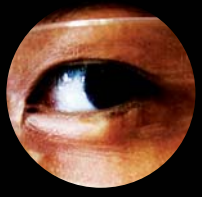
UNVEILING
THE FACE OF PROGRESS



Abstract

The deadly use of chemical agents in unconventional warfare and terrorist attacks needs no introduction.

With one of the highest geographic densities in the world, such an attack in Singapore will be destructive. The possibility of such an attack cannot be underestimated, and Singapore must be ready to deter and defend herself from this threat.

As Singapore's national defence research and development organisation, DSO National Laboratories (DSO) has been building up chemical defence capabilities since 1989.

This commemorative magazine is a celebration of the 20th anniversary of chemical defence research in DSO, and provides a rare insight into the programme's tribulations and triumphs over the past two decades.

DSO'S CHEMICAL DEFENCE PROGRAMME 20TH ANNIVERSARY

CONTENTS

Foreword

In 1972, Singapore's first defence science laboratory was born. Named as the Electronics Test Centre (ETC), it was staffed with just a small team of engineers and scientists. ETC grew and evolved over the years. Today it is known as DSO National Laboratories and is recognised as Singapore's premier and largest R&D organisation, with more than 1000 scientists and engineers.

The establishment and development of DSO's chemical defence programme shares a similar history. It began in 1989, against the backdrop of increased use of chemical weapons in conflicts.

Fresh from the university, the first few scientists recruited into the programme faced tremendous challenges in the early years. Facilities were very basic, information was scarce, and expertise was virtually non-existent. Against this was also the very toxic nature of chemical agents.

Armed with youthful enthusiasm, excellent scientific training and a strong dedication to the mission, they put their heart and soul into chemical defence research.

Over the past 20 years, this pioneering spirit continues to drive our scientists as they develop deep competencies in chemical defence, and establish a credible chemical defence capability benchmarked against international standards.

This commemorative magazine is a tribute to these people and their inspiring journey. Unveiled for the first time, the collection of stories brings to life the passion of our scientists, engineers and technologists, whose dedication and tenacity have made a difference to the security of our country.

Indeed, at the heart of this capability, lies our people.

As we mark the 20th anniversary of the chemical defence programme, it is timely that we reflect upon the pioneering spirit of our people that has brought us here, the generous friendship of our collaborators who have helped us so much, and the unwavering support of our partners who have given us the time and space to develop.

DSO's chemical defence programme has come a long way since its humble beginning 20 years ago. However our mission has not changed. We remain resolved to develop the capability to protect our country from the threats of chemical agents.

Sincerely,

Mr Quek Gim Pew
Chief Executive Officer
DSO National Laboratories

"This commemorative magazine is a tribute to these people and their inspiring journey. Unveiled for the first time, the collection of stories brings to life the passion of our scientists, engineers and technologists, whose dedication and tenacity have made a difference to the security of our country."

Message

BRACING FOR THE UNEXPECTED

Over the last 20 years, global perspectives on Chemical-Biological (CB) defence have been shaped by three defining series of events.

The first event took place in the late 80s when Saddam Hussein used chemical weapons during the Iran-Iraq War. Then in the early 90s, the chemical defence preparedness of US-led coalition forces and the Israeli populace were put to the test during Desert Storm, when he fired Scud missiles assessed to be capable of carrying chemical payloads. This first series of events were stark reminders to the world that though chemical weapons had not been used for several decades, they could still pose a threat in modern warfare.

The second series of events can be traced to the Tokyo subway sarin gas attack in 1995, 9/11 itself and the various anthrax powder incidents in the US in the aftermath of 9/11. These events awoke the world to the possibility of terrorists or other non-state parties possessing CB weapons and Radiological Dispersal Devices (RDDs), or *dirty bomb*, for use as weapons of mass disruption.

The third defining series of events were marked by the SARS outbreak in 2003 and the recent H1N1 flu outbreak. Though they were acts of nature, their rapid spread, global reach and multi-faceted impact showed how disruptive novel infectious diseases, regardless of whether they are man-made or otherwise, could be on various sectors beyond security such as public health, the economy, education, transportation and tourism.

It was Saddam Hussein's use of chemical weapons in the late 80s that prompted us to embark on our journey to build up our own chemical defence capability 20 years ago. When we set out on this journey, we could not have foreseen the subsequent defining events. Yet, whether it is in the OPCW inter-laboratory proficiency tests, screening suspicious anthrax specimens or in combating the SARS and H1N1 viruses, we have shown that we could quickly adapt and made commendable contributions each time we were called upon. Why have we been able to do so?

I think it is because we have in the CBRE Programme in DSO a very committed group of professionals who believe passionately in what they are doing, and are always looking for ways to stretch themselves to deepen and broaden their expertise, and to collaborate with others. Over the years, the group has also forged excellent partnerships with potential users in the CBRE and medical communities in the SAF, as well as with other agencies and institutions involved with national security, civil defence and public health in Singapore. I believe it is these same ingredients which will enable the CBRE group to seize opportunities to build new capabilities, remain relevant, and cope well with the more complex and uncertain security environment that we now operate in. We can expect the unexpected to continue to pop up over the next two decades as they did over the last two. Though we do not know what will be the defining CBRE events between now and 2029, when the CBRE programme celebrates its 40th Anniversary, we hope to look back and once again say that we have done well in coping with the surprises of the preceding two decades.

The DSO CBRE programme has done well in its first two decades, and has made significant contributions to our defence and security. I wish the programme well in the next lap of its journey, and in rising to the challenges of the next two decades.

Mr Quek Tong Boon
Chief Defence Scientist and Chief Research and Technology Officer
MINDEF

"The DSO CBRE programme has done well in its first two decades, and has made significant contributions to our defence and security. I wish the programme well in the next lap of its journey, and in rising to the challenges of the next two decades."

Introduction

DSO's chemical defence programme was established in 1989. It was a time when chemical defence work was taboo science, and little information on chemical warfare agents was available in the public sphere. The early years in building up the programme were challenging times. It was equipped with nothing more than a basic chemistry lab, staffed by a consultant and a handful of scientists, fresh from their postgraduate studies. They were keen to make a difference, but had little knowledge of chemical warfare agents.

The team decided to focus on the fundamentals and began their research using simulants. Four key thrusts were defined for the programme, namely in the areas of Decontamination, Physical Protection, Analysis of Chemical Warfare Agents and Research in Simulants. The Applied Chemical Laboratory (ACL) was eventually established in DSO to house Singapore's first chemical defence programme.

In the early 1990s, ACL was able to jumpstart its capability development, as it forged its first overseas collaboration. The team was given the opportunity to visit FOI*, Sweden's National Defence Research Establishment, where it had dedicated laboratories capable of handling chemical warfare agents.

The team was also able to observe the stringent safety protocols and procedures in place. The collaboration eventually paved the way for the first training attachment of ACL's scientists in FOI.

Over the next few years, ACL continued to eagerly pursue overseas collaborations and gradually developed its competencies, and was able to contribute significantly in international research collaborations.

In 1998, ACL was relocated to new premises which provided state-of-the-art facilities for its R&D work. It also paved the way for the growth of the Biological Defence programme in DSO. As part of DSO's corporate restructuring, ACL was renamed the Centre for Chemical Defence (CCD) in 1999.

The new millennium marked a new renaissance, as the Centre was recognised as the de facto national agency for chemical defence research. It was able to play out its national role when its Biosafety Level 3 (BSL3) facility was identified as the only portal of entry to test suspicious samples during the Anthrax scare, following the tremulous period of 9/11. In 2003, during the Severe Acute Respiratory Syndrome (SARS) epidemic, DSO joined the Singapore SARS Clinical Consortium. The Centre actively participated in the clinical processing of samples.

CCD eventually achieved its first chemical agent synthesis, and also received the prestigious status as a designated verification laboratory by the Organisation for the Prohibition of Chemical Weapons (OPCW).

In 2003, CCD merged with the Defence Medical Research Institute (DMRI) to establish the Defence Medical and Environmental Research Institute (DMERI) in DSO. Today, the chemical defence programme in DMERI continues to play a critical role in enhancing the nation's chemical defence capabilities.

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*Since 2001, FOA, the National Defence Research Establishment in Sweden, has merged with FFA, the Aeronautical Research Institute to become FOI.

The Pioneers

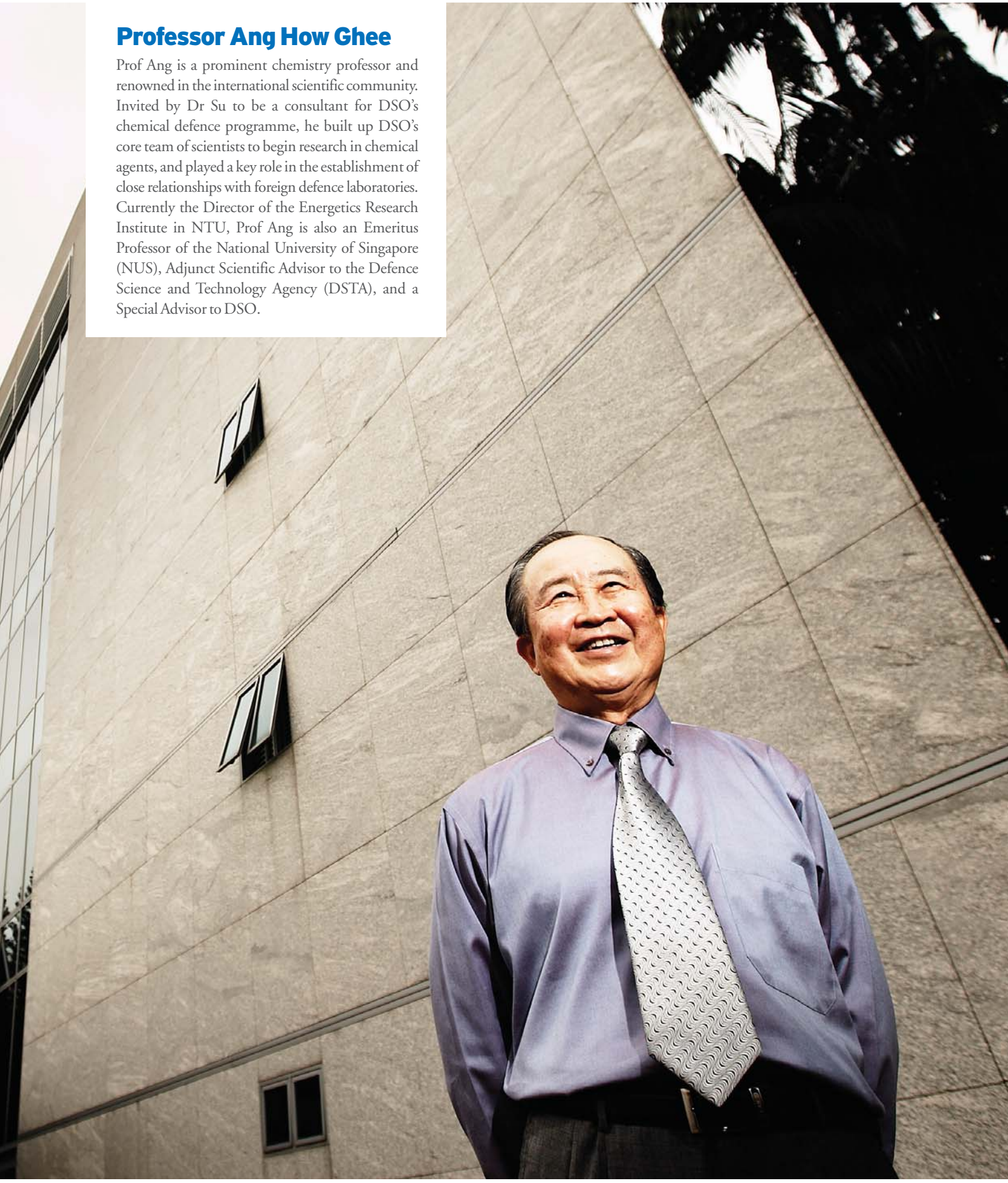
In their different but definitive capacities, they played an instrumental role in the early years of DSO's chemical defence programme. The achievements of today are a testament to their pioneering spirit. They have witnessed the trials and tribulations of the programme, and these memories remain poignant twenty years later, as they share their journey on how it all first began.

Dr Su Guaning

In 1983, Dr Su was appointed the Deputy Director of DSO. He later assumed full directorship in 1986, and was credited for leading the organisation into a new, research-oriented phase. Dr Su went on to hold several leadership appointments within the defence technology community before assuming his current appointment as the President of the Nanyang Technological University (NTU), Singapore.

Professor Ang How Ghee

Prof Ang is a prominent chemistry professor and renowned in the international scientific community. Invited by Dr Su to be a consultant for DSO's chemical defence programme, he built up DSO's core team of scientists to begin research in chemical agents, and played a key role in the establishment of close relationships with foreign defence laboratories. Currently the Director of the Energetics Research Institute in NTU, Prof Ang is also an Emeritus Professor of the National University of Singapore (NUS), Adjunct Scientific Advisor to the Defence Science and Technology Agency (DSTA), and a Special Advisor to DSO.



Dr Lee Fook Kay

Dr Lee was a PhD student under Prof Ang's mentorship. He was encouraged to join DSO's chemical defence programme by his father, so that he could make a meaningful contribution to the nation. In 1989, he joined DSO and was subsequently appointed the laboratory head for ACL and then, Head for CCD. After spending 17 years in DSO, he assumed the appointment of Chief Science and Technology Officer in the Ministry of Home Affairs, where he continues to contribute to national security in the homefront arena.

Mr Ho Kong Wai

COL (NS) Ho Kong Wai was one of two pioneer SAF officers sent overseas to train and acquire knowledge about chemical defence. He spearheaded the SAF's first chemical defence unit in 1993 and was its commanding Officer from 1996 to 1997. In 2002, COL (NS) Ho established the SAF Chemical, Biological, Radiological and Explosives (CBRE) Defence Group and was its first Commander. He left the SAF in Sep 2007 to set up the CBRE Force Protection Technology Group in the Defence Science & Technology Agency (DSTA). He is also appointed as the Subject Matter Expert (SME) for CBRE Force Protection Technology in DSTA.

STRAIGHT TALK

Dr Su Guaning
- The Director

You were the Director of DSO when the chemical defence programme was borne in 1989. Can you share with us why the programme was established in the first place?

The programme naturally had to be in DSO as we were the official defence R&D establishment for the Ministry of Defence (MINDEF). It got started when Saddam Hussein attacked his own people using chemical agents. During the Gulf War, the United States Army was very worried about the use of chemical agents against its troops. Analysing what was happening in the Gulf War, the Singapore Armed Forces (SAF) tried to take lessons from there. The SAF realised it could not be sure if Singapore's defence was adequate in this area. In other words, if somebody tried to attack us with chemical weapons, can we defend ourselves fully? Do we have sufficient knowledge of chemical agents and its related issues? We had absolutely no knowledge at that point in time. In fact, I would say, chemical defence was almost non-existent in DSO then.

So there was a need to develop further capabilities in this area? Who was entrusted with this task then?

There was an engineer in DSO named Kua Soo Hock who was in the guided systems programme, and he was tasked to develop the chemical defence programme. He began by gathering a few technical people, I suppose engineers at the time. In those days, we did not have many people who were knowledgeable in chemistry. They started doing some open literature searches in chemical agents, but after a while, it became difficult not knowing what to do next. His team collected all those pieces of open literature, but how did these information lead to improving the security of our armed forces? How could the SAF better defend Singapore against a possible chemical attack? I don't think we had the right people working on the problem then.

It must have been a difficult start. How did we move forward?

I think things really started taking off only after we were able to engage Prof Ang How Ghee. Prior to him, the initial team assigned to this task was concerned because they did not have a basic understanding of chemical agents. Naturally, they were afraid of handling any agents, afraid of getting things started, and even afraid of proposing things. After some time, the initial group dispersed and some people left to focus on other things. On the other hand, Prof Ang and his group of PhD students in NUS were working on fluorine chemistry then, which was quite dangerous. He was a very

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meticulous person and he trained all his students very well. His students knew exactly how to handle things. When you start from the fundamental, you are able do everything yourself and slowly gain the confidence. His group of students was quite fearless because they knew what they were doing. And we needed people with that kind of mentality to come into DSO.

After getting the right people, what was the next crucial step?
After we engaged Prof Ang as a consultant, his student, Fook Kay came in as the programme's first scientist. We were finally starting to get somewhere. I remembered one of the early things we had to do was starting up the laboratory. But everybody in DSO was concerned where this laboratory should be. Nobody wanted to be near it. There was an available space just next to my office, on the 4th storey of the building. As the director, I had to lead by example and show that I had faith in the team and trusted them. I remembered many people being rather apprehensive and asking questions like "Why are these people located next to us?" People were also worried about chemical agents leaking through the ventilation systems, so we had to create something separate. Of course, nothing happened, so after a period of time, everybody was okay with the laboratory being housed in the building. It was certainly quite interesting in those days.

What were the key challenges in starting up the whole new chemical defence capability from ground zero and how were they addressed?
This question comes back to Prof Ang again. The team started gathering a lot of new literature at a deeper level with his guidance. However, there were still a lot of things not in the open, so the big question was "How do you obtain the really deep knowledge that other countries have already acquired in the process?"

The opportunity arose when we started talking with Sweden about some of those things, and Prof Ang was key to this. The Director-General of FOI, Sweden's National Defence Research Establishment, wanted to have a prominent chemist and professor to review their chemical defence establishment. In return for Prof Ang's help in this area, we were given access to some of their labs. The Swedes have a defensive mentality like us. They do not want others to attack them and certainly do not intend to attack other people with chemical weapons. We shared the same kind of approach and it took a little bit of time to convince them of our similar intentions. Of course, after we were able to gain access, a confidence-building process slowly began where the Swedes got to know us better, and we slowly learnt from what they were doing. The relationship eventually grew deeper.

In other words, this valuable access to new knowledge and facilities allowed us to kickstart our own CD programme?
Certainly. In fact, the chemical defence programme was the first area where we went deep into research in DSO. Previously, I would say, we tended to be more focused on development than research. After gaining experiences through our work with FOI, we started seeking collaborations in other research areas, and establishing our credibility with the Swedes. We even went on to other countries such as France and others to grow our R&D capabilities in this field.

Do you recall setbacks or disappointing moments during the development of the programme?
I think some of the disappointing moments were when we needed access to certain parties, but ended up not having the right kind of access to them. There were also some setbacks later when we started going more deeply into the OPCW verification regime, participating in the tests and not hitting the mark on several occasions. But I think every setback makes people tougher. It spurs them to work harder, do better the next time and to achieve what they seek. This is our strength and it has great deterrence value. People know that we have the capability to defend ourselves against chemical threats.

What more needs to be done to further develop the programme's capabilities?
We must constantly ensure we have the right kind of defence against possible chemical threats. We need to know what to do if we are faced with the threat and how to counter the threat. So it is imperative that we continue to participate internationally in the various multi-national and multi-lateral forums. We must continue to position ourselves as a responsible member of the international committee to counter the spread of chemical weapons, and to work against the use of chemical weapons. On a broader level, I see that the work in chemical defence will encourage more chemists to join the defence eco-system. Indeed, chemistry has applications everywhere. You can actually broaden the group of people, and the application of their knowledge to overcome other defence-related issues.

STRAIGHT TALK

Professor Ang How Ghee - The Consultant

You were tasked to start a whole new defence capability from ground zero. What were the building up years like?

In 1989, Dr Su, then the Director of DSO, invited me to be a consultant for a new programme they were starting. I remember my first meeting with then Director of Joint Operations Planning Department (JOPD), Rear-Admiral Teo Chee Hean, now Deputy Prime Minister and Minister for Defence. They were aware that I had many PhD students working on fluorinated organophosphorus and arsenic chemistry. The message to me from the meeting was very clear: no more chemical research, but to help build up new capability for Singapore's defence against chemical agents. The field of chemical defence was new to me, where I had no prior experience. It was not easy building up a new and very specialised area of chemical defence. It was a heavy responsibility. What I found particularly useful was the overseas missions to chemical defence institutes and companies organised by the SAF, which I was invited to join. They were of invaluable experience and gave me new insights on protective facilities, decontamination reagents and medical countermeasures against chemical agents like sarin, tabun and sulphur mustard.

One of the biggest challenges must be getting the right people to join the programme. How did you manage to build a core team of scientists willing to work with chemical agents?

There was actually already an initial chemical defence team of 3 or 4 members. But within 6 months after I joined DSO, the initial team literally disappeared. They must have resigned. At that time, they were dealing primarily with pesticides & insecticides, and I had to persuade them to come into the heart of the problem. We needed to acquire experience and know-how in chemical warfare agents. These were the most toxic chemicals in the world and they must have found it uncomfortable to make the adjustments. I could sense their difficulties. For the first time, I felt being left alone with a sinking feeling. It was not a good way to start the programme. But I could not let myself be discouraged. Solutions had to be found. My attention was thus directed at my Masters and PhD students. Eventually, quite a number of them joined me and became members of the programme's pioneering group.

This was unfamiliar territory. Why were your Masters and PhD students suitable?

I think the main reason is because they had been exposed to the field of chemistry which has its share of hazards for a good many years, some 3 to 4 years on their postgraduate research training. That was a great help, as they have been immersed working on very hazardous research chemicals. In fact, a number of them had even experienced

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explosions in their experimental work. So they had built up the right temperament, and were fairly well adjusted when they had to eventually handle chemical warfare agents in DSO. In fact, it was not such a big adjustment for them, although they had to get used to the many stringent measures that were imposed in dealing with a different classes of phosphorus compounds, and other agents with a very high level of toxicity.

You mentioned chemical defence was a new territory for you. How did you begin developing the programme's core capability?
For this, we had to turn to overseas institutions to learn from their experience. But it was not easy to get to them to open up to us. The kind of work was very classified and in more ways than one, very controlled areas of scientific work. I still remember my first international conference on chemical defence held in Umea, Sweden in 1990, where I called on Dr Åke Bovallius, then Director of FOI – Nuclear, Biological and Chemical (NBC) Defence.

The meeting lasted about 20 minutes and I was disappointed that I was not allowed to visit any of his labs despite the long journey I had to make. The response became more positive in subsequent visits, and he agreed to take on DSO staff for training. One of the first DSO staff sent for training in FOI was Wai Leng, a returning DSTA scholar who took a first in the Cambridge Tripos exams. She picked up techniques in a lab on chemical analysis very quickly within weeks, but was not given access to other labs nor the library. In subsequent collaborations, the focus was not just on training, but to participate in areas of research which were useful to us in our capability development. This meant that our staff were able to interact more freely which allowed us to move forward much faster. This approach served us well to jumpstart our development efforts. Credit must be given to our staff, as they had to work harder on their overseas attachments. They had to interact with more people, observe the facilities and activities around them and take on what was important to the development of our core capability. It was good to see how staff like Fook Kay and Weng Keong have benefited much by interacting with experts and contributed to new knowledge and techniques on chemical defence.

Did FOI also help us in the area of Synthesis, which is very sensitive?
Initially, we had some difficulties in gaining access into their synthesis work. The Synthesis Lab was a restricted area even to their local staff. However, it was important for DSO staff to gain experience by working in a synthesis lab in order to move forward. We needed to overcome the 'fear factor', to acquire hands-on experience on how to work safely with the most toxic agents in the world. I remember that in one of our trips to Sweden, Dr Åke Bovallius invited us to join him and a few of his senior staff for a picnic in one of the small islands. I explained my concerns about the safety of DSO staff, and the need to gain hands-on experience with chemical agents. We were fortunate to link up with FOI's synthesis expert, Dr Gösta Linberg, and also able to get to know him better with each visit we made to Sweden. The door eventually opened up. I was pleased that he later accepted our invitation to DSO to help upgrade our synthesis work and make possible biomedical research in DSO involving chemical agents.

Safety is of paramount concern in the programme. Did the collaborations with FOI and other defence institutes help us in this area?
FOI has a brilliant record of safety. This is a result of the high standards they set for their safety protocols and procedures. Through our collaborations, we were able to learn and incorporated them into our own labs. Safety must be maintained at the highest standards with nothing left unturned. A safe environment gives the team a sense of confidence, rigour and professionalism. Of course, as we learn from other institutions, we need to remember how our operating environment is unique with differing needs. For example, we needed to factor in our congested environment and the high and humid temperatures. So we had to adapt the techniques that we learnt to our own local environment and requirements.

To do it all over again, what would you have done differently?
We did the best we could. We were lucky to have met people who responded positively and opened the door to give us access to their facilities and expertise. We could not have asked for more. For that, I am very grateful. I am pleased that Dr Åke Bovallius was given the Singapore Defence Technology Distinguished Fellowship by MINDEF.

As we mark the programme's 20th anniversary, what must it continue to do to prepare itself for the future?
Chemical defence work is never static. There is always something new to pick up as changes can move so quickly. DSO's chemical defence efforts must remain professionally competent, cost-effective and relevant to Singapore's defence needs. Its core skills, competence and safety must be maintained at the highest international standards. Likewise, its scientific endeavours must remain focused and innovative. The defence programmes must continue in its search for the best technologies, including information technology, so as to defend Singapore against any possible chemical attack.

STRAIGHT TALK

Dr Lee Fook Kay
- The Programme Head

You were the first scientist engaged by Prof Ang to join DSO's chemical defence programme. What were the early years like?

It was a very nurturing environment. The importance of chemical defence was highlighted by the Iran-Iraq War, as well as the use of Agent Orange in Vietnam. A lot of literature research was then done, and MINDEF wanted to select the right people to start the programme.

Chemical Defence is about science and not engineering, so the team needed the necessary autonomy and bandwidth to do scientific research. The programme was very conducive in that aspect. We got a lot of seed funding because DSO was not corporatised then. With this funding, our research gave us a stronger understanding of the field. In 1995, we slowly opened up our R&D in chemical defence work and had more freedom to explore collaboration opportunities.

Was the team able to build up its capabilities quickly then?

On the contrary, it was very challenging in the beginning for the pioneers, who actually took about 10 years to start their first synthesis! Safety was and still is a top priority. When we first started working with agents, some DSO staff were very concerned. Every time someone got a migraine or smelt something funny, they suspected it had something to do with our work.

What were some of the achievements you and your team were proud of?

In 1996, we were very bold and participated in the first OPCW proficiency test. We learnt many things from it. In 2003, the laboratory received its designation status from the OPCW. This was not an easy feat; we needed to be very competent to achieve this. This achievement put our name in the international arena and we should be very proud of it. This success is due to the dedication of everybody in the team. We had very good scientists working in the field, wanting to do something for the country, and managed to progress the knowledge.

Another impressive achievement is the synthesis capability that was built up from scratch. The group of people who developed the agent synthesis protocols certainly deserves recognition.

Indeed, all projects, big or small, have added to the stature of the Centre. The proudest moment, I have to say, is not when we receive

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awards and recognition, but when you see people working closely in a crisis. Just after 9/11, I remembered Mr Peter Ho, then Permanent Secretary (Defence Development), MINDEF, visiting the lab to thank all the scientists for their contributions. That was a proud moment for me.

Share your insights on the development of biological defence in the programme.

Nine years after the chemical defence programme started, I was tasked to start the biological defence programme. The following years were a renaissance for the programme, due to 9/11 and the resulting spate of bioterrorism (anthrax), as well as the Severe Acute Respiratory Syndrome (SARS) crisis. I am very glad we had very good scientists in the field of biological defence, and I believe there should be synergy between scientists from the chemical and biological fields.

In 2003, we merged with the Defence Medical Research Institute (DMRI), which led to the conglomeration of both chemical and biological capabilities. We then set up the BSL3 lab, which was then ready for SARS. Till today, our labs are also in the consortium of labs for SARS and the avian influenza.

SARS is highly infectious. This must have made staff very concerned during the crisis?

Honestly, everybody in the team had very little time to worry, due to the backlog of samples in the Pathology Lab in the Singapore General Hospital. During this period, all other work was put away and the team was focused on analysing blood samples. I believe communication with the staff was very important. I had to make sure they were willing to take the risk, especially when SARS has a high mortality rate of up to 15%. I am very proud that all the staff were very dedicated and stood up to the challenge. They even had to do things like stool samples, which were difficult to process and had a high viral load.

Why did DSO organise the first SISPAT? What was its significance to the programme?

It was a very memorable time for me. Dr Ake Bovallius encouraged us to organise SISPAT in Singapore, and Mr Peter Ho was supportive of it. In 1998, he felt we were ready to engage the world, so he challenged the team to organise the 1st SISPAT. It brought people from all parts of the world to come together to discuss common topics. It was very R&D focused, with scientific papers presented and discussed, and not so much a trade show with products and demonstrators.

In 2002, during the 3rd SISPAT, we could even afford a rejection rate of 40%. It was a sign of our international stature, and we could be more selective of what we want presented at SISPAT.

Do you think the investment in DSO's chemical defence programme paid off for the SAF?

Certainly, and the Tokyo Sarin attack in March 1995 reinforced the SAF's confidence in us. At the time, the Home Team didn't have the capability to cope and the SAF was called in to help enhance Singapore's national security against such threats. The scientists at DSO had enough information from collaborations to know about detectors, decontamination solutions, and ways to mitigate and remediate the toxic chemicals in the environment. This incident indicated to the SAF that they were right to build up chemical defence research in DSO. Another event would be after 9/11, where we had a good team of people ready to fight bioterrorism.

How has the face of chemical defence changed? What is the biggest challenge that you foresee?

As we enter the new millennium, there has certainly been more concern over the use of toxic chemical, biological and even radiological agents. The research and studies against these agents are also slowly shifting from the military to the home front. After 17 years in the defence arena, I felt a strong urge to bring science and technology to the Home Team. This preparedness for the future needs to involve the Home Team as well. Moreover, the 2nd tier leadership in DSO's chemical defence programme was already maturing.

Many challenges certainly await us in the future. We need to maintain our relevance to defence operations continuously. With the SAF doing more peace-keeping missions, the scope of chemical and biological defence could broaden to cover these areas. Radiological research is also an important part of the future work, as the region is going to be quite active in its use of nuclear power.

We will also need to be more aggressive in engaging the international community. The new generation can bring new ideas and think of a new renaissance.

STRAIGHT TALK

Mr Ho Kong Wai - The User

What was the impetus to start chemical defence research in DSO?
Way back in 1988, after having been "educated" overseas on the threats posed by chemical warfare agents, we recognised that this field was both highly technical and scientific in nature. So we turned to DSO, the principal defence R&D agency for MINDEF to better understand the science behind these dangerous threats. This was done in conjunction with the operational users. It is interesting to note that although the by-word "Ops-Tech Integration" was not even coined yet, DSO and the SAF had already put this concept into practice in the area of chemical defence development then.

Who were the decision-makers in SAF then & where are they now?
The key personnel, I have to say, is Deputy Prime Minister and Minister for Defence, Mr Teo Chee Hean. He was then the Director of JOPD, and gave this "Ops-Tech" development in chemical defence research and capability build-up much support and emphasis in its formative years.

What kind of scientific support has DSO been able to provide to the SAF?
Through our own Ops-Tech integration model, various R&D work was developed that was directly relevant to Singapore's requirements. This included studies into agents' properties, their behaviour and the effects on our local environment, as well as when exposed to differing conditions. Agent fate studies enabled the SAF to better understand and effectively conduct decontamination operations on various matrices with different decontaminants. Modelling and threat analysis studies conducted for both urban outdoor and indoor environments contributed significantly to enhance operational planning and consequence management. All these have effectively enhanced our chemical defence capability and operational response to any chemical or biological incident that may occur. As much as we learnt from the many successful projects that we undertook, we learnt even more from those that failed.

In terms of operational impact, how has DSO been able to contribute in this area with its research in chemical defence?
With the scientists of DSO collaborating closely with the SAF, it has enhanced the technical knowledge and technology edge of the SAF. This provided the needed confidence back then to develop our unique doctrines, techniques, tactics and procedures that are suitable for the tropical environment.

A fine example of this was in 1991, when Dr Lee Fook Kay and his team worked with us to research, train, equip and prepare our SAF Medical Team for Ops Nightingale in Riyadh, Saudi Arabia during the Gulf War. More recently in 2004, DSO was consulted to prepare our CBRE Team for the Boxing Day Tsunami humanitarian and disaster relief mission in Meulaboh, Indonesia, as part of Ops Flying Eagle.

What was the working relationship like between the soldiers in the SAF & the scientists in DSO?
From the beginning, we had a wonderful working relationship, with great mutual trust and respect that grew through the years. Till today, many of us are still good friends and colleagues. This is very important for achieving successful collaboration work between soldiers and researchers.

To further develop this, we had an "exchange programme", where Chemical Defence specialists from the 39 SAF Combat Engineers were attached to appreciate laboratory work in DSO, and vice versa to better understand the needs and challenges faced by the users. Building on this "exchange programme" we had, I even managed to source out the NSmen serving in DSO, and had them converted to serve their NS stint with the Combat Engineers. The first to do so willingly was Dr Ang Kiam Wee, and he contributed significantly to the various stand-by events that his unit was involved in.

"It is interesting to note that although the by-word "Ops-Tech Integration" was not even coined yet, DSO and the SAF had already put this concept into practice in the area of chemical defence development then."

A Tribute to the Late Dr Åke Bovallius 1937 – 2009

A Distinguished Scientist, Visionary and Friend

Dr Åke Bovallius was the Director for the Nuclear, Biological and Chemical Defence Research Institute in FOI from 1984 to 1996.

During his tenure, he was instrumental in the development of DSO's Chemical Defence Programme. He paved the way in promoting the exchange of knowledge between Singapore and Sweden, and launched cooperative research programmes. Some of these projects have facilitated the development of efficient detection and analytical techniques for toxic compounds in the environment, and effective systems for studying protection materials.

Through his continuous belief in Singapore's defence needs and capabilities, Dr Bovallius fostered closer ties and cooperation between both countries in chemical defence research. In 1997, Dr Bovallius was conferred the first Singapore Defence Technology Distinguished Fellowship (SDTDF). Established by Singapore's Ministry of Defence in 1996, the title recognises his significant contributions to the development of Singapore's defence technology capabilities in the area of chemical defence.

Dr Bovallius was also a strong supporter of the Singapore International Symposium on Protection Against Toxic Substances (SISPAT), organised by DSO since 1998. As a prominent expert in this field, he has addressed the symposium on topics such as the importance of R&D in combating the threat of chemical weapons and trends in the 21st century.

Indeed, Dr Bovallius believed in a safer world without chemical warfare agents. Besides working tirelessly to advance Sweden's chemical defence capabilities for peaceful means, he was also passionate in contributing to global efforts in enhancing protection against chemical weapons. During the 1990s, Dr Bovallius was a member of a United Nations team in evaluating Iraq's biological weapons capability. In subsequent years, he continued to head the biological weapons analysis in the United Nations Monitoring, Verification and Inspection Commission.

Dr Bovallius's passing is a great loss to the scientific community. He has received widespread respect for his dedication and outstanding contribution in the area of chemical defence. Dr Bovallius will be sadly missed by everybody in DSO.

"Dr Bovallius believed in a safer world without chemical warfare agents. Besides working tirelessly to advance Sweden's chemical defence capabilities for peaceful means, he was also passionate in contributing to global efforts in enhancing protection against chemical weapons."

Growing Capabilities

Developing a capability edge is not easy. Starting from virtually nothing, the pioneering team focused on building a sound foundation. They began their fascinating journey into developing and growing core competencies to enhance SAF's defence capabilities against potential chemical threats.

PROTECTIVE EQUIPMENT RESEARCH

It was identified as one of the fundamental thrusts for the programme, necessary to affirm the SAF's confidence that they are well protected.

With the SAF's purchase of Nuclear, Biological and Chemical (NBC) protective suits from France in the early 1990s, simple experiments were carried out to test the suits' protection against selected toxic chemicals. The experiments were essential to determine the level of protection the suits could provide.

Over the years, DSO's chemical defence programme built up significant expertise in this area, developing indigenous test capabilities for the evaluation of the full NBC ensemble, mask and gloves. Further assessment also provided useful insights into the material's performance against certain chemicals, and how well the various components integrate with each other.

Today, protection equipment research remains one of the programme's key thrusts. As biological threats become increasingly complex, DSO's team of scientists have already started developing capabilities to test protective equipment against possible biological agents. There are also progressive efforts to innovate more efficient means of assessing the SAF's protective equipment.

"Protective Equipment Research was identified as one the fundamental thrusts for the programme, necessary to affirm the SAF's confidence that they are well protected."


TRELLCHEM

"Of course, we had our fair share of troubles, set-backs and disappointments. However, we were able to openly discuss the problems we faced with our peers and superiors, to collectively find the best solution."

STRAIGHT TALK

Dr Ang Kiam Wee

Deputy Director,
Defence Medical and Environmental Research Institute
DSO

Profile

Dr Ang Kiam Wee was one of Professor Ang How Ghee's PhD students who joined DSO in 1991. His first assignment was in the area of Protection Research. Over the next 13 years, Kiam Wee's passion and expertise grew with the programme, assuming new roles such as managing the biomedical and decontamination defence R&D in DSO. He spent the next five years in the Singapore Ministry of Education to establish and manage a new school focus in Applied and Health Sciences. Currently the Deputy Director of the Defence Medical and Environmental Research Institute (DMERI) at DSO, he is involved in the long-term strategic development and management of the Institute.

What were some of the challenges facing the team then, and how were they overcome?

Assessing the NBC protective suit's effectiveness may look easy, but it was in fact a very difficult task, as some key parameters were unknown.

For example, in the beginning, we were unaware of the required level of toxic chemicals used for testing. Likewise, the acceptable penetration levels of the chemicals were unclear, making it more uncertain when the experiment should be considered a failure. Without these information, it was indeed very difficult to start. Since these two parameters are considered a part of threat analysis, these figures are thus never publicly available. Even for protective gear that are purchased and sent for evaluation tests in advanced countries, the tests are only stated to conform to the North Atlantic Treaty Organisation (NATO) standards.

We were thus very fortunate that we managed to collaborate with Centre d'etudes du Bouchet (CEB) of France on protective research in 1994. This was the time our protection research took off. France is very advanced in protective equipment testing and research. In fact, our NBC clothing is from France till this day.

Did the team feel like giving up?

Frustration is part and parcel of R&D work. I do not recall any occasion when we felt like giving it all up. This is because we always had very supportive bosses. Under the leadership of Dr Lee Fook Kay, we were not just a team, but a family. Of course, we had our fair share of troubles, set-backs and disappointments. However, we were able to openly discuss the problems we faced with our peers and superiors, to collectively find the best solution.

What were some of the significant milestones achieved?

I think there were several milestones achieved in our protection equipment research.

First of all, despite the lack of information available in open literature, we were able to set up the capabilities to test and evaluate protective equipment through various collaborations with international partners. The earliest was with CEB from France, Netherlands Organisation for Applied Research (TNO), and then with the US Natick Soldier Research and Development and Engineering Center.

Secondly, our evaluation capabilities went beyond international standards. For example, the early standard in a NATO test for agent penetration through a protective clothing is marked with either a pass or fail grade. In the test, the protective material is exposed to the chemical agent for a fixed period of time. It is checked later on the level of penetration after the fixed time. When we built our test system, we were able to provide on-line detection capabilities to detect exactly when the penetration of the chemical took place. With this, we were able to provide the SAF with a performance ranking of the protective gear performance.

For example, some protective materials cannot totally prohibit a chemical breakthrough, but have a very slow chemical penetration rate. On the other hand, other materials have a longer resistance period. But once a chemical breakthrough occurs, complete penetration takes place almost instantaneously. Such detailed understanding of protective clothing performance has allowed us to better advise the SAF on the type of protective equipment that best serves their needs.

Lastly, we are also amongst the first few in the world, to build a mannequin-in-agent test system to evaluate the full protective ensemble against both chemical and biological challenges. This is a significant breakthrough, as it helped to change our mindset and research strategy on the protection against toxic substances.

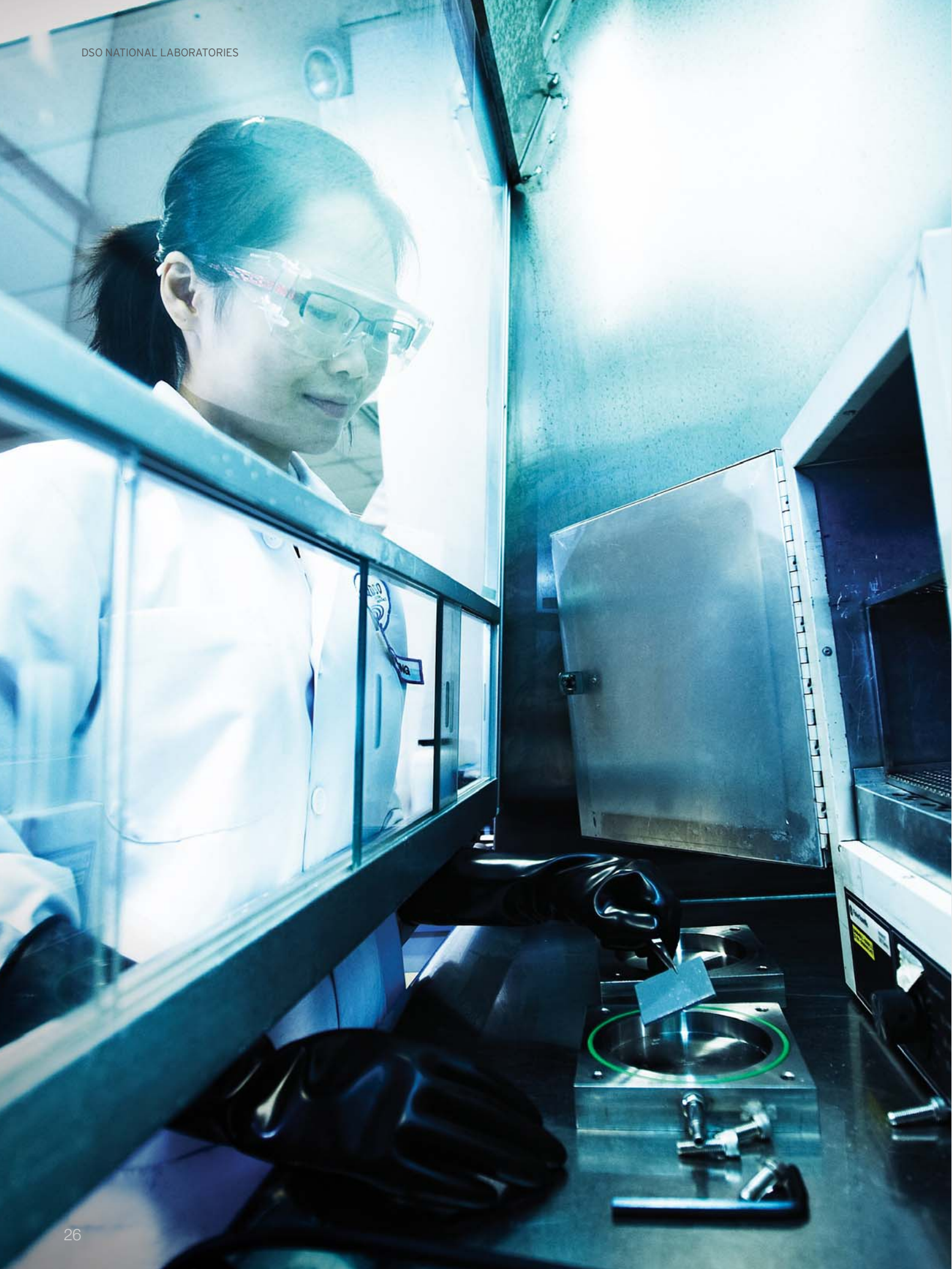
Instead of assessing different protective equipment in isolation, we began evaluating the entire suite of protective equipment as a complete system. This has given the SAF valuable insight into the best in-class set of equipment to purchase, so as to protect its soldiers against toxic substances.

Who are the people attributed to the success of this research area in DSO?

One of the key people who helped to grow this area of research was certainly Dr Lee Fook Kay. He started this area of research and believed it was a key area for the future.

The other key driver was certainly COL (NS) Ho Kong Wai. As the user, he believed in the importance of the SAF having the best possible equipment to protect its soldiers.

The next person is Dr Claude Eon, the former director of CEB, who was instrumental in facilitating our first collaboration with them. Despite our relative inexperience, Dr Eon opened the doors of CEB to us. Through CEB, we had access to protective equipment manufacturers, and were able to better understand their design and production process.



DECONTAMINATION RESEARCH

Starting as one of the earliest thrusts in DSO's chemical defence programme in 1991, decontamination research has been a key area in the programme since.

Over the years, the research has evolved from test and evaluation, to the formulation of new decontamination solutions. It has also moved beyond the decontamination of chemical agents to include biological agents and toxins.

Trials during the early days were less advanced. Chemists in the laboratories were required to first perform all engineering tasks required in the trial. Manual control and data recording were the norm then. As decontamination trials become more effective, engineers were introduced within the team, and automatic control and logging have taken precedence.

Another capability enhancement in this area is the establishment of the climatic chamber, where larger scale trials with toxic chemicals can be conducted. Previously, only simulants could be used. Constant improvements are still being made to the chamber by our engineers to incorporate improved safety features and automation.

"Starting as one of the earliest thrusts in DSO's chemical defence programme in 1991, decontamination research has been a key area in the programme since."

STRAIGHT TALK

Dr Koh Cheng Heng

Assistant Director, Partnership and Plans
DSO

Profile

Dr Koh Cheng Heng was one of the pioneers in building up DSO's chemical defence research capability. She joined DSO in December 1991 to spearhead the area of decontamination research and was also involved in the capability build-up of other areas such as agent fate, modeling & simulation, verification and synthesis. Cheng Heng was also the project lead for the development of the Marina Hill facilities, and the main lead in organising the 1st SISPAT in 1998. Her strong management skills brought her over to the corporate side, and she is currently DSO's Assistant Director for Partnership and Plans.

Describe one of your earliest projects in the area of Decontamination. What was the task at hand then?

I was recruited in 1991 to spearhead the area of decontamination research in the CD programme, and the broad objective given then was to develop a non-aggressive decontaminant.

Being a novice in this area, I spent a good part of my first year doing literature reviews, and started a series of evaluation studies using existing decontaminants, first in the laboratory and subsequently in the field.

However, the studies could only be conducted with simulants, due to the lack of live agent facilities. Nonetheless, we had gained useful insights into gaps in the area and the operation of the users, which was critical for subsequent capability development. It was also through such trials that we gained the confidence of the users in the group.

Subsequently, as we gained more experience, we started to explore new ingredients for our own decontamination formulation, and the group delivered Demul-X after more than 10 years, just 3 - 4 years after the establishment of the live agent capabilities. By then, I had already left the programme, but I was proud of the group's achievement.

Who did you have to work closely with then?

SAF CBRE Defence Group has been our closest partner since day one. During the infancy stage, we were learning from each other, and we conducted numerous trials and studies with them. At one stage, I was at their camp so often that I knew the names of almost all the regulars there, from the CO to the storemen. I had a good time working with the ops managers on the many AOR (Approval of Requirement) papers.

What were some of the challenges facing the team then and how were they overcome?

In the beginning, we could only use simulants for our studies. The simulants could only mimic the physical properties, but not the chemical nature of the agents. We were also very primitive in terms of the ability to analyse the chemicals in the environmental matrices. These had, in some ways, hindered our capabilities in the investigation of decontaminants.

The lack of facilities for large-scale decontamination trials had always been a problem. This was partly overcome by collaboration with others, who had the open range for live agent tests.

What were some of the significant milestones achieved then?

One of the significant milestones was the commissioning of the facilities for live agent work. In particular, the walk-in climatic chamber enabled us to conduct bigger scale studies under realistic conditions. This was one of the very important facilities for us to leapfrog our capabilities.

Another significant milestone was the formulation of Demul-X, the first generation decontamination solution. The achievement laid the foundation for the development of better formulations now.

Any memorable moments?

I missed the field trials. Spending a few days together in the field had not only strengthened the comradeship among team members, but also reinforced rapport with the users. One challenge for our female staff though, was that our visit to the washroom had to coincide with the lunch hour.

I also had good memories of the training for our staff. We got the experts in HQ Combat Engineers to train us on the proper way of wearing the protective gears, using the same drill as the uniformed personnel. The grand finale for the training was to walk into a chamber filled with tear gas, and remove the face mask subsequently, so as to illustrate the effectiveness of the protective gears. It was quite fun watching those emerging from the chamber with red faces and tears in their eyes.

"One of the significant milestones was the commissioning of the facilities for live agent work. In particular, the walk-in climatic chamber enabled us to conduct bigger scale studies under realistic conditions."

DEVELOPMENT OF AN OPERATIONAL SAMPLING KIT

In 1997, the World Trade Organisation (WTO) meeting was held in Singapore. DSO's chemical defence programme was given the challenge to develop an operational sampling kit to enhance defence against potential chem-bio threats. It gave DSO an opportunity to showcase how it was able to respond quickly and apply innovative technologies to meet operational demands.

DSO's verification team provided the requirements for sample collection, and the operational sampling kit was developed within a month, ready for use before the WTO meeting. Although it was assembled within a short period, the kit was capable of collecting samples from air, water, soil, carpet and through surface swabs, essentially all critical samples required by the verification team. It was also portable and could be operated without the need for it to be placed on and exposed to the ground.

The verification team also further improved and brought about a newer version of a field automated Solid Phase Microextraction (SPME) sampling kit, enabling rapid sampling of chemical agents from various environmental matrices. It can also be introduced directly into analytical instruments, without the need of using organic solvents in the sample extraction process. This makes it more convenient, removing the requirement to bring organic solvents into the field.

"The verification team also further improved and brought about a newer version of a field automated Solid Phase Microextraction (SPME) sampling kit, enabling rapid sampling of chemical agents from various environmental matrices."


EYELA
ROTARY EVAPORATOR

OPCW PROFICIENCY TEST

In 1996, DSO's chemical defence programme attempted its first proficiency test conducted by the Provisional Technical Secretariat (PTS). With the establishment of the Organisation for the Prohibition of Chemical Weapons (OPCW) in 1997 to spearhead the Chemical Weapons Convention, subsequent proficiency tests were organised and managed by OPCW.

To obtain the OPCW Designated Laboratory status, participating laboratories are required to partake in three consecutive proficiency tests and achieve a minimum grading of two 'As' and one 'B'. Laboratories are also expected to be accredited with the ISO 17025 certification.

In 2003, DSO achieved its first OPCW Designated Laboratory status, joining a selected group of 14 other labs in the world to be designated. It was also the only laboratory in South East Asia to achieve the designation, and to be able to receive samples from OPCW to test for suspected chemical agents.

The official designation marks an important milestone for chemical defence research in Singapore, and is a strong reflection of DSO's chemical verification capabilities being on par with some of the world's best. In recognition of the programme's chemical verification capabilities, it was awarded the Defence Technology Prize in the R&D category from the Singapore Ministry of Defence in 2003.

Since then, it has continuously achieved an 'A' grading in following proficiency tests to maintain its prestigious status as an OPCW Designated Laboratory.

"In 2003, DSO achieved its first OPCW Designated Laboratory status, joining a selected group of 14 other labs in the world to be designated."

STRAIGHT TALK

Sng Mui Tiang

Programme Director
(Chemical, Biological, Radiological and Explosives)
DSO

Profile

She was one the earliest scientists to join DSO's chemical defence programme in 1991, and tasked to work with analytical instruments to develop methods for analysis of simulants and chemicals.

Over the years, Sng Mui Tiang has played a key role in setting up DSO's analytical instrumental laboratory, as well as developing methodologies for the extraction of chemical agents and degradation products from environmental matrices. In 2003, under her leadership, DSO's verification test team achieved its first OPCW designation status.

As the Programme Director of the Chemical, Biological, Radiological and Explosives (CBRE) programme in DSO, Mui Tiang oversees four laboratories to enhance Singapore's defence capabilities against potential CBRE threats.

"It took seven long years, 10 tests and the unwavering effort of many staff to finally receive our designated status!"

What were some of the main challenges the team faced during the first few proficiency tests?
The early days were extremely difficult times. We were really plunging into the unknown. There were chemicals that we had not worked with before. We were unsure how they behave in the matrices that they were put in, or the best methods to pull them out. Our procedures were also not as robust.

Success in the proficiency test really hinges on strong technical leadership and staff who are willing to experiment, and to keep trying till we succeed. The team has to be mindful of the need to be fluid at all times, and not follow procedures blindly. Each test is a constant brainstorming session to propose and implement effective solutions.

Each test will always remain challenging. We will not know the identity of the spiking chemicals, nor how many are present, and the level of technical difficulty.

So internally, we document lessons learnt after each test and introduce new processes to close the loop. We also developed clear responsibilities for each team member, created checklists, and cross-checked each other's work to reduce errors. In every test, we pull out every single trick from our sleeves and leave no stones unturned.

We achieved the 'A' grading in some of the earlier tests, but were unable to maintain the same standard throughout. Why?
We were not able to perform consistently for a few reasons.

Firstly, the level of difficulty for each test is different. At the start, we were able to do well in easier tests. For the more difficult ones, we stumbled because of a lack of experience with the chemicals or the matrix. We also lacked the experience to handle unfamiliar situations, thus failing to anticipate ahead.

Secondly, we only began documenting our standard operating procedures in 1999. After each test, we modified and improved our procedures until we developed the robust ones we have today. The enhancements were done to address specific gaps that we identified and to anticipate future problems.

Lastly, we only developed our synthesis capability in 1998. This has a large part to play in our confidence in the verification of chemicals. It is only with reference standards that we can confidently confirm our interpreted findings. Without the reference chemicals, our verification capabilities were backed by interpretation and comparison from published data.

In each proficiency test, what was the team's mood like? What keeps them going?
The team's mood is all hyped up in every test. They are always enthusiastic and game to keep on trying. The never-say-die attitude is always present. The team spirit is also very strong and everybody extends a helping hand.

To succeed, nobody in the team can be left behind. This is because every test is a big mystery and everybody's contribution provides a clue towards solving the problem. However, we are never completely sure when the next clue will surface, thus we need to keep looking. This is when the thrill and the suspense builds up. When we start filling in the report and the pages start growing into a 100-odd page report, the satisfaction is truly indescribable.

Is there a main reason that can be credited for our first consecutive 'A' grading that earned us our official designation?
It was the failure of the test before that woke us up! Our performance in the 9th Test was something that I am not proud of. Although it was one of the most difficult tests we had taken part in, we were clouded by too many problems during the test, coupled with poor judgement and failure to see the big picture. That was the cause of our downfall in that test. Subsequently, we became more focused. We implemented a quality system to ensure compliance to proper procedures and processes.

What does achieving this prestigious designation mean to you personally and to DSO's CD programme?
I remembered vividly that when I received the spiking list for our 12th Test in November 2002, my hands were trembling. I knew that the 3rd A was within reach!

It took seven long years, 10 tests and the unwavering effort of many staff to finally receive our designated status! At one point, I think there were people who did not believe that we could make it at all. To finally achieve this with the team is of great personal satisfaction to me.

Of course the pressure to attain the designation was tremendous, but the pressure to maintain it is equally high. Once you have set the bar, everybody expects no less, including ourselves.

I am very pleased with the motivated and technically competent team members I still work closely with. It is their trust and support that have kept me going. Management's belief in us also never swayed. We are definitely very proud as a team to have reached a level on par with other prestigious international defence laboratories.

To be recognised by our peers as being able to contribute at the same scientific level as them is something I am also very proud of.

The 'Blue Books' are a series of publications by the Finnish Verification Laboratory, one of the oldest and most established analytical defence laboratories in the world. Recently, there was a new initiative to produce a new set of books, as they recognised that there is a lot of good research beyond their laboratory.

A few of the designated laboratories were approached to take part in this initiative and to compile a new set of guidelines on chemical agent analysis. DSO is proud to be included in this effort.

Expanding the Programme

As DSO's chemical defence programme began to slowly unveil its presence and capabilities in the public, it was able to position itself as an expert in its field. This gave rise to new initiatives and transformation to propel the programme to a new era.

1997

DSO was tasked by the Singapore Ministry of Trade and Industry to establish the National Authority for Chemical Weapons Convention (CWC) in Singapore. CWC is an international treaty which prohibits the development, production, stockpiling, transfer and use of chemical weapons. It also stipulates their timely destruction.

As the National Authority, it works closely with OPCW on the effective implementation of the Convention in Singapore, and is responsible for advising relevant governmental and industrial bodies on the integration of CWC's requirements in their operations.

This appointment is in recognition of DSO's knowledge in global chemical disarmament issues. It also demonstrates DSO's commitment to contribute to OPCW's global efforts to enhance protection against the effects of chemical weapons. The National Authority for CWC continued to reside in DSO for the next nine years.

1998

DSO's chemical defence programme, then known as the Applied Chemistry Laboratory (ACL), shifted into its new premises at Marina Hill.

Housing a comprehensive suite of chemical laboratory facilities, ACL was able to complement its overall capabilities with new research in biological defence, as well as in pharmacology and toxicology.

ACL also organised the inaugural SISPAT. It was an opportunity for DSO to engage the world, and reinforced ACL's stature in the chemical defence community. The first forum of its kind held in Southeast Asia, it attracted experts and participants from top defence industries, with the aim of fostering research in advanced technologies for chemical defence.

1999

As part of DSO's corporatisation and restructuring, ACL was renamed the Centre for Chemical Defence (CCD). It paved the way for the growth of the Microbiology programme, enhancing CCD's capabilities in environmental detection and verification of biological agents. During this period, CCD also built up its competence in chemical agent synthesis and in 2000, it synthesised its first agent.

CCD merged with the Defence Medical Research Institute (DMRI) to form the Defence Medical and Environmental Research Institute (DMERI). This merger gave rise to the consolidation of biomedical and human science research (DMRI), as well as environmental protection and chem-bio defence research (CCD) under one roof. It provided DSO with an opportunity to better organise its resources and expertise to spearhead research to enhance the survivability and performance of SAF personnel.

2003

THE MARINA HILL STORY

The current chemical defence R&D facilities at Marina Hill (MH) were part of the overall MH redevelopment plan from 1994 to 1998.

As the laboratories would be handling toxic gases, it was decided that the facilities would be situated in a separate new building. Planning for the building infrastructure began in 1995, and the team responsible for the project visited some of the most established laboratories around the world to observe their building plans.

The final decision was to model FOI's laboratories, as they were closest to our requirements. As there was no local contractor capable of delivering what was required, a Swedish contractor was engaged to design and build most of the new chemical defence facilities in MH.

Between 1996 and 1997, the team conducted various design reviews and factory acceptance tests in Sweden, since most items were designed and fabricated there before shipment to Singapore for assembly at the DSO site. The installation of the facilities started in early 1998. The mechanical infrastructure was first put in place, followed by integration with the ventilation system and lastly, the laboratory work benches, furniture, laboratory equipment and instruments.

"It was a challenging project, but the completion of the new chemical defence facilities in MH was certainly a major milestone in the programme's journey."

The most challenging part of the project was the ventilation system for the building to ensure the correct air flow in the laboratories and other parts of the building, as well as the system design for the treatment of chemical waste. The electrical system also had to be able to deliver uninterrupted power supply to the building.

To address these issues, the team worked very closely with the architect and engineers from the Land and Estate Organisation (LEO) of the Defence Technology Group, (now known as the Protective Infrastructure & Estate Programme Centre in DSTA), and the Swedish contractor and their designated local partners responsible for the subsequent maintenance of the facilities. Naturally, staff safety and the protection of the environment were the main considerations. In fact, more than half of the project budget went into the infrastructure needed to support work safety. Dr Gösta Lindberg, a FOI scientist with more than 20 years of experience in agent synthesis, as well as Dr Claude Eon, ex-Director of CEB, was invited to audit our facilities to ensure confidence to our stakeholders and staff.

It was a challenging project, but the completion of the new chemical defence facilities in MH was certainly a major milestone in the programme's journey.

STRAIGHT TALK

BG (NS) DR Wong Yue Sie

Group Chief Operating Officer
Singapore Health Services

Profile

After receiving his MBBS from NUS in 1984, BG (NS) Dr Wong Yue Sie re-enlisted into the SAF as a full-time National Serviceman. He was awarded the Best Cadet for the 26th Medical Officer Cadet Course, and was posted to HQ Medical Services as a staff officer. In 1991, he served as a member of the SAF Medical Team deployed to the Gulf War. In recognition of his contributions, BG (NS) Dr Wong was awarded the Public Administration Medal (Silver), and the SAF Overseas Service Medal.

In 1996, he was appointed the Acting Chief Army Medical Officer, HQ Army Medical Services, and for the next decade, assumed numerous appointments including the Chief of SAF Medical Corps where he strategised the SAF's and MINDEF's health and operational policies.

Currently the Group Chief Operating Officer of Singapore Health Services, BG (NS) Dr Wong is also a board member of several organisations, and sits on various national committees.

What is the mission of the SAF Medical Corps, and how does DSO's chemical defence programme contribute to this mission?

The mission of the SAF Medical Corps is to provide comprehensive healthcare for our soldiers, and optimise their combat performance to enhance the SAF's operational edge. DSO's chemical defence programme was an integral aspect of this mission, as we recognised the need for the SAF to operate in a variety of environments that would place our soldiers under substantial physiological and psychological stress. To protect them in such situations, we have to ensure that the measures that we put in place are safe and effective.

In particular, how is DSO's research in pharmacology and toxicology relevant to the SAF Medical Corps?

Building up pharmacology and toxicology capabilities provided us with the expertise to evaluate and understand the behaviour of various chemical threats, and the measures to identify these threats. It also provided us with the ability to develop treatment, and other intervention protocols to mitigate the effect of these chemical agents in the event of an exposure.

The breadth of the programme was therefore substantial, as it ranged from the very basic research work done in a laboratory, to understanding chemical behaviour and its impact on biological systems. It also includes field work such as evaluating detector devices, and developing networks for chemical detection.

What were some of the biggest challenges faced and how did both parties work closely to bring about proven capabilities?

The first challenge in working together was to understand the different language and concepts of the two organisations. The SAF Medical Corps comprised mainly of military healthcare professionals with an operational and clinical orientation, while DSO brought scientists with a strong science and research background. To begin, we had to build a common understanding of the issues that had to be tackled. We had to better understand DSO's skill sets and capabilities, as well as the clinical and operational challenges that needed to be solved.

Both teams spent many hours working together to build up the insights required to drive development programmes that address specific issues. The end result is the ability to develop critical solutions for our soldiers in the field. This dialogue is an ongoing process as the user's demands continue to evolve.

What significant milestones were achieved in this close working relationship?

We have had a number of successes. These would include the development of specific protocols for treatment of nerve agent exposure. These protocols have since become the national standards. Likewise, the development of Scentmate is another great example of the outcome of the close collaboration between the two organisations.

"Both teams spent many hours working together to build up the insights required to drive development programmes that address specific issues. The end result is the ability to develop critical solutions for our soldiers in the field."

Surging Ahead

Over the past decade, DSO's chemical defence programme has been able to sharpen its technical capabilities, and develop cutting-edge innovations to enhance the SAF's operational readiness against potential CBRE threats. As DSO's scientists continue in their quest to bring forth novel CBRE applications, their achievements have established DSO as the national authority in this field, and a key partner to the SAF.


DSO
DORIS HO
eppendorf

SCENTMATE

In 1995, the Sarin attack at Tokyo's subway led to an overcrowding in hospitals, due to an influx of anxious members of the public who did not require emergency care. This increased the patient load and logistics for the hospitals that could have been avoided if an on-site diagnostic kit was available to identify the true casualties.

To better prepare Singapore against an attack of such similar nature, DSO developed the Scentmate test kit that can detect trace levels of nerve agents such as Sarin and VX, as well as Organophosphate pesticides such as Dichlorvos. Its diagnostic application has a sensitivity level equivalent to the detection capability of an analytical laboratory, but only requires a reduced blood volume of 1,000 times less.

The first version of the Scentmate test kit was initially able to only diagnose eight people by two operators within one hour. It was also limited by the need for a visual detection approach. The subsequent improved test kit however, was able to provide an impressive high throughput analysis for 96 persons instead.

The technology evolved from the Scentmate test kit has also enabled us to embark into R&D for field diagnostic kits, particularly in the areas of immobilising labile biological sensor molecules onto platform surfaces, and stabilising the immobilised bio-molecules in harsh outdoor environments. Further research areas include test kit ruggedisation and precision, as well as consistency evaluation methodologies that are on par with European Union (EU) standards.

Currently, these capabilities are used to develop immunoassay test kits for the diagnosis and detection of toxins. A handheld version of this diagnostic tool, known as the Lab-On-a-Chip (LOC), is also in the pipeline.

"The technology evolved from the Scentmate test kit has also enabled us to embark into R&D for field diagnostic kits, particularly in the areas of immobilising labile biological sensor molecules onto platform surfaces, and stabilising the immobilised bio-molecules in harsh outdoor environments."

STRAIGHT TALK

Dr Loke Weng Keong

Head, Agent Diagnostics & Therapeutics Laboratory
DSO

Profile

Dr Loke Weng Keong joined DSO in 1995, and was instrumental in establishing the Pharmacology and Toxicology (P&T) programme in 1998. Deeper research in the area of P&T has provided DSO with the additional expertise to diagnose and treat casualties of chemical warfare. Currently the Head of the Agent Diagnostics & Therapeutics Laboratory, Weng Keong and his team continue to develop effective medical countermeasures for chemical agents, toxins and for radiological related conditions.

What were the main challenges involved in the Scentmate project and how did you overcome them?

One of the main challenges is to detect trace levels of nerve agents in the blood from asymptomatic, but exposed subjects. This is not easy.

Prior to this project, the only viable means of detecting the presence of a nerve agent in blood samples at trace levels is in well-equipped analytical laboratories. It is also not ethical and impossible to carry out human challenge studies involving nerve agents, thus making it difficult to validate the test kit's capability for diagnosing asymptomatic exposure of nerve agents in humans.

To overcome these limitations, we had to develop a novel technique to recover nerve agents from the nerve agent blood protein complex, and try to detect it with the Scentmate test kit. We also had to develop animal models that are challenged by nerve agents, but do not produce intoxication symptoms, and use these animal models to validate the test kits.

When were your most disappointing and proudest moments?

I think the most disappointing moment was at the start of the project. Progress was slow and the budget risked running out. We also ran into some manpower issues.

Certainly, the proudest moment was when the team developed a breakthrough technology to overcome all the limitations involved. We were also overjoyed when we achieved our second breakthrough, where we were able to adapt Scentmate technology onto a chip-based platform within two years of our collaboration with NTU.

When was your most memorable moment working on this project?

It had to be the time when we used nerve agent spiked human blood samples, and demonstrated the capabilities of Scentmate to former Deputy Prime Minister, Professor S. Jayakumar. He was visiting DSO to better understand our role in strengthening the nation's security in the fight against terrorism. The entire project team felt much appreciated that someone so senior took the effort to come down to our laboratory and view our innovation.

We are currently collaborating with NTU to further the Scentmate technology. How did this come about?

In order to meet the requirements for a diagnostic kit that is more portable and easier to use, we identified LOC as a suitable platform.

As the team members had no background in LOC technology, we attended a micro-fluidic course conducted by NTU. We managed to establish contact with Prof Nam-Trung Nguyen who specialises in micro-fluidic research, and who has a keen interest to apply this technology for further applications.

Both parties are still collaborating in the next spiral of development to invent a LOC platform that could be used in the field. It needs to be easy to use, highly portable and require minimal energy consumption, while remaining completely reliable.

"Certainly, the proudest moment was when the team developed a breakthrough technology to overcome all the limitations involved."

DEMUL-X

The development of Demul-X began when DSO started its research to better understand the formulation for decontaminants.

It was done on a part-time basis then, amidst the many other decontamination projects that DSO was actively involved in. The team experimented with active ingredients, but had no access to actual chemical agents to test the effectiveness. They had to use simulants instead.

In the early 2000s, the project reached a turning point. DSO was able to synthesis its own agents, and the team was able to experiment with real chemical agents to ascertain their choices and formulations. The commissioning of DSO's climatic chamber, the first in Singapore, also allowed the team to test the formulation under a more realistic setting.

The main draw of Demul-X was in its ability to effectively decontaminate a wide variety of chemical and biological agents, ranging from nerve to blister agents. It was also formulated with relatively non-toxic and environmental-friendly ingredients. These properties were lacking in decontamination formulations before the mid 2000s.

Since the development of the first decontaminant formulation, it has since advanced to an exploratory phase, providing DSO with a better understanding of decontamination requirements, both scientifically and operationally.

It also gave DSO the opportunity and confidence to improve the formulation and enhance Demul-X using micro-emulsion technology. With better decontamination properties and requiring less preparation, the new Demul-X has the potential to be another leading-edge innovation that will enhance Singapore's defence capabilities against possible chem-bio threats.

STRAIGHT TALK

Dr Eunice Sim

Head, Agent Research Laboratory
DSO

Profile

A scientist with DSO's chemical defence programme since 1995, Dr Eunice Sim began her R&D career in the area of chemical decontamination. Over the years, Eunice has amassed a wealth of experience in this field, and expanded her research to include biological and radiological decontamination. As the Head of the Agent Research Laboratory, her expertise in this field has helped kickstart the programme into dispersion modelling, in a bid to better understand the dispersion patterns of chemical agents in different environments.

What was the main challenge in developing Demul-X?
It would have to be the development of the delivery system and its translation to field use. Development of a suitable delivery system needs to marry the knowledge of chemistry, chemical and mechanical engineering, ergonomics and understanding of the users' operation. There are also constraints imposed. The most difficult part is to balance between meeting the properties of the emulsion to be delivered, and the overall weight requirement.

Many trials must have been conducted for Demul-X. Were there any interesting moments?
To be honest, trials are not the most enjoyable part of the work. They are actually rather stressful because you have to work with many parties within the constraints of time, resources and under a less controlled environment. You also have to pray that the weather goes well, nobody gets hurt, and the electronics and mechanical parts do not fail, so nobody's time is wasted.

However, I think the most heartening thing during the trial is seeing everyone in the team working together, helping each other to get the job done. Some of those involved are not even core members of the team, but just lending a helping hand.

You have been involved in Demul-X since its inception. When was your proudest moment?
In 2002, McKinsey and Company were hired by DSO to review our new technologies that were developed at that time. It was very gratifying to know that Demul-X was commended as a promising technology.

Explain how micro-emulsion technology can improve the effectiveness of Demul-X as a decontaminant.
The application of micro-emulsion technology allows better solubilisation of the targeted toxic chemicals to improve their degradation and removal. In fact, the particle size is smaller and will provide better reaction kinetics. On top of this, as it is a thermo-dynamically stable system, it is also easier to prepare and deliver.

You have been involved in chemical decontamination research for 14 years. Why does this area of research fascinate you?
It is really a mixture of things, but in summary, I think the job matches my ideals and personality.

Firstly, it is the purpose of the research, which is for the good cause of protecting people from harmful substances. Secondly, it is the challenge of using one's knowledge, analytical skills and innovativeness to solve the various problems. There is always a sense of thrill and satisfaction when we manage to solve certain problems. Thirdly, the research world is always dynamic, with new things to learn and apply. It keeps your mind excited and thinking.

What are the future challenges in the area of chemical decontamination? How can DSO better prepare itself against these challenges?
I think as with all other defence research areas, the basic problems have already been addressed, and a certain level of capability has been delivered to the users. Small improvements to their current capability will not be of great value to the users. The biggest challenge ahead, is to come up with something that will deliver a significant capability edge.

Currently, I would say that initial mitigation of gross contamination is no longer a problem. However, there are still problems in returning an area to normalcy for long-term occupation. I think it is important for us to first do a good characterisation of the problem, before plunging in to look for solutions.

"I think the most heartening thing during the trial is seeing everyone in the team working together, helping each other to get the job done. Some of those involved are not even core members of the team, but just lending a helping hand."


DSO

AGENT SYNTHESIS

In 1989, a suite of new chemical defence facilities at Marina Hill was completed. This included customised containment facilities, which enabled DSO to conduct agent synthesis, and further expand its research in chemical defence capabilities.

Taking close to two years to prepare, the first phase began with the documentation and validation of the synthesis of the precursors for each of the five classic chemical agents. Subsequently, the safety procedures and protocols pertaining to the agent synthesis and storage techniques were designed, documented and validated. An emergency response plan was also developed.

With all requirements in place, DSO synthesised its first live agent in year 2000. This was an important achievement to the programme, as the access to live agents now allowed DSO to build up its database of standards and analytical data. It also brought about the validation of its methodologies, standard operating procedures and other research findings. DSO was thus able to provide a more effective assessment and evaluation of the claims by potential suppliers of protective and detection equipment to the SAF.

STRAIGHT TALK

Dr Diana Ho

Senior Manager, Partnership
DSO

Profile

Identified as having the right skill set, attitude and mindset, Dr Diana Ho was tasked to synthesise the first live agent in DSO. A scientist with DSO since 1998, she came on board during a time when DSO was seeking to develop its synthesis capability of chemical agents and other related materials. In 2001, Diana was given another challenge of heading both the Synthesis and the Detection programmes in DSO. Over the years, she has also contributed in the area of Intellectual Property Management, as well as fostering collaborations with local industry partners when she was seconded to DSTA in 2007. She returned to DSO in 2009 and is currently Senior Manager, Partnership.

What initial preparations were made before DSO synthesised its first agent?

For a start, we had to make sure that all containment facilities had safety and emergency evacuation aspects built in. We also had to develop synthesis methodologies for precursors, and ensure that all agent syntheses would be properly documented and validated. Likewise, we need to ensure the safe handling when synthesising agents.

This means countless training with the use of necessary protective equipment. Beyond equipment and procedures, a team of well trained "cooks" with the appropriate attitude and mindset is crucial!

Who did you have to work closely with during your first agent synthesis attempt?

We had a Swedish consultant from FOI, Dr Gösta Lindberg, who was very experienced in agent synthesis. He was here for 6 weeks leading up to our agent synthesis.

Gösta was my mentor who guided me in my preparation, and provided me with strong emotional and mental support. I also worked closely with Dr Koh Cheng Heng in building the necessary safety protocols. For my first agent synthesis attempt, Dr Lee Fook Kay, Dr Koh Cheng Heng and Dr Eunice Sim took turns to be my buddy.

I remembered synthesising one agent per week. Gösta would tell us not to rush and to do things step by step. Every morning, he would check if I slept well and felt good. He made it clear that it was important to stay focused. Gösta used to say, I quote, "Learn to respect the colourless liquid!"

So was it ensured that the synthesised agents were of pure quality?

The chemical agents are purified through the process called distillation. This process should be conducted in a controlled manner so that the only agent in the correct boiling point range is collected. Following the purification process, the storage of the agent under inert conditions in sealed vessels is also important in maintaining the quality of the agents.

Were you confident that you were well prepared for this challenging task?

Yes. My team and I had built up our knowledge in preparing for the synthesis. We had constantly refined the safety protocols and synthesis methodologies, and had participated in countless evacuation drills. We also kept practicing our synthesis techniques with the use of protective equipment.

However, some people had doubts if I was suitable for the job. Others questioned if our safety protocols were sufficient. Even when the agents were synthesised and analysed, their quality was questioned. Well, I think the end results have spoken for themselves.

Were you nervous during your first agent synthesis attempt?

Not really! Actually I was more excited than nervous, now that Singapore could finally have its own access to chemical agents to further DSO's research. We had been anticipating and planning this for a long time! Even after Gösta left and we had no one to watch over us, I remained fairly confident. I learnt to build a lot of trust in my buddies.

Eventually, I also managed to train the next generation of scientists to carry out agent synthesis work. I am proud to say that in all my years synthesising agents in DSO, our synthesis work has been accident free.

Did you ever feel like giving up?

No, because we had to make it happen. MINDEF had the faith in us by funding and supporting the build-up of the facilities and capabilities, so we had to succeed, safely, of course. For me, it has been a humbling experience, knowing that I have been a part of Singapore's history in building up this new capability, which is a milestone for DSO's chemical defence programme.

"For me, it has been a humbling experience, knowing that I have been a part of Singapore's history in building up this new capability, which is a milestone for DSO's chemical defence programme."


WARNING
CAUTION HOT

COMBATING THE SARS EPIDEMIC

In 2003, the highly contagious Severe Acute Respiratory Syndrome (SARS) virus created a health epidemic in Singapore, resulting in 33 deaths.

At the onset of the SARS outbreak in March then, DSO was approached by the Ministry of Health (MOH) to provide support to the Singapore General Hospital's Pathology Laboratory to identify the etiological agent of SARS.

DSO's team of chem-bio scientists were able to identify the Coronavirus in several clinical and cell culture samples. We conducted the RiboNucleic Acid (RNA) sequence analysis of amplified products of the positive cases, and found them to be identical to those reported by the Centers for Disease Control and Prevention (CDC) in the United States, and the Bernhard-Nocht-Institut fÜr Tropenmedizin (BNI) in Germany. These results were then presented at the World Health Organisation (WHO) meeting in Geneva in April 2003.

At the height of the crisis, DSO joined the Singapore Clinical SARS Consortium, and was tasked to work with the Genome Institute of Singapore (GIS) to develop and validate a diagnostic kit to detect the virus. GIS was provided initial part sequences of the Coronavirus from DSO's preliminary investigations. In addition, DSO provided diagnostic support for clinical samples, so as to lighten the load of the hospitals. More than a total of 1,600 clinical samples for the SARS virus were screened during this period. DSO's scientists were also able to provide further assistance to national hospitals, such as Singapore's National University Hospital, (NUH) to test their protective hoods with blowers used by the medical community in high risk situations.

The selfless contribution by DSO's scientists during the SARS crisis was a reflection of their professionalism and dedication to their work. It also highlighted DSO's role as a national laboratory, and the responsiveness and versatility of its built-up capabilities.

STRAIGHT TALK

Dr Tan Yian Kim

Senior Member of Technical Staff,
Detection and Diagnostics Laboratory
DSO

Profile

Dr Tan Yian Kim joined DSO in year 2000 and was assigned to work on the detection of biological agents in various environmental matrices. He was amongst the 28 scientists in DSO who was awarded the Courage Medal for their involvement in the battle against SARS. The award is given to honour and pay tribute to those who had demonstrated immense courage and self-sacrifice. In 2005, he was granted the DSO Postgraduate Scholarship where he pursued his PhD, researching the effects of the anthrax toxin on mammalian cells. He returned to DSO in 2009 and is currently a Senior Member of Technical Staff in the Detection and Diagnostics Laboratory.

"After the anthrax scare and the SARS incidents, we are certainly better prepared to handle similar crises requiring our assistance in diagnostic work."

What kind of expertise and facilities was DSO able to offer during the SARS crisis?

During the SARS crisis, DSO housed one of the few facilities in Singapore that was capable of handling dangerous agents such as the SARS virus. This high containment facility, also known as the Biosafety Level 3 (BSL3) laboratory, was also designated as the National Single Portal of Entry after the 9/11 attack in 2001 to analyse chemical and biological agent contaminated samples.

Having the appropriate facilities to handle the SARS virus is of course only one part of the equation. Equally important, is the competency of the laboratory personnel. As we were already familiar and proficient in handling a similar category of biological agents in the high containment lab, we were able to quickly process and analyse clinical samples with only some minor changes to our laboratory operating procedures.

What were some of the biggest challenges faced during our battle against SARS?

Some of the biggest challenges are usually issues that are beyond the control of the laboratory or even the organisation.

For example, reagents that were routinely used in the laboratory suddenly became hot commodities, with so many laboratories vying for the limited existing stocks. However, we managed to get priority once the supplier was aware that we were working on SARS. Some other technical issues included the standardisation of protocol across all laboratories. This is because different laboratories use different protocols. Another challenge was the lack of sufficient high containment facilities in Singapore that can safely handle the SARS virus. Now that Singapore has several additional certified BSL3 laboratories, it will allow a more even distribution of work during times of crisis.

What was the mood and atmosphere at the labs during that period of time?

The initial stage of the outbreak is a classic situation where there are more "unknowns" than "knowns" about the virus. Although our lab has prior experience in handling suspected anthrax samples, this event seemed to be more "real", as we had people falling sick and even dying from the disease right in our country. This is opposed to no recorded cases of anthrax in Singapore.

Naturally, most of us had an element of fear in dealing with something with so many "unknowns" and which was deadly. Despite the initial fear, all of us instinctively accepted our new role without hesitation when we were called upon to assist in the diagnosis of clinical samples.

The fear quickly subsided when we knew that the additional safety precautions that we adopted surpassed the guidelines, and were more than adequate to handle the SARS virus. One unintended consequence from this crisis is that the group became closer to each other, a result of having spent so much time at work than at home!

How many people were involved during the SARS crisis? Did people have to work round the clock?

In normal times, the microbiology group undertake research work relating to the detection and verification of biological agents from different environmental matrices. With a team of less than 10 personnel, the whole laboratory team had to switch gear from largely R&D centric activities, to full time processing and testing of clinical samples.

We worked in two groups, with one group concentrating in extracting the genetic material, and the other performing the molecular diagnostic. Time is of the essence when it comes to effective contact tracing, isolation and patient management. Therefore, we strived to analyse all the samples that were received on that day.

The day only ends when the results are tabulated and submitted. Depending on the number and types of sample received for that day, it could stretch well beyond midnight. Needless to say, it was not uncommon to work on weekends then.

What is the difference in the work involved during the SARS crisis and during the anthrax scare?

During the SARS crisis, the samples that we were tasked to analyse were usually confined to clinical samples such as blood, stools and sputum. Samples from the latter however, took the form of letters and parcels. Among other tests, a common test for both the SARS crisis and the anthrax scare involve the Polymerase Chain Reaction (PCR) amplification of a specific target region. However, the upstream sample processing prior to PCR requires rather different procedures. And while the working hours during the SARS crisis were long, the samples were usually sent in during the working hours. On the other hand, anthrax samples were sometimes delivered in the middle of the night, and we had to return to office to work on it immediately.

After this incident, how are we better prepared for such similar crises in the future?

One of the most important lessons that we learnt from this crisis is how to ensure business continuity.

Already overstretched due to the heavy workload and long working hours, any loss in manpower due to either infection or home quarantine would have taken a toll on the smooth operation of the workflow. As such, we implemented processes that will ensure business continuity if any staff is unable to work due to various reasons. If the primary facility is down, we also have provisions to work at a secondary site.

After the anthrax scare and the SARS incidents, we are certainly better prepared to handle similar crises requiring our assistance in diagnostic work. In fact, our most recent involvement in H1N1 screening for MOH didn't catch us by surprise, as we were closely monitoring the development of the H1N1 pandemic. We were able to prepare ourselves better.

Global Collaborations

Strategic partnerships with local universities and top defence institutes from around the world have helped DSO's scientists to develop its competencies in chemical defence. This has provided an excellent opportunity for the programme to benchmark its capabilities to international standards, and push the technological envelope of excellence to leapfrog new CBRE innovations.

FOI, Sweden

Biomedical Research for Countermeasures against Nerve Agent Toxication

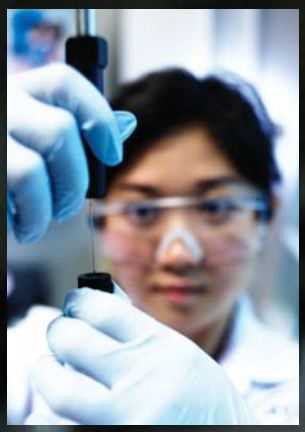
Since the inception of the Pharmacology and Toxicology programme in DSO, FOI has been instrumental in assisting DSO in the build-up of diagnostics research capabilities. Previous collaborations on micro-dialysis and neuro-transmitters analysis also provided the technical push into starting chemical defence therapeutics research.

In a subsequent collaboration, DSO and FOI developed a novel neuro-protection antidote combination, capable of protecting the brain from continuous seizure events initiated by nerve agent poisoning. As part of this collaboration, two joint journal publications were published and four conference papers have been presented. This has also brought about cross-attachment of staff between the two organisations.

Moving forward, the focus of this strategic partnership will be in radiological defence, a critical research area, as nuclear energy gains prominence in an energy-hungry world.

Solid Phase Microextraction (SPME)

In this synergistic collaboration, DSO worked closely with FOI to explore the use of SPME as a technique to remove chemical agents from environmental samples for analysis. This provided DSO the opportunity to validate the SPME technique and its performance on chemical agents, which it did not have access to. Previously, DSO was only able to study these agents from the samples provided during the OPCW proficiency tests. The collaboration also saw deeper research in the degradation products of chemical agents and mycotoxins, and resulted in two joint publications.



Since 1996, DSO has been applying the SPME technique in its OPCW proficiency tests. Today, it is considered a leading laboratory in SPME for analysis of chemicals related to the Chemical Weapons Convention. With the maturing of this technique, DSO has gone on to explore new applications such as the Hollow Fiber-Liquid Phase Microextraction (HF-LPME). This is a more cost-effective technique with potential for a much broader range of compounds and more complex matrices.


ALICIA HO

Defence Science and Technology Laboratory (DSTL), United Kingdom

Decontamination Research

In an effort to develop a more effective decontaminant against chemical and biological agents, DSO and DSTL explored using micro-emulsion technology to develop a decontaminant formulation.

Using DSTL's micro-emulsion technology and the active ingredients provided by DSO, this collaborative project gave rise to the first series of micro-emulsion decontaminants. It has also brought about an enhancement to the formulation of DSO's Demul-X.

Centre d'etudes du Bouchet (CEB), France

Protection Research

At the beginning of our collaboration, both parties explored ways to improve the Nuclear, Biological and Chemical (NBC) protective suits purchased by the SAF.

One such improvement was to make the suit more comfortable, such as altering and enhancing the air permeability of its exterior fabric, while ensuring its protective capability was not compromised. Today, the SAF is still using this enhanced version of the NBC protective suits for their operations. Due to the high susceptibility to humidity and eventual degradation of carbon, the collaboration also saw the exploration of an alternative carbon adsorbent for SAF's NBC suits.

This joint effort helped DSO to translate the idea of deploying carbon alternatives in chem-bio protection via foam impregnation. DSO was also able to establish links with the only French industrial firm that manufactures individual protective ensemble carbon foams and gained technical know-how on the manufacturing of carbon impregnated foams.

Standoff Detection Research

This collaboration started with a joint validation of CEB's developed sensor based on infra-red thermal imaging, in a tropical environment. During the infancy stage of DSO's chemical defence programme where it had no access to such technologies, this collaboration provided valuable insights. This includes the effect of humidity on its performance, and how to conduct a large-scale chemical trial in an open environment.

As a result, both organisations came together to overcome the problem of the sensor's poor sensitivity due to the humidity. In this win-win partnership, a stand-off chemical sensor suitable for use in a tropical climate was identified and validated. Likewise, CEB was able to validate their system in an environment outside of France.

Drawing on each other's expertise, both organisations are currently exploring new standoff technologies, such as hyperspectral imaging for both chemical and biological agents.

STRAIGHT TALK

Loh Wai Leng

Head, Applied Chemistry and Engineering Laboratory
DSO

Profile

Loh Wai Leng began her career in DSO's chemical defence programme in 1992. Starting out in the area of chemical detection, her work included assessing bio-sensors for chemical agent sensing, reviewing commercial detectors, and developing test methodologies and test facilities for evaluation. Over the years, Wai Leng's research expanded to include, amongst others, the testing and evaluation of NBC protective gear.

Currently heading the Applied Chemistry and Engineering Laboratory, Wai Leng is instrumental in providing engineering expertise to the programme. She is also passionate in exploiting novel material and future technologies for the next generation of Chemical, Biological and Radiological (CBR) defence equipment.

How many collaborative projects have you been involved in?
Three! They are with CEB, France; Natick Soldier Research and Development and Engineering Centre from the US; and the Defence Science and Technology Organisation, Australia.

How have these collaborations been beneficial in furthering our research and know-how?
Collaborations can help further our research, and allow us to benchmark our capability with peers in the international arena. Our collaboration with France exposed us to the NBC suit industry, and gave us valuable insight into how protective foams are manufactured. This spurred us to explore alternative materials and technology for individual protection application. With our collaboration with DSTO, we were able to leverage on their technical expertise to shorten our learning curve in the capability build-up for aerosol generation, characterisation and aerosol challenge on different types of protective materials.

How do you seek out collaboration partners, and what do you look out for?
International conferences, overseas missions and networking events are some of the many ways we establish the first point of contact. Whether the collaboration is successful depends on many factors. These include the sincerity of both parties and their willingness to share. Management support and funding are critical factors.

Collaborations are not always smooth flowing. What are some of the challenges in a partnership?
When there is a change of the principal investigator or point of contact during the collaboration, the handing over may unfortunately not always be smooth and complete. This has led to lapses in communications and delays. When there are various layers of management and different governmental organisations involved in complex issues such as Information Exchange and Intellectual Property, communicating over long distances can also be challenging. These are often the factors that will have an impact on the project timeline.

How can this be better managed?
Most of the communications issues can be resolved with more regular meet-ups with each other, face to face. Nothing really beats the personal touch.

Over the years, what lessons have you learnt to better manage collaborative projects?
I think it is important not to assume, and always adopt an open communication between the two parties. Having frequent meet-ups to build rapport is good too. It would be useful to include exchange programmes for scientists to encourage mutual learning, and provide interesting exposure to the work culture of different countries. In most instances, there are many more intangible benefits besides the collaboration work itself.

This is interesting. In fact, you were the first scientist from DSO to be attached to FOI, Sweden on a three-month attachment. How did it benefit you?
It was an eye-opening and enriching experience. In FOI, I had the opportunity to interact and work with different scientists working in diverse areas. I was also exposed to their culture of open sharing and frequent interaction. The skills, knowledge and exposure acquired during the attachment were certainly both tangible and intangible. Working in the FOI test laboratory also exposed me to numerous European standards, methodologies and set-ups for the conduct of different filter tests and qualification. The exposure to the analytical laboratory, as well as the test and evaluation laboratory for chemical warfare agent detectors, brought back new and useful techniques which benefited DSO's subsequent research, testing and facility development. For example, the technique of enzyme kinetics for potential chemical warfare agent sensing was acquired and brought back to DSO after the attachment.

"It would be useful to include exchange programmes for scientists to encourage mutual learning, and provide interesting exposure to the work culture of different countries."

Defence Science and Technology Organisation (DSTO), Australia

Antibody Characterisation

Antibodies are the critical reagents that enable rapid immunoassays for toxins in both environmental and clinical matrices. Scientists at DSO and DSTO seek to develop joint antibody resources, so as to provide suitable combinations of antibodies for specific detection and/or diagnostic applications.

Currently, a joint antibody library has been developed by both parties. This shared library has been used to develop a ricin detection platform, based on Surface Plasmon Resonance technology for ricin aerosol samples. Further innovations include the development of an enzyme-linked immunosorbent assay (ELISA) diagnostic kit for validating ricin exposure in an animal model.

Efforts are now being undertaken to validate the ELISA Test kits, using a broad range of clinical samples obtained from the hospitals. There are also plans to produce and operationalise this ELISA diagnostic kit. Both organisations will also cooperate in the area of developing and designing mutant toxins. It can be used as a calibration standard for antibody based detection and diagnostic applications. Mutant toxins will also be useful for field training by operators.

Bundeswehr Institute of Pharmacology and Toxicology, Germany

Oxime Re-activators

This strategic partnership seeks to determine the variance in nerve agent inhibitory potency, and oxime antidote efficacy between human and various animal models.

Studies are carried out *in vitro* (outside the body). These variances are vital for the extrapolation of animal data obtained from the therapeutic action of candidate drugs to the expected outcome in humans. Without this understanding, it is not possible to translate therapeutic research carried out in the chem-bio programme to clinical applications.

Currently, all desired drug constants and variances between animals and humans have been determined successfully. The next step is to perform oxime antidote trial studies in large animal models, and establish the optimal therapeutic regime for human application.

Nanyang Technological University (NTU), Singapore

Micro-fluidic Research

The successful adoption of a lab-on-a-chip technology will enable many current laboratory-based diagnostics and detection assays to be transferred to the field and used by first responders.

In this collaboration with NTU, we successfully transferred complex blood sample processing protocols onto the chip. It was able to detect regenerated nerve agents from human blood sample using the Scentmate technology. This positive outcome has enabled the team to successfully bid for additional funding, and further our research with an enlarged collaboration team, comprising experts from the Singapore Institute of Manufacturing Technology from the Agency for Science, Technology and Research (A*STAR), and the National Institute of Education.

In addition, the team developed alternative plastic platforms, and directly stabilised the detection of bio-reagents onto the plastic chip. An on-chip pneumatic-based actuation mechanism was also developed to process the sample on the chip.

Further research includes switching from a syringe pump actuation to pneumatic action, and converting the optical detection to amperometric or electrical detection on the chip.

National University of Singapore (NUS), Singapore

Liquid Crystal Research

Current capabilities for Botulinum Neurotoxins (BoNTs) detection in DSO are polyclonal antibodies-based. Antibody-based detection techniques however, have limitations due to the batch variation of antibodies from suppliers. They may also give a high false positive rate, especially if the sample matrices are complex.

In this joint collaboration with NUS, the aim is to develop a portable liquid crystal based bioassay as a cost-effective way of detecting and differentiating BoNTs A, B, E and F. The new liquid crystal-based technology can be applied to produce low-cost and easy-to-use BoNTs test kits, which can be distributed to soldiers for on-site usage. Likewise, it can be used as a fast screening method in the laboratory to identify samples that require further analysis. This detection principle also has the potential to be extended to other types of biological agents in the future.

As one of the laboratories approved by the Singapore Ministry of Health to work with Biological Agents and Toxins Act (BATA) toxins, DSO has been able to provide the technical expertise in BoNTs to NUS, while leveraging on NUS's expertise in the liquid crystal technique to explore its potential as a detection technology.

Charting the Future

Global events have shown the grave reality of emerging terrorist threats. It is a reminder that Singapore's national security faces new challenges, and the need for DSO to constantly innovate key enabling technologies that will contribute to the security of the nation. For the coming years, DSO's scientists will continue to strengthen their scientific competence, and exploit the rapid evolution of technology to keep pace with new emerging threats in the future.

NEW FOCUS FOR DECONTAMINATION RESEARCH

As an urbanised nation, it is important that DSO continues to expand its research into decontamination applications in urban scenarios. Besides enhancing Demul-X, DSO's scientists are exploring the development of a self-decontaminating coating for surfaces. This aim to remove remnant residues of toxic chemicals after gross decontamination is now complete.

To sharpen our focus in decontamination research, the future plans include developing comprehensive plans to conduct decontamination of building interiors, and conduct studies on the persistence of chemical agents in materials used in buildings.

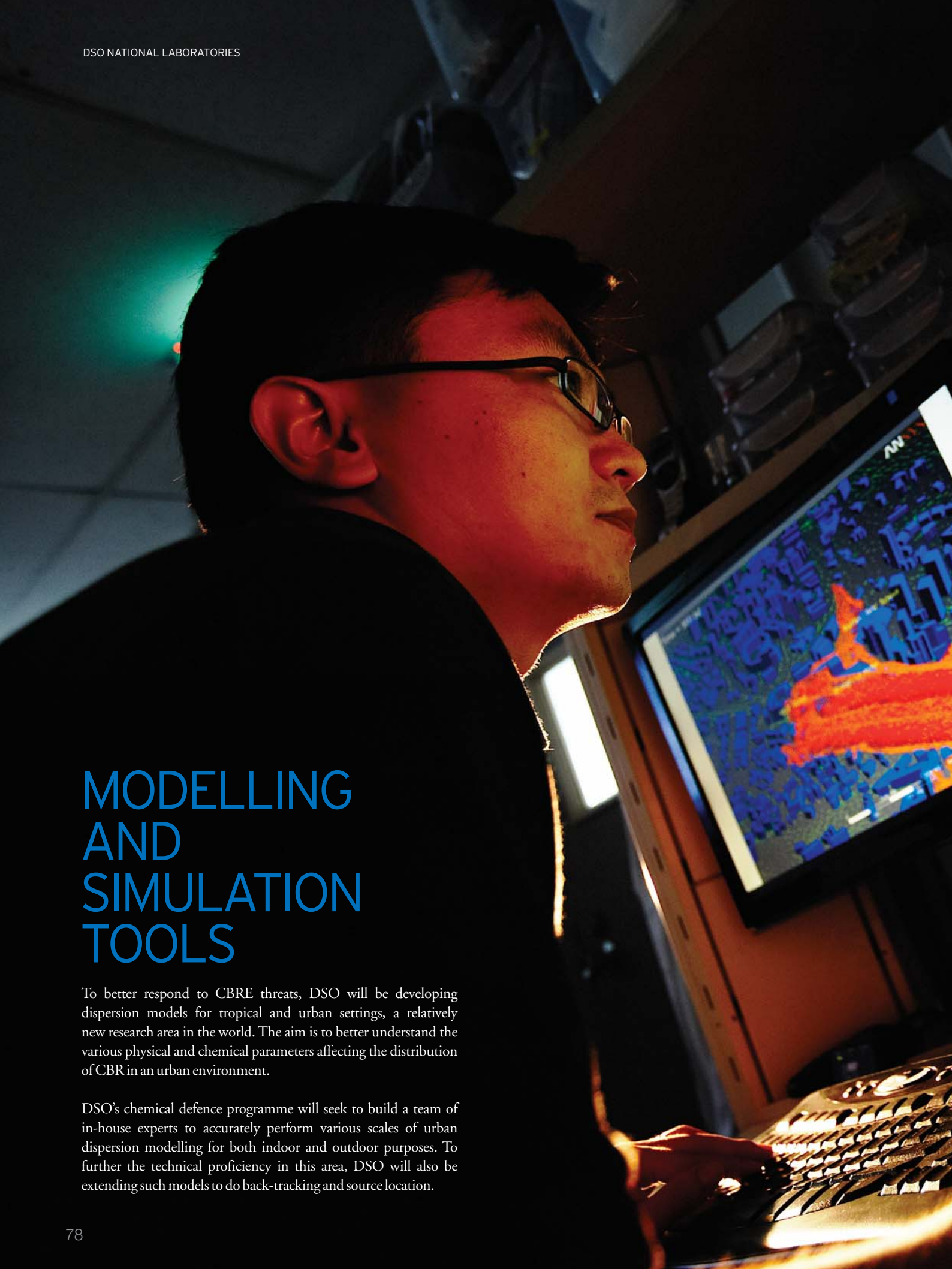
Another exciting area of research will be in the decontamination of equipment that is sensitive to water, and to explore the use of Fluorosolvent and vacuum treatment.

STANDOFF DETECTION

In recent years, hyperspectral remote sensing has become increasingly important for military surveillance applications. By harnessing the potential of this technology, DSO seeks to explore the use of Long-wave Infrared (LWIR) hyperspectral technology for standoff detection and identification of chemical agents.

In hyperspectral systems, the observed scene is divided into many pixels, and spectral information for each pixel is available for analysis. The threat can thus be mapped and tracked accurately, providing a true standoff chemical detection and monitoring capability. With vast information made available, false alarms are also potentially reduced, thus increasing the confidence in detection from a remote distance. By detecting potential chemical threats from a safe distance, early warning and mitigation measures can also be planned to reduce damages.

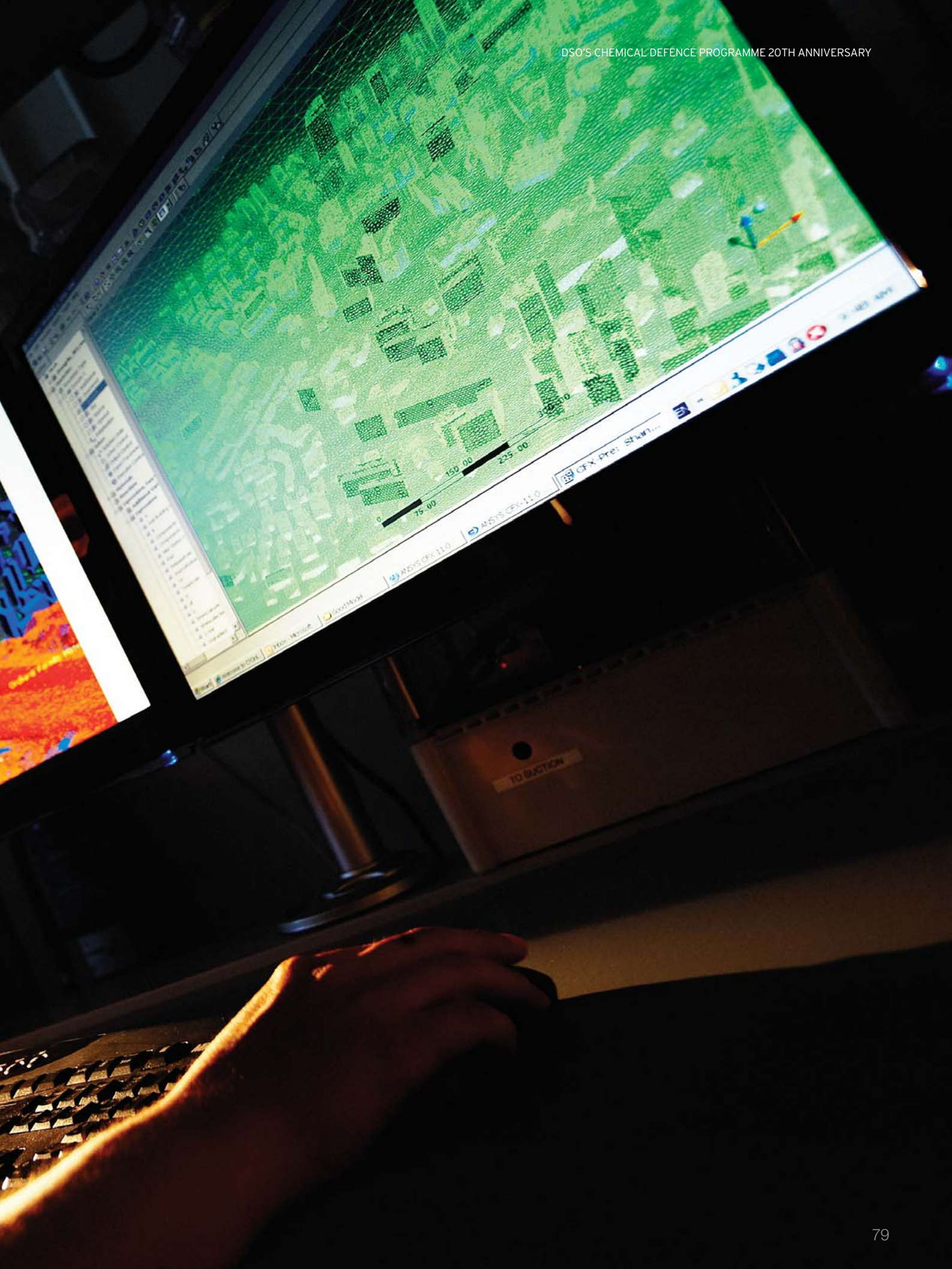
To advance our research in this area, we are exploring the development of a test tunnel facility, establishing a simulant database library, and validating detection algorithms through outdoor field trials.



MODELLING AND SIMULATION TOOLS

To better respond to CBRE threats, DSO will be developing dispersion models for tropical and urban settings, a relatively new research area in the world. The aim is to better understand the various physical and chemical parameters affecting the distribution of CBR in an urban environment.

DSO's chemical defence programme will seek to build a team of in-house experts to accurately perform various scales of urban dispersion modelling for both indoor and outdoor purposes. To further the technical proficiency in this area, DSO will also be extending such models to do back-tracking and source location.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STRAIGHT TALK

Colonel Lee Heok Chye

Commander
(Chemical, Biological, Radiological & Explosives Defence Group)
Singapore Armed Forces

Profile

Colonel Lee Heok Chye was enlisted in 1986 and was awarded the SAF Military Training Award in 1988. In the course of his military career, COL Lee has held several command posts, and also served as a Military Observer in the United Nations Iraq-Kuwait Observer Mission (UNIKOM) from 1994 to 1995. Since assuming the appointment as Commander of the Chemical, Biological, Radiological and Explosives Defence Group (CBRE DG) in 2007, COL Lee has been instrumental in strengthening the integration of CBRE DG, and the build-up of full spectrum operational capabilities in the SAF against ever-evolving CBRE threats.

What is CBRE DG's mission and when was it established?

CBRE DG's mission is to provide CBRE support and advice across SAF's full spectrum operations. In the past, we had established simple and basic chemical defence for the SAF. But in the aftermath of 9/11, it was decided that the existing capabilities were insufficient to meet new operational requirements. That was when we started to re-strategise and chart out the CBRE capability development roadmap. It took us a few years to integrate EOD (Explosive Ordnance Disposal) and CBRD (Chemical, Biological, Radiological Defence) as one entity, and to officially form the CBRE DG in 2005.

How has DSO's chemical defence programme contributed to CBRE DG's mission?

CBRE DG has grown hand in hand with DSO since the establishment of its chemical defence programme. The way I see it, DSO does not just support us, but is an integrated part of us. For example, the verification capability that has been developed by DSO is a requirement for the SAF's operational capability. So it is more than just a partnership between DSO's scientists and the SAF. From the past till present, we have DSO personnel like Dr Ang Kiam Wee, Dr Loke Weng Keong and Dr Alex Chin Piao, who served and are still serving as National Service (NS) men in CBRE DG. This provides opportunities for scientists to develop capabilities that are relevant to us, as they have close interaction with the ground. This integrated Ops-Tech is niche to our capability development.

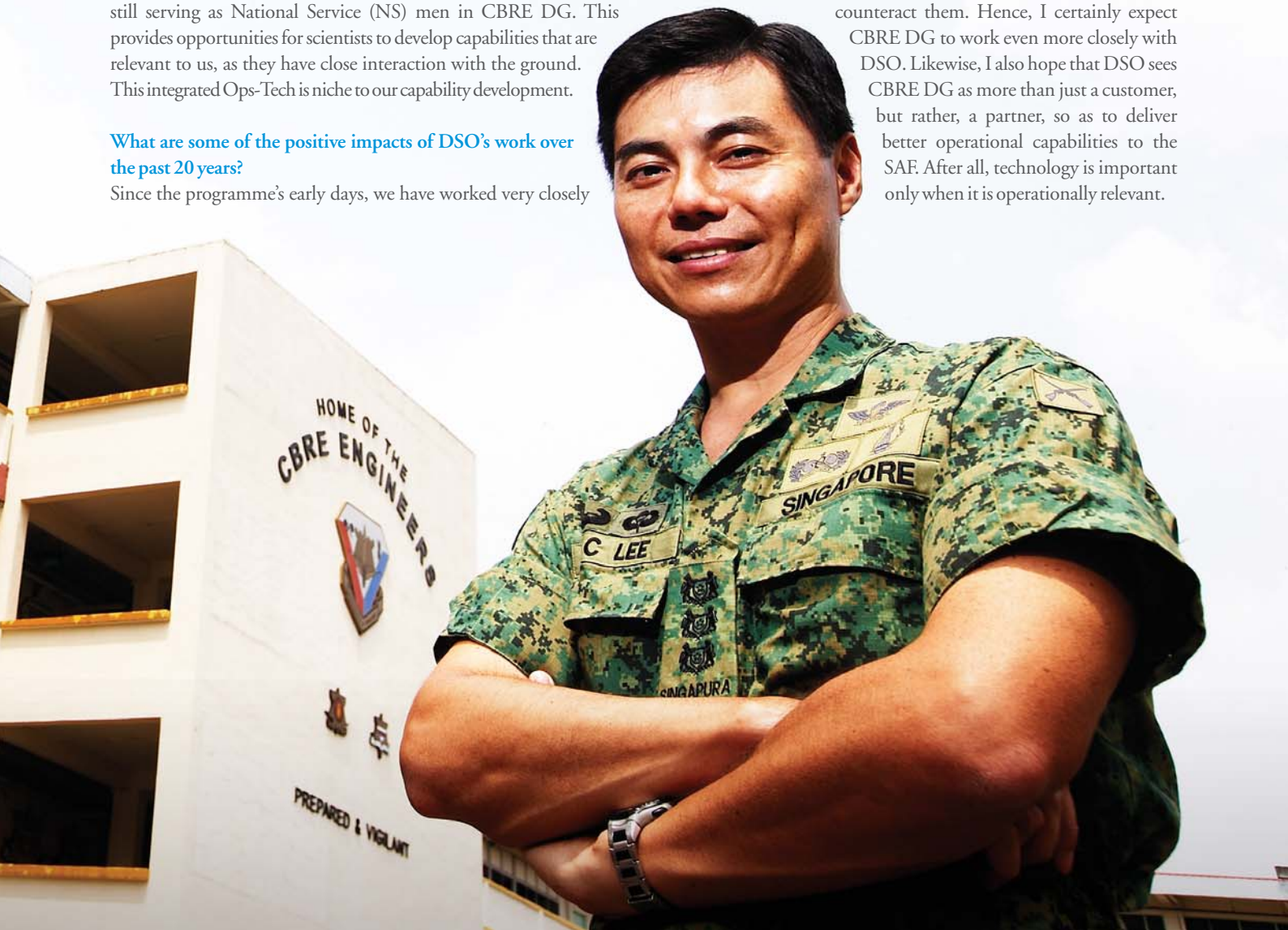
What are some of the positive impacts of DSO's work over the past 20 years?

Since the programme's early days, we have worked very closely with DSO to test and design individual protection equipment. They are still being used by the SAF in the present day. The suite of detection equipment that SAF procured was also evaluated by DSO to ensure that both the detection limits and reliability were good. Our collaborations have also extended to the area of decontamination, where we formulated and developed Demul-X. There are also other areas, such as in software and modelling for threat assessments.

> **"CBRE DG has grown hand in hand with DSO since the establishment of its chemical defence programme. The way I see it, DSO does not just support us, but is an integrated part of us."**

With chemical threats ever changing, how can DSO help CBRE DG to meet these challenges?

I envisage that the world in the future will be more complex with CBRE threats being highly integrated. DSO has a strong understanding of the technical aspects of these threats, so it has a very important responsibility to design technology that can counteract them. Hence, I certainly expect CBRE DG to work even more closely with DSO. Likewise, I also hope that DSO sees CBRE DG as more than just a customer, but rather, a partner, so as to deliver better operational capabilities to the SAF. After all, technology is important only when it is operationally relevant.



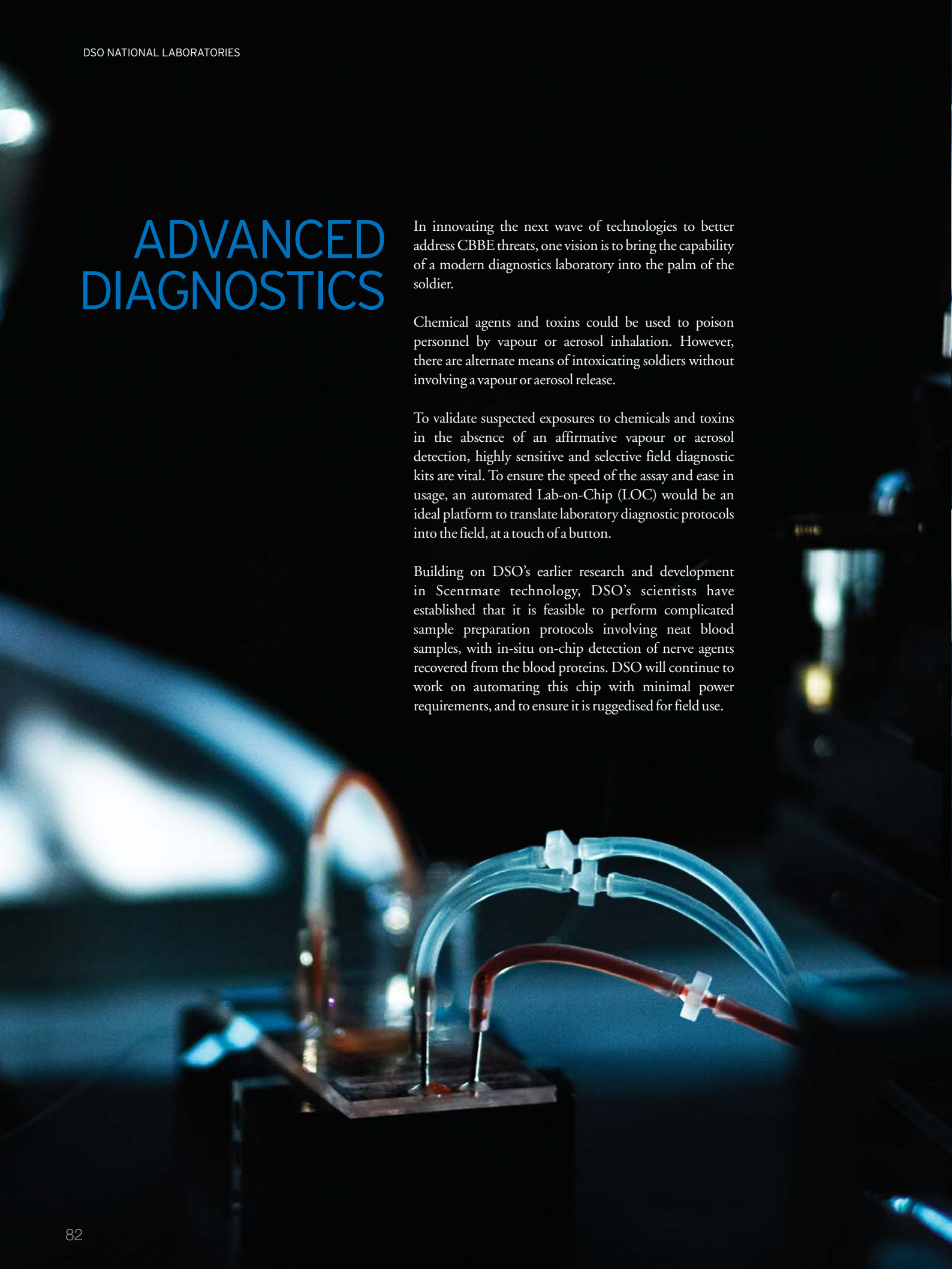
ADVANCED DIAGNOSTICS

In innovating the next wave of technologies to better address CBBE threats, one vision is to bring the capability of a modern diagnostics laboratory into the palm of the soldier.

Chemical agents and toxins could be used to poison personnel by vapour or aerosol inhalation. However, there are alternate means of intoxicating soldiers without involving a vapour or aerosol release.

To validate suspected exposures to chemicals and toxins in the absence of an affirmative vapour or aerosol detection, highly sensitive and selective field diagnostic kits are vital. To ensure the speed of the assay and ease in usage, an automated Lab-on-Chip (LOC) would be an ideal platform to translate laboratory diagnostic protocols into the field, at a touch of a button.

Building on DSO's earlier research and development in Scentmate technology, DSO's scientists have established that it is feasible to perform complicated sample preparation protocols involving neat blood samples, with in-situ on-chip detection of nerve agents recovered from the blood proteins. DSO will continue to work on automating this chip with minimal power requirements, and to ensure it is ruggedised for field use.



BUILDING RADIOLOGICAL DEFENCE CAPABILITY

Since the inception of DSO's chemical defence programme, it has been growing in tandem in anticipation of evolving threats. As we enter a new decade, new trends are clearly emerging.

The world is seeing an increasing frequency and intensity of terrorist attacks, with each attack more deadly than the last. Secondly, there is a resurgence of nuclear energy as a viable energy source. The convergence of these two trends could have dire impact on national security.

While DSO has basic facilities and personnel for handling radio-isotopes, we will continue to develop more extensive facilities and expand our research into radio-chemistry, detection, diagnostics and decontamination, as well as medical countermeasures, collective protection and radio-forensics.

Our People

DSO National Laboratories is Singapore's National Defence R&D Organisation. The establishment of its chemical defence programme is a reflection of DSO's role as a national laboratory, as it seeks to protect Singapore against emerging threats. The achievements by DSO's chemical defence programme are a testament of the passion and dedication of its scientists who have made a difference in safeguarding the security of the nation.

Epilogue

Before the merger between the Defence Medical Research Institute (DMRI) and DSO's Centre for Chemical Defence (CCD) in 2003, I was the concurrent Chief of the SAF Medical Corps, and Director of DMRI.

As a medical officer tasked to set up the medical training, responses and treatment in the area of chemical defence, I had the opportunity to visit numerous countries and view the core capabilities of their R&D establishments. It was clear to me then that DSO and their young team at CCD had gaps to bridge. They were facing a daunting task in developing a very niche expertise that was evolving very quickly.

With the successful merger in 2003, I assumed the Director appointment in the Defence Medical Environmental and Research Institute (DMERI), and was both surprised and impressed with CCD's progress and accomplishments over the years. The pioneering team of leaders, such as Prof Ang How Ghee and Dr Lee Fook Kay, amongst others, have led the team well. Special mention must be credited to the late Dr Ake Bovallius, who generously imparted his wisdom and invaluable knowledge to the team, that helped jumpstart DSO's chemical defence programme.

As the programme enters its third decade of enhancing Singapore's defence against potential CBRE threats, I am heartened that we have continued to draw on our strengths to establish DSO as the national repository of expertise and information in chemical defence.

Our achievements would not have been possible without the vision and support from MINDEF and the SAF. We are grateful for the special relationship between DSO and SAF's CBRE DG. Moving forward, we will continue to foster closer ops-tech integration, and streamline our R&D activities to deliver more impactful innovations. Likewise, we will continue to embark on new collaborative research with our overseas partners. These cross-fertilisation efforts will become more enriching, as we seek greater discoveries in the chemical defence landscape.

Above all, we will be focusing on our efforts to build on our key strength – Our People.

Today, DSO's chemical defence programme has grown to a modest number of more than 60 research scientists and engineers, specialising in diverse research fields such as chemistry, pharmacology and biology. This has brought about greater synergy for interdisciplinary R&D in the programme. The larger family of DMERI that comprises of molecular biologists, physiologists, geneticists and bio-engineers will provide a congenial environment for the further exchange of ideas to help shape the future for our CBRE programme.

Beyond research, we will continue to focus on growing the vibrancy and dynamism of the team, which I believe, is the essential ingredient in propelling our programme to the next level. While we have managed to keep key staff from among the pioneer team, we have also been able to attract new talents to maintain a team with an average age of 31years.

The next lap for this team of scientists will be both challenging and exciting. I am confident that DSO's chemical defence programme will be equal to the task, and will continue to provide the technological innovations to accomplish our mission.

BG (Ret) Prof Lionel Lee
Director, DMERI
Adjunct Professor, Duke-NUS Graduate Medical School

"Today, DSO's chemical defence programme has grown to a modest number of more than 60 research scientists and engineers, specialising in diverse research fields such as chemistry, pharmacology and biology."

Management Team

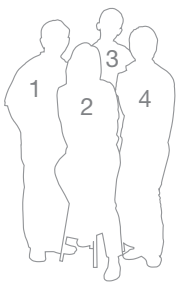
They are the leaders that provide the vision for DSO's chemical defence programme. An inspiration to their research team, they work hand-in-hand to overcome new challenges and identify strategic opportunities to push forth novel innovations that will strengthen Singapore's chemical defence capabilities against evolving threats.

1. Sng Mui Tiang
2. Loke Weng Keong
3. Loh Wai Leng
4. Lee Kim Hock Lionel
5. Sim Soo Hoon Eunice
6. Ang Kiam Wee

Technology Support Group

From infrastructure development and facility management, to project management support, the Technical Support Group forms the backbone of DSO's chemical defence programme. Working seamlessly with the management, scientists and engineers, the team enables and ensures the efficient running of all CBRE research operations.

1. Lim Jui Sui
2. Lim Chew Har Claudia
3. Ho Peng Yip
4. Tan Soo Bee



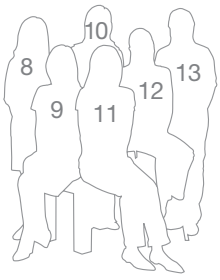
Agent Diagnostics and Therapeutics Laboratory (ADT)

ADT is active in diagnostic and pharmacological research to counter toxic effects posed by chemical agents and toxins. It focuses on the development of diagnostic laboratory capabilities and test kits, as well as the development of antidote solutions by using US Food and Drug Administration (FDA) approved medication that may have potential in combating against new human ailments. In addition, ADT also conducts operational toxicology studies on nerve agents, blister agents and toxins.

1. Seow Josefina
2. Chen Hsiao Ying
3. Sew Wenhui Tracey
4. Loke Weng Keong (Laboratory Head)
5. Chua-Soh Poh Chiang Emily
6. Huang Meijin
7. Ho Mer Lin Doris

8. Ng Siew Lai
9. Yit Pui Yin
10. Tan Hsih Yin
11. Chang May Ling Joyce
12. Ho Lai Kwan Alicia
13. Tan Yong Teng

Absent:
Chua En Lin Christelle
Foo Ling Yann
Lim Chau Wen Kevin
Loo Howe Kiat

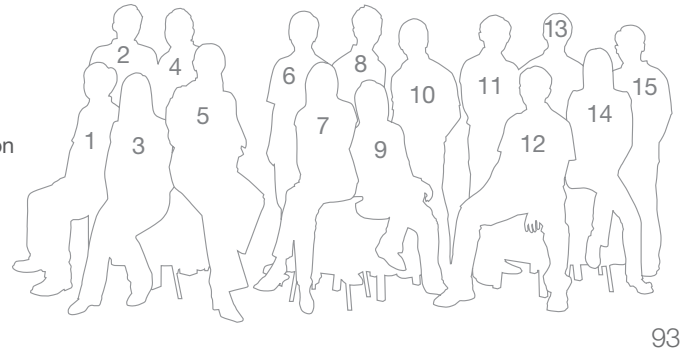


Agent Research Laboratory (ARL)

ARL's focus is to build up knowledge and understanding of CBR threats, especially in Singapore's environment. It seeks to understand the properties, reactions and degradation of toxic substances through information gathering, laboratory experiments and computational modelling.

1. Ma Yifei
2. Yang Wenchao Adrian
3. Ang Lee Hwi
4. Voo Keng Soon Vinc
5. Sim Soo Hoon Eunice (Laboratory Head)
6. Tan Peng Yen
7. Lim Kai Shuang Cari
8. Wong Choon Kiat Benjamin
9. Saw Xiao Ting
10. Tan Wee Kwok
11. Chin Piao Alex
12. Lim Yong Hao
13. Ng Teck Chuan Jason
14. Ang Linda
15. Neo Tiong Cheng

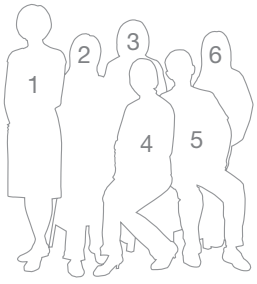
Absent:
See Mei Eng Elaine
Tay Bee Kiat



Analytical Research Laboratory (ANL)

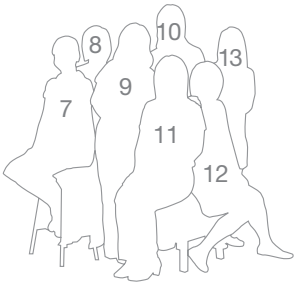
ANL aims to detect and unambiguously verify chemical and toxin threats using the most expeditious technologies, and set the standard for all analytical methodologies for chemical and toxin analysis.

1. Sng Mui Tiang (Laboratory Head)
2. Siow Siew Lin Linda
3. Chua Hoe Chee
4. Tan Hiong Jun Angela
5. Yeo Thong Hiang
6. Woo Huizhen Jessica



7. Tan Sook Lan
8. Xu Xiuhui
9. Cheh Mei Yee
10. Lim Meiyun
11. Chan Shu Cheng
12. Kwa Soo Tin
13. Yeo Mui Huang Veronica

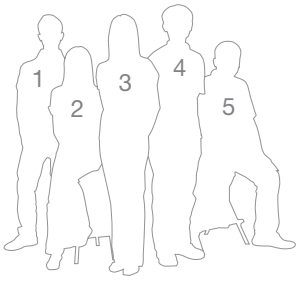
Absent:
Lee Hoi Sim Nancy



Applied Chemistry and Engineering Laboratory (ACE)

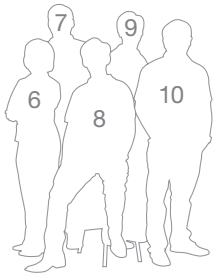
ACE strives to apply knowledge from chemistry and engineering science to identify, develop and evaluate novel materials and engineering solutions for the next generation of CBRE defence equipment and needs.

1. Li Jingxian Russell
2. Yee Caiyun
3. Loh Wai Leng (Laboratory Head)
4. Ng Ming Horng George
5. Mun Cheok Hong



6. Chan Lai San Clareene
7. Chew Khee Siah Kendrick
8. Tan Jinhui
9. Pong Boon Kin
10. Koh Wai Heng

Absent:
Koh Yaw Koon



Gallery

The history of DSO's chemical defence programme began 20 years ago. This compilation of photos tells an intimate story of its humble beginnings. It shows an inspiring story of how a team of DSO's scientists ventured into the unknown, and successfully built up a strong and operationally ready chemical defence capability.







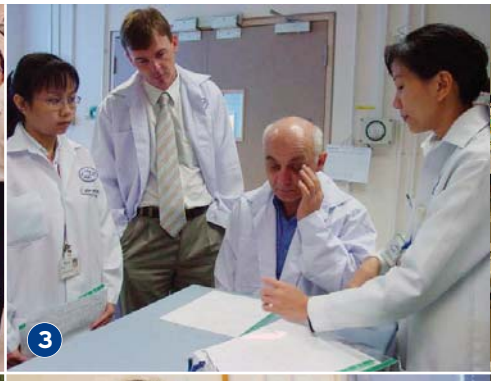

1. Visit to ACL by former Deputy Prime Minister (DPM), Dr Tony Tan (left)
2. Mr Peter Ho (left), Dr Su Guaning and Dr Åke Bovallius at the inaugural SISPAT
3. Dr Su (left) with former DSO CEO, Mr Quek Tong Boon (right) at a SISPAT luncheon
4. Dr Bovallius (middle) in one of his visits to DSO
5. Dr Lee Fook Kay (left) with Dr Bovallius and Prof Ang How Ghee at FOI
6. Mr Quek receiving a Certificate of Commendation from His Excellency, President S R Nathan, for DSO's contributions during the SARS crisis
7. Ms Loh Wai Leng in the lab
8. Visit to ACL by Mr David Lim, former Minister of State for Defence
9. DSO signing a collaboration agreement with CEB
10. Dr Lee in the ACL Laboratory
11. Former CBRE DG Commander, LTC Ho Kong Wai (middle) in a field trial discussion



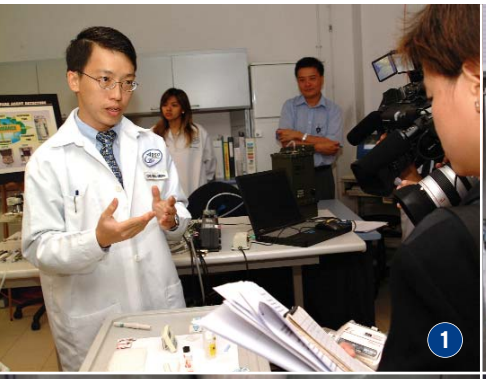
1. Dr Ang Kiam Wee (right) and his Proctetion Research team members
2. Dr Koh Cheng Heng (second from left) hosting SISPAT participants in a visit to DSO
3. Dr Koh's attachment to FOI
4. Dr Ang in a discussion with a FOI scientist in DSO
5. Swedish collaborators from FOI in a visit to DSO
6. Dr Bovallius with Mr Quek at DSO's TechShowcase
7. Dr Koh and fellow colleagues at an outdoor trial
8. DPM Teo Chee Hean (middle) and Prof Lui Pao Chuen, former Chief Defence Scientist (fourth from right) with Dr Lee (left) and Sng Mui Tiang (holding trophy) in a group photo after receiving the Defence Technology Prize
9. Dr Ang Kiam Wee in the ACL lab
10. Mui Tiang with collaborators from the US
11. Visit to ACL by the first Director-General of OPCW, Dr José Bustani
12. Dr Gösta Lindberg (middle) from FOI after an agent synthesis

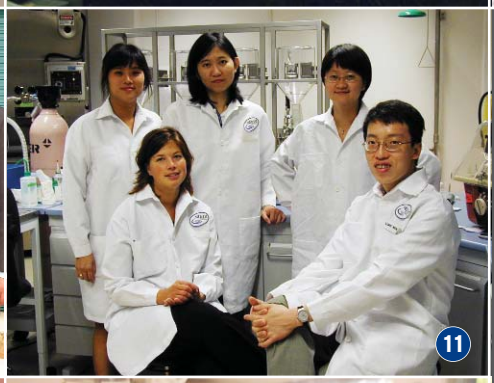
1. The new building in Marina Hill housing DSO's chemical defence programme
2. Official Opening of Marina Hill by former DPM Tony Tan (right) and Prof Lui
3. Official Opening of Marina Hill by then DPM, Dr Tony Tan
4. Group photo of the participants from the inaugural SISPAT
5. Dr Lee (right) with SISPAT participants during their tour in DSO
6. Dr Lee (left) explaining to former DPM, Dr Tony Tan (right) on the new facilities in Marina Hill
7. Dr Koh welcoming Guest-of-Honour, Mr David Lim to the inaugural SISPAT
8. DMERI Director, BG (Ret) Prof Lionel Lee (front row, second from left) with his management team at the opening of the DMERI building
9. Mr David Lim at the inaugural SISPAT
10. DSO's team of scientists in their visit to ECBC
11. Visit to DSO by MG Lim Chuan Poh (left), former Chief Defence Force of the SAF

1. Loh Wai Leng (middle) presenting her work to her US counterparts
2. Dr Bovallius and Dr Lee at a SISPAT symposium
3. Dr Lee (front row, middle) with his team of dedicated scientists
4. Dr Loke Weng Keong (left) explaining his research at the inaugural SISPAT
5. Dr Eunice Sim presenting her decontamination work
6. Dr Diana Ho presenting her agent synthesis research to the Director-General of OPCW, Ambassador Rogelio Pfirter during his visit to DSO
7. Initial team of chemical defence researchers
8. DSO scientists at work in the BSL3 laboratory
9. Wai Leng presenting her research to visitors from the SAF
10. Detection Standoff trial in Singapore with Dr Philippe Adam (second from right) from CEB
11. The DSO team visiting their CEB counterparts in France
12. DSO scientists on attachment at FOI
13. DSTO's scientists in a visit to DSO



1. Dr Lee (left) with Prof Ang in his DSO office
2. Prof Ang (middle) with his pioneering team of scientists in DSO
3. Mui Tiang (right) in a discussion with personnel from OPCW
4. Standoff Detection Trial with CEB
5. Dr Tan Yian Kim in the lab
6. Prof Ang and Mr Quek Gim Pew (right) during a technical talk in 1997
7. Dr Eunice Sim showcasing her prepared decontamination solution
8. Mui Tiang checking the samples for the OPCW Proficiency Test
9. Prof Lui (middle), as part of the main committee for the inaugural SISPAT
10. An OPCW personnel checking DSO's preparations for the Spiking Exercise
11. Opening address by Mr David Lim, former Minister of State for Defence at the inaugural SISPAT





1. Dr Loke Weng Keong in a media interview on the Scentmate technology
2. Dr Loke presenting his work during a laboratory visit
3. The DSO team with CEB counterparts
4. A trial being conducted in the climatic chamber
5. Prof Lui (right) and Prof Lionel Lee (left) with SISPAT participants during the symposium dinner
6. Dr Lee Fook Kay delivering his Welcome Address at the inaugural SISPAT
7. Director-General of OPCW, Ambassador Rogelio Pfirter, presenting the Designation Certificate to Mr Quek
8. Dr Koh thanking Dr Gosta Linberg
9. Visit to DSO by SISPAT participants
10. Dr Lee (right) with Ambassador Rogelio Pfirter during his visit to DSO
11. Dr Loke and his team members with Ms Lena Maria Waara from FOI (left) on attachment to DSO
12. DSO researchers with their German counterparts
13. Scientists at work in a DMERI laboratory

The Editorial Team

What started out as a challenging assignment became a project of a lifetime. The team of three spent months researching, putting together interviews and coordinating photo shoots. Amidst the fervent writing, zealous editing and chasing closing deadlines, we were able to experience the incredible passion and dedication of each member of the CBRE family. It left an indelible impression, and putting together this commemorative magazine has been a humbling and rewarding effort.

1. Siow Siew Lin Linda
2. Lim Chew Har Claudia
3. Wong Eng Cheng Kenny

We take this opportunity to thank the following personnel whose advice and guidance have been invaluable:

- **Mr Quek Gim Pew, CEO, DSO**
- **BG (Ret) Prof Lionel Lee, Director DMERI**
- **Dr Ang Kiam Wee, Deputy Director, DMERI**
- **Ms Sng Mui Tiang, CBRE Programme Director, DMERI**
- **Ms Vivien Goh, Corporate Communications Manager, DSO**

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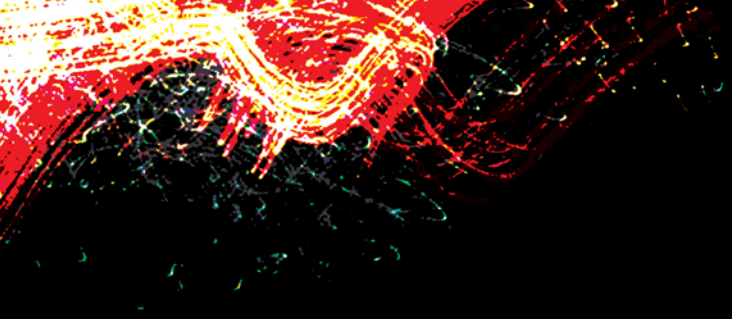

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