TECHNOLOGY THAT TRANSFORMS

AIR

Maintaining air superiority, or at least a favourable air situation that allows a country relatively unconstrained use of its air space while denying the same to opposing forces, is critical to supporting and safeguarding its surface forces from attack.

AERONAUTIC TECHNOLOGIES: Enhancing our air power

"Developments in technology have greatly enhanced the effectiveness and lethality of air power and will play an even more vital role in future warfare."
(South African Defence Review: Consultative Draft 2012, page 171)

The time-proven *Principles of War* penned by Von Clausewitz in 1812 are as applicable today as they were back then. The only shift, is a considerable emphasis on the role of superior technology. Irrespective of conventional or asymmetric warfare, the adage that "he who has the best technology will win the fight" remains critical to the effective performance of every air force in every nation across the world.

Principles of war

Certainly, the South African Air Force embraces the classical ten principles of war as part of its armour in combat operations and to retain air superiority. Equally important however, is the decisive role of intelligence in precise ordnance delivery, rapid force projection and the quick and effective deployment, support and recovery of our forces from combat situations.

Effective air defence depends on detecting, identifying, tracking, intercepting and destroying potential air threats. This requires well-integrated airspace surveillance and command and control systems. While static systems provide much of this capability, South Africa's deployed forces can also rely on mobile, organic air, land and sea systems for protection.

South Africa's range of airborne assets is used to protect the country against air threats, provide fire-support to our forces and protect our infrastructure through interdiction and close-air support. Our key air capabilities are also used in peacekeeping missions and combined security operations, providing air transport for ordered and diplomatic commitments, and air support to civil authorities and for South Africa's international obligations.

The use of our air capabilities has, in fact, become indispensable to defence support operations. Our air force is often called up to assist in military evacuation and rapid deployment, strategic lift, air supply and airborne operations or civil society operations such as search and rescue, support to other security services, diplomatic interventions, humanitarian assistance and disaster relief.

As part of a joint defence responsibility, an integrated air defence system is critical to providing collaborative intelligence from air assets and electronic sensor data. This is where innovative engineering can best deliver real-time intelligence and threat analysis.

The technology dilemma

Air forces globally agree that 'going high-tech' in air defence is tempting, can be cost-effective and certainly provides a competitive 'edge'. Smaller air forces that argue against the cost of new technologies are in danger of finding themselves outmanoeuvred by better equipped opponents. Still, technology choices have to be taken judiciously on a case-by-case basis and must be well-supported by superior technology testing, evaluation and development. This is where support from a strong science partner such as the CSIR will ensure competitiveness by enabling smart buying, smart usage and smart management of capabilities.

While seemingly costly, the local development of aircraft technology and associated systems offer significant long-term value. Benefits include strategic and technological independence and equipment that is optimally tailored to the operational style of our Defence Force. Valuable spin-offs are often also generated for industrial development and job creation, all of which benefit the wider economy.

Niche items such as air-to-air and air-to-ground munitions, active and passive electronic warfare systems, unmanned airborne systems, secure command and control communications and information warfare equipment can also be manufactured locally.

CSIR's contribution to air power

The CSIR supports 'classical' air power through its mandate to –

- provide the SANDF with the aeronautical science, engineering and technological capability to support **force development and air operations**;
- extend the SANDF capability to develop and maintain a **strategic defence capability**;
- provide research capabilities that support the **national aeronautics research strategy**;
- contribute to national science, engineering and technology (SET) themes, science missions, industrial initiatives, national human resource development objectives and flagship projects launched by the Departments of Science and Technology (DST) and Trade and Industry (dti) and other stakeholders;
- generate knowledge and acquire experience that positions the CSIR as a national centre for aerodynamic testing and evaluation.

The CSIR responds to this mandate with superior capabilities in experimental and computational aerodynamics, aerostructures, propulsion, flight dynamics, modelling and simulation and weapons integration.

Smart user acquisition

A defence force needs equipment to conduct operations and meet potential short-notice challenges. In order to meet these needs effectively, a smart user approach to acquisition is required: That is a phased approach to equipment acquisition that avoids the potentially fatal block obsolescence of equipment or the equally detrimental trap of under- or over-equipping.

The ultimate aim is to ensure that South Africa's Defence Force is configured and equipped to defend and secure its national interests and protect its people, as well as participate in peacekeeping missions and render military assistance to other nations.

As the leading multi-disciplinary scientific research and technology agency locally and in Africa, with a constitutional imperative to "improve the quality of life of all citizens", the CSIR deploys its resources to achieve government's national security and development objectives. We remain steadfast in our commitment to provide the country with superior air power and safety in the skies.

DEFENCE AND SECURITY IN AEROSPACE

CSIR-designed flutter-flight test equipment is being used to prepare South Africa's combat aircraft to carry new stores in preparation for dealing with new threats and countermeasures.

Reality in simulation

A simulated environment comes to the rescue in dealing with the reality of different military scenarios simultaneously and effectively.

Working closely with Armscor, the local defence industry and SA National Defence Force, the CSIR developed a virtual environment to support this kind of decision-making. The CSIR's Command, Control and Information Warfare team uses simulated environments to assist the SANDF in a range of activities, from computer-aided exercises and doctrine development support to evaluating new concepts and acquisition decisions.

The ability to assess complex scenarios in a virtual setting before committing expensive equipment or scores of people has added significant value to decision-making processes within the SANDF.

The many international publications by the CSIR's virtual simulation research team attest to international recognition of their processes and methodologies by their peers and the defence community globally.

The support to the SANDF using the virtual environment identified other needs, such as developing architectures for distributed, real-time simulation and approaches to data modelling, automated decision support and situation awareness technologies, as well as the fusion of data and information. All such efforts are coordinated to provide SANDF commanders with information, decision and engagement superiority.

Meeting new flutter challenges head-on

Preparing aircraft to carry new stores in the face of ever evolving new threats and countermeasures

Mitigating the risk of flutter – a self-sustaining structural vibration that can destroy an aircraft in a second – is imperative for the South African Air Force (SAAF) as they prepare aircraft to carry new weapons and sensors to mitigate new threats and countermeasures that evolve constantly.

Introducing new external stores on an aircraft always creates the risk of flutter. Without exception, aircraft with new stores should undergo a flutter clearance process. This determines the structural dynamic properties of the aircraft and analyses its performance to identify flutter risk in the intended operating range of the aircraft with the stores. A flutter-flight test should follow to confirm the analysis.

During such a test the aircraft is 'shaken' while flying at a constant speed. Accelerometers distributed over the airframe measures the structural response, which is analysed to determine whether the margin between the test and flutter speeds is sufficient to be safe. If safe, the speed is increased and the procedure repeated.

The output: The CSIR's involvement in flutter-flight testing over the past thirty or so years has recently led to the development of a simple and effective flutter excitation system (FES) that uses a rotating annular wing. An aerodynamic exciter is more effective at low frequencies and control surface excitation becomes less effective at high frequencies due to the inertia of the control surface.

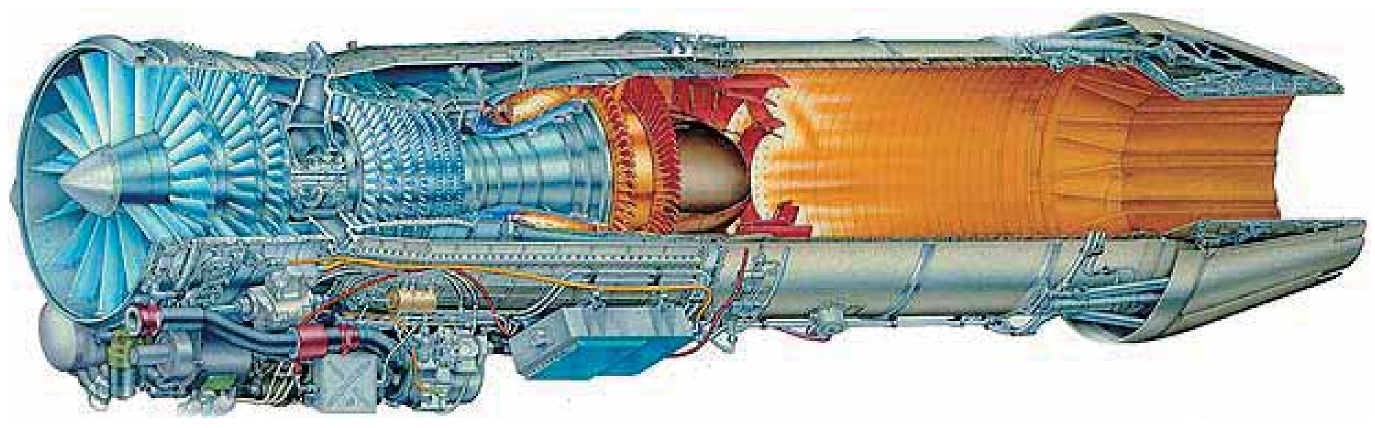
Since the CSIR's rotating annual wing rotates rather than oscillates, it remains effective at high frequencies. The aircraft requires no structural modification for the testing, as the annular wing exciter is built into the flutter-flight test dummy of the store that needs to be tested. Some wiring is required, but once installed to a particular store station it can be used for any store to be carried at that station.

The current FES has been successfully utilised in a number of local and overseas flight test campaigns.

DEFENCE AND SECURITY IN AEROSPACE

Scientists from the CSIR have attended every Volvo Rm12 User Group Meeting (UGM) and the analytical teardown and display of the Swedish Air Force's lead engine, making them the only South African organisation to have maintained consistent contact and records of these informative sessions on behalf of the SAAF. The CSIR continues to perform gas turbine research in an effort to assist the SAAF as both a smart user and buyer of these high complex systems.

Contact with Volvo Aero has also led to the CSIR entering into a number of European Union funded research programmes aimed at improving the efficiency and reducing the fuel burn, weight and emissions of civil aircraft.



AIR: Detection and protection: Testing and evaluating the Gripen's flying qualities

By far the most technologically advanced combat fighters in our skies, with the ability to swing between air-to-air, air-to-ground and reconnaissance at the flick of a switch, the SAAF Gripens are also outfitted with one of the most sophisticated human-machine interfaces in operational fighters today.

Compared to aerodynamically stable conventional aircraft that are 'easy' to fly, Gripens are designed to be aerodynamically unstable, with cockpit controls that are not mechanically linked to control surfaces to increase their tactical manoeuvrability. To help deal with the complexity, each Gripen is equipped with a fly-by-wire (FBW) control system that essentially 'flies' the aircraft by continually making corrections to stabilise it. This leaves the pilot free to concentrate on optimising the fighter's flying qualities for the mission at hand. Should the control system computer fail, however, the aircraft will be unflyable and the pilot will have to eject.

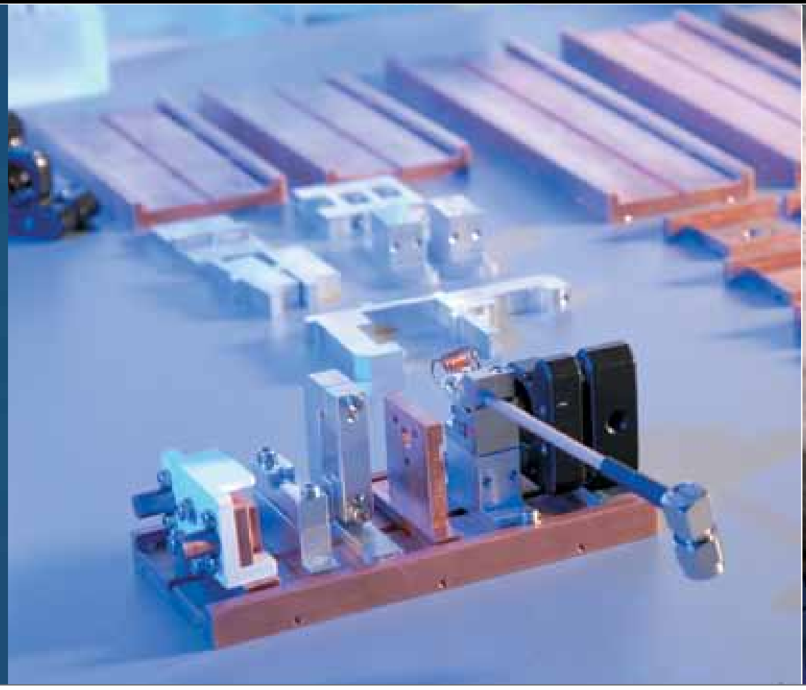
The use of the FBW control system allows design engineers to optimise performance aspects during the design phase, while manufacturers can make small improvements throughout the life of the aircraft, as long as improvements in one area do not interfere with other areas.

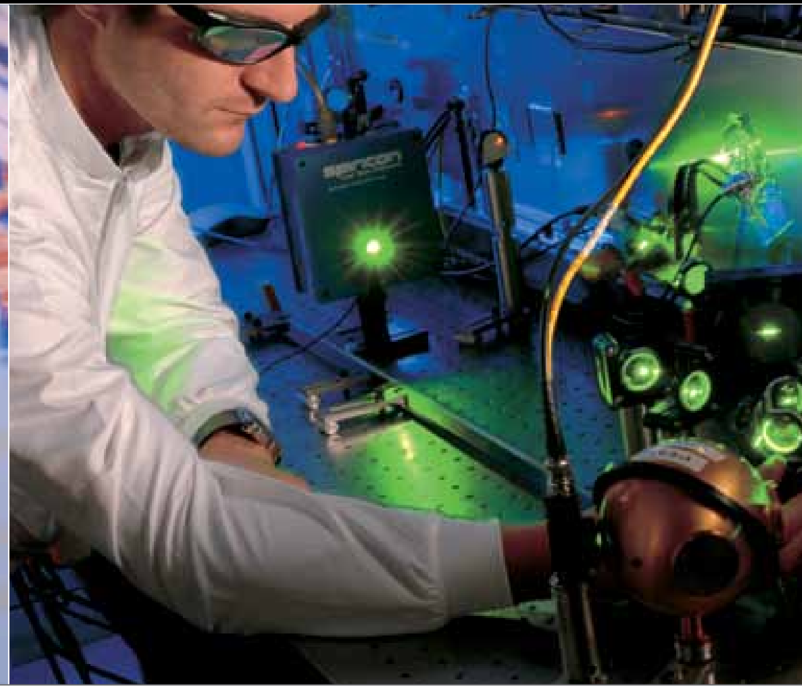
Since 2004, one the CSIR's principal aeronautical engineers, Dr Bennie Broughton, and a team of CSIR engineers, SAAF flight test personnel and the Gripen Flight Test Centre (GFTC), have been instrumental in creating a knowledge base to fully understand and support the FBW technology, while assisting the SAAF in its interaction with the equipment manufacturer. The CSIR team also had to determine areas that required special attention and identify shortcomings on the FBW-equipped aircraft, as well as develop test and analysis techniques to evaluate the Gripen's flying qualities and find a way to deal with related software changes.

The collaboration has led to the development of a custom Gripen Flying Qualities Reference Specification that engineers use to ensure all flying qualities are tested in a systematic and complete way. The reference specification also gives guidance on the associated test and analysis techniques. Since 2010, the joint team made up of SAAF, CSIR and GFTC specialists have been testing the aircraft to create a baseline set of data to use for comparison when changes are made to the software or hardware of the aircraft, when new weapons are integrated, and to better understand how to utilise the aircraft optimally.

The SAAF's acquisition and operational development of its Gripen fleet has benefitted greatly from the CSIR's work. CSIR supported the flying qualities component of the type acceptance process of the aircraft and continues to develop new test and analysis techniques used to optimise the utilisation of the aircraft. The flying qualities baselining process has resulted in a dataset used to monitor the impact of software and hardware changes as well as the integration of new stores on the aircraft. Spin-off technologies are used in areas such as unmanned aerial system programmes and aerodynamic systems identification techniques used in characterising manned and unmanned aircraft.

DEFENCE AND SECURITY IN AEROSPACE





CSIR radar knowledge integral to Gripen acquisition

As the ears and eyes of modern fighter aircraft, multifunction radar provide pilots with enhanced situation awareness.

At the heart of South Africa's acquisition of a 26-strong fleet of 4th-generation front-line Gripen fighter jets was the successful acquisition of the radar system, mounted in the nose of the aircraft.

2011 saw the culmination of the CSIR's 16-years of radar acquisition support on this truly modern fighter, spearheaded by CSIR radar engineers Francois Anderson and Andre le Roux.

Multifunction radar is integral to the Gripen's ability to enhance the pilot's situation awareness, in accurately launching and guiding air-to-air and air-to-ground weapons and undertaking all-weather, day and night aerial reconnaissance. As one of the more complex subsystems of a modern fighter aircraft, it can also account for a significant part of the aircraft's total cost.

Anderson and Le Roux's long period of support started with providing radar expertise in developing the SAAF User Requirement for a multifunction radar system and continued throughout each phase of the Gripen's radar acquisition process. Regular interaction with the Gripen Joint Project Team and visits to the aircraft and radar industries in Sweden included attending design reviews, accepting radar function and performance verification evidence, developing the electronic counter-countermeasures definition and accepting specification verification evidence.

The team also defined the SAAF's radar data acquisition requirements, developed acceptance procedures and supported decisions about changes in aircraft radome paint types and radar cross section verification methods.

A direct benefit of the successful conclusion of the Gripen radar acquisition programme is the SAAF's direct access to the CSIR's invaluable source of knowledge about the multifunction radar in their front-line fighters. Subsequent projects for the SAAF have also been based on this knowledge, such as a tactics development tool for the Senior Staff Officer Air Capability Planning.

For this CSIR team, the future holds continued support of the SAAF as users of advanced technology radar to equip their pilots with a 'winning edge' and superior combat proficiency as they fly their missions in Africa.

Multifunction radar is integral to the mission success of fighter aircraft. It is incumbent upon the radar acquisition team to ensure that the radar performs as specified under all conditions expected in probable operational scenarios, even when faced with an adversary's counter-measures.

Advanced photonics manufacturing facility to ensure new laser-based products

The CSIR is set to establish an advanced photonics manufacturing facility to bridge the gap from laboratory demonstrator to commercial product. "This will allow the transfer of laser technology in the form of advanced photonics products to the South African and international industries," says Dr Daniel Esser, project manager and laser sources research group leader. The CSIR is keen to collaborate with existing and new industrial partners to develop niche products that could provide South African industry with a competitive advantage. "The establishment of such a facility will directly support the national photonics strategy by creating an environment where technological innovation can be transferred in a structured way to industrial partners," explains Hardus Greyling of the CSIR. Esser adds: "This will be a well-equipped facility, with the mindset of advanced product development, in contrast to a research lab." The CSIR is known for demonstrating state-of-the-art laser technologies.

"Our focus now is to develop these lasers to a state which can be adopted by industry," says Esser. "Defence and aerospace applications include Directed Infrared Countermeasures (DIRCM) against heat-seeking missiles; laser ranging and mapping; as well as several industrial applications."
The following laser products are being developed by the CSIR:

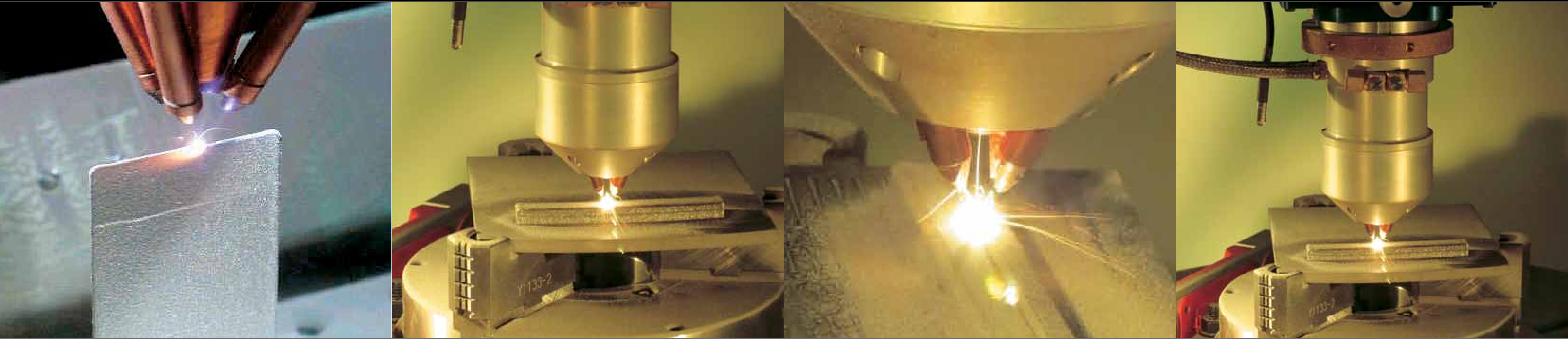
Multi-wavelength high-power laser (product name Rigel)
Output power: 10 W at 2 μm
10 W at 3-5 μm
1 W at 8-12 μm
Applications: Directed Infrared Countermeasures (DIRCM)
Mid-infrared & far-infrared illumination
Gated imaging for IR cameras

DIRCM laser (product name Southern Star)
Output power: 5 W at 2 μm
5 W at 3-5 μm
Application: Directed Infrared Countermeasures (DIRCM) on fixed & rotary wing platforms

High-energy laser (product name Nd:YLF)
Output Energy: 50 mJ at 1.053 μm at 1 kHz
Applications: Laser ranging; Industrial materials processing

Short-pulse laser (product name Nd:YVO 2 ns)
Peak power: 5 kW at 1.064 μm at 100 kHz
Output pulse: 2 ns pulse duration
Application: Laser ranging & laser mapping

DEFENCE AND SECURITY IN AEROSPACE



Laser additive manufacturing: Building SA's future one layer at a time

The CSIR is developing a suite of unique laser additive manufacturing systems and processes that will place South Africa at the forefront of this technology, with tremendous potential benefits for the local manufacturing industry.

Compared to conventional manufacturing technologies which are often subtractive (materials are removed via cutting or milling), additive manufacturing relies on various energy deposition technologies to fuse materials into three-dimensional functional parts; materials are joined to make objects, one layer at a time. Laser additive manufacturing (LAM) allows for this to be done using lasers.

This emerging manufacturing technology lends itself to the development of components from unique ceramic, alloy and light metal materials. It will be key in the beneficiation of South Africa's titanium resources – around which efforts are being accelerated to establish a titanium industry – and affords the local aerospace industry a significant competitive advantage over international competitors.

This innovative technology will be used for the production of unique finished goods for the aerospace, defence, automotive (in areas such as motor racing) and medical industries. It is against this backdrop that the CSIR has created a programme focusing specifically on additive manufacturing.

The goal of the additive manufacturing programme is to promote and advance the knowledge, capabilities, and economic opportunities in this field for the benefit of local industries. To achieve this objective, the CSIR will focus its resources on supporting three main initiatives in additive manufacturing.

Laser metal deposition additive manufacturing (current state-of-the-art technology)

During 2012, the CSIR will establish an additive manufacturing workgroup, focusing on laser-engineered net-shaping (LENS) technology, with academia, industry and relevant government agencies. "LENS technology uses a high-power laser (500 W to 4 kW) to fuse powdered metals into fully dense, three-dimensional structures," says Hardus Greyling, acting manager of laser materials processes at the CSIR. "The LENS three-dimensional system uses the geometric information contained in a computer-aided design solid model to automatically drive the LENS process as it builds up a component, layer by layer," he notes. Additional software and closed loop process controls ensure the geometric and mechanical integrity of the completed part.

The goal is to identify critical components and industries, in addition to the identified target markets in aerospace and biomedics, that can benefit from either manufacturing or refurbishment/repair using LENS technology. The CSIR will be a key link and driver in coordinating and forging partnerships of potential users.

High-speed, large-area selective laser melting (cutting-edge technology development)

In a second project, called 'Aeroswift', the CSIR has teamed up with Aerosud, an established leader in the South African aviation industry. The main goal of this project is to establish a functional first-generation, high-speed, large-area selective laser melting system that will be capable of building aerospace components with dimensions within a range of 2 m by 0.6 m by 0.6 m. Such a system is currently not available commercially and therefore will have a niche market with high impact, as there are a variety of aerospace components that fall within these dimensions.

Creating this technology in South Africa in collaboration with the Titanium Industry Initiative will contribute to South Africa increasingly becoming a key player in the aerospace sector. Major aerospace companies have indicated that they are paying close attention to the success of this project, with 2016 targeted for a fully operational system, capable of producing its first parts.

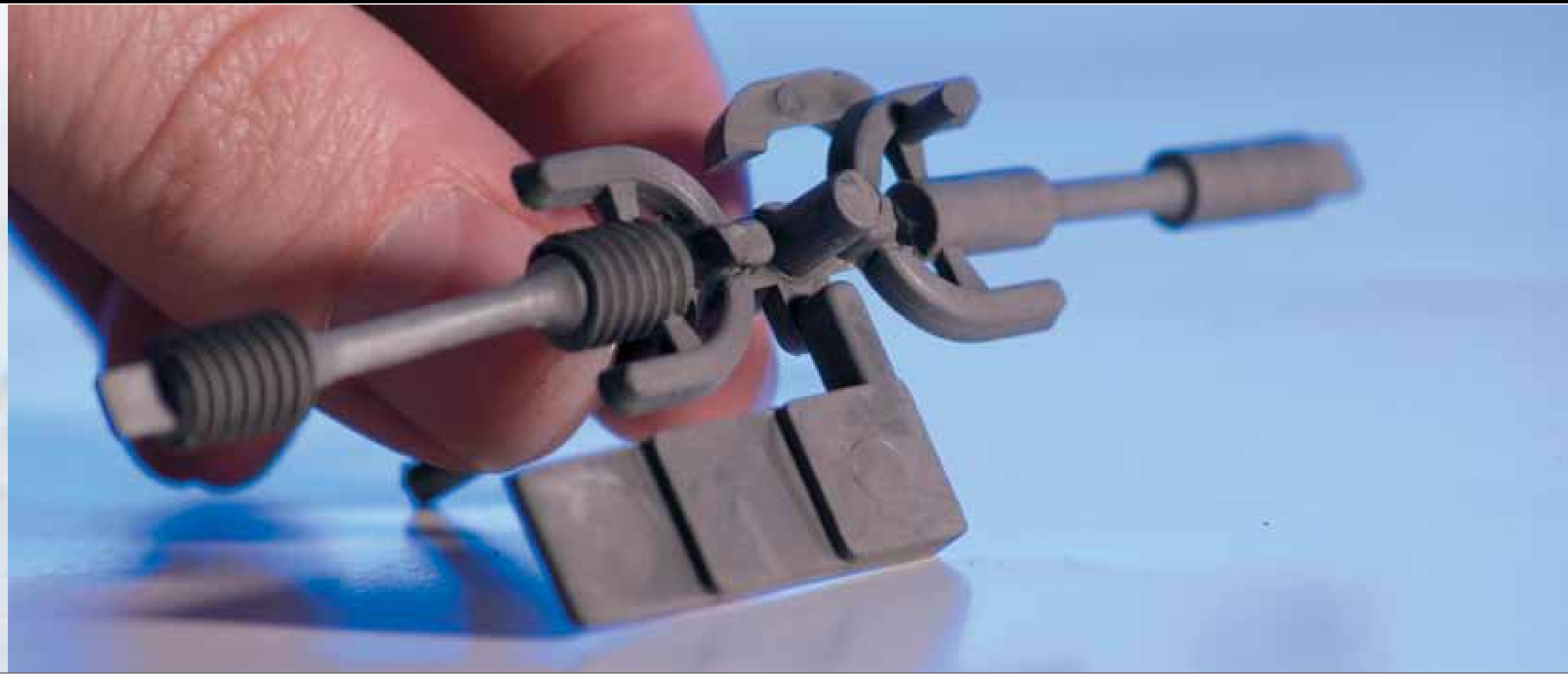
This would be a tremendous boost to the manufacturing sector in South Africa and would allow companies like Aerosud to expand their product range. It would also see South Africa cover the full value chain from a raw product (titanium powder) to high-value components.

Ultra-high-speed laser additive manufacturing (next-generation, radical design technology development)

For the third project, called 'Umuvi', the long-term objective is to create future generation high-speed, large-area, laser additive manufacturing systems, to stay ahead of the trend worldwide and capture future revenue streams by meeting future demands for more efficient and higher productivity systems. "The underpinning technology for all these projects is laser-enabled additive manufacturing and our LENS system will set the tone for the Aeroswift and Umuvi projects.

The system enables immediate entry into the refurbishment market, where worn-out parts or components are repaired, and the working life or performance of the component becomes even better, compared to the original part," says Greyling."If we succeed in showing the value of this technology, projects Aeroswift and Umuvi will be welcomed by industry," he adds. "Successful completion of these initiatives will see the creation of a knowledge base and capacity that will enable South Africa to generate sustainable wealth and future opportunities in additive manufacturing," concludes Greyling.

DEFENCE AND SECURITY IN AEROSPACE



CSIR to pilot a titanium metal production process

The CSIR has developed a process to produce titanium powder directly in a continuous manner on a commercial scale from titanium tetrachloride ($TiCl_4$ – the usual precursor used for titanium production). To date, no organisation in the world has been able to do this.

Being able to produce titanium powder at a much lower cost than present imported powder will make this light metal an economically viable option, from which many industries can be created and sustained.

The CSIR's process is being developed in a stage-wise manner to manage the inherent scale-up risks, and it has now reached the stage where the design, construction and operation of a small pilot plant have been approved by the Department of Science and Technology (DST) and the CSIR.

The pilot plant has a nominal design capacity of continuously producing 2 kg/ h of titanium powder. Construction and commissioning of the plant are to be completed in the first half of 2013. Test campaigns to gain scale-up information regarding the process, and to produce sufficient product for evaluation by potential customers, are planned following successful commissioning of the plant.

In parallel to the technical work, a commercialisation task team with representation from industrial and financial concerns has been formed to plan and manage work to ultimately realise commercial implementation of the technology.

South Africa's entire titanium beneficiation strategy depends largely on the success of this pilot plant and its further commercialisation. The national benefits that would arise from a world-scale, low-cost titanium metal plant, are considerable.

Titanium metal injection moulding: A cost-effective technology crucial for establishing a titanium industry

Powder metallurgy techniques, among which metal injection moulding can be counted, are cost-effective and offer a huge advantage in material savings. Using these methods, the low-cost locally produced CSIR titanium powder can be converted into finished and semi-finished products.

With the favourable strength-to-weight ratio of titanium, the CSIR is investigating in the use of powder metallurgy technologies as one of the production methods for, among others, aerospace parts.

Powder metallurgy is the process of blending fine powdered metals, pressing them into a desired shape (compacting), and then heating the compressed material in a controlled atmosphere to bond the metal particles (sintering). Components can be made to final dimensions or very close to these with little or no subsequent machining operations required. This technology is generally used to manufacture smaller, intricately shaped components.

The CSIR's Light Metals team has already established the ability and the facilities to produce small titanium components using press and sintering as well as metal injection moulding techniques. Now they are planning to expand into the development of technologies to make larger shapes, such as mill products. This will be an essential building block for establishing a competitive downstream titanium industry in South Africa.

DEFENCE AND SECURITY IN AEROSPACE

CSIR-developed airframes

Early 1980s Seeker prototype
1988 Delta Wing UAS demonstrator
1992 Skyfly target drone prototype
1989 OVID/ACE turboprop military trainer prototype
1992 Hummingbird 2-seater observation aircraft prototype
1993 Keen-eye UAV
1994 UAOS/Vulture prototype
2005 Indiza – a mini hand launched UAS
2007 Sekwa – unstable, tailless UAS
2008 The 4m span Modular research UAS

Research infrastructure for unmanned aircraft systems (UAS)

"No longer in the realm of science fiction, unmanned aircraft may be part of the future 'army' that secures our nation."

More than 30 years ago, when the CSIR first became involved in developing an airframe for the Seeker prototype, it was not clear what the future held for unmanned aircraft systems (UAS).

Today, there is clear purpose to the development of a UAS Integration Laboratory at the CSIR – to develop real UAS that can demonstrate long-range border surveillance, persistent monitoring of maritime traffic, detecting of fire from the air, as well as undertaking traffic and security patrols.

The aeronautics systems capacity and facilities that has supported the research in this field since the early 1980s were recently expanded to include the development of a UAS laboratory.

The facility consists of a high fidelity flight simulator in which the UAS can be test-flown virtually, using real aircraft sub-systems such as autopilot and control surface servo actuators. Where sub-systems that have not been developed, are simulated.

The modelling and simulation-based systems engineering approach to UAS development is a cost-effective and efficient way to develop the concepts. The laboratory can be linked to the CSIR's UAS airframes and autopilots, with open-source graphics engines providing the visual environment.

Researchers John Monk, and John Morgan have linked the laboratory to the 'Iron Bird' modular research UAS, a complete airframe with all the operational systems but not designed to fly. The CSIR collaborated with the University of Stellenbosch to develop the avionics of the 'Iron Bird'.

The outputs: The capabilities of a high fidelity flight model of the modular UAS completed during the first phase development of the laboratory have been demonstrated to industry and universities to encourage more research.

The CSIR also has two characterised mini UAS airframes, Indiza and Sekwa, each capable in their own right. With a 2-m span, the land-launch mini research UAS, Indiza has been aerodynamically characterised in the CSIR wind tunnels and is available for national research, while Sekwa with its 1,7-m span variable-stability UAS, is used for relaxed stability and systems identification research.

The benefits of unpiloted flight – from conflict zone to civil society

Unmanned Aircraft Systems have given us a new reality – the elimination of a war target with clinical precision and minimal collateral damage from a control room far away from the conflict zone. The success of these remotely controlled aircraft in conflict situations is changing the acquisition priorities of defence forces world-wide.

Not dissimilar to model airplanes, but far more sophisticated, UAS are complex aeroplanes that fly autonomously by remote control. They range from large to micro, the ones that can fly above commercial airliners nonstop for more than 24 hours to those you can hold in your hand that carry intricate cameras for surveillance in an office block.

As one of the first countries to develop this technology in the 1980s, South Africa is manufacturing and exporting the smaller UAS through Denel UAS and ATE. UAS also have significant potential in civil society and that our local population and natural resources will be the beneficiaries. Applications in areas such as crop spraying or the inspection of millions of kilometres of power lines may soon be possible if some regulatory issues around unmanned flight in the national airspace can be overcome.

The outputs: CSIR's development of UAS over the past 30 years concentrated mainly on airframe development for military applications. Now tasked by the Department of Science and Technology to lead the country's UAS research and development for civil applications, the focus has changed to local civilian use.

The first UAS civilian application was the use of Denel's Seeker during the 1994 election and subsequently for anti-crime operations. The CSIR's first out-the-door UAS for commercial application is a concept demonstrator for power line monitoring developed by the mechatronics and micro-manufacturing research group. The demonstrator has a unique multi-spectral camera mounted on a rotary wing that acts as the primary sensor for picking up electrical faults on power lines.

Disruptive technology results in permanent change to the familiar, such as the impact of the Internet, email and cell phones on the way we communicate. Similarly, unpiloted aircraft is permanently changing the face of warfare and peacekeeping.

DEFENCE AND SECURITY IN AEROSPACE

A desktop tool to unlock 4th-generation aircraft capabilities

Pilots and tacticians are using simulations in a desktop environment to evaluate tactical postures that can increase the nation's safety

The sophistication of the fleet of 4th-generation Gripen fighter aircraft 'at the ready' in their hangers at the South African Air Force (SAAF) to defend and protect all in our rainbow nation called for a full understanding of their advanced capabilities to develop new tactics and operational procedures to fully utilise the technologies.

As a cost-effective solution to what could be a very costly exercise, a group of simulation specialists at the CSIR created a simulated, synthetic environment in a desktop tactical simulation tool can be used to develop the required new tactics.

This development saw a progression in the CSIR's assistance to the SAAF to be smart technology buyers – acquiring the new aircraft and systems – to becoming smart technology users by providing them with the operational insight to unlock the technological capabilities of the Gripen fleet.

Utilising smart capabilities

Since the arrival of the Gripen aircraft, the SAAF adopted a four-phase approach to unlocking the 4th-generation capabilities, so that pilots would understand them fully and utilise them effectively.

Firstly, the CSIR was tasked to develop a desktop tactical simulation tool to test and select different aircraft posturing concepts without the need to access expensive equipment. Pilots then plan suitable missions in the squadron based Mission Support System (MSS) to test the newly-created postures and use the MSS to play back the flights in real-time to assess the success of the tactics.

The third phase entails test-flying the missions in the Squadron Level Mission Trainer (SqLMT), which consists of two flight simulators that replicate the interior of the aircraft with a full dome and a representation of the cockpit. Missions are flown in the simulators to keep costs down while practising the various tactical manoeuvres in conflict situations. The MSS and simulators were supplied by the Gripen manufacturers SAAB along with the aircraft.

Finally, when the capabilities of the Gripen aircraft are fully understood and the utilisation of the technology perfected, missions are flown in the real aircraft with, of course, a substantial increase in costs.

The desktop alternative

The MSS and SqLMT simulators are located at the Makhado Air Force Base in Limpopo. Only pilots at the base can use the simulation facilities, while the MSS contains sensitive information that precludes wide distribution. The practical limitations of using these facilities spurred the SAAF to look for an alternative, easy-to-access system that could be used freely.

An effective mission simulator with which pilots could gain as much knowledge and understanding as possible in the first phase increases the efficiency and reduces the cost of the entire process, as the cost of each subsequent phase indicated above grows exponentially.

The output: The CSIR delivered the perfect solution. Pilots use the desktop tactical simulation tool on a portable but secure laptop to develop and define concepts before moving them to the MSS, SqLMT and finally the aircraft. This allows them to understand the new technology in an environment that encourages creative thinking.

Various individuals and defence organisations cooperated in developing the tool as the CSIR needed information from aircraft, missile and radar suppliers to simulate performance in the related areas. The eventual product was a group effort that combined the CSIR's skills and knowledge with those from external sources.

The collaborative development of the desktop tactical simulation tool not only responded to a client's need for an alternative solution, but once again exemplified the CSIR's important role in bringing together different role players to, in this instance, safeguard an entire nation.

DEFENCE AND SECURITY IN AEROSPACE

Advances in short-range infrared air-to-air missiles have progressed well beyond the classic dog-fight scenes in *Top Gun* movies.

Recently, 4th-generation missiles boasted significantly improved agility and seeker sensitivity, with helmet-mounted displays (HMDs) that allowed pilots to merely look at targets before firing.

Now, 5th-generation missiles have even greater seeker sensitivity, are more resistant to countermeasures such as flares and have a more versatile lock-on-after-launch capability.

The helmet-mounted display (HMD) steps into the future

Mastering 'over-the-shoulder' shots with helmet-mounted displays will maximise the effectiveness of the Gripen's 5th-generation missiles

The use of 5th-generation missiles by the South African Air Force (SAAF) became a reality with the arrival of the final Gripen aircraft in the country recently. Their arrival completed South Africa's four-year acquisition of a 26-strong fighter aircraft fleet.

The JAS 39 Gripen fighters are armed with 5th-generation missiles and their pilots equipped with the Cobra HMD targeting system, developed by BAE Systems, Denel Optronics and Saab.

HMD technology today enables fighter pilots to keep their hands on the two control sticks because their helmet visors provide them with all the information they need about airspeed, altitude, target range and threat and engagement data. This reduces pilot workload and increases the ease of flying.

The new advances in HMD now use head angle as a targeting system, enabling pilots to fire at anything they can look at. The tactical advantages of this development include less need for aircraft manoeuvring, greater situation awareness and increased chances of pilot survival.

Despite remarkable technological advances, missiles still only 'see' what is in front of them, while pilots can glace backwards to see what is behind. This begs the question of whether the latest HMD can be used to fire at 'over-the-shoulder' targets when aircraft are outside of the missile seeker's view limits. If this were possible, the aircraft would communicate data about the target's position from the HMD to the missile pre-launch for it to turn towards and lock onto the target post-launch.

New technology requires new guidelines

New technology advertently requires new guidelines for pilots to use it effectively. According to CSIR Aeronautics manager Major-General Des Barker, a former SAAF fixed-wing test pilot, Gripen pilots needed a new set of tactics and standard operating procedures to maximise the use of 5th-generation missiles without placing the wingman in danger.

The SAAF asked the CSIR to explore 'over-the-shoulder' scenarios and develop HMD guidelines to designate off bore-sight targets.

The output: The CSIR's expertise in modelling and simulation was brought to bear on developing a set of guidelines for the SAAF to use the 5th-generation missiles in 'over-the-shoulder' firing. The study team used a computer simulation to evaluate different conditions and parameters and develop a sound understanding of the factors involved. Distances between aircraft, flight speed and range, which affect the amount of time available to launch a missile, where investigated to improve manoeuvrability and success rate of the missiles.

The objective of providing the SAAF with guidelines that would give pilots confidence in the performance of the new Gripen missiles was well-achieved. The CSIR will continue to support the SAAF in the optimal use of its new fleet of Gripen fighter jets.