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AUSTRALIA

Vibration energy harvesting

Modelling for quieter sub operations

**Aircraft structures that double as antennas**

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, Dr Alex Zelinsky, and employs about 2500 staff, the majority of whom are scientists and engineers. It is one of the two largest research and development organisations in Australia.

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*Cover image: Fabrication in DSTO workshop of an aircraft component to serve as both structural member and antenna.*

# Tapping into a vibrating energy source

## A technology developed by DSTO puts to good use the vibration energy prevalent in vehicular structures as a supply of electrical power for *in situ* monitoring devices.

To better manage the maintenance of Australia's military aircraft, ships and land vehicles – very expensive forms of Defence equipment – devices for monitoring structural health are being developed for installation at critical parts of their structures.

These devices will serve to continuously monitor loading and accelerations and also detect damage and damage growth to facilitate near real-time damage assessment.

"The advent of this form of continuous monitoring will enable a transition from maintenance safety inspections based on non-destructive approaches, which are costly and time-consuming, to more efficient approaches based on monitoring with structurally integrated sensors," says DSTO researcher Dr Scott Moss. "The advantages for Defence will be to reduce through-life support costs while increasing asset availability."

A problem for implementation, however, is that the structural health monitors require electrical power to function. Wiring them into the asset's power supply may not be readily achievable, meaning that a power generator *in situ* is really the only practical solution.

With such systems working quite successfully on small amounts of power, a generator based on harvesting vibration energy has been seen to be an obvious choice.

### DSTO's approach

Other designs for vibration energy harvesters have sought to harness vibrations using devices that capture energy in just one axis of movement. Moss and colleagues have instead pursued a technology design that is biaxial in nature. This increases the potential for energy harvesting from a single axis to 360 degrees in a plane.

This design features a 20 millimetre diameter chrome-steel ball bearing that rolls on a tungsten carbide wear pad plate atop a copper wire coil with a permanent neodymium-iron-boron magnet underneath.

The ball bearing is free to oscillate over the copper coil, impelled by vehicular vibrations. As it does so, a region of varying magnetic field passes through the coil, inducing an electric current that can be used to power an electronic device or be fed into battery storage.

An advantage of this design over the single axis kind is that it delivers a more compact form of electricity generator.

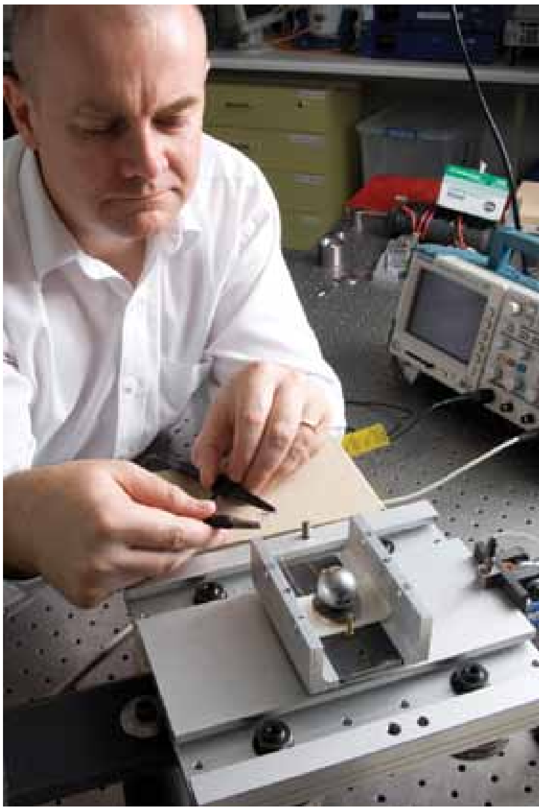
### Modelling theoretical performance

The first steps taken by the DSTO researchers were to model the device mathematically to arrive at predictions for performance in terms of a concept known as 'power density' – the capability of the device to produce power at a given size and weight.

One finding of the modelling was that the power density of energy harvesters decreased markedly with designs having lengths less than 1.3 centimetres, indicating that the optimal size for such a device in terms of compactness as well as power generating capacity was just above that size.

### From theory into actuality

A prototype version of the device was then produced, with the ball bearing chamber (the active part of the mechanism) amounting to 25 cubic centimetres in volume. The most recent prototype device developed in the course of demonstration trials was shown to be capable of producing 20.3 mW from vibration levels typical of those propagated on airframes.



Following from the success of this work, DSTO applied for a full patent on the biaxial vibration energy harvesting concept in the United States, United Kingdom and Australia in May this year.

The DSTO vibration energy harvesting work has been undertaken collaboratively with the University of California, Los Angeles, and (through TTCP) the United States Naval Surface Warfare Center, Naval Undersea Warfare Center, and the Defence Research and Development Canada-Atlantic.

Future work will investigate broadband multi-axis vibration energy harvesting for use on military aerospace platforms.

*Above: Dr Scott Moss with vibration energy harvesting experimentation setup.*
*Left: DSTO's prototype vibration energy harvester.*

# Innovative dual-purpose structures boost aircraft capabilities

DSTO is developing a design approach where airframe structures also serve as antennas, thereby offering dramatic increases in aircraft capabilities.

The ability to transmit and receive radiofrequency signals is an essential requirement for modern military aircraft, and antennas are vital to that capability. To date, antennas have been mounted as dedicated units outside the aircraft. Although this eases design complexity, it adds weight and aerodynamic drag, thereby reducing speed, range, endurance and payload.

DSTO's new approach involves adapting load-bearing parts of the aircraft's skin in ways that enable them to also serve as antennas. This not only reduces weight and drag, but also allows for much larger antenna arrays.

"With larger arrays, radiofrequency sensing can be conducted with greater precision, communications can be conducted more securely and advanced communications become feasible in smaller types of aircraft, all of which significantly enhance military capabilities," says DSTO researcher Dr Paul Callus.

Development work on the innovation began during Dr Callus's tenure on a Defence Science Fellowship at the United States Air Force Research Laboratory (AFRL) in the years 2006 to 2007.

### Putting top hats to new uses

The design innovation arrived at by Dr Callus and his AFRL colleagues arose from the realisation that the tube-like hollows under many aircraft skins, called top-hat cross-section stiffeners, were similar in appearance to the tube structures in radiofrequency systems known as waveguides.

Radiofrequency waveguides, commonly made of metals due to their electromagnetic conductivity, carry electromagnetic waves within radiofrequency circuits, much in the same way that coaxial cables carry signals between components of household audio-visual equipment.

Cutting appropriately sized and located slots through waveguide walls creates a type of antenna known as a slotted waveguide antenna. The aerodynamic exterior can then be restored by filling the slots with a material transparent to radiofrequency signals.

This design concept became known by the team as Slotted Waveguide Antenna Stiffened Structures (SWASS).

## Exploring the SWASS approach

Development of the SWASS technology is continuing under a joint US-Australian Project Arrangement and collaboration between DSTO and RMIT University.

One area of interest concerns the material used to make top-hat stiffeners – carbon fibre composite – which is not as electromagnetically conductive as metal. The researchers have found that it is, nevertheless, conductive enough to serve as a waveguide.

The team has also arrived at an understanding of how radiofrequency signals are conducted through carbon fibre composites. This has enabled their antennas to be designed using computational electromagnetic software, thereby eliminating much expensive trial-and-error testing.

The work has established that the SWASS concept can potentially deliver decisive advantages. “Integration of antennas into the aircraft structure will allow for enhancement of aircraft capabilities far in excess of current levels, despite having to account for the reduction in strength arising from the slots and the finite conductivity of the carbon fibre composite,” says Dr Callus.

The team recently designed, manufactured and tested a structural panel that also acted as an antenna array. The next stage will be to produce a larger array on a curved structure, after which, the technology will be ready for demonstration on an aircraft.


*Opposite: Dr Paul Callus with Slotted Waveguide Antenna Stiffened Structures apparatus.*
*Above: Fabrication of an aircraft structural panel-antenna array in DSTO workshop.*

# Better naval damage control tools and technologies on tap

## DSTO research is improving the damage control measures available to Navy for responding to shipboard emergencies.

Damage to vessels, caused by accidents or hostile fire, may be manifested in a range of ways including loss of critical services as well as outbreaks of fire, smoke and flooding. The response measures involve identifying, managing and suppressing damage. Taken together, these measures enable enhanced crew safety, ship survivability, recovery of capability and, ideally, mission completion.

While much of the detection of damage is now undertaken via automated means, most damage control work still needs to be undertaken manually. Moreover, in the event that mechanised systems sustain damage, manual measures will be called for.

Such tasks are generally complex, time-critical and resource-intensive. With vessels being crewed with fewer personnel nowadays, the need for more efficient damage control methods has become apparent.

DSTO has accordingly undertaken to investigate various ways of improving the damage control tools available. In the process, prime consideration has been given to ensuring the ease and efficiency of tool usage by damage control personnel.

### Pipe patching tools

The supply of sea water, fresh water and chilled water in pipes is critical for Navy vessel operations. The various uses of these supplies include cooling machinery as well as surveillance and weapon systems, and for fire fighting.

"Damage to pipes can lead to a critical loss of water pressure or total loss of supply as well as flooding at the damage site," says DSTO researcher Grant Gamble.

One means of managing this problem is through the use of pipe patching repair systems. Two existing technologies were investigated by DSTO, the Jubilee pipe clamp, and a banding clamp currently in use on Navy ships.

*Above: RAN Able Seamen engaged in DSTO pipe patching trials at the RAN School of Survivability and Ship Safety.*

The Jubilee clamp performed better than the banding clamp in reducing the leak rate, and had a shorter implementation time. However, both these pipe patching technologies exhibited variability and limitations in their effectiveness, implementation time and leakage rate.

DSTO therefore sought to devise a new design, known as a lever clamp. This was developed in single lever and in triple lever versions.

### Pipe patching trials

The DSTO lever clamps were tested along with the banding clamp system in trials conducted at the RAN School of Survivability and Ship Safety.

The single lever version was deployed with the use of a copper sheet placed over a sheet of rubber, acting as gasket. The triple lever version, meanwhile, included a curved piece of spring steel plate and rubber gasket as part of the design. These systems could be used to patch up to three quarters the diameter of a ruptured 15-centimetre diameter pipe.

Four RAN Able Seamen with experience in damage control were used as test personnel, having been given some training in the use of the new devices. The test criteria included time taken to fit the devices, ease of fitment, and extent of residual leaks.

The tests were carried out on ten-centimetre diameter pipes, one at head height and the other at waist height. The damage to be managed with the overhead pipe was a cut half a centimetre wide by twenty centimetres long, with water pressure in the pipe set at 5.5 times atmospheric pressure. With the waist-high pipe, three cuts were made each half a centimetre wide and ten centimetres long, with water pressure set at 4.8 times atmospheric pressure.

The findings indicated that the outcomes from fitting the triple lever clamp were better overall than those of the single lever clamps and the banding clamp in both scenarios at different pipe heights. The triple lever clamp generally took less time to fit, clearly provided better leak reduction, and was rated as the easiest to use.

Work on refining these tools is continuing.

## Pipe jumper

Where the damage to a pipe is too extensive to be covered with a lever patch, another kind of system, known as pipe jumper technology, can be applied.

This involves making square cuts at both ends of the damaged section of pipe and fitting couplings with watertight seals. A length of flexible fire hose is then connected to the couplings to breach the gap.

The system was tested by fitting it to lengths of ten-centimetre rolled steel fire mains pipe, with the water pressure level kept at ten times that of atmospheric pressure. A small amount of seepage was noted around the seals of the couplings, but this was not considered significant in the context of damage control activities.

"Our work showed that the pipe jumper system is able to restore flow to damaged piping systems, and therefore can significantly assist the ship recoverability process," says Gamble.

Further work to be done here could include exploration of system performance on other pipe diameters and kinds, development of a new type of coupling that incorporates barb fittings for hose attachment, and use of polypropylene hose to reduce hose weight.

## Valve systems

Water supply systems on modern naval vessels are designed as a grid of interconnected pipes. These have far higher carrying capacity than required, so that if damage occurs, the damaged part can be isolated and the service maintained by looping supplies around the damage. This is done by opening and closing valves via remote control.

"A disadvantage associated with the current set-up is that the systems for controlling valves can similarly be vulnerable to damage also," explains Gamble.

A proposed solution is to use 'smart' valves with local control and power supply systems that operate autonomously. The valve set-up includes pressure sensors on both pipes connecting to it. If the sensors detect an unacceptable drop in pressure and increase in flow for a time duration, indicating a pipe rupture, the valve is programmed to close. The built-in time delay before closing ensures that valves furthest from the system supply close first, minimising the number of sections put into isolation mode.

The smart valve technology found to work most reliably is known as Hydraulic Resistance Logic. Theoretical testing by DSTO showed that this system can correctly close the required valves to isolate pipe ruptures. A bench-top system is currently being built at DSTO to facilitate further testing.

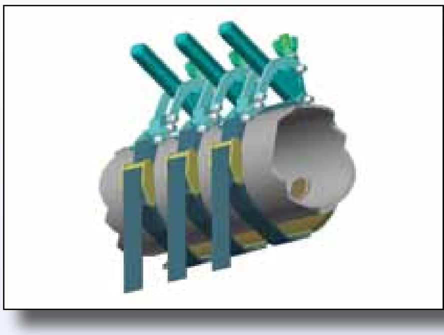
## Fire fighting and suppressant systems

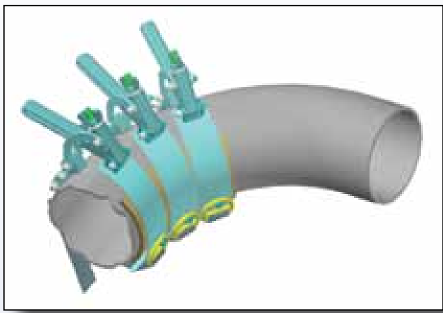
Gaseous fire suppressant agents, used mainly in engine and machinery rooms to counter flammable spray and liquid fires, are often considered problematic due to their hazardous nature.

DSTO is currently evaluating a water mist system for use on Navy ships, with a number of tests having been already conducted to date. These have established that the water mist technique is capable of rapidly cooling compartment atmospheres and reducing fires to sizes manageable by manual fire fighting techniques.

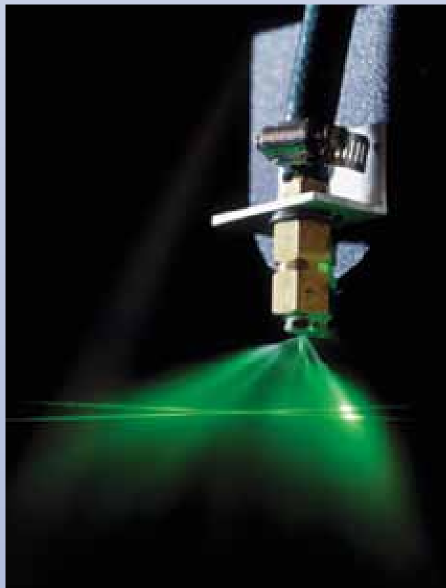
Modelling techniques are being developed to optimise the implementation of water mist systems including the effects of nozzle location, nozzle characteristics such as flow rate and droplet size, compartment configuration, ventilation effects, and fire scenario.

Overall, DSTO is continuing to advance its knowledge of damage control tools and technologies, building towards the eventual goal of providing Navy with informed advice on effective and efficient damage control systems for fleet-in-being upgrades and future naval platforms. Ω





*Top: Graphic depictions of the DSTO-designed triple lever clamp and single lever clamp.*
*Above: Pipe jumper apparatus.*
*Below: Water mist unit.*



# Testing crowd control measures

Computer modelling devised by DSTO has improved understanding about ways to minimise excessive force when using non-lethal weapons to manage civil unrest.

When troops are given the task of maintaining order in urban conflict zones, they need to do so with minimal harm to civilians and avoid possible escalations in violence. Achieving this goal requires the use of non-lethal weapons (NLWs) that serve to deter riotous behaviour through the physical and psychological effects they bring to bear.

While high-level use of NLWs against a crowd may trigger further violent responses, it is also true that the use of insufficient force may encourage violence if crowd members come to believe that such behaviour will not bring consequences.

"Given that there are many unknowns about NLW effectiveness, and that real-world experimentation is not an option, we have sought to arrive at better understandings by using computer modelling," explains DSTO researcher Martin Wong.

The DSTO work focused on investigating the relationship between the intervention strength of the control forces and the level of crowd rioting.

The study technique applied is known as agent-based modelling in which the behaviour of types of players and their interactions are described and explored in algorithmic form. For the NLW research work, the categories of players include control force agents and crowd agents.

## Crowd anger analysis

The modelling done by DSTO was predicated on a number of insights about crowd psychology.

These included the supposition that each crowd agent makes an assessment from his or her viewpoint of the strength of control agents to crowd agents, which then determines the rate and extent of the individual's anger level build-up. If crowd agents increasingly outnumber the control force agents, the crowd becomes more hostile, and the reverse is similarly true.

Crowd anger levels are influenced also by incidences of rock throwing, which have the effect of inciting immitative violence by others.

The sequence of psychological states involved in rock throwing begins with a crowd agent overcoming his or her fear of the control forces in order to approach close enough to effectively throw a rock. After throwing a rock, anger levels drop to a minimal value but may quickly build again, fuelled by observations of other crowd violence.

Meanwhile, when a crowd member is struck by a NLW round – if not physically incapacitated – he or she will exhibit increased fear levels, lower goal motivation and increased anger, and those crowd members within observation range may also behave similarly.

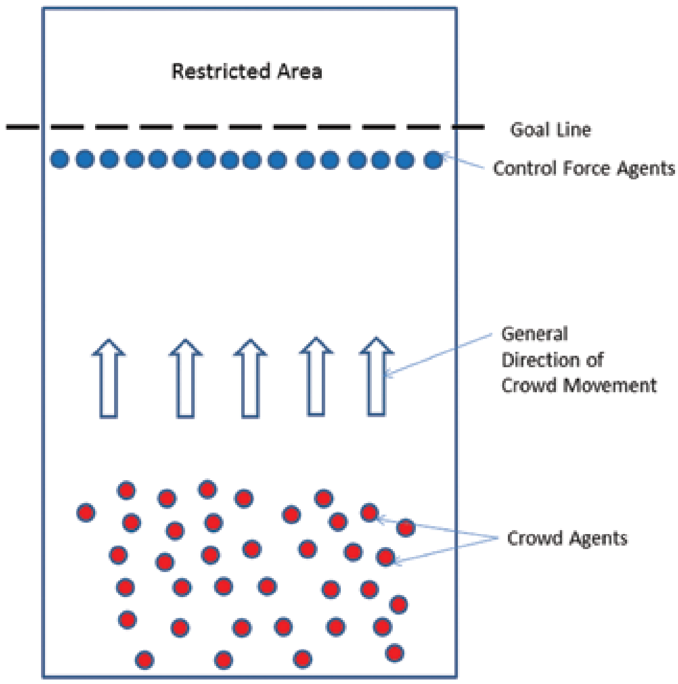
This latter effect depends on the strength of identification levels within the crowd. "In cases where social cohesion is strong, individuals tend to experience the same emotions as others because the notion of self is overtaken by a collective form of identity and feeling," says Wong.

## Modelling setup

The scenario DSTO proposed featured a platoon of twenty soldiers positioned in a line across an area with a crowd of a hundred milling in front, a ratio of one to five. While the crowd members were intent on entering the restricted area, the aim of the platoon was to prevent such entry and, if possible, disperse the crowd with minimal crowd casualties.

The behaviour of the crowd was analysed in terms of four variables; desire to goal, fear of control forces, anger and social cohesiveness.

Crowd members had three actions available to them; move towards the restricted area, move away from the restricted area, or throw a rock. The control force personnel, equipped with



an NLW armament such as rifles firing rubber bullets were seen to have an effective range twice that of the rock-throwing crowd members.

The accuracy with which the deployed weapons and thrown rocks impact on their respective targets was set according to known probabilities of success for each at given distances, creating some randomness in outcomes.

The control force response to incursions or rock throwing was to fire on the crowd members. The intensity of their response was set by the instructions issued by their commanding officer.

Successful hits on individuals in the crowd by the control force were deemed to render the crowd member incapable of participating in further crowd actions. Successful hits on the control force by the crowd, however, were assumed to have no consequence since the troops had riot shield and body armour protection.

## The experiments

The DSTO work investigated two basic scenarios – deployment of NLWs with low and high effect.

At low intervention strength settings, the control force agents shot less non-lethal weapon munitions per rock thrown by the crowd. At high intervention strength settings, the crowd control force matched or exceeded the violence displayed by the rioting crowd.

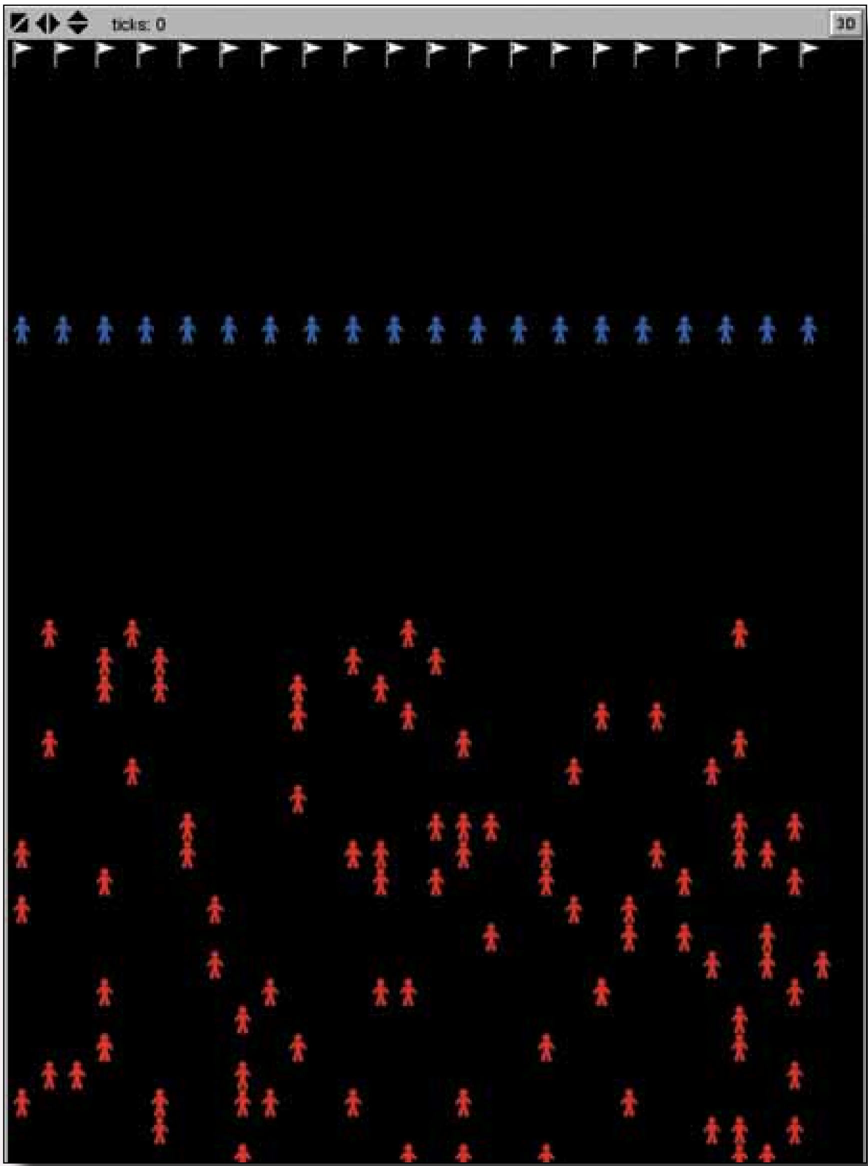
A number of simulation runs was undertaken, each with particular settings for levels of initial crowd anger, social cohesiveness and intervention strength of the control forces. Each run was performed one hundred times so that the impact of the randomly varying inputs would emerge in a spread of results. These results were then averaged across all runs.

The data outputs included the number of rocks thrown, crowd member incapacitations, average distance of crowd members from goals and average final anger level of crowd.

The first two categories of data gave an indication of how violent the encounter was, while the latter two indicate how successful the control force was in dispersing the crowd. These measures were then plotted against intervention strength to see how they varied with increasing levels of control force intervention.

## Conclusions drawn

The results, presented in graph form of one variable plotted against another, showed firstly that if intervention strengths are very low, the occurrence of violent behaviours will be high. Increasing the intervention level eventually leads to a minimum level of violence, after which, no further decrease is effected.




Unlike other research, the DSTO work did not show an increase in violent behaviour after high levels of intervention were reached, but did indicate that the remaining crowd may be left in a high state of residual anger. The researchers observe that this end-state may set the grounds for further violence at some future time.

The experiments also showed that low level interventions, surprisingly, will result in increased crowd casualties. More incapacitations arose in this scenario because crowd members were not repelled effectively enough. Sensing the NLW deterrent to be less potent than actual, they approached the control forces so closely that NLW hits were more probable.

## Possible applications and further developments

Another form of data analysis was made showing the trade-off between incapacitations of crowd members to achieve a required end-state distance of separation between the control force and crowd.

This analytical tool, according to Wong, could usefully inform commanders about the level of incapacitations expected to achieve a required minimum separation distance.

Moving on from here, the researchers plan to do work to improve modelling fidelity. Aspects under consideration include modelling the crowd as a collection of sub-groups, factoring in the different crowd personality types and improving the realism of crowd movement. Improved modelling of the control force agents will see the use of a mix of lethal and NLW types as well as making them susceptible to attrition through fear and injury.

Additional scenarios that the researchers envisage could be explored with the modelling are prison or refugee camp break-outs, and improvised explosive device incidents.

*Opposite: Schematic diagram of agent-based modelling set-up.*
*Above: Screen display of DSTO crowd control simulation run.*

# The quest for quieter submarines

To reduce the acoustic signatures of Australia's submarines, DSTO and its research partners are seeking to develop better research tools.

Operating a submarine inevitably entails the emission of various acoustic signals, known as signatures. One such is its flow-related signature. This is influenced by the shape of the boat, the properties of the propulsion system and the hydrodynamic 'cleanness' of ancillary equipment attached to it.

The louder the signature, the more likely an adversary will be able to detect, identify and track the boat's presence, and thus, the more seriously its all-important stealth status will be compromised.

A further operational concern is the boat's manoeuvring performance. This is largely determined by water flow over the hull and its appendages. Other influential factors include the manner in which the boat's control systems maintain direction, speed and trim, and interactions with the sea-surface and seabed sometimes play an important role.

To get a better understanding about such matters, and ultimately to provide advice to Defence on optimising submarine design and operations, DSTO is developing validated computational modelling tools.

"With the increasingly sophisticated modelling of turbulence that we have available, the complex nature of the flows in which control surfaces and propellers operate is now being revealed," says DSTO researcher Brendon Anderson.

"These flows are both spatially and temporally non-uniform, and need to be understood and characterised if more efficient equipment for propulsion and control is to be developed."

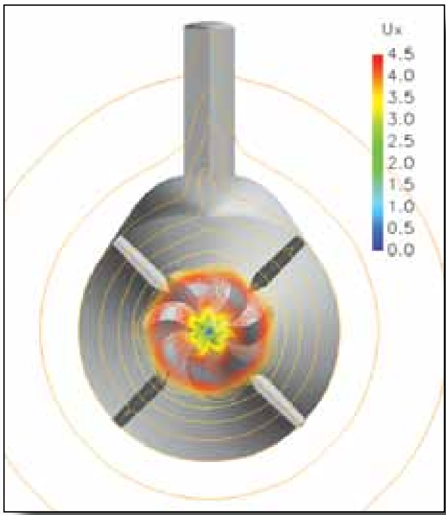
### Forging ahead with OpenFOAM

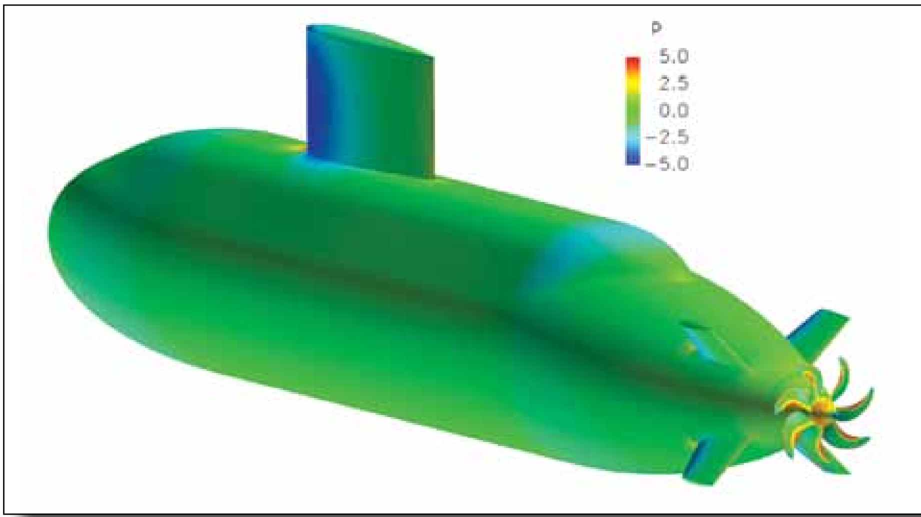
The computational fluid dynamics modelling tool used by DSTO for this research is called OpenFOAM, chosen for its flexible and cost-effective approach to a highly computationally intensive problem.

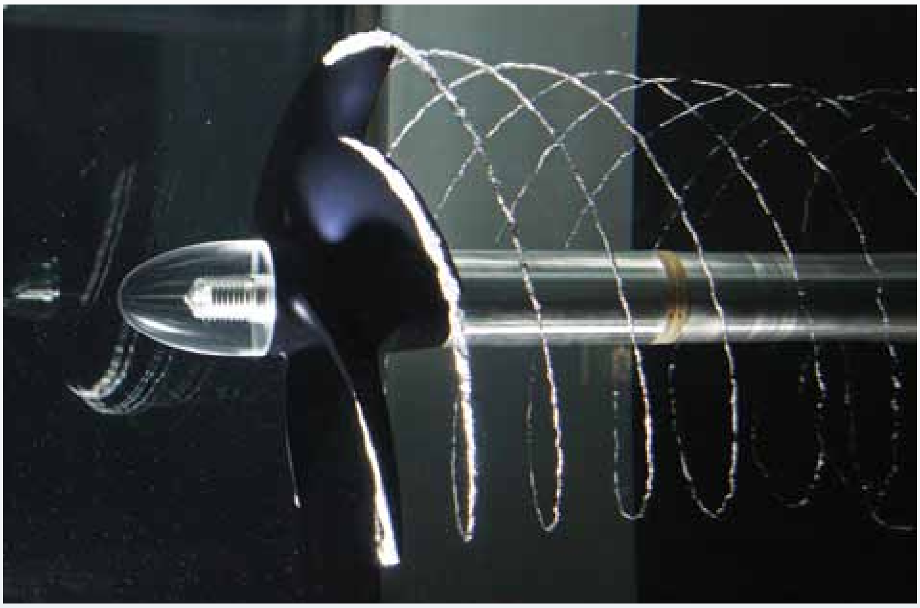
To ensure the OpenFOAM modelling will produce accurate results, scale-model wind and cavitation tunnel testing of submarine flow properties is undertaken. The real-world experimental outcomes thus obtained are used to validate the computer modelling.

The wind tunnel testing was carried out in DSTO's Low Speed Wind Tunnel – a conventional, continuous flow, closed-circuit, single-return wind tunnel with a maximum airspeed of about a hundred metres per second. Work undertaken in this facility has included research on the Collins class submarine and the DSTO generic submarine model as well as the Landing Helicopter Dock vessel to be acquired by Navy.

The cavitation tunnel testing was undertaken at the Australian Maritime College's Cavitation Research Laboratory. This provides high-uniformity, low-turbulence flow with fine control of velocity and pressure, and can sustain flow speeds of up to twelve metres per second. Its capabilities provide an essential basis for experimental studies on propeller and appendage hydrodynamics, including the effects of cavitation.



## Probing the mysteries of cavitation

Cavitation is not only a major source of acoustic emissions but can also lead to a loss of propulsion efficiency due to thrust breakdown, and may ultimately result in surface erosion and fatigue-induced failure of metal structures.

Propeller cavitation arises when the water flow about a propeller blade or hub causes the water pressure to drop below vapour pressure. This leads to the formation of cavities that comprise bubbles or sheets of air and water vapour. After just milliseconds, these bubbles implode with violent force, producing sound and vibrations that possibly also cause physical damage.

"Factors influencing cavitation include propeller geometry, propeller revolution speed and speed of the boat through the water, along with water flow structures arising from the hull and any appendages on it forward of the propeller," explains Anderson. "Naturally occurring microbubbles also influence the onset of cavitation."

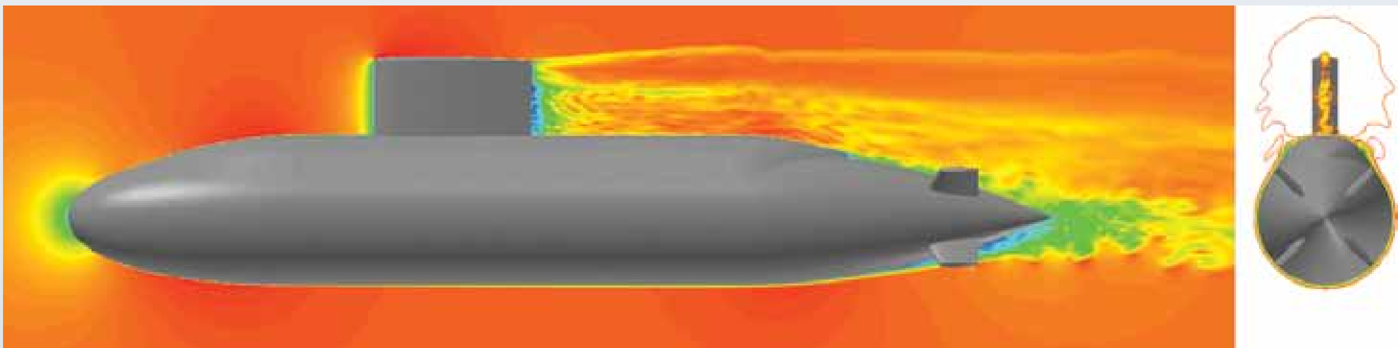
Researchers at the cavitation tunnel are able to study the causes of cavitation through the use of high-speed photographic imaging, with the associated propeller loads being measured with specialised force dynamometers.

Through such means, they can see at what flow speeds and conditions cavitation will begin and how noisy it will become.

## Projected outcomes

The computational modelling capability being developed with this experimentation-based support is expected to eventually deliver an improved means of predicting and managing submarine hydroacoustic signatures.

The work is being undertaken in association with the Swedish Defence Research Agency, the Australian Maritime College, the University of Melbourne, Monash University and the University of New South Wales. Ω



*Opposite: Flow field measurements being gathered for generic submarine design in DSTO's Low Speed Wind Tunnel.*
*Top: Graphics of computational fluid dynamics predictions of pressure and flow field for generic submarine design.*
*Lower right: Testing of generic five-bladed propeller in the Australian Maritime College cavitation tunnel.*
*Bottom: Graphics of computational fluid dynamics predictions of axial flow velocity around generic submarine.*

# Field-portable kit for testing aircraft fuel

A new way of detecting additives in jet fuel has been developed by DSTO, now enabling this kind of testing to be done on site where the fuel is stored.


A problem concerning Australia's military jet fleet operators is the presence of trace metal ions, such as copper, cadmium, iron and zinc, in fuel.

These metal ions act as catalysts for oxidation reactions, which degrade the stability of the fuel when exposed to heat and when stored for long periods. One solution being applied is to add a material called Metal Deactivator Additive (MDA) to bulk fuel supplies.

"MDA is not normally added to military jet fuel and is only included to correct thermal stability problems associated with high metal contents in fuel," explains DSTO researcher Paul Rawson.

### The MDA issue

The use of MDA in fuel in turn gives rise to two concerns. One is that it may be used by fuel suppliers to mask fuel quality issues without its addition being disclosed. The second issue concerns the management of aircraft defuelling operations at Australian Defence Force bases.

Any aircraft that is scheduled to remain on base for an extended time has its fuel tanks drained and the contents taken into storage. This is done as a routine fuel management measure and to facilitate maintenance operations. In the case of aircraft arriving from coalition countries, some of these may have fuel containing a United States Air Force additive package for thermal stability improvement called S-1749 (also known as JP-8+100), which includes MDA.

This fuel cannot be directly taken into RAAF fuel storage since the additive will disable the apparatus for fuel system filtering. The methods available for managing such fuel are

either to keep it in segregated storage, or to render it safe for storage with other fuel by dilution with additive-free fuel.

Hence, to manage all these concerns, a fuel testing method is required for detection of MDA so that it can be rapidly applied during base operations.

## Existing MDA test techniques

The available testing techniques include laboratory-based kinds, which are of little practical use given their extensive turnaround time for delivery of results.

A range of portable test systems has been developed, but for various reasons these are also not able to meet the full range of field-based testing needs in the required timeframe. A further impediment for some is that they require the use of specialised equipment and materials such as portable spectrophotometers, solvents and reagents.

Seeing this shortfall in MDA testing capabilities, a team of DSTO researchers undertook to fill the gap. The test methodology they opted to develop was qualitative in nature rather than quantitative, whereby the presence of the material of interest, MDA, would be indicated through a colour change in another substance rather than a numerical read-out.

Success here required that the colour formation reaction produce a distinct colour, free from interference from any colour naturally occurring in the fuel. In addition, the colour intensity needed to be strong enough to indicate a reaction with MDA at very low concentrations.

## Gel-based test apparatus

The method adopted is known as open column chromatography, in which a liquid sample to be tested is passed through silica gel infused with chemicals that react only to the presence of a particular molecule.

In this case, the reactive chemicals were metal salts that produced a colour change reaction in the presence of MDA.

The set-up involved four layers of silica gel placed in a polypropylene tube. The first gel layer was dope-free while the second was doped with metal salts, and the latter two layers similarly alternated. Samples of fuel were inserted by syringe or via laboratory glassware apparatus in hundred millilitre amounts.

This arrangement enabled a clear comparison between any colour changes occurring in the doped layers with the white of the dope-free layers. It also gave some means of quantitatively indicating the relative strength of MDA concentrations, with the lower doped layer only showing colour when MDA levels were more pronounced.

## In quest of the optimal test set-up

Several aspects of the method were investigated in order to determine which materials and methods would produce the best MDA testing technology.

A significant aspect was the choice of metal salt used, since ones that were soluble in fuel tended to bleed out of the silica gel when the fuel samples passed through. Copper salts, which largely remained in the gel, were found to be the most useful in this regard.

A further issue concerning choice of metal salt was the colour produced in the presence of MDA.

Nickel salts produced a red colour at very high MDA concentrations and yellow at low ones. Since another additive is commonly present in fuel for antioxidant purposes that shows up as a distinct yellow band, any low-level nickel-MDA reaction would thus be effectively masked.

Iron salts, meanwhile, produce a faint rusty brown colour at low MDA concentrations. This is also the colour produced by their reaction with moisture in air, and so, no firm conclusions about the true cause of the colour change reaction could be drawn. Copper salts, however, produced a reddish-purple colour at all MDA concentration levels.

The size of mesh used to separate the dope-free and doped layers of gel was also significant, with finer mesh sizes producing more intense colour banding.

## MDA test method passes the test

The DSTO procedure arrived at was found to be capable of indicating the presence of MDA in fuels via the colour change reaction down to levels of 0.5 parts per million.

Furthermore, the test process readily satisfied requirements for a field-based testing system, being quick and easy to apply and at minimal cost, requiring only a disposable syringe and test tube by way of equipment.

The researchers note, however, that this can only detect MDA when the molecule is in solution. Fuels that have been stored for some time may appear to have lower concentrations of MDA due to its reaction with metal ions in storage, making it non-reactive to the MDA test. However, since current fuel management procedures stipulate that fuel stored for a certain period must be used or diluted with fresh fuel, the presence of undetected MDA is not seen to be of concern.

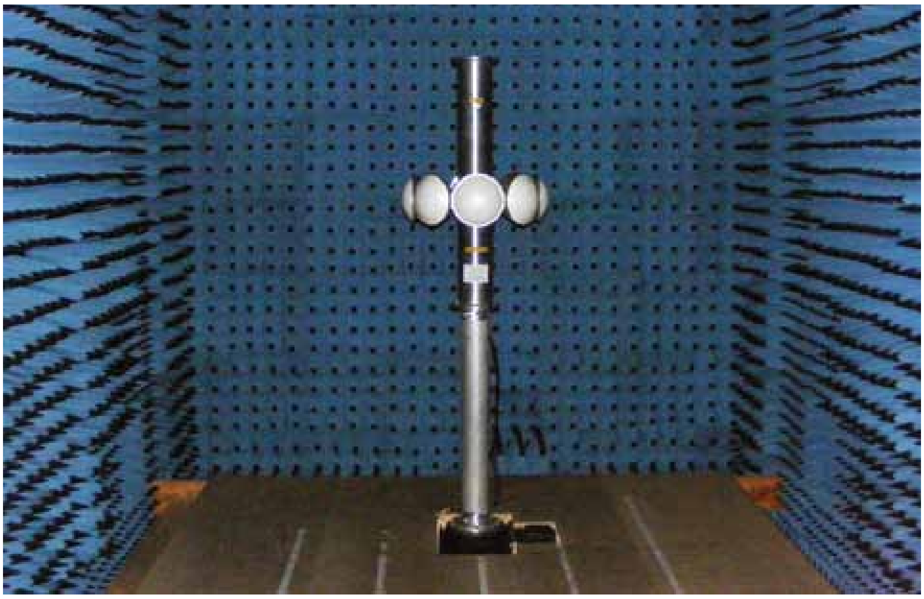
DSTO's MDA test has now been made available to the United States Department of Defense to help overcome the problem of MDA being added to its fuel supplies by refiners without notification. The development of the test also clears the way for the possible use of the S-1749 additive by RAAF fuel managers.

*Opposite: DSTO researcher with MDA test apparatus developed by DSTO.*

*Above: Outcomes of experiments to test MDA in fuel samples, with positive results indicated by purple bands in test apparatus.*

# Detecting the detection capabilities of others

An electronic support system, developed under the Capability and Technology Demonstrator (CTD) program, could enhance the operational effectiveness and safety of Navy ships and crew.



The purpose of electronic support systems is to give shipboard command an awareness of any electromagnetic emissions coming from other ships or aircraft at ranges beyond the capabilities of radar to detect the other asset.

The situational awareness information that can be obtained in such a way includes the direction of emitted energy, the type of ship or aircraft involved and whether the other asset is seeking to launch an attack. This capability provides more time to assess a potential threat and to formulate a response than would be possible using radar detection alone.

A problem for electronic support systems currently in use, however, is that they are designed to detect pulsed radar transmissions. A radar system typically sends shorts burst of energy at regular intervals, with return signals detected in the intervals between transmission. When operating in environments where radio transmissions are continuous – as emitted by ultra high frequency television stations, microwave data links and cellular telephone transmissions – this continuous signal input tends to swamp the detection capabilities of the electronic support system.

## Low band solution

A solution to the problem, proposed by Sydney-based SME Jenkins Engineering Defence Systems and developed through the CTD program, has taken the form of an apparatus known as the Low Band Direction Finding Sub System (LBDFS).

"The design of LBDFS was aimed at providing a versatile electronic support system that can operate without interference in traditionally challenging environments," says CTD Program Director, Dr Alan Hinge.

Development work involved testing the design in an anechoic chamber. This facility is a room lined with pyramid-shaped rubber foam structures impregnated with iron and carbon particles that absorb radiofrequency emissions, thus eliminating radar wave reflections that may otherwise distort the test results.

The LBFDS was then installed on a vessel and tested at sea in the waters off Jervis Bay. These field trials demonstrated the capabilities of the new system to provide high sensitivity and direction finding functions with greater accuracy than standard electronic support systems.

## Approved for Navy use

As a result of these successful demonstrations, the LBDFS is now to be installed as the core component of the electronic support suite on the Air Warfare Destroyer vessels currently being constructed for Navy. In the process, the suite's capabilities have been improved with more capable receiver and processing hardware.

This outcome is another success for the CTD program that overall has delivered more than 90 successful technology demonstrations since 1998. Of those, 14 technologies have entered service with the Australian Defence Force and 15 are in development for possible transition into service. Ω

*Top: Low Band Direction Finding Sub System undergoing tests in anechoic chamber.*
*Above: Electronics equipment used in field trials of the system.*

# Briefs

## Bushmaster protection upgrade tested

DSTO recently completed a series of experiments to assess the effectiveness of the Bushmaster survivability upgrade kit (SUK). The Australian Army's Bushmaster Protected Mobility Vehicle is an armoured form of transport designed to carry infantry to and from combat engagements and to conduct patrols.

The SUK was installed on Army Bushmasters a year and a half previously to provide better protection against improvised explosive device (IED) blasts. The SUK modifications included changes internally to the seats and floor of the vehicles.

DSTO's experimental program involved comparing the outcomes of identical IED blasts on two Bushmasters equipped with SUK and one without.

The test vehicles were extensively fitted with sensors to measure blast loadings and damage to their structures. To study the effects of IED blasts on humans, three mannequins were seated inside each test vehicle, and one was placed outside in the blast field. These were fitted with accelerometers in their helmets and sensors around their bodies to detect damage to critical regions. Six high-speed cameras were installed inside each vehicle along with several placed outside to make a visual record of the blast impacts.

After analysing the data gathered from the trials, DSTO gave advice to Army about the level of survivability provided by the SUK enhancements. It also offered direct advice on operational procedures to Australia's force deployment in Afghanistan.

## Hypersonic flight trials over Norway

A hypersonic flight trial was recently undertaken by DSTO and the US Air Force Research Laboratory at the Andøya Rocket Range in Norway.

The fifth in a series of nine flight trials being conducted in the Hypersonic International Flight Research Experimentation (HIFiRE) program, its purpose was to obtain flight data from a scramjet engine – a type of air-breathing engine being developed to facilitate flight at hypersonic speeds.

The trial involved launching an engine and its support module with a two-stage rocket booster to an altitude of 350 kilometres. After leaving the atmosphere, the test vehicle was readied by removal of protective shielding, and the spent second stage rocket motor and test vehicle were then turned to align the test vehicle to the atmosphere at a specific angle of attack before re-entry.

This crucial and difficult manouevre was carried out over the course of three minutes using an autonomous cold gas thruster system developed by DSTO, with some newly developed technology being tested in flight for the first time.

During descent through the atmosphere, the vehicle reached speeds in excess of eight times the speed of sound (about 9,000 kilometres per hour) under conditions of ballistic flight. At a height of 32 kilometres, fuel was fed into the scramjet engine and combustion initiated.

Over the next seven kilometres of descent, measurements were made of pressure and temperature at various points on the engine, and the test vehicle's speed and altitude were also recorded. High quality readings of these were successfully transmitted to four ground stations.

With all aspects of this trial being successfully accomplished, the extent of flight experiment success will become known when data analysis is completed early next year. The outcomes will be used to inform investigations into scramjet engine operations via wind tunnel experimentation and computational fluid mechanics modelling work.

## Accolade for chemical sensor microchip development

An innovative and portable plastic microchip sensor that can quickly detect and identify toxic chemicals has won the 2012 DSTO Eureka Prize competition for outstanding science in support of Defence or national security.

*HIFiRE test vehicle launched from the Andøya Rocket Range in Norway.*

A prototype device has been developed by Professor Yonggang Zhu at the Commonwealth Scientific and Industrial Research Organisation

Designed for use at the scene of suspected terrorist attacks, it enables fast and reliable detection of a range of chemical warfare agents, including sarin, soman, tabun and VX and their degradation products. It is capable of identifying these even when mixed with harmless substances such as soft drinks, and can potentially be used for detection of other kinds of chemicals such as explosives, pesticides, food contaminants and drugs.

The apparatus has been designed as a disposable device, with testing carried out by applying swabs or samples of soil or water to the chip. The results it provides, available in about thirty seconds, have the same accuracy as those produced in a fully equipped analytical lab.

This plastics-based sensor technology is significantly more compact, portable and field-deployable as well as faster and less costly to use than other available chemical sensor technologies. Given further development, it will be of great benefit for Defence as well as law enforcement, security and counter terrorism agencies.

Professor Zhu's research represents a world-leading development in the field of microfluidics, with the possibility that his device could be mass-produced in Australia.

# Calendar

**12 – 13 Feb 2013**

**ADM2012: 10th Annual ADM Defence/Industry Congress**

*An annual forum attracting senior Defence, national security and industry executives operating within the Australian defence business sector.*

Hyatt Hotel
Canberra
**http://www.australiandefence.com.au/event/adm2013-10th-annual-adm-defence/industry-congress**

**24 – 26 Feb 2013**

**2nd Annual Unmanned Vehicle Systems Conference**

*An event focusing on aviation and aerospace applications both military and civilian as well as presentations highlighting applications of terrestrial and marine unmanned systems.*

Melbourne Convention and Exhibition Centre, Avalon Airshow (last day)
Melbourne
**http://www.auvsi.org/Australia/Home/**

**25 – 28 Feb 2013**

**HUMS 2013**

*The eighth international conference presented by DSTO on health and usage monitoring systems.*

Melbourne Convention and Exhibition Centre,
Melbourne
**http://www.humsconference.com.au/**

**25 – 28 Feb 2013**

**15th Australian International Aerospace Congress (AIAC15)**

*Australia's premier aerospace forum, held in association with the Australian International Airshow and Aerospace & Defence Exposition.*

Melbourne Convention and Exhibition Centre,
Melbourne
**http://www.aiac15.com/**

**26 Feb – 3 Mar 2013**

**Avalon 2013: Australian International Airshow and Aerospace & Defence Exposition**

*The essential aviation, aerospace and defence event for the Asia Pacific, Avalon 2013 will celebrate the 'Power of Flight' with an unrivalled gathering of vintage, commercial and military aircraft.*

Avalon Airport
Geelong, Victoria
**http://www.airshow.com.au/airshow2013/index.html**

**21 Mar 2013**

**Biometrics Institute New Zealand Conference**

*A one-day event that provides insights into the latest developments in biometrics technologies.*

Te Papa Museum
Wellington, New Zealand
**http://www.biometricsinstitute.org/events.php**