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# DEFENCE SCIENCE

Talking through air with light

Smart sensor system getting smarter

Safe stores release in flight

Detecting drive shaft wear



# C O N T E N T S

- 1** Talking through air with light
  
- 2** Smart sensor system getting smarter
  
- 4** Safe way to release stores in flight
  
- 6** Unmanned systems the way to go for maritime applications
  
- 8** Sensing shakiness for safer Sea King operations
  
- 10** Tool for efficiently targeting surveillance data
  
- 12** Monitoring a ship's health on dry land
  
- 13** BRIEFS
  - Outstanding physics researcher appointed Chief Defence Scientist
  - REMUS shows the way for sea mine hunters
  - Quantitative Phase Imaging technology on target

**14** Calendar of events



**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 2200 staff, including some 1300 researchers and engineers. It is one of the two largest research and development organisations in Australia.

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# Talking through air with light

DSTO researchers working on a laser-based missile countermeasure device have seen a way of also putting the laser into service as a communications device, using pulsed laser light.

According to DSTO's Dr Ken Grant, the concept of using pulsed frequency modulated (PFM) light transmitted by a laser for communications has been around for some time, but the DSTO team is seemingly the first to hit upon the idea of applying a missile countermeasure laser to this task.

"We decided to investigate the possibility of giving the laser in the directed infrared countermeasure (DIRCM) system this extra functionality in order to enhance the communication capabilities of Australian Defence Force (ADF) aircraft," he says.

The development of the technology will allow for communications between aircraft as well as aircraft to ground in complete radio silence.

## Radio silent communications

"Laser transmissions offer the significant advantages of not being detectable unless you have an optical receiver directly in the line of sight of the transmitting laser," explains Dr Grant.

"This scenario is very different to that of radio communications where other people can potentially eavesdrop with relative ease because radio waves are detectable over a broad range of angles and at great distances. Even if the message remains encrypted, the action of transmitting inescapably reveals the presence, position, speed and direction of travel of the transmitter at the very least, which would negate the advantage that stealth aircraft have over detection by radar."

While the primary purpose of the DIRCM laser is for defence against missile attack, it can be readily used for communications because the DIRCM system is typically idle most of the time.

## Steely notes for first trials

In November last year, the DSTO team successfully sent a signal over a distance of 50 metres inside a tunnel at DSTO's Edinburgh site in South Australia, using a commercially available mid-infrared laser as the transmitter. No modification of the laser was needed to attain the required transmission capability, but the receiver for capturing and decoding the signal was custom-designed by the team.

The first test material transmitted was the song, *FM*, by pop group Steely Dan of 1970s heyday fame. Grant chose it because the song title, *FM*,



*DSTO's infrared laser communications device undergoing field trials, transmitting from tower to desk.*

seemed apt, being an acronym for 'frequency modulation', and the band also being a favourite of his.

Further trials were carried out in December to test the system outdoors over a distance of one and a half kilometres. At the same time, the team investigated its abilities to transmit digital data in addition to voice communications.

These trials successfully demonstrated the system's functionality for communicating voice and data at this range. The researchers expect that it can be shown to work over significantly greater distances at several tens of kilometres.

# Smart sensor system getting smarter



Devices developed by DSTO for use in monitoring the structural health of Defence ships, aircraft and land vehicles have evolved into more advanced forms that can harness a much wider range of health monitoring sensor inputs, and thereby provide a more complete health update.

As reported in Australian Defence Science, Volume 13 Number 1 in 2005, DSTO had made significant advances in devising a structural health monitoring system that automatically gathered measurements for detection of corrosion damage.

A key feature of DSTO's achievement at that time was the development of a device known as the Universal Sensor Interface (USI) for collecting structural damage data generated by sensors placed at selected sites on the body of an asset. This device was seen to offer performance capabilities and characteristics superior to those of similar types commercially available, thereby paving the way for easier application and more effective use of health monitoring systems.

Previously, standard maintenance procedures for assets involved a manual inspection process undertaken at regular intervals to check for damage, with all parts prone to wear and tear being replaced after a certain period of use regardless of whether these were still serviceable or not.

Using the new smart sensor system approach, maintenance work and part replacements are only done on an 'as required' basis. This has the effect of minimising the personnel time needed for inspections, reducing the asset operational downtime required and eliminating the waste arising from replacement of still serviceable components.

*Above: Navy's new patrol boats, being studied for wear and tear using smart sensor system monitoring.*

The considerable gains provided by this approach overall are to increase asset operational safety and availability, greatly reduce maintenance costs, and provide a clearer understanding of how operations affect the life of a platform, leading to improved fleet management practices.

## More comprehensive health check system

In order to broaden the health status reporting capabilities of the system beyond just that of corrosion, DSTO sought to facilitate data gathering by other smart sensor types. A problem encountered here, however, was that the USI could not manage data from the extra sensors.

The solution arrived at was to develop a range of devices known as Specific Sensor Interfaces (SSIs). Designs for software and hardware were devised by DSTO based on lessons learned from the USI.

Like their predecessor, SSI-type devices are small in size with a low profile to enable ease of installation in the often-confined spaces of an asset. They have been 'ruggedised' to withstand harsh operational conditions, and require only very low electric power input.

Both the hardware and software for the SSI have been designed in modular form, which can run electronic circuitry and software to match specific sensor requirements.

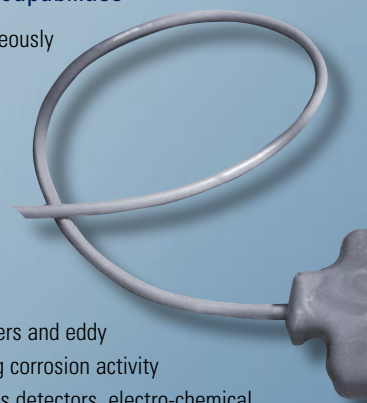
The adaptability this offers means that SSI devices can be developed faster and more cheaply than otherwise, since only the interface to enable its use with a particular sensor has to be developed. The SSI devices are compatible with a wide range of commercially available sensors as well as those developed by DSTO.

Another system advantage the SSI design offers is that it provides a consistent interface between the sensors and any data logging or control device that might be applied.

## Greatly expanded system capabilities

A number of types of SSIs can be run simultaneously on the same network to manage data sent from different types of sensors; one such SSI is designed to operate with structural health sensors, and another is to operate with corrosion activity and environmental condition sensors.

The types of sensors used for structural health monitoring include strain gauges, accelerometers and eddy current crack detectors. Those used for sensing corrosion activity and environmental conditions include mass-loss detectors, electro-chemical sensors, chemical signature detectors, thermometers and humidity gauges.



*DSTO and MiniFAB-developed corrosion sensor suite with fully encapsulated electronics.*

Explaining the gains in system capability made, DSTO researcher Alan Wilson says, "With the advent of the SSI, it is possible to monitor both strain and corrosion data on the one network, even though readings for the first are gathered continuously while those for the second are sampled at discrete moments only a few times an hour."

"What's more, the SSI can be tailored either for high-speed operation, as needed for strain sensors, or low-speed, very low-power operations, such as monitoring corrosion."

"Additionally, following from some initial work done on wireless sensors, we've established that a corrosion sensor suite could be run for more than three years using just two AA alkaline batteries."

### Recent applications of the new SSIs

A network of SSIs is currently being installed in HMAS Glenelg, one of Navy's new patrol boats. This will enable health monitoring data to be collected from over 100 sensors at 22 locations on the boat.

These boats are of particular interest in terms of health monitoring activities since they are the first all-aluminium semi-planing hulls in use by Navy.

The primary objective of the venture is to provide Navy with a capability to monitor hull condition throughout the boat's operational life. The data obtained will be analysed by naval architects in DSTO and Austal to gain understandings of the effect that operational conditions have on the boat's structural integrity and durability.

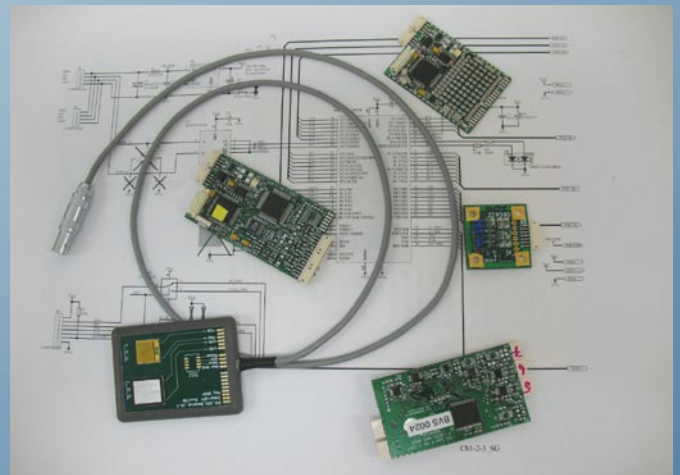
DSTO has also been working with MiniFAB (Aust) Pty Ltd on the development of a fully packaged corrosion-environment monitoring system suitable for aircraft. The project is being undertaken as part of the Smart Technologies Cluster, a Victorian Government Strategic Technology Initiative to develop micro-technologies.

Outcomes arising from this venture have included two new innovative manufacturing processes for DSTO health monitoring devices. One of these is for the production of DSTO's thin foil sensor technology; the other is for the production of an integrated SSI corrosion-environment monitoring suite.

A feature of the latter product's design is that only the sensor devices are exposed to the environment while the rest of the components, including the SSI electronics, are protected.



DSTO structural monitoring network sensor node being installed on Navy patrol boat, HMAS Glenelg.



Specific Sensor Interface (SSI) devices designed for different sensor data management purposes.

This entire suite measures just 63 mm by 43 mm by 12 mm, weighs less than 40 g, and uses power at an average rate of less than half a milliwatt. Its built-in sensors enable monitoring for corrosion activity, wetness, temperature and humidity.

Looking to the future, Wilson says, "With the current rate of progress we're making on developing these type of systems, we expect that automated health monitoring will soon become a common everyday reality for Defence fleet managers."

### Better sensors for corrosion monitoring

*In addition to improvements being made to data management capabilities, DSTO has also improved on the range of sensors available and their method of manufacture.*

*Fabrication of the DSTO-patented thin foil sensors – typically 10 mm by 15 mm in area, 120 microns thick, with features 20 to 150 microns in size – has moved to a more commercial basis using a batch manufacturing process to reduce production costs and increase product reliability.*

*Also, a novel thin wire corrosion sensor has been developed for monitoring long lengths such as along sealant beads, and large areas, such as over painted surfaces.*

*Both types of sensors can be mounted either on top of a structure, or under protective sealants or paints applied to the structure.*

*A particular feature of these sensors is that they can be fabricated from the same material as the structure being monitored. This means that the rate of corrosion on the sensor can be directly related to that occurring on the structure, unlike other sensors proposed for corrosion monitoring.*

*Sensor devices have been made from aluminium alloy, copper, titanium, gold, platinum and steel, and the technique is applicable to any metal foil.*



# Safe way to release stores in flight



The F/A-18 Hornet has the capacity to carry a wide range of devices, called stores, on external mounting points that enhance its capabilities in various ways. Many of these stores are intended for release during flight.

DSTO is providing research support to ensure that an aircraft carrying stores can be operated to its full potential, and that if released, stores can be deployed without risk to the crew or aircraft.

The types of stores being fitted to the F/A-18 include fuel tanks, targeting pods and weapons such as bombs, missiles and rockets. These are generally attached to the aircraft at locations called 'hard-points' along the wings and fuselage on suspension equipment specifically designed for their carriage, like pylons, racks and rails.

Stores vary in size, weight and shape, according to their capabilities and uses. Some stores may be powered by jet or rocket engines, while others are unpowered. Larger, more advanced stores can have multiple moving control surfaces, such as wings, canards and tail fins, and are directed in-flight by complex guidance and control systems.

The carriage of stores on an aircraft can considerably affect its flight behaviour in several ways, including how far and long it can fly, its manoeuvrability, and the airspeed, altitude and attitude at which it can be flown.

Furthermore, the release of stores during flight may pose a hazard to the aircraft and its crew if there is contact between the store and aircraft after release.

For these reasons, the Australian Defence Force (ADF) sees as essential the need to have a thorough understanding of a store's effect on an aircraft as well as the store's free-flight behaviour in order to establish that its use poses no risk.

## Dangers and drawbacks posed by stores

DSTO researcher Andrew Snowden says, "The pilot must be confident that if a store is released, it won't inadvertently collide with the aircraft.

"In instances where the clearance tolerances between stores are very small, safe release can be very difficult, and accurate store separation modelling becomes very important.

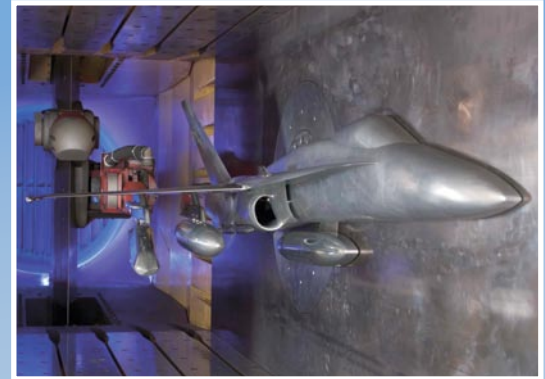
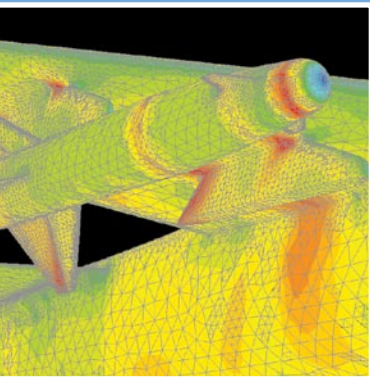
"It's also vital that the combination of stores and suspension equipment remaining on the aircraft don't compromise the aircraft's flight behaviour."

DSTO provides an Australian-based source of technical support and expertise to the ADF for managing these issues by undertaking research in disciplines such as stores clearance, vibration, aero-elasticity and aircraft loads.

This work is being carried out in close collaboration with the Aerospace Operational Support Group, the Aircraft Stores Compatibility Engineering (ASCEng) Squadron and the Aircraft Research and Development Unit (ARDU) of the RAAF.

DSTO's work on stores analysis has continued over many years on a range of aircraft types, with focus being placed more recently on F/A-18 operations.

*Above: F/A-18 carrying detachable fuel tanks and launch-deployed weapons.*



*Left: Fluid Dynamic modelling of airflow around F/A-18 fuselage with attached store. Centre: JDAM-ER store carried by F/A-18 during recent Woomera trials of the JDAM-ER device. Right: Scale model F/A-18 with mounted stores for study in DSTO's transonic wind tunnel.*

### Wind tunnel testing

In order to make decisions about the safety of carrying and releasing stores, detailed aerodynamic data must be gathered for the various store combinations to be used on the aircraft and the flight conditions likely to be flown.

One aspect of this work involves undertaking wind tunnel testing of highly accurate sub-scale models of the aircraft fitted with various stores. This testing is carried out in DSTO's transonic wind tunnel in Melbourne.

The ability to test these models at representative flight conditions at speeds up to Mach 1.4 allows DSTO scientists to investigate and quantify the aerodynamics of stores when attached to the aircraft.

It also enables the study of the stores behaviour, both in the vicinity of the aircraft and in free flight.

### Computational Fluid Dynamic modelling

This real-world experimental capability is complemented by computational fluid dynamics (CFD) modelling, whereby specialists use advanced computer models running on state-of-the-art hardware to predict the complex aerodynamics and flow physics around the aircraft and stores.

The aerodynamic information obtained from both the transonic wind tunnel and CFD modelling is integrated into a program called the DSTO release evaluation suite (DSTOres). The DSTOres program is used to predict the trajectory of the store during and after its release from the aircraft.

These trajectory predictions are reported to ASCEng, forming an important consideration in determining whether or not the store can be safely carried and released.

The certification process for qualifying a store for safe carriage and release usually involves extensive flight-testing. During this flight-testing phase, DSTO continues to work closely with ASCEng and ARDU.

### Flight testing

A further vital part of stores clearance involves flight testing to determine the safe operating limits for the aircraft carrying particular store combinations.

The effect of the additional mass of the stores on the aircraft coupled with the aerodynamic forces experienced by the aircraft in high-speed flight can induce oscillations, which, at particular frequencies, may lead to catastrophic structural failure.

Ground vibration testing, computer modelling and flutter flight testing investigation techniques are used to identify the circumstances under which such hazardous flight conditions occur, and which are therefore the conditions to be avoided.

DSTO also provides expertise in determining the aerodynamic loads caused by the carriage of stores for assessment of the likely impact this will have on the operational life of the fleet.

### F/A-18 stores clearance programs

Recent stores clearance programs carried out for the F/A-18 have included work on carriage and deployment of the Advanced Short Range Air-to-Air Missile, the Joint Direct Attack Munitions-Extended Range and the Joint Air-to-Surface Stand-off Missile (JASSM).

The integration of the jet-powered JASSM has required a significant research effort from DSTO due to the store's unconventional shape and relatively large size compared to the F/A-18, in addition to complexities arising from its deployable wings and tail fins.

By applying various experimental capabilities and CFD modelling together with extensive flight-test support, DSTO is undertaking to ensure that the JASSM weapon can be successfully added to ADF capabilities.

# Unmanned systems the way to go for maritime applications

Future advances in maritime capabilities will increasingly make use of unmanned sensor and vehicle systems launched from submarines. DSTO's concept *Murula* launch system is designed to deploy such systems from the torpedo tubes of Collins class submarines, thereby eliminating the need for costly and time-consuming modifications to the boats to provide this ability.



Australian Defence Force (ADF) planners have been looking at ways that commercially developed 'off-board' underwater sensor and unmanned vehicle systems, which are put to work untethered from the host vessel, can be used to enhance military capabilities.

One such area of operations where these technologies are seen to give a significant advantage is that of reconnaissance and surveillance.

Sensor and communications systems covertly deployed from a submarine into an operational zone can be used to collect environmental data in support of mission planning, or assist with information gathering during operations.

However, the design of the Collins class submarine places certain limitations on the deployment of these devices.

While the original Collins design allows for the underwater launching of certain types of signals and decoys, along with the standard-type armaments of torpedos and missiles, there is no such launch capability for the newer kinds of off-board systems currently being developed or being brought into service.

## *Murula* solution to launch problem

To understand how these technologies might impact on submarine capability, DSTO is developing a mechanism for deploying them from the submarine's torpedo tubes using a launch system called *Murula*.

*Murula* features a torpedo-shaped case into which various types of payloads can be fitted.

The launch case and payload are ejected from the torpedo tube in the same manner as a heavy weight torpedo. At an appropriate time and position, the payload is released from the launch case, after which, the *Murula* launch case either surfaces to be recovered, or is scuttled.

This approach potentially offers a way of quickly bringing into service a range of new devices and without the need to modify the submarine – thus enabling the submarine capability to exploit rapidly changing developments in payload technology.

According to DSTO researcher Joshua Rodgers, "*Murula* is expected to help us understand the potential for enhanced submarine capability using off-board systems such as autonomous vehicles and sensor systems."

## Two devices that can be launched by *Murula*

The *Murula* project is currently looking to demonstrate the feasibility of deploying two types of unmanned devices from a Collins class submarine; one named the Slocum Glider and the other, the Rapidly Deployable Sensor (RDS).

*Above: Murula launch case undergoing developmental testing.*

*Right and next page: Murula and Slocum Glider on show at Pacific 2008 in Sydney.*

The Slocum Glider is considered representative of the long-endurance, low observable unmanned underwater vehicles that are currently available commercially, and which are already in use by many organisations around the world.

As its name suggests, this device glides through the water in a 'saw tooth' vertical profile, using buoyancy control. It operates at depths between four and 200 metres, developing a salinity, and temperature profile of the water column during its mission. In addition, an acoustic sensor records the presence of marine traffic.

The glider can be programmed to periodically surface during its mission, allowing the user to connect to it via satellite for downloading sensor data, and to re-task the glider if priorities change. Typically the glider is deployed for periods of up to 30 days, in which time, it can travel up to 1,500 kilometres.

The RDS acoustic sensor array system being considered for deployment in *Murula*, also developed by DSTO, is representative of static surveillance system technologies that are emerging.

This RDS system, featuring new fibre optic technologies to minimise size and power usage, will be deployed from *Murula* on the seafloor by a small unmanned vehicle. Communications and power management systems fitted on board *Murula* will ensure the operation of the RDS system to collect and relay acoustic sensor data to ADF operatives.

Future launch payloads for *Murula* could also include various unmanned underwater vehicles, static maritime sensor and weapons systems as well as Special Forces and diver support payloads.

### Murula trials

The *Murula* project, which began in May 2007, has progressed rapidly towards the initial goal of demonstrating the deployment of a Slocum Glider from a Collins Class submarine in open ocean.

A trial carried out in May this year at HMAS Stirling in the Weapons Handling and Discharge Training Rig revealed that only minor changes were required to the *Murula* launch case for employment in a Collins Class submarine. Some further studies are required to ensure that the case can be safely ejected from a Collins Class submarine.

Future deployment trials of the Slocum Glider from the *Murula* launch case will be conducted in DSTO's new underwater test facility in Melbourne as well as at Corio Port in Geelong, for which, the *Murula* launch case will be integrated with DSTO's unmanned research vehicle *Wayamba*.

Work is currently under way to finalise the software and electronics for the *Murula* launch case, and is expected to reach completion before June next year.

DSTO aims to have the *Murula* launch case and Slocum Glider ready for a submarine demonstration in early to mid-2009, well ahead of the originally projected date of late 2010.

### Towards a one-size-fits-all launch capability

Additional studies are planned to investigate current and emerging underwater vehicle and sensor technologies to establish the correlations, if any, between physical characteristics, such as shape, size and weight, and their capabilities.

The purpose of the work is to establish an understanding of the likely physical characteristics of sensors that meet the requirements of ADF submarine operations.

These findings will allow for accurate prediction of the design margins necessary to ensure that the *Murula* launch capability remains viable under conditions in which both unmanned maritime device technologies and the ADF's needs are rapidly evolving.

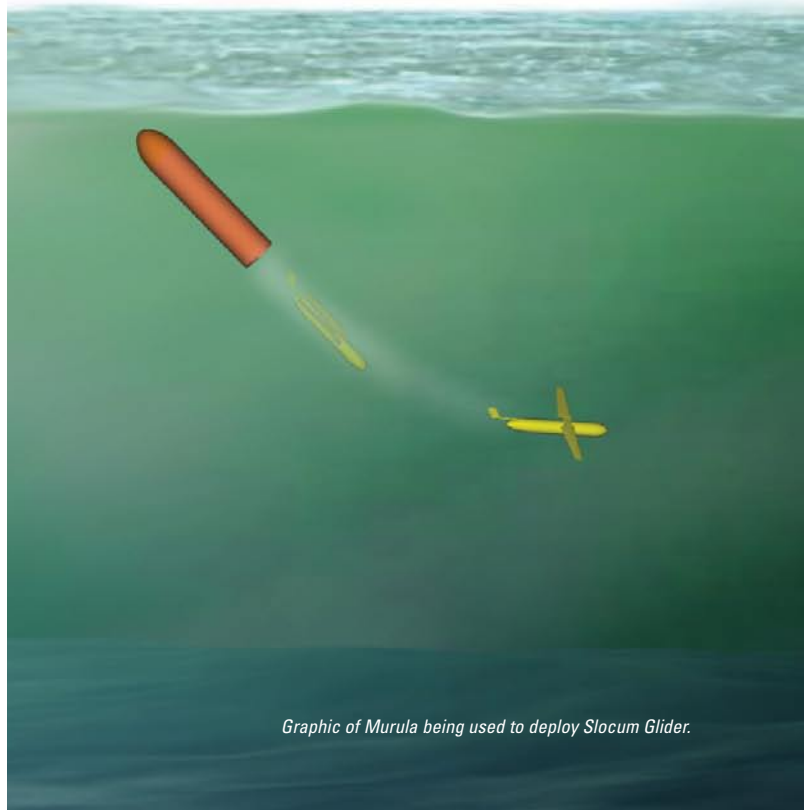
One of the assumptions involved here is that torpedo tubes will continue to be built into submarines for the ADF fleet as well as those of coalition partners.

By establishing a generic launch capability, the hope is that industry will design and develop future off-board systems with physical characteristics to suit, simplifying their integration into service.

"The challenge is to find out if the development of a generic standard is possible, and if so, what that might be. *Murula* is DSTO's first experiment with this in mind," says Rodgers.

Another part of the work is to investigate the adaptability of next-generation ADF submarines for deployment of such devices.

The aim is to establish ways of ensuring that future boat designs include appropriate physical, power and communications interfaces so that the submarine can exploit new deployable device technologies as they are developed over the life of the submarine.



Graphic of *Murula* being used to deploy Slocum Glider.

# Sensing shakiness for safer Sea King operations

DSTO has developed a simplified, cost-effective vibration analysis system to check the condition of engine drive shafts in Sea King helicopters

Navy currently operates a fleet of six Sea King helicopters, with the aircraft having been flown by 817 Squadron since 1975.

The helicopter has two Rolls Royce Gnome gas turbine engines that supply propulsive power through gearboxes to the main and tail rotors. The input drive shafts constitute critical parts of this drive train.

The effects of catastrophic drive shaft failure were made known to Navy several years ago during the flight of a Sea King on deployment in the Middle East when one engine unexpectedly shut down. The aircraft was nevertheless able to return to ship powered by its remaining engine.

A subsequent investigation found that the splines on one input drive shaft had sheared, bringing about automatic shutdown of the associated engine.

## The wider problem of spline fretting

Spline fretting was a known problem before this incident. The aircraft manufacturer, GKN Westland, had issued a bulletin recommending a fleet-wide once-only visual inspection of both sets of input driveshaft assembly splines – a difficult and time-consuming operation involving the removal of both engines and the input drive shaft assemblies.

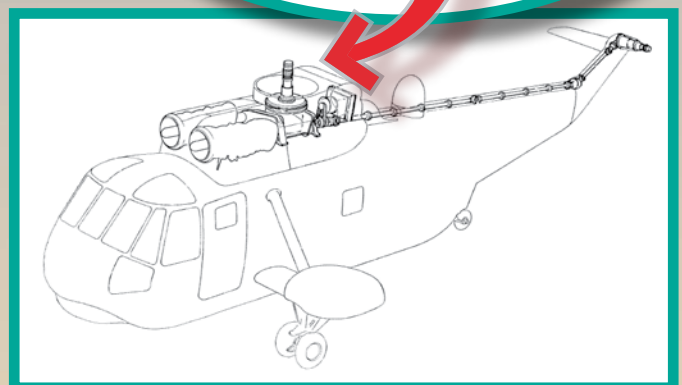
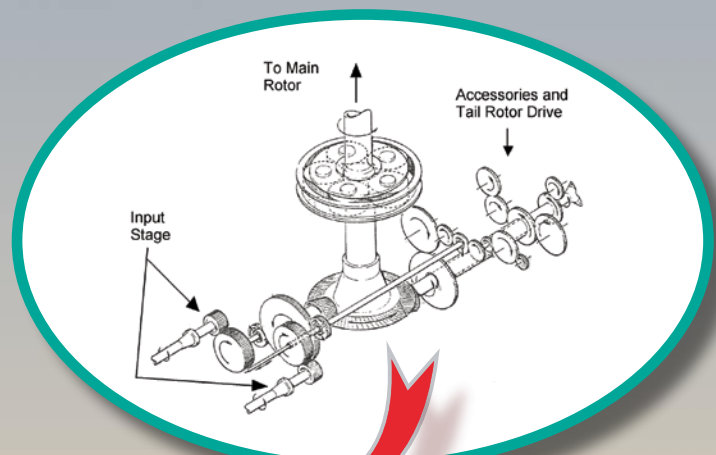
Navy technical advisers then issued a Special Technical Instruction that required this inspection process to be carried out for Navy's Sea Kings at intervals of 100 flying hours as an ongoing part of routine maintenance work.

Another method for detecting wear was also in use at the time. Called spectrometric oil analysis (SOA), it indicates possible problems by detecting iron particles in samples of gearbox oil created as a result of wear.

However, the SOA process was not considered robust enough to be relied on in place of visual inspection; the reason being that SOA depends on the flow of oil over a component to bring wear debris back to the gearbox sump where samples are taken for testing, and this may not occur if oil jets become blocked – as was thought to be happening in this instance.



*Navy Sea King helicopter in operation.*



*Schematic diagrams of Sea King drive train.*

### On-condition assessment system concept explored

Because the visual inspection process was seen to significantly impact on aircraft availability, the Naval Aviation System Program Office (NASPO) and DSTO decided to explore whether modern vibration analysis could dependably indicate when a visual inspection process was necessary, thus avoiding the need for routine checkups.

The work was undertaken at this point only to demonstrate the validity of the vibration analysis concept.

The Sea Kings had already been fitted with vibration sensors, cabling and junction boxes to enable vibration-related maintenance work on rotor track and balance functions, carried out using data gathering equipment temporarily brought on board.

The accelerometers used in this system were connected by cabling to a single multi-pin terminal in the aircraft cabin that facilitated recording of gearbox vibration data on a laptop computer mounted in the cabin as a 'carry on, carry off' item for the vibration checks.

The laptop was customised for the purpose by running DSTO software.

### Data analysis for spline wear detection

"While the process of collecting vibration data is generally relatively straightforward," says DSTO researcher Andy Becker, "the task of detecting deterioration in aircraft machinery using vibration analysis, however, can be notoriously difficult.

"Fortunately, DSTO has a great depth of expertise in advanced vibration analysis, and is considered to be a world leader in this field. Also assisting with the work, we at DSTO have an extensive knowledge of naval aviation operations not found elsewhere."

The method used by the DSTO researchers involved taking snapshots of synchronously averaged data from the entire fleet.

After analysing these data, the presence of an unusual vibration at the 7th order frequency was found to indicate that drive shaft deterioration had progressed beyond acceptable limits; a conclusion that was later confirmed with 100% certainty by visual inspections in cases where such vibration levels were experienced.

NASPO and DSTO then developed a method for assessing the health of the input shaft assembly in the field, which was further refined with input from 817 Squadron.

Although the DSTO system was only intended initially to be a concept demonstrator, the procedure has since been implemented as part of the standard maintenance regime for the Sea Kings.

As a result, seven input shaft assemblies to date have been identified by this means as needing inspection, all of which were found to have deteriorated beyond acceptable limits.

Meanwhile, no further failures of the input shaft assembly have occurred during operations.



Sea King input drive shafts, showing aftermath of spline shearing at top.

Four vibration analysis computers, supported by DSTO, are now deployed by Navy for the work. NASPO, having seen the value of modern vibration analysis technology, is currently planning to procure commercially available and supported equipment to sustain this important condition monitoring task.

### Less maintenance and more aircraft availability

The savings in maintenance time made possible by the on-condition check are considerable.

The new procedure, carried out every 50 flying hours, takes just four hours to complete – a mere tenth of that required for the previous visual inspection process every 100 flying hours.

Over the lifetime of the Sea King fleet, planned to be withdrawn from service in 2010, the on-condition check is estimated to produce net savings of 2,880 hours of maintenance time, with this same number of hours therefore being added to aircraft availability for operations.

These gains have been effected at an estimated cost of less than \$200,000, with 817 Squadron having fitted the equipment and undertaken the engineering needed for modifications.

Other investigations carried out by DSTO on the causes of input drive shaft spline failure plus damage sustained by bearings have found that the spline wear was caused by misalignment in the front and rear gear box housing structures that support the drive shafts, and that the damage to bearings resulted from blocked oil jets.

Oil filters with finer mesh are now being used to prevent oil jet blocking, and NASPO is currently looking at ways to address the input drive shaft misalignment problem.

# Tool for efficiently targeting surveillance data

The Analysts' Detection Support System (ADSS), being readied by DSTO and its development partners for military use and commercial release, harnesses a range of surveillance image analysis tools to detect targets of interest much more efficiently than by any other means.

The huge amount of data collected by wide-area surveillance systems these days poses a massive processing problem for analysts wanting to identify small force movements and placements, comprising a task well beyond the abilities of manual searches to manage.

Meanwhile, the various automated search assistant tools available only offer partial solutions, since these are typically applied to just small portions of imagery, and furthermore, the results they provide are only available well after the event.

The ADSS image processing application improves on this situation by undertaking analysis on the full size of wide area surveillance imagery and with the results delivered in real-time speed when required, presented as geographically registered targeting information suitable for operational use.

"ADSS is designed to cue analysts to likely target sightings contained in surveillance imagery," says DSTO researcher Dr Nick Redding.

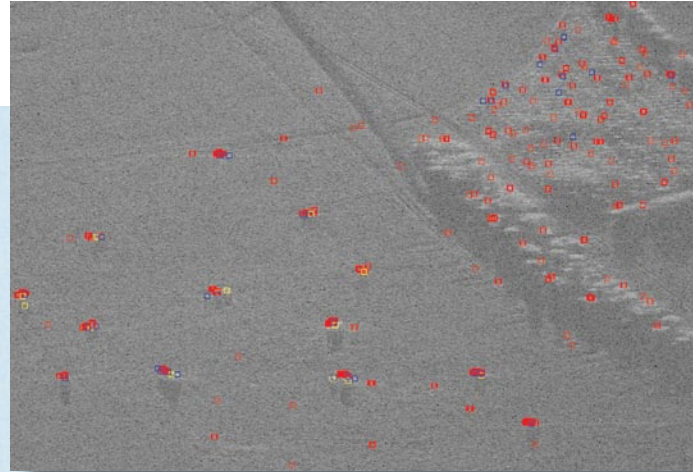
"The system is intended to supplement the information available to an image analyst. We see that the analyst will always need to make the final call on whether a sighting is in fact a suspected target."

## Versatile application made of many tools

ADSS consists of a suite of around 300 algorithms assembled into a hierarchical framework through which surveillance imagery can be examined in a variety of ways in order to produce findings on likely target locations.

The system is capable of processing imagery generated by synthetic aperture radar (including inverse synthetic aperture images), electro-optic and infrared camera systems, video, satellite and hyperspectral image sources and less conventional image sources such as Ground Moving Target Indicator radar.

ADSS supports the processing of a wide range of image file formats including JPEG, MPEG, GIF, TIFF, NITF and PGM in sizes as large as terabytes, and it can handle video streams in compressed and uncompressed formats.



The system output consists of cues on the surveillance image that designate the site of suspected targets. These cues can then be provided to an operator within the tools of their normal operating environment. In such a way, the system architecture enables its ready integration into larger information processing systems.

The system requires minimal operator involvement, with sensor data being collected unattended while analysis proceeds simultaneously. It can be run on a single computing processor or by an array of processors on a machine or network, thereby taking advantage of all available computing power.

Another advantageous system design feature of ADSS is that algorithms can be added in as required to enhance its capabilities.

DSTO is currently developing algorithms for improved video moving target indication, change detection, video surveillance, and maritime surveillance.

## High-speed analysis with low false alarms

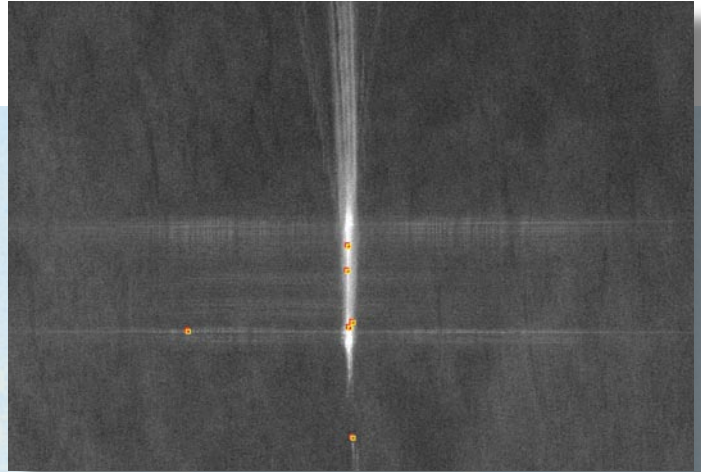
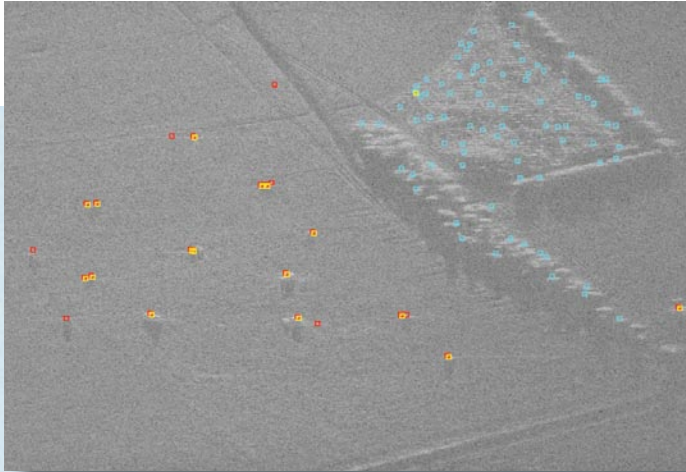
ADSS is able to deliver analysis in quick time with a lag of just a few minutes. It can also be used to provide real-time analysis when necessary.

The targeting data it provides has shown to be 'high-probability, low false alarm' in nature.

"Although automatic target detection algorithms don't miss much," says Dr Redding, "they do produce a lot of false positives. ADSS reduces the incidence of false target signals considerably.

"At the same time, imagery analysis is a very complex process, meaning that the ADSS resource needs to be adaptable to new imagery challenges.

"Addressing this need, the design of ADSS is such that if the first analysis result is poor, the system can be retrained using additional data to



improve on the previous result by applying automatic mixing and matching approaches from its large library of techniques. The process requires the input of human analyst experience to decide when a product is 'good enough'.

"This adaptive capability enables new analysis techniques to be refined and then reused when required – a significantly more useful outcome than having a fixed technique that simply fails on crucial but challenging images, leaving no fall-back position."

The advent of ADSS is seen to be very timely for Defence, having great potential for assisting with surveillance operations such as those involving border security.

The system is also seen to have considerable uses in the civilian domain, with potential applications including geological prospecting for hard minerals, environmental monitoring and medical image processing.

*Photos on previous page and this page: Surveillance images processed by ADSS revealing the location of suspected targets.*

### **The ADSS development process**

*ADSS was developed by DSTO in collaboration with the Defence Science and Technology Laboratory (Dstl) in the United Kingdom and the Defence Research and Development Canada (DRDC) in Canada.*

*The project began within DSTO in 1998 after the idea occurred to Dr Redding that instead of looking for a single perfect algorithm solution to the surveillance data sorting problem, a software framework could be created that drew together a number of partial solutions.*

*Dr Redding continued with the work at the former UK Defence Evaluation and Research Agency (DERA), now called Dstl, after being posted there in 2000. DERA had already developed a number of automated target detection and recognition algorithms over the course of many years and at a cost of many millions of pounds.*

*A formal collaboration was then established between DERA and DSTO in which the DERA algorithms were made available for*

*inclusion into the ADSS framework. The set of algorithms included in ADSS feature the best of those developed by DERA together with those developed by DSTO.*

*In 2003, a Dstl researcher was posted to Australia to work with DSTO on further development of ADSS, and a researcher from the Canadian DRDC has also spent time working in Australia on this project.*

*Recent work carried out by the collaboration has expanded the system to enable processing of a range of additional sensor data types, particularly video, with a capability to handle this media form in real time.*

*In a further development on the commercialisation front, DSTO this year signed a licensing agreement with Adelaide software development company, Sydac Pty Ltd, to market the Australian core of ADSS.*

# Monitoring a ship's health on dry land

DSTO is applying Condition Based Maintenance (CBM) technologies to more effectively protect Navy assets against the wear and tear of life at sea; a procedure that involves data transfer from ship to shore-based analysis facility.

The Royal Australian Navy (RAN), like many navies, has for many years followed the well-worn path of a mix of calendar-based and hours-based maintenance regimes for its assets, largely guided by Original Equipment Manufacturer specifications.

Meanwhile, over the last three decades, many such operators of large assets have been moving away from rigidly planned maintenance routines towards condition-based programs where the timing of maintenance work is much more flexible.

This shift reflects a growing acceptance of the logic that a maintenance program based on actual knowledge of real conditions rather than mere assumptions about them will be ultimately more effective, both in terms of reliability of asset operations and cost.

"CBM is, in essence, a data-driven decision-making process," says DSTO researcher Lloyd Hammond.

"The process of applying this approach involves not only collecting real-time data on an asset's condition, but also requires an understanding of its operating context as well as knowledge of failure histories and likely failure modes," he says.

The CBM approach is seen to be just one of a mix of available maintenance management strategies rather than an alternative to them, but at the same time, its use is increasingly relied upon.

## Anzac feasibility study for better data access

When RAN planners first came to consider the use of CBM for maintaining the Anzac class frigates, the vessel fit-out already featured an onboard control and monitoring (C&M) system with a network of nearly 3,500 alarms and sensors, but with no capability for real-time monitoring of condition data.

In light of this situation, a feasibility study was commissioned in 2005 by the Anzac Systems Program Office to look at ways of extending the Anzac's C&M system to accommodate a CBM approach. The study proposed an enhanced system design that would be capable of capturing all C&M data and making it available to a shore-based facility for review.



*Condition-Based Monitoring system apparatus mounted on board HMAS Ballarat.*

For the proposal to succeed, it necessitated the development of a systems interface unit (SIU) between the Anzac C&M system and an information technology Local Area Network (LAN), also onboard, called NAVSYSLAN.

A SIU was specifically designed and built by DSTO for this purpose. The device stores and then periodically forwards the C&M system data via satellite to the onshore Defence Restricted Network (DRN) where it is made available for interrogation by appropriate web-based software. The software for this analytical process is still in development by DSTO.

Meanwhile, naval contractor Siemens, maker of the Anzac's C&M system, was given the task of modifying the existing alarm monitoring software to enable the streaming of all the ship's C&M system sensor data from a Machinery Control Room workstation.

## CBM system testing

The SIU underwent preliminary testing earlier this year in a C&M system training facility at the Training Unit Anzac Ship Support Centre at HMAS Stirling, Western Australia.

This onshore facility was used for these initial trials to avoid disruption to Anzac operations.

Extended trials are now taking place at sea on HMAS Ballarat to evaluate the SIU hardware's capability to access, buffer and transfer data, and also the performance of the SIU's internal software that controls the collection and transfer of data from ship to shore.

DSTO recently successfully transmitted C&M data via satellite from HMAS Ballarat to the Defence Restricted Network, thereby providing, for the first time, remote access to data for a variety of maintenance analysis purposes.

Plans are in place to fit SIUs onboard more Anzac class ships in the near future, and it is envisaged that all the Anzac vessels will eventually be fitted with SIUs.

BRIEFS

Outstanding physics researcher appointed Chief Defence Scientist

**Professor Robert Clark** recently took on the role of Chief Defence Scientist at DSTO, marking the latest step in a highly distinguished career.

After ten years of RAN service, he pursued a growing interest in science that eventuated in research and teaching positions at the University of Oxford, being appointed Lecturer in Physics there in 1984.

In 1991, he returned to Australia to become Professor of Experimental Physics at the University of New South Wales, founding the National Magnet Laboratory and Semiconductor Nanofabrication Facility at the university.

In 2000, he also established the Australia Research Council (ARC) Special Research Centre for Quantum Computer Technology (now the ARC Centre of Excellence for same) and served as its Director till joining DSTO in October this year.

He has been much acclaimed for his work, having won the Australian Defence Medal and the Centenary Medal, plus the Australian government's Federation Fellowship on two occasions. In August, he was awarded the Eureka Prize for Leadership in Science for



his pioneering role in making Australia a world leader in nanotechnology and quantum computing.

Professor Clark's considerable expertise in these scientific fields has been harnessed by his appointment to numerous prestigious national and international research bodies.

REMUS shows the way for sea mine hunters

An unmanned underwater vehicle (UUV), called the REMUS 100, was put to work during recent trials carried out by DSTO at Jervis Bay to investigate its possible use in sea mine countermeasure operations.

Using standard procedures, clearance divers would locate a mine using hand-held sonar, then undertake to find it underwater and attach a marker buoy so that it could be raised to the surface for disposal.

When this task involves searching in cold and murky water – these being working conditions described in diver jargon as 'dull, dirty and

dangerous' – it may lead to diver 'burn out' for several divers before the mines are found.

The REMUS device, equipped with side scan sonar, is able to generate images and GPS information that help divers find mines much more quickly, with search time cut by up to half.

The greater part of the advantage REMUS was seen to offer is that its sonar imagery provided proof of what the targets were and exactly where they were located.

Quantitative Phase Imaging technology on target

Melbourne company latia Limited recently gave the final demonstration of a new optical imaging technology that allows images to be gained of objects concealed by camouflage, dust and smoke, and also determines how far distant the object is.

This research and development project has been undertaken over the past three years as part of DSTO's Capability and Technology Demonstrator program.

The technology exploits a property of light to convey information about the shape of objects. This can be used for imaging (via appropriate technology) even when information about shading and colour, the means by which the human eye perceives the world, is obscured.

During the demonstration at the Australian War Memorial, latia showed that its technology was able to form three-dimensional, grey-scale and artificially-coloured phase-based images of inconspicuous objects at ranges appropriate to Defence operations.

The technology was seen to be capable of defeating camouflage concealment and accurately determining the distance to targets from more than a kilometre away.

The presentation included a practical demonstration of the imaging system given outdoors in an adjacent park.

The demonstration was attended by about 30 people, including personnel from Army, Navy, the Defence Imagery and Geospatial Organisation and representatives from two international companies.



Quantitative phase images of face, with image on left colour-enhanced to highlight depth difference in features.

C A L E N D A R

- 17 - 19 Feb 2009 Artificial Intelligence and Applications  
Innsbruck, Austria  
<http://www.iasted.org/CONFERENCES/home-639.html>
- 17 - 19 Feb 2009 Signal Processing, Pattern Recognition and Applications  
Innsbruck, Austria  
<http://www.iasted.org/CONFERENCES/home-643.html>
- 10 - 15 Mar 2009 Avalon 2009 - Australian International Air Show  
Geelong, Victoria  
<http://www.airshow.net.au/avalon2009/index.html>
- 23 - 26 Mar 2009 Health and Usage Monitoring Systems 2009  
DSTO Fishermans Bend, Grand Hyatt Melbourne, Avalon Airport  
Victoria  
<http://www.dsto.defence.gov.au/HUMS2009/>
- 30 Jun-2 Jul 09 The Defence and Industry Conference and Expo  
Adelaide Convention Centre, South Australia  
<http://www.defenceandindustry.gov.au/>
- 6 - 8 Jul 2009 Wireless and Optical Communications  
Banff, Alberta, Canada  
<http://www.iasted.org/CONFERENCES/home-648.html>
- 6 - 8 Jul 2009 Antennas, Radar and Wave Propagation  
Banff, Alberta, Canada  
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- 13 - 15 Jul 2009 Visualisation, Imaging and Image Processing  
Cambridge, United Kingdom  
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- 17 - 19 Aug 2009 Signal and Image Processing  
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- 12 - 14 Oct 2009 Robotics, Telematics and Applications  
Beijing, China  
<http://www.iasted.org/CONFERENCES/home-661.html>
- 2 - 4 Nov 2009 Intelligent Systems and Control  
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