CSIR FUTURE PRODUCTION: MANUFACTURING

Geared for the future: Transforming manufacturing platforms, introducing new technologies and improving processes in local industries to make South Africa a competitive participant in the global economy.

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

CSIR
Touching lives through innovation

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.

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

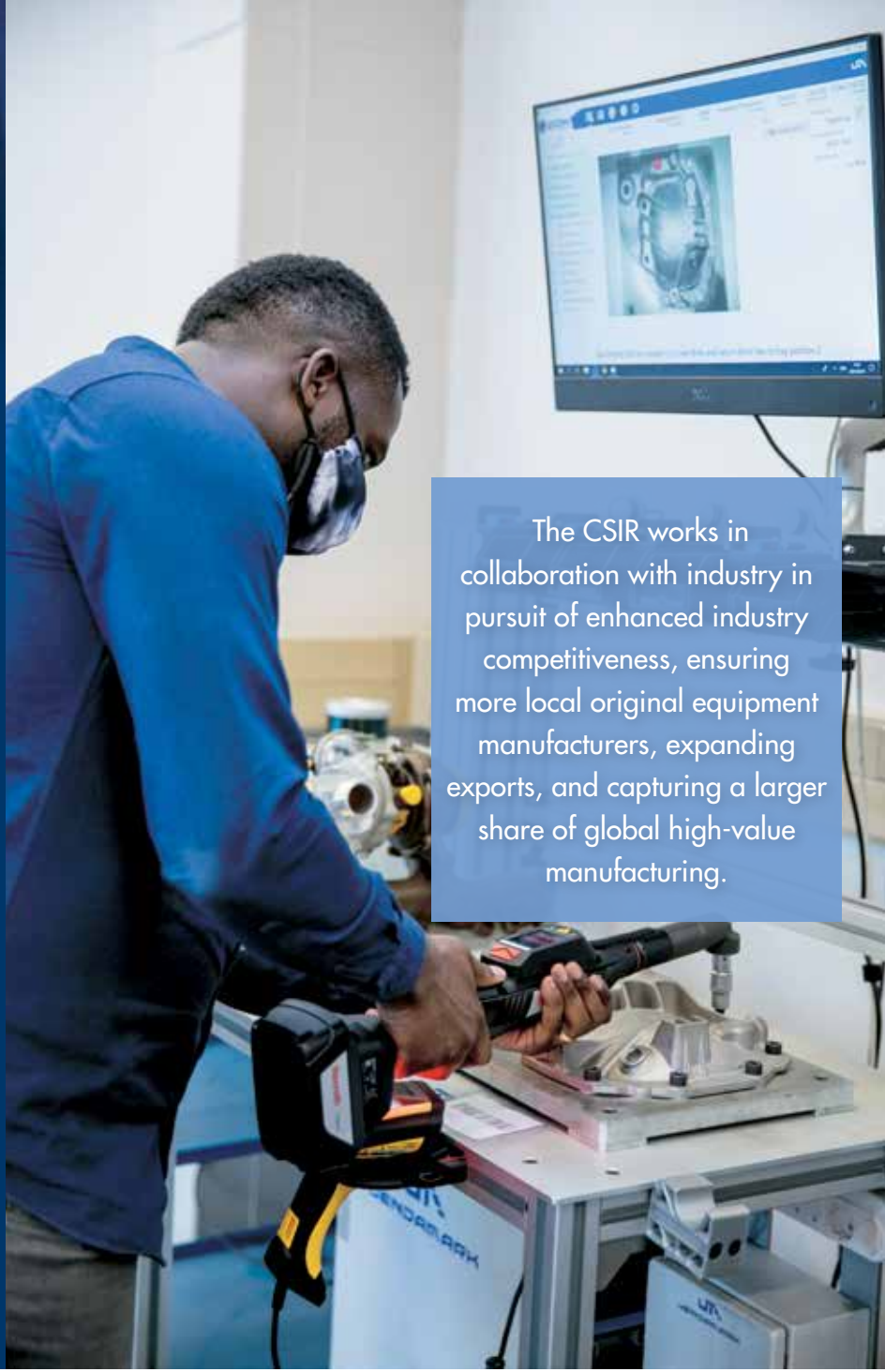
INTRODUCTION

CSIR Future Production: Manufacturing is geared to contribute to South Africa's re-industrialisation and the competitiveness of the strategic local industry by developing or disseminating new technologies that lead to novel or improved manufacturing equipment, products and processes.

The cluster assists industry with the implementation of end-to-end digital engineering and logistics that facilitate traceability and improved production efficiencies. Specialised industrial services are also available and easily accessible by small, medium and micro enterprises (SMMEs) and big business alike.

Core to these value offerings is the use of cutting-edge digital transformation and fourth industrial revolution (4IR) technologies to build capabilities (skills, processes and equipment) within industry in fields such as robotics and automation, augmented reality, biotechnology, advanced manufacturing and the Internet of Things (IoT) (including health and usage monitoring systems).

The CSIR also supports the state through localising key technologies that contribute to better service delivery and socioeconomic growth.



The CSIR works in collaboration with industry in pursuit of enhanced industry competitiveness, ensuring more local original equipment manufacturers, expanding exports, and capturing a larger share of global high-value manufacturing.

TECHNOLOGY FOCUS AREAS IN FUTURE PRODUCTION

- **Advanced manufacturing:** Development of advanced additive manufacturing (3D printing) and other manufacturing machines, as well as more efficient and on-demand batch production of multiple complex customised parts.
- **Advanced materials and processing technologies:** Downstream beneficiation of local resources and improved process and product performance, for example, creating polymer composites that result in lighter, more durable products and advanced surface engineering technologies to increase the usable life of high-value products.
- **Advanced robotics:** Utilisation of novel platforms for inspection and automated production. Robots can assemble, monitor and inspect materials, parts and machinery and work with humans in an integrated way.
- **Artificial intelligence:** Cognitive technologies for big data analytics and automated inspection, quality control, inventory management and materials handling. These technologies can autonomously learn, continuously improve decision making and respond faster to changing systems and environments.
- **Biophotonics:** Application of optical or photonics-based techniques to facilitate single molecule and/or cell studies with a major focus on the development of point-of-care diagnostic devices.
- **Human enhancement technologies:** Improving production and workforce efficiencies through wearable technology for the enhancement of physical and cognitive capabilities (augmented and virtual reality) and collaborative robotics.
- **IoT:** Networks of low-cost sensors for data collection, monitoring and decision-making, allowing real-time operational improvements.
- **Training and skills development:** Technical awareness and skills development in and using 4IR technologies. Training extends from theoretical courses using an e-learning platform, to applied training in a virtual environment, using virtual reality technology and applied training in a hands-on physical (controlled) environment.

IMPACT AREAS – ADVANCED MATERIALS ENGINEERING

The CSIR focuses on developing high-value, knowledge-intensive capabilities in various manufacturing processes to better utilise our national resources, develop skills and transfer technologies to industry to support the country's re-industrialisation. The CSIR also pursues options for import replacement of specialty metals and alloys, advanced polymers, plastics and next-generation composites and fibres.

The Advanced Materials Engineering group leads in areas such as structural design and analysis, the development of advanced casting, and powder metallurgy technologies.

The group hosts the Light Metals Development Network and the Titanium Centre of Competence (TiCoC), multiuser national platforms supporting industrialisation initiatives, as well as other SANAS-accredited facilities that are accessed by stakeholders, such as universities, science councils, as well as local and regional small to large enterprises.

The Advanced Materials Engineering group, in particular, focuses on:

- Developing transformative technologies in support of the establishment of a new titanium industry, using the TiCoC at the CSIR as implementation platform;
- Supporting the improved global competitiveness of our existing aluminium industry and developing national roadmaps (such as, but not limited to, aluminium, titanium and magnesium), and hosting SANAS-accredited facilities (ISO/IEC 17025-2017) used by universities, as well as the private and public sectors;
- Building and transforming high-end infrastructure for training and skills development through the Centre of Competence Models and establishing research and innovation chairs in titanium to fast-track human capital development and innovation platforms, plus 4IR skills; and
- Supporting small to medium enterprises by establishing industry incubation platforms that will produce components and systems for different sectors, using existing CSIR-developed technologies. The CSIR also offers collaborative technical support through directed research and consultancy services, finding sources of funding and building relationships between industry and academia.

The CSIR works across the materials value chain, exploiting 4IR technologies, as well as developing advanced materials, to provide the local industry with novel and unique offerings and a globally competitive edge.

CORE CAPABILITIES

Design, Analysis and Testing

Exploiting the benefits of advanced technologies, the CSIR covers the full development path of functional prototypes and manufacturing methods.

This includes concept development, design and analysis within a product lifecycle management paradigm, development of the required manufacturing technologies, prototype manufacture, and qualification/testing.

Undertakings are commonly applied to titanium, aluminium, magnesium and carbon fibre-based products, and are also applicable to a broader range of metallic, composite and polymer-based products.

Powder metallurgy technologies

The CSIR focuses its efforts in powder metallurgy technologies on developing low-cost, energy-efficient manufacturing techniques for mass-producing components for industrial applications in sectors such as automotive manufacturing, mining and health.

Through these technologies, the CSIR aims to support industrialisation, localisation and commercialisation in domains such as metal injection moulding, direct powder rolling, and press and sinter technologies.

In terms of metal injection moulding, the focus is on attracting investment for setting up a local manufacturing facility for the local production of custom feedstocks. The focus for press and sinter technologies is the localisation of the production of copper-based bushes. For direct powder rolling, the focus is on demonstrating the commercial viability of converting powder into sheets.

Researchers have access to SANAS-accredited facilities for mechanical testing, as well as powder characterisation, in addition to a metallographic laboratory.

Advanced casting technologies

The main research focus is on investment casting, semi-solid metal forming and high- pressure die casting. The team builds on CSIR expertise developed over many decades. While emphasis was initially on fields such as investment casting of high-temperature alloys for gas turbine applications, (e.g., nickel and cobalt-based super-alloys) the focus has shifted to light metals technologies and, in particular, aluminium, titanium and magnesium.

IMPACT AREAS – ADVANCED MATERIALS ENGINEERING

SPECIALIST RESEARCH FACILITIES

Mechanical testing facility (SANAS accredited)

The testing of the mechanical properties of structural components is vital to understand its performance under stress. The CSIR mechanical testing facility tests metallic materials and ceramic materials, and powder compacts. It can also work on materials such as polymers, glass and composites. The facility is ISO/IEC 17025-2017 accredited.

The facility is used by local industries and universities, as well as international clients for material and component evaluation and qualification.

Some large projects undertaken include testing of materials used in the construction of the Square Kilometre Array, Eskom power stations, the Nelson Mandela Bridge in Johannesburg, and the 2010 soccer world cup stadia.

The mechanical testing facility collaborates with other test facilities, including private sector companies and the South African Bureau of Standards.

Powder Characterisation facility (SANAS accredited)

The CSIR Powder Characterisation Facility is accredited to ISO/IEC 17025-2017 quality system standards. The aim of the facility is to offer a standardised approach to the testing, qualification and certification of powder and powder metallurgy processes.

The SANAS-accredited facility performs a range of procedures – from standard high-volume testing to complex materials analysis and in-depth granular dynamics investigations for a large variety of sectors.

Available equipment allows for chemical composition analysis, powder sieve analysis, particle size distribution, flow rate, apparent density, tap density, and gas pycnometer – a method of measuring an irregularly shaped solid object's volume.

This facility supports universities and national initiatives such as the CSIR National Laser Centre and The Centre for Rapid Prototyping and Manufacturing based at the Central University of Technology.

Investment casting facility

The CSIR Investment Casting Facility is the only foundry in South Africa with a production-level vacuum casting capability. The foundry was founded on the ability to produce single-crystal nickel-based superalloy turbine blades for gas turbine engines from standard equiaxed grained blades to complex single-crystal hollow blades that were bench-tested on commercial military jet engines. The technology has since been transferred to industry.

The CSIR has also entered the niche area of investment cast titanium alloys.

In recent years, the CSIR has been working closely with several industrial partners to localise the manufacturing of products. The most significant intervention was the casting and qualification of the 9 mm pistol for the South African Police Service, in collaboration with Hausler Scientific. The first batch of 500 pistols was produced and, subsequently, the foundry assisted with limited production for Hausler Scientific.

The metal injection moulding facility

The CSIR has developed a custom metal injection moulding technology platform that can undertake cost-effective mass production of complex near-net-shaped components from fine titanium powder and related metal powders. This technology makes it possible to overcome the geometrical and productivity limitations of traditional production techniques.

The Metal Injection Moulding Facility offers a combination of tooling design and manufacturing capabilities, in addition to the mass production of a wide range of small metal parts. Outputs have high dimensional accuracy and replication fidelity on a nearly unlimited choice of material, through powder metallurgy. While the existing metals industry is already benefiting from the facility, a future downstream titanium industry is also set to benefit significantly.

Funding for the facility was primarily through the Department of Science and Innovation's (DSI) Advanced Metals Initiative and the TiCoC flagship programmes.

The facility is the only one in South Africa to successfully develop in-house methods of fabricating products and custom feedstocks using metal injection moulding. It houses expertise and equipment as part of a one-stop resource for conceptualising, designing and manufacturing complex precision components.

The facility is in the process of acquiring a new industrial-scale metal injection moulding furnace to scale up from a small batch to a mass-production scale.

IMPACT AREAS – ADVANCED MATERIALS ENGINEERING

Metallographic facility

The CSIR Metallurgical Engineering Facility offers unique and broad heat-treatment and metallographic capabilities to serve domestic and international customers in diverse manufacturing operations.

The facility houses heat-treating capabilities, meeting high industry standards and successfully servicing a broad range of industries, including the medical, military, stampings, hi-speed tool steels and forging tooling.

The facility also houses a fully equipped metallurgical testing lab. It handles the full complement of metallurgical sample preparation, from, cutting, polishing and lapping facility, high-resolution microscopes and photographic capability, element content testers, and hardness testers.

Expertise at the facility is from the disciplines of materials science, electron microscopy and physical metallurgical engineering.

Non-destructive testing facility

Non-destructive testing (NDT) is the process of inspecting materials, components and assemblies to find discontinuities or anomalies in their characteristics that negatively impact their integrity, without destroying the serviceability of the part or system. The CSIR houses a range of NDT capabilities and skills, including a Gecco Phased Array UT system; a dual frequency Nortec ET system with a complete range of probes; and a 160 KV micro focus X-ray system. The facility provides the manufacturing industry with effective, application-oriented NDT solutions that are essential for sectors where the operational sustainability of high-value components is crucial, like the aviation industry, automotive sector, energy and environment sectors, transportation sector, medical technology and life sciences. This ensures that South Africa remains competitive with the international research community and decreases dependence on internationally sourced NDT expertise.

IMPACT AREAS – INDUSTRIAL SENSORS

The Industrial Sensors Impact Area has established a significant technology and product development capability in the field of sensors.

It is ISO 9001 and ISO 13485 certified and undertakes custom product development projects on sensor products targeted at industrial inspection and monitoring applications. The team's focus on innovation has seen it successfully develop solutions that are used across a range of industries, locally and internationally.

Historically, the CSIR has focused on two key technologies in this domain, namely electro-optics and ultrasonics. The *electro-optics* capabilities have been directed at inspection systems for the energy transmission and distribution industry and has seen the world-leading CoroCAM range of cameras developed and commercialised through a CSIR start-up company Uvirco (www.uvirco.com).

The *ultrasonics* capability has been applied in multiple domains, including establishing the CSIR as the wet-end sonar partner to the South African Navy. The ultrasonics capability has also been applied into air-ultrasonics for level measurement, medical ultrasonics for primary healthcare and guided wave ultrasonics for real-time rail-break detection on heavy freight haul lines.

In recent times, the group has applied its product development capabilities in support of South African SMMEs that are innovating their own products to support them in the areas of technical development and regulatory approval. The group has also engaged in machine learning research on medical datasets as part of the CSIR's collective drive to implement 4IR technologies.

IMPACT AREAS – INDUSTRIAL SENSORS

FOCUS AREAS

- **The Sonar Research Group** conducts research and development of next-generation technologies for the naval and commercial underwater domains. This includes design and prototyping of ultrasonic transducers and arrays, and undertaking a range of acoustic, electrical and pressure-related tests. Current projects include high-resolution underwater imaging using synthetic aperture sonar arrays, as well as broadband underwater communications technology for real-time underwater data communications between autonomous underwater vehicles and surface vessels.
- **The Industrial Systems Research Group** develops advanced inspection systems, such as multispectral imaging systems for powerline inspection that operate across the infrared (IR), visible and ultraviolet (UV) wavelength bands. CSIR-developed, world-first systems have achieved extensive commercial success internationally. The team has also developed imaging systems for gas-leak detection on electrical switch gear installations and petro-chemical plants.
- **The Human and Societal Systems Research Group** focuses on point-of-care medical devices that empower health workers at primary healthcare clinics to conduct screening tests that have historically only been possible at secondary and tertiary hospitals. As an example, the Umbiflow™ system, which is used for third trimester women at around 30 weeks gestational age, has seen drops in the still-birth rate by up to 50% in the communities where it was implemented.

PROJECT EXAMPLES

Powerline inspection systems

In partnership with Eskom, the CSIR developed a range of inspection camera systems that permit electrical field workers to inspect power pylons, sub-stations and other electrical transmission and distribution infrastructure for faults.
The cameras simultaneously image in a combination of IR, UV and visible wavelength regions to provide diagnostic information for asset maintenance and repair. Through its spin-out company, Uvirco, these specialised systems have achieved significant international success as the CoroCAM™ range of products, sold in some 45 countries and capturing around 50% of the world market for such systems. Next-generation systems that can detect and quantify the IR and UV emissions, as well as detect gas leaks, are nearing market release via Uvirco.

Sonar research and development

The CSIR, Armscor and the South African Navy are long-time partners in underwater ultrasonic sensors, conventionally referred to as 'sonar'. The capability is currently being further refined for future high-resolution underwater imaging and data communications, based on in-house developed ceramic-polymer composite sensor materials. Application areas include navigation and surveying underwater in shallow waters (such as harbours and rivers), as well as deeper, open waters. Imaging applications, which make use of advanced synthetic aperture sonar array, electronics and signal processing capabilities, include the use of systems deployed directly from a naval vessel, as well as mounted on autonomous underwater vehicles. The underlying technologies are also

used for broadband underwater communications and high data-rate/low error-rate communications capabilities have been successfully demonstrated.

Umbiflow™ – Fetal monitoring system

The CSIR's ultrasonics, electronics and signal processing capabilities have also been applied to empower health workers at primary healthcare clinics to conduct tests and diagnostic interpretations conventionally only done at sophisticated, higher levels of healthcare. The Umbiflow™ system can be used by registered nurses and midwives to measure the blood flow characteristics between a mother and child in the womb to detect whether the fetus is receiving sufficient oxygen and nutrition during its development phases. Testing under clinical trials in South Africa showed up to a 50% reduction in still-birth rates and opens the door for a step-change in South Africa's path to the United Nations Sustainable Development Goals targets around maternal and child health. Umbiflow has been clinically tested in Ghana, Rwanda, Kenya and India as part of a World Health Organization study and has received funding for technology upgrades and market development from Grand Challenges Canada.

Building on the Umbiflow™ technology, Cardiflo™ is targeting primary healthcare level population-wide screening for cardio-vascular disease incidence. A prototype system is currently undergoing clinical trials to establish its efficacy and potential for impact.

IMPACT AREAS – INDUSTRIAL SENSORS

MeDDIC Programme

The Technology Innovation Agency (TIA) of the DSI has established a medical device and diagnostics innovation cluster programme (MeDDIC) to promote local innovation in medical devices. As part of this initiative, the CSIR is providing support to aspirant SMMEs on technical product development and regulatory approvals. The goal is to assist SMMEs in navigating a range of barriers-to-entry that are typically encountered in the medical devices market, such as technical product development, product/component testing, intellectual property management, quality management systems, clinical testing, medical device establishment licensing and market-access issues. The CSIR works with subject-matter experts as required to fulfil this goal, while utilising its own experience in medical device development and working in the ISO 13485 (medical) regulatory environment.

Prevention of heavy-freight train derailments

In partnership with Armscor's Institute for Maritime Technology, the CSIR has developed a world-first ultrasonic monitoring system that detects breaks in heavy-freight railway lines remotely and in real-time. The Ultrasonic Broken Rail Detection system has been implemented on the 860 km-long Sishen-Saldanha heavy-haul line and proven itself able to detect rail breaks as they happen and, via wireless alerts to a control centre, prevent the derailment of the 4 km iron-ore trains that run along this line. Through further research, a next-generation system that detects metallurgical defects prior to their appearance as cracks in the rail line, thereby permitting a condition-based-maintenance philosophy to be conducted, is under development.

FACILITIES

- Underwater acoustic testing tank of approximately 120 m^3 volume for the test and acceptance of underwater transducers and arrays. Tests can be conducted between a few kHz and several hundred kHz under a range of distances and rotational angles.
- Pressure test vessel to simulate underwater depths of up to 1 000 m.
- Laser vibrometer system to measure and map physical vibrations/deformations on vibrating structures. Sub-nanometre resolution has been demonstrated.

INDUSTRY CONNECT

Industry Connect is an initiative aimed at supporting industry by improving competitiveness in niche areas, fostering new technology development, de-risking technology, facilitating technology transfer, and supplier development. This is in support of the CSIR's strategic objectives of collaboratively innovating and localising technologies and providing high-impact industries with access to infrastructure and expertise.

Industry Connect capabilities include:

- **Technology-based supplier development:** Providing a platform for facilitating partnerships and collaboration among well-developed companies and SMMEs. Helping SMMEs integrate within the supply chain and become independent suppliers.
- **Technology road mapping:** CSIR specialists in technology road mapping assist business owners with the implementation of new strategies, techniques and systems, in line with advancing technologies to increase operational efficiency – now and into the future.
- **Techno-economic assessment:** Conducting techno-economic assessment using widely recognised methodologies for the aerospace, maritime and other high-tech industries.
- **Technology development and enhancement:** Developing relevant industry-focused capabilities and facilitating associated transfer of technology to industry. The CSIR also supports companies with de-risking new technology.

INDUSTRY CONNECT

THE AEROSPACE INDUSTRY SUPPORT INITIATIVE

The Aerospace Industry Support Initiative (AISI) is a South African government initiative through the Department of Trade, Industry and Competition (**the dtic**) with the express aim of improving the competitiveness of local businesses in the aeronautics, space, defence and the marine sectors.

The AISI takes its strategic direction from government's objectives, with a specific emphasis on industrialisation and localisation of technology, and technology-based supplier development and, ultimately, ensuring integration with global supply chains.

the dtic utilises the CSIR and its position in the National System of Innovation as an independent, strategic directed research and development (R&D) entity to give industry access to national expertise and infrastructure to improve its capabilities and offerings.

FOCUSED PROGRAMME-LEVEL INTERVENTIONS

Established in 2006, the AISI achieves impact in industry through focused programme-level interventions. The programmes are designed to assist industry to improve and acquire new and advanced capabilities that, in turn, enable improved competitiveness. Collaboration between the local industry and the AISI is a key element in improving competitiveness and establishing a global footprint in the advanced manufacturing environment. Over time, the AISI has supported over 100 companies, directly and indirectly as benefitting organisations. This has been achieved through the following programmes:

- **Technology-based Supplier Development:** The AISI's Technology-based Supplier Development intervention provides enabling mechanisms to assist industry to improve productivity, implement quality management systems to obtain certification, and optimise operations and integration into global supply chains. These interventions are implemented with the specific aim of broadening the industrial base by encouraging original equipment manufacturers, integrators and sub-systems suppliers to work with SMMEs and lower-tier suppliers on technology programmes.

- **Industry Development and Technology Support**: This programme focuses on advancing production innovation such as the use of advanced manufacturing and other 4IR technologies to build more durable, compact and efficient products. Access to new and existing processes, products and methods is also facilitated to ensure that beneficiaries develop products and services that enable them to exploit multiple market opportunities. This includes testing, evaluation and prototyping utilising CSIR experts and facilities. Integrators and sub-system suppliers are encouraged to include SMMEs and lower-tier suppliers in their supply chains to enable the continuous transfer of knowledge, expertise, capabilities and technologies, and, in doing so, broadening the industrial base.

- **Coordination, promotion and awareness:** The AISI plays a pivotal role in coordinating activities in and promoting awareness of the aerospace sector in South Africa. A flagship event is the annual Aeronautical Society of South Africa Conference that brings together local industry players to showcase projects and associated impact achieved in the year.

- **Sector Strategic Support Initiatives:** The AISI implements, oversees and contributes projects of national interest through this programme. This includes the development of the Commercial Aviation Industry Development Strategy, the hosting of the Joint Aerospace Steering Committee and contributing to the development of the Aerospace and Defence Masterplan, at operational and strategic levels.

INDUSTRY CONNECT

MARINE MANUFACTURING, ASSOCIATED SERVICES AND OTHER MANUFACTURING INDUSTRIES SUPPLIER DEVELOPMENT PROGRAMME

The Marine Manufacturing and Repairs Supplier Development Programme was initiated in 2019 on behalf of **the dtic** to assist small enterprises to achieve accreditation and compliance with marine standards for their products and services.

The programme assists suppliers in ship- and boatbuilding, maintenance and repair, and the associated services industry to enhance their visibility within local and global supply chains and increase their competitiveness.

The ship and vessel manufacturing and repair sector has significant scope to achieve growth and job creation in the local economy. The sector was designated for local procurement and public working vessel procurement to have at least 60% of local content to support component manufacturers. However, very few local suppliers have the required accreditation and components are still being sourced from abroad, which prevents the local industry from developing and benefitting.

The programme focuses on strengthening the sector's stance in the manufacturing supply chain by achieving the required accreditation and contributing to the localisation of marine technologies and products.

The programme focuses on two interventions, namely support for marine standards and accreditation, and support for technology enhancement. The marine standards and accreditation intervention was created to address the need for local companies to supply approved and certified products and services to designated public procurement in the ship- and boatbuilding industry. The technology enhancement intervention aims to assist suppliers to enter new markets or enhance existing market positions in the marine and related industries.

This approach is replicable in other sectors.

CENTRE FOR ROBOTICS AND FUTURE PRODUCTION

In the Robotics and Future Production Centre, the focus is on the application of digital transformation and 4IR disruptive technologies to enable local manufacturing industries of all sizes to be globally competitive. The centre collaborates with partners (from universities to private sector players) and places emphasis on skills development and training – particularly in and using 4IR technology.

Key focus areas include automation and connectivity, and localisation of robotic infrastructure and equipment, as well as broader product development for uptake by local companies in priority sectors such as mining, health, automotive and agriculture or agro-processing. Capabilities include automated inspection and quality control, automated materials handling solutions, customised robotic equipment development, machine monitoring and predictive maintenance, augmented reality and virtual reality solutions and human-centred automation through assistive/collaborative robotics.

In addition, the centre has a strong capability in 4IR assessments and benchmarking, plant and process model development, equipment instrumentation and data gathering, data analysis and optimisation and digital integration into supply chains. This allows us to enable industry to participate in the global value chain.

THE LEARNING FACTORY

The pilot site of the Learning Factory (LF) was established in March 2021 on the CSIR campus. This initiative, a partnership between the CSIR and the Sector Education and Training Authority for Manufacturing, Engineering and Related Services (merSETA), is geared towards promoting skills development and innovation, applied to digital technologies underpinning the fourth industrial revolution (4IR). In addition to the LF at the CSIR, a target of 18 LFs are to be established at South African technical and vocational education and training (TVETs) institutes around the country. The first of these are already contracted with the EastCape Midlands TVET College.

WHAT WE OFFER

- Skills development (training, upskilling, reskilling, cross-skilling) and innovation platform for the operation, implementation, research and design of key 4IR technologies;
- Test-bed platform for de-risking of 4IR technologies applied to all stakeholders;
- Support of technology localisation using 4IR technologies;
- Technology transfer to stakeholders, including SMMEs, in support of re-industrialisation pertaining to 4IR technologies
- Support platform for LFs that will be established at TVETS in terms of technologies, curriculum, best practices, etc;
- Platform to serve as a research enabler applied to innovation in 4IR applications – i.e. Applied research informed by stakeholder needs.

CENTRE FOR ROBOTICS AND FUTURE PRODUCTION

COME AND SEE

The pilot site includes demonstrations of the following:

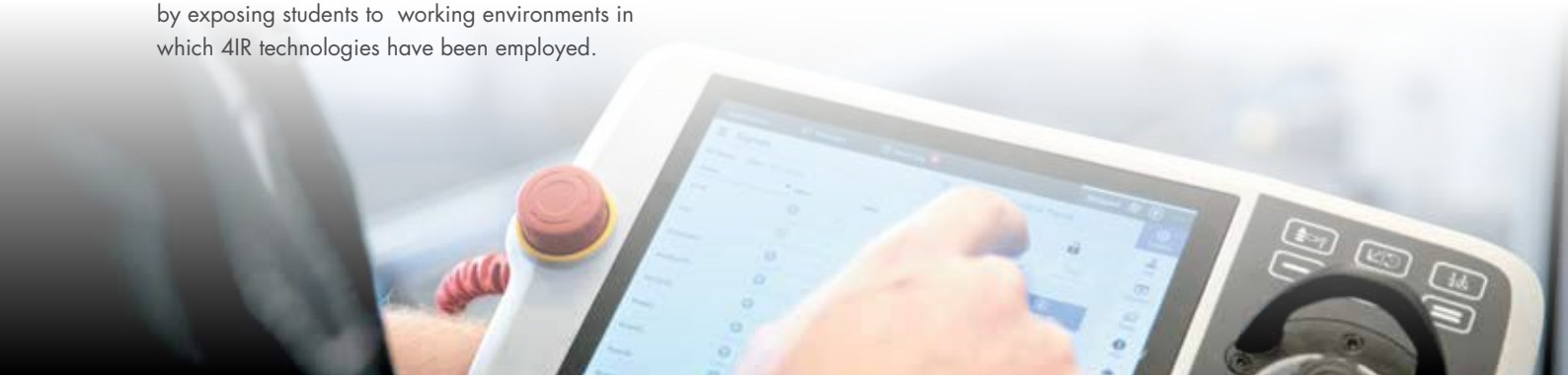
- Skills development of 4IR technologies as well as use of 4IR technologies to support skills development;
- Theoretical training introducing candidates to generic 4IR applications from a South African perspective;
- Practical training on 4IR technologies such as Robotics, the Internet of Things; cyber-security, simulation and additive manufacturing to name a few;
- Application of theoretical and practical training to specific industry related areas such as a modular and flexible, configurable manufacturing cell, assembly station using collaborative robots, smart home and energy optimisation cell;
- Research Labs that support research and innovation activities in the 4IR space with respect to design, incubation, and prototyping;
- Experience Centres that support experiential learning by exposing students to working environments in which 4IR technologies have been employed.

Online training modules have already been designed for roll-out in 2022. Training is currently free of charge and offered in different modalities whereby attendees can take advantage of full online training, virtual training, or hybrid training that is virtually linked to real physical equipment, as well as practical experiential training on the physical equipment that is located at the CSIR Campus in Pretoria.

Interested parties in the manufacturing sector – including managers, technologists, engineers and trainers are invited to visit www.4irsa.co.za for more information.

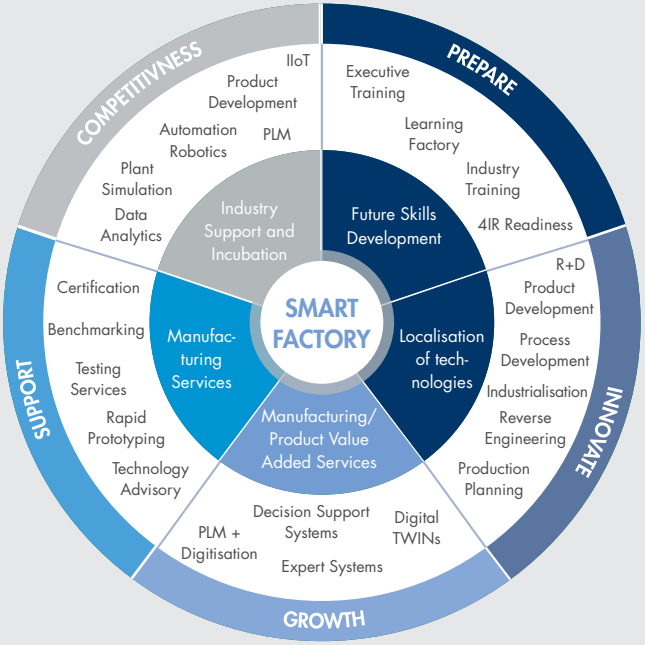
Training covers:

- Artificial Intelligence
- Augmented Reality
- Robotics
- Additive Manufacturing
- The Internet of Things
- Big Data Analytics
- Cloud Computing and Edge Processing
- System Integration
- Digital Twinning
- Simulation
- Cyber-Security



UNDERSTANDING THE SMART FACTORY CONCEPT

The Smart Factory value proposition comprises 5 focus areas:



1 **Offerings that PREPARE industry for the future through:**

- benchmarking and assessment of companies to determine their maturity in terms of 4IR adoption and implementation, and
- Implementation of Learning Factories at various organisations.

2 **Helping industry to INNOVATE by creating integrated products through:**

- new product development and industrialisation, and
- new manufacturing processes integrated into existing lines.

3 **Unlocking the GROWTH potential of each organisation through:**

- application of AI technologies;
- digital transformation of business processes, and
- new business model development.

4 **SUPPORTING industry by providing:**

- testing services and
- by facilitating standardisation of processes.

5 **Improving COMPETITIVENESS of industry by providing:**

- Product Development – Use of digital and product lifecycle management to accelerate time to market;
- Totally integrated automation of the shop floor; and
- Plant optimisation through digital twinning of the plant.

CENTRE FOR ROBOTICS AND FUTURE PRODUCTION

EXAMPLE OF RAPID, DIGITAL DEVELOPMENT: VENTILATOR PRODUCT RANGE FOR COVID-19 PATIENTS

The CSIR – in collaboration with a number of local partners – developed a ventilator that was rapidly rolled out nationwide to patients showing respiratory distress in the early phase of COVID-19 infection. At the time, shortages in ventilator systems in the country impacted on the health system's ability to cope with rising numbers.

The development formed part of government's National Ventilator Project (NVP) under the auspices of the Department of Trade, Industry and Competition (**the dtic**), and with support from the Solidarity Fund.

The CSIR solution is a Continuous Positive Airway Pressure (CPAP) device that uses an innovative design to provide a mild level of oxygenated air pressure to keep the airways open to assist patients with breathing.

The units are non-invasive and fill the need for readily available breathing apparatus, deployed and applied easily – even outside of hospitals if needs be – for intervention in cases where patients are at an early, not-intensive stage of respiratory distress caused by the Coronavirus. Therefore, the device can be used in both high-tech clinical environments, as well as temporary settings, such as field hospitals and quarantine facilities that have been established across the country to handle rising COVID-19 cases.

Under the project name, *'CSIR L.I.F.E.'* (Lung Inspiratory Flow Enabler), the system uses standard, hospital-grade oxygen supply, and features easy-to-use, on-device flow gages to adjust Fraction of Inspired Oxygen in steps of 10% oxygenation.

DESIGN AND MANUFACTURE

The device is wholly designed and produced in South Africa by the CSIR and local manufacturing and industry partners such as Siemens, Simera, Akacia, Gabler, Umoya and the University of Cape Town (UCT), with others soon to join.

The clinical requirement from the NVP was for the rapid development and distributed production of a non-invasive pre-intubation ventilation solution that could be used for most hospitalised COVID-19 patients as part of government's response plan to the pandemic.

Despite short timeframes, a rigorous, documented product lifecycle methodology was followed that would ensure scalable manufacturing, as well as compliance and licensing under the South African Health Products Regulatory Authority (SAHPRA) and guidelines of the World Health Organization.

Siemens provided the necessary software support for the product lifecycle management, as well as software to facilitate rapid production scaling. This included components for systems engineering processes, computer-aided design tools, manufacturing execution tools, as well as quality management solutions that would ensure compliance with health product regulations for certification. Using a digital product lifecycle design methodology also ensures that the product can be manufactured in multiple factories in the industry and in large volumes.

The CPAP system was tested at UCT's Medical Devices Laboratory, which houses specialised apparatus to evaluate such products. This led to regulatory approval and licensing obtained from the SAHPRA.

Between May and September 2020, in the order of 10 000 units were issued.

Following this first round of development, the CSIR continued working on a Bi-level Positive Airway Pressure ventilator with a local partner to develop a solution for patients with more severe symptoms. These units assist with both inhalation and exhalation, either in fixed pressure modes or by sensing the oxygen supply required by a patient and adjusting the pressure accordingly.

NATIONAL PHOTONICS CENTRE

The CSIR houses a critical core of photonics expertise and scientific infrastructure for R&D and innovation in photonics-based technologies and applications at its National Photonics Centre.

The aim of the National Photonics Centre is to equip South African industries with laser and photonics tools and processes to transition, transform and maintain their global competitiveness. A wide range of sectors are targeted, from manufacturing to health, defence to mining and power generation.

The main offerings, tools and processes include:

- Additive manufacturing
  - Custom selective laser sintering machines
  - Large parts size up to 600 x 600 x 2000 mm
  - Fast printing speeds
  - High quality printed parts
  - Multiple materials (titanium, aluminium, steel and a range of new alloys and polymers not available elsewhere)
- Laser surface engineering
  - Laser cladding and onsite repair of large equipment
  - Laser shock peening to enhance durability of high wear surfaces
- Laser welding and cutting (2D and 3D)
- Fast, large-area laser marking machines
- Biophotonics diagnostic tools to detect HIV, tuberculosis, Covid-19 and substandard medication

- High-power lasers in all wavelengths across the infrared spectrum from 1µm to 10µm for a suite of applications
- Custom high-power laser and remote sensing solutions

The centre also focuses on supporting R&D at universities and other research institutions, as well as training and developing the next generation of scientists, engineers and technicians in fields where photonics-based technologies are key.

The centre hosts the Photonics Prototyping Facility, which supports the industrialisation and commercialisation of photonics-based technologies. Entrepreneurs or existing industry can mature their technologies to a higher technology readiness level through the development of prototypes at the facility to enter the market.

The main research themes include:

- **Additive manufacturing (metal and polymer)** – contributing to the competitiveness of industry across the value chain – from investigating the best materials for 3D printing, to the development of new lasers and machines with monitoring and optical technologies to optimise the production process, to defining an efficient post processing strategy through to the eventual test and evaluation of final parts. Almost without exception, if a part can be modelled on a computer in three-dimensional form, it can be sliced and printed, layer by layer. This advantage, combined with the fact that there is very little raw material wastage in additive manufacturing, makes this technology highly attractive. The aerospace industry, in particular, values this manufacturing technology to produce lightweight, complex parts from high-performance materials, such as titanium. The medical industry values the capabilities of the technology to produce individually customised parts for a range of medical related applications. Other uses include production of uniquely finished goods for the defence, automotive, and casting and jewellery industries. Concerning refurbishment applications, the CSIR has local industrial partnerships to support new technology development for specific industrial requirements.
- **Laser surface engineering –** working to support the manufacturing, transport and power-generation industries through the improvement of material properties of structural or functional equipment, or the material processing of raw material or production components in industrial processes.
- **Development of photonics-based point-of-care devices and sensors** for detection of viruses (HIV, Covid-19), bacteria (TB) and substandard medication.

The main national support themes include:

- **Enterprise creation and development –** boosting the local photonics industry (established, new and small enterprises) by providing access to a Photonic Prototyping Facility with the necessary infrastructure, skills and expertise for the prototyping and development of novel products.
- **The Rental Pool and African Laser Centre programmes** are principally directed programmes to grow a corps of top laser and laser application researchers with postgraduate qualifications to increase international research and innovation competitiveness. The CSIR provides critical infrastructure to students and supports collaborations on the African continent.

NATIONAL PHOTONICS CENTRE

RESEARCH GROUPS

NOVEL LASERS RESEARCH GROUP

The centre develops novel high-power and high-energy laser systems and laser sources for selective laser melting applications such as 3D printing of metal and polymer parts. The goal is to improve the manufacturing speed, quality and traceability of final parts for the aerospace and medical industries.

The centre has a track record in the development and positioning of multi-kilowatt laser beams, beam shaping of high-power laser beams, compensating for thermo-optical distortions, and high-power bulk mid-IR laser sources with wavelengths at 1 µm, 1.3 µm, 1.9 µm and 2 µm. The groups host the CSIR's solid-state laser R&D laboratories, housed in a class 1 000 clean room facility with isolated class 100 and class 10 areas for highly sensitive dust-free work. The laboratory is well equipped with a range of optical diagnostic equipment that supports the development, analysis and optimisation of novel laser systems across the optical spectrum. The research focuses on power and energy scaling, while maintaining good beam quality of the laser output. This includes research into novel laser concepts and geometries, thermal handling, laser resonator design and numerical modelling of the laser. Other areas of interest are special operating regimes, such as high-spectral purity and single frequency.

CSIR researchers and engineers work closely with clients to develop tailored laser sources suited for their application. Should the required laser already be available commercially, CSIR laser technology experts also offer specialised consulting services to help perfect the solution.

LASER-BASED MANUFACTURING GROUP

The CSIR has a diverse and specialised portfolio of laser-based manufacturing technologies in place to support the South African industry by helping to reduce costs, enhancing performance, coming up with novel designs and processing technologies to support innovative manufacturing practices. This capability is hosted in two groups with complementary capabilities for laser-based manufacturing. The Laser-enabled Manufacturing research group offers research and development capabilities, and the Laser Engineering Services group offers services and implementation directly to industry.

Such services include laser welding, laser hardening, laser shock peening, metal 3D printing, laser cutting and a mobile unit for on-site processing for refurbishment and performance enhancement applications. Key application areas for these technologies are the power generation, defence, mining, marine and transport industries.

The CSIR has established a dedicated laser workshop and a mobile facility to support work in laser-based manufacturing. The group also hosts the CSIR's additive manufacturing research facility.

BIO-PHOTONICS RESEARCH GROUP

Biophotonics applies optical or photonics-based techniques to facilitate single molecule and/or cell studies. The field covers different disciplines, including medicine and biological, chemical and physical sciences.

Different optical regimes are used to ensure design and development of portable laser-based point-of-care HIV diagnostics, TB biosensors and screening devices for substandard medication. A major focus area is the development of point-of-care diagnostic devices. These devices enable early disease diagnosis and can be used in under-served populations in resource-limited settings. The use of light and optics affords many advantages because of the multidimensional data that can be collected and analysed.

The group provides visionary leadership in photonics to national stakeholders, strengthens the science, engineering and technology base through uptake of postgraduates, and seeks out partners in local and international industries to extend the local knowledge base, as well as to grow a robust optics and photonics capability in South Africa.

The long-term objective is to position the group as an internationally recognised biophotonics player that provides excellence in scientific research, technology development and transfer of laser and related technology.

NATIONAL PROGRAMMES

The CSIR hosts several collaborative initiatives that involve research organisations, higher education institutions and stakeholders in the public and private sectors. The shared objective of these programmes is the R&D and utilisation of technologies in the interest of the photonics industry and skills pool.

The African Laser Centre (ALC) is an initiative under the New Partnership for Africa's Development and funded by the DSI through its Africa Multilateral Cooperation programme. Launched in 2003, the ALC is a virtual organisation that brings together researchers from across Africa in the fields of lasers and spectroscopy.

The main objective of the ALC is to encourage research collaborations between African researchers and facilitate researcher and student exchanges between African institutes that are active in photonics-based research. At present, the ALC in South Africa supports four programmes, namely a research collaboration programme, the scholarship programme, the training programme and the knowledge exchange programme.

The Collaborative Programme in Additive Manufacturing focuses on supporting research, development and innovation at local research institutions, and in cooperation with industry, to drive the manufacturing readiness of additive manufacturing and its adoption in industry. The programme focuses on four main themes, namely the qualification of metal additive manufacturing for industrial applications, a design-for-additive manufacturing programme, an industrialisation of polymer additive manufacturing programme and an industry development programme.

The Photonics Prototyping Facility comprises a range of laser and optical workshops and laboratories that are well equipment with a range of specialised test, diagnostic and other ancillary equipment. Funded by the DSI, the facility, as well as the photonics experts from the CSIR are made available to technology developers and entrepreneurs working on photonic-based products to take it to prototype stage.

Laser Rental Pool Programme

The CSIR has access to an extensive suite of photonics equipment – specifically laser sources, photonics-based diagnostics and ancillary equipment that would support photonics and photonics-based R&D and application development. The CSIR Laser Rental Pool programme is funded by the DSI and allows researchers at higher education institutes to access and use state-of-the-art equipment, based on approved research projects. The success of the programme is evident from the number of successful graduates, and the large numbers of scientific journal publications and patents. Students are from different fields in the natural, engineering and health sciences, and collaboration among different institutions is encouraged.

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