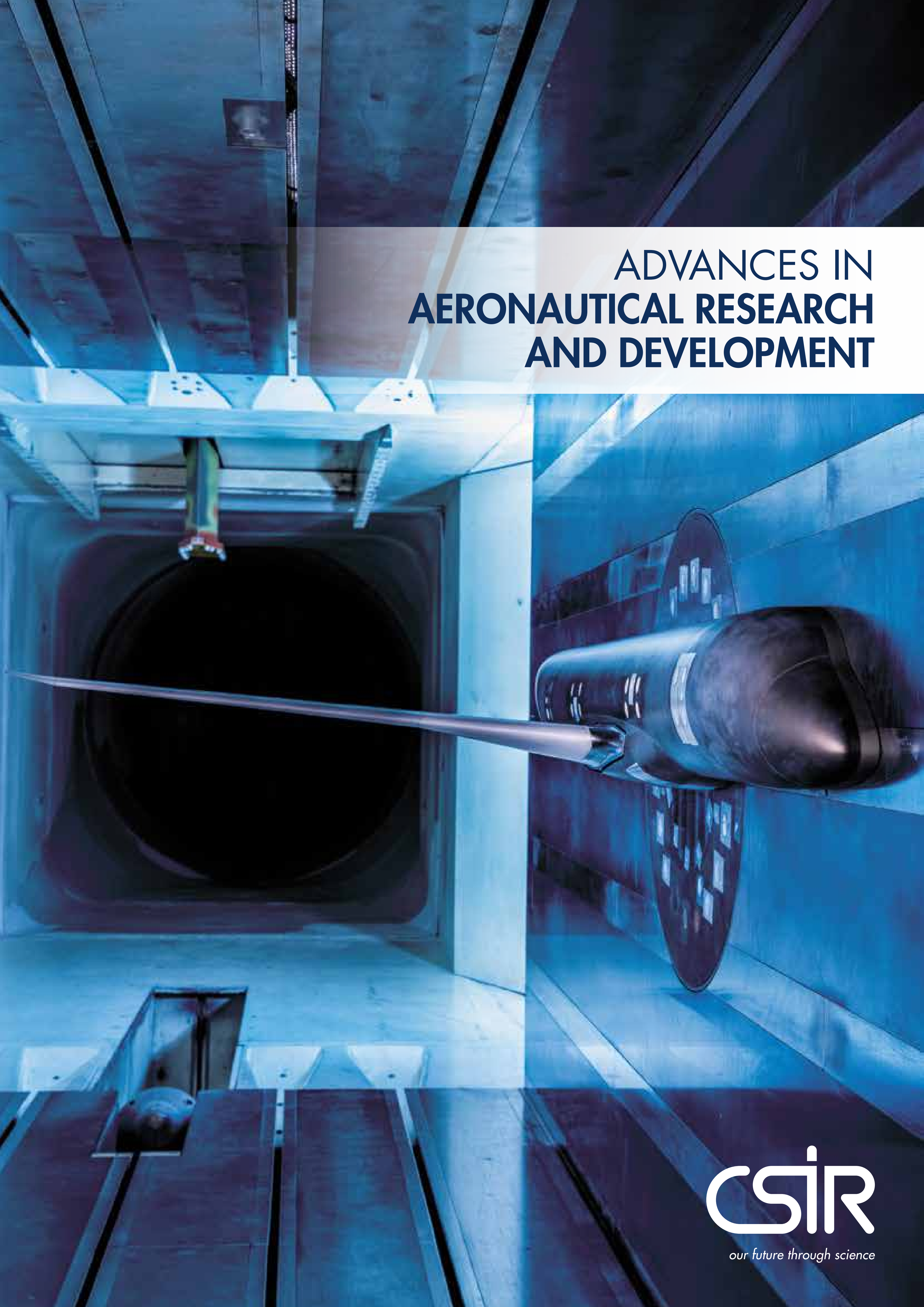
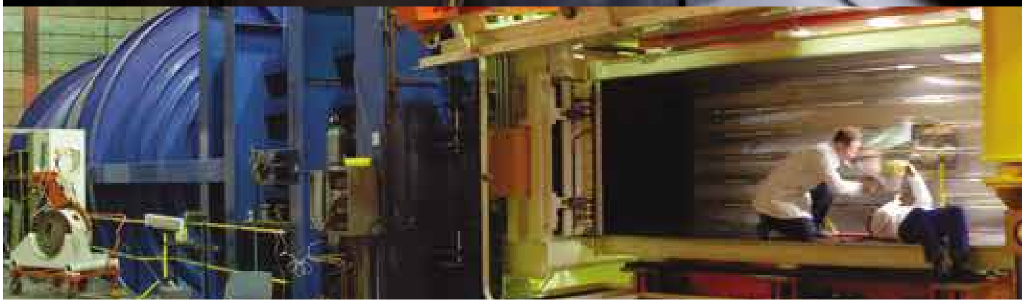
ADVANCES IN
AERONAUTICAL RESEARCH AND DEVELOPMENT



CSIR

our future through science

The Council for Scientific and Industrial Research (CSIR) is home to leading aeronautical research and development. Engineers and scientists, access to specialist infrastructure and equipment, and global technology collaborations contribute to the CSIR's status as a world-class aeronautics capability.



Wind Tunnel Testing

The CSIR's suite of wind tunnels has provided a scientific research and experimental foundation to the aerodynamic design efforts of the South African aeronautics industry for many years. The suite was installed in the mid-1960s and has become a popular test capability in the Southern hemisphere.

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

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

The **seven-metre wind tunnel** (7mWT) is a continuous, open circuit tunnel powered by 28 axial flow fans of 30 kW each. Uniform flow distribution across the speed range of the tunnel is created by running the fans in one of 13 different symmetrical patterns.

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

The **high-speed wind tunnel** (HSWT) is a trisonic, blowdown wind tunnel equipped with a colour Schlieren system for flow visualisation.

Subsonic and supersonic Mach numbers are tested using the standard wind tunnel setup, while tests in the transonic regime employ an extra cart which is fitted with a plenum evacuation system and porous walls.

HIGH-SPEED WIND TUNNEL – MAX SPEED: MACH 4.0

SEVEN-METRE WIND TUNNEL – MAX SPEED: 32 m/s

LOW-SPEED WIND TUNNEL – MAX SPEED: 120 m/s

MEDIUM-SPEED WIND TUNNEL – MAX SPEED: MACH 1.4

LSWT specifications:

- Speed range: 5 m/s to 120 m/s
- Test section: 2.1 m x 1.5 m
- Rectangular with corner fillets
- Atmospheric tunnel
- Reynolds number: 6 x 10^6/m

7mWT specifications:

- Speed: 2 to 32 m/s in discreet steps
- Test section: 7,5 m x 6,5 m x 13 m
- Continuous, open circuit

MSWT specifications:

- Mach no. range: M 0.2 to M 1.4
- Test section: 1,5 m x 1,5 m x 4,5 m
- Reynolds number: 31x10^6/m (M 0.8)
- Closed circuit, variable pressure, continuous wind tunnel
- Stagnation pressure: 20 to 250 kPa

HSWT specifications:

- Mach no. range: M 0.6 to M 4.0
- Test section: 0.45 m x 0.45 m
- Run time: 10 to 30 seconds
- Reynolds number: 6 to 50x10^6/m
- Stagnation pressure range: 70 to 950 kPa
- Trisonic intermittent blow down wind tunnel

Flutter Clearance

Flutter is a dangerous dynamic instability that all aircraft can encounter. It is driven by the mass and stiffness distribution in the aircraft structure, combined with its aerodynamic characteristics. Changes to those characteristics due to the addition of a new store configuration to an aircraft can cause flutter. It is essential that the aeroelastic properties of all new aircraft store configurations are evaluated to ensure that flutter does not occur.

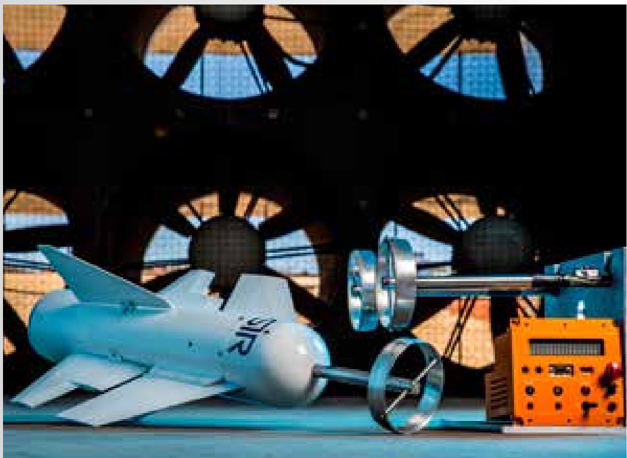
The CSIR is a leader in aeroelasticity technology and has cleared more than 200 aircraft configurations for the South African Air Force (SAAF) as well as local and international clients since the 1970's. It has a full range of aeroelasticity-related capabilities including:

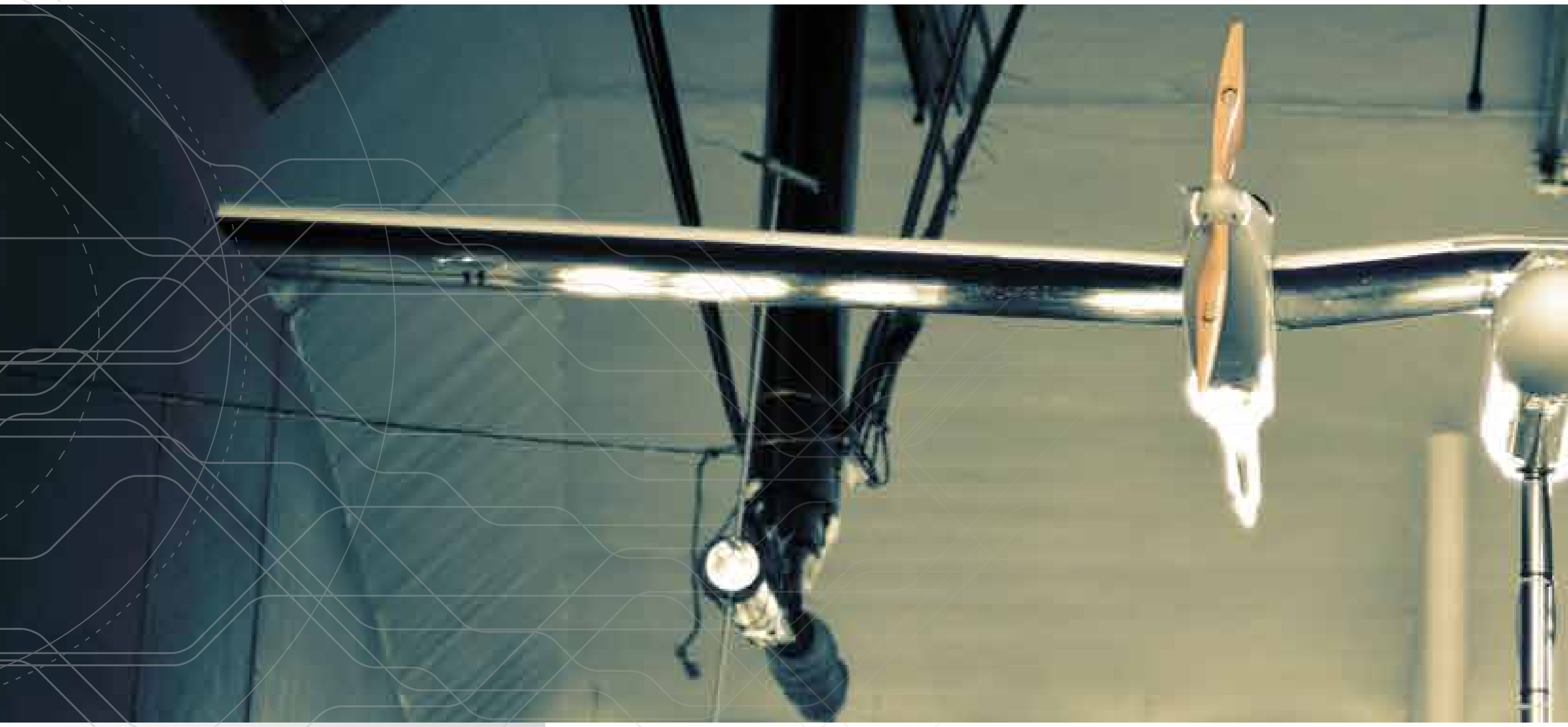
- Ground vibration testing (GVT) and modal analysis
- Finite element modelling (FEM)
- Unsteady aerodynamics analysis
- Flutter analysis
- Flutter flight test tools
- Flutter excitation systems to support flight testing

The CSIR Flutter Excitation System

The purpose of a flutter exciter is to impart a vibration into a structure. Installed on the flight test aircraft, it provides an energy input for aircraft structure to excite all the natural modes. These structural vibrations are measured by accelerometers and the responses are used to determine if flutter onset is likely or not. A flutter excitation system improves the signal-to-noise ratio of the accelerometer responses and provides higher fidelity structural data.

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





Indiza

Indiza is a small, rugged and highly efficient hand-launched UAS (Unmanned Aircraft System). The fuselage is fitted with a modular payload system which can support a number of interchangeable cameras or other systems. The airframe contains the GPS based autopilot, radio modem and video transmitter. The ground-based equipment currently consists of a laptop-based mission planner and tracking antenna system for the video and data links. There is an optional radio control transmitter and airborne receiver for man-in-the-loop control of both the airframe and the camera system.

The system has been used to provide photographic and video information in the border safeguarding environments.

The airframe can accommodate a number of generic camera pods. These interchangeable pods consist of three different types of camera systems including:

- A pan, tilt and stow twin-camera system
- A stowable high-definition wide-angle video camera
- A 3G cellphone based camera

SYSTEM SPECIFICATION:

- Span: 2 m
- Maximum mass: 3.5 kg
- Maximum payload: 0.5 kg
- Duration: 1 hour
- Launch: Hand-launched

Unmanned Aircraft Systems

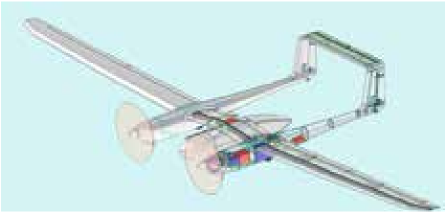
The CSIR's R&D portfolio in Unmanned Aircraft Systems (UAS) has grown considerably with increasing demand for the use of its research platforms as well as its aerodynamic design and optimisation capability. The CSIR houses a UAS laboratory which incorporates high-fidelity flight simulators with aircraft sub-system hardware-in-the-loop, such as autopilots and control surface servo actuators.

The Long Endurance Modular UAV (LEMU)

The Long Endurance Modular UAV (LEMU) is a research platform, designed to provide the capability for validating novel technology components and/or basic sub-systems by integration and demonstration in a relevant flight environment. A central hard point on the wing provides the capability to mount custom-sized payload pods. All major aerodynamic control surfaces (ailerons, elevator, rudders and flaps) are replicated, introducing redundancy into the airframe. A horizontal stabiliser joins the two vertical fins. Two variants of LEMU are currently in development at the CSIR:

LEMU Internal Combustion Variant – powered by two fuel injected internal combustion engines and providing up to eight hours of endurance.

LEMU Electric Variant – powered by two brushless electric motors and providing up to 1 hour endurance.



System specifications	LEMU Internal Combustion	LEMU Electric
Performance characteristics		
Maximum take-off mass	65 kg	65 kg
Payload capability	Up to 20 kg (excluding fuel)	Up to 20 kg
Maximum speed	48 m/s	38 m/s
Maximum climb rate	>250 ft/min	>250 ft/min
Endurance/range requirements	Up to 8 hours endurance (dependent on payload)	Up to 1 hour endurance (dependent on payload)

Umgeni Gas Turbine Engine

The CSIR developed Umgeni Turbojet engine consists of a single stage mixed/diagonal flow compressor with a tandem bladed transonic diffuser coupled to a reverse flow annular combustor. The turbine section consists of a hybrid configuration axial nozzle guide vane with a conventional radial-inflow turbine rotor. The engine is a 1 000 N (1 kN) thrust class advanced cycle turbojet for thrust. The engine is able to provide up to 1,6 kW of electrical power and is in the process of being designed for high altitude self-start capability between 15 000 – 20 000 ft.

The engine fuel system, structural design, power electronics, turbomachinery and combustion system have been developed at the CSIR.

Umgeni engine

Umgeni exploded view

Store Integration

The CSIR has the capability to integrate the client's store with any aircraft. This includes functional integration as well as compatibility evaluation for airworthiness certification. A systems engineering approach is followed that complies with military and airworthiness standards.

The CSIR has particular expertise in evaluating the aero/mechanical impacts of integrating stores with the aircraft. This work is done in compliance with MIL-HDBK-1763 and covers the following aspects; aeroelasticity (flutter); store separation behaviour; loads on aircraft during carriage and impact on aircraft performance and handling characteristics. These aspects are summarised below:

PHOTO CREDIT: John Stupart, http://www.africandefence.net/rheinmetall-denel-defence-day-in-pictures/.

Store separation analysis

Stores that are individually stable can behave differently in the flowfield of an aircraft. This can result in unexpected dynamics with the store possibly colliding with the aircraft. It is essential to verify that stores can be released safely over the full release and jettison envelopes.

Store separation analyses are very complex and require the use of advanced computational and experimental tools. The CSIR has developed store separation analysis tools in-house and leads the field in South Africa. These tools include:

- In-house panel code
- Computational fluid dynamics codes
- The Medium-Speed wind tunnel fitted with a captive trajectory system
- The Analyse Ejection code system

Carriage loads analysis

Stores exert loads on the aircraft structure while it is being carried. These loads include:

- Aerodynamic
- Landing
- Manoeuvre
- Ejection

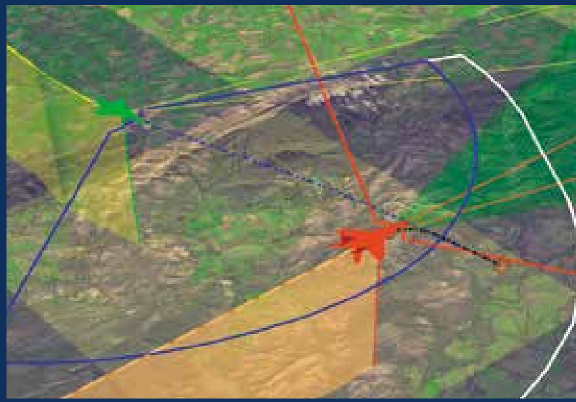
It is important to ensure that the aircraft structure is not overstressed at any point. The CSIR performs analyses in compliance with the applicable regulations using a range of aerodynamic, simulation and dynamics tools.

Performance and handling analysis

Carrying a store affects the performance and handling of the aircraft. It is important to compare the actual performance envelopes against the specifications for the configurations with the store. It is also necessary to ensure that the aircraft is controllable and has acceptable handling in all phases of flight. The CSIR performs analyses in compliance with applicable regulations.

Other core capabilities

The Mission Simulation Framework (MSF) is a scenario simulation tool capable of simulating the interactions between a large number of land or air based entities. It runs faster than real-time with optional visualisation that can be run at a large range of speeds. Its primary purpose is to provide insight into the outcome of various engagement scenarios including air-to-air and air-to-ground missions.



Two types of models are currently utilised in MSF. Generic models exist of aircraft, missiles, radars, guns, launchers, fire control systems and data links. Specific system models have been created from open information sources, through consultation with experts in the relevant fields and physics modelling.

Terrain modelling is included to model line of sight link limitations for scenarios that have terrain based sensors.

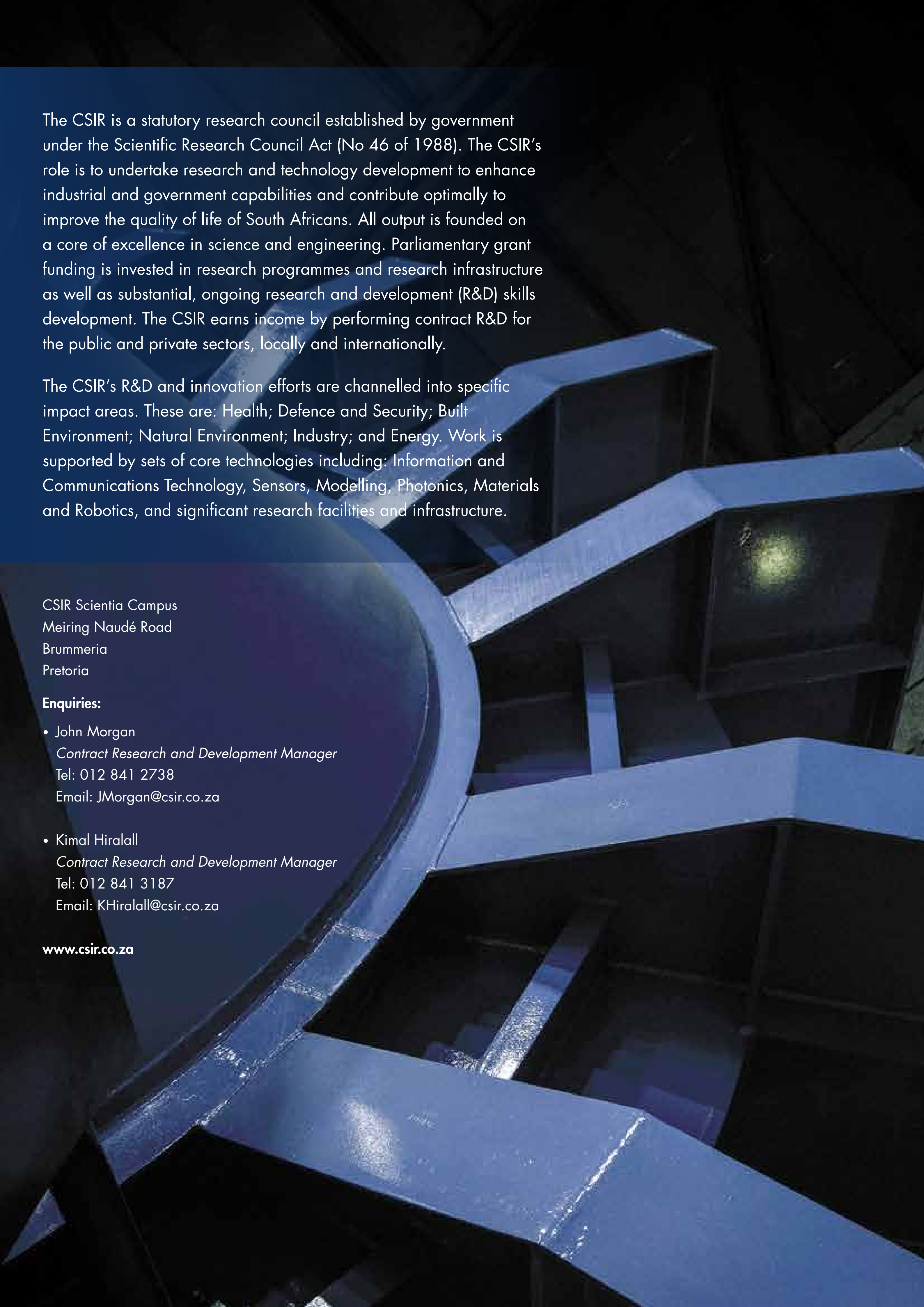
Decoy Rockets Ballistic rockets fired as decoys are used to protect high-value vessels against the threat of anti-craft radar missiles. The CSIR undertakes concept development, design, prototyping and testing – up to the point where actual, measured performance during a flight test can be correlated to theoretical intentions.

CSIR Aircraft Design and Evaluation Capabilities The CSIR has developed a number of aircraft in the past, starting with the SARA series of gyrocopters, the all carbon fibre military turboprop trainer ACE and the Hummingbird, a very low speed observation light aircraft. The CSIR undertakes conceptual design, detailed design, aerodynamic characterisation through wind tunnel testing or through computational methods.

Various other scientific experiment techniques are used, as well as high fidelity man-in-the-loop simulations of both fixed and rotary winged aircraft for validation of flight data and the evaluation and optimisation of handling qualities

Simulation Environment The CSIR and Cybicom Atlas Defence have jointly developed a prototype helicopter simulator primarily aimed at the Navy requirement for a Helicopter Flight Deck Trainer. It is designed to provide joint training for flight deck controllers and marine helicopter pilots. It provides a safe, cost-effective solution to train personnel in a realistic and controlled environment. The flight deck trainer is a flexible, modular system that can be supplied in various levels, from a simple, portable, desktop trainer, to a multichannel, high-performance tracking system that can accommodate multiple trainees and provide a 360-degree, high-fidelity simulation with full-environment simulation.

The distributed simulation environment integrates three man-in-the-loop simulator stations, namely; a helicopter flight simulator with pilot interface that models the helicopter, the airflow over the deck and the ship interaction dynamics complete with an image-generation system that displays the external world view to the pilot; a ship bridge simulator that includes sea-state, rain, and cloud-cover models with a bridge interface for the captain; as well as a deck landing officer station.



The CSIR is a statutory research council established by government under the Scientific Research Council Act (No 46 of 1988). The CSIR's role is to undertake research and technology development to enhance industrial and government capabilities and contribute optimally to improve the quality of life of South Africans. All output is founded on a core of excellence in science and engineering. Parliamentary grant funding is invested in research programmes and research infrastructure as well as substantial, ongoing research and development (R&D) skills development. The CSIR earns income by performing contract R&D for the public and private sectors, locally and internationally.

The CSIR's R&D and innovation efforts are channelled into specific impact areas. These are: Health; Defence and Security; Built Environment; Natural Environment; Industry; and Energy. Work is supported by sets of core technologies including: Information and Communications Technology, Sensors, Modelling, Photonics, Materials and Robotics, and significant research facilities and infrastructure.

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