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A U S T R A L I A

Ionospheric studies for better
over-the-horizon radar reception

Marine anti-fouling measures
drawn from nature

Modelling events to understand
the course of calamity





Australian Government

Department of Defence

Defence Science and
Technology Organisation

The Defence Science and Technology Organisation (DSTO) is part of the Department of Defence and provides scientific advice and support to the Australian Defence Organisation. DSTO is headed by the Chief Defence Scientist, Professor Robert Clark, and employs about 2300 staff, including some 1300 researchers and engineers. It is one of the two largest research and development organisations in Australia.

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Cover image: DSTO researchers with field equipment used for ionospheric studies conducted in Australia and the Caribbean.

Identifying castor oil plant origins for security benefits

DSTO is applying an innovative means to determine the variety and place of origin for castor beans, source material for a deadly toxin called ricin, thereby assisting with investigations into any improper uses of this material.



Ricin is a highly lethal extract obtainable in liquid or powder form from the beans of the castor oil plant *ricinus communis*.

In today's world where some socially and politically disaffected groups seek to wreak havoc through whatever means they can access, the compound is considered a potential threat.

Not surprising since the source material for making it is readily available. The castor oil plant is widely cultivated as an ornamental garden shrub and there is no specific antidote for this very powerful agent.

Discerning the compound's provenance

In order to deter the use of ricin by providing a ready forensic ability to identify the origins of various strains, a research effort at DSTO led by Dr Simon Ovenden is applying study methods known as metabolomics.

This form of research, already being applied to commercial crops, investigates the chemical make-up of castor bean extracts to produce a definitive 'fingerprint' of certain molecules indicative of particular varieties as well as the soil and rainfall conditions for plant growth unique to an area.

The main tools being used for this work include nuclear magnetic resonance spectroscopy and liquid chromatography mass spectrometry. For safety of the research staff involved, all traces of ricin are removed at an early stage of processing, with metabolomic analysis being conducted on the remaining plant material.

"The work involved building up a database of results obtained by analysing samples from different castor oil plant varieties as grown in different parts of Australia and overseas, so that samples obtained during police or military investigations can be analysed and quickly matched to a plant variety and source area," explains Dr Ovenden.

As part of the study process, DSTO has undertaken to grow castor oil plants in controlled conditions in green houses to examine the effect of different environmental conditions on the metabolomic signatures of specimens.

World-leading research

The work so far shows great promise of delivering a diagnostic capability, with DSTO's means of identification having performed very well during blind testing of samples.

DSTO is the only organisation globally to apply metabolomic methods for the purposes of ricin source identification.

Other agencies involved in the research include the Universities of Melbourne and Western Australia, Curtin University, Metabolomics Australia, and the Australian Quarantine and Inspection Service.

The research is funded by the Australian Government's National Security Science and Technology Unit and supported by Emergency Management Australia and the Australian Federal Police. [D](#)



Above: Dr Simon Ovenden with castor beans plant and (right) Nuclear Magnetic Resonance spectrometer being used for castor bean research.

Studying the changeable sky for better radar imaging

Defence is using over-the-horizon radar (OTHR) for wide-area surveillance to Australia's north, and findings about the state of the ionosphere are crucial to its operation.

The Jindalee Operational Radar Network (JORN) enables the Australian Defence Force (ADF) to effectively monitor all air and sea activity to the north of Australia up to a distance of 3,000 kilometres.

This capability greatly improves on the surveillance coverage provided by Navy ships, which can only detect targets in direct line-of-sight of their radar masts, meaning that targets on the earth's surface over the horizon or hidden by landmasses cannot be detected. Surveillance aircraft provide a more extensive overhead view, with ranges of several hundred kilometres, but this capability is only available while the aircraft flies, and in the area where it flies.

OTHR radar systems like JORN operate by using the ionosphere to bounce transmitted signals onto targets far beyond the horizon, reading a return signal via the same route. However, the operation of these systems is dependent on knowing what state the ionospheric 'mirror' is in at any time so that variations in refractive performance can be compensated for.

The ionosphere varies in thickness and density on a predictable daily, seasonal and solar-cycle basis. These qualities similarly vary with latitude, and are also affected by the earth's magnetic field, which creates anomalous high-density regions around the magnetic equator and at the Arctic and Antarctic circle.

In addition, the ionosphere is subject to random variations, caused by influences including solar storms, atmospheric disturbances and lightning. One such variation is termed a 'travelling ionosphere disturbance' (TID). These take the form of wavefronts up to thousands of kilometres long, travelling at speeds of several hundred metres per second. They effectively alter the height of the ionospheric 'mirror' by tens of kilometres, considerably affecting OTHR accuracy for durations of several minutes to several hours.

Towards better knowledge of the ionosphere

While much is known about the regular types of variation in the ionosphere and the effects of large and medium-scale TIDs, further work is required to understand the nature of smaller sized, shorter-term disturbances.

DSTO is carrying out a research program to this end called the Spatial Ionospheric Correlation Experiment (SpICE).

DSTO researcher Dr Trevor Harris explains, "The aim of this program is to study and characterise ionospheric disturbances occurring in timescales less than 20 minutes, and spatial structures of the order of 300 kilometres or less.

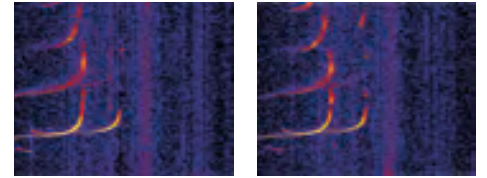
"We also seek to understand the relative influence of TIDs compared to *in situ* effects, and the use of oblique-incidence ionospheric sounding techniques for measuring the state of the ionosphere compared to vertical-incidence soundings."

Three experiments have been conducted to date.

The experimental program

SpICE-1, a small-scale demonstrator experiment, was undertaken over an area of southeast South Australia and southwest Victoria.

This involved taking measurements of the ionosphere as rapidly as possible through High Frequency (HF) radio transmissions bounced off the ionosphere to a receiver. The work was conducted using four ground sites, two of which were 300 kilometres distant from each other, and also to another two that were only 40 kilometres apart. Using this basically triangular configuration of sites, the ionosphere was sampled at the midpoints between sites, these sample points forming a parallelogram with corners all spaced about 150 kilometres apart. "One outcome of the experiment was to reveal the existence



The ionosphere

This uppermost part of the atmosphere ranges from about 50 to 1,000 kilometres above the earth's surface, where high-energy ultraviolet and x-ray radiation from the sun ionises atoms and molecules.

These charged particles have the effect of refracting High Frequency radio waves. The higher the frequency, the greater the ability of the signal to pass through the ionosphere unaffected, so that reflection heights become progressively higher until the signal passes through.

Only part of the signal energy that is sent out ever returns to the radar, meaning that over-the-horizon radars need very large antennas and vast amounts of computing power to obtain useful images from the high-level background radiation 'noise'.

Nevertheless, this technology has been developed to the point that details as small as boats and light aircraft can be detected, as well as natural phenomena such as ocean wave height and direction of travel. Some researchers suggest that hundred-fold improvements in image quality may be achievable.

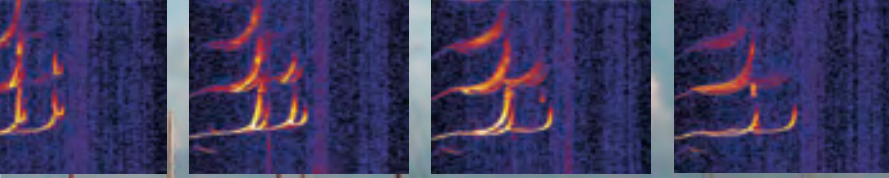
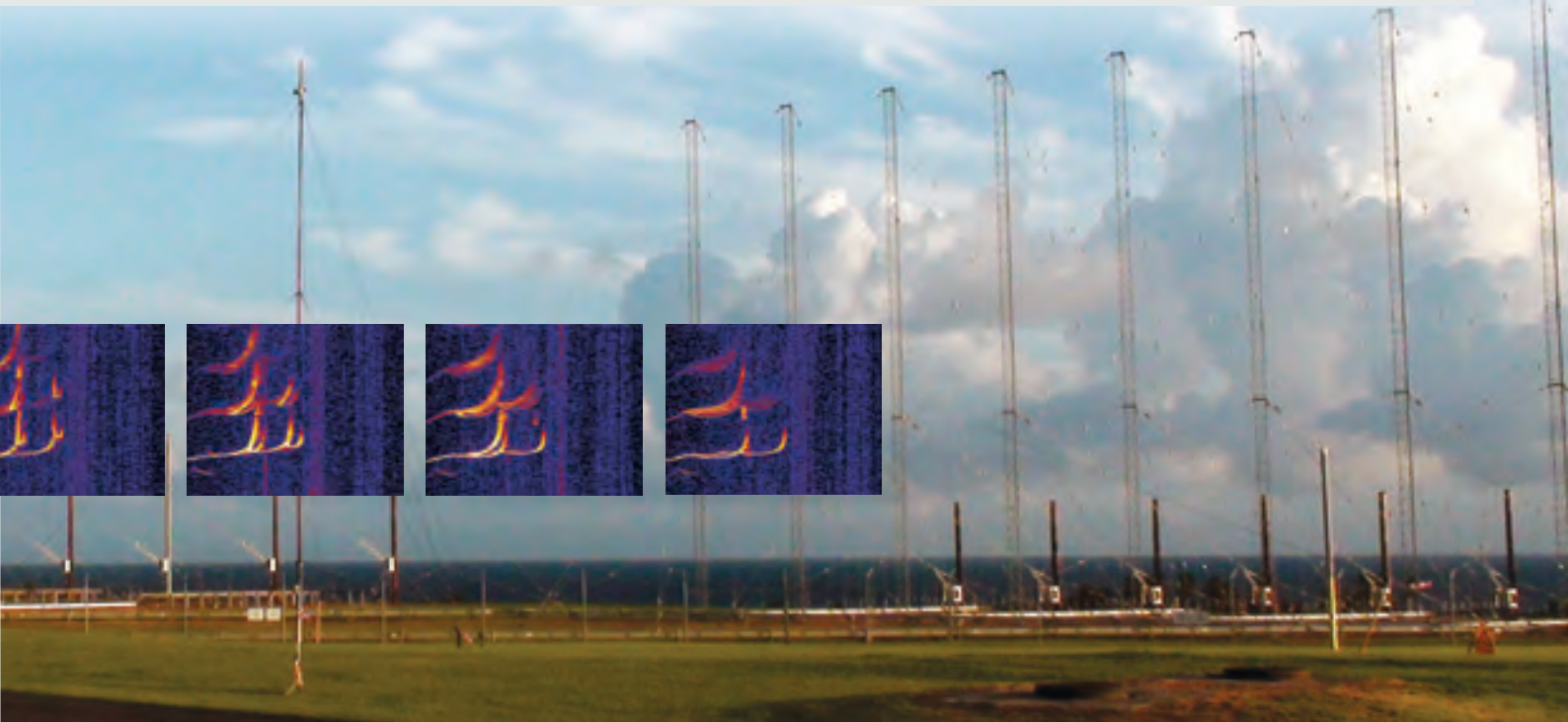
of many small-scale, possibly travelling, ionospheric disturbances less than 300 kilometres in wavelength," says Dr Harris.

"The inference we drew was that ionospheric sampling points must be spaced closer than 150 kilometres to effectively probe them."

SpICE-2 across Australia

A second SpICE campaign was planned using sites in Australia that would effectively replicate conditions in the Northern Hemisphere.

Fulfilling these requirements, a set of four transmission and reception sites was identified in Far North Queensland (FNQ),



and two reception sites were selected for long-path transmissions, one being DSTO Edinburgh, near Adelaide, with the other located at Denmark, Western Australia.

Using the four FNQ transmission and receiver sites, the ionosphere was once again sampled at the corners of a parallelogram, but this time, the distance between sample points was set at around 50 kilometres, in accord with the SpICE-1 findings.

Long-path transmissions were also sent from FNQ to the west and south coasts of the Australian landmass, and both FNQ transmission sites were used to conduct vertical transmission and reception studies. Another objective of the experiment was to study capabilities for transferring diagnostic

data over an internet link to a remote server for display and investigation by all researchers, presented in ionogram form.

SpICE-3 across the Caribbean

The third SpICE campaign was undertaken in the Northern Hemisphere in Puerto Rico to investigate the different ionospheric phenomenology of that region.

Conducted over 19 days in October 2009, it involved thirteen DSTO researchers and technicians, with collaboration from Raytheon Integrated Defense Systems and the Arecibo Observatory.

As with SpICE-2, the experiment involved ionospheric soundings made vertically above the transmission sites, quasi-vertically between

transmit and receive sites spaced 50 to 100 kilometres apart, and long-path transmissions.

“In addition,” says Dr Harris, “incoherent scatter radar measurements of the real vertical electron density profile of the ionosphere were made by the Arecibo Observatory, and readings were also obtained of a phenomenon called ‘airglow’ over Puerto Rico by the University of Illinois to inform the experiment data analysis and interpretation.”

Further SpICE campaigns are planned for 2010 in the continuing quest to better understand the ionosphere.

Mirror in a constant state of flux

The ionosphere is constantly monitored for JORN operations by a network of thirteen vertical incidence sounders (VIS), also known as ‘ionosondes’, located around Australia to provide a real-time map of the ionosphere.

Using a vertically directed antenna, the ionosonde transmits short pulses of High Frequency (HF) radio waves that progressively rise in frequency across the entire HF wavelength range. The strength of the signal at each frequency returning from the ionosphere is analysed for presentation in the form of an ionogram.

*This graph depicts the reflection heights for particular frequencies, displaying the ionospheric conditions at a site at that time. The data thus obtained enables OTHR operators to adjust the transmission frequency and waveform being used to optimise radar performance. **D***



Top of page (inset): Series of ionograms depicting the changing state of the ionosphere measured at a particular time and locality.
Background image: US Navy Relocatable OTHR system in Puerto Rico.
Above: SpICE research team members erecting an antenna in Puerto Rico for SpICE-3 experiments.

Measuring stress keeps ageing fleets flying

With Defence aircraft service lives now routinely exceeding their original design lives, DSTO has developed a way of quickly measuring flight stress loadings to enable timely structural integrity assessments.

When aircraft are kept in service beyond their planned withdrawal date, the fatigue lives of critical components and the associated structural certification need to be reassessed to ascertain fatigue management requirements.

Furthermore, as operational needs increase over time, aircraft are being subjected to higher usages and 'loads' – stresses on the airframe incurred during flight – than were contemplated when their design life was originally set. In such cases, fleet operators need to understand the impact of these higher usages and loads on the 'fatigue

consumption' of the aircraft – the rate at which usage wears out the aircraft structure – and what the implications of this are for fatigue management of aircraft yet to reach their planned withdrawal date.

Determining the fatigue consumption of aircraft requires information about the number, duration and types of missions performed, and the stress levels typically experienced in flight. The most accurate way of determining stress levels is to make in-flight measurements via sensors fitted to an aircraft, placed at structurally critical locations, known as 'hot spots'.



While older aircraft lack sensor systems entirely, recent-model aircraft generally have such sensors built in, but these are typically attached to a handful of benign structural locations, and not at the more critical 'hot spots'.

Several commercial systems are now available and can be retrofitted to give the requisite coverage of 'hot spots'. However, they are difficult to install and remove, requiring extensive certification documentation and substantial aircraft downtime, which makes the exercise quite labour intensive and costly, and also reduces aircraft availability.

In light of these issues, the Aircraft Structural Integrity-Director General Technical Airworthiness (ASI-DGTA) asked DSTO to devise a better approach that would give the Australian Defence Force (ADF) a capability to rapidly measure operational loads.

Simply advantageous CMPL

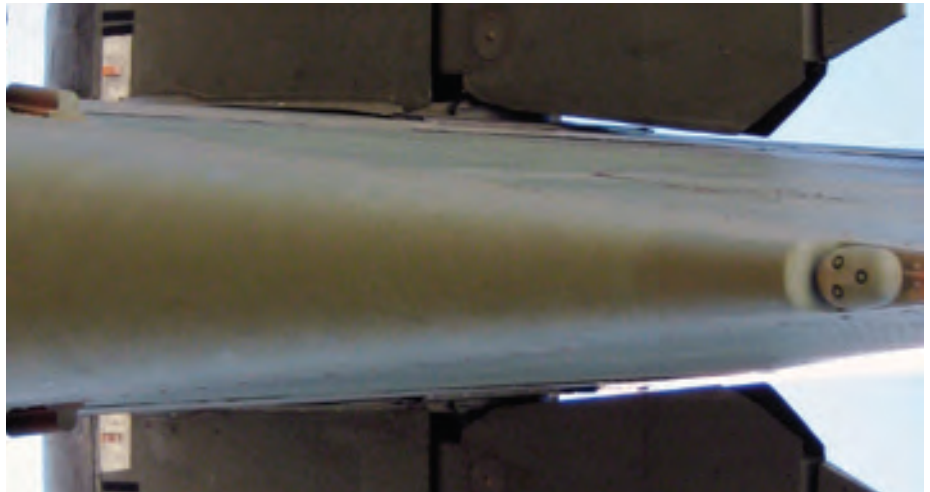
DSTO's Compact Multi-Parameter Loads Evaluation (CMPL) system provides just such a capability.

CMPL features sensor modules that are capable of independently but synchronously collecting operational data. Each sensor module contains a battery, microprocessor, memory and sensors that allow for autonomous sensing function.

"During in-flight testing, there is no need for wire connectivity to an external power source, control device or sensors, and similarly, no need to use the aircraft's power supply or for external system control hardware to be carried, or external sensors installed," explains Dr Steve Galea.

The data collected includes time-series readings for strain and temperature, or acceleration and temperature. After landing, this data is downloaded for analysis using a laptop computer connected with cable via an interface, undertaken concurrently with battery recharging and re-setting of the module for subsequent flights.

The autonomous modular nature of CMPL thus delivers a key advantage over previous systems – ease of fitting and certification, since only its sensor modules need installation on an aircraft.



The way in which module fitting and removal is undertaken delivers another key advantage, being simple and quick. The sensing modules are affixed with epoxy resin, called ElectRelease™, onto a prepared paint-free surface. CMPL is equipped with apparatus that generates a vacuum to hold the sensor tightly onto the aircraft surface while applying heat to cure the glue. Installation typically takes less than one hour.

Dismounting the sensors after flight-testing is equally straightforward. A voltage is applied across the glue for around 30 to 45 minutes, causing it to release. The module can now be removed using only light finger pressure, leaving a clean surface with minimal resin residue on the aircraft. This surface is then restored to pre-testing condition.

Other CMPL system advantages are that it is quick and easy to calibrate, able to obtain reliable data from a small number of flights, usable on any aircraft and readily reapplied.

Caribou trials

In 2008, while CMPL was still under development, DSTO was tasked to use the system to determine peak stress loadings at critical tail plane structural locations for RAAF's DHC-4 Caribou aircraft.

Six sensing modules were fitted to a Caribou for this purpose, four used in the strain measurement mode and two in the acceleration measurement mode. All remained firmly attached for a series of three flights during a weeklong loads flight trial, performing as required.

Data on strain load, acceleration and temperature were successfully collected, demonstrating both the practicality of doing so with the CMPL system and the minimal aircraft downtime its use required.

Lessons learned from the Caribou flight trials have since been used to make the CMPL system more robust and versatile. **D**

*Opposite: DSTO researcher fitting a CMPL sensor module to an aircraft structure.
Top of page: Two CMPL modules fitted to the underside leading edge of RAAF Caribou tail plane.
Below: The CMPL interface apparatus being used to download data from a mounted module.*

Model ways of delivering answers for accident analysis

DSTO has a distinguished record as an innovator in accident investigations, beginning half a century ago with the invention of the Black Box flight data recorder, and the skills it now applies have boosted this status.

In addition to delivering the prototype Black Box technology, which is arguably one of the most important and successful innovations to come out of Australia, the organisation has developed expertise in crash scene investigations, in-lab testing and event reconstruction modelling that has already assisted numerous Australian Defence Force (ADF) inquiries.

Three recent mishaps occasioning requests for DSTO investigative and analytical support have all involved helicopters.

Black Hawk mid-air crash

In June 1996, two Army Black Hawk helicopters collided mid-air while on a night operations training mission near Townsville, Queensland, resulting in the total loss of both aircraft and the loss of 18 ADF personnel lives with 12 also injured.

The ADF Accident Investigation Team (AIT) asked DSTO to assist with research into the cause of the accident and to deliver its findings in the form of a video presentation depicting the collision.

Since neither aircraft was fitted with flight data recorders, exact details of the events leading to the collision were unknown. Hence, the only information available to investigators was the eyewitness accounts of survivors, the aircraft ground impact points and final resting positions, and the state of various components recovered from the crash site.

DSTO staff attended the accident scene to assist AIT with metallurgical and fracture assessments of the wreckage. A detailed examination of the fuselage, rotor blades and several other flight control and power train components was made at the crash site, with

further work carried out on some items later in DSTO's Melbourne laboratories.

"An analysis of all the observed outcomes led to the formation of two possible accident scenarios. Computer-generated simulations of these were then devised, with a number of flight trajectories being studied for the two aircraft that together produced collision conditions," explains DSTO researcher Ashley Arney.

From this work, one scenario was found to be more probable according to the known outcomes: that the two aircraft, labelled by investigators 'Black 1' and 'Black 2', came together, with Black 1 behind, to the left of, and below Black 2, moving forward and/or to the right relative to Black 2, with the result that Black 1's main rotor entered the other's tail, tail boom and rear fuselage, after which, both aircraft became uncontrollable and crashed.

Working with this scenario, a range of initial conditions for altitude, relative closing speeds and flight path convergence angles were used as inputs for the simulations to see the range of outcomes that would be manifested in terms of impact point and final aircraft positions.

Out of this experimentation, one set of initial conditions was found to result in flight trajectories producing outcomes that correlated well with the actual ground impact points and final resting places of the aircraft as well as the damage they sustained.

Upon showing the animation of this collision scenario to accident survivors, they reportedly confirmed that DSTO's simulation matched well with their recollections of what happened.



DSTO modelling of Black Hawk mid-air collision.

Sea King crash on Nias during aid effort

In April 2005, a Navy Sea King Helicopter carrying ADF medical personnel on a humanitarian aid mission for earthquake disaster relief crashed on the island of Nias, Indonesia, resulting in nine fatalities and two survivors with serious injuries.

Acting on a request from the ADF, DSTO's work began in Nias by supporting an on-site crash investigation, followed by removal of the helicopter wreckage for in-laboratory studies in Melbourne.

While the physical evidence strongly indicated that disconnection of part of the main rotor control mechanism had led to the accident, modelling assisted to confirm this.

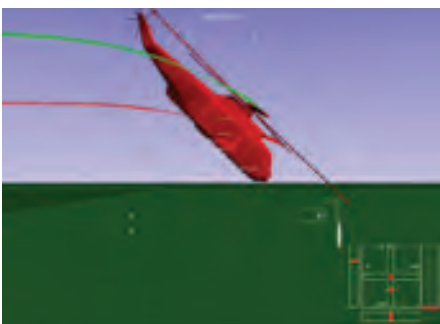
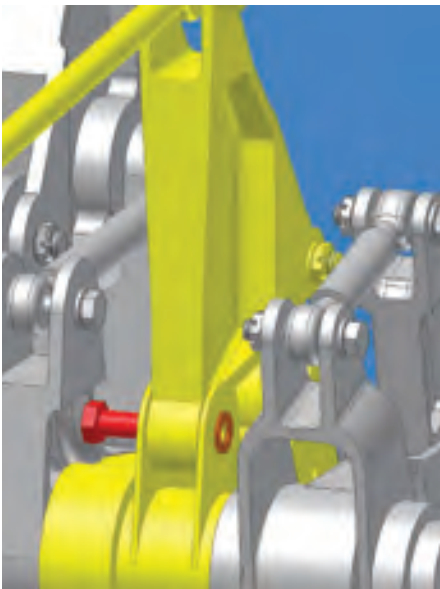
Flight simulation modelling of the Sea King showed that when this control system mechanism was disconnected, the aircraft would have assumed a nose-down attitude in an uncontrolled descent leading to the crash – findings consistent with evidence obtained at the crash site.

A simplified conceptual version of the Sea King control system was also developed in order to study the effects of disconnecting particular control system parts, and the results obtained were similarly consistent with the crash-site evidence.

A three-dimensional (3-D) computer graphic model of the system was created for Board of Inquiry demonstration purposes, and 3-D modelling undertaken of the final moments of flight was likewise used at the Inquiry.

DSTO's investigations overall showed conclusively that a missing split pin had caused failure of the Sea King control system, leading ultimately to the crash.

"We managed to establish there was only one possible cause of the crash by showing that competing theories were untenable, either because our analysis found evidence contrary to those theories or because those theories failed to explain crucial parts of the evidence," says DSTO researcher Nicholas Athinotis.



DSTO modelling of Black Hawk approach to HMAS Kanimbla immediately before collision.

DSTO's work contributed to a speedy identification of the cause of the accident, leading to a quicker return to operational status for the Sea King fleet – immediately grounded after the accident – than would otherwise have been the case.

Black Hawk collision with HMAS Kanimbla

In November 2006, an ADF Black Hawk helicopter on routine training operations off Fiji crashed into the deck of HMAS Kanimbla while attempting a landing and then plunged into the sea. Of the ten ADF personnel onboard, seven were injured and two died.

With the helicopter's flight data recorder yet to be recovered – the wreck having sunk in three kilometres of water – available information initially included a few seconds of video footage captured on a hand-held camera onboard the helicopter, and footage taken by the ship's *in situ* flight deck monitoring system of the aircraft's flight immediately before and at the point of impact. The DSTO researchers tasked to investigate the accident began by evaluating this footage.

"From the video material, we were able to determine a flight profile for the helicopter at the critical times of approach and impact using photogrammetry techniques," says DSTO researcher Dr Jeremy Blackwell.

Photogrammetry is a method of establishing the relative positions of objects in a scene by measuring distances between them in a photo of the scene, and then measuring the size of an object in the photo of known real-world size to find the appropriate scale-up factor to determine real-world distances.

DSTO modelling of Sea King control mechanism, plus flight of Sea King before and after control mechanism failure.

The DSTO team then conducted flight simulator trials with experienced Black Hawk crew who attempted to fly the crash sequence, as depicted by the flight profile modelling work. This was to develop better understandings about what may have happened in the lead-up to the accident.


The key findings arising from the work were that the available power of the aircraft appeared to be insufficient to arrest both the speed and descent of the final approach to the ship for safe transition into a hover over the deck.

"The wind direction plus aircraft speed of ingress, weight and offset distance from the ship during approach were all factors that contributed to increasing the power margin beyond that available from the aircraft," says Dr Blackwell.

The researchers then carried out analysis of the data obtained from the helicopter flight data recorder after successful recovery of the wreckage some four months later.

The conclusions they were able to draw were that the aircraft was functioning normally up to the point of impact, and that the simulations devised by DSTO beforehand were valid, with very good agreement between the two data sets.

DSTO has similarly assisted with inquiries relating to HMAS AE2, HMAS Sydney and the crash of RAAF Canberra bomber 'Magpie 91'.

In-depth discussion of these projects is presented in Australian Defence Science articles in the respective issues Volume 15 Number 2, Volume 17 Number 1, and Volume 17 Number 2, available on DSTO's public website at: <http://www.dsto.defence.gov.au/publications/3182/> 

Nature's success stories inspire bio-fouling countermeasures

To find ways of dealing with bio-fouling, researchers are investigating microstructures and materials produced by organisms, such as the features that enable some marine organisms to remain free of this scourge.

Bio-fouling is one of the biggest, most pervasive and most intractable problems faced by Navy. While it particularly affects vessels operating in tropical waters, it also presents a significant problem elsewhere.

Even small amounts of bio-fouling, such as the slime resulting from bacterial growth, can cause substantial increases in drag, thereby reducing the speeds and fuel efficiencies attainable.

In addition, the transport of pest marine organisms on hull structures or in ballast waters is regarded as a major environmental issue worldwide, having already caused many cases of large-scale infestations with devastating effects on local marine life.

Previous solutions have involved the use of marine coatings on hulls that kept bio-fouling growth at bay by poisoning it. With some of these toxic measures now banned by the International Maritime Organisation due to the harm they themselves do environmentally, researchers around the world have been seeking environmentally friendly alternatives.

Shellfish non-stick nano-size solutions

One possible solution being investigated by DSTO in association with James Cook University is to be found in the surface texture of certain marine shellfish.

"Specimens living on the Great Barrier Reef have come to the attention of researchers because they manage to remain free of fouling despite their constant immersion in warm tropical water," says DSTO researcher Dr Andrew Scardino.

"This ability is attributable to patterns of tiny grooves on the shell surfaces that prevent the adhesion of fouling larvae. By copying these intricate designs, we've been able to create fouling resistant surface materials for human-constructed marine structures."

The most advanced anti-fouling surface materials developed to date are silicone-based. Rather than deterring fouling growth, their design causes growth to be readily shed when water streams over the surface, as happens when a vessel gets under way.

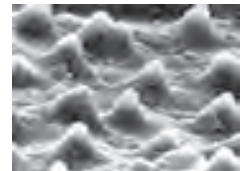
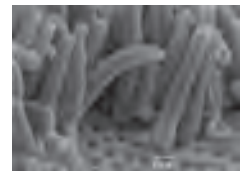
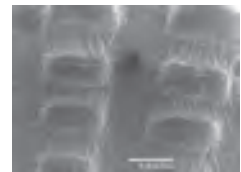
Additional research in this area is being undertaken by DSTO and the University of Melbourne to investigate the strength with which bacterial and slime fouling attach to a surface during the initial stages of the fouling process. The work aims to quantify the adhesion strength of the most problematic species so that low-speed self-cleaning silicon coatings can be developed.

Extraordinary unwettable reptile skins

Another phenomenon being investigated by DSTO in association with the University of Melbourne is the ability of surfaces with certain types of nano-scale textures to either strongly repel or attract water.

The quality of extreme water repellence, known as 'super-hydrophobia', is seen to occur in nature with some kinds of reptile skins, like those of geckos.

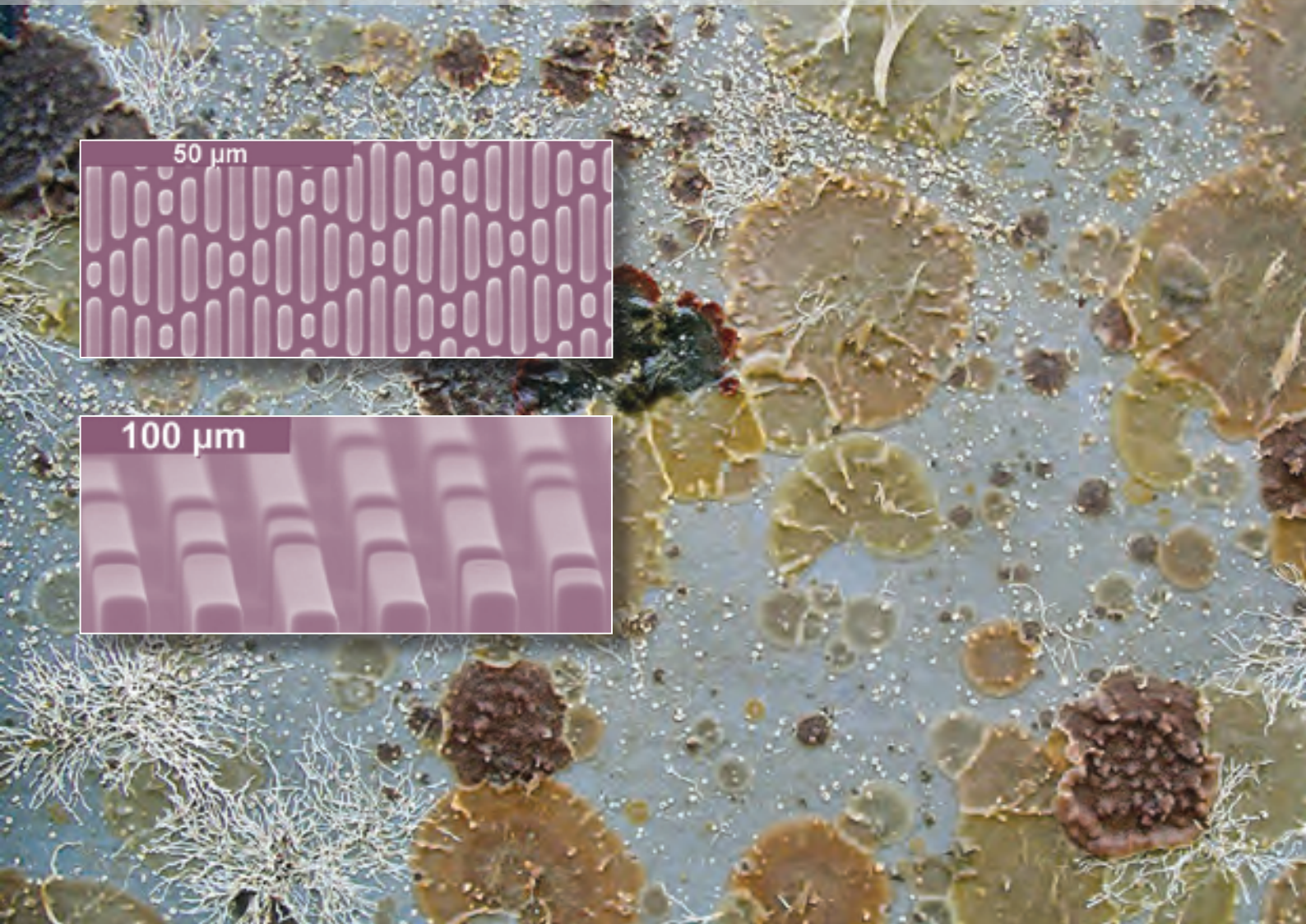
Human-made super-hydrophobic materials with designs taken from nature are already used extensively in the textile and building industries. Such materials used underwater have the ability to hold an air layer at the surface of the coating, preventing fouling adhesion.



Given this property, Dr Scardino sees great potential for them to complement antifouling technologies.

"We're undertaking to develop self-cleaning, super-hydrophobic coatings for a variety of applications. So far, we've had some success in the lab with coatings that deter a range of fouling larvae. Our aim now is to maintain fouling deterrence for extended periods in the field, and to achieve this, further developmental work will be required to retain the air layer for longer periods of immersion," he says.

Another form of natural fouling control being studied is that of anti-settlement compounds found on the surface of marine mussel shells, which prevent the growth of certain fouling organisms.



An exciting future for anti-fouling work

Dr Scardino envisages an extraordinary future for the work in which the many challenges posed by the marine environment will be met by the development of 'smart' forms of protective material.

With changes in temperature, light, turbidity, salinity and oxygen influencing the kind of organisms that settle on a surface, it may be possible to devise smart materials that feature multiple forms of defence, each providing protection under certain conditions, and which are also capable of adapting to changed conditions.

One strategy that may be applied for future smart skins includes micro-textured topography modelled from sharkskin that not only reduces settlement of certain organisms but also improves hydrodynamic efficiency.

An anti-fouling measure considered as possibly attainable in the much longer-term is the development of 'living paint' coatings of marine bacteria found naturally on marine organisms that repel all forms of fouling. **D**

Opposite page: Electron microscope images of marine organism microstructure surfaces (Source: Scardino, 2009).

Above, mauve images: Silicone materials with micro-textured surfaces (Source: Schumacher et al, 2007).

Background image: Bio-fouling growth on ship's hull.



HiVe buzzes with potential to assist capability acquisition

A software tool produced by DSTO makes the process of requirements development, design modelling and systems assurance for a new capability much more rigorous and efficient.



Experience has shown all too often that Defence acquisition of new capabilities can entail cost and schedule overruns if system requirements are not clearly defined. The acquisition of complex software-intensive computer-based systems is known to be a particularly high-risk activity in this regard.

“Many of these are what are called critical systems, where certain requirements must be met to attain safety, mission or security certification,” says DSTO researcher Dr Tony Cant. “In a safety-critical system, for example, it’s necessary to provide assurance that hazardous system states – those that could lead to death or accident – cannot occur.”

Key parts of the systems engineering process thus involve designing requirements for the system, ensuring that these are complete as well as consistent with each other over the life of the capability, and establishing that the capability can deliver the requirements listed, while also tracking all of this information and communicating it to the relevant stakeholders in documented form at appropriate times.

The process of overseeing all these intricacies for human operators is often so complex – with thousands of system requirements commonly included – that the task becomes highly daunting and error-prone. Because of this, automated aides have been developed to assist.

While there are many proof and modelling tools commercially available to support system analysis and assurance, and similarly many document editing systems for producing system documentation, the two products cannot be easily brought together. Also, some theorem proving tools can be extremely painstaking to use, which deters many users.

A scientifically rigorous systems engineering tool

DSTO’s Hierarchical Verification Environment (HiVe), produced with assistance from the Defence Materiel Organisation, is a new approach to the development, evaluation and certification of complex critical systems that addresses these deficiencies.

HiVe consists of three linked modules, labelled the Writer, Prover and Modeller.

The Writer, the most developed of these modules to date, is a tool for creating suites of technical documentation. It supports a range of documentation styles, from natural language descriptions through to fully formal mathematical models. The ability to interact with the Writer in such a way is a considerable advance in ease of use over other tools that allow only constrained interactions with raw modelling data.

One such style, the free-text mode, involves the use of plain English that gives the author maximum expressive freedom. Another style, the structured-text mode, involves the use of technical notation that enables the construction of a centrally managed database of system modelling data. The two modes can be mixed freely in a single document.

“When entering technical information, the way the Writer modelling database operates ensures this has to be correctly entered or else the tool will not accept it,” explains Dr Cant.

“Furthermore, the Writer manages references to this information throughout the documentation suite, which helps ensure consistency and greatly mitigates against the kind of problems that arise when changes to system requirements are not correctly propagated. This means in effect that greater productivity and lower costs can be attained.”

A key application the Writer can be used for in a typical defence project is that of enabling stakeholders to develop and track system requirements from capability development through to retirement.

Unifying analysis and documentation capabilities

The HiVe system as a whole provides a unified, plug-in based framework for analysis of entire design projects. In addition, documentation can be produced for design, explanatory and technical purposes at various levels of abstraction ranging from plain English to fully formal mathematical modelling to suit different audiences and purposes.

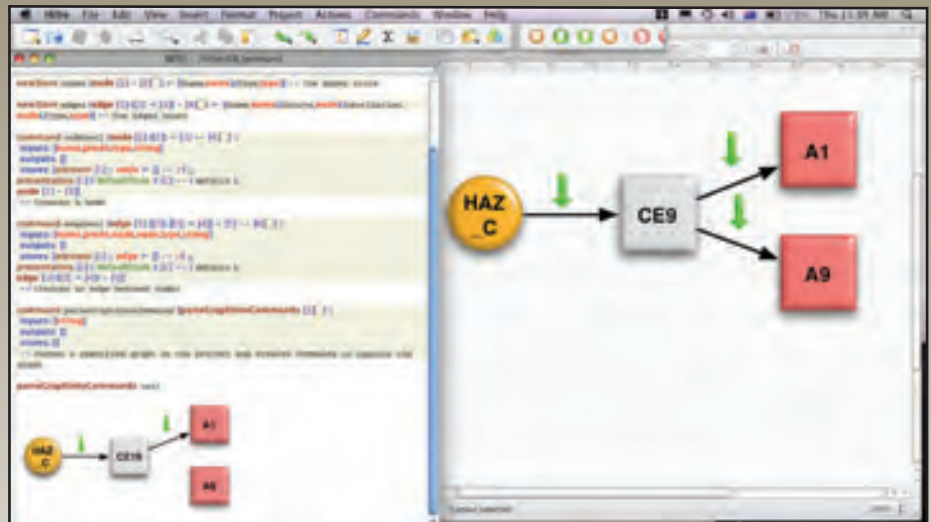
The two primary objectives of HiVe documentation production are to manage complexity by enforcing consistency through use of logic tools for data input and processing, and to provide stakeholders with proof of the correctness of the system design in terms of compliance to standards, through the same use of logic.

HiVe achieves these ends via the application of mathematical techniques called 'formal methods', whereby system requirements entered in structured text are also rendered automatically into mathematical statements consisting of terms and operators in a form known as 'propositional calculus'.

This approach then enables the application of logic operations to determine the internal consistency of a set of requirements for a system, possibly vast in size, and to verify that a design is capable of meeting all these requirements.

Through the exercise of logic, formal methods can provide assurance that critical requirements are met in situations where repeated testing is inadequate for doing so, as may be the case with computer software applications.

Their use also makes the process of preparing structured technical documents more reliable and error-free.



Advantageous upshots of HiVe

The advent of HiVe is seen to offer a number of improvements on existing practices.

"The construction of documentation is now straightforward, and summaries of desired information can be presented at all stages in complex reasoning and development," says Dr Cant.

"As soon as requirements are written, it is immediately possible to reason about their consistency, study their completeness, develop their consequences, break them down into component properties, construct implementations at various levels of abstraction, verify that the properties indeed satisfy the requirements, and verify the refinement relation between levels.

"Another beneficial feature is that any documents created within the Writer are constrained to be consistent with the central datastore, and therefore with each other.

"Overall, HiVe provides a means for establishing assurance in a complex system development or procurement process in a timely manner, and – often of greater importance – of transferring that trust to all stakeholders."

All this translates into time and cost savings for the organisation.

Dr Cant continues, "Also, by making formal methods analysis available in a light-weight user-friendly way, the arrival of HiVe may lead to greater use of such methods for ensuring safety-critical system compliance, thereby improving safety standards for ADF operations."

Developmental work on HiVe is continuing, with the software expected to be ready for release within a couple of years. **D**

Opposite and below: DSTO researchers working on HiVe software development.
Above: Screen capture of the HiVe software.



Quick way of probing murky churning waters

DSTO has evaluated an airborne electromagnetic bathymetric technology for use in mapping inshore waters.

The technique, known as time-domain airborne electromagnetics (AEM), is being investigated as an alternative means for rapid mapping in areas of turbid water and the surf zone where optics-based Light Detection and Ranging (LIDAR) sensing systems may be ineffective.

“The AEM approach can be used in waters with optical opacity and bubbles because its operation depends on the bulk electrical conductivity of seawater, which is unaffected by these conditions,” explains DSTO researcher Dr Julian Vrbancich.

A further advantage offered by AEM is that it can image the shape of geological structures under the seabed, such as sediment layers over bedrock.

The AEM method uses a transmitter loop to create a primary magnetic field that induces a time-varying current in the ground. These currents in turn induce a secondary magnetic field, which is then detected by the airborne AEM system.



AEM view of Broken Bay

The helicopter-mounted AEM system (SeaTEM) being evaluated features an aerial apparatus consisting of a single-turn outer transmitter loop concentric with an inner receiver loop.

This was towed as a slung load about 30 metres below the helicopter, with typical survey altitudes being around 25 to 35 metres above sea level.

The shallow coastal waters of Broken Bay, north of Sydney, were chosen as an environment suitable for evaluating the technology because of the unique geology of the area.

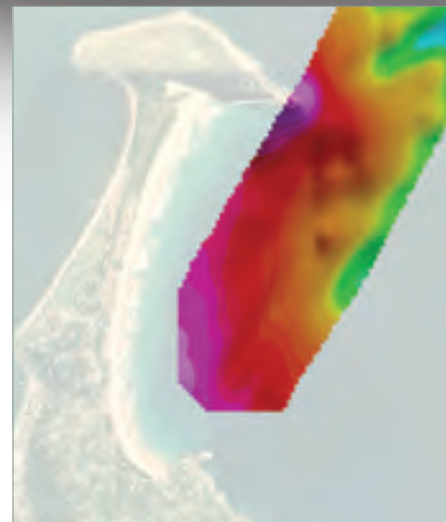
At the bottom of Broken Bay are several paleovalleys – valleys in-filled with unconsolidated sediments – formed by Brisbane Water, Pittwater and the Hawkesbury River that drain into it. Sediment depths in these paleovalleys range from zero to 150 metres.

The survey area also included a tombolo – a strip of sand or shingle between two landforms – with Palm Beach and Barrenjoey Beach either side that provided the opportunity to test capabilities for measuring water depth through a surf zone.

Getting a measure of AEM’s measures

To make an appraisal of the AEM system’s performance, data collected during the survey was compared with known bathymetry and estimated depths to bedrock of the same area obtained from marine seismic reflection studies.

The AEM data showed good agreement with the seismic measures in water depths shallower than about 25 to 30 metres. One of the geological features detected by SeaTEM was a moderately narrow paleovalley extending to depths of 90 metres below sea level and passes underneath Palm Beach.



“These results indicate that the AEM technique can be applied to bathymetric mapping. It additionally has potential for surveying sediment thickness and bedrock topography, and characterising seafloor electromagnetic resistivity in shallow coastal waters,” says Dr Vrbancich.

One proviso for effective use noted by the DSTO researchers is the need to carefully calibrate AEM instrumentation to accurately determine water depths.

This enabling research is eventually expected to lead to delivery of a mapping capability that will valuably assist Navy littoral operations, particularly those undertaken in the muddy waters of northern Australia. **D**

Left: AEM surveying apparatus in use during DSTO’s recent trials.

Top: Photo of the Broken Bay survey area showing the poor visibility conditions (prohibitive for optically-based survey methods) in which AEM data for the bathymetric map, above, was obtained.

Briefs

Biometrics trial to assist workplace implementation

DSTO recently carried out the second in a series of trials aimed at assessing the technical and human factors aspects associated with facial recognition performance.

The purpose of this trial was to study the ability of human operators to determine whether an image presented on an identity card (ID) and the person presenting the card are the same individual.

The study involved 129 DSTO staff members acting as test subjects, each given an ID card, some of which were erroneous to varying degrees. The test subjects presented their ID cards to a group of 32 human operators that included trained members of four government departments and others who were untrained. The operators were required to determine the validity of the ID carried, indicating also the confidence of the decision made.

Initial findings indicate that overall performance was slightly better, but not significantly so, for the trained group. The researchers surmise that this may be attributed to the limited participant sample and high variability of reported training and experience. Further research to understand the impact of training and experience on facial recognition performance is currently underway.

The work was undertaken as part of a PhD study being conducted by the University of Adelaide's School of Psychology.

WISE approach to delivery of a common operating picture

A Saab Technologies Australia innovation that facilitates connectivity between information systems is being investigated for Defence use in the course of a Capability and Technology Demonstrator (CTD) Program project.

The software tool, called the Widely Integrated Systems Environment (WISE) is able to provide an enhanced common operating picture for operators of command, control, communications, computers, and intelligence systems.

The range of systems that could be connected through such means includes the Australian Defence Force's Battlefield Command Support System, the ground-based air defence Tactical Command and Control System, NATO tactical data links and the ANZAC naval combat management systems.

By merging operating pictures from a range of maritime, land and aerospace systems, WISE enables the creation of a joint picture, and does so without need to re-engineer the software of existing systems.

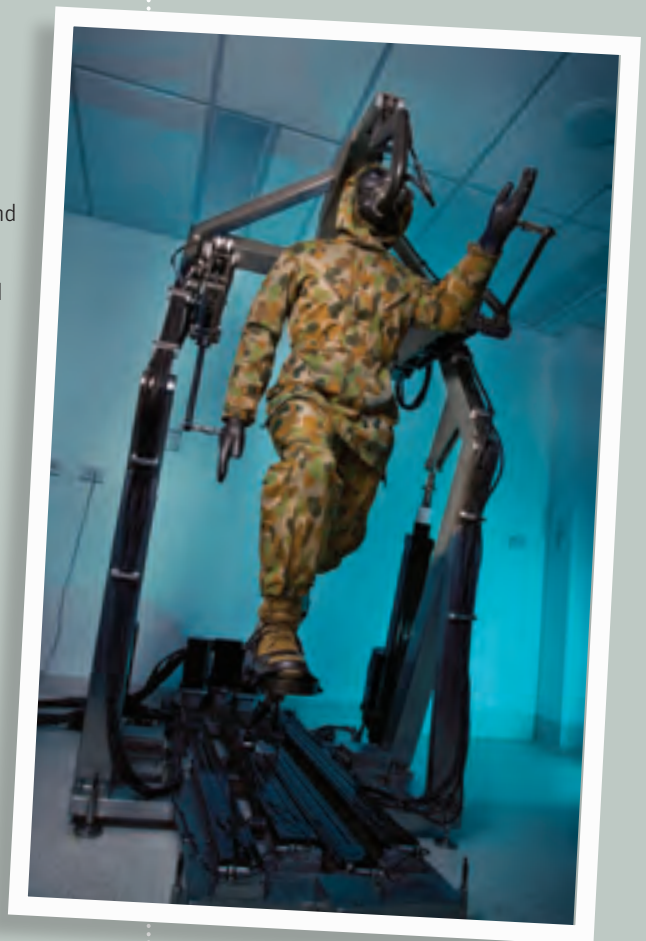
The CTD project is expected to run until early 2011.

New facility for testing of personnel protective equipment

A purpose-built chamber for testing protective uniforms and equipment worn by Defence personnel was recently installed at DSTO Melbourne.

This sixteen-tonne stainless steel facility will allow research to be carried out on individual protective equipment (IPE) ensembles and other such items under a wide range of environmental conditions, including those of chemical and biological warfare.

The work is undertaken using fully mobile mannequins that are capable of simulating a range of movement types – walking, jogging, running, squatting, lifting, carrying, sitting, and reaching – typically involved in the conduct of missions.



Part of DSTO's apparatus for fully mobile testing of protective clothing and equipment.

By exposing IPE to hazards in this way, assessments can then be made of how effective the various garment materials and closure devices used are at providing protection.

The facility is expected to be fully operational later this year.

Calendar

17 Aug 2010

Eureka Prize awards function

The annual gala awards dinner at which Eureka Prizes for Science are presented, including the DSTO sponsored prize for Outstanding Science in Support of Defence or national security.

Royal Randwick Racecourse, Sydney

<http://eureka.australianmuseum.net.au/>

23 - 27 Aug 2010 The 20th International Congress on Acoustics

An opportunity for acousticians around the world to meet and discuss recent advances in their fields of interest.

Sydney Convention and Exhibition Centre, Darling Harbour, Sydney

<http://www.ica2010sydney.org/Home.htm>

11 - 12 Oct 2010

Defence Human Sciences Symposium

The principal Australian forum for those interested in the application of human sciences research to enhance defence capability.

DSTO Edinburgh, South Australia

<http://www.dsto.defence.gov.au/dhss2010/>

13 - 15 Oct 2010

Defence Operations Research Symposium 2010

An annual event staged by DSTO to examine the practice of military operations research and analysis.

DSTO Edinburgh, South Australia

<http://www.dsto.defence.gov.au/dors10/>

8 - 13 Nov 2010

Multi Autonomous Ground-robotic International Challenge (MAGIC 2010)

Staging of grand challenge event. Jointly sponsored by Australian and US Defence to attract innovative proposals for development of next-generation fully autonomous ground vehicle systems for military and civilian emergency situations.

South Australia, Australia

<http://www.dsto.defence.gov.au/MAGIC2010/>

15 - 19 Nov 2010

Land Warfare Conference 2010

A major event for users, providers, academics, designers and manufacturers to share new and visionary ideas on Land Systems.

Brisbane Convention and Exhibition Centre, Brisbane

<http://www.dsto.defence.gov.au/lwc2010/>