

# DEFENCE SCIENCE

VOLUME 2 ISSUE 3 SEPTEMBER 2011 | ISSN 1837-8404 and ISSN 1838-0093 (Online)

A U S T R A L I A

Supersonic metal repairs

Oxygen sourced from thin air



Radar imaging advances  
for rotational object detail



**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 2500 staff, including some 1300 researchers and engineers. It is one of the two largest research and development organisations in Australia.

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ISSN 1837-8404  
ISSN 1838-0093 (Online)

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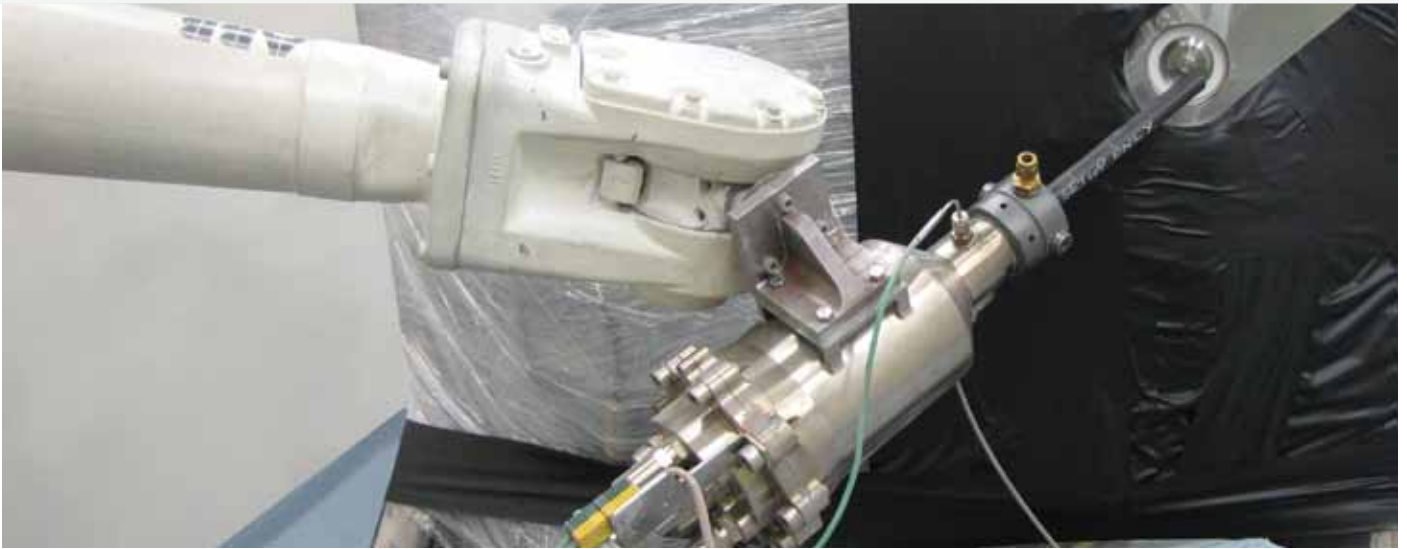
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*Cover image: DSTO researcher investigating radar imaging of rotational objects.*



# Superfast metal corrosion fixit

A portable technology for corrosion treatment and prevention has recently emerged from a DSTO Capability and Technology Demonstrator (CTD) project.

The Australian company behind the work, Rosebank Engineering (RBE) has developed the technology in collaboration with DSTO, and both are now recognised as world leaders in the field.

This technology, known as supersonic particle deposition (SPD), can be used to apply corrosion-protective coatings to metallic substrates and to rebuild the surface of components damaged by corrosion.

“The SPD process involves the use of a heated high-pressure inert gas such as helium or nitrogen to propel 10 to 100 micrometre-diameter metal particles from a de Laval profile nozzle,” explains DSTO researcher Dr Tony Trueman.

“Particle speeds of 700 to 1,200 metres per second are attained, causing the metal particles to bond upon impact with the target metal surface and form a coating or free-standing structure.”

Although the gas needs to be heated to several hundred degrees Celsius to produce such projectile speeds, the metal particles are not melted or oxidised, and heating of the target metal substrate is minimal.

## Cost-effective renewal of metal components

The bonded surface so formed is tough and durable with no detrimental physical or mechanical effects to the metal structure. At the same time, the cost of applying the process is very low, with most of the expense involved in such repairs being that of setting up the component for treatment.

Defence organisations that have taken a keen interest in SPD’s capabilities include the Directorate General Technical Airworthiness - Australian Defence Force (DGTA-ADF) as well as the Navy Aviation Systems Program Office (NASPO), the Tactical Fighter Systems Program Office (TFSP) and Strike Reconnaissance Systems Program Office (SRSP).

NASPO has shown strong interest and support for the application of this technology in the first instance to remedying corrosion on helicopter magnesium gearboxes. A number of applications on selected Seahawk components have been undertaken, with some of these currently in service. This initiative has already delivered demonstrable savings.

Rosebank Engineering, DSTO, NASPO and DGTA are currently part of a Technology Transition Working Group collaborating on an engineering approval process that aims to offer the SPD technology as a standard repair tool not only for corrosion protection and geometry restoration but ultimately also for structural restoration.

In addition, Rosebank Engineering has completed studies for the application of SPD to the Joint Strike Fighter under a contract.

At present, all applications of SPD for ADF purposes have to be carried out using the company’s large SPD facility in Melbourne. This involves the time-consuming and costly process of disassembly and transport of components to the facility.

## Towards a smaller field portable version

The CTD project mounted by Rosebank Engineering was therefore aimed at developing a much smaller and more compact version that can provide an SPD capability at Australian Defence Force air bases, on ships and with Army in the field.

A Field Deployable SPD prototype was accordingly developed by the company and recently went on trial at HMAS *Albatross*, Nowra. The prototype has now been delivered to DSTO, marking the completion of this CTD project.

DSTO’s contribution to the research and development effort was to provide important understandings about particle physics, interacting shockwave behaviour, coating performance, surface physics and chemistry.

The SPD technology in this portable form has captured NASPO’s attention as a readily applicable means for recovering corroded structures on the Seahawk. [Q](#)



Top: Supersonic particle deposition apparatus ready to apply metal coating.  
Above: Surface of a machine component after treatment.

# Clearer radar images of rotating objects



Rotating objects such as propeller and rotor blades of aircraft can be identified using a technique called Doppler radar tomography, and DSTO research has arrived at better ways to discern their presence.

Radar systems operate by sending out a series of electromagnetic pulses that echo off suitably reflective surfaces. The distance and bearing of the object can be determined according to the time taken for echo return and the position it emanates from.

The return signal also offers valuable information about the object through frequency shift. This shift may be caused by the particular radio wave absorption properties of the reflective object and the relative speed of the object to the radar transmitter in a phenomenon known as the Doppler effect. With the

Doppler effect, objects traveling towards the transmitting radar will lead to rising frequencies, and those traveling away, falling frequencies.

This information can be harnessed through Doppler radar tomographic imaging techniques to reveal the characteristics of rotating objects, such as helicopter rotor blades. Properties in terms of length, number of blades, rotation rate and rotor hub features can be discerned. This enables a particular kind of aircraft to be identified using automatic target recognition tools.

## Discerning fine detail

The ability to accurately estimate these features affects the ability to correctly classify targets quickly and is directly related to the frequency resolution of the system.

“The resolution of a tomographic image depends on, among other factors, the resolution of the input projections,” explains DSTO researcher Dr Hai-Tan Tran.

“To achieve resolution of fine detail in a narrow-band radar picture, we need to be able to process return signals from

*Top: DSTO field trials being conducted to study Doppler radar tomography imaging capabilities.*

longer dwell times on the target so that closely spaced sources of signal returns can be resolved, and hence, appear in the tomographic image.”

The problem here is that the rotation motion of the target causes non-uniform Doppler frequency shifts in the return signals, giving rise to an outcome akin to motion blur when taking a photo under conditions of camera shake with a slow shutter speed.

Each scattering centre on the target, and there could be many such scattering centres, imparts its own frequency spread, or ‘chirp’, in the return signals, resulting ultimately in smeared images.

### Solution to ‘chirp’ problem

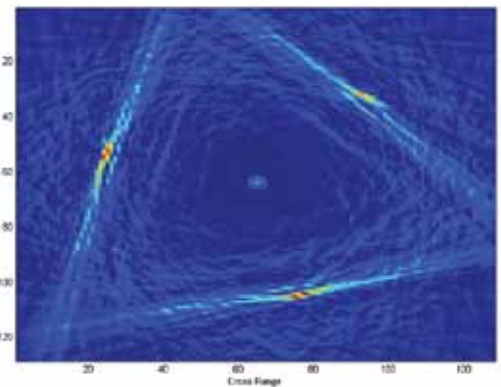
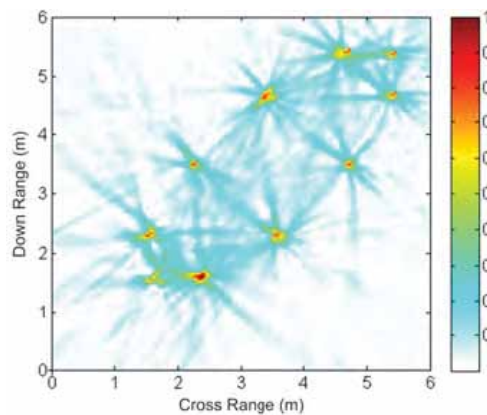
To overcome this problem, the DSTO researchers used a recently developed mathematical tool called the fractional Fourier transform (FrFT). This tool, in conjunction with another technique called the S-Method, can be used to identify, extract and compress separate chirps in a signal.

“The FrFT can turn the spread-out spectrum of a chirp signal into a well-compressed spike in the ‘fractional frequency’ domain,” says Dr Tran.

“In effect, the FrFT is as efficient to a chirp signal as the traditional Fourier transform is to a pure tone signal.”

“By combining this with use of the S-Method, we arrived at an algorithm for extracting and spectrally compressing multiple chirp signals. The outcome is high resolution projections, without the frequency spread, and correspondingly, a clear and sharp tomographic image.”

DSTO’s research undertook to apply the fractional Fourier transform and the S-Method techniques on simulated rotating point sources of signal returns as well as real helicopter data. The work demonstrated improved resolution in mathematical projections, which translated into clearer tomographic images.



In effect, this meant that the positions of highly reflective parts of targets could be more easily identified, thereby making features such as the blade tips and other reflective parts of the hub of helicopter rotors more readily discernible in the radar imagery.

These advances are expected to improve the performance of automatic target recognition systems. The range of rotational objects such radar systems could be used to detect include not only the main rotor blades and hubs of helicopters but also their tail rotor blades, propellers on aircraft and slower rotating objects such as rotating antenna structures on ships.

### Other applications

Another application of the work is for detection of airborne accelerating objects against a surface clutter background – surface clutter being radar signal ‘noise’ caused by reflections off seawater and moisture in air. A report on the work, titled *Application of the Fractional Fourier Transform in the Detection of Accelerating Targets in Clutter* was issued by DSTO in April this year.

This technology again involves the use of the fractional Fourier transform. Similar to a target with rotating components, an accelerating target also induces chirps in the return signals, and hence, the

FrFT used in Doppler tomography can be used for detecting such a target.

“Fortunately, the surface – land or sea – clutter component doesn’t get compressed by the FrFT, but rather, actually spreads out with application of the FrFT, which benefits the process of target detection in an extra way,” explains Rocco Melino, another member of the DSTO research team led by Dr Tran.

Meanwhile, a further application being investigated by DSTO is for imaging of rotating objects in water using sonar. The same mathematical principles used for radar tomography can be applied to sound waves in water.

Provided there is sufficient relative rotational motion between the object and a sonar transducer, and the object is within a certain range, it can be imaged with sound signals regardless of how murky the water might be.

Publications on this maritime-based application are expected to appear in the near future. [Q](#)

Above left: Theoretical study outcomes of Doppler radar tomography imaging of an elliptical array of rotating objects.  
Above right: Actual Doppler radar tomography imaging of the main rotor of a three-bladed helicopter, with red and yellow colours indicating the position of blade tips and the central white dot the (heavily attenuated) rotor hub.

# A step closer to optical fibre sensor applications

Getting next-generation optical fibre sensors out on the job for structural health monitoring (SHM) of high-value assets has been problematic for various reasons. Work done by DSTO is helping overcome these difficulties.

Optical fibre sensing systems have long held great promise in terms of the advantages they offer compared to electronic forms.

These include freedom from interference by electromagnetic fields, greater tolerance to high strains and temperatures and the ability to support many spatially separated sensors along a single fibre.

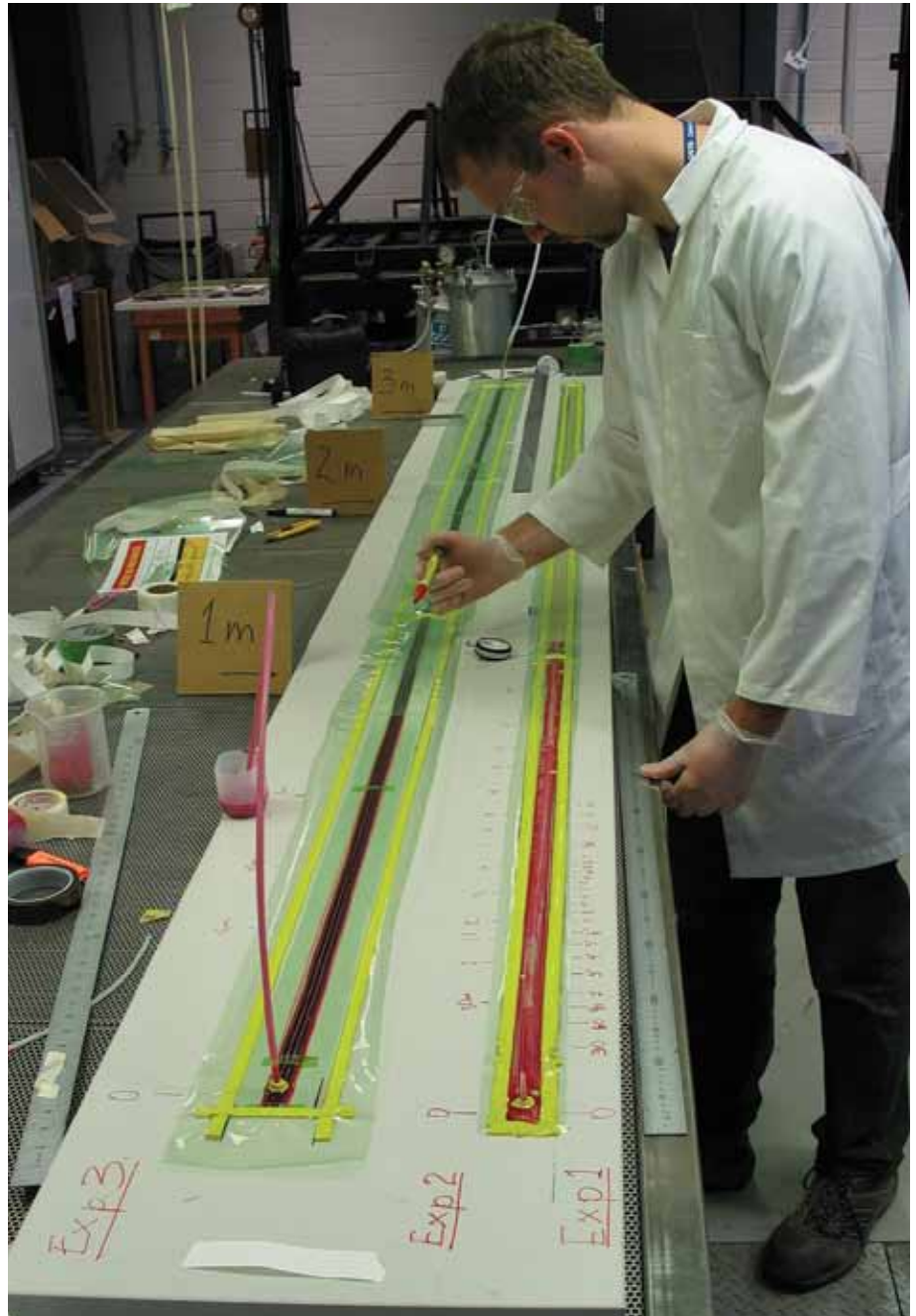
However, various problems hinder their implementation, one aspect being a lack of suitable methods to package and mount the delicate fibres with sensors when retrofitted to large and complex structures. Although the fibres are delicate, for ease of handling, they are best encapsulated when attached to the surface of such structures.

To improve on this situation of retrofitting delicate fibres to larger structures, DSTO is participating in a three-year research program (sponsored by the United States Office of Naval Research) that aims to achieve robust, reliable and repeatable optical fibre strain measurement.

## Readily available materials to the rescue

DSTO's work took the form of a series of small-scale laboratory experiments to identify materials and processes to facilitate system retrofitting applications.

"The sensors used in the studies were created by stripping the protective outer coating from a three-millimetre section of fibre and fabricating the sensor device, known as a Fibre Bragg Grating, onto the



exposed glass using a laser,” explains DSTO researcher Dr Claire Davis.

“Any stresses experienced by the structure are transferred to the optical fibre and registered by the sensor as a change in the reflected light wavelength.”

The technique initially used for attaching sensors *in situ* involved taping the sensor to the structure with a commercially available adhesive tape.

While this approach provided good sensor performance for strain detection, the incidence of a condition known as creep – the permanent deformation of a material after force is applied – introduced errors of up to 15% in strain readings.

To overcome this problem, the researchers investigated a variety of different techniques including bonding the fibre to the structure with epoxy resin infused under the tape.

### Vacuum assist process

A new issue to consider was how to get the epoxy resin – an adhesive that involves mixing two components to activate a hardening reaction – into this confined space before it sets. Although the force of capillary action helped draw it in, the rising viscosity of the resin meant that there was a likelihood of it setting before complete coverage was attained.

To ensure thorough resin penetration, the researchers eventually brought to bear a technique called Vacuum Assisted Resin Transfer Moulding (VARTM).

In this approach, the optical fibres are firstly stuck to the structure with an open-weave glass-fibre tape, which allows resin to easily penetrate around the optical fibres. Overlaying the glass fibre tape is a polyester fabric, porous to the resin, which is put in place to enable the outer coatings of resin to be easily peeled off once curing is complete. Above this is an open weave plastic shade cloth to ensure an even spread of resin. The outmost layer comprises a vacuum bag that covers the whole application in an airtight manner. This allows for the creation of a partial vacuum force at one of the open ends in order to draw resin through from the other.

A range of commercially available resins was investigated, with the appropriate one chosen on the basis of availability, cost and performance. The resin selected was a low viscosity thermoset type,

which provided properties of optimum viscosity during application along with high strength and low creep after setting.

### Strain gauges under stress

With a suitable attachment system worked out, the researchers undertook to investigate the effects of resin encapsulation on sensor performance. The results in all cases showed that shrinkage of the resin during curing caused the sensor’s length to be slightly compressed, but that this compression did not affect the sensor performance. Meanwhile, very little shrinkage was found to occur in the post-cure state.

Testing was then undertaken on a series of test specimens to compare the performance of the fibre optic strain gauges and VARTM packaging to standard electronic strain gauges.

The outcomes were that the optical fibre strain gauge performed as well as, and in some cases, better than the electronic kind on a range of criteria, including linearity of sensor output, hysteresis, sensitivity and creep.

Building on these successes, the VARTM optical fibre bonding technique was successfully extended from lengths of 200 millimetres up to 3.3 metres through a range of modifications to the process. In the words of DSTO investigator Dr Ivan Grabovac, “Those modifications allow application of fibre optic sensors for large-scale structural health monitoring.”

### Packaging and handling methods

The researchers also investigated ways of packaging the fibre optic sensor lines to protect them from damage both before and during installation.

Applying the self-adhesive open-weave glass-fibre tape to the optical fibres and sensors at a component assembly stage was found to be beneficial in ensuring the optical fibres were protected when rolling the fibres onto a cylinder ready for transport. It also ensured they remained correctly aligned when being applied to a structure – vital for effecting uniform application when multiple sensor lines are being applied for wide area sensor coverage.

The applicability of this approach was tested by rolling the materials onto the cylinder from a laboratory bench and then unrolling them

onto the bench to establish whether straight lines would be maintained. The optical fibre was also tested to ensure that it was still intact and functioning as a conduit for light after being handled in such ways, with no failures found.

One issue identified by the researchers was that the optical fibres sometimes broke at points where the coating had been stripped to make sensors, and where the fibre had been joined to the optical connector cables. A proposed way to overcome these weak points is to fabricate the sensor gratings onto the fibre during fibre fabrication before the coating is applied. This would mean that the fibre being attached to a structure will have coating protection along its entire length. The coated fibre with the sensors can then have connectors applied directly to the end of the fibre to avoid the need for joins to other cables.



Further research is underway to look at special optical connectors that can be incorporated into the fibre packaging, and to transition the work from the concept demonstrator stage to large-scale structural health monitoring applications. [1](#)

*Opposite top: Optical fibre sensor mounting experiment to study vacuum-assisted adhesive penetration rates. Opposite bottom: Close-up of mounting material layers, from bottom: open-weave glass fibre tape, polyester fabric, open-weave plastic shade cloth material and clear plastic sheeting for airtight seal. Above: An optical fibre sensor strain gauge being mounted on a rudder fin.*

# Smaller health monitor fit for confined spaces

DSTO has already made major advances with the development of structural health monitoring devices embedded in aircraft. Recent successes with miniaturisation have further improved the usefulness of the technology.



Various *in situ* health monitoring systems have been designed and prototyped by DSTO for potential Defence use on high-value platforms including ships and aircraft.

One such is the Compact Multi Parameter Load Evaluation (CMPL) unit, which has been flight-tested on a RAAF DHC-4 Caribou aircraft. The system consists of sensors fixed to vital aircraft structures for collection of various kinds of flight data, which are then downloaded by a detachable unit mounted on the aircraft between flights.

These trials demonstrated that the inexpensive rapid mount-dismount CMPL system can valuably assist Defence airworthiness authorities with structural integrity assessments of RAAF's ageing fleet. CMPL does so by continuously monitoring airframe loads and accelerations during flight, detecting damage and damage growth and other structural problems, and providing a basis for near real-time damage assessment.

The technology could also potentially permit a safe reduction in inspection and regular maintenance costs, and therefore lower aircraft through-life support costs.

A proposed enhancement to CMPL investigated by DSTO is the use of a technology called Acoustic Electric Feedthrough (AEF) to provide power and two-way communications to CMPL sensor units mounted in places with restricted physical access.

## Direct access to hard-to-reach spots

The AEF system concept consists of two devices, one mounted inside the metal skin of an aircraft, the other used externally for transmission of power and communications with the internal unit. Both units feature piezo-ceramic disks and electronic circuitry.

When a transfer of power and communications is required, the external unit is placed directly adjacent to the internal unit.

DSTO researcher Dr Scott Moss explains, "An electric current flows to the external unit's piezo-ceramic disk, which undergoes rapid cyclical deformations, producing ultrasound waves that travel through the metal skin.

"The physical energy transmitted then deforms the piezo-ceramic disk of the internal unit, converting it back to electrical energy. This transmission delivers not only power for storage in a Li-ion battery but also digital instructions encoded in the waveform.

"Correspondingly, communications the other way – from internal to external unit – can be carried out on digital command."

The first type of AEF system investigated by DSTO involved piezo-ceramic disks 38 millimetres in diameter and 2 millimetres in thickness. While the system was found to perform well, the area of disk used was considered inconveniently large for mounting within an aircraft.

The researchers therefore turned to consider an AEF system design with piezo-ceramic disks just 10 millimetres in diameter, delivering a 93% reduction in surface area.

### Checks on performance

To investigate the performance of this smaller device, measurements were made of power transfer efficiency, battery charging capability, and upstream communication data rate, using a test apparatus with the transmitter and receiver piezo-ceramic disks bonded to either side of a 1.6-millimetre thick aluminium plate.

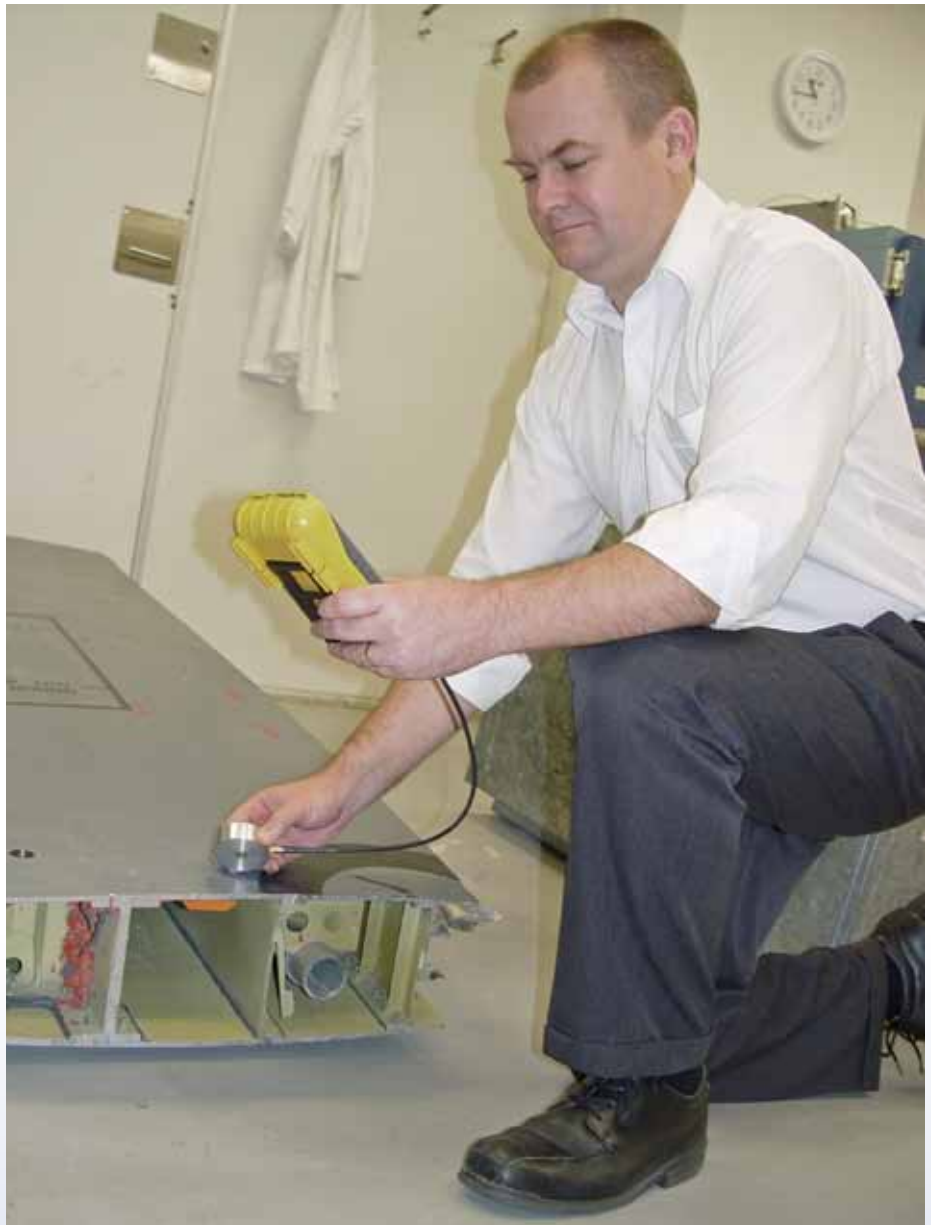
The findings were that this system had a power transfer efficiency of 42%, and with a 1 watt input, transfers of 420 milliwatts were attainable – capable of charging an 80 milliampere hour Li-ion battery. In addition, data transfer rates of 115 kBits per second were recorded.

“These power and data transfer capabilities are equivalent to those previously reported for the larger AEF device design,” reports Dr Moss.

Meanwhile, a peripheral issue arising from the use of the smaller AEF device, with the ratio of diameter to thickness falling below 10 to 1, is that existing computer models of the piezo-electric system were not sufficiently accurate to model the smaller version’s performance.

To address this problem, a computer model was developed by DSTO, and predicted outcomes produced by the model were then compared with measured real-world outcomes. These showed that the modelling was accurate enough for it to be useful for future AEF design and optimisation work.

More recently, refinements were made to the hardware design in the form of a mechanism that reduces to zero the



AEF footprint external to the aircraft, and ensures the two units line up correctly for power and communications transfers.

The piezo electric disks on each unit have rare-earth neodymium magnets bonded to them, and their powerful forces of attraction reach through the aluminium skin to draw the units together. The magnetic material used was found to work well with the piezo-ceramic disks, having acoustic impedance properties that match extremely closely.

Tests on performance of the detachable system showed power transfer efficiencies had reduced a little to 34% with

340 milliwatts transferred – still capable of charging the 80 milliampere Li-ion battery – with data transfer rates the same as before, thereby establishing this form of system as viable for use.

Research on what is now known as the Detachable Acoustic Electric Feedthrough (DAEF) technology is continuing in the areas of both hardware and software development. □

*Opposite: AEF devices mounted either side of an aluminium sheet for laboratory tests.*

*Above: Detachable AEF concept for providing wireless electrical power and data transfer to a sensing unit mounted inside an F-111 aircraft wing structure.*

# Keeping noise down below the waves

Plate structures making up the hulls of vessels vibrate under the influence of shipboard machinery, leading to water-borne noise that compromises stealth status. DSTO research shows great promise when it comes to delivering better countermeasures.



The problem for Navy is that mines and torpedos home in on a number of passively emitted vessel signatures, including the acoustic kind. Passive signatures are also used to detect and identify vessels more generally. Hull vibration emissions are thus a significant operational concern for all Navy vessels.

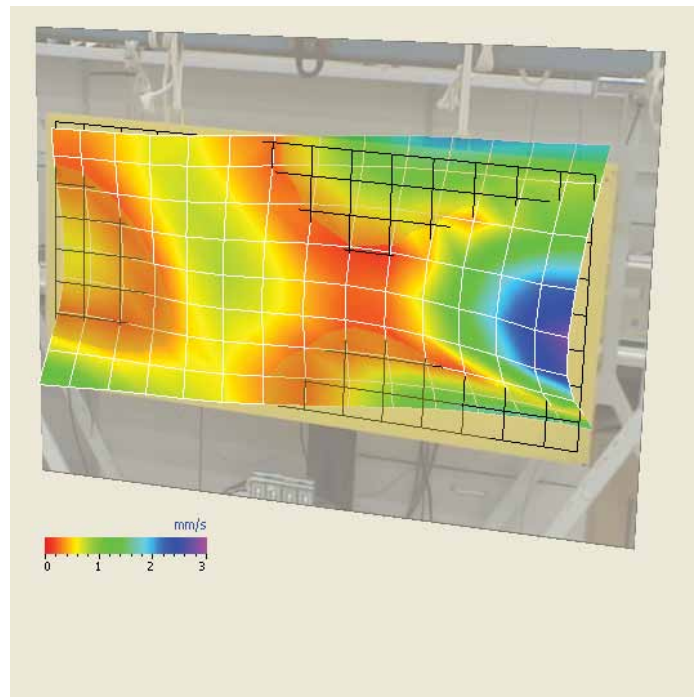
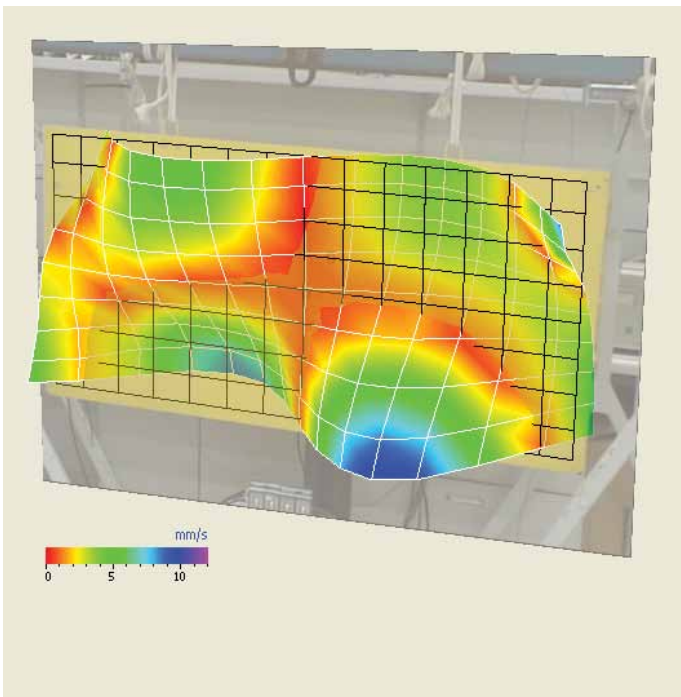
The technology being developed as a countermeasure uses electromagnetic actuators that vibrate the plate structures

to actively cancel out or dampen the machinery-induced vibrations.

One approach to this kind of countermeasure is known as 'feed forward' control. Here a reference signal measured near the vibration source is used by an electronic controller to calculate how much each of several actuators should be driven to cancel out the unwanted vibrations. A number of accelerometer 'error sensors' on the plate structure are used by the controller to adjust its output for best vibration minimisation.

Another approach is called 'feedback' control, in which a small amount of the vibration measured by an accelerometer sensor is fed back to drive an actuator placed at the same spot on the structure. This set-up provides a local damping force to reduce vibration levels.

Researchers James Forrest and Xia Pan, with expertise in active sound control developed over many years, have been investigating both kinds of approach. Much of their research to date has been carried out in the virtual digital realm with computer modelling tools.



### Preventing controller instability

An issue the researchers sought to come to grips with for current feed-forward system designs is that these could in fact exacerbate vibration problems, similar to the way that a microphone placed too close to a public address system speaker can result in runaway feedback.

“With a centralised controller operating numerous actuators based on data obtained from numerous sensors, the feed-forward controller adjustment process becomes quite complicated,” explains Forrest.

“The process can sometimes go unstable, resulting in the actuators adding to the total vibration levels instead of reducing them, thereby making things worse than without any active control.”

Building on work done overseas, the somewhat counterintuitive solution Forrest and Pan decided on was to decentralise system control, applying instead several independent pairs of sensor and actuator, each with their own feedback controller. These could eventually be built as compact self-contained units for practical application.

Computer modelling done by the DSTO researchers has shown that the operations of these independent units as a whole always remain stable.

### Random versus regular placement

Another major finding to come out of the work is that placement of control actuators at random points on a structure gives more effective control than placing them uniformly in a grid-like pattern.

“A plate at resonant frequency has nodal lines where there are no vibrations, so actuators placed on these lines won’t be effective,” says Forrest. “By randomising feedback locations, there will be at least one actuator working to counter vibrations at each resonant mode of the plate.”

In the scenarios explored by the researchers, involving many vibration modes and uncertain structural dynamics, their computer modelling work indicated that the feedback system provided a better solution to vibration control overall than the feed-forward approach.

### Real-world studies

Meanwhile, the researchers have also been undertaking real-world research on vibration damping technology, with the help of acoustician Vinh Trinh.

Here, Forrest and Pan seek to expand on overseas work that has established the viability of feedback control for vibration damping over a plate of small

surface area in air. Their intention is to make this workable at much larger scale in the laboratory, and then for testing to be undertaken on a section of ship or submarine hull.

The work currently involves studying the behaviour of such a system using a one-square metre sheet of steel plate suspended in air in a laboratory space. Once the system is shown to perform in a stable manner, investigations will be conducted in water, with the sheet of steel floated on the surface of a large water tank at DSTO Melbourne.

According to Forrest, “This approach looks to be very practical and achievable, since we require very little actuator force to dampen hull vibrations, and the control process we are using is very stable. It’s showing a lot of promise. We think we have the capability to build it.” [Q](#)

*Opposite: DSTO apparatus for real-world studies of vibration damping technology.*

*Above left: Laser measurements of a metal sheet deformed by vibrations with no damping forces applied.*

*Above right: Measurements of the same sheet with ‘feed forward’ damping measures applied.*

# Good neighbour approach to marine mammal welfare



## DSTO has undertaken studies on sonar signal propagation in the waters of Shoalwater Bay to ensure marine animals are not adversely affected during Navy exercises.

Shoalwater Bay, an important training ground for Navy, is also part of the Great Barrier Reef Marine Park. As such, it is home to large numbers of dolphins and endangered dugongs as well as humpback whales on a seasonal basis.

After a few cases of mass whale strandings coincident with naval exercises in the northern hemisphere, concerns were raised about the effects of active sonar on marine mammals. The use of mid-frequency tactical sonars during such exercises is considered a likely cause.

“While a direct causal link between sonar use and strandings has not been determined, evidence suggests that the strandings probably arose as a behavioural reaction to sonar use,” explains DSTO researcher Paul Clarke.

There is little information about the effects of other types of active sonars on marine mammals, but precautions are considered appropriate, since the ability of these animals to use sound for communication is crucial to their survival.

Dolphins in particular are very social, and rely greatly on sound to communicate, hunt prey and navigate. The sound communications of humpback whale are widely recognised as amongst the most complex of any animal species. Dugongs too use sound to communicate, and also to avoid predators.

“Human-caused sounds can thus potentially impinge on all these species by partially or completely masking sounds that are important to them,” Clarke says.

### Protection for marine mammals

The Australia Defence Force Maritime Activities Environmental Management Plan (MA EMP) covers, among other things, the avoidance and mitigation measures required for maritime exercises to protect marine mammals.

Designed to ensure that human-induced sound levels experienced by marine mammals do not exceed certain thresholds, the measures to be applied vary according to the particular kinds of sonar in use. These measures have been determined through reference to the best available scientific advice.

To ensure Navy conducts exercises in the Shoalwater Bay locality in an environmentally sustainable manner, the Royal Australian Navy Environment Manager asked DSTO to provide more accurate determinations of how distant a vessel should be from these types of marine mammals when using sonar systems.

Clarke and colleagues at DSTO undertook the task by modelling sonar signal propagation in the Shoalwater Bay area to study how distant the different kinds of sonar signals would travel at sound pressure levels considered harmful.

The results delivered were to be used to check and, if necessary, modify MA EMP mitigation procedures.

### Animal types and sonar signals

The types of sonar system included for this study were those fitted to a Leeuwin-class hydrographic ship – the CMAS Forward Looking Sonar, the Fansweep 20 Multibeam Echo Sounder, the Klein 2000 Towed Light Weight Side Scan Sonar, the EDO Model 3060 Doppler Velocity Log and the Atlas DESO 25 Single Beam Echo Sounder.

With dolphins and dugongs being the animals of primary concern, the research focused on sonar frequencies audible to them. These ranged from 1 to 8 kHz for dugongs and 1 to 150 kHz for dolphins.

Sonar operations at frequencies above 200 kHz were not considered since the effects on dolphins and dugongs were assumed inconsequential.



The lowest frequency emitted by the hydrographic ship – 12 kHz – is above what is thought to be the upper limit of dugong hearing, but to ensure conservative mitigation ranges were arrived at, the dugong auditory range was assumed to extend to this frequency.

Data used in the modelling were obtained from existing sources such as the Australian Geological Survey Organisation and the World Ocean Atlas.

### Conservative approach for animal conservation

Adopting a worst-case approach overall for the modelling to ensure ample safety margins, factors taken into consideration included topography, seabed composition, sea state and season.

With this approach, the presence of rough seafloor terrain and sea grasses were thus ignored since these have the effect of reducing sound levels propagated.

Meanwhile, sea states were factored in, since calm water – as predominately found in Shoalwater Bay – has the effect of enhancing sonar propagation. With shallower water, the variable of depth was also considered important.

Additionally, the influences of season were taken into account since temperature along with salinity and pressure affects the way sound propagates through water.

### Modelling outcomes

The results emerging included a variety of findings.

The effect of sea state was, as expected, that low sea states required the greatest stand-off distances.

As for depth of water, while increasing depth has the effect of dissipating sonar signal

strength, no consistent trend was seen due to large variations in beam patterns of the Leeuwin class hydrographic sonars.

For the influence of season, the modelling showed small to medium effect on the stand-off ranges required due to seasonal changes in sound speed profiles.

Pertinent to findings here was the fact that sound speed profiles can vary significantly on a daily basis, so monthly averages are not a reliable means of setting mitigation distances from one season to another.

### Recommendations

Overall, the modelling results indicated that very large differences in stand-off distances were required depending on which type of sonar was being used and which animals were present.

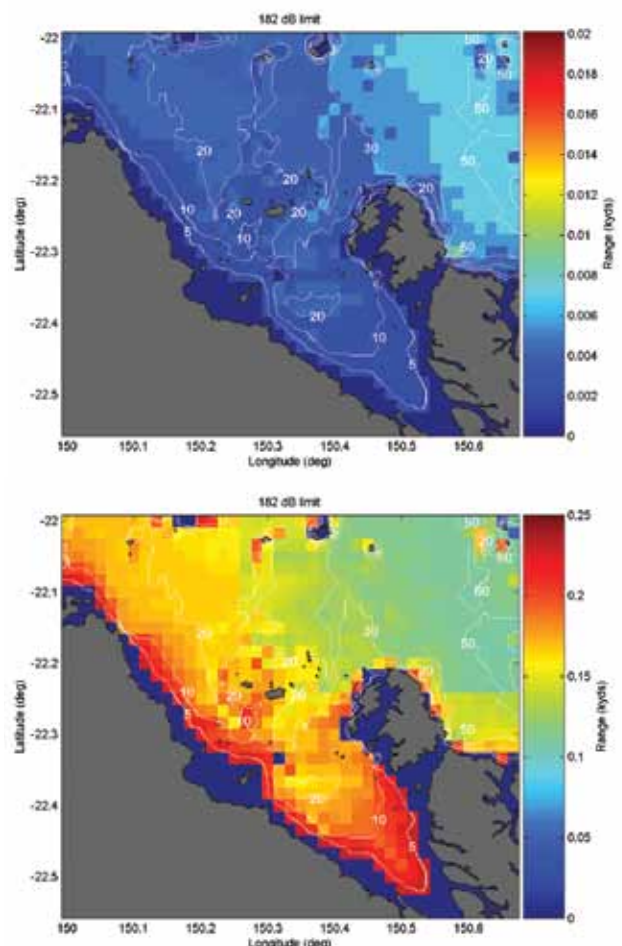
One manner of output took the form of maps of the Shoalwater Bay area that show through variation of colour the stand-off ranges required for every point in the bay that would limit received sound pressure levels to 160 dB re 1  $\mu$ Pa or 182 dB re 1  $\mu$ Pa. The two different sound pressure levels are the thresholds of noise disturbance and noise harassment respectively for marine mammals. Each map was generated for a particular type of sonar in a given season and sea state over an assumed seabed of medium sand.

Given the very large number of scenarios involved, a single worst-case stand-off distance was determined for use of each sonar in the presence of dolphins and dugongs separately. This was done to simplify the recommendations provided for mitigation strategies.

For encounters with dolphins, stand-off distances were set at 2,000 yards when operating the CMAS Forward Looking Sonar, 700 yards for the Fansweep 20 Multibeam Echo Sounder and Klein 2000 Towed Light Weight Side Scan Sonar, and 200 yards for the EDO Model 3060 Doppler Velocity Log and Atlas DESO 25 Single Beam Echo Sounder.

In the case of dugongs, a stand-off distance of 200 yards was set for use of the Atlas DESO 25 Single Beam Echo Sounder when operating at 12 kHz.

Navy exercises have since been carried out in Shoalwater Bay using these recommendations without any apparent harm being caused to its marine mammal inhabitants. Defence intends to use the results of this DSTO research to ensure that Shoalwater Bay remains an important refuge for dugongs and dolphins, species under significant pressure from human activities elsewhere on the Queensland coast. [1](#)



Above: A RAN Leeuwin class hydrographic ship; sonar emissions from this type of vessel were studied in DSTO's mitigation measures modelling.

Right: Two maps of Shoalwater Bay showing the vessel stand-off distances required for two different sonars under particular sets of environmental conditions to avoid causing marine mammal noise harassment.

# Oxygen on tap in the wilds

A Defence Capability and Technology Demonstrator (CTD) project has delivered a better way of supplying oxygen for medical uses in remote areas.

The shortfall being addressed by this project is oxygen supply, vital for provision of medical services along with various other capabilities, when Defence forces are on deployment far from industrial sources.

“The volatility of pure oxygen means that it is expensive and difficult to provide in remote areas,” says CTD Program Manager Jamie Treleaven.

“Supply of bottled oxygen, usually transported by sea and road, can take a considerable amount of time and entails a large impost logistically in terms of weight and bulk of cylinders.

“Meanwhile, the use of oxygen filters and concentrators, currently the only deployable option for generating oxygen supplies *in situ*, are also costly and require a large logistics footprint.”

## Solution drawn from thin air

In 2009, Tectonica Australia proposed a novel approach to oxygen generation for medical use by Defence and non-government organisations.

Partnering with CSIRO in the DSTO CTD Program, Tectonica developed a device called the ceramic membrane oxygen generator (CMOG) that takes ambient air and produces 99% pure oxygen.

“While the science of oxygen ions passing through a solid electrolyte membrane has been known for many years, and has been widely developed for oxygen sensor and fuel cell applications, it has only now been successfully applied to oxygen separation,” explains Treleaven.

The technology involves the use of solid electrolyte membranes made of materials such as yttria-doped zirconia that selectively allow oxygen-ion passage at high temperatures.

The CMOG operates by heating this membrane to temperatures where bonded oxygen molecules freely floating in air separate into single negatively-charged oxygen ions. These ions are then able to

pass through the otherwise impermeable membrane structure, drawn across by an electric current applied to catalytic electrodes attached to either side of the membrane.


## Wonder membrane material

Since only the negatively charged oxygen ions can pass through the membrane, CMOG is thus able to generate pure oxygen in contaminated environments such as those affected by biological and chemical warfare agents.

The membranes are stable at high temperatures, have high ionic conductivity, can be manually handled and are easily fabricated. One advantageous form of fabrication is a tubular design that offers a more robust structure than previous flat plate designs. It is more easily sealed for containment of the pure oxygen produced.

Importantly, the strength the ceramic membrane material maintains at high temperatures allows the device to deliver oxygen at high pressure. This means that a buffered supply can be generated with little or no additional mechanical compression, thus reducing the need for bulky ancillary equipment to support field deployments.

Last year, Tectonica successfully demonstrated that a minimum rate of 2.6 litres of pure oxygen per minute is deliverable by the CMOG device. As well as field medical services, CMOG can also be used in the field for recharging oxygen bottles in aircraft and decompression chambers.

Work is currently under way to ensure that the system is sufficiently rugged and appropriately packaged for field use. Trials to test these aspects of CMOG performance are planned for 2013. 



Ceramic membrane oxygen generator device developed by Tectonica Australia and CSIRO.

# Briefs

## Setting international standards for simulation studies

DSTO research in the field of distributed interactive simulation (DIS) has helped deliver new international standards for its use.

DIS is a technology that facilitates the conduct of wargaming scenarios in a virtual domain through which Defence simulations and simulators based in separate facilities may participate.

In order for distributed simulations to participate in a shared synthetic battlespace, well-defined standard protocols are required. With digital technology in a state of continuous development, these standard protocols occasionally need to be revised to reflect the changes in technologies and advances in capabilities.

The standard for DIS was last set in 1998 by the Institute for Electrical and Electronic Engineers (IEEE), with a decision being taken in 2004 by the Simulation Interoperability Standards Organisation (SISO) to update this.

After many years of DSTO participation in IEEE and SISO deliberations on system interoperability problems, the expertise gained has been valuably put to use on arriving at a new standard, an achievement six years in the making. Three DSTO researchers are cited as co-developers of the new standard. [n](#)

## Bio-derived jet fuel prospects investigated

DSTO has been involved in a study on the feasibility of producing jet fuel from biological materials.

Titled *Flight Path to Sustainable Aviation*, this CSIRO investigation was commissioned by and developed in consultation with the Australasian members of the Sustainable Aviation Fuel Users Group (Air New Zealand, Boeing, Qantas and Virgin Australia) and DSTO.

The study found that aviation fuel derived from non-food biomass sources, such as crop stubble, municipal waste and algae, could be economically produced in substantial quantities in Australia and New Zealand.

Important recent milestones in the development of this new industry include the successful demonstration of fit-for-purpose performance of bio-derived jet fuels in commercial and military aircraft over the past three years, technical certification of one class of bio-derived aviation jet fuel in 2009 with a second due in 2011, establishment and demonstration of alternative biomass to jet fuel refining processes (although below commercial scale), and international development and trials of bio-derived fuel sustainability principles and guidelines.

A study 'road map' scenario sees the construction and operation of two commercial scale bio-fuel refineries by 2020, the first in 2015. These could provide 5% of Australasian jet fuel requirements by 2020.

The effects of further such developments by 2030 are projected to include savings of over \$2 billion per annum on jet fuel imports and a 17% per annum reduction in aviation greenhouse gas emissions. [n](#)

## Determining fitness levels required for military tasks

DSTO recently conducted research on Physical Employment Standards (PES) in collaboration with the University of Wollongong to determine the physical demands placed on personnel when defending RAAF airfields.

The study, one of many being conducted to determine the physical demands required of personnel across the military, involved 38 Ground Defence Officer and Airfield Defence Guard volunteers over a ten-day period at RAAF Base Tindal during Exercise Nomad 2011.

The volunteers were put through simulations that included battle drills such as repulsing assaults, quick reaction force operations, urban operations, and casualty evacuations.

During these drills, DSTO researchers collected data on oxygen uptake using an apparatus called a Cortex MetaMax 3B, from which measures of



Cover of the aviation biofuel study booklet produced by CSIRO

the cardiovascular endurance required to perform certain workloads can be derived.

Other data collected included heart rate, and in some cases, distance travelled and body orientation. These extra data were collected through the use of wearable physiological sensors such as heart rate monitors plus global positioning satellite devices combined with accelerometers and gyroscopes. The data thus obtained allowed for analysis of body movements and orientations together with physiological exertion to assist in determining the physical demands of a job.

This phase of research is expected to be complete by the end of 2011 with the PES project to eventually provide specifications of physical fitness required for all military trades. [n](#)



# Calendar

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**12 - 13 Oct 2011**

## **Joint Warfare Conference**

*An event hosted by the Australian Department of Defence for local and overseas attendees with a focus on the development of joint capability against the backdrop of current operations.*

Canberra

<http://www.australiandefence.com.au/events/joint-warfare-conference>

**16 - 17 Nov 2011**

## **Defence Human Sciences Symposium**

*The principal Australian forum for defence-related human science research.*

DSTO, Melbourne

<http://www.dsto.defence.gov.au/dhss2011/>

**28 - 30 Nov 2011**

## **8th Annual Global Maritime Domain Awareness: Coastal Surveillance 2011**

*A conference for discussion on the technologies and strategies to develop the first line of defence against growing maritime asymmetrical threats.*

Singapore

<http://www.coastalsurveillancemda.com/Event.aspx?id=457444&MAC=DL>

**31 Jan - 3 Feb 2012**

## **Pacific 2012 International Maritime Exposition**

*The commercial maritime and naval defence showcase for the Asia Pacific.*

Sydney Convention and Exhibition Centre, Sydney

<http://www.pacific2012.com.au/content-exposition/index.html>

**31 Jan - 3 Feb 2012**

## **Royal Australian Navy Sea Power Conference 2012**

*The seventh biennial RAN Sea Power Conference, to be held in association with Pacific 2012.*

Sydney Convention and Exhibition Centre, Sydney

<http://www.pacific2012.com.au/content-exposition/index.html>

**22 - 26 Oct 2012**

## **Land Warfare Conference**

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

Melbourne Convention Centre

<http://www.dsto.defence.gov.au/lwc2012/>