NEW DISCOVERY

Showcasing excellence across AWE

AWE

In this issue:

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- Profiling our people
- Excellence in STEM
- Achievements
- Collaborations
- National security

Winter/Spring 2017/18

AWE plays a crucial role in the defence and national security of the UK

If you have any feedback or suggestions for future articles, we would love to hear from you!

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Welcome to New Discovery

I am delighted to introduce New Discovery which is a refresh, with a contemporary twist, of our previously long-running Discovery publication with which many of you will be familiar.

We decided to launch New Discovery because we wanted to showcase the breadth of our work and the talents of our people whilst reaching out to a broader audience. I feel this exciting and engaging new publication showcases the wider remit of what we do in maintaining UK nuclear deterrence and keeping our country safe, as well as the way we conduct our business and operations, and how we support our people in being the best they can be.

As I go about my travels within the company, I am constantly impressed by examples of what our people are achieving day in, day out.

From working on developing the Orion laser using innovative techniques, through a supernova playing a 'starring' role at science events, and specialists leading the way in non-destructive testing, to profiling our people who share their experience of what it's like to work here. Also highlighted is an account of one of our fire and rescue officers who supported the hurricane relief effort and an insight into our expertise, in supporting an international treaty in keeping our nation safe.

You'll see examples of just that and more in this first issue.

The articles demonstrate excellence and variety across the organisation, with people from diverse backgrounds and interests, being at the core of accomplishment and turning AWE into a better place to work each and every day.

I hope you enjoy reading New Discovery and find something that interests you.

Iain Coucher
Chief Executive and Managing Director

Worth its **weight** in gold

As well as supporting key electroplating electrical contact work in AWE's long-established surface finishing workshop, gold has other properties that are of significant interest to our scientists and engineers.

This includes being able to exploit its infrared and x-ray resistance – in the manufacture of tiny sub-millimetre targets (typically the size of a grain of sugar) – for plasma physics research at the world-leading Orion laser.

So why gold?

Gold is being used to support our understanding of the safety and performance of the UK's nuclear deterrent – in the Comprehensive Nuclear Test Ban Treaty era – because of the unique properties of this precious metal.

And in a drive to improve efficiency, process and cost, our specialists investigated the Gold Bug® method. This method uses an extremely high surface area cathode, of a known weight, enclosed within a housing (the Gold Bug® cell) which also provides the anode to complete the circuit.

The complete 'cell' is placed within the plating solution, and in AWE's case the outlet of the process filtration is directed into the cell to provide fresh plating solution to be 'seen' by the cathode. Using a 25-30 amp DC power supply, through conventional electrolysis, the gold is deposited directly onto the high surface area cathode. Recovery rates can reduce plating solution strengths to less than five parts per million (the normal operating gold content is in the region of 25g/l or 25000 parts per million).

After a period, the cathode is removed from the cell, washed, rinsed, dried and then reweighed. The increase in weight is the result of actual gold recovered. The plated cathode can then be sent directly for reclaim as a non-hazardous material.

Additionally while the process is in operation, through disassociation, it helps to destroy the free cyanide within the plating solution and the remaining cyanide solution can then be neutralised within the plating tank. This is then disposed of as a safer non-cyanide containing solution, at a significantly reduced cost.

Each cathode is capable of recovering up to 3kg of gold – at which point the cathode is simply replaced with a fresh one and the process repeated.

For AWE, as well as the cost savings, the innovation is seen as a substantially efficient and environmentally friendly method of reclaiming gold.

The Gold Bug® has also been identified as a suitable means for the recovery of silver and other precious metals used at AWE from spent plating solutions. Additionally, by placing the Gold Bug® within the rinse water effluent system, any gold or metal ions passed to these rinses through 'drag out' can also be recovered in the same way – further reducing wastage and increasing the cost benefit.

Gold-Bug® is a registered trademark and is the property of Precious Metals Processing Consultants, Inc.

Plated high surface area cathode – £1800 worth of gold has been recovered

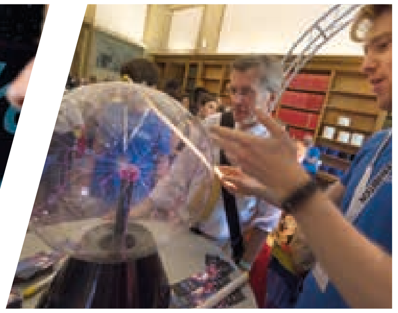
Close-up of high surface area cathode – gold loaded honeycomb matrix

Unplated high surface area cathode

Supernova plays 'starring' role at *science events*

Thousands of visitors, of all ages and interests, were wowed by our participation at The Royal Society Summer Science Exhibition, the Science Museum Lates event and New Scientist Live – each held separately in London this year.

There were interactive exhibits being demonstrated, which included how you can create a 'shock wave' using an air vortex cannon made from a dustbin – or bask in the power of plasma globes conducting electricity with your bare hands.



Visitors learnt how giant lasers like Orion can recreate astrophysical conditions like supernovae in the laboratory – albeit for a very short timescale. They also had an opportunity to chat to AWE scientists and engineers about their careers cutting across a whole range of disciplines.

All events highlighted the diversity of scientific ingenuity and creativity in the UK from the world of science, medicine and technology.

"The AWE team was amazing and included everyone from apprentices and graduates to distinguished scientists and engineers – engaging with members of the public of all ages. It was a fantastic opportunity to raise our profile and to inspire the future generation of STEM professionals," says Philippa Kent from Corporate Communications, who coordinated AWE's participation in New Scientist Live.

"The Royal Society Exhibition provides an excellent platform to tell the public about the exciting research that is going on in the field of laboratory astrophysics – in particular it is a great opportunity to enthuse young people, who will be the next generation of scientists"

Professor Justin Wark
University of Oxford

Profiling our People

Rebecca
Mechanical engineer

I joined the graduate programme at AWE about three years ago, following a Masters in Mechanical Engineering.

During the programme, I moved around the organisation doing placements in systems, non-destructive testing, surety and a secondment at the Foreign & Commonwealth Office. I enjoyed the chance to find out about each area before deciding what to do permanently.

The thing I enjoy most about my job is the practical aspect; I often spend time in the lab as well as time doing design work using CAD. I also enjoy the pace of research and development. The best thing about my job is its uniqueness and the people with whom I work.

International Women in Engineering Day highlights the importance of diversity and inclusion within STEM industries. I think the perception of engineering needs to change. A lot of people in the UK think engineering is just a guy under a car covered in oil. Not a lot of young people appreciate that engineering is a massive field covering civil, electronic, mechanical, electrical, and chemical. I think the problem is parents aren't aware what engineering is and so can't sell it as a career to their children.

Another issue is the perceived thinking that maths or physics is a boy's subject and it isn't cool for girls to be good at it – although exam scores show otherwise!

The advice I'd give to someone who would like a career in STEM would be to ignore the misconceptions of anyone around you who thinks engineering isn't appropriate for females. Rise above them and know you'll be pursuing a career that benefits the whole of society.

An engineering degree opens a lot of doors for various careers. This means that as a society we'll be more educated about what an engineer is and in the long run have more people choosing the profession.

"The advice I'd give to someone who would like a career in STEM would be to ignore the misconceptions of anyone around you..."

Leading the way in non-destructive testing

Caroline Bull, as president of the British Institute of Non-Destructive Testing (BINDT), presided over the 56th annual Non-Destructive Testing Conference of the BINDT held on 5-7 September 2017 in Telford – to support AWE's work and our collaborations in the field of non-destructive testing.

Caroline specialises in non-destructive testing, which is fundamental to understanding the performance and reliability of the UK deterrent. She is also an advocate for those in the early stages of their careers in the STEM area.

Also invited to the conference was Owen Price who is AWE group leader, Systems Integration and Engineering. He delivered the keynote speech (the 2017 President's Honour Lecture) entitled 'Nuclear Safety, More Valuable than Gold – the role of non-destructive testing.'

"It is a privilege to have been elected to the prestigious role of president of BINDT. I am pleased to have had the opportunity to foster links between the Institute and industry, including AWE"

Caroline Bull
Early careers capability lead

Historical Insights

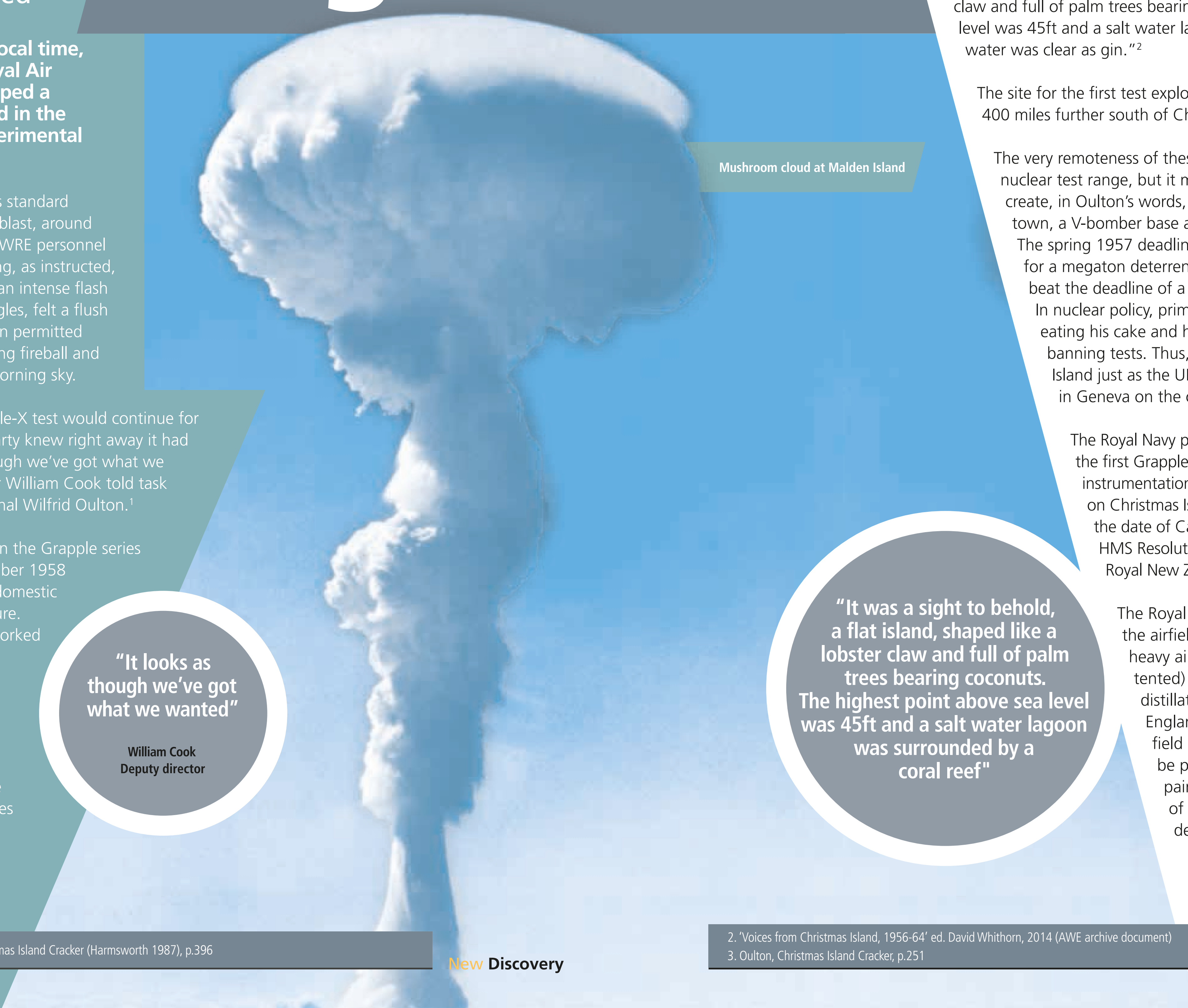
Operation Grapple: It looks as though we've got what we wanted

Sixty years ago, at 0843 local time, on 8 November 1957, Royal Air Force Valiant XD824 dropped a bomb off Christmas Island in the Pacific containing an experimental thermonuclear device.

As the Valiant turned away in its standard escape manoeuvre to avoid the blast, around 3000 services and 100 civilian AWRE personnel on and around the island – facing, as instructed, away from the explosion – saw an intense flash of light through hands and goggles, felt a flush of heat on their backs and, when permitted to turn round, watched the rolling fireball and mushroom cloud rise into the morning sky.

Analysis of data from the Grapple-X test would continue for many months, but the AWRE party knew right away it had been a success. "It looks as though we've got what we wanted", AWRE deputy director William Cook told task force commander Air Vice Marshal Wilfrid Oulton.[1]

Successive thermonuclear tests in the Grapple series between May 1957 and September 1958 were conducted under intense domestic and international political pressure. Military and civilian personnel worked day and night with a palpable sense of time running out – and a last-minute drama at sea nearly derailed Grapple-X. This short account outlines the tasks carried out by AWRE during the Grapple tests and introduces life on Christmas Island, the pressures faced and the results achieved.



Mushroom cloud at Malden Island

> **"It looks as though we've got what we wanted"**
>
> **William Cook**
> **Deputy director**

Serious logistic planning for testing British thermonuclear weapons – 'H-bombs' – in the Pacific began in September 1955 with a photo reconnaissance by the RAF. Christmas Island, sighted on 25 December 1777 by Captain Cook, is a large coral atoll in the remote Pacific, over 1000 miles south of Hawaii. Then part of the Gilbert and Ellice Islands colony, its few attractions included an abandoned wartime US staging base with airfield, a sheltered harbour, a transient population of Gilbertese copra harvesters and very little fresh water. One veteran recalled: "It was a sight to behold, a flat island, shaped like a lobster claw and full of palm trees bearing coconuts. The highest point above sea level was 45ft and a salt water lagoon was surrounded by a coral reef. The water was clear as gin."[2]

The site for the first test explosion would actually be off Malden Island, 400 miles further south of Christmas Island and uninhabited.

The very remoteness of these islands was their key advantage as a nuclear test range, but it meant an elaborate military operation to create, in Oulton's words, "all the essential infrastructure of a small town, a V-bomber base and a high-class scientific establishment."[3] The spring 1957 deadline was based on the military requirement for a megaton deterrent weapon and the political requirement to beat the deadline of a nuclear test ban, first discussed in 1954. In nuclear policy, prime minister Harold Macmillan was for eating his cake and having it: developing the H-bomb, and also banning tests. Thus, in May 1957, testing began at Malden Island just as the UK tabled specific proposals through the UN in Geneva on the operation of a ban.

The Royal Navy provided heavy lift, guard ships and, for the first Grapple tests, the HQ ship HMS Warrior and instrumentation ship HMS Narvik. The small naval facility on Christmas Island was known as 'Naval Party 2512' after the date of Captain Cook's discovery, until it was renamed HMS Resolution in December 1957 after his ship. The Royal New Zealand Navy also contributed ships.

> **"It was a sight to behold, a flat island, shaped like a lobster claw and full of palm trees bearing coconuts. The highest point above sea level was 45ft and a salt water lagoon was surrounded by a coral reef"**

The Royal Engineers did back-breaking work to bring the airfield up to standard for Valiants and other heavy aircraft, also creating laboratories, (mostly tented) living accommodation, fuel storage, water distillation plant, communications, Church of England and Roman Catholic churches and a field post office, where coconuts could later be posted provided the address was clearly painted on and stamps affixed to the sum of around four shillings and six pence, depending on weight.

1. AVM Wilfrid Oulton, Christmas Island Cracker (Harmsworth 1987), p.396

2. 'Voices from Christmas Island, 1956-64' ed. David Whithorn, 2014 (AWE archive document)
3. Oulton, Christmas Island Cracker, p.251

As well as Valiants to drop the bombs, the RAF provided transport, reconnaissance, air and cloud sampling, and search and rescue aircraft and helicopters. The last of these boasted, in the unofficial newsletter Mid Pacific News, that "our other task on the island is ferrying everything from boffins to bananas anywhere at any time."[4]

These boffins, from AWRE, were divided into three groups for weapon assembly, test measurement and technical services. Weapon assembly meant bringing together complex radioactive, high explosive and electronic components safely and loading onto aircraft without in any way compromising the standards expected at bigger, permanent facilities in the UK. Test measurement covered air and ground shock and radio, heat and gamma-ray flash effects, photographic measurement of the fireball, radiochemical analysis and monitoring the condition of the test devices throughout. Technical services included health physics and decontamination for all military and civilian personnel.

HMS Warrior off Malden Island

"These boffins, from AWRE, were divided into three groups for weapon assembly, test measurement and technical services"

Life on Christmas Island was basic, with camp beds, set just high enough to avoid the ubiquitous local coconut crabs. And showers and DIY laundry where lathering soap – in salt water – was quite a chore. AWRE civilians in particular complained about the food. Potatoes were especially hard to keep fresh in the humidity of Christmas Island, and several barrels of Watney's Pale Ale had to be condemned and buried. Recreations included fishing, swimming in the lagoon, cricket and a golf net, and the scientific party was generally a happy one. William Cook's deputy for the first Grapple tests, and head of the weapon assembly group, was Charles Adams; Ken Bomford led the measurement group; and John Challens headed technical services. Bomford later took over as scientific superintendent, overseeing all three groups under Cook.

Cook, in particular, remained unflappable, never without his trademark pipe, despite seriously sunburning his legs on first arrival and then falling victim to food poisoning. At home at Aldermaston, Cook maintained a strong personal grip on the whole thermonuclear programme, the parallel low-yield tests underway in 1957 in Australia and the production of service weapons for the RAF. His boss, AWRE director, Sir William Penney, meanwhile faced the sombre task of preparing a personal report for Macmillan on the Windscale fire of October 1957, and for two months in summer 1958 played a key part in the disarmament talks in Geneva. Both men were also called upon for important meetings with their US counterparts; 1957-58 were the years in which the Anglo-American atomic relationship was rebuilt.

The first and third Grapple tests, in May and June 1957, were of staged thermonuclear devices. Whilst they proved the key concepts involved, their yields were below the megaton prediction, and although the second, intervening test had a higher yield, it was a large pure fission device, a generation behind in design. Cook, with British phlegm, admitted to Oulton that "we haven't quite got it right."[5] Returning to the UK, he plunged into planning the methodical steps and calculations necessary to improve understanding of AWRE's staged devices and increase their yield, efficiency and useability. More tests would have to follow, and Oulton, to his surprise, was ordered to reassemble a task force that had thought it was going home. Meanwhile, sensitive to previous complaints about food, AWRE planned its own independent catering facilities in future on Christmas Island.

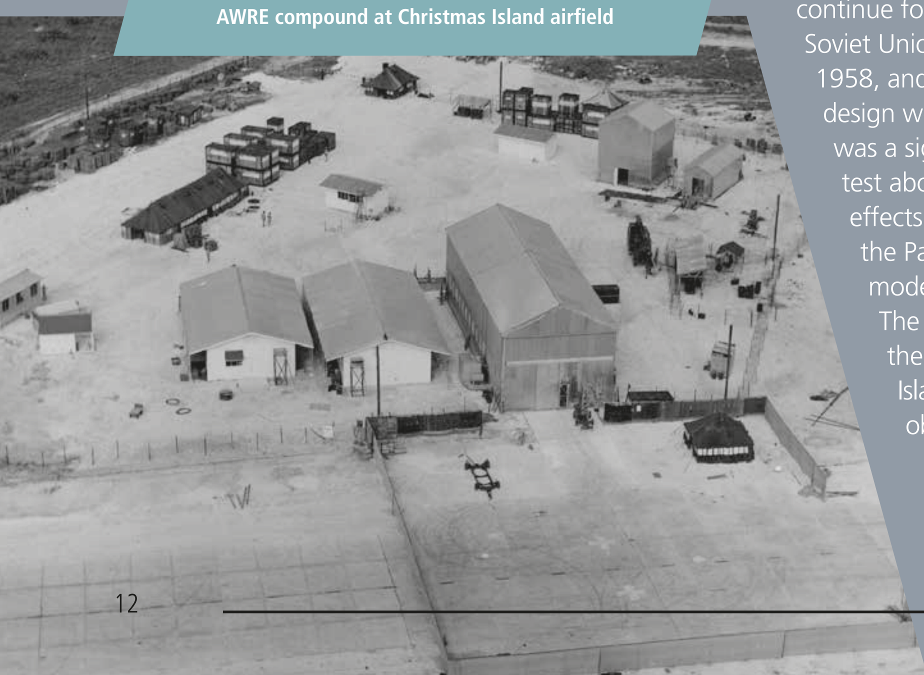
4. Mid Pacific News, Special Issue Megaton Test, 8 Nov 1957 (copy in AWE archive)

5. Oulton, Christmas Island Cracker, p.356

AWRE high-speed cameras

HM Ships, including the ageing Warrior, about to be sold to Argentina, would be unable to support further tests and this drove the decision to withdraw from Malden Island. Instruments and equipment on board and at Malden had to be reinstalled at the remote south-east corner of Christmas Island itself, where a new radar and airstrip were also built. Tests would now be offshore of this point. A new test – known initially as Windmill and later as Grapple-X, to emphasise continuity with earlier and later tests – was set for November. The Foreign Office feared this would be Britain's last chance, as a UN General Assembly resolution, eventually passed on 14 November, would increase pressure for an immediate test ban. International tension increased in October with the launch of the Soviet Sputnik; on Christmas Island, a film was stopped to allow the audience to watch the little satellite pass in the night sky overhead.

The design of the Grapple-X device was finalised at an extraordinary meeting of Cook's Weapon Development Policy Committee in September. Components were flown out to Christmas Island via Newfoundland, Nebraska, San Francisco and Honolulu between 24-29 October and assembled in the AWRE compound on the main airfield. Weather forced a three-day postponement on 5 November, then all seemed set fair until, at 0100 on the day of the test, an RAF Shackleton patrol aircraft found the Liberian-registered steamer Effie, not only heading towards the island but inside the danger area defined in an Admiralty Notice to Mariners, issued in London too late to reach the ship on her lonely course in the Pacific. Frantic efforts by Shackletons and the guard ship HMS Cossack eventually roused the crew and Effie headed out of the danger area at high speed, just an hour before the test.



AWRE compound at Christmas Island airfield

British nuclear testing at Christmas Island would continue for another year before the US, UK and Soviet Union declared a moratorium on 31 October 1958, and AWRE's thermonuclear warhead design would improve further. But Grapple-X was a significant milestone: the first British test above a megaton yield. Sixty years later, effects data recorded by AWRE scientists in the Pacific are still used to validate computer models in support of today's nuclear mission. The achievements of all three services and the spirit of cooperation on Christmas Island were outstanding. American observers, invited and encouraged to take measurements on neighbouring islands, were impressed too: Doyle Northrup, head of the US Air Force's monitoring effort, offered his "personal congratulations… your shot was heard literally around the world. Every one of our acoustic stations recorded the shot."[6] The Grapple tests reinforced AWRE's credibility in US eyes and strengthened the US-UK atomic relationship when it was restored in 1958.

Testing was controversial, domestically and internationally, as prime minister Macmillan recognised. But he also reflected the views of most British people at the time when he wrote in his diary that tests were "absolutely vital to the safety and strength of Britain."[7]

"Sixty years later, effects data recorded by AWRE scientists in the Pacific are still used to validate computer models in support of today's nuclear mission"

Map of Christmas Island

6. Doyle Northrup to Sir William Penney, 22 November 1957 (AWE archive document)
7. Peter Catterall, ed., The Macmillan diaries Vol.2: Prime Minister and after 1957-66 (Macmillan 2011), entry for 29 May 1958

Route to Success

A team of 14 AWE enthusiasts embarked on a once-in-a-lifetime 1000-mile cycle ride – supported by four crew – as part of promoting our outreach and recruitment activities across Britain.

Journeying through the wonders and adventures of Britain, the Route to Success strengthened our recruitment campaign and enhanced our relationship with UK academia. The expedition also showcased our advanced manufacturing and STEM capabilities and developed our team of cyclists with skills and experience beneficial to their careers.

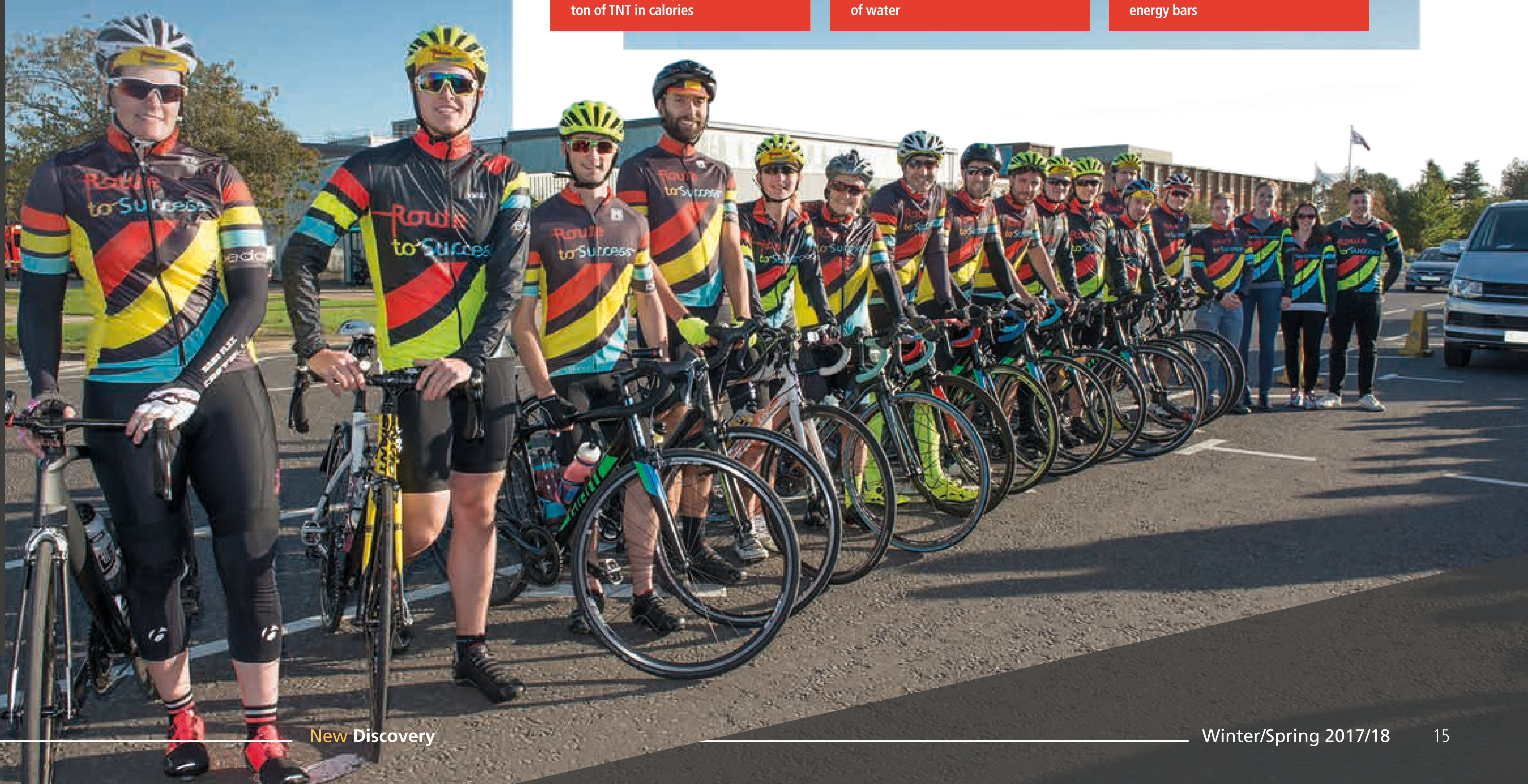
AWE technical adviser, Nicole Webb, says, "Delivering Route to Success and the journey we have been on to do so have been invaluable. The people involved invested a great deal of time and effort to ensure the successful delivery of the project, which made me feel incredibly proud throughout. It's been a privilege to have worked with so many colleagues from across the company. I hope the hard work continues to positively impact our recruitment strategy to support the programme."

Jake Clulow, a senior buyer at AWE, says, "We've spoken to over 250 students at five universities, and have already had students email to say how good the event was and that they are submitting an application for the graduate programme. This shows that our approach and message to the students was very positive. We will continue to track and monitor the level of engagement from students over the next 12 months."

Route to Success also provided awareness for our corporate charity, Living Paintings. Over the course of the training and event, we raised over £3000, and donated 100 hours of service to this worthwhile cause.

Fun Facts

- As a team we cycled enough miles to go to China and back
- Each rider climbed the height of 1.5 times that of Everest
- Only suffered seven punctures, with zero accidents on the road
- We burned the equivalent of half a ton of TNT in calories
- As a team we drank over 8000 litres of water
- As a team we consumed over 1000 energy bars



Developing the Orion laser

One of the largest scientific projects ever delivered in the UK, Orion is AWE's high power laser facility.

Producing conditions of extreme density and temperature, Orion's mission is to conduct experiments in high energy density physics, to support our understanding of the reliability and performance of nuclear warheads. It welcomes external collaborators as well as local users, and its services are fully subscribed.

The laser development team is striving continually to improve the capability and reliability of Orion. We have three approaches to doing this. The first is upgrading equipment to more modern systems. Much of Orion is already 10 years old and in some areas technology has moved on significantly. The second is increasing our understanding and control of the systems that we have. The third is developing new technologies and techniques, enhancing capability in the longer term. Orion has a suite of laser laboratories which we use to develop, test and characterise new equipment off-line before it is fielded on the high power beamlines.

Laser amplifiers are a good example of where we are upgrading our equipment. These crucial components store optical energy supplied by an external source. This energy is picked up by the laser pulse as it passes, being amplified in the process. Traditionally, the optical energy is supplied by flashlamps, which add a significant amount of heat to the laser material and operate at high voltage. Laser diodes, which are now a cost-effective alternative, avoid such a heat load and operate at low voltage.

Last year, we upgraded our small aperture rod amplifiers, then flashlamp-pumped systems operating at a repetition rate of 1Hz. The new diode-pumped amplifiers such as those shown on the bottom – run at 10Hz – are capable of supporting laser pulses that are twice as long as before. They act as the alignment beams of the main beamlines. We are working currently to upgrade our larger-aperture rod amplifiers, from systems that can be fired only once every 10 minutes to diode-pumped systems that also run at 10Hz. Alongside these developments, it has been necessary to create optical designs which naturally compensate for the thermally induced deformation of the beam, which disrupts its focus. This may lead to enhancement of the main beamlines. These developments will allow us to improve the effectiveness of our system set-up. Operation at 10Hz enables optimisation of Orion effectively in real time.

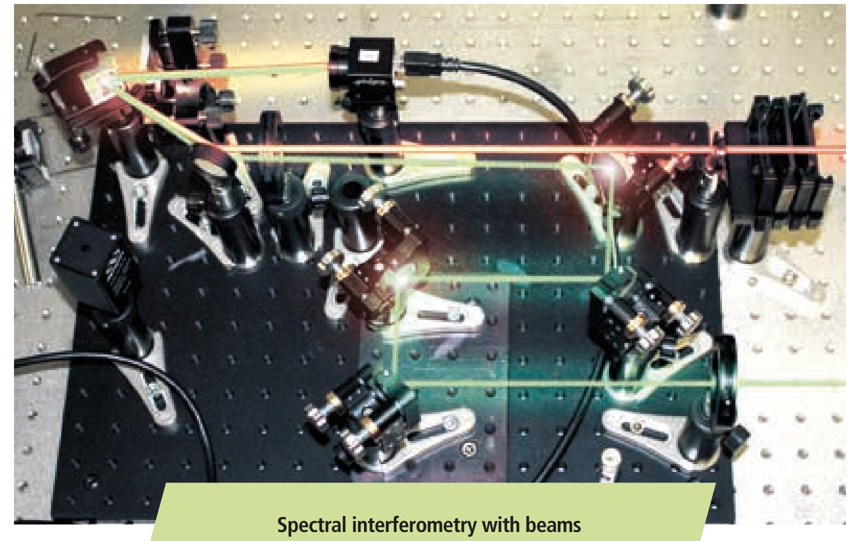
While 10 of Orion's beamlines deliver pulses lasting around one billionth of a second (1ns), another two produce pulses which are even shorter. These deliver a similar energy in less than one million-millionth of a second (1ps), resulting in extremely high power. To produce such short pulses requires correspondingly broad spectral content. We now talk in everyday life about "broadband", meaning an internet connection: increasing speed depends on shorter optical pulses, which in turn require broader spectral coverage. To generate optimally short pulses, however, this is not enough. The relative phase of the different optical frequencies in the bandwidth needs to be controlled. We are working on diagnostics that are based on spectral interferometry to measure this.

The device shown above compares two laser pulses. One is a well understood reference pulse the second is the pulse which we want to measure. These pulses are synchronised then diffracted off a grating and overlapped on a camera. Where the beams overlap an interference pattern is generated that contains information about the

Larger aperture under test in the off-line development laboratories

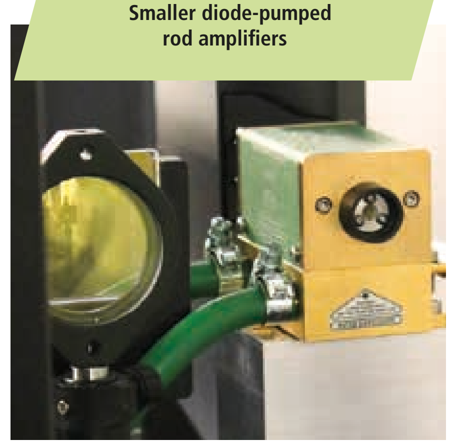
"Moving away from flashlamps is a great step forward. It means a significant improvement in capability, reliability and ease of use"

Di Hussey
Laboratory manager



Spectral interferometry with beams

Smaller diode-pumped rod amplifiers



phase difference between the two pulses. When this information is combined with a device that gives fine control of the spectral phase, we will enable Orion's ultra-short pulses to deliver the highest possible power.

As well as our work in-house, we collaborate with a range of companies and academic institutions and are part of an industrial-academic consortium developing 'negative-curvature' hollow-core optical fibres. Typical optical fibres, which confine light in a solid core, can handle only limited pulse energies. Hollow-core fibres do not suffer the same limitation and enable laser pulses of much higher energy to be transmitted over long distances. This capability has application in other areas also: for example, precision machining, gas detection and provision of novel light sources, such as Raman lasers, gas lasers and ultra-broadband sources.

"The measurements we made at Orion have shown some of the highest energies ever transmitted over single-mode fibre"

Stephen Elsmere
Project scientist

Power conference

AWE scientists Mark Sinclair and Neal Graneau, acting as conference chair and treasurer respectively, participated at the 21st IEEE (Institute of Electrical and Electronics Engineers) International Pulsed Power Conference to promote our application of pulsed power in the physics of nuclear deterrence.

Mark says, "It has been a long journey for me from first proposing that the UK hold the Pulsed Power Conference to the IEEE back in 2012 to the successful delivery of the conference this year. Myself and my treasurer, Neal Graneau, have learnt a lot in the process, I know there are things we would do differently, but it was a rewarding experience and seeing the looks on the attendees' faces at the i360 tower, the world's tallest moving observation tower in Brighton, made it all worthwhile. I can wholeheartedly recommend that others at AWE put themselves forward to support or run the conferences we have an interest in, as the connections made and the boost to AWE's reputation are invaluable."

The event covered the full range of applications of pulsed power. From radiography and effects testing familiar to AWE, through military applications such as rail guns and high power microwave devices to the more recent uses for academic, industrial and medical purposes, such as in particle accelerators, air and water purification, and cancer treatment.

Held in the UK for the first time in Brighton, the conference attracted over 500 delegates from 27 countries during which over 400 papers were presented – raising AWE's profile on a truly international level.

Dismantlement facility options:
Building solid foundations

A team of AWE experts, who specialise in arms control verification research, has been analysing the pros and cons of possible facilities in which inspectors could conduct verified nuclear warhead dismantlement in fulfilment of a treaty.

The team acts as the focal point for technical advice to the UK Government on nuclear treaty verification – and aims to ensure that the UK is in a position of strength should the Government decide to pursue further arms control measures.

As part of this work, the team is collaborating with colleagues from FOI in Sweden (the Swedish Defence Research Agency), a partner non-nuclear weapon state.

The work is seen as an early step in providing advice on how to approach verified warhead dismantlement. The work also contributes to the commitment the UK made to work toward disarmament when it ratified the Non-Proliferation Treaty in 1968.

What we are trying to achieve

The fundamental question being addressed is: 'In what kind of facility is it best for dismantlement to take place?'

An obvious first answer may be 'In the areas in which the weapons were first built.' This does make a lot of sense; these are existing secure facilities designed for handling warheads and their components. They already carry the bespoke tooling required for assembly and maintenance. There are however a few reasons why assembly/maintenance areas may not be as appropriate as first thought.

A significant difference in verified dismantlement, when compared to weapon assembly or maintenance is the presence, potentially, of both foreign inspectors and a variety of measurement equipment, designed to increase confidence of inspecting parties that dismantlement of real weapons is taking place. Another difference is the reversibility of the whole assembly process, which may not correspond to a facility layout for assembly and maintenance, and which may also require further storage for pre-dismantlement warheads and post-dismantlement components.

To bound the 'What kind of facility is best?' question, four types of facility have been considered

A current facility being used for weapons related activities

A facility which has previously been used for, but no longer carries out, weapons related activities

A facility previously used for industrial, non-nuclear purposes

A dedicated facility built for dismantlement

Approach

The methodology used brings a systems engineering approach to the problem. First, a statement of aim and a 'rich picture' were created. The statement of aim captures the overall direction for the project. The rich picture defines the problem space, including everything that might be considered to do with dismantlement and verification at a notional 'facility', with the facility being 'the single location at which dismantlement takes place.' From this all-inclusive rich picture a smaller, clearly delineated 'focus picture' was defined as shown on the bottom right. This bounds which parts of the rich picture are 'in-scope' for the task. The problem space is now bounded, and more tractable.

From information contained in the focus picture, five overarching themes are derived. These are the smallest number of thematic areas in which all the parts of the focus picture can fit. The themes against which to assess dismantlement facilities are compatibility, verification, confidentiality, safety and security. Underneath these five themes sit groups of standard functions which flesh out what a dismantlement facility must be able to achieve. Solutions (processes or things which address the requirements) are detailed for each function, with some functions capable of being fulfilled in a variety of ways.

Solutions are scored for our four facility types, indicating the perceived level of difficulty in implementing the solution.

Numerous assumptions underpin this assessment such as the number of items processed at one time, the repeatability of the process and the global and political environment.

Finance was omitted from consideration as details regarding price for large building projects are often difficult to determine with confidence. We also assumed that the dismantlement facility would be sited on host country soil.

Example of confidentiality

To illustrate the first stage of the analysis exercise, we take an example function from the 'confidentiality' area. Confidentiality here is defined as the idea that any facility must 'enable adequate procedures and measures, to prevent the proliferation of knowledge, technology and materials, to be implemented.' Measures must also protect the interests of national security. A relevant function would be that the 'facility allows protection of proliferative aspects of warheads during dismantlement.'

As noted we must define at least one solution to this. In this case there are two, as depicted below.

Entire dismantlement/proliferation sensitive aspect occurs only in presence of host staff	Use of managed access procedures (e.g. shrouding, walkways and restricted views)
Solution A	**Solution B**

A dedicated facility should have either solution designed 'implicitly' into the building, giving a zero value for difficulty. Also considered implicit is conducting the entire process only in the presence of host staff for existing facilities. An existing industrial building may need modification to accommodate dismantlement so it would be slightly harder to implement either solution in this case.

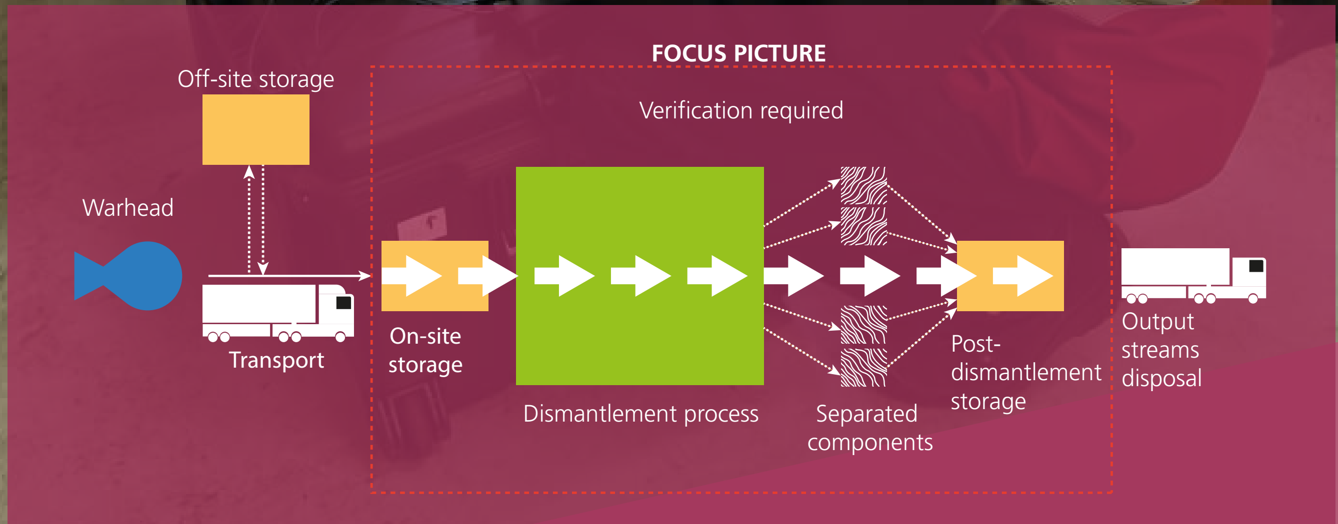
If protection of proliferative aspects is solved using managed access (Solution B) then existing facilities may find this challenging to implement. An industrial facility however may be more manageable because it is easier to redesign the interior of the industrial building than existing nuclear facilities. Scoring for other functions is in progress. Analysis of the scores will follow and the project is expected to be complete in late 2018.

The future

The output of this work will be a technical report on the relative challenges and advantages of implementing verified dismantlement in the chosen representative dismantlement facilities. It is expected to be of use to both the UK and other states wishing to evaluate dismantlement options and that the results will be presented at international fora.

Future work may include focussing research on areas which are shown by the scoring to have greatest negative impact. Quantitative consideration of the costs of these facility types is currently omitted to reduce confusion between financial and functional benefits. It would also be interesting to take it out of the abstract and consider specific countries to host the facility. This may highlight country-specific issues which would change the analysis.

"The themes against which to assess dismantlement facilities are compatibility, verification, confidentiality, safety and security"



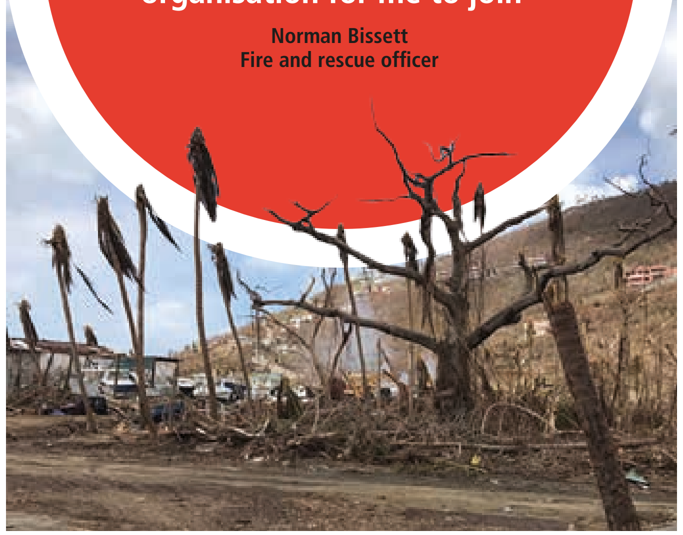
Fire officer supports hurricane relief effort

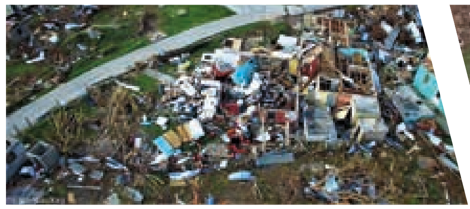
Norman Bissett, who has been a member of AWE's fire and rescue service for 27 years, was part of the first disaster response teams to work in the Caribbean in October to assess the damage caused by the devastating effects of Hurricane Irma.

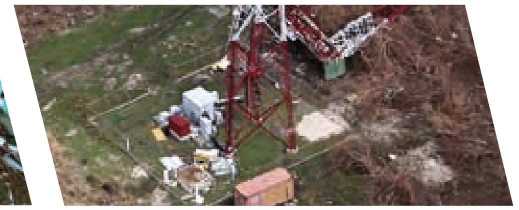
An ex-military serviceman, Norman joined Team Rubicon UK as a volunteer a year ago after being inspired by their advert on the television. The charity recruits military veterans and first responders to rapidly deploy response teams to communities hit by disasters both at home and overseas.

"Along with my military background, the training and experience I have gained in AWE Fire and Rescue Service made this the ideal organisation for me to join"

Norman Bissett
Fire and rescue officer

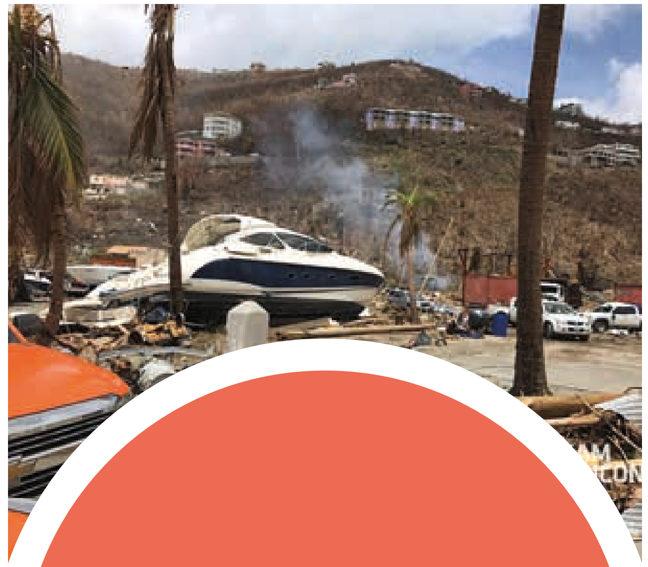






During his two-week deployment, Norman and his five-strong assessment team visited a number of Caribbean islands assessing damage and priorities, which were reported back, with images, to major world aid agencies via the Team Rubicon UK mission hub.

"This was my first deployment with Team Rubicon UK, I'd never seen the effects of a Cat 5 hurricane before," says Norman. "In Barbuda, it was 95 per cent total devastation, everything had been flattened and there was nothing that we could do to help, the entire population of 2000 people were evacuated to Antigua. On Gorda in the British Virgin Islands, we created a makeshift water purification system which supplied 750-1000 litres of clean drinking water per day, and set up an incident management system to help locals deal with the situation.



"It was surreal coming back to the UK after seeing those scenes, it had quite an impact. I would go back tomorrow if I could to give practical help"

Team Rubicon UK currently has 78 volunteers working in the disaster zone helping to bring some sense of normality back to the population of the islands. Building temporary schools, medical facilities and road clearances are among the many ongoing projects.

Profiling our People

Amanda
Knowledge engineer

I always had an enquiring mind as a child. My father had a range of interests and I naturally developed a curiosity for them too: cars, trains, aircraft, astronomy and art. He was also an engineer, having trained as a machinist and toolmaker.

After leaving sixth form college with four A-Levels, my interest in cars first led me to the motor industry and then to motor sport. However, this was at a time when a woman making a technical career in a perceived 'men only' environment was as good as non-existent!

I moved into hands-on scientific research in the dairy industry, and as a mature student began a self-funded part-time degree in physics at University College London. On the strength of my studies alone, I was offered a role at the National Physical Laboratory (NPL) – the UK's national measurement standards laboratory in London. I spent 10 years there in various research and measurement areas, including engineering metrology and nuclear material physics.

I applied to AWE after being made redundant by NPL. As a 'mature entrant' to the company, with a long and varied career behind me in other areas of science, I was quite difficult to place. The only post available at AWE at the time was as a Frontline Worker, but having been out of work for a significant length of time, beggars cannot be choosers. Within two months of starting I'd already moved to Quality Assurance as an inspection engineer. After a tour of the Educational Collection (our museum of artefacts associated with the British weapons systems over 60 years), I was inspired and 18 months on from there, I joined the Warhead Knowledge Team, and that's where I've remained.

The most enjoyable part of my role is being able to access a very broad base of people and nuclear deterrent knowledge. There aren't many roles at AWE where you get to acquire such a diverse range of technical information.

"The best thing about my job is expressing science and engineering in a creative way. People don't always consider science or engineering as being related to anything artistic"

Supporting an international treaty in keeping our nation safe

A team of AWE experts attended the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) in Vienna – to support a working group in the area of treaty verification – which is a major part of our commitment to nuclear threat reduction and to keeping our nation safe.

UK ambassador to the United Nations in Vienna, HMA Leigh Turner, met the AWE team and thanked them for their hard work in supporting the UK's commitments to the CTBT.

The MOD is the National Authority for the treaty in the UK, and AWE has supported the technical verification elements of the treaty for many decades. We send experts covering key areas of the verification regime, such as seismology, infrasound, hydroacoustic, radionuclide and inspection techniques, allowing MOD to execute the UK's treaty obligations.

AWE technical sponsor for nuclear treaty verification, Claire Watt, says, "The work of our multidisciplinary team of scientists at the meeting ensures that the UK fulfils its CTBT commitments to international monitoring and verification. Within this international forum, we provide technical advice including input to the UK national statement and support at the P5 experts meeting. The chairperson for the Waveform Expert Group for the past 10 years, David Bowers, is also part of the UK delegation. Both the MOD National Authority for CTBT, and wider government, have expressed their appreciation for the continued support provided by our experts."

"The work of our multidisciplinary team of scientists at the meeting ensures that the UK fulfils its CTBT commitments to international monitoring and verification..."

Claire Watt
Technical sponsor

Analyst appointed to general council

Colin Kendall, who works in the field of operational analysis, has been appointed to the general council of the prestigious Operational Research Society (ORS) to work on publicity, membership and with the website committee.

He is ensuring that future generations of analysts, researchers and STEM recruits are aware of the opportunities and support available to them in the crucial field of operational research.

Operational research (OR) is at the forefront of all large government projects and a mandatory component of all procurements. Through use of simulation, statistics and many other methods, OR analysts provide the customer with confidence that they are getting the optimal solutions to their problems in a cost-effective manner.

Colin, an Associate Fellow of the ORS, says, "It's an honour to be appointed to the society's general council and I look forward to working with them to reach future generations of analysts and just as importantly those who don't realise that their work falls under the umbrella of OR, whom could benefit greatly from being part of the community. Since arranging for AWE to become corporate partners of the society three years ago I have witnessed OR go from strength to strength, and I am excited to further enhance the relationship between AWE and the society to deliver mutual benefit."

A representative from the ORS, says, "The general council is an essential part of the ORS's functioning – GC members hold the Board to account, provide a committed and responsive sounding board and oversee much of the work of the society through committee membership and Colin is playing a very important role in our work."

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