UNSW@ADFA
CANBERRA • AUSTRALIA

# Defence-related Research Grant Scheme 2009 Outcomes Report

## INTRODUCTION

UNSW@ADFA is the only national academic institution with an integrated defence focus, excelling in defence-related security and engineering research and supported by the Defence and Security Applications Research Centre. The 2009 Times Higher Education Supplement's World University Rankings published in the UK ranked UNSW 33rd out of the top 100 technology universities, and 47th overall. UNSW@ADFA is acutely aware that undertaking top-quality research is essential to providing the best possible education to the Australian Defence Force. The Defence-related Research Grant Scheme was established in 2006 to provide seed funding to academic staff to pursue defence-related research and to further promote research collaboration between UNSW@ADFA and Defence. The results of the 2006, 2007 and 2008 projects are summarized in the respective Outcomes Reports.

Project proposals under this funding scheme are assessed by the Faculty Research Grants Committee which makes recommendations to the Defence-related Research Advisory Committee for approval. The membership of the Defence-related Research Advisory Committee comprises equal representation from UNSW@ADFA and the Australian Defence Force. This report encapsulates the highlights and achievements of the research projects funded under this scheme in 2009.

## OUTCOMES

A total funding of $100,000 was allocated to seven projects across all four schools: Business (SBUS); Engineering and Information Technology (SEIT); Humanities and Social Sciences (HASS); and Physical, Environmental and Mathematical Sciences (PEMS). Two journal articles and ten conference papers have already been published from this research. In addition to the 12 chief investigators, the projects involved a research associate, two PhD students and a number of undergraduate students. Two projects entailed collaboration with the Defence Science and Technology Organisation (DSTO).

The projects, which are summarized below, illustrate the wide range of research fields which have defence relevance, from communications engineering to chemistry and political science. Prof Frater's undersea communications work represents a research response to a clear technical defence need as does Prof Morozov's work on ballistic composite materials, whereas Dr Liow's project on microdevices for liquid or gas identification has more to do with the security end of defence operations. A/Prof Markowski is using economic analysis to assess the future threat to stability in the Asia-Pacific from increasing regional defence spending, whereas Dr Zhang seeks to understand the Chinese naval build-up from a political science perspective. Dr O'Byrne's application of laser spectroscopy techniques to vehicle exhausts may have a range of defence applications related to aircraft signatures, but also to engine health, whether military or civilian. Finally, Dr Wallace continues her work on explosive manufacture and wastewater remediation, topics which remain of clear defence relevance.

## PROJECT SUMMARIES

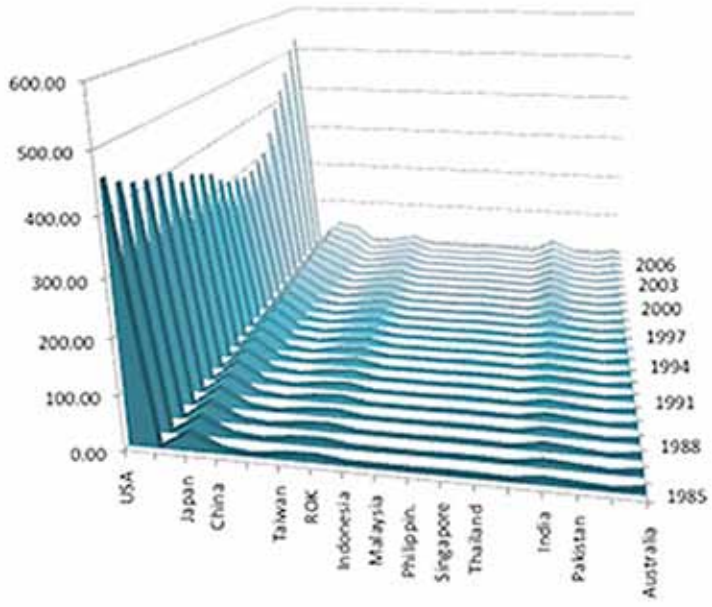
### Defence expenditure, spill-ins and threats in the Asia-Pacific

**A/Prof Stefan Markowski**

At the turn of the century, the Asia-Pacific accounted for about a quarter of global military expenditure. While military spending in other parts of the world declined or grew slowly in the 1990s and the 2000s, it surged in the Asia-Pacific. This surge has been accompanied by concerns about an incipient arms race.

This project explores the growth of and interdependencies ('spill-ins') between the military spending of different countries in the Asia-Pacific region during the period 1985-2007 to determine whether the observed surge in defence spending is a reflection of the region's increased prosperity, changing perceptions of military threats, or growing aspirations to project power within and beyond the region. The project's scope has been restricted to conventional ('symmetric') security concerns posed by states rather than 'asymmetric' threats associated with terrorism, domestic insurgency, illicit small arms, and the like.

Preliminary findings show little evidence of a regional expenditure race, i.e., no action-reaction driven escalation in regional defence spending. The surge of military spending in the region has largely been associated with its strong economic performance over the past two decades. And despite the surge, the 'burden of defence', measured as the share of military spending in real GDP, remains relatively light for most countries. However, while many countries have had their particular reasons for increasing defence spending, the overall build-up, disposition and increased lethality of military capabilities in the region pose a growing threat for its future stability.




The changing landscape of defence expenditure in the Asia-Pacific and USA 1985-2007 (US$ billion, 2000 prices)

# Project Summaries

## Development of a low-cost, omni-directional projector for high capacity underwater acoustic communication networks

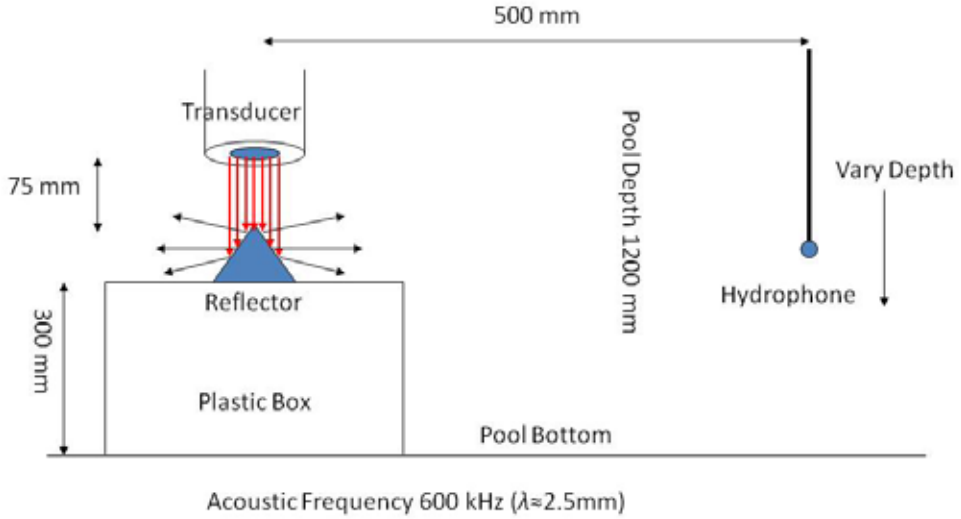
**Prof Michael Frater, Dr Michael Ryan, Dr Craig Benson**

Acoustic communications systems are commonly used for underwater communications. Alternatives such as optical and electromagnetic communications have significant limitations that preclude their use in many applications. Electromagnetic signals have only very short range in sea water, and their usefulness is further reduced by the small bandwidth available. Optical communications systems require very precise pointing of transmitters, and tend not to be effective in turbid water.

Future Defence maritime operations will require the support of a high-density, high-capacity underwater acoustic network. A key barrier to the development of such a network is the difficulty of manufacturing omni-directional acoustic projectors to operate at high frequencies. Standard high-frequency acoustic projectors have very narrow beams, which require very accurate pointing to communicate between two nodes in a network. In most defence applications, this pointing is not practical, and omni-directional projectors are required, particularly in mobile networks. In this project, the team developed a prototype projector system, in which the narrow beam from a conventional high-frequency projector is broadened using a reflector. This process is illustrated in the figure.

The performance of the system has been validated by theory, simulation and measurement, including ocean testing.

A new indoor test facility for underwater networks has also been constructed. The ability to make accurate measurements in a controlled environment will support further development of high-frequency omni-directional reflectors.




Prototype projector system

## Micro-device for optical detection of compounds

**Dr Jong-Leng Liow**

Spectrometry is an invaluable tool in the laboratory for the accurate identification of compounds. However, current laboratory spectrometers are large, heavy machines that are unsuitable for use in the field. This project exploits new developments in mechanical micro-end mill machining to construct a micro-spectrophotometer. The aim is to develop a highly portable micro-device that can be used to analyse fluids with minimal hardware or energy source backup.

The device consists of three major components: the pump, the flow and analysis section, and the optical detection section. Layering of the material for machining of the flow and analysis section has been made possible by a spin-coater purchased with the funds from this grant. Work on the sealing of the device has identified two viable means of securing a leak-tight seal. One involves the use of polydimethyl sulfoxide (PDMS) with high voltage activation, and the other uses polymethylmethacrylate (PMMA) via monomer polymerisation. The optical detection section uses a grating to produce a spectrum that is then captured with a CCD (Charge-coupled Device) sensor. On-board image-capture electronics enable the image to be downloaded through a USB connection ; the colour image is then analysed to produce the characteristic spectrum of the compound.

Further work is currently being carried out to incorporate an on-board micro-pump using ionic polymers running on low voltages.

The outcome will be a portable micro-spectrophotometer that can be plugged into a netbook through the USB cable, enabling results to be readily available for use or transmission.

Micro-milling facility in the microfluidics laboratory

## China's expanding maritime interests and naval modernisation: implications for Australia

**Dr Jian Zhang**

China is in the process of transforming itself from a continental power to a maritime power in the Asia-Pacific region. In recent years, maritime security issues and naval development have assumed an unprecedented prominence in China's national strategic thinking and its program of defence modernization. This project set out to examine China's expanding maritime interests and naval modernisation and their impacts on Australia's national security and defence planning. In particular, it addressed two interrelated questions: what are the strategic intentions and domestic political factors behind China's recent naval modernisation at a time when Beijing is trying to project the image of a peaceful and responsible power? How will the emergence of an increasingly sea-power-minded China affect Australia's maritime security interests?

Through extensive archival research and interviews with Chinese scholars from both government think-tanks and universities, the research identified a number of factors which are shaping China's maritime strategy. One is that China's rise as a trading power brings with it a need to secure its sea lanes of communication. The recent deployment of Chinese warships in the Gulf of Aden is an example of this. Another factor is the series of running territorial disputes with South-east Asian countries over islands in the South China Sea and with Japan in the East China Sea. Yet another major driver of the naval build-up is the rising nationalist sentiment inside China.

Beijing wishes to protect its expanding maritime interests. The very rise in Chinese naval power, however, renders the regional maritime security environment unstable, which makes it more difficult for Beijing to do this. Beijing also seeks to promote itself as a responsible stakeholder in regional security, and here it faces the twin challenges of reducing external suspicions of China's growing sea power, and managing the influence of rising domestic nationalism on China's maritime strategy. The research also finds that concerns over the strategic uncertainties caused by China's expanding naval power have profoundly shaped Australia's defence planning for the coming decades, and that both countries should seek greater cooperation in regional maritime security affairs.

## Innovative design of a composite, flexible, multi-layered, bullet-resistant ballistic panel for body armour

**Prof Evgeny Morozov and Dr Krishna Shankar**

With Australian troops deployed in dangerous theatres such as Afghanistan, force protection is one of the highest Defence priorities. There is a great need for body armour which will resist a high-velocity bullet, but is light and comfortable to wear. Many-layered composite materials show great promise in this regard, but with large numbers of parameters, there are many research questions to be answered. One of those questions is whether sticking the different layers of the material together increases the energy absorption of the material or not. The more bonding between layers, the more heavy and rigid the final material, and the more it will impede the freedom of movement of the wearer.

'Finite element modelling' is a tool frequently used in engineering where there are many interdependent variables involved. In this study, a finite element model was developed to simulate the impact response of rigid composite panels with fixed edges, and the results were validated by experimental testing. Further experimental impact testing was performed on composite panels with free edges mounted on a modelling clay (Roma Plastilina) foundation. Different lay-up configurations were tested: fully bonded, fully unbonded and hybrid lay-ups with only some of the glass fabric layers adhesively bonded. The impact testing was performed using a drop tower instrumented with a velocity sensor, a load cell and an accelerometer (see figure). The panels were subjected to impact loads at various levels of energy.

At all energy levels tested, the energy absorbed per unit mass was highest for the fully unbonded lay-up. More significantly, the hybrid laminates, in which 8 layers of bonded glass fabric were sandwiched between two sets of 8 layers of dry fabric, exhibited higher energy absorption than the conventional fully bonded rigid panels. These are positive indications for the feasibility of using these materials for body armour.

The numerical modelling is currently being extended to high-velocity impact simulation to study the response of various lay-up configurations to ballistic impact. Experimental facilities are also being developed for high-velocity impact testing of clay-mounted, hybrid lay-ups of fibre-reinforced composite laminates.

Set-up for impact testing

# Project Summaries

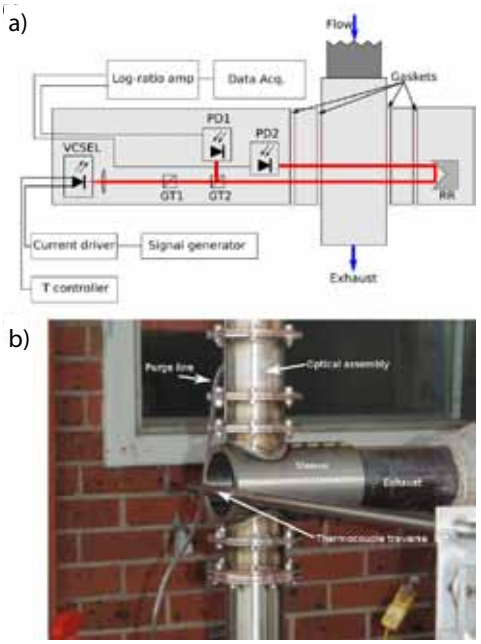
## Water vapour temperature and concentration measurements at the exit of a military combustion test facility

**Dr Sean O'Byrne and Dr Nigel Smith (DSTO)**

This project set out to test the feasibility of building a sensor which can measure the temperature of water vapour in the exhaust of a combustion engine without impeding the exhaust flow. Determining the exhaust temperature is important for monitoring engine health and could potentially be used to determine the infrared signature of the exhaust gases. The aim is to develop reliable, non-intrusive gas sensors which can be applied to measure temperatures and concentrations of important combustion gases in fields such as automotive pollution detection and in hostile environments such as industrial furnaces and aircraft engines. Non-intrusive sensors are particularly important in high-speed engines where probe sensors can cause large-scale flow disturbances.

The experiments were performed at a facility at DSTO, Fisherman's Bend, which simulated the exhaust of a Chinook helicopter. Temperatures in the range of 300 to 600 degrees Celsius were measured at rates in excess of 100 measurements per second, using the absorption of light from a small laser diode module. Light was passed twice through the flow and the total absorption was measured as the laser wavelength was scanned across a water vapour absorption feature. Since the absorption spectrum varies according to temperature, the temperature can be inferred by fitting the absorption spectrum to calculated spectra at known temperatures: the closest fit to the measured absorption spectrum gives the best estimate of the average gas temperature along the laser beam path. The resulting temperature estimates were directly compared with temperatures measured using a thermocouple traversed through the exhaust flow. Agreement between the two measurements was good at lower temperatures but worsened at the higher temperatures, most likely because the measurement sensitivity decreases with increasing temperature.

The results showed that it is possible to build an absorption sensor that is rugged enough to operate at gas temperatures of up to 600 degrees Celsius for measurement periods of more than 10 minutes, with no adverse effect on the measurement system. This is a lot hotter than the exhaust of a passenger car, but only about half as hot as that of an aircraft jet engine. The results of this work have been presented at the American Institute of Aeronautics, at the Aerospace Sciences Conference in Orlando, Florida and at the Australian Combustion Symposium in Brisbane.




a) diagram and b) photograph of the experimental rig

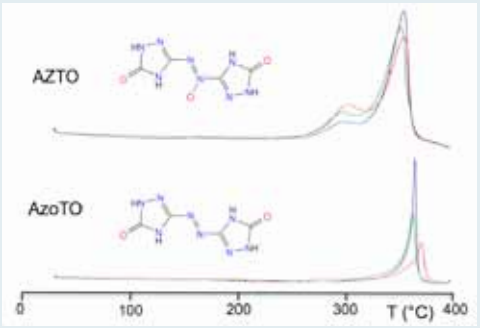
## Environmentally friendly methods for the synthesis of novel high-nitrogen compounds and remediation of wastewater from explosives manufacture

**Dr Lynne Wallace and Dr Anthony Day**

In defence agencies worldwide, there is a move towards replacing conventional explosives with insensitive high explosives (IHE), which retain high performance but are less sensitive to accidental initiation, and are thus safer to use. Two new explosive compounds have been discovered at UNSW@ADFA in the course of investigating the electrochemical treatment of the wastewater generated from the manufacture of NTO, an existing IHE. These new compounds are 'azoxytriazolone' (AZTO) and 'azotriazolone' (azoTO). Their synthesis from wastewater is a real bonus.

Explosive testing of AZTO and azoTO was carried out at DSTO Edinburgh courtesy of Mr Craig Wall and Dr Arthur Provatas. Both compounds behave as low-to-medium power, insensitive high explosives (IHE) with exceptional thermal stability. The team's work in 2009 has shown that AZTO is more powerful than azoTO as expected from its chemical structure, and that while azoTO has even greater thermal stability than AZTO, it is more sensitive to electrostatic discharge. The electrolytic reaction mechanism has now been fully elucidated, and the effect of cell conditions on product distribution is well understood.

The results have further shown that in the synthesis of AZTO, concomitant formation of azoTO cannot be completely eliminated, but the explosive testing indicates that AZTO sensitivity and performance are not significantly compromised by small amounts (2-15%) of azoTO. Finally, these studies have identified two more possible products of NTO electrolysis, hydrazotriazolone and aminotriazolone, which might also have application in energetic formulations. In particular, salts of aminotriazolone have the potential to act as nitrogenous ionic liquids for use as desensitising and performance-enhancing agents in propellant mixtures.




Differential scanning calorimetry of AZTO and azoTO samples

The University of New South Wales
at the Australian Defence Force Academy
Canberra ACT 2600
Tel: +61 2 6268 8111

www.unsw.adfa.edu.au
CRICOS Provider Code 00100G
ETS 11766 September 2010