has been operating successfully and collecting imagery. The technology is currently undergoing performance verification and validation.

OPTRONIC SCENE SIMULATOR

The development of sophisticated electro-optical equipment, such as infrared missile seekers and thermal imagers, requires radiometrically calibrated imaging scene simulators in order to evaluate and optimise system performance under diverse environmental conditions. The optronic scene simulator (OSSIM) is an engineering development tool developed to meet this need. The simulator is written in C++ and runs on Windows and Linux systems. Accurate atmospheric modelling in OSSIM requires that MODTRAN be present. Current applications are mainly in the defence domain, but OSSIM can also be applied in the civilian world.

LONG-RANGE BORDER-SAFEGUARDING CAMERA

The optical detection and tracking of targets at long ranges of 5km to 20km, using cost effective solutions, is a challenge. Over the years, the CSIR has developed an impressive portfolio of solutions for long- range imaging, including Cyclone, which was sucessfully integrated into the Meerkat 1 system, and demonstrated and deployed in an operational environment.

The Cyclone camera was eventually replaced by Otus cameras, which are currently integrated into Meerkat 2. The latest version long-range camera, Rino, is currently being finalised, and will boast improvements in size, weight, power consumption, and production cost. The CSIR is also developing a radar independent lightweight border surveillance camera, called Tyto, which will make use of a wide view infrared channel for target detection, and a narrow field-of-view near infrared channel for day and night operations.

THE TEST AND EVALUATION LABORATORY

The situational awareness and threat identification afforded with surveillance cameras, night-vision devices and infrared cameras, depend on the quality of images produced by these sensors. Performance deterioration occurs during normal use, storage or from abuse. This laboratory's capabilities include testing and evaluation of image quality on new and used sensors, in the field or in the laboratory. A range of real or simulated lighting and environmental conditions are possible. For clients, such test results provide confidence in continued tactical suitability of the sensor, or empower smart, informed acquisition or maintenance decision-making.

WIDE-AREA SURVEILLANCE SYSTEM

The wide-area surveillance system (WASS) provides instantaneous wide-area situational awareness. With a panorama of 360° and a high-resolution digital video encompassing 4 000 x 1 000 at 20 frames per second, the sensor initially began operations in the visual band. The system evolved into a ruggedised module that was tested in the maritime domain for the detection of small craft, in support of anti-piracy operations. The WASS was further upgraded to employ thermal cameras and active cooling. Calibration of the cameras was done using the CSIR's patented automatic photogrammetric camera calibration system.

TECHNOLOGY FOR SPECIAL OPERATIONS

The CSIR has a track record in providing technology support and innovation to the special operations forces in defence and security environments. Its independence, scientific and engineering expertise, rapid response to requirements and a comprehensive understanding of the challenges facing these forces, put the CSIR in an exceptional position to be the science, engineering and technology partner of choice.

Specialist capabilities in the CSIR's Technology for Special Operations team include mechanical, electronic, mechatronic and systems engineering; explosives and chemistry; quality and project management; rapid prototyping; product development; and small-scale manufacturing.

When it comes to the operational needs of the South African National Defence Force (SANDF), skills from across the CSIR can be harnessed to deal with challenges effectively.

The range of specialist areas is broad – explosives research, mobility solutions, specialised GIS, maps on smart phones, 3D printing, adaptations to vehicles or infrastructure, observation and sensor systems, geophysical intelligence systems, other tech tools and weaponry and customisation, plus operations research and training. This ensures that the CSIR contributes to maintaining the safety of the state and its national assets – including anti-piracy, anti-poaching and counter insurgence.

Apart from standing R&D projects for a wide client base, groups such as the SANDF (Special Forces), South African Police Services and other government departments rely on the CSIR to assist with quick-reaction tasks to address operational emergencies. Science and engineering staff also engage directly in strategic planning, policy and doctrine development, training, test and evaluation projects, exercises, actual operations, as well life-cycle management of operational systems.

Often, the outcome is a specialised part, piece of equipment or complex operational capability set to operate under very specific conditions specified by the client.

This is supported by several expert facilities within the CSIR, such as an explosives test site, wind tunnels, various simulation products – including those featuring radar and electronic warfare platforms, flight simulations, and such, used for training and tactical planning.

PROJECT EXAMPLES

ESCAPE SYSTEM FOR SUBMARINES

The Tower escape safety system was initiated by the South African Navy in conjunction with ARMSCOR, the Institute of Maritime Technology and the CSIR.

Typically, in case of an emergency, submariners can escape via the submarine tower. The submariners climb on to a ladder fixed inside the tower taking position below each other. The tower is flooded for their escape. However, the safety suits they wear are inflatable and cause the submariners to raise to the surface causing members to get stuck at the hatch opening.

The new system sees a special mechanical rail system fitted on the inside of the tower. Each submariner hooks on to this rail system, below each other. As the tower floods, the rail system keeps the submariners fixed in position, despite the air in their suits.

The submariners are released by means of a hold-trigger and release mechanism that is automated upon opening the tower upper hatch. This system works even if the submariners are unconscious. The entire procedure takes approximately three to ten seconds for both submariners to surface at a depth of ten metres. The escape cycle is repeated until such time as the complete crew has escaped.

It is envisaged that the system will eventually be incorporated into all SA Navy submarines. The successful completion of the Tower Escape will be an additional requirement to qualify as a submariner.

THE ADVANCED DESIGN AND MANUFACTURING INNOVATION CENTRE

The CSIR has established an advanced manufacturing facility that offers capabilities such as additive manufacturing – using polymers and powders – 3D scanning and product life cycle management to a range of clients in both the military and civil sectors.

The Advanced Design and Manufacturing Innovation Centre (ADMIC) also provides ongoing research into new manufacturing techniques, technologies and materials, as well as specialised design and manufacturing training for local and international industries.

The centre is dedicated to the complete process, from conceptualising or designing a solution, through to material selection, prototyping, testing, manufacturing and delivery. Firm security measures are in place at the centre, making it ideal to serve defence clients, as well as companies performing pre-competitive prototyping, conceptual design and low-volume manufacturing of new products for testing. This ensures the security of clients' intellectual property and confidentiality.

With the new equipment barely in place, ADMIC found itself at the heart of the fight against Covid-19 in South Africa. The centre was used for the rapid design and production of face shields for use by soldiers deployed to infection hot spots at the start of the pandemic. A couple of other projects have since been initiated for the defence industry.

Clients in the aerospace, automotive, agricultural, maritime and medical sectors are set to benefit from the technologies at the centre in future as part of the CSIR's commitment to supporting industry competitiveness and accelerating industrialisation.

COMMAND CONTROL AND INTEGRATED SYSTEMS

Projects undertaken by the CSIR's team for command, control and integrated systems are typically of significant scope, with multiple contributors and shareholders, across the boundaries of function or organisation. The deliverables focus on providing decision support, sustainable capability development and multi-platform, innovative solutions that address public or private sector safety and security challenges.

- Improve organisational effectiveness by enabling interpretation of complex systems through simulation modelling for decision support and the development of interventions with knowledge centricity.
- Research and development of innovative solutions to address vandalism and crime in large, complex industrial installations and government departments, through the exploitation of transformative technologies.

Command and control in the defence sphere are a critical capability to ensure data gathering, storing, analysis, sharing and collaboration, enhanced through tools such as modelling and simulation to be used as intelligence in operational situation awareness. Increasingly, the need for such large-scale interventions are occurring in business and civil society where it is used in asset management, incident management and large event management.

Integrated capability management comprises a process of definition, specification, establishment and employment. The underpinning tools and techniques include enterprise architecture, system-of-system engineering, concept development and experimentation facilities and building blocks such as the data models, interface specifications and task lists.

Specific examples include the design and implementation of interventions aimed at border safeguarding and counter-poaching.

PROJECT EXAMPLES

BORDER SAFEGUARDING

Concepts developed at the CSIR are demonstrated in the field in multi-agency exercises. This ensures operational efficiency and supports doctrine development, force design and management, appropriate procurement and other aspects of decision making.

A priority for national stability, safety, economic growth and peace in the region, border safeguarding is a multi-faceted and complex challenge. Factors such porous borders, poaching, illegal immigrants and insurgence, smuggling and trafficking of arms and people, illegal grazing and cattle theft are just some examples.

The emphasis is on innovative and integrated capabilities to better gather information, develop tactics and coordinate resources in time-critical operations. Without the financial freedom to invest in new technology or added manpower at every obstacle, the right combination of existing or optimised solutions can be orchestrated to fulfil needs. This is the smart defence approach.

CMORE COLLABORATION PLATFORM

Cmore is a CSIR-developed software ecosystem facilitating collaboration across teams, organisations and borders. By acting as an information sharing mechanism, Cmore helps the dissemination of situation awareness data, promotes interoperability and integration, enables advanced analytics and predictive modelling, and supports automated reporting. The system is secure: Participants are in full control of their information and decide how and what they want to share with others when facing a shared objective. Ultimately the aim of Cmore is to enable decision makers, commanders and field operators to achieve a quick understanding of their situation, be able to plan, take action and review.

In the disaster management domain, this means that local, provincial and national level players are able to manage the various stages of disaster management, including response and preparedness, planning, monitoring and awareness, risk reduction, enforcement and compliance and rehabilitation and post-recovery. All of this can be done across organisational boundaries with all the relevant role players.

Cmore is a proudly South African designed and developed technology. It has been specifically built with the South African national security interest in mind and as a collaboration platform for national security capabilities. Disaster management is a key national interest required to create a sustainable, safe and secure South Africa.

In fact, Cmore development started before the Soccer World Cup hosted in South Africa in 2010. A number of tools were created to support the SANDF during their interoperability exercises with other government departments. Subsequent to the big event, some of the tools were combined into a single platform whilst conceptualising possible tools for border safeguarding support, again to the SANDF. Cmore became the backbone to the Kruger National Park (KNP) Mission Area Joint Operations Centre as part of counter rhino poaching efforts.

At present the security, operations, protection, enforcement, compliance and conservation use of Cmore in the wildlife domain remains the most sophisticated and biggest use case. However, other uses cases are highlighting Cmore's great flexibility, and multi-use nature in domains such as health, transport, risk management and environmental management.

SECURITY SOLUTION FOR STOCK THEFT

The Department of Correctional Services discovered livestock losses of up to R250 000 per month from a farming project in the Eastern Cape. The CSIR's team of systems engineers rapidly responded with a risk assessment and threat analysis and developed a security operational concept. To speed up development, the CSIR worked with a local manufacturer of a perimeter intrusion monitoring system as part of the overall solution. The system detects movement through radar and video capabilities, using day and night cameras. After the first attempted intrusion was detected and thwarted, the theft ended.

RADAR AND ELECTRONIC WARFARE

A world-class research, development and innovation capability for radar and electronic warfare technology development and applications.

The CSIR's radar and electronic warfare (EW) capability originated from the British signal services deployed in South Africa during the Second World War. The CSIR's founding President, Sir Basil Schonland, led the team that received the first radar echo in South Africa in 1939. He then established a radar research and development (R&D) capability within the CSIR which was the foundation of the radar and electronic warfare industry in South Africa. Over almost eight decades the CSIR has – and continues to make – a critical contribution to the National System of Innovation in the radar and electronic warfare sector. Local and international clients rely on the CSIR to deliver cutting-edge products and systems, as well as to assist in the establishment of look-alike capabilities of this calibre in other organisations and countries.

Offerings

- **Contract research and development** into advanced radar and EW sensor techniques and technologies and using these to develop innovative modern product concepts and specialised radar and EW solutions, including bespoke designs to customised client requirements;
- **Supporting industrial growth:** Utilising the technologies above in partnership with industry to develop and industrialise new concepts, enabling industry to broaden market access through advanced radar and EW products;
- **Testing, evaluation, modelling and measurement systems and services:** Evaluating and optimising the effectiveness of radar and EW systems;
- **Training:** Providing course-based, modelling and simulation-based as well as field deployable radar and EW facility-based training;
- **Defence evaluation and research services:** Providing technological support, performance requirement studies, acquisition support, operational testing and evaluation support and expert consultation; and
- **Radar and EW capability establishment:** Assisting countries to develop identified gaps in their radar and EW capability, and establish programmes to build capability through joint technology development programmes and human capital development initiatives.

Focus Areas

- **Surveillance radar systems:** For persistent, ubiquitous surveillance of wide areas which are optimised to provide situational awareness in asymmetrical threat environments by means of optimised detection, tracking, classification, recognition, fusion, situation assessment and intent estimation;
- **Synthetic Aperture Radar (SAR):** Airborne (including unmanned aerial vehicles) and spaceborne SAR for high-resolution and wide-area imaging, reconnaissance, moving target detection and earth observation applications;
- **Platform protection radar:** Compact short-range radar for detection, confirmation and alerting of missiles and hostile fire;
- **Radar technology and techniques R&D:** Research into advanced radar signal processing techniques, phenomenology and technologies to support sensor development which includes Non-Cooperative Target Recognition (NCTR), Active Electronically Steered Antenna (AESA) technology, small target detection, compact transceiver technology and modern signal processors;
- **Electromagnetic signature measurement and modelling:** Measurement facilities and modelling tools to allow accurate characterisation of platform Radar Cross Section (RCS);
- **Passive coherent location technology development:** Aimed at realising cost-effective passive radar-based solutions for wide area surveillance of air traffic as applied to air traffic control and border safe guarding;
- **EW test, evaluation and training solutions** which include the development of airborne fast jet pod-based systems, field-deployable test and evaluation systems, mobile EW command and control systems, laboratory-based Hardware in-the-Loop (HWIL) systems, Digital radio frequency memory (DRFM) technology, antenna angle simulation systems/ technology, radar threat simulator systems and integrated multi-spectral EW test and training ranges;
- **Adaptive jammer/electronic attack technology development** utilising ultra wideband, active, electronically-scanned antenna array technology, multichannel digital radio frequency memories (DRFM), digital beam forming, advanced signal processing, including machine learning and multi-threat engagement capabilities based on open architecture standards; and
- **EW software product development**, which includes Sensors and EW Engagement Simulation (SEWES) and EW mission support systems (EWMSS).

RADAR AND ELECTRONIC WARFARE continued

EXAMPLES OF WORK IN RADAR AND ELECTRONIC WARFARE

GROUND-BASED SURVEILLANCE AND CLASSIFICATION RADAR (GSCR)

Utilising the insights and experience gained from the successful development and three-year operational deployment of the Meerkat system in the Kruger National Park to counter Rhino poaching, the CSIR has developed a next generation ground surveillance system with radar-based target classification designed into the fundamental radar architecture. This enables unprecedented merging of the detection and classification functions to provide a true non-cooperative recognised area picture, with or without the intervention of an operator. Using the system, rich, up-to-date information can be placed in the hands of decision-makers to enable appropriate responses to developing situations on the ground.

HOSTILE FIRE INDICATION SYSTEM FOR HELICOPTERS

The CSIR, together with an industry partner in the airborne self-defence market, has developed a radar-based hostile fire indicator sensor for helicopters. Helicopters are particularly vulnerable to small arms fire, since they often fly or perform manoeuvres at low speed, or close to the ground, placing them within the effective range of these weapons. The radar-based system detects bullets in real time, thus granting the pilot the opportunity to take immediate evasive or offensive action.

After tests with a technology demonstrator, the system underwent successful field trials using actual gunfire aimed at a helicopter. It succeeded in providing the desired bullet detection and measurement. The next step is maturing the technology, with the industry partner, to develop a product prototype.

INUNDU TEST, EVALUATION AND TRAINING POD

The CSIR has developed a multi-purpose electronics pod which is flown underwing on a fast-jet aircraft for airborne EW and radar testing and evaluation and training applications.

In essence, the pod is a "laboratory in the air" and is designed for network-centric, high-fidelity simulation of advanced radar sensors, platform self-protection systems and missile threat systems. A key feature is a very high level of programmability and modular, interchangeable payloads that are easy to reconfigure to suit different requirements.

Uses include:

- Evaluation of the performance of operational EW and radar systems;
- Development of radar and EW payloads;
- Operational support for doctrine development and optimisation; and
- Training of fighter pilots and naval combat suite crews.

AIRBORNE AND SPACEBORNE SYNTHETIC APERTURE RADAR (SAR)

performs imaging and surveillance of wide areas in all weather during the day and at night.

Supported by the Department of Science and Innovation, an L- and C-band airborne SAR testbed was established to be used in technology research and the development applications of SAR in the civilian and military domains. From this technology base and the C-band phase array technology developed at the CSIR since 2015, the CSIR is partnering with the local space and UAV industry to develop SAR sensor solutions. This includes the first homegrown Spaceborne SAR (SAR-C) with a high-resolution, wide swath sensor utilising digital beamforming and other advanced features. The C-band phased array technology further allows custom solutions to be developed for UAVs with an excellent cost to performance trade-off.

RADAR AND ELECTRONIC WARFARE continued

SYSTEM FOR RADAR TEST AND EVALUATION

Enigma is a hardware-in-the-loop (HWIL), radar target and ECM simulator based on the high resolution Digital Radio Frequency Memory technology developed at the CSIR. Enigma is designed to generate a diverse range of radar engagement scenarios including target (radar skin echo), advanced counter measures and radar environment simulation. It is easy to transport and has a user-friendly interface for ease of programmability.

Enigma can be utilised for evaluation of operational radar robustness, acceptance testing of new radar systems and radar technology development (e.g. testing tracking filters and Electronic Counter-Counter Measure (ECCM) functionality).

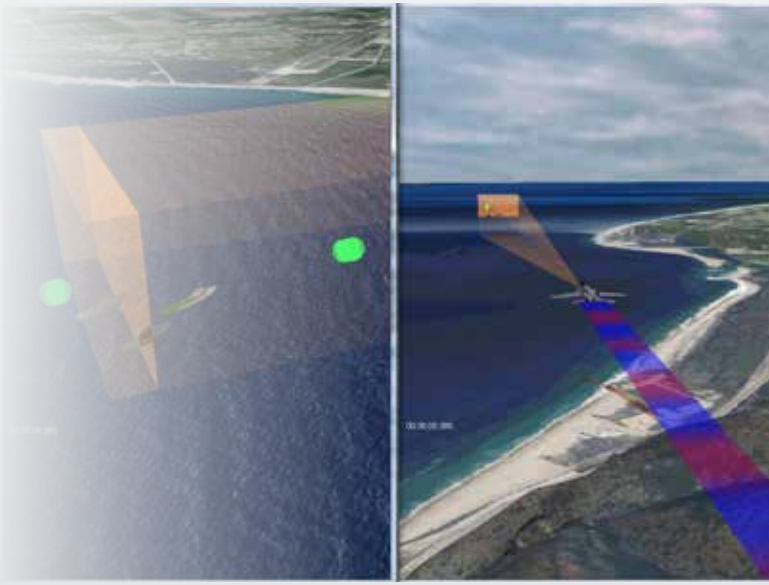
It also supports R&D into advanced ECMs and ECCMs, training and doctrine development.

SEWES

The CSIR's Sensors and Electronic Warfare Engagement Simulation (SEWES) is a few-on-few EW simulation environment. Any number of platforms, consisting of any number of sensors and EW systems, can engage each other in a simulated environment.

SEWES is used by defence research institutes for ECM and ECCM research and development and by defence contractors for system development and optimisation, EW effectiveness evaluation, doctrine development, planning, debriefing and training.

SEWES can simulate "what if" scenarios for commanders to develop and evaluate doctrine.



LANDWARD SCIENCES

Just as much as science and technology drive innovative new additions to warfare the war theatre, it can also provide the answers to better defences and deterrents to new threats.

The CSIR undertakes R&D to contribute to the effectiveness and safety of soldiers in the South African National Defence Force during operations and deployments. Work encompasses several aspects of landward defences, notably -

Soldier systems: Situational awareness, interfaces for and easing of equipment load, tools for border control or special operational and mission needs; detection, clearance and disposal of armaments; waste management.

Firepower: Understanding threats, detection, development of surrogates to test effects of blast events, analysis and validated modelling of data, protective methods, utilising unique infrastructure.

Mobility: Developing and evaluating emerging military mobility technologies and enhancing existing system capabilities to meet changing asymmetric battle space. Interrelated with protection capabilities. Includes validated (test and evaluation data) modelling and simulation ranging from mobility technology evaluation through to development and finally vehicle system trafficability within Geospatial Information Systems; Vehicle dynamics, suspension, tyre characterisation, terrain profiling and autonomous vehicles - i.e. operationally hard, off-road military applications in restricted environments.

Vehicle and crew survivability: Significant contribution to international protection test standards and the assessment authority for landmine and IED protection; Distinction of conducting trauma biomechanics research - different from other test houses.

Research and quantification of shock and blast impact loading on assets and soldiers and research to enhance survivability and resilience. Research on both active and passive protection technologies, using a range of unique self-developed capabilities that provide high resolution load and response data. Work is supported by validated (high-resolution test data) computational modelling with specialised software covering linear as well as non-linear systems - i.e. models for both structural and human body models with focussed high strain rate material models as needed.

THE CSIR'S DETONICS, BALLISTICS, AND EXPLOSIVES LABORATORY (DBEL) is a uniquely equipped facility, outside of the City of Tshwane, where experimentation is conducted to determine the impact of blast effects on soldiers, vehicles and infrastructure.

The outcome is used to develop protective technologies, define optimal mobility solutions, evaluate products or systems to assist with procurement decision making and, ultimately, ensure effective yet safe military operations.

Annually, in the order of 80 blast tests are conducted at the site. The laboratory was established with partners such as the South African National Defence Force and over the past 30 years, the facilities, processes and capabilities have been developed, refined and continuously expanded.

DBEL is licensed to handle explosive events of net explosive content from less than 100g, up to 50kg (typically from small arms fire up to large explosive devices). To cover different test types, DBEL has facilities for water-borne explosives, grenade launchers and mine detection, supported by the necessary explosive magazines, explosive ordnance disposal facilities, plus high-speed photography capabilities and a safe shelter for viewing of blast tests.

The laboratory is the only national facility for validation of vehicle protection against landmines and IEDs. A considerable amount of research focuses on characterisation of IEDs, which are increasingly used in modern warfare and for which limited protection solutions and standards exist. Using projectile impact, such devices have extreme penetrative force – even through armoured protection.

DBEL is home to unique blast impact test and measurement capabilities for detonics, ballistics and explosives, including a newly established energetic materials laboratory. The capabilities include a wide rage of explosive surrogates as well as emulating a range of IED's in order to meet the unique operational requirements of armed forces.

Through this facility, the CSIR has developed and contributed to both international and local protection standards, and is able to provide a training platform for explosives experts.

Protective technologies and disruptor devices have also sparked commercial interest and aside from establishing patents, have also created opportunity for transfer to industry and establishment of manufacturing businesses.

EXPLOSIVE SCIENCE

The CSIR's measurement methodology is based on comparing various explosives and munitions in terms of blast wave characteristics. Elements of the research include analyses of pressure, stress, load or force, velocity, acceleration, displacement and impulse.

The acquisition of data during explosive tests is accomplished by the integration of various sensors, medium, high and ultra-high speed cameras (capturing up to two million frames per second), various data acquisition systems and X-ray systems. However, not all research requires the detonation of explosives. For instance, a device can be inspected dynamically or non-destructively through the use of X-ray facilities.

Ultra-high-speed-photography (recording speeds up to two million frames per second) and the Flash X-ray system are used for ultra-fast diagnostics of explosive events. These diagnostic tools capture events in nanoseconds.

The CSIR performs explosive event testing, evaluation and measurements to validate or design protective solutions. At the CSIR Detonics, Ballistics and Explosives Laboratory, various threat types are tested. These include landmines and side-impact improvised explosive devices. Using anthropomorphic test devices (or dummies) fitted with instrumentation, the impact on crews can be measured during such explosive events. Technologies such as X-ray, impulse measurement and ultra-high-speed photography are also used as well as validated human response assessment software, digital image correlation capabilities combined with unique test rigs that allow for getting three-dimensional, high-speed structural response and measures of the blast load applied synchronously.

A complete offering from laboratory quantification and parameters supported with appropriate software, through to large-scale testing and quantification using the wide range of equipment and specialised test rigs supported by leading methods.

PROJECT EXAMPLES

VEHICLES FOR BORDER PATROL

The SANDF required a family of vehicles to perform the various border patrol tasks and the CSIR completed a requirements analysis for this purpose. A cost-effective family of commercial vehicles was identified and adapted for the border patrol role. A special roll-over protection structure was developed with ISO certification to enable the safe transport of troops. The structure had to be innovated from new steels and interfaces to comply with load restrictions. A field medical support vehicle was developed, able to carry two patients in lying positions. The third, a field command and control vehicle was developed that uses the common roll-over protection structure with the medical support vehicle. The vehicle can accommodate a team of three persons to perform normal command and control actions such as terrain planning, issuing of orders, higher and lower level communications, integration with various field sensors and military systems. The border-safeguarding mobility package was found cost-effective, with easy mid-life upgrade and provided opportunity to transfer technology to local industry.

ADD-ON PROTECTION FOR VEHICLES

The CSIR has developed add-on armour systems for infantry fighting vehicles to protect the occupants from side-impact improvised explosive devices. These systems are significantly lighter than steel armour and provide the same level of protection, which allows the mobility of the vehicles to be retained. The add-on protection is a low-mass/low-cost and customizable solution.

TECHNOLOGY DEMONSTRATION PLATFORM

To accurately demonstrate various applied technology outputs and their value on the battlefield, the CSIR created a test-bed military vehicle called the Landwards Technology Demonstrator. The demonstrator platform is based on existing vehicle technologies and reflects a current six to eight ton military vehicle to allow the SANDF to easily assimilate and evaluate different technologies.

GREEN SOLUTIONS FOR TROOPS

Troops deployed in environmentally sensitive areas, such as national parks that lie on the South African border, require innovative solutions in waste and power management. In close collaboration with the defence force, the CSIR is developing systems that support the formation of green platoons.

The CSIR developed biological-based eco-friendly products that use natural bacteria to treat waste. This is particularly useful in remote deployments where no waste handling systems are in place.

ANALYSIS OF ENERGETIC MATERIALS

Conventional and unconventional energetic materials (such as those used in IEDs) are analysed at a CSIR chemical laboratory to identify the contents, composition and quality of the materials used in product development, manufacturing and in-service support activities.

Analytical methods include:

- Chemical tests (based on colour reaction),
- Chromatographic methods, such as thin layer chromatography,
- Gas chromatography and,
- Differential thermal analysis.

The characterisation of explosives involves the measuring and evaluation of chemical and structural basis data, of both new substances formulated in-house as well as of commercially available substances prior to and post detonation. Prior detonation data collection will include the investigation of purity, molecular weight distribution, traces of other substances; the identification of side products and of thermal properties, the migration pattern of plasticizers, solvent residues and the emission behaviour of polymer-bonded materials, sensitivity and compatibility.

INFORMATION AND CYBER SECURITY CENTRE

CSIR specialists undertake research and innovation in home-grown identity management for private and public sector clients to securely identify and protect people (cradle to grave) and systems (physical and digital) against vulnerabilities, threats, and risks in the digital realm.

The centre strategically partners and collaborates with stakeholders to design, develop, commercialise and localise transformative security technologies.

Information and Cybersecurity centre capabilities:

- Governance, privacy and trust research.
- Secure identity systems research.
- Cybersecurity systems research.
- Data security and analytics research.

Multi-modal biometric capability development: The CSIR develops algorithms to verify or determine identities of people using biometrics such as fingerprints, ears, irises, and others. These are generally packaged into software development kits for clients who develop biometrics recognition systems. The CSIR also assists with the establishment a holistic identity management process to identify, authenticate and authorise those who are allowed access to applications, systems or networks.

Laboratory for network testing: The Cyber range and network emulation and simulation laboratory is used to study the effects of network traffic within a controlled environment. It is used as a testbed for hardware and software verification, which helps carry out performance, vulnerability and resilience testing. The laboratory is also used for live fire exercises, capture-the-flag events, sandbox testing, skills development and awareness training.

Cybersecurity testing, verification and compliance services: The CSIR has a suite of services to ensure products, services and processes follow appropriate information and cybersecurity standards and best practices. The centre provides specialised testing, verification and compliance services including digital forensic services, smart cards and tokens certification, and mobile applications verification, internet-of-things testing and other relevant tests.

Virtual security operational services: The Centre has developed the necessary skills to assist with the design, establishment and operation of security operations centres and computer security incident response team capabilities for private and public sector, including design and development of these capabilities in line with the National Cybersecurity Policy Framework.

Cybersecurity awareness and training: The Information and Cyber Security Centre offers a cybersecurity awareness programme to educate and train employees to understand their role in avoiding cyber-attacks, threats and risks. Training covers the nature of threats such as phishing attacks, online security,

email security, physical security, password management, mobile device security, ransomware, malware, social engineering, as well as basic information security concepts. The training programme is available online and through board games.

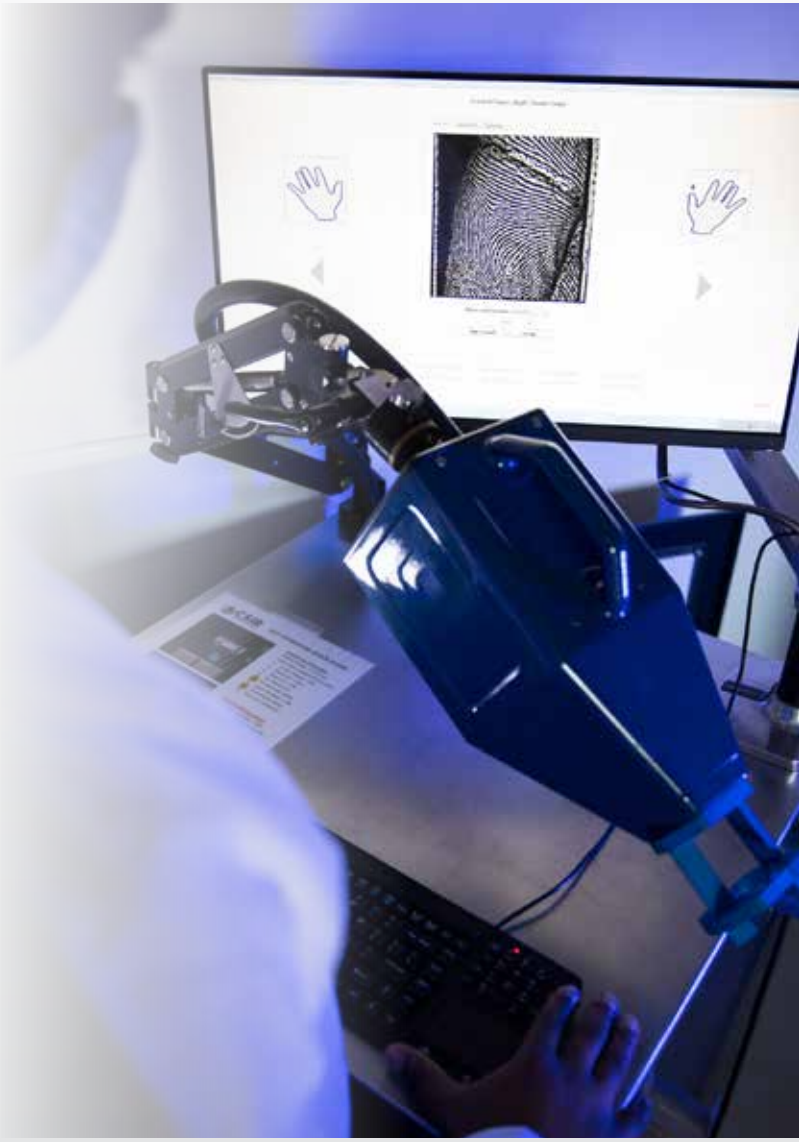
Other services are:

- Governance, risk and compliance;
- Computer security and networking (R&D) of technologies, processes, and practices to protect networks, devices, programs, and data from attack, damage, or unauthorised access); and
- Secure software design and system development of stand-alone applications, web-based systems, proof of concepts as well as mobile applications.

National role

The CSIR is an important player in support of the National Cybersecurity Policy Framework. Cybersecurity incident response teams and security operations centres are two important instruments in any country's cybersecurity capability. The CSIR has developed a solution to assist local organisations with establishing such in-house capabilities, plus training of staff to manage it efficiently.

The CSIR is also home to the country's cybersecurity hub as a national level cybersecurity incident response team meant to protect South African citizens and businesses online, and to contribute to the security of national critical infrastructure.



PROJECT EXAMPLES

BIOMETRIC RECOGNITION OF MINORS

Fingerprinting is the commonly used biometric measure to link a person to an identity. However, a child can be linked to more than one identity which can lead to defrauding the social security system with false claims for child support grant funding. Since features of children change over time, the choice of biometric is not simple and could include ear lobe shape, iris, heels, to name a few. The team has identified a suitable biometric and is developing software algorithms to sit at the core of a system that would reliably capture and correlate biometrics of newborns and minors.

SYSTEM PROVIDES EARLY WARNING OF IMPENDING CYBER ATTACKS

The CSIR developed a prototype software package for personal computers and servers that rapidly and accurately detects network port scan activity. The technology allows the host to block further network communication from the initiator of the scan, thereby preventing it from discovering certain vulnerabilities to exploit.

The CSIR detection algorithm uses a novel detection metric that incorporates statistical modelling of connection attempts. It significantly improves the accuracy and the reliability of port scan detection as compared to a widely used open source intrusion detection system.

The technology was successfully demonstrated on network traffic data recorded over three weeks on a segment of the CSIR's intranet.

CYBERSECURITY CENTRE FOR THE CITY OF JOHANNESBURG

The City of Johannesburg (CoJ) Metropolitan Municipality depends on its significant stores of information and communications technology capabilities to provide services to citizens. To enable this important responsibility, COJ requires assurance for the security of systems, and protection of data in its information assets. The CSIR Information and Cyber Security Centre provides technical support and expertise to support the City in building an integrated cybersecurity capability.

LOST PACKET WAREHOUSING SERVICE

The Lost packet warehousing service is a technological solution that functions as the primary source for cybersecurity data sets within the CSIR. The service allows for the continuous but passive collection, sanitisation and maintenance of cybersecurity data sets. This strategic project aims to position the CSIR as a primary source for cybersecurity data within South Africa.

CREDENTIALLING USING WORLD WIDE WEB CONSORTIUM VERIFIABLE CREDENTIAL STANDARDS AND DISTRIBUTED LEDGER TECHNOLOGIES

As society becomes more digitised, so the need grows to keep track of and cryptographically verify a subject's digital credential(s). Distributed ledger technologies can provide a more persistent form of identity that can be linked to attestations about a subject's credentials and can be verified due to the data immutability guarantees that the technology possess. A CSIR credentialling project aims to comply with the latest international and local data regulations, as well as the emerging World Wide Web Consortium standards, to enable citizens to be in control of their personal data such as academic qualifications or other certificate and license attestations.

EDUCYBER

EduCyber is an online cybersecurity awareness and training platform that can be used by organisations, schools and other entities to design and deploy security awareness content across the entire organisation with limited resources. It provides more information and knowledge on how users can identify security and related threats and protect themselves when surfing the internet. The initiative is in support of a cyber-smart SA.

NETWORK EMULATION AND SIMULATION LABORATORY

The CSIR network emulation and simulation laboratory provides a platform for the high fidelity replication of existing or planned networks through a mixture of physical and virtual devices. This solution ensures the reliable testing of concepts and products before deployment in an operational environment. In addition, the platform also provides a realistic operational environment for effective cybersecurity training.

The laboratory provides a web-based environment for cybersecurity researchers with the ability to perform network bandwidth modelling, cybersecurity training, device research and advanced analytics to study cyber risks and to deliver effective and practical security solutions. Simulating both good and bad traffic to validate and optimise networks with the most realistic conditions.

INTEGRATED SECURITY SOLUTIONS FOR COMPLEX CIVIL AND MILITARY SCENARIOS

Security can no longer be achieved with fences and cameras. Citizens, organisations and the state face complex and vast security threats, and solutions are not always within reach or suited to local conditions.

Drawing on its experience and multidisciplinary skills base, the CSIR dismantles assumptions and finds new directions to address complex problems. The process starts by developing a full understanding of the security threat and drivers of change to define the right capabilities. These capabilities include not only technology, but the personnel, processes and governance that enable clients to conduct their operations sustainably. Support includes selection and procurement of best-suited products, testing, and integration of technology into operational capabilities. Where the solutions don't exist, a team of R&D engineers develop the required technologies. There is no 'one size fits all' approach or picking one random deterrent such as a camera system, to deal with any and all modes of operation. Systems engineers are critical in such endeavours to analyse and design.

Maintaining the integrity of protected areas is becoming more and more challenging due to multi-national organised crime syndicates exploiting weaknesses in the public and private security systems. South Africa has seen an increase in theft and damage to critical infrastructure such as cabling and power plants. The vulnerability of large areas such as farms, border areas or game parks, even schools, is also increasingly in the spotlight.

Some of the technologies that form part of such a solution include:

- Perimeter intrusion detection systems.
- Tactical field equipment (such as night-vision devices and weapon systems, or canine deployment.)
- Integrated radar and optronic surveillance systems – manned or unmanned, day and night.
- Manned and unmanned aerial support technologies.
- Secure communication systems.
- Predictive modelling to be proactive against criminality.
- Gunshot detection.
- Best-suited mobility choices for all terrains and purposes.
- Training and doctrine development.

PROJECT EXAMPLES

SUPPORTING COUNTER POACHING

Work undertaken over many years in counter poaching, counter piracy and border safeguarding has honed the CSIR's expertise in finding solutions to specific, complex security threats. Key is understanding the threat, the drivers of change, and the best-suited technology options that are integrated into a holistic safeguarding system. Poaching attempts are predicted, detected and effectively accosted with the right combination of tools, tactics, systems and operational swiftness.

RAPID RESPONSE TASKS

Where operational needs go beyond available technologies, R&D engineers develop custom solutions. Being able to deploy fast surface craft from a slower moving frigate, gives naval forces the edge in counter-piracy on South Africa's coasts.

COMMERCIALISATION OPPORTUNITIES

Industrialisation is a key component of the CSIR strategy. Technology transfer and commercialisation efforts aim to grow industrial activity and generate income for reinvestment into the development of further, innovative technologies and capabilities.

CSIR Defence and Security has a significant number of technologies that are ready to enter the commercialisation stage, as well as a pipeline of technologies under development or refinement.

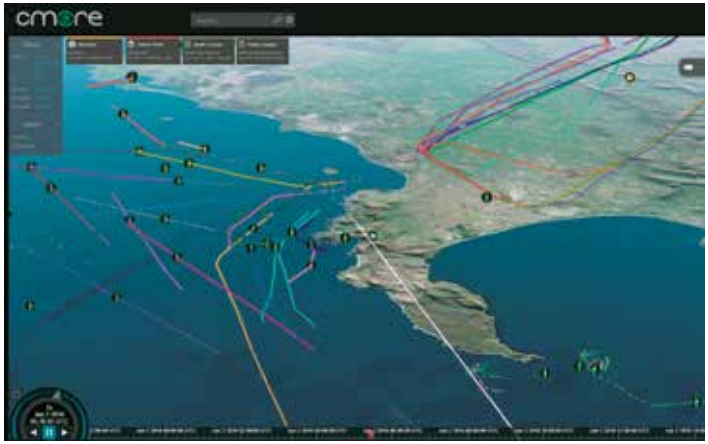
Various models for commercialisation are pursued.
With industry collaboration high on the agenda, the CSIR is open to partnerships, co-development agreements, licensing and venturing.

EXAMPLES OF MATURE TECHNOLOGIES

THE CMORE COMMAND AND CONTROL PLATFORM

Cmore is a web-services platform, with both web and mobile applications. It is used for collaboration and awareness or information sharing within and across organisational boundaries during operations. In counter-poaching, for example, it strengthened the collaborative effort between nature conservation officials, defence forces, policing, border control and legal agencies. By sharing information from different sources and platforms, Cmore achieves force multiplication, accurate reporting with less effort, and proactive interventions as opposed to reactive operations.

Cmore has been in use in operational conditions over long periods with a large, active user-base which has benefitted from the refinement and enhancement of the system to a truly useful and robust operational backbone.



THE MEERKAT ALL-SEEING WIDE-AREA SURVEILLANCE SYSTEM

The CSIR developed a wide-area surveillance system to detect and intercept rhino poachers in the Kruger National Park – before they attack. It was optimised to operate in the undulating bush savannah environment, in any weather, day and night and had to integrate with the existing tools, staff, and procedures used in the park.

The system uses a land surveillance radar plus radar-designated, long-range cameras with laser illumination for night operations. The radar detects and localises a moving target, and the cameras confirm detections as well as distinguishing between humans and animals. All components are locally sourced and supported.

The sensor system is self-sufficient and can be used continuously for months at a time at unprepared and unattended sites. This allows maximum continuous coverage over poaching ingress routes. The system is quickly moved by pick-up truck and/or helicopter. The system can be used in any large area requiring perimeter protection – including border safeguarding, industrial plant security and farm security. Its success was proven in the Kruger National Park, where it has been in operational use since 2017.

www.csir.co.za