Forensic and Data Centres – science in support of policing

'There are no such things as applied sciences, only application of science,'
Louis Pasteur, French chemist and biologist, 1822-1895

The National Manager of AFP Forensic and Data Centres, Dr James Robertson, speaks to *Platypus* about science futures for the AFP.

"In the forensic world we look to use fundamental science to answer questions of interest to the justice system, and in more recent times, in the security space," Dr James Robertson said.

Forensic science has evolved from a relatively obscure scientific specialisation to a mainstream, accessible and feel-good science for the public. The AFP is committed to ensuring high quality outcomes in policing and criminal justice for the Australian community.

The Forensic and Data Centres portfolio consists of three areas dedicated to strong research and development that contributes to the success of AFP operational and intelligence efforts. These three areas are Forensic Operations, Business Support, and the Data Centres: including the Australian Bomb Data Centre, the Australian Chemical, Biological, Radiological and Nuclear Data Centre (CBRN), and Forensics Drug Support.

More than 260 scientific staff contribute to the many projects within the Forensic and Data Centres portfolio. Under Dr Robertson's leadership, the portfolio has grown significantly and has developed a number of national and international strategic relationships with academic partners, major research organisations and law enforcement agencies. In contrast, 20 years ago only 60 officers across Australia made up the 'forensic team'.

Dr James Robertson, National Manager of AFP Forensic and Data Centres

Photo: Mel Hill

"In 1985, when I arrived in Australia from Scotland, the forensic academic scene was pretty much non-existent," Dr Robertson said. "In fact, there were no vocational training programs and university courses to educate students in forensics."

Dr Robertson worked for the Forensic Science Centre in South Australia for five years and in 1989 joined the AFP to head up the forensic services team. Since that time, he has worked hard to evolve the role of the team, grow the research and development capability of the AFP, and drive the development of forensic education programs in Australia.

The Coordinator of the AFP's Laboratory services Simon Walsh says that the honorary degree of Doctor of the University awarded to Dr Robertson by the University of Canberra (UC) for his outstanding contribution to higher education, demonstrates how highly respected he is in the science and law enforcement community.

"It is one of the highest honors a person can receive in academia," Mr Walsh said. "His aspiration for his work has never ceased to amaze me. He is one of a few professionals I know that not only manages a large centre of specialised staff, but also takes the time to research specific projects and actively work in the laboratory with his colleagues, meet with undergraduate and postgraduate students to discuss their careers, attend meetings and conferences around the globe, chair a range of government and university committees and groups, and maintain currency and a proactive contribution to operational forensic science."

When *Platypus* interviewed Dr Robertson he was adamant that this article should reflect the work being produced by his staff, who are making intelligent use of the opportunities provided by technology, industry engagement and relevant research and development.

"We have some terrific staff with a mix of high level skills, and quite a few pursuing

further studies," Dr Robertson said. "In the past 10 years or so, our members have received awards from varying science organisations and universities for their contribution to the advancement of forensic and technical science in a law enforcement capacity."

Forensic and Data Centres scientists are pursuing any number of interesting and complex issues that encompass recovery of fingerprints from banknotes, the use of cutting edge technology including Raman spectroscopy in the analysis of paint, fibre and explosives, and the challenges being faced with the admissibility of electronic evidence in technology-enabled crimes. As difficult as the task was, *Platypus* selected three scientists to represent the diversity of skills and knowledge being applied in forensic science.■

Photo: Mel Hill

Building a capital of knowledge in the Capital

From tertiary qualifications to post graduate qualifications at MSc or PhD level, AFP scientific staff are encouraged to create, innovate and ensure that the community benefits from science.

The future of forensic DNA testing

Simon Walsh is highly regarded by Australian and International forensic practitioners for his research into Deoxyribonucleic acid, commonly known as DNA. Dr Robertson is pleased that Mr Walsh, who is currently an Adjunct Lecturer at the UC, has joined Forensic Operations and is leading the Laboratory Services team. Mr Walsh is equally pleased to be there as he believes he has joined a strong culture where scientists and practitioners are encouraged to excel and innovate in research and training.

"I joined the AFP in late 2006 after working and teaching in the fields of forensic biology," Mr Walsh said. "The AFP was, and continues to be, recognised as a driving force in the forensic world. The opportunity to work on such diverse investigations, which are not necessarily encountered in other organisations, was the attraction for me to make the switch."

There are 39 members in the Laboratory Services team who provide a range of services including biological and chemical criminalistics. The main focus for the biological criminalistics team has been to develop and improve the sampling and testing of forensic DNA since its revolutionary emergence in the late 1980s.

Mr Walsh said that in the past two years he and his student Ms Runa Daniel, who is undertaking a PhD at the University of Technology Sydney (UTS), have been working on a project exploring novel techniques that will allow scientists to ask additional questions from DNA beyond the standard 'who is it'.

"One of the more routine and robust analytical technology used by the forensic industry in identification testing is based on 'short tandem repeats' or for short, STRs," Mr Walsh said. "Put simply – a method used to resolve the identity of the donor of a particular sample of biological evidence."

"Ms Daniel and I have been able to explore beyond the question of identification of the source, and look at other characteristics of the DNA such as hair, eye, and skin pigmentation," he said.

This new technique, single nucleotide polymorphisms - known as SNPs (pronounced 'snips'), is being investigated for use in two main areas of forensic – identification and intelligence.

Mr Walsh also explained that SNPs can be used to trace a person's ancestry and the characteristics of a concentrated group.

"As the DNA is passed on through family lineages we get patterns of DNA within communities and populations," Mr Walsh said. "These patterns show more similarity to other members in that group than they do to people who are from other countries or populations. This means that parts of the DNA of a person can be representative of the population or community that they descended from."

In routine cases, completing STR analysis on items of evidence can take a minimum of two weeks. This is mainly due to the extent of quality checking that is required during and after the analysis. SNP typing is not by nature any quicker. However, as it will be used for intelligence rather than evidence, the objective is to develop procedures that produce a SNP DNA result very quickly so that it can feed back into the investigation.

"While this research is still on-going, the technique was used in the Madrid train bombing investigation in March 2004," he said. "Spanish forensic scientists were able to assist in the identification of the perpetrators by excluding certain nationalities and identifying a group of Spanish and Moroccan profiles, based on the biological evidence left at the crime scene."

"While the AFP did not attend this incident, it has been able to collaborate with a group known as SNPforID Consortium to share information on testings and interpretations," Mr Walsh said. "This group is made up of scientists from the UK, Europe and the USA and has led the international forensic effort in this highly specialised area.

In March this year, Mr Walsh and Ms Daniel received an award for Best Literature Review Paper 2006-2007 from the National Institute of Forensic Science, for their paper *The Continuing Evolution of Forensic DNA Profiling – from STRs to SNPs*. The full version can be found in the *Australian Journal of Forensic Sciences, 38:59-74, 2006*.

The team also participates in other research projects with academic and research agencies that are funded through the grants schemes offered by the Australian Research Council (ARC) and National Security Science and Technology Unit (NSSTU).

"The research is difficult and many forensic personnel dedicate much of their own time to participate in addition to their daily operational duties," Mr Walsh said. "The forensic science community in Australia is made up of people who genuinely love their work and want to use their skills to make a difference in the criminal justice system. The staff at AFP forensic is no different."

Age is no barrier

In December 2007, AFP member Elizabeth Brooks graduated at the age of 53 with a Masters of Applied Science. While some people at this age are contemplating early retirement, Ms Brooks is not one of them.

Photo: Mel Hill

Ms Brooks is a forensic biologist with more than 25 years experience, including eight years with the AFP. She currently works in the Biological Criminalistics team. Ms Brooks is an example of the type of practitioner Dr Robertson is keen to keep in the AFP as an integral part of the AFP's knowledge capital.

"Developing people is essential and education is an obvious starting point for building capacity regardless of age," Dr Robertson said. "Ms Brooks has demonstrated her ability beyond her practical experience and through the AFP's support has successfully completed her masters, built on her skills and continues to impart her knowledge to up-and-coming science graduates."

Ms Brooks acknowledges that biology is hard work and requires dedication. However that has not deterred her, and she enjoys all aspects of the work from studying ants and probing insect guts, to the capture, examination and analysis of hair features.

"I was a technician practising entomology for 25 years at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and circumstances at the time combined with a redundancy package made me look elsewhere to pursue my interest in biology," Ms Brooks said. "It's such a rewarding and diverse field, and since joining the AFP, I've had opportunities that would have never been available previously."

In 2003, Ms Brooks approached Dr Robertson to pursue further studies in the analysis of hair and capturing of images, as there was a lack of hair examiners at that time. The quality, innovation and potential of the possible research outcomes attracted Forensic and Data Centres to support her studies.

"The benefits were two-fold. Initially, undertaking masters by research allowed the implementation of high-quality and fully focused images of hair. This had not been possible previously due to the physical nature of hair samples. The images themselves formed the base materials on which the rest of the research revolved," Ms Brooks said.

Based on images from brown-haired subjects, two means of quantifying hair evidence using digital imaging and image analysis were developed. The quantification involved the analysis of images by internationally recognised colour models and pigment pattern analysis. Ms Brooks also explained that this method allowed the development of an objective measure of hair analysis that would support the hair examiner's microscopy-based decision.

"This application is the first accurate numerical means of supporting a comparative hair examiner's decision," Ms Brooks said. "And there are few scientists who would disagree with both the need and desirability of objective measures of their results."

The second benefit for Ms Brooks was the training in advanced hair examination that she and others received from Dr Robertson.

"Dr Robertson was the only hair examiner in Australia at one point and it was a significant commitment on his part to expand our knowledge and skills base," Ms Brooks said.

In 2006, Ms Brooks was one of two recipients awarded the Michael Duffy Travel Fellowship by the National Institute of Forensic Science (NIFS). The fellowship provided Ms Brooks with the opportunity to travel to the United States, United Kingdom and Europe in June 2007 and present the outcomes of her research on the use of numerical features in the forensic examination of hair.

During this trip Ms Brooks presented at the 8th Multinational Congress on Microscopy held in Prague, Czech Republic. Ms Brooks said that the value of being able to visit forensic facilities, meet hair examiners and academics in the forensic sciences and train forensic faculty staff in the new techniques, could not be overstated.

"During my visit I was able to establish a network of like-minded practitioners who were enthusiastic about hair examination. Positive feedback on new techniques developed indicated a level of acceptance by other scientists and in turn, validated the provision of resources by the AFP to enable research in this field," Ms Brooks said.

In November last year, Ms Brooks reported to NIFS on the outcomes achieved through her research and the benefits for the AFP and the broader science community. One such outcome has since enabled the AFP to collaborate with the University of West Virginia in the USA on a joint project focused on the development of a hair database for use by the forensic community.

Ms Brook's papers are due to be published in the *Australian Journal of Forensic Sciences* later this year: *Digital imaging and image analysis for numerical analysis of a comparative biological science: colour and pigmentation of human hair. Part I, Discussion of the methods involved and Part II: Presentation of results*. An abstract of Part I follows this article.

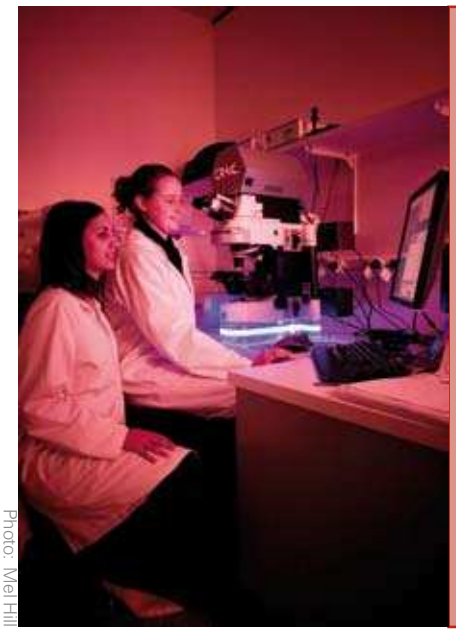

Photo: Mel Hill

Too hot to handle

Occupational health and safety is always a serious issue for any organisation and even more so in a forensic laboratory. Ms Serena Abbondante's role is to make sure that forensic evidence is not 'too hot to handle'.

Ms Abbondante (far left) is a member of the Radiological Intelligence team in the CBRN Data Centre and her role is to provide technical advice and intelligence on prevention, preparedness and response issues relating to the illicit use of radiological and nuclear materials.

Dr Robertson says that Ms Abbondante's techniques in cleaning up contaminated biological material are novel and this type of creative thinking reflects the next generation of scientists coming out of Australian academia.

"Ms Abbondante is one of our younger graduates who joined the AFP on a full-time basis at the beginning of this year," Dr Robertson said. "During her studies she volunteered to work with us and as a result of her area of studies, we were able to sponsor her while she collaborated with an industry partner on a ground-breaking project."

While undertaking postgraduate studies at the UC from 2005 to 2007, Ms Abbondante was supported by the Australian Institute of Nuclear Science and Engineering (AINSE) based in Lucas Heights. Her studies focused on forensic analysis procedures for radiologically contaminated biological evidence, a counter terrorism initiative. Through a collaboration with the UC and the Australian Nuclear Science and Technology Organisation (ANSTO), the AFP provided Ms Abbondante use of its laboratories to support her research with ANSTO scientist David Hill.

In September 2007, ANSTO announced via its online magazine *Velocity* that 'world-first counter terrorism research at ANSTO has discovered a new method to safely decontaminate radioactive DNA and preserve the sample ... The technique has been proved and adopted by law enforcement agencies in the United Kingdom, the United States, Canada and Singapore ... "The technique can be used in the analysis of crime scene evidence after the terrorist use of a 'dirty bomb', where radioactive materials are dispersed with the aid of explosives, or possibly for use in intelligence gathering at clandestine laboratories where manufacture of these devices take place," Ms Abbondante said.'

In November 2007, Ms Abbondante was invited by AINSE to present her paper, *Radiologically contaminated evidence: extraction procedures and the effect of radioactive materials on forensic DNA profiling*, at the 15th Australian Conference on Nuclear and Complementary Techniques of Analysis and 9th Vacuum Society of Australia Congress, held at the University of Melbourne.

The Institute recognised Ms Abbondante's contribution to nuclear science and engineering and awarded her with the Best Student Presentation in an Open Category Prize for her work.

Ms Abbondante says she has always had an interest in science and was grateful for the opportunity which the AFP provided her so early in her career.

"I consider myself to be very fortunate that Dr Robertson was so open to meeting a second year student and providing work experience in the biology team in Forensics and Technical while completing my degree," she said. "That opportunity has since opened many doors and I would certainly encourage younger students to consider science as a rewarding career."

Strategic partnerships with academia and industry

Training for the future

In 1985, there were no training and education programs on forensic science in Australia. Nearly 25 years later there are more than 90 courses offered at the vocational and academic level.

On receiving his Doctor of the University, Dr Robertson spoke to the UC's *Monitor Online* and said he was honored to receive the degree and be recognised for his contribution to higher education.

"I have been associated with the University of Canberra since the 1990's, and this relationship with the University will certainly continue with the increased interest in forensic studies at an academic level and with the history of partnership between the forensic studies centre and the AFP. Together we will continue to build momentum in the field of forensic studies in Australia", said Dr Robertson.

As part of that momentum, a Memorandum of Agreement was signed between the AFP, the Canberra Institute of Technology (CIT), and the UC to formally establish the National Centre of Forensic Studies (NCFS). This partnership demonstrates a unified commitment to forensic science education, training and research for the benefit of students, law enforcement personnel and forensic scientists.

Deputy Commissioner Tony Negus signed the agreement on behalf of the AFP saying:

"This centre will make a vital contribution to solving crime in Australia by providing investigators with the latest skills in the field. It will also enhance our national security by helping our neighbours to develop rigorous forensic programs of their own and address crime and terrorism in our region."

Dr Chris Lennard, who previously worked for the AFP as the Coordinator of Laboratory Services and Manager of the then Forensic Operations Support, is the new Director of the NCFS. Dr Chris Lennard is also Professor of Forensic Studies at the UC and he is the External Scientific Advisor for the AFP's forensic science research program.

The aim of the NCFS is to develop and deliver enhanced education, training and research opportunities for the benefit of the partner agencies and the wider forensic science community," Dr Lennard said.

As part of the NCFS initiative, a forensic science laboratory has been established at the UC as a teaching and research facility. The AFP has provided analytical equipment on loan to the university to assist in establishing this facility. The facility is able to provide backup support for the main AFP forensic laboratory if additional capacity is required.

Five Indonesian forensic biologists studied at the university in 2007. The four-week training program was delivered by members of the AFP, UC and CIT. A similar training program will be conducted this year for six Thai forensic biologists. These training initiatives form an important part of the AFP's regional capacity building program.

Research in the national interest

Dr Robertson believes it is essential that organisations engage in, and support, relevant research and development.

"We have a very strong program of industry engagement with a number of academic partners and increasingly with Australia's major research organisations – Commonwealth Scientific and Industrial Research Organisation, Defence Science and Technology Organisation, Australian Nuclear Science and Technology Organisation and Geosciences Australia," he said.

Dr Robertson is a member of the steering committee for the Publicly funded Agencies' Collaborative Counter Terrorism (PACCT) research program which is chaired by Prime Minister and Cabinet (PM&C) and brings together the Defence Science and Technology Organisation, CSIRO, ANSTO and Geoscience Australia to further work on counter terrorism related projects within their existing resources.

"This program ensures that these agencies are allocating appropriate funding into areas that have been identified as a research priority for Australia," Dr Robertson said.

During 2006–07, PACCT agencies commissioned research projects in the areas of nuclear forensics, radiological modelling and situational awareness, threat assessment methodologies and improved cargo and luggage scanning technologies. It also developed research requirements for current and future counter terrorism research programs.

The AFP has partnered with several academic and research agencies that have received grants through the Counter-Terrorism program run the by the NSST of PM&C.

ARC is also another government agency which provides funding through its National Competitive Grants Programs.

In 2007, four projects were granted $1.5 million from the ARC Linkages program to advance the use of forensic science as a law enforcement tool. The funding will allow Forensic and Data Centres staff to work with academics in a long-term strategic research alliance.

Turning heads – forensic experts gaining recognition in law enforcement

"... Forensic science and investigation have become a central part of the criminal investigation process and of the justice system. Through the huge popularity of the media and television programs such as CSI, the microscope has been turned on forensic science in a much more public way. Forensic science has contributed to both the failures of the justice system and to its successes. The role of forensic science in correcting miscarriages of justice is well documented ..."

Opening address by Interpol Secretary General Ronald K Noble, 23 October 2007

In late October 2007, Dr Robertson, the Manager of Forensic Operations, Paul Reedy, and the Director of NIFS, Tony Raymond, represented Australia at the 15th International Forensic Science Symposium in Lyon, France. More than 170 forensic scientists, investigators and researchers from 55 countries attended the four-day symposium.

The symposium convenes to discuss and present advances made in scientific methods since the last meeting, to explore future forensic needs, facilitate the exchange of information, and share ideas for future progress.

Dr Robertson chaired the organising committee for this 15th symposium. He

Opposite page: ACT Attorney General and Police Minister Simon Corbell at a forensic demonstration during the launch of the National Centre for Forensic Studies in August 2007; CIT Chief Executive Dr Colin Adrian, Dr Chris Lennard, UC Vice-Chancellor Stephen Parker, Minister Corbell, AFP Deputy Commissioner Tony Negus and Dr James Robertson at NCFS launch; VC Parker, DC Negus and Dr Adrian signing a Memorandum of Agreement.

Below: Forensic Crime Scene Case used in the 1970s to analyse ink on documents. Right: AFP DNA Mouth Swab Kit and DVI Volunteer authorisation form to collect DNA used in identification of victims in the 2002 Bali bombings

Photos courtesy of AFP Museum

explained that a number of countries take turns in collating the latest information on research and developments in their country.

"Nearly 900 pages of reviews are then produced and distributed. In today's world, most managers are finding it challenging to keep up with the latest literature and this instant summation is a fantastic shared resource," Dr Robertson said.

During the 15th symposium, an historic agreement was signed for the creation of the International Forensic Strategic Alliance (IFSA), which brings together forensic scientists and laboratories from the Americas, Asia-Pacific region and Europe.

Future of forensic science

For the first time in Australia, the effectiveness of forensic science in the criminal justice system will be examined.

In March 2008, the University of Tasmania, in collaboration with the Victoria Police and the AFP, was granted with $700,000 from the ARC Linkages project scheme. As part of this project, researchers will examine the impact of science on policing in Victoria and the ACT, both in the early stages of an investigation and in securing court convictions. Dr Robertson says that one of the key questions in forensic science is how to measure its contribution to the whole justice system.

"We think we do a terrific job and know where to invest our resources," Dr Robertson said. "But it is one area that has not been measured from an academic perspective. We are not social scientists and this project will provide us with a better understanding of the return on investment and where we may need to put the research dollars to produce more effective forensic support."

Dr Robertson was also keen to point out that forensic science is not a substitute for police investigation but should rather be thought of as a key support.

"While it is almost inconceivable today that forensic science will not be a part of any major investigation," Dr Robertson said. "It is important to keep a realistic view of what forensic science can and cannot do. With the emerging young, and not so young talent in the AFP's Forensic and Data Centres group, the future for investigations and the AFP is in good hands."

Photo: Alex Kirkham

On June 19, the spotlight was on the AFP's Forensic and Data Centres members when the ABC's science program *Catalyst* aired a special half-hour episode on forensic in Australia.

The National Manager for Forensic and Data Centres, Dr James Robertson, was pleased when *Catalyst* researcher Dr Holly Trueman approached the AFP late last year through a recommendation from the National Measurement Institute (NMI). The science program and its producers wanted to explore the relationship between the AFP and the NMI in drug analysis capabilities for the show's 2008 season.

Dr Trueman and the *Catalyst* team had been looking at a series of stories that would examine issues related to Australia's security. The stories would complement the theme with an episode

Photos courtesy: *Catalyst*

Above left: *Catalyst* reporter Maryanne Demasi with Detective Sergeant Nick Read on the beach at Lorne, Victoria; Above right: In the Sydney based Crime Scene National Laboratory.

on the role of science in protecting Australia from illegal drug importation.

Dr Robertson said that the AFP, through its media team, had previously worked on stories with *Catalyst* and agreed it was an excellent opportunity to showcase the high-level of scientific qualifications and expertise within the AFP's Forensic team.

"The show's researchers were aware of the importance of organisations like the AFP and NMI sharing skills and data in the analysis and tracing of narcotics being smuggled into Australia and the linking of drug importations by their chemical signature, "Dr Robertson said.

For the past 15 years, the AFP has been working with scientific and research organisations, such as the US Drug Enforcement Administration, to develop chemical profiling techniques that assist in identifying the geographic origin of drug crops. In addition, scientific techniques have provided invaluable intelligence to investigators about trafficking routes and the trademark of drug syndicates.

A number of high-profile cases conducted by the AFP, and in collaboration with the NMI and overseas agencies, provided a platform from which *Catalyst* could showcase forensic and policing successes.

AFP Media personnel liaised with Coordinator of Forensic Drug Support (FDS) Ian Evans in the AFP's Sydney office and he identified that the 2004 Operations *Junglefowl* and *Daedal* were ideal case studies to reflect the role forensic had in shaping policing investigations.

Media Officer Alex Kirkham said the media team reviewed the files for each case and prepared a synopsis of how the events unfolded.

"With the help of Juuso Huttenen of FDS and Federal Agent Todd Peachey of the Sydney based Crime Scene National Laboratory, we accessed photos, briefs and files from each case," Ms Kirkham said. "It was a fascinating process and both cases highlighted how diverse the role can be in forensic investigations."

In *Operation Daedal*, the offenders had used a 'scatter' importation via the mail system and openly sent hundreds of 10 gram parcels of cocaine from Canada to different post office boxes throughout Melbourne.

Forensics investigators were able to intercept the letters, test the substance in the laboratory and link all the cocaine to the same source by its chemical signature. This research provided necessary intelligence to assist investigators pursue the investigation.

Operation Junglefowl was a very different case. Smugglers used a Brazilian merchant ship, the *MV Marcos Dias*, to offload more than 100 kilograms of cocaine powder which was then buried in sports bags in the bush near the Albany Port facility. During the operation, forensic investigators were required to do a preliminary identification of the drugs using field testing kits and provide their findings to investigators.

This was a significant seizure for the AFP and according to the Crime Commission's report on *Cocaine in 2004-2005*, 'this single shipment represented 52 per cent of the weight of cocaine detected in the year'.

In January this year, Dr Robertson, NMI's Dr Michael Collins and Communications Manager of Science, Yen Heng met with *Catalyst* producer Paul Schneller and Dr Trueman and it was agreed that in addition to the two cases, *Operation Sorbet* would also be profiled.

Operation Sorbet was an investigation by the AFP and Victoria Police into the attempted landing of 125 kilos of heroin in Victoria from the North Korean freighter the *Pong Su*. Dr Robertson said that from a forensic perspective the case was quite unique.

"Our scientists were able to see a new variety of heroin that fell outside the chemical parameters of anything they had seen before," Dr Robertson said.

The *Catalyst* program will feature a range of AFP members who were involved in the cases and highlight the intrinsic role forensic science play when contributing to policing investigations and protecting Australian shores.

The *Catalyst* program forensic special aired on 19 June at 8.30pm on ABCTV1.

Abstract, *THE APPLICATION OF DIGITAL IMAGING AND IMAGE ANALYSIS TO THE NUMERICAL FEATURES OF HAIR IN FORENSIC HAIR EXAMINATION*, 2008

Elizabeth M Brooks, Ian McNaught and James Robertson

The advent of nuclear DNA (nuDNA) analysis altered the way forensic biology was both practised and viewed by the forensic biologists, police, the legal system and the general public. The ability of nuDNA to individualise analysis of evidence and attach a statistical frequency ratio to the result, created an expectation that numerical objectivity should be part of all forensic analysis. There are few scientists who would disagree with both the need and desirability of objective measures of their results. Forensic hair examiners are no exception as indicated by numerous scientific publications specifically discussing means of objectively assessing hair and its characteristics. While mitochondrial DNA offers a partially objective measure of hair, the result is destructive of the sample. A method that objectively supports the hair analysts' microscopic findings and is non destructive would be beneficial to forensic hair examination. This project attempted to develop an objective measure of hair analysis by using both traditional light microscopic comparative techniques combined with a high end digital imaging and image analysis capacity.

Where objectivity equals an empirical set of numbers that can be manipulated for statistical significance, the comparative biological sciences such as histology, anthropology and forensic hair examination struggle. Forensic hair examiners have long acknowledged the difficulty, even inability, of assigning numerical values to the features that characterise one hair as being different from another. The human scalp hair is a 'morphological' unit that is not readily split into component parts or even that these parts lend themselves to a number value. There have been at least nine separate studies which favourably compare the specificity of microscopic hair examinations. The challenge this study addressed was to appraise the use of numerical features in forensic hair examination, with particular emphasis on those features currently resisting numerical evaluation; specifically, colour and pigmentary characteristics.

The techniques used were based on obtaining high quality digital images, and using the pixels inherent in the images to obtain numerical values of such features as colour and pigmentation. The project sample was taken from the telogen scalp hairs obtained from the hairbrushes of ten nominally brown haired Caucasians, both male and female. The focus was twofold:

- Compare colour analysis of hair images from brown haired Caucasians within three standard, internationally recognized colour models, namely Red-Green-Blue (RGB) colour model; CIE XYZ Tristimulus (1931) colour model; and CIE L*a*b* (1976) colour model.
- Using the same sets of digital images, undertake pattern recognition analysis both intra and inter individual hair samples.

Discriminate analysis of the mean colour values collected for each of the inherent colour variables in the three colour models (red, green, blue; X, Y, Z and L*, a*, b*) indicated the RGB colour model gave the least separation of brown haired individuals; CIE XYZ and CIE L*a*b* separated several individuals for all their individual samples and several other individuals were mostly separated with only one of their own samples overlapping with another.

Pattern analysis used a small area that represented the overall pigment patterning observed along the length of the hair shaft. This area was extracted from the digital image within V++ Digital Optics image analysis software. The extracted pattern piece was then compared with other sample images within the same hair and four other hairs from the same individual. Pattern extracts were also compared between person hair samples. The comparisons generated a set of numerical values based on the pixel number on the 'x' axis of the whole image and the average difference between the extracted pattern image and the whole image. Analysis of this data resulted in log distributions when persons were matched with themselves. It was also possible to refer an unknown pattern extract to this distribution and based on probabilities, predict as to whether or not the unknown sample fell within any of the known sample's distribution.