SPRING 2014

THE NAVAL ENGINEER

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It is produced on behalf of the Chief Naval Engineer Officer.

Chief Naval Engineer Officer, Chief of Materiel (Fleet) and Chief of Fleet Support

Vice Admiral S R Lister CB OBE CEng, FIMarEST

Vice Admiral Simon Lister joined the Royal Navy in 1978, and studied Naval Engineering at the Royal Naval Engineering College Manadon and Royal Naval College Greenwich before qualifying as a Nuclear Officer of the Watch in HMS Valiant in 1984. Based at Faslane, Valiant was then the oldest nuclear submarine in commission.

Returning to Greenwich to gain an MSc in Nuclear Engineering in 1986, he was subsequently appointed as Marine Engineer Officer of HMS Odin, a diesel submarine running from the Clyde.

A period of Russian language and specialist training led to a tour with the Foreign Office as Assistant Naval Attaché Moscow, during the extraordinary period covering the collapse of the Soviet Union and communism, and east/west military rapprochement.

In 1993 he returned to sea as the Marine Engineering Officer of first (briefly) HMS Torbay and then Trenchant, where he was promoted Commander in 1994. A two year spell as Naval Assistant to the Chief Executive of the Ship Support Agency followed, during which the Agency was formed, the dockyards were privatised, and the first contract for Devonport nuclear infrastructure (D154) was placed.

In 1996, he was the first Naval Officer to attend the Sloan Fellowship at the London Business School. He specialised in consulting/change management techniques within organisations, and the future of the European Defence Industry. Graduating with distinction in 1997, he was appointed to DN Plans in the Ministry of Defence. In the MOD HQ he introduced a new performance management regime to the Naval Sector, working closely with the Navy Board.

Promoted Captain in 1999, he became an Assistant Director in the newly formed Directorate of Performance and Analysis, tasked to spread performance management techniques to the MOD as a whole. In 2001, he was appointed as Naval Attaché Moscow, leading the Naval Co-operation Programme with the Russian Federation Armed Forces, the UK Resettlement Programme and UK's involvement with the Arctic Military Environmental Co-operation Group for nuclear clean-up in Russia[1]. In 2002 he was awarded the OBE.

In February 2003, he was appointed Team Leader of the Marine Electrical Systems IPT in the Warship Support Agency. Promoted to Commodore in 2004, he took over as Team Leader of the DLO Restructuring Team, and completed the merger of four headquarters and the formation of DLO corporate services before being appointed as Naval Base Commander Devonport in April 2005. He moved to London in April 2008, where he took up an appointment as Naval Senior Directing Staff at the Royal College of Defence Studies as a Rear Admiral. In March 2009, he became Director Submarines, responsible for the procurement, in-service support and disposal of the UK nuclear submarine flotilla. He assumed responsibilities as Chief Naval Engineer Officer in June 2011.

Promoted Vice Admiral in November 2013, and appointed to his current post as Chief of Materiel (Fleet), he has also assumed the role of Chief of Fleet Support on the Navy Board. He is responsible for all Defence Equipment & Support outputs across ships, submarines and naval bases.

Simon is married to Anita and they have three children. Free time is spent sailing, skiing, tinkering with old cars that have exceeded their economic life and using them for long distance exploration (they drove their Land Rover to Mongolia through Siberia in 2002 and a Ford Fiesta from London to Mali in 2008). He is Commodore of the Royal Navy Sailing Association and President of the Royal Navy Triathlon Association.

1. See *Arctic Military Environmental Cooperation* in *The Naval Engineer* Winter 2010.

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• The magazine is published for information, entertainment and to promote discussion on matters of general interest to engineers of all sub specialisations (Air, Marine, Weapon and Training Management).
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Photographs:
The front cover – HMS Ocean: moored on Greenwich Reach in 2012 in preparation for Operation Olympic (upper photo – by the Editor) and undergoing a major upkeep and upgrade programme being undertaken by Babcock, heading the amphibious COM team, in HM Naval Base Devonport (lower photo – courtesy of Babcock).
Acknowledgements to the Fleet Photographic Unit who supply most of the general photographs.
Other photos supplied by the authors or as credited.

The Naval Engineer

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BZs

Congratulations to the RN Engineers who have recently received honours and awards:

In the 2013 New Year's Honours List:

Appointed as Commander of the Most Excellent Order of the British Empire (CBE):

Rear Admiral C.J. Hockley
Commodore R.C. Thompson OBE

Appointed as Member of the Most Excellent Order of the British Empire (MBE):

Warrant Officer 2 (AET) (Avionics) B.I. Firth
Warrant Officer 2 Engineering Technician (ME) P.R. Hutchinson

Award of the Meritorious Service Medal (MSM):

Warrant Officer 1(AEM) C.A. Bleakley
Chief Petty Officer (CIS) A.P. Brown
Chief Petty Officer WEM(O)(SM) K.J. Clements
Warrant Officer 1 Engineering Technician (ME) A. Cray MBE
Chief Petty Officer AEM(M) M. Davies
Warrant Officer 1 Engineering Technician (WE) S.T. Haidon
Warrant Officer 2 Engineering Technician (ME) P.M. Hodge
Warrant Officer 2 Engineering Technician (WE) R.M. Holder
Chief Petty Officer AEM(R) N.S.R. Lewis
Chief Petty Officer Engineering Technician (WESM) I. Robertson
Warrant Officer 1 MEM(M) G.P. Smith

Commander Joint Forces Commendation

Lieutenant Commander S. Peck

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ENGINEERING OUR FUTURE

OUR STRATEGY FOR NAVAL ENGINEERING

From the Chief Naval Engineer Officer (CNEO), Vice Admiral Simon Lister CB OBE CEng FIMarEST

Engineering is a fundamental enabler of Naval Capability. As such, the First Sea Lord has charged me with overseeing the development of the Naval Engineering Strategy and its subsequent implementation in order to optimise our capabilities **today and in the future**.

The Future Navy Vision outlines an operationally versatile Royal Navy that is capable of projecting maritime power worldwide. Many of the fundamental components that will build towards this vision are already in place. We have an exciting equipment programme that sees the introduction and development of the Type 45 destroyer, Astute class SSN, Queen Elizabeth class aircraft carriers, Type 26 Global Combat Ship, F-35 Joint Strike Fighter and Wildcat helicopter, whilst a series of capability upgrades for our existing fleet of ships, aircraft and supporting sensors and weapon systems is underway.

This represents a very significant investment in the intellectual horsepower of many, along with a substantial slice of the Nation's treasure. It therefore behoves us all to make sure that we put in place the correct strategy that spans everything from: our approach to Innovation; Acquisition; Support; the delivery of Operational Engineering and our underpinning Engineering Philosophy captured in appropriate Policy and Doctrine.

But none of this matters unless we manage our People correctly. Our Engineers and our engineering culture are the key differentiators that will ensure the Royal Navy retains its war winning edge compared to many of our potential adversaries. In warfighting parlance, our People should be considered as our Centre of Gravity and as such they are rightly placed at the centre of this Engineering Strategy. Consequently, everything we do to develop the wider strategies that frame the way our capabilities develop in the future should be tested for their impact on our People.

THE CURRENT STATE

THE AS-IS STATE

We have high calibre, motivated and skilled people but the way in which we have driven for affordability has generated incoherence between the equipment programme, the support solution and our personnel and training programmes. This is, to some extent, inevitable given the lag that exists between the imperative of strategic choices made attempting to match budgets to aspirations and the ability to achieve affordable and sustainable change. But the impact is a frontline struggling to sustain the materiel readiness required by our tasking and commitment. Our current position is unsustainable in the context of the Future Navy Vision, threatens our reputation for excellence, and requires us to ACT, now!

The following snapshots represent a perceived view in 2013; it will require updating to remain relevant as time takes us forward. It points at the 'burning platform' issues that require us to change and demands a strategy to do so.

People

The state of flux created by the Strategic Defence & Security Review, reductions and broader restructuring across branches has created pinch points, increased churn and outflow, especially in key senior rate cadres in the engineer and warfare branches. This, coupled with reduced training investment and increasing transfer of engineering responsibility to industry, has reduced confidence, whilst increased tempo has reduced capacity for risk.

Additionally we do not have a coherent approach to the training of Officers in their second stage careers, particularly where they are employed alongside Civil Service counterparts, industrial partners or elsewhere in the maritime enterprise. We do not have a joined up approach to skills and training.

Operational Engineering

Overall material readiness, especially in the Surface Flotilla, continues to decline despite the endeavours of hard pressed teams in the front line. From the submarine perspective the numbers of force elements at readiness have been driven low by the late delivery of Astute and platform ageing. Operator technical knowledge in some capabilities is insufficient to exploit performance and on occasion actively reduces availability, and thus capability[1]. Our maintainers' ability to assure available systems has been reduced by support solutions that are excessively reliant on industry and, in parallel, by reductions in career and targeted employment training. Whilst it is easy to reflect on the negatives, there are many examples of excellence[234] and clear evidence of engineering ethos that underpin these. Nevertheless, the price of unrelenting operational tempo and high utilisation is reduced contingency and unsustainable pressure on engineers in the frontline as every slim opportunity for maintenance is squeezed out of busy programmes.

1. For example the lack of operators trained to stream and recover Type 23 towed sonar.
2. Forward Support Unit support to the Op Kipion (Arabian Gulf) Mine Countermeasures Force.
3. 1710 Naval Air Squadron deployed to Afghanistan for helicopter repair.
4. HMS Trenchant's 333 day deployment in 2012/13.

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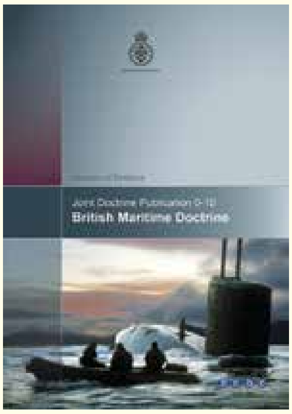
Engineering Support

Support is increasingly over reliant on industry for diagnosis, repair and more complex maintenance. This philosophy is often seen as cost effective from the support organisations' perspective, yet builds in declining competence and confidence in the front line maintainer. Whilst contractor logistic support is undoubtedly with us for the long term, the lack of consistency in the current support solutions, and pinch points in industry expertise, contribute to a reduction in availability and readiness. It also reduces organic resilience, particularly in supporting contingent operations, where access to original equipment manufacturers in theatre and up threat cannot be assured. Furthermore our support solutions have a UK focus and are inflexible in their consequent demand on the 'Purple Gate' and 'Contractors Deployed on Operations' processes.

Acquisition

The major decisions on capability acquisition over the period of the Future Navy Vision have either been made or are well developed. That said, affordability continues to put pressure on capability trade off, which increases the reliance on effective requirements setting, technical vision and programme management acumen within those facing industry. It also means we have to be realistic when setting detailed requirements and in developing potential solutions.

Doctrine and Policy



The role of technology and engineering in achieving operational success is not as clear as it should be in current policy and doctrine. The removal of reference to technology 'edge' in British Maritime Doctrine is one example, and the demise of effective and centrally governed engineering and maintenance policy has inevitably contributed to a broader lack of understanding. Along with emerging work in Navy Command HQ and the Defence Equipment & Support organisation to provide support strategies and principles, we will draw the doctrinal threads back together into a coherent piece that places engineering and technology at the core of our policies and plans.

Current Broader Context

Our strategy is situated in the context of four key pressures:

- The **changing focus of operations** post Afghanistan anticipates the need for an agile, flexible, well integrated expeditionary force with a preventative, risk-based approach to operating, in parallel with the demands inherent to the re-introduction of significant strategic capabilities, such as carrier strike.

- The impact of **emerging technology** upon both the threat and our response to it (eg unmanned vehicles, ballistic missiles and cyber).

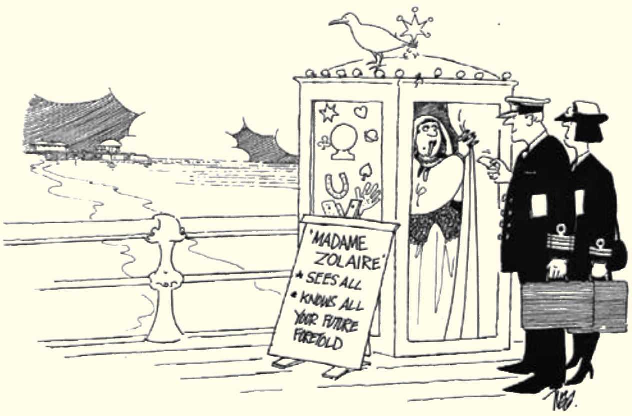
- The need to **control costs within the funding available to deliver and sustain a reliable and balanced Fleet today, out to 2025 and beyond,** in the context of continuous organisational change with the pressures and opportunities that may provide.

- An enhanced regulatory environment in which the standards of **safety and environmental compliance** will inexorably increase.

THE NAVAL ENGINEERING VISION

A Naval engineering capability that successfully innovates, acquires, supports and delivers effective, reliable, interoperable and affordable platforms and systems, along with competent people, today and in the future.

Our intent for Naval engineering must directly align with the Future Navy Vision.



……..to communicate our needs to the rest of the Royal Navy

SO HOW DO WE GET THERE?

MAKING A DIFFERENCE

The Chief Naval Engineer Officer will be responsible to First Sea Lord for the success of the Naval Engineering Strategy. The capability is complex, and so delivery will use the engineering capability model and assign 2* champions to each pillar, governed through the Naval Engineering Board. The responsibility to drive improvement rests with us all, and the engineering capability principles should encourage initiative and innovation using the mission command ethos.

In order to take us forward and to achieve the vision, we must have a strategy to ensure that we all pull in the same direction. As well as providing guidance for ourselves, the Engineering Strategy is needed to communicate our wider needs to the rest of the Royal Navy. The strategy – outlined below – is clear, has long term relevance and describes how the vision will be achieved.

Our Engineering Strategy is underpinned by five pillars, which are illustrated in the figure opposite.

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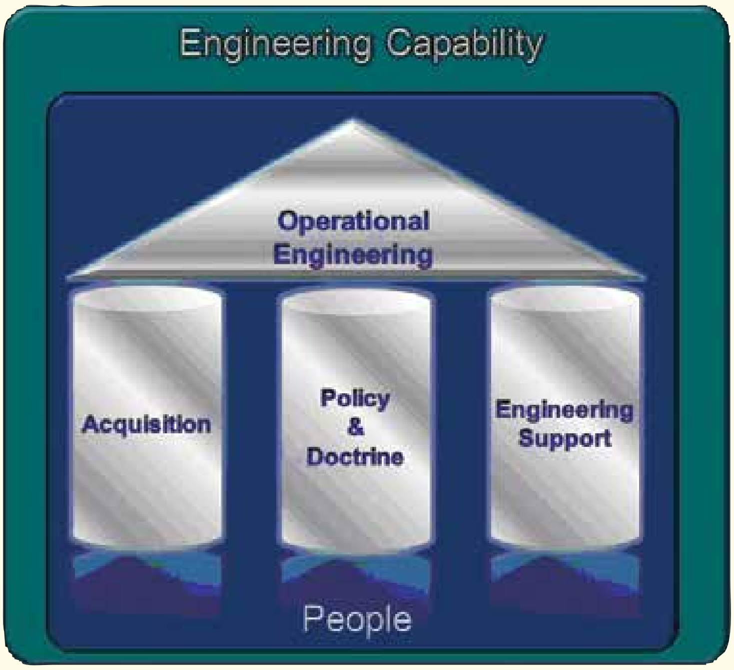

Figure 1: Engineering Capability

Each pillar has a Champion, a 2* engineer, selected according to where they are currently appointed. Each Champion is supported by an engineering Warrant Officer. This structure will ensure that the 2* owners not only have visibility and accountability for their pillar but also the ability to influence them at a practical level.

The strategic role of the Naval Engineering Board (NEB), which I chair, is to ensure coherence within and across the plans that are developed by the 2* Champions. The NEB provides a 'lens' to measure the combined impact of policies sourced from across Defence on the Naval Engineering Strategy and to advise me of the necessary action to rectify any perceived shortfalls or to exploit our engineering capability.

The NEB is underpinned by the four existing Advisory Panels (APs): Air Engineering, Marine Engineering, Training Management and Weapons Engineering. The APs are made up of a cross-section of Officers and Warrant Officers from the respective branches. Although the Strategy is deliberately high level in managing the direction of resource towards enhancing our operational engineering output, these resource changes will seek to improve the day to day performance of our naval engineering function.

In order to achieve immediate impact, the strategy will also exploit rapid improvement events to make the work of our operational engineers more effective and more rewarding in the short term. The role of the sub-branch APs will be to focus their attention on whether the improved tools, training, information, spares and empowerment is actually being seen at the front line – as well as to ensure the time needed to exploit these benefits is made available. To speed up front line improvements, the Panels will report directly to the Naval Engineering Board,

The Strategy provides me, the NEB, the Pillar Champions, the DCNEO and the Advisory Panels with clear terms of reference, detailing their membership and required actions. The five pillars (with their 2* Champions and WO1s) are:

PEOPLE

Rear Admiral Woodcock (Assistant Chief of Naval Staff & Naval Secretary)
WO1 Rachel Harris (Navy Personnel Air Engineering Branch Manager WO1)

Scope: The Maritime Engineering Enterprise; Air Engineering, Marine Engineering, Weapon Engineering, Submarine/ General Service, Royal Fleet Auxiliary, Defence Science & Technology Laboratories, Defence Equipment & Support, Industry, Trainers, the wider Naval Service

Ownership and Organisation: This pillar is owned within the Second Sea Lord's organisation, which is governed by policy from MOD/CDP. The Pillar Champion is NAVSEC.

The Personnel Vision: A technically confident and innovative maritime engineering enterprise populated by professional, capable and confident people available at the right place and time.

Technically confident…..

OPERATIONAL ENGINEERING

Rear Admiral Jess (Assistant Chief of Naval Staff (Support))
WO1 Jonnie Roome (ASWEO2 PORFLOT)

Scope: The Operational Engineering function extends from the UK base to all theatres of operations and encompasses the planning and execution of engineering in support of military tasks enabled by the right equipment and effective support. All of this is underpinned by our people.

Ownership and Organisation: This pillar is managed from within Navy Command Headquarters. The Pillar Champion is ACNS Support.

Operational Engineering Vision: Operational Engineering is the point of delivery of the overall Engineering Strategy and is facilitated by a capable, reliable, interoperable and affordable Royal Navy.

ENGINEERING SUPPORT

Mr Tony Graham (Director Ships)
WO1 Gary Barlow (DE&S PMS Cell Manager, In service submarines)

Scope: The Engineering Support function extends from the Naval Bases, Air Stations, Forward Deployed Support Bases, to the DE&S and its associated contracted support in Industry. The community includes servicemen, MOD civilians and industrial partners and covers the three primary operating domains: air, surface and subsurface.

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Figure 2: the underpinning pillars

Ownership and Organisation: Director Ships (DE&S Abbey Wood) is nominated as the Pillar Champion, assisted by the Strategic Class Authority Team Leader for Frigates and MCMVs. They will act in an integrating role across the engineering support community to draw together a coherent strategy.

Engineering Support Vision: Working with DE&S, Industry and other partners to generate and sustain an optimised support environment that supports the delivery of Operational Engineering in line with the Future Navy Vision.

ACQUISITION

Rear Admiral Brunton (Director Acquisition)
WO1 Andy Farquhar (DE&S Maritime Maintenance Support Group)

Scope: The Acquisition function extends from Naval Command HQ (including MOD and Joint commands), Defence Equipment & Support, the Defence Science & Technology Laboratory through the Naval Bases and Air Stations to the industrial base. The community includes service, civil service and industrial engineers working in functions ranging from specialist solution engineering to supporting programme and project management. The maritime acquisition cadre extends from warfare branch personnel involved in requirements management, engineer branch personnel throughout the process and logistics branch personnel supporting equipment.

Ownership and Organisation: The bulk of the acquisition effort is carried out through contracts managed from Defence Equipment & Support in Abbey Wood. This large and diverse community has Director Ships Acquisition as the Pillar Champion.

Acquisition Vision: Professional, intelligent and demanding customers, in positions of leadership for future acquisition projects and working with Industry to deliver the full range of equipment and systems required across the maritime domain to ensure the Future Navy Vision.

DOCTRINE AND POLICY

Commodore Shipperley (Assistant Chief of Staff (Ships and Submarines))
WO1 Bill Porteous (Fleet Operations Maintenance Officer – Deputy 6)

Scope: The doctrine and policies needed to enable the successful exploitation of operational engineering extend from British Maritime Defence Operating doctrine, through Joint Logistic doctrine and policy down to single Service specific engineering policies.

Ownership and Organisation: This pillar is managed from within Navy Command Headquarters. The Pillar Champion is ACOS(SSM), in his Deputy CNEO role.

Doctrine & Policy Vision: To establish a universally accepted engineering doctrine at the heart of Defence underpinned by a coherent set of Joint and single Service policies that enable the delivery of the Engineering Strategy.

SUMMARY

Our Strategy is deliberately high level in seeking to influence the management and direction of resource towards delivering our operational engineering output. Its success will make the work of our Operational Engineers more effective and more rewarding. I am therefore also driving to deliver short term effect. To me, this looks like better tools, training, information, spares and empowerment at the front line; as well as the time available to exploit these benefits. I have therefore directed that the sub-branch Advisory Panels should focus their attention on providing me with feedback as to whether these benefits are being delivered and where and how we can direct and influence the quick application of resource to achieve this. To speed up this feedback, the strategy provides for these reports to come directly to me at the Naval Engineering Board.

This is the first time we have chosen to overtly capture our thoughts in this way. It will evolve as we receive feedback, nevertheless, as an outline for the future, I would commend that you read it, challenge it and embrace it as best you can. The Naval Engineering Board and I will oversee the development of detailed plans, under the guidance of nominated 2* officers to put flesh on the bones of the individual strategies and to make sure that collectively we Engineer our Future.

The full Naval Engineering Strategy has now been published. Should you wish to read the finer details of our Strategy it has now been published on the CNEO's website at http://cwd-r-web-001.cwd.dii.r.mil.uk/CNEO/index.html[5]. Here you will find the full Strategy document and its associated publicity material.

To contribute to the healthy evolution of our Strategy, in the first instance please contact the Naval Engineer Warrant Officer (WO1 Nick Sharland) or the appropriate pillar Warrant Officers.

5. This will become a DII site once the Maritime Warfare School migrates to DII.

The key points explained above have been summarized from the full text of the Strategy by CNEO's Warrant Officer, WO1 Dan Archer..

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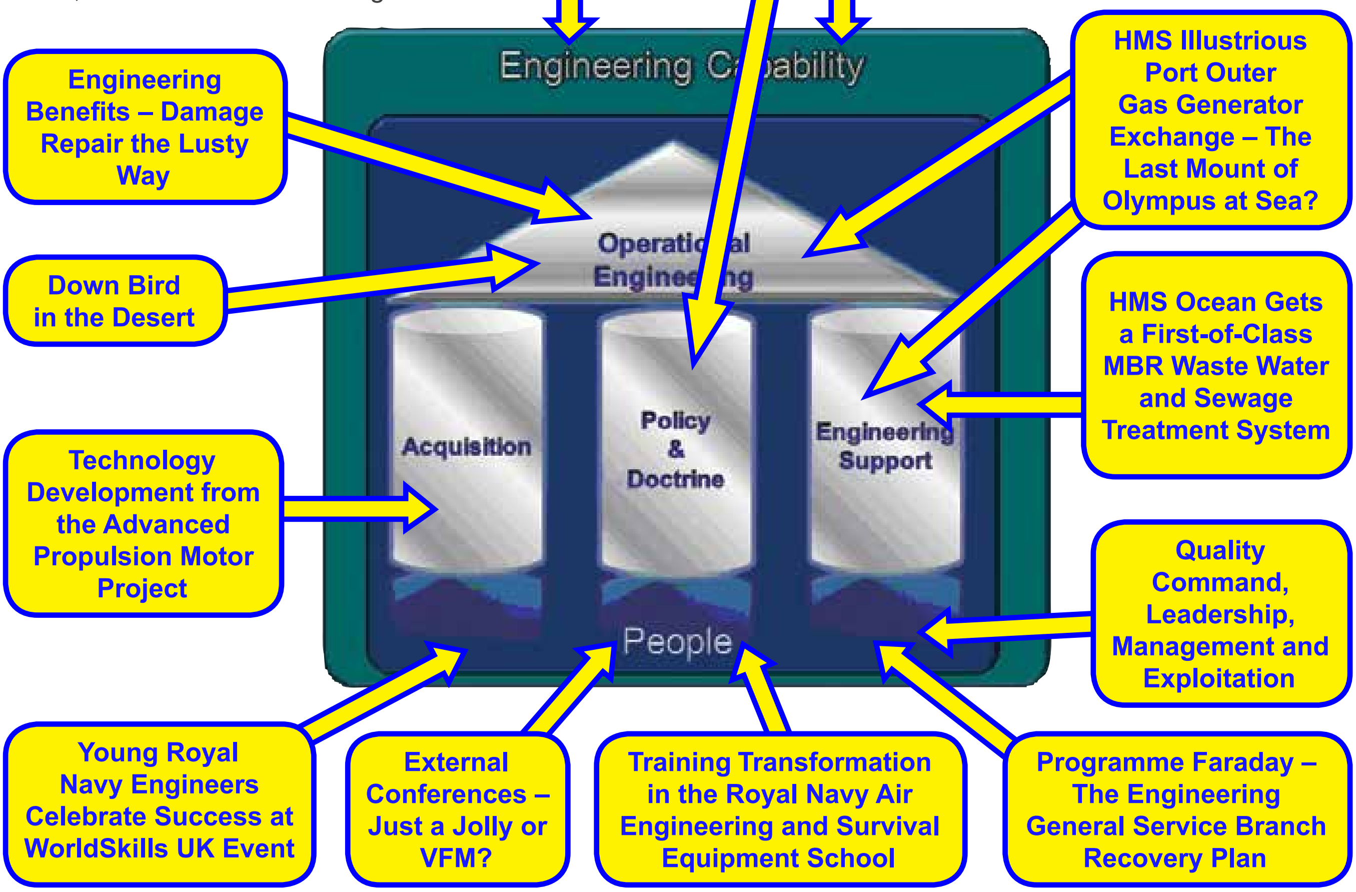
Editor's Corner

THE NAVAL ENGINEER AND NAVAL ENGINEERING STRATEGY

What's the linkage? Well, hopefully, it's obvious – the foregoing article, written by the outgoing CNEO's Warrant Officer and based upon the full text of the Strategy, summarises the position very well. However, if further explanation is needed, just review the subject matter of the other articles in this issue of *The Naval Engineer*, and you'll find that each one addresses matters relevant to one of the pillars of the Strategy – and, in some cases, relevant to more than one pillar. The diagram below gives a flavour of this, but there are other linkages which are, perhaps, less obvious – to give just two examples, the MBR fit in HMS Ocean goes some way to de-risking the fit in HMS Queen Elizabeth (Acquisition Pillar)and the Chartered Engineer status of the authors of the APM and Conferences articles indicates the value of professional, capable and confident people (the vision of the People Pillar). It's also worth noting that this linkage spreads across all elements of naval engineering – just because an article such as that on Programme Faraday is focussed on General Service engineers, or that on the Down Bird majors on air engineering, doesn't mean there are elements applicable to engineers in other environments – for example, work in parallel to Faraday is ongoing in the submarine world.

The bottom line, however, is that the Strategy impacts on all aspects of our work – as evidenced by the articles which appear in *The Naval Engineer*. That's not because the content of this issue was specially arranged to coincide with the Strategy's publication – far from it – the same analysis can be done to most, if not all, issues!

Finally, if you have a view on the subject (and you should have), I'm sure it will be addressed at CNEO's Seminar!



Thinking of writing for TNE? Deadline for articles or letters is Friday 23 May 2014.
The Naval Engineer is also available on the Intranet at *http://defenceintranet.diif.r.mil.uk/Organisations/Orgs/Navy/Organisations/Orgs/FOST/Pages/TheNavalEngineer.aspx*
A full index of The Naval Engineer, and of Review of Naval Engineering, and soft copies of recent back issues are available at: *http://cwd-r-web-001.cwd.dii.r.mil.uk/mws_csg/publications/naval_engineering.html*.
Back issues of the Journal of Naval Engineering (JNE) can be found through the JNE Internet webpage: *http://www.jneweb.com/login.aspx*.

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DOWN BIRD IN THE DESERT

By Air Engineering Technician Dean Ball, 845 NAS

On Sunday 23 September, a Sea King Mk4 of 845 NAS flying as part of the Joint Helicopter Force (Contingency), embarked in HMS Illustrious for the Cougar 13 deployment, had to make a precautionary landing in the United Arab Emirates (UAE) desert following a malfunction with the Main Rotor Gear Box oil system.

A Down Bird Team of 845 NAS engineers deployed ashore and the subsequent recovery of the aircraft thoroughly tested skills learnt during their 'Junglie' training.

The following is an account of the recovery by AET Ball from 845 NAS who formed part of the Team.

AET Dean Ball (23) is from Wallasey in the Wirral. He's been in the RN since 2009 and has been working with 845 Squadron for the past 18 months. He has worked with the Commando Helicopter Force since he passed out of HMS Raleigh. Cougar 13 was the first time Dean had been at sea for longer than two weeks.

It's Monday the 24th of September and I am watching the sun set over a Sea King in the desert over 100 miles from where I woke up this morning, and it's my job to help recover it! Over the next few days I will work long hours, in temperatures that reach 50º Celsius but that's me getting ahead of myself, for the moment I've just turned to on HMS Illustrious in the Gulf of Oman and have some flight servicing to be getting on with.

I had just begun to go about my day to day flight servicing duties in the hangar, a hangar that frequently seems to top out at over 30º Celsius, when my supervisor told me to hand over to one of the other Air Engineering Technicians on the watch and go and get my down bird bag as one of our Sea Kings has had a problem and been forced to land in the desert.

I quickly handed over my work to a colleague and got myself through the airlocks to my mess to get my kit! Unsure of exactly what I needed to take I packed everything I thought I would possibly need. There was no time to wait around; once this was done I went straight to the other side of the ship and up towards the flight deck where the rest of the Down Bird Team had been told to meet. We all quickly dressed in our survival equipment and headed out onto the flight deck where another of our Sea King Mk4 was ready and waiting to take us ashore.

As our helicopter lifted off the flight deck and out over the sea the Petty Officer briefed me on what we knew about the situation. I was told that they had fluctuations in the transmission oil pressure and oil was seen to be leaking out of both sides quicker than the Ship's Company when the gangways are open for a run ashore. Looking out the window as we crossed the UAE coast near the city of Fujairah, I couldn't help but notice how mountainous the area was. I was half expecting to see a Sea King perched awkwardly on the edge of a cliff, but luckily the aircrew had managed to find what looked like a safe area to land, preventing an already awkward situation from becoming much worse.

Our aircraft landed about 50 meters from the down bird, kicking up a substantial dust cloud as we touched down. We quickly offloaded all of our kit into a pile and huddled around it in an arctic huddle to protect ourselves and our kit from the sand blast as the aircraft departed.

We were then met by the force protection team already on site from the previous evening. They gave us a general brief on the area and introduced us to the local police and military that were there to ensure we didn't attract any unwanted attention while going about our work.

Our initial investigation highlighted a number of things that could have caused the leak and following twelve hours in temperatures up to 50º Celsius and with the light fading fast it was time to retire to the relative comfort of a nearby airbase, before returning tomorrow fresh to tackle the problem, or so we thought.

Unfortunately for us it transpired the RAF Regiment could no longer provide a guard for the aircraft and, unable to leave to helicopter unattended for obvious reasons, it looked like a night under the stars in

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All packed up and ready to go

the desert was on the cards. Initially this put a dent in the morale having gone from the promise of a cooked meal, wash and sleep to a shower using my camelback hung from the hoist hook whilst using my bare hands to dig a hole to go to the toilet. However, this is ‘Junglie’ territory and I was well prepared, as these are all things you’re taught when completing the Air 338 course. The course is where Royal Marines spend five weeks teaching us the basics of living and fighting in the field.

Following days of tirelessly working in the desert it transpired that it was unlikely that we would be able to get the aircraft fixed in situ within the timeframe we were given and therefore we needed to come up with another plan.

It was decided that we would move the aircraft via road, supported by a Joint Aircraft Recovery and Transportation Squadron team from the UK. The recovery would require extensive engineering preparations to get the aircraft ready to crane onto a trailer. This was not without its frustrations as firstly the crane got stuck in the sand requiring some backbreaking digging and heaving in the midday sun to get it moving again before to our horror we watched exactly the same thing happen to the lorry. Finally we watched the aircraft settle onto the back of the low loader and I settled down to some hard earned scran and a bottle of ice cold water, hoping my work was finally done.

I soon learned this wasn’t to be; in fact when I learned of the various bridges and obstacles littering our route back it dawned on me that this was going to be another long night. Turns out towing a Sea King on a trailer down the motorway is more complicated than I thought. The first obstacle was a small roundabout which was tricky but the professional local driver squeezed us past the narrow bend. Then came the biggest or ‘smallest’ problem in the middle of the motorway. A bridge that was smaller than we were tall. My initial thought as we came to a stop was that there is no way this is going to work, however following a spark of genius from one of the lads it was pointed out that if we removed part of the damper reservoir on the top of the main rotor head we might just squeeze through. We all stood and watched with clenched teeth as the lorry eked forwards and scraped under the bridge with millimetres to spare.

A tedious eight hours later, having sat on the motorway at 20 mph for what seemed like an eternity we finally arrived back at the camp at about 6 am, the end of a 26 hour day. At the time my feelings were only of tiredness but looking back I was proud to have been part of a team utilising ‘Junglie’ cunning and endeavour to overcome the multitude of obstacles we seemed to keep coming up against. Finally we got the aircraft back to Minhad Air Base where we could finish up the repair job before flying it back onboard.


The excess baggage on this was going to be eye watering ...

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PROGRAMME FARADAY

THE ENGINEERING GENERAL SERVICE BRANCH RECOVERY PLAN

By Commander Mark Sullivan BEng MBA CEng CMarEng MIMarEst RN Faraday Programme Manager

As I'm sure many of you are aware by now, Faraday launched on 15 October last year. In this article I want to explain what Faraday has done so far to restructure the Engineering General Service training and careers, what is likely to follow and what needs to be done in the future. This is how we plan to deliver the sustainable recovery our branch needs and deserves. Whilst this is focussed towards the general service there is plenty of common ground with the Submarine Service. Faraday and the Sustainable Submarine Manpower Programme speak regularly.

WHAT HAS BEEN DELIVERED SINCE LAUNCHING PROGRAMME FARADAY?

Since the launch of Programme Faraday, substantial progress has been made.

Faraday, alongside the Royal Navy Personnel Strategy, has initiated the removal of the WO2 Rate . This was announced on 3 December 2013 and will re-focus the employment of EGS WOs to the jobs that demand their expert level of competence. Removing the WO2 rate will provide a common WO cadre across all RN branches with a common route for CPO to WO promotion.

This change will also remove the Pay 2000 CPO IL7 cap, resolving the pay disparity between technical and non-technical CPOs, and avoid the issue being exacerbated by the roll out of the New Employment Model. There will be a review of all WO liability posts such that the majority of the existing WO2 posts will remain WO, effectively being upgraded to WO1. A minority will be de-enriched to CPO[1]. The transition towards a single WO starts on a Single Vesting Day on 1 April 2014.

On the 18 December 2013 the Interim Fast Track was launched. This has been introduced to provide accelerated career progression opportunities for current eligible ETs and LETs. If you are a successful candidate, you will be accelerated onto POETQC and then to promotion to LET and POET. RNTM 288/13 explains all of the detail and the first Fast Track selection board will sit week commencing 3 March 2014. If you have not applied, but are serious about getting on with your engineering career, then why not apply?

WHAT IS COMING NEXT?

Training redesign has started in both HMS Collingwood and HMS Sultan. The first new style Marine Engineering ET Initial Career Course will start at HMS Sultan on 26 May 2014, with the first newly trained ET(ME) joining the Fleet on 23 January 2015.

The Faraday team is currently generating the competence based approach to training and developing people. This will also include the task of writing the new syllabus for all Professional Exams for your next higher rate. The policy for Streaming is also being drafted and all three pieces of work will be ready for release after Easter.

The current branch badges are being re-designed so that, once again, both the Marine and Weapon Engineering branches have their own identity.

Other initiatives are examining how we can supplement the branch with additional qualified personnel in the short term to ensure the recovery takes hold. Both a Lateral Entry Scheme (something we used to do) and employing engineers within the Royal Naval Reserve are being explored.

THE FUTURE

By the start of April 2015, all EGS personnel will have been issued with the Individual Competence Framework and their Log Book to record their evidence of competence. Everyone between LET and CPO will have been streamed and will be wearing a new branch badge. The Fast Track selection board will be regularly selecting Fast Track candidates for accelerated training and the redesigned Career Courses will be ready. Finally the 'Journeyman's Time' concept will have been designed ready to receive POETs on completion of the new Career Course.

SO, WHAT CAN YOU DO TO HELP?

The analysis has been done, the Faraday Team have **diagnosed** the problem and have a number of **repair** solutions. This is our opportunity to fix the branch and everyone has a role to play. Faraday cannot deliver an immediate overnight solution, but it will fix deep rooted causes in our training and career structures to ensure we train and develop correctly trained technicians.

Our young technicians need to seize the opportunity and become up-skilled in **diagnostics** and **repair**. You can do this by understanding the Competence Framework when it is issued and use the Log Book to compile your portfolio of evidence. Sitting the new Professional Exams will allow you to demonstrate your technical ability for promotion. If you are up to the challenge, then apply

1 WO2 in these posts will not be required to relinquish their rate and they will remain eligible for promotion to WO1 along with every other CPO & WO2.

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for the Interim Fast Track. Now that the WO2 rank is being removed, it is within your grasp to become a WO1 well within OE1.

There is a specific role that we must all play in recovering the branch; that is to mentor and guide the current and next generation of technicians and engineers to support the work of Faraday.

THE DETAIL

As a recap, there are three main areas where Faraday is focussing its efforts on fixing Engineering General Service training and career structures:

Competence Based Approach to Training

Competence based learning allows individuals the freedom to demonstrate their skills against a set of competence, rather than ticking off a mandated list of tasks. This freedom will provide the flexibility to demonstrate ability in a variety of different situations. The practice of a competence based approach is now common practise for training engineers across industry.

A Competence Framework has been established for the Marine and Weapon Engineering General Service and this will deliver against our new ‘headmark’ statement for what we expect of our Engineers and Technicians:

“*The RN requires its engineers and technicians to provide the organic capability to safely operate, maintain, diagnose and repair platform equipments and to optimise platform system performance within defined envelopes (and beyond in extremis), following established procedures, in order to sustain the highest levels of Operational Capability. This capability must be available at sea or bases ashore, in worldwide theatres of operation, and in circumstances ranging from peace through crisis to war. RN engineers and technicians should be the focal point of platform equipment support solutions and support partners should recognise the central role of RN engineers and technicians as their organic ‘agents’, in the delivery of support.*”

As well as assessing an engineer’s ability to operate and maintain equipment, this new framework also increases the training content for **diagnose** and **repair** skills, providing the knowledge and tools that will allow our engineers to grow in confidence, whilst maintaining their equipment.

Each competence is broken down into awareness, practitioner and expert levels, providing a measure of competence as an individual’s career progresses. This will all be recorded in a portfolio of evidence (Competence Log Books or Journals) which an individual will keep throughout their careers as engineers, proving their competence level. Professional Examinations, based on the Competence Framework, will be introduced as a pre-requisite for promotion from LET through to WO. This will replace OPS and allow technicians to demonstrate their technical suitability for promotion, addressing a concern that is frequently raised.

The ICF will be the common thread that links together the Faraday work.

Training and Career Development

Training is currently delivered at the wrong time in an individual’s career. It takes an average of 10 years to promote someone to POET at which point they start their technical training. We are in the process of redesigning your training and intend to have it ready for April 2015. ET training will include far more engineering skill of hand, allowing them to innovatively maintain and repair their equipment and become better technicians.

The current construct of the LETQC and POETQC are going to be combined together so that the new LETQC will provide all the technical training required to empower LETs and allow them to confidently perform as the Deputy Section Head. The POET QC course will be reduced with the focus more on management and bespoke area of specialist technical training, giving POs the right managerial skills to run their sections.

... demonstrate their technical suitability for promotion ...

In re-designing the POETQC we expect to free up a six month period, and this will be recycled as ‘Journeyman’s Time’. This will allow an individual to spend time in their base port, and will be used as a technical consolidation period, allowing our senior technicians to practice their trade and dive much deeper into their specialisations through employment supporting ships at the Waterfront.

Streaming will allow development of deeper knowledge, meaning a change of emphasis from a ‘Jack of All Trades’ to a ‘Master of One’. We will be able to wrestle system and equipment knowledge back from contractors and reduce the over-reliance on external assistance. The Marine Engineer General Service will be split into two specialisations, ML and EL, whilst the Weapon Engineer General Service will specialise into three areas; Sensors, Weapons and an amalgamation of WE and CIS personnel. Both branches will be streamed between the rates of LET and CPO.

Fast Track Training

We have been slow to realise the potential in our young engineers so a Fast Track training scheme offers a solution. At present over 30% of ETs who join the Navy would have achieved the entry standard for the old Artificer scheme, so we know that the talent is available; it is just being held back by process.

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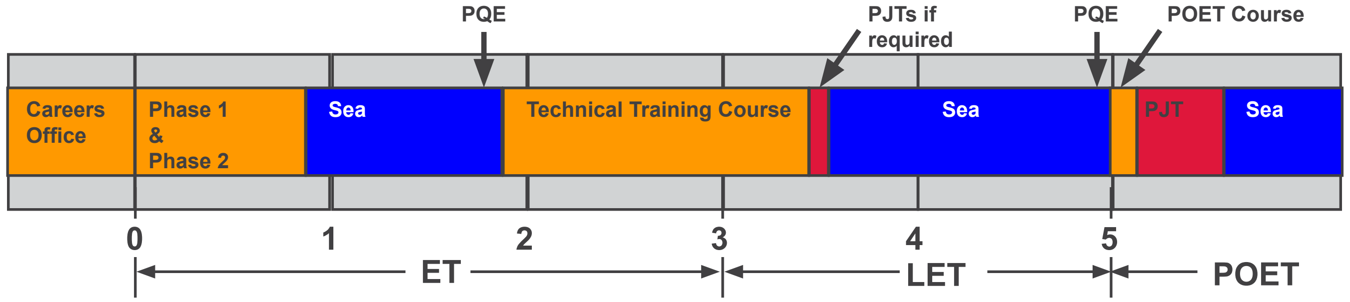

Figure 1: Steady State Fast Track

Under the Fast Track scheme, an individual completes exactly the same training as everybody else, but with reduced sea time. This provides the opportunity for promotion to POET in approximately five years rather than the current average of 10 years.

Figure 1 above details the generic route from joining the FT scheme to advancement to POET for the future fast track scheme using the April 2015 re-designed courses.

Fast Track will allow people to take ownership of their own careers, with recognition and reward for their hard work and good results. This will provide the opportunity for increased responsibilities and challenges earlier in their careers as well as allowing those interested in becoming an officer to demonstrate their potential for selection earlier.

THE LAST WORD

The plan to repair the Engineering Branch is in place, and collectively it is up to all of us to drive it forward. If our young technicians embrace the opportunity to raise their skill levels, and our Senior Rates continue to mentor the next generation of our engineers and technicians, then collectively we can recover our branch.

I want to hear your ideas and feedback. If you have any questions or would like to get involved in Faraday then please get in contact.

WANT TO KNOW MORE?

The Faraday Team is located in Room 13, First Floor, Walcheren Building (No. 33), HMS Excellent, and consists of the following:

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WO1 Andy Parker	Faraday WO1b	NAVYPERS-FARADAYWO1b@mod.uk	02392 547439
WO1 Darren Duery	Faraday WO1c	NAVYPERS-FARADAYWO1c@mod.uk	02392 547440

Further information can be found on the Faraday Intranet website: http://defenceintranet.diif.r.mil.uk/Organisations/Orgs/Navy/Organisations/Orgs/ACNS(Pers)NavSec/CNPS/Pages/Faraday.aspx

NAVAL ENGINEERING

Readers may be expecting to see another *Lessons Identified* article; as these have historically focussed on safety issues which often have impact on the wider RN, and not only on the engineering community, it's been decided to subsume this topic into the new *Sea Sense* magazine (http://defenceintranet.diif.r.mil.uk/libraries/library1/Navy/NavySafe/SeaSenseWinter13.pdf).

— LESSONS IDENTIFIED —

In the Autumn 2013 edition of *The Naval Engineer*, the article entitled *Maritime Force Capability Assurance – A New Vision* described the work BAE Systems and QinetiQ have conducted in developing a collaborative data recording and analysis capability for the purpose of assuring combat system performance. These tools have been successfully demonstrated in a Type 45 platform and specifically highlight the benefits and utility of the Correlation Figure of Merit (CFoM) functionality. The CFoM metric, which is fundamental in contributing towards developing a new vision of MFCA, is BAE Systems' IPR, having been devised by their Mr Andy Bowden. BAE Systems rights to the CFOM metric, and the TRACIT tool, should be given additional acknowledgement.

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RN ENGINEERS CELEBRATE SUCCESS AT WORLDSKILLS[1] UK EVENT

Taken from an HMS Sultan press release

Two Royal Navy ratings recently have scooped medals at the WorldSkills UK (WSUK) final competition, held at the NEC Birmingham, in the UK's largest skills and careers event.

WSUK is a high profile government-sponsored approach for showcasing apprenticeships delivered by the National Apprenticeship Scheme in partnership with the Sector Skills Council for Science, Engineering and Manufacturing Technologies. Its aim is to drive excellence in the workplace through competition.

Held annually at the National Exhibition Centre Birmingham during November, the WSUK – Skills Show Competition is the culmination of regional events in a variety of diverse trades intended to pit the country's top apprentices within their specialisations against one another.

In June, the Fleet Air Arm had entered two apprentices within the regional Aeronautical Mechanical category which was held at HMS Sultan. LAET Ratcliffe, from 702 NAS, and LAET Foulkes, from the Commando Helicopter Force, were both selected for the final national competition. Sultan also sent two entrants to compete in the Avionics section of the competition, hosted by Gloucester College, with LAET James Kempsell, now also of 702 NAS, successfully beating off competition to take the total RN representation to three out of the 12 places on offer, ensuring a strong representation from the RN in the final national competition in Birmingham.

Now in the final, the RN competitors, by then all serving at RNAS Yeovilton, were joined by representatives from a number of Level 3 apprenticeship providers which included, amongst others, the RAF and QinetiQ, for two and a half days of competition.

The engineers were thoroughly tested in six stances covering all aspects of aeronautical engineering under strict competition protocols. The mechanical entrants were tested in engine boroscope and blade blending, complex sheet metal production, hydraulic system design and build, and flying control rigging.

LAET Kempsell (left) took Gold in the Avionic and LAET Foulkes (right) took Silver in the Mechanical specialisation

The avionic entrants were tested in circuit board repair, motor building, loom repair and electrical system fault diagnosis. Both categories were also required to carry out a pre-flight inspection on the Harrier GR9 aircraft and component removal and replacement.

With a total footfall in Sultan of over 100,000 people, a backdrop of a Harrier aircraft from HMS Sultan and clad in their Royal Navy corporate polo-shirts, the three engineers were certainly a focal point of interest with multiple requests from the public for insight into life as a Fleet Air Arm technician.

With the results a secret until the lavish closing ceremony on Saturday, it was therefore a welcome result when LAET Kempsell took Gold in the Avionic and LAET Foulkes took Silver in the Mechanical specialisation. LAET Ratcliffe was unfortunately placed outside the medals. After the ceremony, LAET Kempsell said "*It has been a physically and mentally testing few days. Although I have completed my Supervisor's course recently, this was as thorough a test I have ever undertaken. With the high standards of my fellow competitors I was surprised but also very thrilled to have won the competition.*"

Commodore David Elford, Commandant of the Defence College Technical Training, based at Sultan, visited the Skills Show to show his support and said: "*I have been very impressed by the sheer scale of the Skills Show as well as by the huge level of interest that it has generated among the country's young people. It is particularly gratifying for me to see young members of the Royal Navy and RAF competing at the show and, as a Fleet Air Arm engineer myself, I must confess to being particularly proud to hear of the success of our young LAETs. My aim will be to try to expand the involvement of the Defence College of Technical Training in future Skills Shows.*"

The WSUK Skills Show is championed by Theo Paphitis from "Dragons' Den" who was delighted to take up a photo opportunity inside the cockpit of the Harrier. Fully endorsing apprenticeships as a serious alternative to university, Theo said "*The Skills Show is about inspiring them to do apprenticeships which I am a big fan of, this lights a passion and if you've got a passion you are likely to be successful.*"

For the avionic trade this is the end of the competition, however the mechanical trade will send its first three placements, along with the WorldSkills 2014 medal winners, to a skills boot camp which will be held in Spring 2015. The winner of this will go to Sao Paolo as the United Kingdom's representative for International World Skills.

1. Worldskills website: www.worldskills.org.

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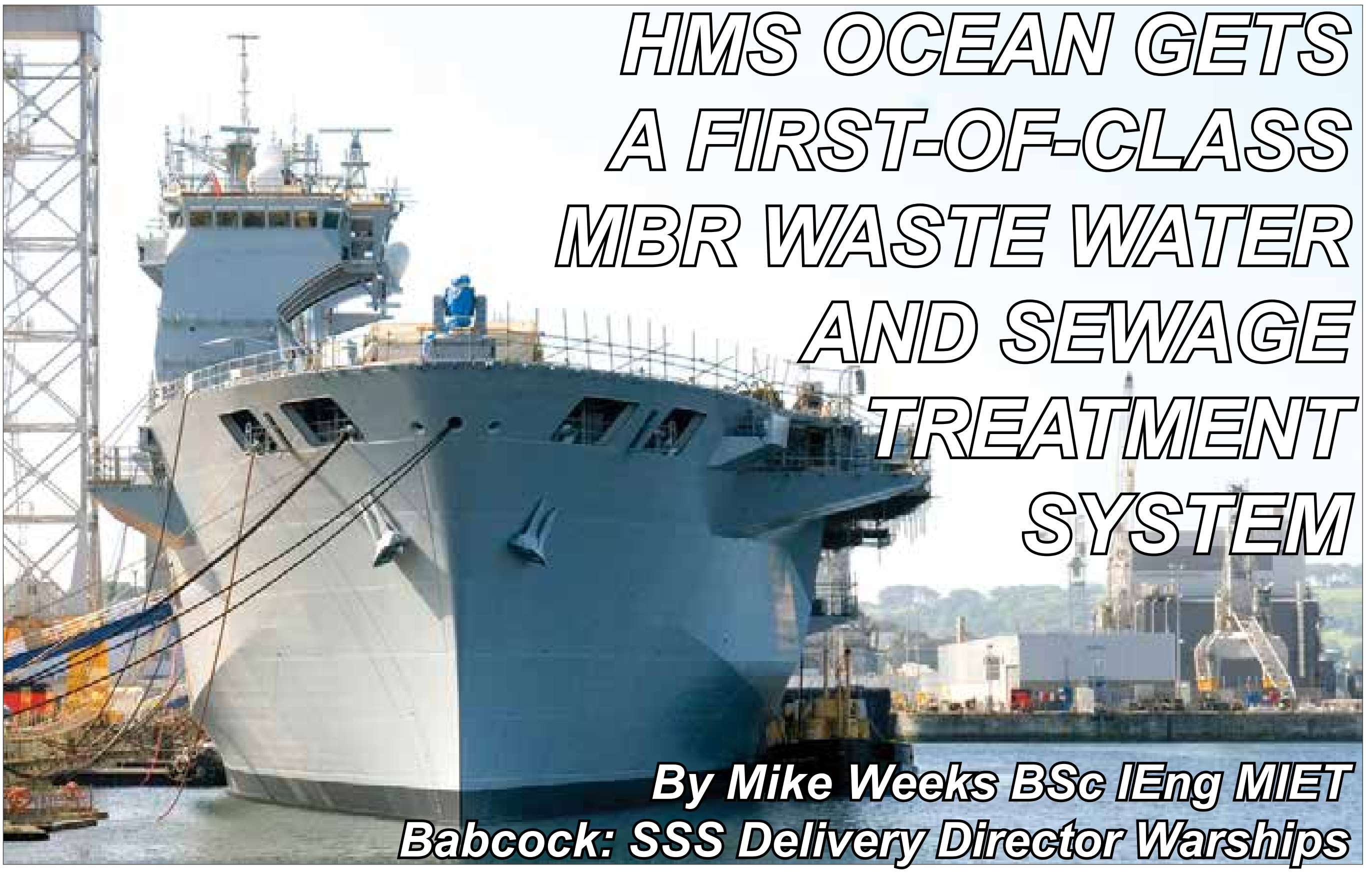

HMS OCEAN GETS A FIRST-OF-CLASS MBR WASTE WATER AND SEWAGE TREATMENT SYSTEM

By Mike Weeks BSc IEng MIET
Babcock: SSS Delivery Director Warships

Mike is an experienced naval support specialist who has worked closely with the Royal Navy for over 35 years on a wide range of projects for both surface ships and submarines.

He started at Devonport Dockyard (later DML Group and now Babcock) as an electrical fitter apprentice in 1976, and has since held a number of positions in Production and Project Management, including a Deputy Project Manager role with Fleet Time Submarines, Head of the Weapons & Systems Engineering Group and Head of the Surface Ship Dockside Test Organisation. In addition he has successfully led the Fleet Time Support Group (Ships) and delivered both HMS Albion's and her sister ship HMS Bulwark's upkeep projects. He was promoted to Head of Operations in 2012 and has subsequently taken up the position of SSS Delivery Director Warships with Babcock's Marine & Technology Division, with responsibility for all warship fleet time and upkeep activity at Devonport as well as worldwide deployed support. He is a trusted advisor to the MOD and Royal Navy for the maintenance of complex warships.

The upkeep and upgrade programme currently being undertaken on HMS Ocean by Babcock is the largest deep maintenance period on an RN warship in Devonport for over 20 years. Among the 60-plus upgrades, mechanical improvements and extensive maintenance package involved, the installation of a first-of-class state-of-the-art Membrane Bio-Reactor (MBR) – replacing the existing sewage treatment plant (STP) – has represented a significant proportion and integral part of the 15 month programme.

Title photo: HMS Ocean in Devonport Royal Dockyard

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Installation of the new MBR system ensures that HMS Ocean will leave this upkeep period in full compliance with current and future planned International Maritime Organisation (IMO) and Marine Pollution regulations due to come into force in 2015, enabling the ship to operate globally in carrying out her designated tasking.

THE MBR SYSTEM

The new MBR replaces the ship's existing 15 year old sewage treatment system and is capable of processing both waste water and sewage, including black and grey water, galley, laundry, sink and shower waste. The MBR process includes biological treatment in combination with ultra-filtration to produce an effluent which complies with the latest IMO Marine Environment Protection Committee 159(55) standard and USCG/Alaska 33CFR159.309.

New black water transfer stations have been installed in the Forward and Aft Auxiliary Machinery Rooms, which automatically send the waste water in batches to the MBR in the Midships Auxiliary Room (MAR). The ship's existing grey water holding tanks are used for grey water storage, with improved level monitoring and control to allow automatic batching of grey water to the MBR. An automatic grease separator has also been installed in the grey water line from the galley to prevent grease contamination of the downstream MBR systems.

New MBR system local control panels are installed in each of the main machinery areas and communicate with each other via a dedicated ethernet network. Each panel has touch-screen Human Machine Interface (HMI); a colour touch screen providing a control and visualisation interface between the operator and the process. The plant’s operating configuration, parameter trending, and alarm history is displayed on a series of graphical screens and text displays. Configuration changes can be made by the operator via buttons on the touch screen. The main MBR HMI is replicated in the ship control centre to give on-watch staff a complete overview of system operating status and alarms.

OPERATION OVERVIEW

Just upstream of the MBR, an automatic screen press allows only particles of less than 2mm in size to pass to the MBR. The rejected compacted and dried screenings are trapped and bagged for subsequent on-board processing and storage.

The MBR first stage reactor is a 40m^3 capacity process tank which is divided into two compartments known as the first and second stages. The smaller first stage tank acts as a buffer tank for the incoming black and grey water with initial biological processing taking place in this stage. The next stage is fine screening to remove the fine solids. Waste water from the first stage is pumped via a 200 micron interstage filter (ISF) to the larger second stage reactor compartment and reject water from the ISF is returned to the first stage via the screen press for further biological processing.

In the second stage reactor, holding the filtered waste water transferred via the ISF, aeration grids (supplied by air from new blowers mounted in the hangar) in the base of the tank promote mixing and breakdown of the waste into water, carbon dioxide and residual solids (sludge) through natural biological processes.

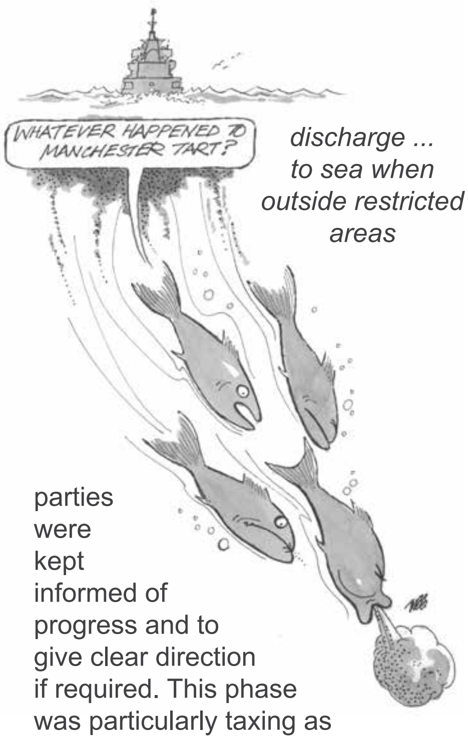
Filtered and processed waste water in the second stage is then recirculated through banks of ultra-filtration membranes which allow only water (permeate) to pass to the final process stage. The small volume of sludge remaining in the second stage is pumped periodically to a 45m^3 capacity aerated holding tank for subsequent discharge to shore facilities, or to sea when outside restricted areas. Final stage permeate from the membranes is collected in a small buffer tank where its quality (turbidity) is automatically checked before it is batched overboard.

PROCUREMENT AND DESIGN

The project to acquire, design, install and set to work the MBR has been a joint effort involving a number of key stakeholders from the MOD, Babcock and the Original Equipment Manufacturer (OEM) Wärtsilä, who have all played major roles in the fitting of this significant equipment upgrade into HMS Ocean. The equipment was procured under standard contract procedures by DE&S Maritime Platform Systems under the auspices of the DE&S Surface Ship Support Alliance (SSSA) Strategic Class Authority who had overall project responsibility.

Figure 1: The amidships shipping route cut into HMS Ocean’s hull

Following contract award, the next phase involved installation design which was closely managed by both the DD/Amph SCA and the Amphibious Class Output Management (COM) team within Devonport, enabling a single point of contact to ensure that all



discharge ... to sea when outside restricted areas

parties were kept informed of progress and to give clear direction if required. This phase was particularly taxing as it involved managing the output from the OEM which was translated by Babcock’s design teams into a design that would fit into the limited space on HMS Ocean, along with the detailed removal and fitting documentation for the operations team. Babcock (responsible for removal of old equipment and installation of the new system and equipment in the installation path) then worked closely with Hamworthy Water Systems (providing custom-built modular components, on-site fabrication of new tanks and setting the system to work) on the final phase of fitting the equipment into the ship.

INSTALLATION

The installation project for the new MBR system extended through the length of the ship at Decks 7-9, impacting on the upkeep schedule at every level.

Considerable preparatory work was required to allow the installation phase of the new system to commence, including cutting three shipping routes (each approximately 2.5m^2) into the hull (Figure 1), removal of the three redundant sewage treatment plants located forward, aft and amidships, and removal or re-routing of systems and equipment in the path of the new equipment fit. By

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Figure 2: The Midships Auxiliary Room, ready to accommodate the new MBR system

Figure 3: Work on the seatings for the new MBR system

April 2013 the MAR – the ship's compartment most affected by the MBR installation – was virtually empty, ready to accommodate the new system (Figure 2).

Additionally during this time, over 35 seating arrangements for the new equipment were manufactured within Babcock's dockyard workshops. These seating arrangements were manufactured from mild steel and ranged in size from under 0.5m^3 (for the screen press control panel, antifoaming dosing tank and cooler isolation seatings, for example) to over 10.6m^3 (nearly 7m long by around 1.25m wide and high) for the cross flow membrane seatings, and weighed from 15kg for the smallest seatings to 1.08 tonnes and 1.6 tonnes for the largest. A total of eight tonnes of seatings were installed (Figure 3).

The scale of the installation project itself was huge, with almost every compartment of the ship seeing some MBR-related work. As well as more than 3km of constructive and mechanical fluid system pipework to be taken out and/or re-sited, over 1.5km of new MBR pipework had to be fitted between the various system components, along with over 3.7km of new cabling to be run and sealed for the new equipment fit.

New holding, collection and pumping tanks had to be fabricated and fitted forward and aft, and transfer pumps, filtration membranes, grease separators, and screen presses integral to the MBR system were also installed, along with control and monitoring equipment. Some 42 tonnes (gross weight) of equipment was installed including 32 different equipment items in the MAR, plus items installed in the STP compartment, hangar, forward pump compartment, high pressure air compartment and lobby. Among the largest of these items were the MBR itself (measuring some 3.75m long by 3.55m wide and 4.12m high and weighing 8.7 tonnes), the cross flow membrane (4.3 tonnes), the sludge tank (over 9 tonnes) and interstage filter and black water tanks (over 2.5 tonnes each).

All seatings and equipment were shipped in through the holes cut in the hull to their designated positions. All the shipping routes were carefully checked to ensure all lifting points had been tested and were adequate for the weight of equipment being moved, and in some instances additional lifting points were installed to ensure heavy equipment was moved safely. Where possible the MBR equipment was delivered in modular, skid-mounted form to minimise subsequent mechanical and electrical fitting work on-board. This was not possible for the larger stainless steel process tanks, which were delivered in 'flat pack' for final welding in-situ, requiring careful planning and co-ordination.

3D MODELLING

One particular challenge lay in the re-installation or re-routing of existing systems and accommodation of the new system equipment within the compartments, particularly the MAR, including providing the necessary comprehensive installation drawings. 3D computer modelling was undertaken to facilitate this, with the drawings agreed and approved prior to starting the system fitting.

A 3D model of the MAR and sewage treatment compartment were created using laser scan information supplemented by the existing 2D datum pack. A series of fixed target reference points were set up in each compartment and the laser scanning device used to take several sets of images, according to the complexity of the compartment. A software imaging programme was then used to bring all the data together in a 3D model. This method was applied to model four key areas for the design of the MBR solution: the complete structural unit of the MAR and STP including all structural components; all equipment seats for existing equipment and for the new MBR equipment installation; existing equipment including electrical panels, lighting, oil purifiers, tanks, plummer blocks and shaft; and walkways and bearer bars.

The design drawings of the system were completed by Babcock personnel in Rosyth and Devonport, with regular meetings held to ensure all drawings were interfaced with the minimum of changes. Continual design reviews were undertaken throughout the installation process

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Figure 4: The MBR installation project underway

to capture all changes due to design alterations and the installation of equipment where different solutions were identified during fitting.

MECHANICAL AND ELECTRICAL FITTING

Drawings for all the new fit electrical equipment were supplied by the manufacturer, enabling a complex design solution to be developed that would allow these systems to interface with the as-fitted plant and control systems. New power supplies were routed from the power distribution units in the main forward and aft switchboards and group starter boards. Fitting details were also provided for the extensive monitoring and controls systems provided with the new MBR. A total of 91 separate equipment units were connected.

Some 14 mechanical system pipe runs were modified for the MBR fit, with new routes for the systems through the MAR and STP compartment identified using the 3D model, which was also used to produce the pipe runs manufactured in the dockyard workshops. Additionally new installations were required for a number of the systems. The black and grey water systems required approximately 1500 metres of galvanised steel pipes in various sizes (ranging from 125mm nominal bore to 40mm nominal bore), as well as 76 new valves of various nominal bores from 125mm to 50mm. Some 150m of 90/10 CuNi pipework was also fitted for various systems including high pressure sea water, hot and cold fresh water, and low pressure air.

The installation of two Daikin Unit coolers in the MAR (required to remove excess heat generated by the new MBR plant) involved work to the high pressure sea water systems supply and overboard discharges, as well as new ventilation ducting for the coolers to ensure even distribution around the compartment. This also involved changes to the ship's existing heating, ventilation and air conditioning system.

TIMESCALES

Installation of the MBR began in January 2013 (Figure 4), working to a tight timescale to achieve a working system ready for the ship's staff to move on board in mid-December. Among the key challenges of this phase was the need to interface the necessary work with the many other simultaneous activities underway within the upkeep programme, and the complex planning which that requires, to ensure that adherence to schedule for this critical path project was maintained.

Installation of the main MBR equipment was complete by the end of July, with final pipework and electrical inter-connections completed by mid-November, followed by commissioning of the system in readiness for ship's staff to move on board a month later. As with all aspects of this massive upkeep period, particular attention has been focused on delivering this installation safely, on-schedule, and at optimum value for money.

APPLYING EXPERIENCE

The MBR project is one of many making up the extensive deep maintenance programme on HMS Ocean, which is the first upkeep period on an amphibious capital ship since full implementation of the SSSA under which Babcock leads the COM team responsible for delivery support to all amphibious vessels.

HMS Ocean is the first RN ship to have an MBR upgrade during the ship's operational life (the Type 45s and Queen Elizabeth class aircraft carriers are having these plants installed during construction, requiring a more straightforward solution). The project has been a challenging one, but the good communication between the various stakeholders has ensured that day to day issues have been addressed promptly.

Importantly, the knowledge and experience gained, complex project management issues addressed, and lessons learned from the successful achievement of this significant project will provide a wealth of valuable information to be drawn on for the planning and execution of similar SSS Alliance projects in future. Similar upgrades are due to be undertaken on all Type 23 frigates (starting with HMS Monmouth in 2014) and the two LPDs during their next planned upkeep periods.

HMS Ocean is expected to leave Devonport for sea trials in early 2014, following the current deep maintenance period.

GLOSSARY OF TERMS

COM	Class Output Management
HMI	Human Machine Interface
IMO	International Maritime Organisation
ISF	Interstage filter
MAR	Midships Auxiliary Room
MBR	Membrane Bio-Reactor
OEM	Original Equipment Manufacturer
SSSA	Surface Ship Support Alliance
STP	Sewage Treatment Plant

***Note**: At time of going to press, work is continuing on HMS Ocean to complete the upkeep period and the MBR system has yet to be proven as fully operational. The ultimate operational success of the MBR will not be confirmed until after Ocean's Very High Readiness period, in mid 2014.*

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TECHNOLOGY DEVELOPMENT FROM THE ADVANCED PROPULSION MOTOR PROJECT

Lieutenant David Blatcher CEng MEng MSc RN
Future Projects Officer, Electrical Systems Group

TECHNOLOGY DEVELOPMENT

The MOD runs technology development projects to investigate the feasibility of opportunities to improve capability and reduce costs through the procurement of new equipment. The value that is gained from these is the increase in knowledge about how capability needs can best be met. This comprises identifying both ways to do things that are attractive and ways that are not. The Advanced Propulsion Motor demonstrator has not met all expectations; however the project has developed real technical opportunities for the future and found 'rabbit holes' that should be avoided. This validates the philosophy of continuing to run technology development activities.

David Blatcher joined the RN as a University Cadet Entrant in 2002 and, after fleet time, read Mechanical Engineering at the University of Southampton. After professional training he was AMEO in HMS Cumberland and DMEO of Westminster then Kent for an Op Telic deployment, home waters tasking and upkeep in Rosyth. He completed an MSc in Marine (Electrical) Engineering at UCL in 2011-12, which included a concept ship design project to replace HMS Scott and assessment of options for the RN to meet new diesel engine emissions legislation (see article in TNE Spring 2013). Since October 2012 he has worked as the Future Projects Officer in DES Ships' Electrical Systems Group on tasks including a 'get-well' programme for maritime electrical defence standards, the Type 23 power system upgrade project and developing a replacement for Astute class main batteries. He became a Chartered Engineer in November 2013.

CONTEXT

Electric propulsion has become the default option for larger RN and RFA surface ships, being used in various configurations by the Type 23, LPD, Wave, LSD(A), Echo, Type 45 and QE classes. It has led to benefits including:

- Reduced fuel consumption by enabling fewer engines to be run when the ship is operating at cruise speeds in lower threat environments (three in Type 22, two in Type 23, one in Type 45).

- Improved flexibility and redundancy of electrical supply systems and associated opportunity to reduce the number of installed diesels and/or gas turbines (propulsive power is almost always available from somewhere when conducting a BDX in a Type 23 despite having fewer engines than a Type 22 or Type 42).

- An easing of the requirement to site all of the propulsion machinery at the forward end of the propulsion shaft (for example diesels above the waterline in the quiet Type 23 and gas turbine generators very close to air intakes in QEC).

It has also been claimed that the potential elimination of the propulsion gearbox can reduce through life costs and increase Availability, Reliability and Maintainability.[1] Despite some recent experience to the contrary, these advantages may yet be realised.

Submarine propulsion plant takes up approximately one third of the internal volume of a submarine so any reduction in the size of

Title Photo: The APM demonstrator

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this system can lead to significant through-life cost savings and capability advantages. There is limited opportunity to increase the power density of the existing submarine mechanical propulsion plant but it may be possible to reduce the size of this plant using novel electrical architectures.[2]

For the Successor submarine and Type 26 frigate projects it was identified (in 2007-08) that the range of electric propulsion motors available was a significant limitation on the choice of propulsion system[1]. The Advanced Induction Motor used in Type 45 and QEC is too large for vessels less than about 7000 tonnes, for hybrid mechanical-electrical drives or for submarines. Lower power motors were identified but these generally had a lower power density and were not designed to military standards such as shock resistance. It was apparent that further technology development was necessary to provide a suitable range of propulsion options for these and other future platforms.

In 2007-08 the MOD was in communication with Converteam Ltd (now General Electric Power Conversion), who had developed a low-speed, high torque, DC-fed 'active stator' machine for wind turbine applications. It was assessed that this could be further developed into a power-dense motor for naval applications. It was argued that this motor could also be manufactured at lower cost than a conventional one of the same power, which would contain more steel and copper.

THE TECHNOLOGY DEMONSTRATION PROJECT

To meet this need, a technology development project was started with Converteam to develop an 'Advanced Propulsion Motor' (APM) as a propulsion option. In order to deliver a motor suitable for system testing and therefore reach an appropriate Technology Readiness Level (TRL) before Type 26 and Successor main gates:

- The development motor was specified to what were assessed to be full requirements for the most demanding (submarine) application.
- Project timescales were specified to meet the short time available between project initiation and crucial Type 26 and Successor milestones.
- No intermediate-scale machines or components were developed between the previous 150 kW demonstrator and the 15 MW APM.

With hindsight it is clear that the complexity of the motor concept used was too high to meet Successor and Type 26 needs within the limited time available. The project has now completed, knowledge has been gained and the demonstrator (Title Photo) has been disposed of, hence my use of the past tense in the following sections, where I describe motor features in more detail. I will then discuss the technical lessons that have been learnt from the process.

THE ADVANCED PROPULSION MOTOR

General Arrangement. The Advanced Propulsion Motor technology demonstrator was a bi-directional 2100 V, 15 MW DC synchronous machine (Figure 1). It incorporated two stators and a split rotor on a single shaft to allow continued operation after the failure of electrical supply to one part. The AC to DC supply converter was adapted from a standard Converteam unit and was separate from the motor. Two RENK-manufactured journal bearings were sized to support the motor thrust and weight at an inclination of up to 30º. Notable features were the use of an active stator philosophy, direct liquid cooling and adaptations to reduce noise; these are described in turn below.

Active Stator. 'Active stator' is a brushless DC machine technology and is central to the APM operating philosophy. It uses a DC-AC converter as an 'electronic commutator' to generate a rotating magnetic field from stator coils. In simplified terms, this stator rotating field interacts with a fixed field developed by the rotor to cause the latter to rotate. The APM used two rotating brushless exciters (one for each field winding) at the non-drive end of the motor to supply a field current to the rotor (see Figure 2).

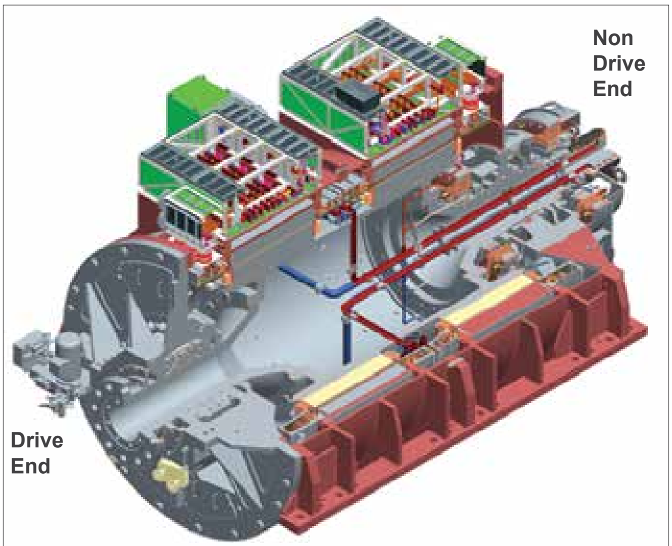

Figure 1: The Advanced Propulsion Motor

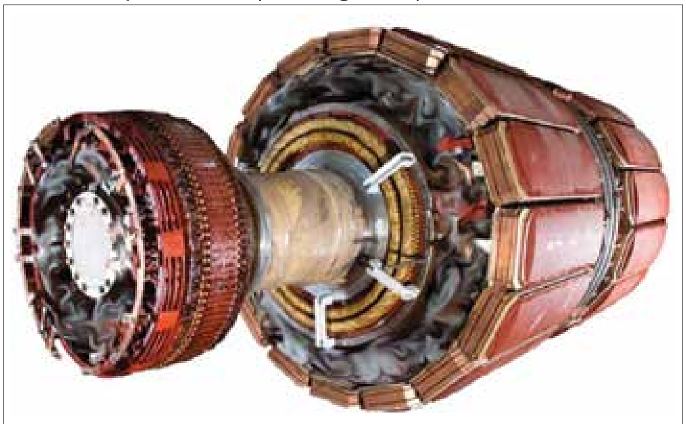

Figure 2: The APM rotor, showing exciters inboard and outboard of the bearing sleeve

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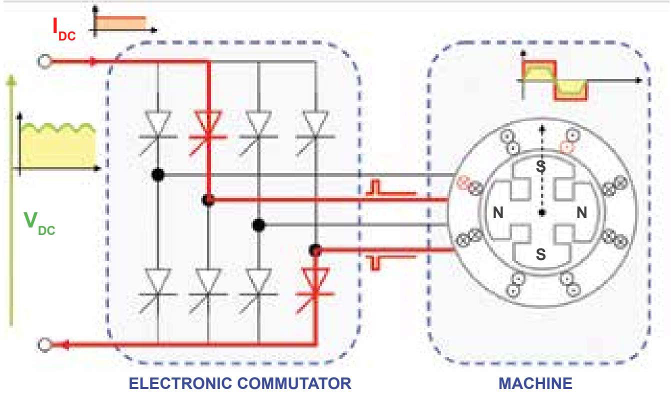

Figure 3: Active stator operation

Whilst this arrangement is similar to a more conventional AC synchronous machine (and shares its spatial advantage of including the field system within the air gap rather than outside it), the active stator converter phase control allows benefits such as use as a motor and generator and the delivery of trapezoidal rather than sinusoidal field currents. Trapezoidal current waveforms allow greater power density without undue problems of magnetic flux saturation in the stator. The absence of a mechanical DC commutator removes the reliability problems caused by carbon dust getting into the machine and poses a significant power density advantage.

A diagram illustrating the active stator concept is shown at Figure 3. For clarity, this shows a machine with four electrical phases and four rotor magnetic poles; the APM had 24 phases and 16 rotor poles. Current is directed to a stator winding by activating one 'supply' and one 'return' power electronic switch in the commutator. This flow of current through the stator coil creates a magnetic field which interacts with a fixed (permanent magnet or separately excited) rotor field to turn the rotor. Current is then directed through a different set of switches to the next winding and rotation continues. The rotor can be reversed by changing the sequence in which the switches operate.

The electronic commutators were mounted on top of the motor frame, as visible in Figure 1. This permitted integration of the motor and commutator cooling systems, a reduced motor deck-footprint and would allow the system to be appropriately tested before installation in a vessel (reducing commissioning time and risk). There were two machine converters for the tandem machine, one for each stator. Each converter consisted of six machine bridge power electronics '*i*-Cans', as shown in Figure 4, and one dynamic braking resistor for electrically reducing shaft speed. The 75 kg power electronic 'line replaceable units' contained 192 Gate Commutated Thyristor (GCT) power electronic switches. These were a bespoke design, required to facilitate the high motor current.

The volume of the electronic commutator was much lower than that of a standard voltage source Pulse Width Modulated (PWM) converter, because highly rated thyristors could be used rather than lower rated Insulated-Gate Bipolar Transistors (IGBTs). The use of thyristors rather than IGBTs also provided reduced switching and conduction losses and increased efficiency[1].

Both active stators were independently controlled by two commercially-available Power Electronic Controllers running bespoke control software. These allowed stable four-quadrant operation (both motoring & regenerating in forward & reverse rotation) across the torque-speed profile. It also allowed 'back-to-back' operation, using one half of the machine as a motor and the other as a generator whilst re-circulating current, to enable extensive testing without a large mechanical load device.

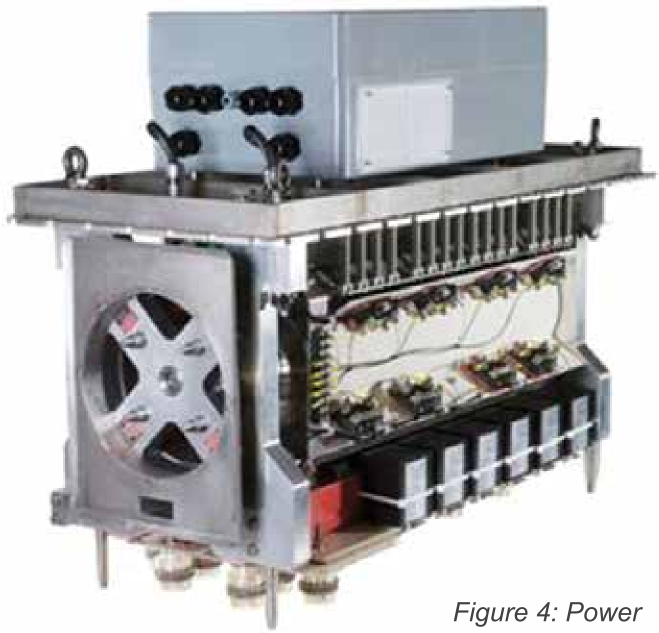

Figure 4: Power Electronics 'i-Can'

Cooling. The amount of current that can be carried by a copper conductor (thus motor power) is limited by the amount of heat which is generated by current flow. By removing heat from conductive components more effectively, the power density[2] of system components can be further improved (at the expense of motor efficiency). In addition, high voltage components insulated by air need to be widely spaced to prevent electrical arcs from shorting between them. By using an insulator that more effectively inhibits arc formation, these components can be moved closer together.

Midel® is a synthetic, electrically insulating oil which has been used for transformer cooling for more than 30 years, including for QEC systems.[3] Its specific heat capacity is an order of magnitude greater than that of air, enabling much more effective heat removal, thus allowing more current to be applied to a machine.

1. Significant losses are experienced when the power electronics are switched on or off and the thyristors only have to switch twice per electrical cycle rather than at the normal PWM frequency of several kHz

2. Strictly speaking, it is greater torque density that is permitted; motor size is dependent on required torque rather than power.

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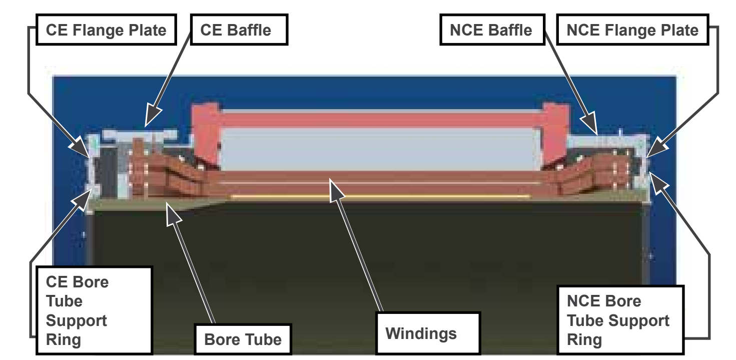

Figure 5: Sectional view of APM stator cooling arrangements

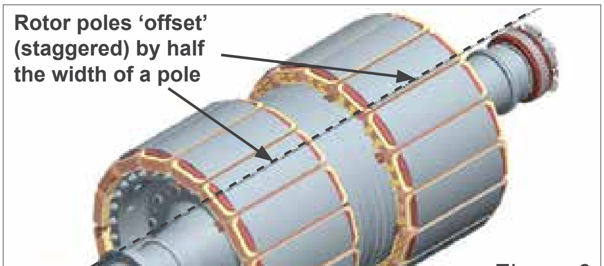

Figure 6: offsetting of poles between halves of the tandem rotor

The heat management philosophy for the APM was to use Midel to cool all parts of the machine, avoiding the need for a separate air cooling system and maximising the power density advantage. This involved providing the coolant to:

- The electronic commutator, immersing the 'machine bridge' and power electronics in Midel.
- The lubricating oil, to maintain the bearing temperatures within limits.
- The inside of hollow stator winding bars, via plenum chambers at each end of the bars.
- The outside of the stator bars, prevented from entering the rotor-stator air gap by a novel, magnetically inactive, glass and carbon fibre stator 'bore tube'.
- The rotor exciters.
- The rotor pole assemblies and windings via two shaft-mounted oil transfer boxes.
- A water cooled heat exchanger for heat removal.

The arrangements for supplying Midel to the stator windings and containing it using the bore tube can be seen in Figure 5, above.

Noise reduction. Noise performance was specified as an important requirement for the project. This was modelled in detail during the concept phase, including an assessment of the effect of the following measures to reduce the noise signature:

1. Using skewed magnetic poles, to 'flatten' torque ripple.
2. Offsetting the rotor poles, to flatten torque ripple (see Figure 6).
3. Trading off some full load performance for reduced noise when determining the pole shape.
4. 'Grading' the rotor-stator airgap along the length of the rotor (see Figure 7).
5. Reducing the strength of the rotor field at lower powers.
6. Attaching the stator to the machine frame using anti-vibration mounts (see Figure 8).

The modelling showed that the effect of skewing the poles was small relative to the additional cost of doing so. The remaining measures were, however, found to be effective and were applied.

PROJECT OUTCOMES – ADVANCES IN CORPORATE KNOWLEDGE

Learning From Experience (LFE). The author's exposure to the project was principally through collation of an LFE report as part of the Post-Project Evaluation (PPE) process[4]. This identified both managerial and technical lessons and copies of this report can be provided upon request to the author. Because the motor itself will not be used in service, these represent most of the value that can be gained from the investment that has been made and relevant project teams are encouraged to review the report. I will focus here on what the team has learnt about the active stator concept, liquid motor cooling and noise reduction measures that were explored in this design.

Active Stator Performance. The active stator concept was successfully employed in the APM, demonstrating that this has significant potential for use in future power-dense rotating machines. Most of the design features were fully validated, such as the construction methods used to produce the hollow stator bars. Lessons were also learnt about how this concept could be better implemented in future, including:

- The maintainability and reliability of the *rotor exciters* could be significantly improved if the unit is sited outboard of the rotor bearings.[5]

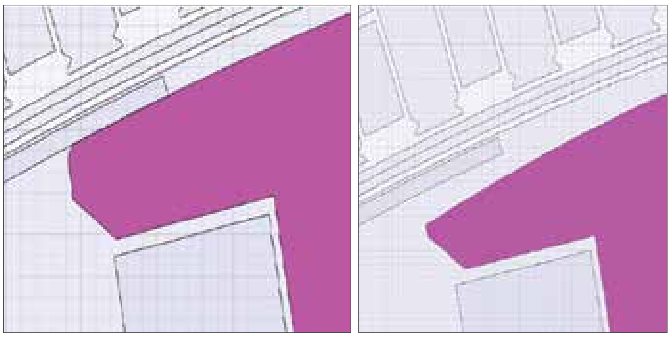

Figure 7: Parallel (left) and graded (right) airgaps

Figure 8: Anti-vibration stator mount

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- Using an *odd number of phases* in active stator machines would have allowed both reduced complexity and reduced machine noise.[6]

- Whilst the stator insulation design margins were comfortable, removing heat has been challenging. There would be benefit in *increasing the voltage and reducing the current* of a future machine with a similar topology.

- For much of the test programme, one half of the tandem motor has been used as a motor and the other half as a generator to avoid the need for a large load device. Control of this has required the development of bespoke software and has meant that time must be spent stabilising the motor at each given power before a test run can be conducted. The disadvantages of back-to-back testing should be carefully weighed against the cost savings during testing planning; however as this software has now been developed, the disadvantages of using this approach for future projects have been reduced.

Liquid Motor Cooling. This was the aspect of the motor design which presented the greatest number of problems. The knowledge generated by this project gives significant potential to improve the power density of static components of electrical machines. The potential advantages of using liquid cooling for *rotating* components are probably outweighed by the associated problems.

- *Using direct liquid cooling for the power electronic converter was remarkably successful*, allowing the power density of the electronic commutator to be reduced by an order of magnitude. This poses a significant opportunity to reduce the size of power electronic converters in a wide range of applications.

- The APM design required all of the '*i*-Cans' to be bolted to the top box to seal the electronic commutator. If one needed to be maintained or repaired then the top box had to be partially drained and the system could not run until all the *i*-Cans were replaced. This design has been superseded by arrangements used in a separate demonstrator funded by the Department for Energy and Climate Change, where *the i-Cans are individually contained* to allow simpler maintenance and reduce difficulties in obtaining a good seal (Figure 9).

- To immerse the stator in liquid coolant it was necessary to contain this with a stator bore tube (Figure 10), for which composite construction is the only feasible option.[6] Only one supplier was identified with the capability to produce it, and their expertise was insufficient to supply to the required quality. It has not been possible to fully assess its shock performance, and there is low confidence that the current design will meet MOD shock requirements. The *use of a stator bore tube should be avoided* in future designs of rotating electrical machine.

- Significant problems were encountered with the manufacture and sealing performance of the rotating seals in the shaft-mounted oil transfer boxes. It is *preferable to design out rotating seals* by avoiding the use of a liquid-cooled rotor. Where high power density is crucial, permanent magnet rotors now present a more attractive option than they did at APM project formation. Air-cooled rotors are more attractive for surface ships.[6]

Figure 9: Individually contained i-Can from DECC 450 kW demonstrator

- Although significant effort went into supplier engagement, there were *difficulties in achieving necessary tolerances on the plenum chambers that transfer liquid coolant* to the hollow stator bars. Design changes reduced the validity of the initial assumptions that drove use of this solution. If used in future machines, these complex and

Figure 10: APM stator showing internal composite bore tube

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novel components should be prototyped at full scale, or manufactured early with contingency time for re-work. Where stator windings are directly liquid cooled, serious consideration should be given to using a manifold-based coolant transfer arrangement. Internally cooling the stator bars was effective.

- Whilst the rotor performance has been successful, *seals between the two halves of the tandem rotor would be impractical to maintain in service*. Design review teams should ensure that all system components can be appropriately accessed for maintenance. A liquid-cooled tandem rotor presents coolant seal maintenance challenges for which solutions have not yet been identified.

- Liquid cooling of a rotating machine will add significant cost, risk and complexity. It should only be used if power density advantages override these drawbacks.

Noise reduction measures. The analysis that was conducted for the APM is a useful point of reference for future projects. The models for noise reduction measures 1 to 5, as listed above, were validated and were Defence Standard compliant for the range that was tested.[7] Whilst other factors made it impossible to do these tests above 4 MW, it is the lower-power structure-borne noise that is most important to submarine operations.

The novel anti-vibration mounts made assembly difficult and were less effective at attenuating noise than anticipated.[6] Further research into anti-vibration mounts would permit informed decisions as to whether the noise performance improvements justify the added complexity.

CONCLUSIONS

The APM as designed for the technology demonstrator was too complex, too expensive to manufacture and not sufficiently optimised for the naval requirement. Different propulsion philosophies are now being pursued for Successor and Type 26 and other motors are being developed for MUFC.

The APM project, however, was successful in that it has generated valuable knowledge and understanding of technology options for the MOD and for General Electric. Its ambition has meant that many positive aspects of the demonstrator (such as liquid cooling of the power electronics) and many unsuccessful aspects (such as manufacturing difficulties for various components as designed) have been identified. Finding out what didn't work is at least as useful as finding out what did when developing systems for future platforms. It has also assisted in "sustaining an intelligent MOD customer base". [8]

The level of uncertainty in selecting a machine with direct liquid cooling, active stator topology and/or anti-vibration stator mounts has been reduced. The experience gained is expected to influence future submarine propulsion strategy work and any further electrical/ electronic power technology development conducted by GE.[9]

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GLOSSARY OF TERMS

AC	Alternating Current
AIM	Advanced Induction Motor
AOF	Acquisition Operating Framework
APM	Advanced Propulsion Motor
APMS	Advanced Propulsion Motor System
BDX	Battle Damage eXercise
CADMID	Concept, Assessment, Demonstration, Manufacture, In-service, Disposal
DC	Direct Current
ESG	Electrical Systems Group
GCT	Gate Commutated Thyristor
GE	General Electric
i-CAN	One line replicable module of GE's power electronic system
IFEP	Integrated Fully Electric Propulsion
IGBT	Insulated-Gate Bipolar Transistor
LFE	Learning From Experience
LPD	Landing Platform Dock
LSD(A)	Landing Ship Dock (Auxiliary)
MGPM	Magnetically Geared Propulsion Motor
MUFC	Maritime Underwater Future Capability
NAO	National Audit Office
PWM	Pulse-Width Modulation (for power converters)
QEC	Queen Elizabeth Class aircraft carriers
SQEP	Suitably Qualified and Experienced Personnel
TRL	Technology Readiness Level

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QUALITY COMMAND, LEADERSHIP, MANAGEMENT AND EXPLOITATION

By Lieutenant Commander Dan Weil MEng CEng MRAeS RN
Air Engineer Officer, 847 NAS,
Lt David Hughes BEng RN, Deputy Air Engineer Officer 847 NAS
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Quality System Controller, Wildcat Fielding Team (Army)

Daniel Weil joined the Royal Navy in 1999 as a University Cadet Entrant. Following studies at the University of Bath and the École Navale, he returned to the Fleet Air Arm and deployed to Op Telic as Deputy Air Engineer Officer of 845 NAS. He then turned the handle through a series of staff jobs including the Wildcat Infrastructure Project, UK Security Manager for the Joint Strike Fighter in DE&S and on NCHQ's Carrier Strike Team. As Air Engineer Officer of 847 NAS, he has supported the unit's deployment to Op Herrick whilst simultaneously being loaned, with the remaining Squadron engineers, to the Army, to be responsible for all engineering and ground support output of the Wildcat Fielding Team (Army), now rebadged as 652 Sqn AAC.

A graduate in Aerospace Systems Engineering at Coventry University, David Hughes joined the Royal Navy as a direct graduate entrant in 2009. During his training he was fortunate enough to experience the embarked aviation challenges of Op Ellamy (see the Winter 2011 edition of *The Naval Engineer*). Having finished his training on 702 NAS (Mk3 and Mk8 Lynx) he joined 847 NAS and converted to Wildcat AH Mk1 in support of Army Wildcat introduction to service. As the DAEO of 847 NAS he has enjoyed the vast range of challenges presented by bring a new aircraft into service and feels he has a lot more to offer the Royal Navy as a result.

Colin Cheston joined the Royal Electrical and Mechanical Engineers in 1998 gaining his engineering education at the School of Electrical and Aeronautical Engineering Arborfield and Kingston University. His first line experience is varied across numerous platform types, including Gazelle, Lynx (Mk7, 9 & 9A), Islander and Apache, in addition to Project Team Experience supporting all marks of Lynx including foreign varieties. On formation of the Wildcat Fielding Team (Army) in 2011 he jumped at the chance to introduce this new platform into service, which, whilst challenging, has been a privilege and professionally rewarding, earning him a JHC Commander's Commendation and, more recently, the MOD Quality Award for his efforts in this area.

QUALITY – A LEADERSHIP PERSPECTIVE

When discussing quality with partners, aircrew, civilian friends and even peers, the sight of eyes glazing over is a regular occurrence. One could question the suitability of the subject matter for such dinner table or bar conversations, however it is the perception of the topic of quality rather than the subject itself that is at fault. Renowned for being something to do with check lists, men in white coats watching production lines, and ISO standards, people fail to recognise the importance of quality in everything they do and participate in.

... men in white coats watching ... ISO standards ...

Particularly in Service life, there seems to be a stigma associated with the term quality. Our perception of quality in our professional world is often taken to be an auditing methodology which encourages/requires individuals and organisations to write down a set of instructions, get themselves and others to comply with the instructions, check that they are following their own instructions and then getting an external organisation to independently confirm that the system of checking is working. That is merely Quality Assurance (QA), and this approach fails to acknowledge the intended outcome or vision for the organisation in the quality approach.

Quality has the opportunity to be much more than assurance; it encompasses continuous improvement, learning from experience, lean, safety management, engineering hygiene, standards and practices, through life management plans – in short, *quality should be a way of life*. The key to living the quality approach is to understand the individual's or organisation's desired quality outcome to ensure good engineering practices that ultimately lead to effective unit operational capability. Just as applicable outside of engineering, does quality result in well written SJARs leading to promotions for the best and self-improvement for the worst, or in fact does it support an ongoing human resource function that facilitates that pyramid promotion structure of the Armed Forces? Quality represents what individuals and the Services perceive to be the

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successful outcome of everything we do – ranging from operational effectiveness to one's professional standards.

QUALITY – THE LEADERSHIP APPROACH

The Armed Forces are rightly recognised for the leadership training they deliver. As engineers we all undertake that leadership training, add some technical knowledge to mix and, over time, achieve technical leadership and management positions on military units. There are key career training courses which build on the initial leadership foundation, and units attempt, despite particularly busy schedules, to maintain a programme of Command, Leadership and Management (CLM) development. We must question how much leadership training is integrated into specialist training, in order to provide a focus on generating an 'engineer who leads'.

As well as providing a holistic approach to military business, quality is a leadership tool, if not a leadership model. We, as engineering leaders, use quality to manage our business, but do we truly understand the quality outcomes of our organisation? Do our teams that work for us understand our vision of a quality outcome? Has there been appropriate feedback and is there someone checking that our quality vision is the right one?

Over time we learn about the various leadership and team work models and theories that are open to us, such as John Adair's Action Centred Leadership[1] and John Boyd's OODA[2] Loop. However, do we ever consider how these are applicable specifically within the engineering environment, or how we apply them to motivate engineers? All these models are valid, but we must also relate them to the technical environment for them to be easy to interpret by engineers of all ranks and rates, in order to provide ongoing CLM education with a technical aspect throughout a technical serviceman's career. In particular this could be couched within the Quality Leadership Model below.

When leading with a quality approach, the leadership must have a *vision* of what the quality outcome will look like and then must *demand* that quality outcome from themselves and their team. The leader must provide *direction* and guidance to the team, to ensure *understanding* of what the quality outcome is. Finally, as with all leadership models and engineering output, it must be recognised that it is generally the team's output and not that of the individual that *delivers* a quality outcome, which can then be assessed to provide assurance and equally *feedback* so that *process can be amended accordingly*.

1. Task, Team, Individual.
2. Observe, Orientate, Decide, Act.

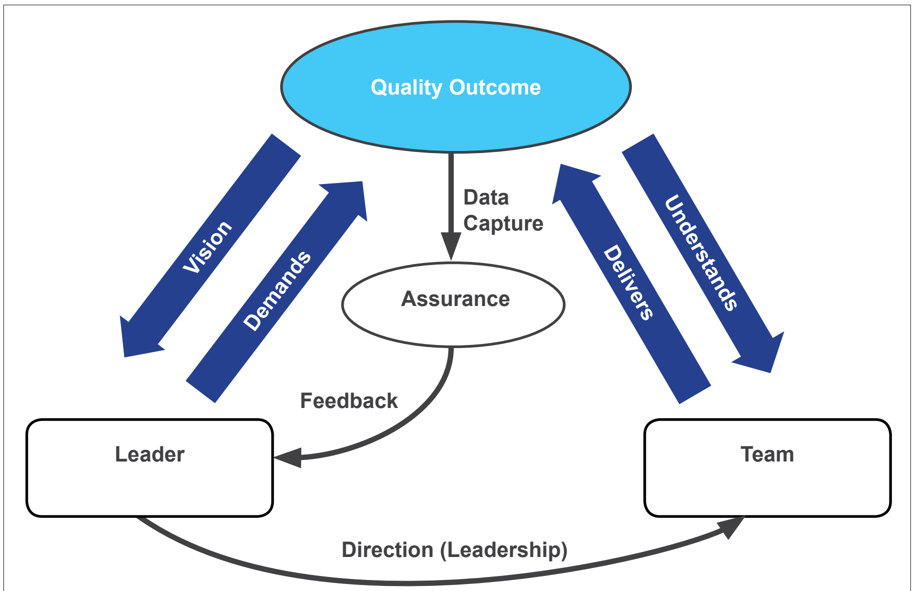

Figure 1: Quality Leadership Model

To demonstrate how this quality model is suitable for both the broadest and most narrow of topics it can be applied to any organisational environment; one could consider the car manufacturing industry and all the organisations that deliver the final output. The car design company has a quality vision of selling cars and generating profit; the car factory's quality outcome is a high and consistent rate of production; the production line seeks to have a consistent production line; the supplier to the production line has the quality vision of delivering serviceable components every time and on time. Each low level vision of quality outcomes builds to deliver the ultimate effect.

A quality vision, and leadership towards a defined quality outcome, must also therefore be central tenets of our military organisations and the sub-units and departments that make up the larger organisations.

QUALITY IN NAVAL AVIATION: A DEPUTY AEO'S PERSPECTIVE

During air engineering training, the emphasis is most significantly focused on the aviation policy that has been termed 'Quality' rather than thinking about what quality is, or what it should mean to a unit engineer. If asked to define or describe quality during training, it would almost have entirely revolved around the structure in the Fleet Aviation Quality Manual, which is paraphrased here for those not from the Air Engineering cadre.

In the Fleet Air Arm there are three mandated levels of quality audit that are used to define our quality assurance policy; Self Audit (SA), where the Squadron assesses its own compliance with local and higher level policy and whether the policy is having the desired effect, this happens on up to a six monthly periodicity; Internal Quality Audit (IQA), where the Air Station quality cell assess local engineering orders/processes and samples compliance on a once per calendar

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year basis; External Quality Audit (EQA), where the Front Line Command HQ quality cell assesses the Air Station's quality cell's ability to conduct an IQA, this is on a biannual basis.

Within a traditional squadron's Quality Management System (QMS), failings within a sub-department would be highlighted by self-audit, identifying that either the sub-department management system for the section was inadequate or incomplete; or, the failings in the section highlighted a lack of leadership, management, training or skills. Other than the Quality System Owner (QSO, normally the AEO, delegated by the CO), the Quality System Controller (QSC) or the specific section head, the majority of the department would remain unaware of any potential failings and thus fail to engage with any pan-unit improvement and identification of similar failings.

The focus currently seems to be on meeting the quality management programme, rather than understanding what the end outcome of the quality programme should be. Whilst the system works to prevent any of the specified engineering sections from failing to meet a defined standard, it does not appear to focus on the intended output of the section and therefore is not really assessing the quality outcome. In conjunction with this, the system seems very rigid and despite the normal professional manner in which they are conducted, and the drive to move away from question banks, it is in our nature to try and prepare for an audit; therefore, how useful is the data collected from the sections? Is quality even the correct term to apply to merely an audit process? In the surface fleet, a similar process is covered under the Ship Administration Check (Engineering).

The key to an enhanced quality regime is to empower all personnel within an organisation to use quality to develop and improve both the engineering organisation and its output. That concept is not currently reinforced for our engineering leaders, either at Senior Rate and Junior Officer level, except for those with specific and mandated quality terms of reference. The key to changing the mindset at all levels is the realisation that audits (and audit reports) are a valuable tool for everyone. Comments on audit reports have to be answered by the QSC and the QSO. If issues get recorded, the senior engineer of the unit is obliged to either take action, accept the risk or pass the risk up the chain of command.

QUALITY – THE WILDCAT MODEL

The Wildcat Fielding Team (Army) (WFT(A)) was stood up at RNAS Yeovilton to field the new Wildcat AH Mk1 (Army Variant). Despite being an Army focussed organisation, the engineering support has been heavily reliant on RN engineers from 847 NAS who will also operate the aircraft once it is in service. Cognisant that the aircraft will be operated by two different Services, with different training and operating models, there has been an attempt to align all Quality policy within both the RN and REME mandated quality methodologies; easing its introduction to service with the frontline units – 1 Regt AAC and 847 NAS. To compound the potential for confusion, the IQA authority is the Army Wildcat Principal Air Engineer, however the IQA function has been subcontracted to be delivered by the RN team on the Air Station. On the other hand, the EQA authority is the Joint Helicopter Command, thus crossing further Service boundaries and quality management and organisational models. This was a real opportunity to adopt best practice from both Services whilst meeting the needs of both operating models. This Joint approach took the most stringent aspects of each quality system to ensure compliance with both Service models; this has been validated by IQA and EQA authorities and demonstrates that Services can integrate and align their differing methods.

... Services can integrate and align their differing methods

WFT(A) taking part in Exercise Wildcat Sunrise on Salisbury Plain

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EXPLOITATION OF QUALITY DATA

One of the main purposes of the QMS is to ensure compliance with regulation and local policies; the QMS could have continued operation at this level but the unit began to consider whether the audits and the resultant data was being fully exploited? The data held within the audit reports could be mined, trended and used to influence management decisions. It has not been an attempt to re-invent the Quality wheel, merely to take the opportunity to use the existing tools and methodology that have been in existence for over half a century.

WFT(A) undertakes data trending of QA activities, where reasonable and useful, to drive forward the quality outcome. QA trending is an excellent tool to monitor the unit's own internal performance and the interface with external organisations where appropriate. Trending also allows limited resources to be focused on high gain areas and monitor the effect of changes and engineering decisions over time. Without data trending, decisions to improve the performance of an organisation may be based on 'gut feeling', experience or emotion. Once gathered, trending data will aid the decision making process at unit level but also has the potential to influence at HQ and PT level as well.

Trending information can:

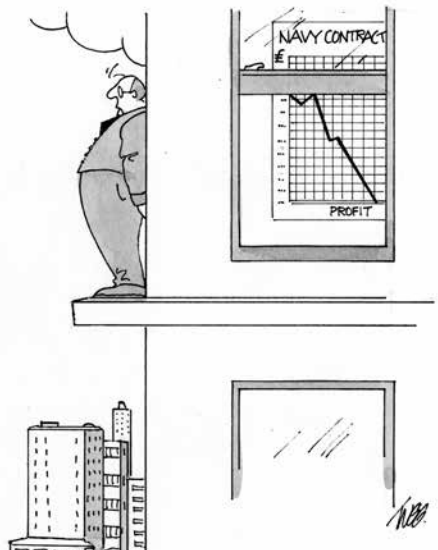
- Determine areas where decisions need to be made.
- Identify problem areas.
- Identify success areas.
- Identify stagnant areas.
- Predict the effects of a decision.
- Evaluate the effects of a decision.

QUALITY – WHAT INFORMATION SHOULD WE LOOK AT?

A trend can be defined as *a statistically significant change in performance measure data which is unlikely to be due to random variation in the process*. Trends can often be identified due to the amount of times a specific event has occurred. Within aviation, the potential severity of the event also has to be considered. A low severity event could occur numerous times before it becomes unacceptable, however just one high severity event occurrence could be instantly unacceptable. Thus Quality management becomes an extension of risk management, engineering supervision and continuous monitoring of mitigation activities.

To identify those suitable audit areas that would benefit from trending analysis the unit has developed a Quality Statistics Review Meeting (QSRM) in support of the policy mandated Quality Review Meeting (QRM). As a minimum, the QSRM determines the following:

- The scope of audit area trending within the unit.
- The manner and format it is to be carried out.
- The reporting interval (frequency of QSRM). If a trend developed, how long could you go without needing to know it? Longer intervals imply more risk is accepted or the risk has less impact.
- The stakeholders and any external organisations are to be identified.
- The exploitation strategy for any gathered trending data.
- Any future expansion/rescinding of audit trending areas.



Identify problem areas

- Setting of trend life cycle and performance measures (review of upper and lower control limits, ie when one needs to take action).
- Reviewing the effect of decisions made based on trending results.

Once WFT(A) decided which data sets to trend, available data was canvassed; many units are already data rich – it just isn't analysed or put to use. The advantage to using existing data is that it's already available to establish a baseline, the unit doesn't have to wait for future audits.

Trend information will not make any decisions for the senior management, however performance results can prompt the decision maker when to ask for more information, ie what happened here? Performance measurement data does not tell the decision maker why the data is the way it is. Proper trending of performance measures can prompt further questions to be asked. It is also important to present trending information in a simple format rather than bamboozling a superior with complicated and unintelligible data.

QUALITY TRENDING, WHAT HAS BEEN THE EFFECT?

Any statistician will say that statistics can be manipulated to say anything. Clearly small sample sizes in terms of events, aircraft population and time can impact upon the quality of that statistic, however WFT(A) has been able to exploit key technical information and effect real change.

An example of how statistics are being exploited is the continual monitoring and minimisation of the amount of aircraft documentation errors observed during audits. Faults are analysed by identifying the number found on any recorded job card. This faults per job card ratio has been then applied as a performance measure, and is used as a monitoring tool to give the QSO an overview of internal performance. When the number of faults per job card reaches a certain level, the organisation can decide to take

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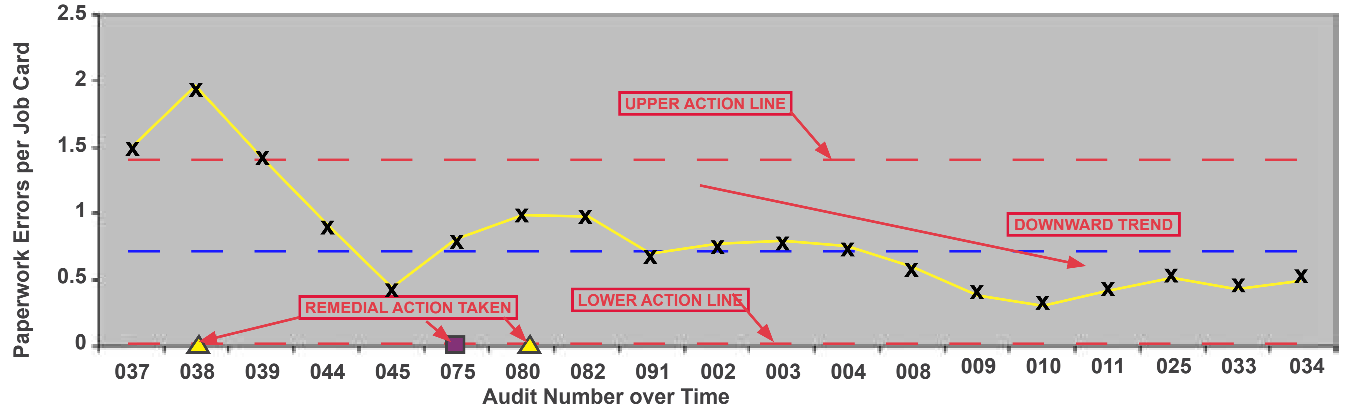

Figure 2: Trend of paperwork errors and effect of taking action

action. This action is also recorded and any subsequent change in error rate is monitored, either identifying a successful intervention or implying more or alternative action is required.

As a further example, REME QA Policy mandates that an Army aircraft must undertake a full strip zonal survey (known as a QA1) every six months. It is in addition to the Design Authority's mandated zonal survey package detailed in the aircraft maintenance schedule, which has the majority of zones inspected on a far more infrequent basis. The result of the QA1 activity found some minor issues, but actually caused more damage with the regular aircraft strips and saw an increase in the maintenance man hour burden. WFT(A) compared the analysis of the QA1 findings, the frequency of assessments, and maintenance effort with the aircraft risk to life model developed by the manufacturer (which defines the more infrequent maintenance schedule zonal inspections). The team engaged with the Principal Aircraft Engineer, the REME QA Policy team and the PT in order to understand the true value of the QA1 with a view to ultimately reducing the maintenance burden.

The final outcome will be a revision to the current level of QA1, focussing it on the processes within the unit rather than the technical standard of the aircraft. Considering every QA1 event took an average of 1000 man hours per aircraft each year, and with a future fleet size of 34, the reduction in the QA1 burden represents a considerable saving of time and effort over the anticipated 30 year life of the platform. Furthermore, the savings across the Service may increase if this QA1 approach is implemented across all REME maintained aircraft platforms.

Quality management, when carefully implemented, is not just about checking systems and engineering standards but is also about exploiting that check to drive the most efficient quality outcome possible to maximise operational capability.

QUALITY – THE WAY FORWARD

Having reviewed our understanding of what quality is, and how it is and isn't applied within the military aviation environment, it is clear there are opportunities both at the unit and Service level that could further exploit the quality concept.

Front Line Commands (unit and Duty Holder level) and Project Teams should look to exploit quality approaches to improving maintenance practices both in terms of equipment and also personnel. Quality should certainly be one medium for identifying failure to follow process, and also the route for implementing change and moulding operating culture.

The air engineering quality approach of all three Services is similar but not the same. Furthermore, non-aviation elements of the three Services also have quality regimes (generally under a different name, eg engineering standards and practices). In the interest of efficiency and smooth integration into Joint organisations and operating platforms this should be standardised wherever practicable.

Quality is not just an engineering function and Navy Command HQ is already developing a policy for a quality approach across the entire aviation spectrum. Could this be applicable outside aviation across the Naval Service?

Quality, in its current policy guise, appears to be considered in conjunction with a process, whether that be assurance or management. As a result, this distracts us from really paying appropriate attention to what the quality is and the tools it can provide us. So as we hear and distil the mantra that people are our most important asset, as well as assessing the quality of our engineering training and the training of the concept of quality, we should also look to specifically develop the leadership and quality values of our engineering leaders and managers, now and into the future.

WANT TO KNOW MORE?
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GLOSSARY OF TERMS

CLM	Command, Leadership and Management
EQA	External Quality Audit
IQA	Internal Quality Audit
QA	Quality Assurance
QMS	Quality Management System
QSC	Quality System Controller
QSO	Quality System Owner
QSRM	Quality Statistics Review Meeting
SA	Self Audit
WFT(A)	Wildcat Fielding Team (Army)

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PARTIAL DISCHARGE IN ROTATING MACHINES

By First Officer Mark Royston-Tonks BSc, IEng, MIET Systems Engineer Royal Fleet Auxiliary

Mark Royston-Tonks is a Systems Engineering Officer in the RFA and has over 25 years experience in the Marine Environment as a Radio Officer and Systems Engineer with over 15 years High Voltage experience (ashore and at sea). Currently working in Maritime Equipment Systems for the Electrical Systems Group (MES-ESG) he is the High Voltage Focal Point Ashore and is the secretary for the Maritime Electrical Safety Working Group (MLSWG) for Defence Equipment & Support (DE&S). He assists in the formulation of High Voltage Policy in conjunction with other RN HV SMEs and acts as HV SQEP for DE&S. For the last two years he has been investigating Partial Discharge effects in HV systems and Arc Flash Hazards wrt current and future Naval Platforms.

INTRODUCTION

The Royal Navy has made increased use of high voltage (HV) electric power systems in its ships in the last ten years, notably in Wave class tankers, Albion and Bay class landing ships, Type 45 destroyers, with the Queen Elizabeth class aircraft carriers being the latest. The UK has become a world leader in the field of electric ship propulsion and this is apparent in the increase in electrical generation capacity; approximately 500MW in 2009 to around 1142 MW by 2021[1].

These higher system voltages impose greater stress on the insulation, increasing the risk of catastrophic failure. At best, this could amount to temporary outages and at worst, insulation failure, which could be accompanied by arc flash, ultimately leading to extensive damage to equipment compromising the vessel's ability to function and possible loss of life.

European Standard IEC60270 (2001) '*High Voltage test techniques – Partial Discharge measurements*'[2] describes partial discharge (PD) as "a localised electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor". It is of note that PD activity is, in general, only seen in equipment operating at voltages in excess of 3.3kV at nominal atmospheric pressure.

The commercial shipping industry is suffering with HV equipment exhibiting high levels of PD activity followed by failures of plant, resulting in loss of operational capability, availability and high repair costs.

The MOD has been investigating the phenomenon and has drawn on information supplied by subject matter experts, operators, manufacturers, class societies and universities to further understand the subject and its possible implications for the RN fleet of HV powered ships.

This article aims to summarise the information gathered, explaining the phenomenon, describing the hazards posed and summarise incidents within the commercial shipping world. It will then go on to list the various testing and detection systems available, explain current actions being taken within the RN and then look to possibilities for the future, offering recommendations as to further work required.

WHAT IS PD?

PD usually begins within voids, cracks or inclusions within a solid dielectric, at the conductor-dielectric interfaces or in bubbles within liquid dielectrics. These discharges are limited to only a small part of the insulation and as such only partially bridge the distance between electrodes. It can also be active on the surface of insulation due to contamination or irregularities.

Voids between the two electrodes charge up like small capacitors (Figure 1). When sufficiently charged, they discharge with a small spark across the air void. These sparks produce heat, light, noise and electromagnetic radiation. This action also erodes the voids making them bigger; as they get bigger the discharge energy increases in magnitude. During this process carbonisation occurs;

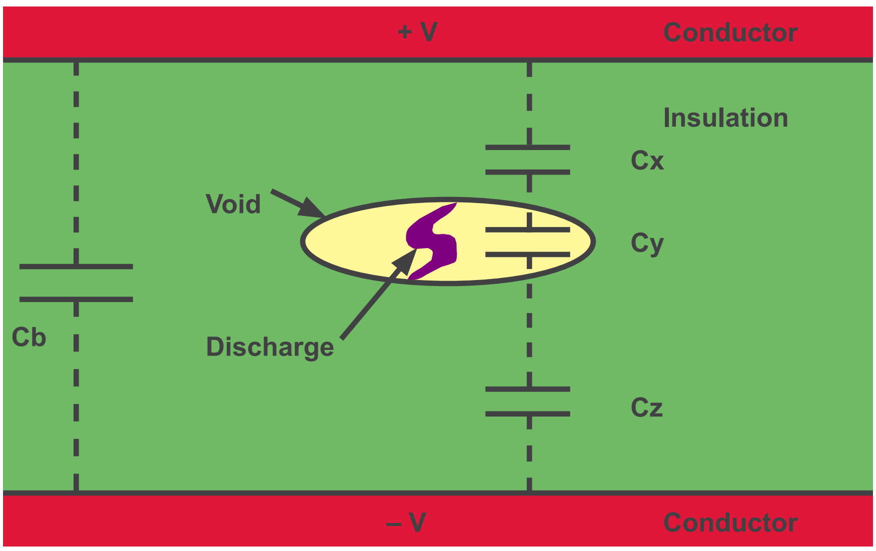

Figure 1: Partial discharge

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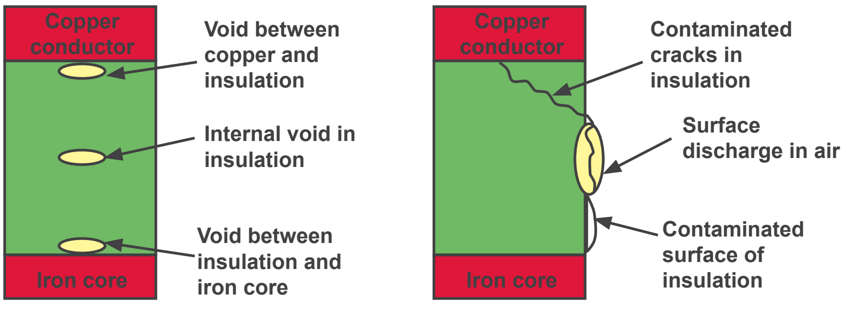

Figure 2: Failure modes in solid insulation

this also builds to make the void more conductive. The stresses on the next void increase, and the process repeats. Eventually there are enough conductive voids to cause the insulation to fail. These effects are permanent and, as the discharge site is generally sealed, the integrated effects of such damage may eventually lead to catastrophic failure of the insulation.

Surface discharges tend to occur between particles of contaminant; in addition to producing heat, light, sound and electromagnetic radiation they also produce ozone and nitrogen gases. Corona, ozone and nitrogen hydrate are formed, which chemically decompose organic compounds in mica paper, shellac, cotton and other organic material. Often moisture combines with the NOx gases to produce nitric acid, which attacks both the insulation and surrounding metal (Figure 3). Areas affected in this way are then susceptible to tracking, electrically shorting out the insulation, causing the process to accelerate to eventual flashover.

PD may be inherent (from design or manufacturing process), or may develop in operation (through electrical/mechanical overstresses, environment, vibration, high temperature or thermal cycling).

HAZARDS POSED

Where protection systems are not fitted or are ineffective, the failure of HV/MV assets is often sudden and catastrophic, producing major damage, injury or death. Sudden failures of live assets often release large amounts of energy, leading to explosions and fires.

Undetected Partial Discharge activity can also be hazardous to personnel, who are exposed to the danger of electrocution by assets which are unexpectedly energized.

HSE Booklet *Ozone: Health Hazards and Precautionary Measures* (Guidance Note EH38[3]) describes ozone as a highly reactive substance; any adverse health effects are to be found essentially at the sites of initial contact: the respiratory tract (nose, throat and airways), the lungs, and at higher concentrations, the eyes. The principal health effects are produced by irritation of, and damage to, the small airways of the lung.

However, individuals have considerable variation in sensitivity. Uncontrolled exposure to relatively high levels of ozone could lead to more severe health effects, including lung damage. At the levels of exposure likely to be normally found in the workplace, the main concern is irritation of the (upper) airways, characterised by coughing and a feeling of tightness in the chest.

Ozone could build up within the casing of machines if excessive PD is present; any access to the machine which involves removal of covers during maintenance could expose the maintainer to the harmful effects of ozone.

EVIDENCE OF PD FAILURES

Lloyds Register (LR) currently classes 125 vessels utilising HV electrical propulsion systems. The majority of these are passenger ships (figure correct at March 2013)[4].

Currently, LR has witnessed accelerated PD on 101 HV generators and six HV electrical motors on 24 different vessels. In addition to this, LR has information that PD has been reported on 61 generators on 20 different vessels not classed under LR.

There is also a concern that not all failure, repairs and evidence of deterioration are being reported.

Of the incidents witnessed by LR, at least six units failed in service and at least 16 units have been rewound in service.

It is of note that, of the failed units, there is no commonality in manufacturer; they operate at different voltage levels (3.4kV, 6.6kV, 11kV) and they use different propulsion technologies.

Figure 3: Damage to coil-to-coil separators

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Figure 4: Stator PD damage

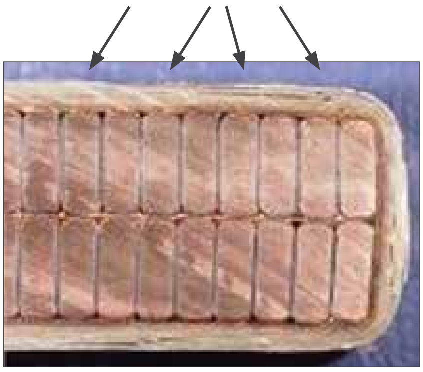

Figure 5: Insulation deterioration

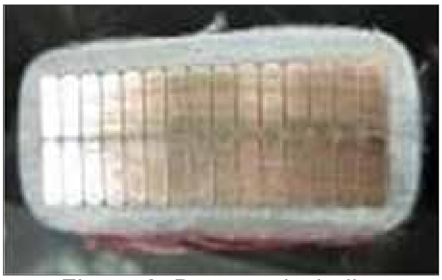
Figure 6: Damaged winding

This poses risks to the operator ranging from:

- Repair costs in excess of $1 million US per machine.
- Considerable time to affect repair – loss of capability.
- Lack of understanding as to the cause of the PD.
- Repairs also rapidly show signs of deterioration.

Some indication of the type of damage and root causes of insulation failure are illustrated in the paper by Rudolph Bruetsch – *Insulation Failure Mechanisms of Power Generators*[5] (Figures 7 and 8 respectively). The paper quotes a survey by CIGRE (International Council on Large Electric Systems) of 1199 hydrogenerators. It goes on to deduce that insulation failure is a significant root cause of the breakdown of HV rotating machines.

Causes of PD can be attributed to the following:

- Poor design – too thin insulation layer, poor electrical field control.
- Operational/environmental stresses (thermal cycling/ moisture).
- Machines supplied or fed from converters seem particularly vulnerable.

PD MEASUREMENT AND TEST TECHNIQUES

PD measurement is able to determine whether the electrical insulation is deteriorating because of loose coils in the slots, resulting in insulation abrasion, thermal deterioration or load cycling which leads to insulation delamination and electrical tracking caused by partly conductive contamination of the endwindings.

Partial discharge monitoring/ detection is a condition based monitoring system and can used direct electrical or electromagnetic methods[6].

The direct electrical method classically uses a capacitive coupler, typically 80pF, which is connected to the machine terminals being monitored. This type of testing can be carried out both off-line and on-line.

Off-line PD is equivalent to factory testing where the PD result will not be influenced by on-site noise from other drives or networks (Figure 9 opposite). All phase connections to the machine must be mechanically disconnected and earthed. This

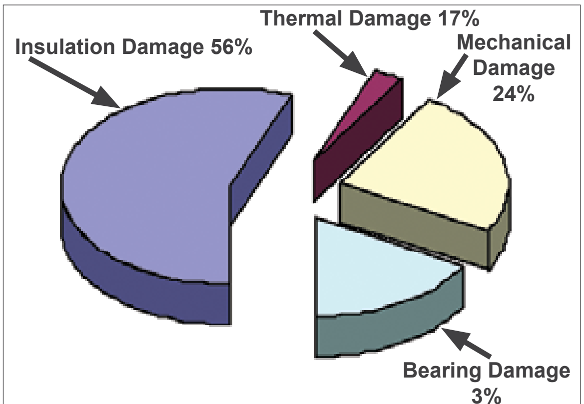

Figure 7: Damage to generators

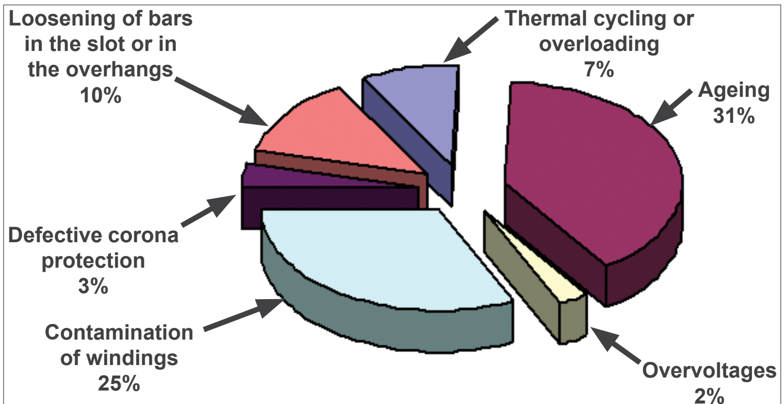

Figure 8: Root cause of insulation damage

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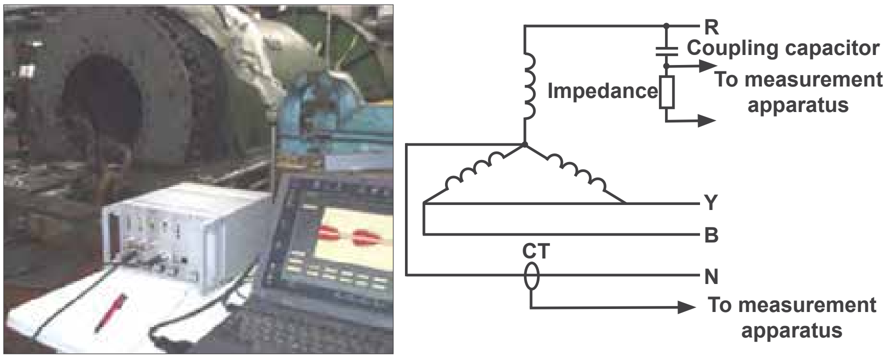

Figure 9: Offline PD testing equipment

ensures PD levels obtained are purely from the machine winding and not influenced by cable, drive and other protection devices.

On-line PD testing and monitoring requires permanently installed capacitive couplers to be connected to each phase of the rotating machine (Figure 10). This enables PD measurement to take place whilst the machine is in service and logs elevated levels of PD activity on each phase. As well as providing the PD signals, the coupling capacitors offer the synchronisation voltage required for PD measurement.

One note of caution: on-line PD monitoring cannot be applied to variable speed converter drive machines, as the converter drive superimposes spikes over the PD analysis, skewing results and masking PD activity. On-line readings are usually taken with converter drives not running. In this instance PD level measurements in converter driven motors are most often gathered using off-line methods.

Electromagnetic methods use current transformers (if the machine has a neutral connection). The output of the CT is taken to the measuring equipment (often an oscilloscope). This mode is simple and safe but has the disadvantages that the equipment cannot be calibrated to determine the magnitude of PD; CTs are susceptible to external noise interference and CTs do not provide phase information.

Stator slot couplers can also be used. They consist of an electrode structure printed on an epoxy-glass laminate and are installed in the stator slots between coils or under the wedge (Figure 11). There is no electrical connection to the winding and they are sensitive to high frequency pulses. It is claimed that they can detect PD in the slot but not in the core. Installation has to take place at assembly or the machine has to be disassembled to fit retrospectively.

By far the most informative measuring/detection method for rotating machines is the direct electrical method.

PROGRESS TO DATE

LR, in partnership with the University of Manchester (UoM), continues investigation into the possible causes of PD within the naval sector, focussing on possible system integration issues which could be the cause.

They are currently developing an electrical model of a typical ship electrical system (including harmonic levels and transient overvoltage levels). Electrical measurements are being gathered on commercial vessels, to assist in validating the model and gather data on operating modes of generating plant.

A model is also being developed to investigate stresses on machines due to thermal cycling. There is significant evidence to suggest that machines with high levels of thermal cycling can be vulnerable to damage due to premature ageing of the insulation. If this is the case, then this could have major implications in a ship's power management regime.

Rules are being developed by the classification society to help mitigate the risks.

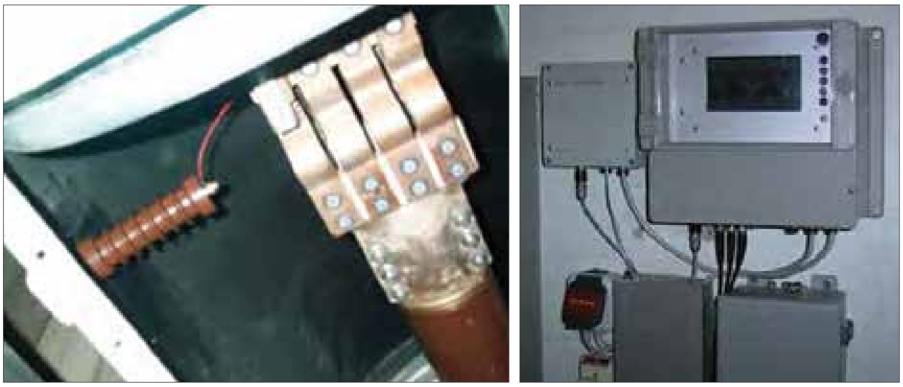

Figure 10: Capacitive coupling arrangement

Figure 11: Stator slot couplers

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The Power and Propulsion section of the Electrical Systems Group (ESG-PP) have instigated off-line PD testing with Pannell & Partners on both HMS Albion and HMS Bulwark. Both have had initial baseline measurements completed, with Albion having had her second set of readings recently taken (June 2013) [7].

Initial indications are that all rotating machines are in a healthy state, with the condition of the machines being equivalent to that of a new machine. It is to be noted that these machines are at least 10 years old and have been used extensively.

Of particular note, the value of PD testing was noticed with readings taken on Albion's auxiliary Diesel Generators.

The ship experienced oil and water contamination after bearing oil cooler failures in mid 2010. PD readings taken in December 2010 confirmed increased level of PD due to surface contamination. The DGs were cryogenically cleaned early in 2011 in preparation for the ship's long term lay-up. As part of the lay-up, the alternators were externally heated and dehumidified to assist in the preservation. At the mid point of the lay-up period (June 2013), a series of inspections and tests were carried out to check for any system deterioration; this included another series of off-line PD tests.

The results for the auxiliary DGs showed reduced levels of PD activity due to the successful cleaning of the machines (Figure 12).

WHAT'S NEXT?

With respect to ozone detection, this has been used on some commercial vessels as a PD detection tool, results of which are somewhat mixed. If levels of ozone are sufficient to trigger an alarm then the level of PD by this point could be excessive. In the author's opinion, the best use of ozone detection would be in the use of portable units which could be used to check levels prior to access into end casings being required by maintainers. These would be used much like atmosphere monitors are used prior to entering an enclosed space.

QEC staff are actively investigating the inclusion of PD testing within the ships' maintenance schedules. It is also understood that the Type 45 COM is embarking upon a PD testing regime to ascertain the baseline status of HV rotating machines.

Further work is being carried out by LR in conjunction with the UoM, the results of which are eagerly awaited and will be disseminated through the MLSWG and its stakeholders.

CONCLUSION

There is significant evidence to suggest that the use of PD testing as a condition based monitoring tool can be a benefit to the long term maintenance planning of the ship, and as mitigation for any risk-based safety issues that have been identified. Results for LPDs show that these ships are not experiencing the problems seen by commercial shipping; whether this is by design in the case of insulation quality, different operating conditions with respect to thermal cycling or for that matter an as yet undiscovered phenomena remains to be seen. Results of the investigations being carried out by LR and UoM are eagerly awaited and will help to form the basis for any further maintenance testing regime updates. On a positive note: whilst excessive PD activity can cause major damage to equipment, with proper planning it is manageable and controllable – "forearmed is forewarned".

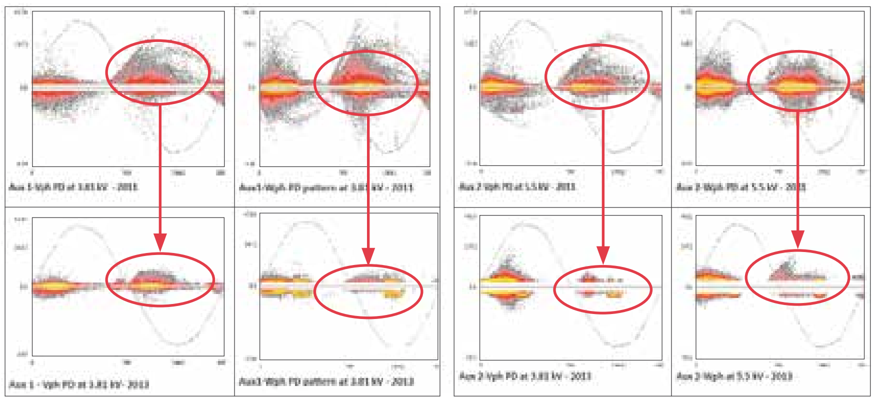

Figure 12: LPD off-line PD test comparisons – 2011 results (upper) v 2013 (lower) [x-axis: phase angle(deg), y-axis: nanocoulombs(nC)]

GLOSSARY OF TERMS

CIGRE	Conseil International des Grands Réseaux Electriques (International Council on Large Electric Systems)
COM	Class Output Management (Team)
CT	Current transformer
ESG-PP	Electrical Systems Group
HV	High Voltage
LR	Lloyds Register
MLSWG	Maritime Electrical Safety Working Group
PD	Partial Discharge
UoM	University of Manchester

REFERENCES

[1] K. Daffey, BEng (Hon), CEng, MIET *Review of Electrical Safety in Naval Platforms* (http://www.jneweb.com/EntityFiles/5/2729/JNEPaperFileName/v45b3p05a.pdf).

[2] IEC60270:2001 – *High-Voltage Test Techniques – Partial Discharge Measurements.*

[3] HSE Guidance Note EH38 – *Ozone: Health Hazards and Precautionary Measures.*

[4] Presentation by Lloyds Register & University of Manchester (Mr Bernard Twomey and Dr Ian Cotton) at the ESG PD Forum – 19 March 2013.

[5] Rudolf Bruetsch, Makoto Tari, Klaus Froehlich, Tilman Weiers and Ruben Vogelsang *Insulation Failure Mechanisms of Power Generators* by.

[6] DBR2000(52)(2) – *Guidance to Testing and Maintenance for High Voltage Systems in HM Ships and the Royal Fleet Auxiliary.*

[7] Ross Pannell (Consultant) and Goran Bezmalinovic (Consultant) – Pannell & Partners Power systems Services *HMS Albion Off-line Partial Discharge Analysis of Rotating Machines* Report date July 2013.

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TRAINING TRANSFORMATION IN THE ROYAL NAVY AIR ENGINEERING AND SURVIVAL EQUIPMENT SCHOOL

By Lieutenant Ross Morrison BSc RN and Lieutenant Stephen Currie BEng RN

The Authors are Academics Officers at the RNAESS in HMS SULTAN. Both are Training Management Officers who manage and teach Electronics, Electrical Engineering Science, Mechanical Engineering Science and Mathematics to the Leading Air Engineering Technician and Petty Officer Air Engineering Technician Qualifying Courses.

The Royal Naval Air Engineering and Survival Equipment School (RNAESS) has recently undergone a busy period of change. Against the backdrop of the Defence Technical Training Change Programme, two major School initiatives stand out as successes and visibly show benefit on a daily basis. With Defence School of Aeronautical Engineering (DSAE) Headquarters support, the RNAESS has driven through an organisational review, which has culminated in structural and behavioural change; this has been complimented by the modernisation of training – which introduces new methods, techniques and equipments into all aspects of our training.

SO WHY CHANGE?

As a relatively small organisation within Defence, the RNAESS is making a valuable contribution to the Defence Reform Programme and having developed a clear link between personnel, financial and infrastructural resource needed and the organisational outputs; in the sense of matching requirements to resources, this aligns to optimal efficiency. In keeping with MOD's Holding to Account process under the Defence Reform Programme, it is safe to say that the RNAESS has indeed made a significant contribution to overall efficiency and cost to run the business.

The secondary objective to develop the quality of training output has led to a School-wide programme to modernise training delivery at the point of need by changing the teaching ethos to mirror techniques used in schools and colleges. By introducing broader mix of training medias in support of facilitative and evidence based training techniques, the aim of this improvement programme is to increase student engagement in the subjects taught, increase the retention of knowledge and information and provide the next stage of the training pipeline (eg Engineering Training Section or Operational Employer) with individuals who can make best use of what RNAESS provide in their careers and the work place.

WHAT ARE THE FACTORS THAT ENABLE DECISIONS TO BE MADE?

In considering the two initiatives described above, namely the RNAESS organisational review and the modernisation of training, the following variables are under Navy Command and RNAESS' control[1] so that training is delivered in the most efficient and effective way:

- **Quantity** – the number of trainees needed to be trained on an annual basis, in each rank in each discipline. This assumes that there will be a proportion of trainees who need re-training and further training for them to meet the operational requirement.
- **Performance** – the endorsed standard to which personnel are trained to carry out tasks in defined

1. *Defence Training Support Manual* 1, Defence Centre of Training Support, Section 1, pp 5-6.

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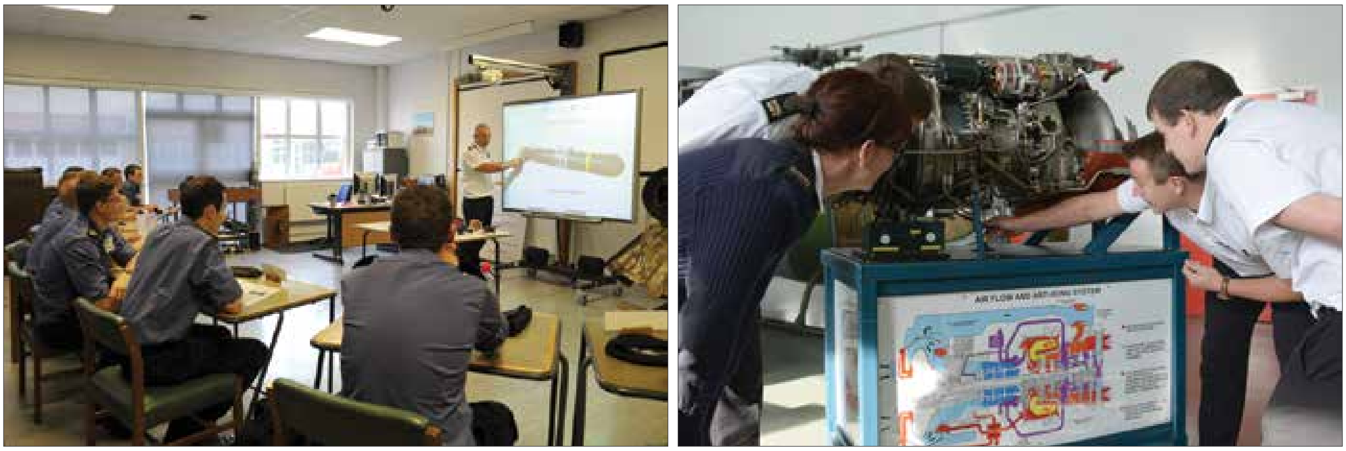

Training Delivery

conditions of work and against set policy and regulatory standards.

- **Time** – the time taken to meet the agreed training need; the balance of training need, if one exists, comprises On-Job Training to be carried out under the Operational Commander. Generally speaking, Schools aim to minimise OJT to reduce the burden on the employer.

- **Cost** – the balance of how the School's resources are used to maximise the use of time to deliver training to the agreed standard.

- **Quality** – of training provided to instructors, which in turn benefits the performance of the trained person in the workplace.

- **Retention** – of knowledge, skill and attitude imparted to the trainee and how much has been implemented in the work place.

ORGANISATIONAL REVIEW – ANALYSIS AND OUTCOMES

During 2013, the RNAESS initiated its Organisational Review[2] which led to the transformation program that got underway in September 2013. This saw the RNAESS develop from a well known but stove-piped Group Structure into a Pillar Structure that could map school output (facilitators, eg management support functions, and enablers, eg instructors and course material) to its resource allocation.

In summary, the organisation review reduced the amount of training delivery groups from three to two, now entitled Maritime Aviation Training and Air Engineering Specialist Training, and also migrated its manpower and infrastructure into its own Training Support pillar. To ensure objectivity of self-audit and evaluation of training, the Assurance Pillar was also removed directly from the role of the RNAESS executive. Table 1 below shows the old and new functions, to highlight key changes.

2. RNAESS TM 52/13 – *RNAESS Organisation Review – Transition Plan*.

WHAT HAS CHANGED AS A RESULT OF THE RNAESS ORGANISATIONAL REVIEW?

The transition resulted in a significant amount of work to amend administrative frameworks such as Joint Personnel Administration and the MOD Human Resources Management System. It also means the movement of personnel between parts of the organisation, filling, in some cases, different positions. However, in other instances, our personnel who are performing exactly the same role as before the change programme began. The most obvious question is why go through this change?

In June 2013 a survey was conducted of all instructional staff within the RNAESS. The survey showed that parts of the organisation's outputs were not aligned to their respective group, resulting in the School being 17%[3] gapped predominantly in civilian manpower. A variety of reasons were identified to explain these

3. Instructor Development Survey, June 2013, Conducted by QSM RNAESS, Data values generated by AEST-ACM.

Pillar	Replaced	Constituent Parts	Core Outputs
Assurance	Executive	Commander, XO, Staff Officer, Assurance Department	Quality Assurance and Management of RNAESS
Air Engineering Specialist Training	Specialist and Common Training Groups	Avionics and Mechanical Sections, Air Operational Safety, Craft Workshops	Academics, Generic AE and Skill of Hand Training Delivery
Maritime Aviation Training	Advanced Training Group	760 and 764 Squadrons	Phase 2 Maritime Training, Phase 3 Training Management
Training Support	Training Support Group	Training Support	Manpower, Infrastructure, Exams and Monitoring

Table 1: Comparison of Old and New

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gaps; most obvious was that roles and functions of personnel within groups had grown over time and that individuals were employed in roles that were not aligned to the employing group's priorities. A founding principle of the review was to align personnel function to pillar output. Having reviewed each position and its role and then aligned its function to the new structure, the gapping is now estimated to be less than 8%. Whilst the amount of personnel in the RNAESS has remained unchanged, the virtual reduction in gapping has affirmed that the revised gapping statistic is now a realistic shortfall in manpower, therefore representing a gap against the School's overall capabilities and outputs.

WHAT DOES THE ORGANISATIONAL REVIEW ENABLE THE RNAESS TO DO BETTER?

Another significant outcome of the RNAESS review, which was triggered by an earlier DSAE HQ Strategic Improvement Event, was the extraction of Training Design and Standards Organisation from the RNAESS organisation. The purpose of this change was to centralise all training development under Commandant DSAE, with the remit to standardise practices across each of the four DSAE Schools. The undoubted benefit to RNAESS is an increase in objectivity of training to be delivered. By removing the need for RNAESS to liaise directly with the Training Requirement Authority (Navy Command), this implies that training delivered by the RNAESS has been agreed by an objective TRA-led process. From an RNAESS perspective, training is delivered to the endorsed and agreed needs of the operational customer; furthermore, through the evaluation process, if issues arise, then there are clearly marked boundaries separating development and delivery of training, which enables the DSAE training organisation to identify which part of the system should address any shortfalls identified.

HOW DOES THE ORGANISATIONAL REVIEW IMPROVE THE QUALITY OF TRAINING?


... needs of the operational customer ...

Having described the alignment of staff and personnel to the new organisational structure, the next area to review was the previously unchallenged approach to instructor led training. Whilst training takes place in set quantities (as described in the agreed Statement of Trained Requirement), set times (agreed in the Statement of Training Task) and to set standards (per the Operational Performance Statement for each training outcome), the RNAESS has been proactive in its modernisation of training delivery.

Again, why change this? Fundamentally there is nothing wrong with how training is delivered – it is delivered in accordance with both Defence and civilian education guidelines and to a very high standard. Through Continuous Improvement, feedback and training evaluation, a noticeable trend has emerged that whilst the Royal Navy has not changed how it operates, the people who are entering the Service have. Those who have joined since mid-2000s have been educated in a media rich learning environment which positively encourages an atmosphere of experiential learning. Our underpinning analysis of training trends indicates that whilst our standards remain very high, there is room to improve the training environment which appears to be different from a traditional military approach. In changing training delivery methodology, it implies that a corresponding adjustment to how our instructors are developed and managed; the bottom line is that a vast amount of research and evidence shows that media rich learning environments staffed by versatile instructors stimulates a greater retention of information.

Retention of information, namely knowledge, skill of hand and environmental awareness, is inextricably linked to quality of learning and standards of output. Given the School's highly successful track record in producing quality personnel, the variable that we can improve upon is the transfer of knowledge to the benefit of the operational employer.

HOW TO WE DEVELOP OUR INSTRUCTORS TO PERFORM BETTER?

Instructors will readily agree that the Defence Train the Trainer and Defence Instructional Techniques Courses provide only an introduction to teaching and instruction. Indeed, the idea of expanding on this base of knowledge is stated in JSP 822[4] which actively encourages that Instructor Continuing Professional Development (CPD) is needed throughout employment as an instructor to become an effective deliverer.

The RNAESS initiated its CPD program in April 2011, its remit to cover all aspects of CPD from Engineering through to instruction[5]. RNAESS took a significant dip in its uptake of instructional CPD in 2012 and 2013 but this was identified early and has corrected with the introduction of a formalised CPD program, as a directed DSAE activity and funded by the Defence College of Technical Training (DCTT). In line with the organisational review, the uptake of CPD, and the priority that the Command places upon this, has resulted in a significant increase

4. JSP 822, Part 3, Chapter 4, Pg 6, Para 17.
5. RNAESS TM 28/11 – RNAESS Continuous Professional Development

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	No. of Instructional CPD Sessions[1]	All CPD Sessions	% Total
2011	11	11	100%
2012	2	11	18%
2013 – Summer	0	4	0%
2013 – Winter	0	6	0%
2013 – Autumn	1	6	17%
2014 – Spring	2	4	50%

1. Data from RNAESS TM's 141/13, 95/13, 05/13, 32/13, 114/12 (Amend 2), 67/11 (Amend 1)

Table 2: Table of Instructional CPD Periods

in late 2013 take-up which is also expected to be reflected in 2014.

Having captured the statistical history of CPD take up, Table 2 above shows how this has been reinvigorated due to the priority applied by both RNAESS and the HQ of DSAE.

WHAT DO GOOD CPD ACTIVITIES LOOK LIKE?

During the June 2013 review of CPD there was recognition that DSAE was lagging behind the civilian sector in two key areas of CPD: Virtual Learning Environment (VLE) and Evidence Based Training (EBT).

A CPD survey concluded that within the RNAESS, 82% had not received any training in the use of the VLE, and 92% did not use the VLE to help deliver training[6]. A similar pattern emerged amongst data gathered for EBT; when surveyed in June 2013, only 37% of instructors had some training in EBT. 77% had received no enduring support. Given that the findings from the research has indicated that some staff had experience of VLE and EBT, it was identified that CPD was undertaken at a personal level and not because of any formal School wide requirement. Given the recognition and success of EBT and VLE in academia and training, the Command made the decision to embed both EBT and VLE into its learning environment. To understand this further, within the School's formal CPD programme, a dedicated plan was produced to train all members of instructional staff to maximise the fruits of EBT and VLE in training delivery.

IS THIS THE END OF THE TRADITIONAL INSTRUCTOR ROLE?

VLE has been part of the MOD's Defence Learning Portal since 2008, and in spite of areas of Defence having good working examples of its use of their VLE, there appears to be reticence in taking full advantage of its concepts. An example of this is the MOD's purchase of MOODLE[7], which is a commercial learning content management system and is freely available for use in training content development[8]. In comparison, VLE is commonplace amongst civilian education establishments, with a noted 76% of all learners[9] have attended a course which utilises some form of VLE. VLE may be as simple as logging on to a training provider's website and reading pre-joining information, or it may include using IT to undertaking complex assessed tasks using a range of physical, written and computer based activity. From a resource perspective, VLE is very efficient method of delivery, as it is able to provide training in remote settings without the direct need of human interface.

That said, VLE is most effective when used in conjunction with a physical instructor and classroom interface, which is necessary to assure that training received has been assimilated and that training objectives are fully met to the needs of the operational employer.

Given the maturity of VLE policies and concepts, RNAESS Command has made the decision to align the range of teaching methods and media by embedding VLE in to appropriate areas of training such that we aspire to achieve two key outcomes; firstly it will provide a familiar learning environment to new trainees, therefore reducing the culture shock and secondly, to maximise learning retention rates. By investing in Wi-Fi access to learn online, this combined approach of training push (information provided to trainees in the formal setting) and learning pull (self-taught information by the trainee), there will be a middle ground where all of our students will find a happy medium of how they can learn in the most effective way.

EVIDENCE BASED TEACHING – LEARNING FROM SUCCESS

EBT has numerous advantages, one of which is that most instructors already use it without realising it. Evidence based practice (ie the bigger concept – EBP originated in medicine before moving across to education) is fairly simple – take an idea, use it and see what effect it has, then stop or continue using it. EBT is, at its heart, about trying to focus on teaching process approaches to solving problems, so that we train our people to quickly pickup and synthesise information then quickly apply it[10]. There are, of course, limitations: there is only so much you can teach from a book or in a simulated environment, some learning only occurs when you do it at the highest possible fidelity[11]. The

6. Instructor Development Survey, June 2013, Conducted by QSMRNAESS, Data values generated by AEST-ACM.

7. Modular Object-Oriented Dynamic Learning Environment (MOODLE) is a software package for producing web-based training and content. It is a global development project designed to support a social constructionist framework of education.

8. JSP 822 Part 33 Chapter 5 Para 9: Policy states that if re-use (of learning technologies (LT)) is not possible, analysis of available license free LT must be evident, when considering new LT requirements.

9. OFSTED VLE Portfolio, *Youth Sight Report*, accessed 26 Nov 13, available from http://www.ofsted.gov.uk/sites/default/files/documents/surveys-and-good-practice/v/VLE%20portfolio%20-%20Youth%20Sight%20report%20-%20summary.pdf.

10. *Teaching Evidence Based Practices: Strategies for Implementation*: taken from *Research on Social Work Practice*, C. Franklin, 12 June 2007.

11. The idea that we can train a man how to

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VLE has considerable advantages and actively promotes the idea of learning away from work which supports the RN's requirements to push towards a learning culture[12]. Not only this but the wide range of material which can be referenced and sourced will lead toward a better blend of methods and media which will only lead to an increase in overall retention of knowledge.

THE WAY AHEAD FOR VLE AND EBT

The studies conducted by RNAESS and findings produced triggered the DSAE to establish the Instructor Development Working Group (IDWG) which has a pan-DSAE remit to manage a co-ordinated CPD programme. With RNAESS initially focussing on VLE and EBT training, this projects that by June 2014, 60 staff will have been fully trained in EBT and 55+ will have been trained in MOODLE which equates to approximately 80% having been trained[13].

A major outcome that the RNAESS will have to focus upon is the capture and exploitation of CPD. Historically, whilst CPD has been of benefit to individuals, in an organisational sense there has been little evidence of collective benefit. In order that the DCTT-funded CPD programme sees a good return on investment, each organisation, in our case the RNAESS, will need to capture, analyse and publish elements of EBT and VLE that are particularly effective in training. Equally, there is merit in applying the same approach when identifying any practices that are noted to have a detrimental effect on training.

Finally, with EBT and VLE established and understood, this program must continue to adapt and expand to include other areas of teaching methodology. Only by directly linking CPD to results for individual instructors and the organisational goals can we hope to achieve the aim of better retention.

SUMMARY

RNAESS has been through a busy period of change and transformation that has helped us better link resources to output and map what we deliver to the Operational Customer, Navy Command Headquarters. Beyond being a desktop exercise, this has enabled us to improve the quality and quantity of output placed upon RNAESS. Although not an entirely straightforward process, we are near to completing this transition and the major structural changes are in place and working well.

Our CPD program is going to improve the confidence of our instructors and their ability to pass along information to students that they will retain. Provided that development remains a constant, the program will undoubtedly become a success that is well received by the instructional cadre. Overall, RNAESS is significantly improving its cost-effectiveness to Defence, assisting in developing the Operational Capability of the RN and looking well into the future to remain relevant, capable and sustainable.

build the weapon, maintain the weapon and pull the trigger, but we can never train him in the ability to pull the trigger at a real human being.

12. *Education within the RN – Is its Relevance Enduring?*: ITEMS, Spring/Summer 2013, P. LeGassick.

13. Figures from Mr K. Laycock, C2, ASME, member of the IDWG.

GLOSSARY OF TERMS

CPD	Continuous Professional Development
DCTT	Defence College of Technical Training
DSAE	Defence School of Aeronautical Engineering
EBT	Evidence Based Teaching
IDWG	Instructor Development Working Group
LT	Learning Technologies
RNAESS	Royal Navy Air Engineering and Survival Equipment School
VLE	Virtual Learning Environment

This article was written with the assistance of Lieutenant Commander Rob Driscoll BSc PGCE RN, Air Engineering Specialist Training Head, RNAESS.

... our instructors and their ability to pass along information to students ...

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HMS ILLUSTRIOUS PORT OUTER GAS GENERATOR EXCHANGE

THE LAST MOUNT OF OLYMPUS AT SEA?

By Lieutenant James Roulston-Eldridge MEng RN

Senior Watchkeeper, HMS Illustrious

James Roulston-Eldridge joined the Royal Navy in January 2006 having graduated from the Royal Navy Engineering Sponsorship Scheme at the University of Southampton, where he studied Mechanical Engineering. Following Initial Officer Training and SEMC, he spent his AMEO's time onboard HMS Edinburgh deploying to the Far East on the Orion 08 deployment. He then joined HMS Nottingham as DMEO in 2008, overseeing her initial transition into extended readiness (R9U), before transferring to HMS Manchester as DMEO from October 2008 to March 2011, completing both APT(S) and APT(N) deployments during that time. He subsequently served as Senior Area Careers Liaison Officer for the North of England Region, as part of the Naval Regional Command (Northern England) staff, before assuming his current post onboard HMS Illustrious as Senior Watchkeeper in March 2013.

BACKGROUND

HMS Illustrious sailed from Fujairah in the UAE on 29 September 2013 to conduct Exercise Sea Khanjar, as part of the Cougar 13 Response Force Task Group (RFTG) autumn deployment.

At 1735[1] on 6 October, a fire broke out in the Port Outer Gas Turbine Module. The fire rendered the Port Outer Gas Generator (POGG) unserviceable and caused damage to the associated power turbine.

As Illustrious approaches her final year of service, this article describes what is potentially the last ever Olympus gas turbine change at sea and outside of the UK within a Royal Navy vessel, and the challenges that such a complex operation brings 3400 miles from base port.

THE INCIDENT

HMS Illustrious was proceeding to take part in the exercise and had assumed CBRNDC State 2 Condition Y. Weather conditions were good, with the outside ambient air temperature over 35º Centigrade. Unfortunately, this meant that temperatures inside the machinery spaces regularly exceeded 50º Centigrade.

Illustrious had been conducting flying operations, running on twin engine drive on both port and starboard shafts for close to three hours. At 1718 the officer of the watch reduced to single engine drive on both shafts, at which point the POGG module temperature was noted to increase, activating the high acoustic enclosure temperature alarm. Given the high outside air temperatures, this was not an uncommon occurrence as the vent by volute cooling effect reduced at engine idle speeds. Watchkeepers were dispatched to check local module temperatures and monitor the engine's performance, before returning to the Ship's Control Centre (SCC).

At 1732, the officer of the watch ordered twin engine drive on port and starboard shafts again in order to launch aircraft. At 1735 the POGG low lub oil tank level alarm indicated in the SCC, immediately followed by POGG exhibiting sub idle characteristics. Emergency slow was passed to the bridge and LET(ME) James was immediately dispatched to the Aft Engine Room (AER) to investigate the breakdown. Permission was granted to trip POGG from the SCC, which was followed by a fire indication at the machinery control panel.

LET(ME) James confirmed that POGG was indeed on fire, with flames emanating in the region of the air start motor. POGG's fire suppressant BCF (Bromo-Chloro-diFluoro-methane) system was operated from the SCC.

At this point the General Alarm had been sounded and the on-watch Defence Watch Emergency Party (DWEP) responded. The fire was confirmed as extinguished at 1739, only four minutes from the first alarm activation.

Watchkeepers conducted a controlled handover of responsibility for the incident to the DWEP. Module temperatures spiked at 169º Centigrade as the latent heat from the gas turbine and associated fire soaked through the module. It took until 2015 for the module temperature to drop to the ambient temperature of the compartment (55º Centigrade) to allow a module re-entry to be made.

The module was vented – no easy task on an aircraft carrier which had been conducting movements on the deck and an upper deck full of aircraft, aircrew and handlers. Once the threat of potential re-ignition and contamination of the space by unspent combustion products and BCF had been removed, a five-man re-entry team conducted a dry re-entry of the module to allow a damage assessment to be conducted.

On confirming there was no potential for re-ignition, State 2 posture was regained and the DWEP was stood down from the incident.

First on the scene of the incident, LET(ME) James said: "*Having heard the pipe* 'Fire in the Port Outer' *on*

1. All times are Time Zone Delta (-4).

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entering the MMS, the training that I had received during Machinery Break Down Drills (MBDDs) gave me the confidence to deal with the incident and to understand the chain of events that would follow. Everything just seemed to be instinctive. Being involved in a real incident really has reinforced the importance of regular MBDDs to me. We have to be well drilled and we have to take them seriously and play it for real."

Examples of shrapnel found when POGG was removed

Damage to POGG exhaust guide vanes

Damage to POGG LP Turbine blades. Note that the outer blade ring no longer forms a full circle

DAMAGE ASSESSMENT

Initial damage assessment indicated that the seat of the fire was located around the air start motor. Further investigation revealed damage to the fire sock covering two on-engine flexible hoses, but no interior damage to the metaflex hose itself.

Investigations continued, which included wet motoring POGG. Within the first 10 seconds, the routine revealed excessive module and engine vibration and the wet motor cycle was aborted. An internal endoscope investigation of the High Pressure (HP) and Low Pressure (LP) turbines and compressors revealed catastrophic damage to the HP turbine blades, at least one of which had detached at the root, destroying the rest of the HP and LP turbine rotor blades as it travelled through the POGG towards the power turbine. This explained the loss of lub oil pressure and the tank level alarm. It also explained the high temperatures of the gas turbine and is believed to have been the root cause of the fire within the module.

The result of an HP turbine blade detaching from its root at over 4150 rpm and travelling through the HP and LP turbines at that speed is devastating. It appears that the turbine blade disintegrated on impact, sending pea-size shrapnel into all the blades of the HP and LP turbines and thereafter into the power turbine.

It was inevitable that there would be damage to the power turbine, although the whole of the ME department had their fingers crossed that this wasn't the case, given the complexity of changing one outside base port facilities.

The subsequent power turbine inspection revealed significant damage to the rotor and stator elements and photographs of the damage were emailed back to the UK for advice from Rolls Royce. When the GTCU was eventually removed from the module it was found that the guide vanes behind the LP turbine had been ripped from the GTCU casing and that one of them had entirely detached from the casing and was found to be resting against the power turbine stator blades.

INITIAL RECOVERY

Illustrious proceeded to anchor on 7 October to provide a stable platform for further assessment and recovery work to be carried

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out. At this point it was unknown whether or not the power turbine could be repaired, but either way the damaged POGG had to be removed.

Illustrious carries two spare Carried on Board (COB) Olympus Gas Generators. Unfortunately, the strip excess kit and engine change kit were held by BAe Systems in Portsmouth. With three days at anchor, good progress was made to prepare the POGG GTCU for exchange, whilst the strip excess and change kit were being flown out to Dubai to meet the ship in the next planned port of call.

Within those three days, the propulsion team, with support from across the ME department and from one BRNC Initial Fleet Time (IFT) instructor who was onboard between IFT embarkations, managed to remove the GTCU from its mounting and relocate it to the base of the Main Machinery Space (MMS) lift, securing it on its stowage trolley ready for removal to the hangar once alongside. This was no mean feat, with clever engineering solutions being generated on an almost hourly basis, including removal and stowage of the cascade bend assembly within the MMS itself.

THE POWER TURBINE

The big question remained as to whether the power turbine could be repaired in situ or whether it would need to be replaced. If so, were there any spares available for a last of class platform already suffering from obsolescence issues?

From the images and reports sent back to the Rolls Royce it was decided that the power turbine could probably be repaired in situ and Mr Steve Harrower was dispatched to meet Illustrious alongside in Dubai to assess and conduct the repair.

This also meant that work had to commence to remove the vent by volute arrangement, the power turbine covers and the stator vanes. This job came with its own engineering challenges, namely the removal of the single use Nimonic 80A bolts and location dowels from the power turbine covers that have been in place and subject to high temperatures for a number of years (getting replacements flown out from the UK in time to achieve the repair also became a challenge in itself).

DUBAI

During all of this initial recovery effort, Illustrious remained in CBRNDC State 2 Condition Yankee. As equipment was removed from POGG, it had to be stowed and secured for action. To move beyond this point, the ship had to proceed alongside.

On learning that Illustrious would need to extend her programmed Operational Stand Down (OSD) in Dubai from four days to seven days to complete the repair work, the propulsion team instantly became the most popular personnel on board!

HMS Illustrious arrived alongside in Dubai on 11 October. Once onboard, Mr Harrower conducted a full damage assessment of the power turbine and although there was damage to every blade on the Power Turbine and a total of three blades were out of standard tolerance, it was assessed that repair rather than replacement was viable.

The process took four days to complete. Each damaged blade was dressed and the rotor re-balanced. Dressing limits were exceeded on three blades in total with Rolls Royce and Platform Duty Holder approval (8mm of material removed from rotor – 5mm limit; 15mm and 13mm material removed from stator blades – 12mm limit). Vibration limits on reinstatement of the GTCU were still a concern but a reduced power limitation, if imposed, would be better than no gas turbine at all until Portsmouth.

With work progressing steadily on the power turbine dressing, the ship's ME team switched focus to removing the spare GTCU from the FER COB stores and relocating it to the hangar. The removed GTCU from POGG was also moved to the

Damaged POGG GTCU being removed from the module

CPOET(ME) Whitwham preparing the damaged POGG GTCU for removal

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hangar via the MMS lifts. With both GTCUs secured, a side by side comparison was completed before lowering the replacement GTCU for POGG into the AER.

Work on the power turbine was completed and approved on 14 October, allowing installation of the new GTCU to commence. At this point slinging operations were assisted by NP1600 who were available in theatre as part of the RFTG Deployed Operational Maintenance and Repair (OMAR) capability. This manpower rotation allowed some well earned down-time for ship's staff.

RETURN TO SEA

By the morning of 19 October, the majority of the work was complete, allowing Illustrious to proceed to sea. A lot of work in way had to be completed, before the focus could switch to commissioning POGG.

Commissioning work continued overnight as Illustrious prepared to transit the Straits of Hormuz en route to the Gulf of Oman for Exercise Omani Cougar.

Having exited the Straits of Hormuz safely, POGG was successfully run off load, followed by a full set to work procedure and tune and balance of the main propulsion plant. All work was completed and POGG was passed as serviceable on the evening of 20 October, some 14 days after the initial incident.

Illustrious is planned to return to Portsmouth in December 2013, at which point the defective GTCU will be returned to Rolls Royce for further analysis and failure mode investigation. Further GCTU changes are planned during the ship's next regeneration period, but hopefully this will be the last unplanned Olympus gas turbine exchange at sea.

Senior ME, Lt Cdr Kev Watkins, with members of the POGG change team; CPOET(ME) Whitwham, POET(ME) Conroy and POET(ME) Healy

POGG change team Junior Rates in front of the damaged POGG

LESSONS LEARNT

The following lessons have been drawn out of the incident:

- Correct reactions saved lives. The training received during realistic machinery breakdown drills really works. A well practiced team and rapid reactions from the watchkeepers prevented this becoming a major fire.
- Whilst Illustrious is designed to carry onboard spare gas turbines, these are useless without the rest of the stores and ASE gear needed to achieve the repair.
- With a last of class ship and limited stores support, contractor support and alternative engineering solutions are becoming more important, not less.
- Our training and the capability of our engineering staff at sea is first class.
- The retention of SQEP within a class of ship is essential to minimise the time to recover essential equipment.
- Support from NP1600 staff proved invaluable.

GLOSSARY OF TERMS

AER	Aft Engine Room
ASE	Ancillary Support Equipment
BCF	Bromo-Chloro-diFluoro-methane
COB	Carried on Board
DWEP	Defence Watch Emergency Party
FER	Forward Engine Room
GTCU	Gas Turbine Change Unit
HP	High Pressure
IFT	Initial Fleet Time
LP	Low Pressure
MBDDs	Machinery Break Down Drills
MMS	Main Machinery Space
OMAR	Operational Maintenance and Repair
OSD	Operational Stand Down
POGG	Port Outer Gas Generator
RFTG	Response Force Task Group
SCC	Ship's Control Centre

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EXTERNAL CONFERENCES – JUST A JOLLY OR VFM?

By Commander Toby Drywood RN CEng FIMarEST and First Officer Mark Royston-Tonks RFA BSc IEng MIET, Defence Equipment and Support

Mark Royston-Tonks' biography can be found on Page 29 of this issue

Toby has just completed 25 years service, following a traditional ME Officers sea career path of DMEO (Type 22), Small Ship MEO (OPV), MEO (Type 23) then Flotilla and NCHQ roles post his charge appointments. These front line roles have been interspersed with additional training (MSc and ACSC) and engineering support or development roles primarily on Abbey Wood. These have included Platform Management Systems and Control Room Simulator EPM, Technical Manager for the Electric Ship Programme Office in the exciting days of getting the Electric Ship Technology Demonstrator working, signature and WE trials planning and delivery for the First of Class Type 45 and finally as the Head of the Electrical Systems Group (ESG). The majority of these roles have had an electrical or electronic bias, including High Voltage. His latest role as ESG Leader covers through life support to electric propulsion and control systems for every ship and submarine class in service, and with inputs and influence into all in build and future projects too.

Attendance at external conference events can be seen by the wider Maritime community as just a "jolly". A chance to sit around with old friends and spin "dits" and attend a free meal or two whilst engaging in discussions with contractors as to their next job opportunity outside of the RN or DE&S.

This amazingly is not the case. Conferences are actually interesting, informative events which are usually fast paced with little time during the day to sit back and relax.

THE NEED

The importance of engineers is coming under more scrutiny than ever due to lack of skills. Of note:

"There are currently weaknesses in the area of personnel in the MOD, namely the undervaluing and dilution of engineers and engineering skills; engineers are not required to have professional status; decline in the ability of the MOD to act as an 'intelligent customer'; and a shortage of manpower and skills fade."[1]

1. *The Nimrod Review,* Charles Haddon-Cave QC, 2009.

"We will continue the most essential investment in Science and Technology. It is a key element of our overall capability."[2]

"Science and technology advice should be used more widely in support of decision-making across Defence."[3]

"DE&S has around 5,000 civilian engineers (figures are from HRMS from people tagged to Eng & Sci and PPM job codes), from Band-D to a 3-star in range of specialist/generalist engineer & project-management roles ... from Engineering Technicians exercising applied judgement within a defined framework through to highly innovative & creative Chartered Engineers undertaking complex engineering, safety & programme-related tasks."[4]

WHAT IS BEING DONE?

Whilst these challenges are being faced by MOD in general, they are currently being addressed by DE&S, these include:

2. Strategic Defence & Security Review 2010.
3. *Defence Reform*, Lord Levene, 2011.
4. DE&S Engineering Strategy presentation 2013.

Conference Banners

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- **Insufficient numbers of SQEP engineers in technical posts:**
    - The regulatory framework has grown in breadth and depth, quickly.
    - Reduction in military manpower.
    - Outflow of engineers is higher than inflow.

- **Insufficient management of the 'engineering flock':**
    - Unclear on SQEP we have or need.
    - Gap in structured technical development identified between organisational levels.
    - Demographic is aging. Up to 40% retiring within the next decade, as can be seen by the graph in Figure 1.

- **Struggle to retain SQEP:**
    - Insufficient engineers gain qualifications or take on responsibilities.
    - Ageing workforce.
    - Following the DESG graduate scheme, graduates often leave MOD.

- **Engineers not feeling valued:**
    - Under development & a lack of professional identity.

In addition to this, one of the points raised in a recent Atkins report of private sector engineering was that staff motivation is key:

- Celebrate being an engineer! – twin vision around identity and business purpose.

- Board-level (or near Board) engineering representation.

- Clear career paths leading to the top.

- Meaningful personal development planning, throughout career.

HOW CAN WE DO IT?

The DE&S board has identified the Means with which we can attract engineers:

- DEFINE: Clear professional structures.
- DEVELOP: Engineers throughout their careers.
- MANAGE: Talent.
- RETAIN: SQEP.

Attendance at external conference events can be seen as an input to achieve at least three of these, namely Develop, Manage and Retain.

One way of improving our engineering personnel and progressing them through to Chartered Engineer is to fully support attendance at external conferences. This has a number of advantages:

- Exposure to the wider engineering community.
- Improves and widens scope of knowledge.
- Adds to life and working experiences.
- Meets the mandatory CPD requirements for professional registration. CPD is fully supported by DTech.

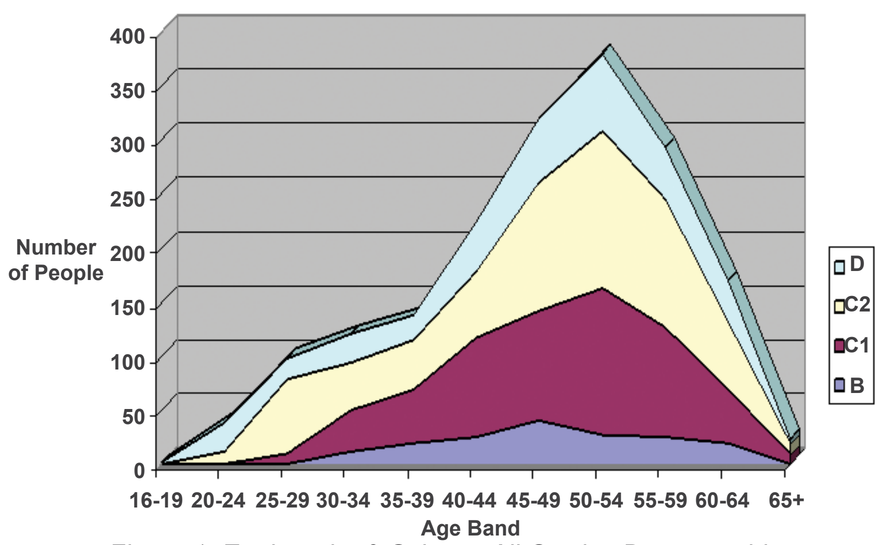

Figure 1: Engineering& Science All Grades Demographic

A link to the DE&S Engineering Strategy intranet site can be found at: http://defenceintranet.diif.r.mil.uk/Organisations/Orgs/DES/Organisations/Orgs/FuncDir/Technical/Pages/EngineeringStrategyPlans.aspx#Content3

Whilst this article does not support the blanket attendance at conferences there are some that provide specific opportunities to the RN & DE&S maritime communities:

EAAW 2013 Bristol

Engine As A Weapon (EAAW) – This covers technology development and platform design and the fact it cannot prevail in isolation, and highly integrated systems are inevitable if affordable and adaptable solutions are to be exploited. The biennial EAAW series provides an acknowledged and exceptional opportunity for delegates and speakers from navies, commercial companies, governments and academia, to expose and explore these integration challenges. Some of the subjects covered in this year's event were:

- Uniting Weapon and Marine engineering knowledge: From goal to reality.
- Integration of combat and platform management systems: developments in the Royal Netherlands Navy.
- The Type 26 Global Combat Ship – the approach to achieving a noise reduced design.

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- Electric and hybrid propulsion considerations for a future SSN.
- Fire fighting and damage control automation: Enabling future crew reduction.
- Power generation and MCAS update of the Type 23 – Re-powering to meet demand.

MECSS 2013

Marine Electrical and Control Systems Safety (MECCS) – This year saw the first controls and electrical safety conference of its type, which aimed to bring together system and equipment suppliers with class societies and operators to present solutions, share best practice and debate just how we can make the marine industry safer, and more reliable using software and electrical technology. Some of the subjects covered were:

- Marine electrical and automation systems – Managing safety across a global engineering and technology business.
- Safety evaluation of advanced DC electrical power plants.
- How the arc flash hazard influences the design and concept of operations of ships.
- The case for simulation and visualisation based training.
- The Royal Netherlands Navy electrical safety training facility.
- Implications of IEC 61439-2 on LV switchgear & control gear; testing, application and reliability.
- Arc protection – Gimmick or ‘must have’?

International Naval Engineering Conference and Exhibition (INEC) – about to have its twelfth outing, it had a central theme in 2012 when it was based around Engineering Naval Capabilities.

In 2014 the central theme is “Innovative Solutions to Global

INEC 2014 Banner

Trends”. The overview of the conference is:

“Many of the ships and submarines in service today, and certainly all new platforms in the early phases of their development, will still be at sea in 2030. Many will be at sea well beyond then. It is perhaps feasible to predict some trends in seagoing operations, even if there are a number of potential scenarios. These trends might include fuel types and availability, population growth and effects of climate change.

In other areas such as politics, the trends are very difficult to predict, and therefore setting exact requirements for our equipment, personnel, training, infrastructure, to name but a few areas, is almost impossible. So, the challenge before us is to design innovative engineering solutions to requirements that give us sufficient flexibility to respond to the most likely plausible scenarios. The sub-themes chosen cover the topics which most affect the maritime operating environment and require the best that our engineers and industry can provide whilst, of course, remaining within tight financial constraints.”

BENEFITS

By attending conferences delegates have the opportunity to participate in environments that are rigorous and fun, scholarly and social.

The learning environment encourages delegates to exchange experiences, ideas and practices from their own areas.

It allows delegates to interact with other companies who may be experiencing similar issues and problems. It allows them to tackle issues together. In turn perspectives will be broadened as a result.

Sponsors and Speakers

All of the conferences above provide a maritime focus with respect to engineering (both Mechanical & Electrical) issues. They are attended by a wide variety of Navies, commercial and military ship operators, designers and shipbuilders, classification societies, machinery and equipment manufacturers, universities and other defence related organisations. This provides and excellent opportunity to gain personal development and substantial networking opportunities to enable future contact.

Certainly, from experience, contacts made at these types of events have directly facilitated our progress with Arc Flash Policy and Guidance and our work in Partial Discharge analysis. So not only do these events give benefits to an individual, but they also give benefit to the wider MOD maritime community by providing information and contacts which help to shape our business and improve our policy, knowledge and skills as a whole.

The three examples shown are arguably the most suited to assist COM(F) in meeting the challenges he faces with his engineering community.

A sometimes forgotten benefit is to industry and the institutes of DE&S and the RN attendance at these events. We provide a unique perspective, we are not only

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operators and maintainers, we are self regulated, safety focussed and still engage in future technology development. It can also be argued that we have a vibrant ship building programme. Our knowledge and experience spans many skills and specialisations and, as such, the attendance of our personnel at these events is highly regarded.

THE FUTURE

Feedback from these conferences is vital to their success and some of the feedback received has been related to the fact that, whilst well attended, there is a high proportion of senior attendance and less at the lower levels. This needs to be addressed to encourage more junior grades to attend, as this is where the greatest benefit can be gained, especially with respect to widening experience. For this to happen, there has to be attitude and budgetary change within the senior management to allow this. Junior grades need to be encouraged to attend and finances need to be increased to training budgets to allow for this. In this respect, the old adage of "you need to speculate to accumulate" is very apt.

There has also been some criticism levelled at the institutes, mainly that costs and venues sometime preclude the numbers we would like to attend. To this end investigations are being made to utilise technology more. For example, live video feeds of presentations being streamed on the internet to allow main centres (ABW & NCHQ) to host screening sessions, thus widening the opportunities for attendance. Whilst there would be an associated cost, it is envisaged that this would be lower than the current fees for attendance (circa £700 for members/£900 non-members per conference); it would also keep associated T&S costs down. Whilst this would widen the audiences, it does have a downside that it could reduce attendance at the main conference and so lessen the free exchange of ideas and follow up discussions that can only happen face to face.

SUMMARY

Ultimately, the value of any conference comes from what your delegate brings back and shares. Returning with just one good idea – a new service, a change in an operational procedure, or a new product or idea that can enhance informed decision-making truly makes the investment worthwhile.

On its own, the personal experience of the individual and the widening of his/her experience is reward alone, as it broadens horizons and improves their knowledge base.

For these reasons, the most important benefit of attendance at relevant conferences is that it helps in putting the "E" in SQEP.

GLOSSARY OF TERMS

ABW	Abbey Wood
COM(F)	Chief of Materiel (Fleet)
DE&S	Defence Equipment and Support
EAAW	Engine As A Weapon
INEC	International Naval Engineering Conference and Exhibition
MCAS	Machinery Control and Surveillance
MECSS	Marine Electrical and Control Systems Safety
NCHQ	Naval Command Headquarters
SQEP	Suitably Qualified and Experienced Personnel

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... free exchange of ideas and follow up discussions that can only happen face to face.

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DAMAGE REPAIR: THE LUSTY WAY

In November 2013, HMS Illustrious was diverted from other tasking to assist in relief operations in the Philippines, following the onslaught of Typhoon Haiyan, which had caused widespread devastation across this nation of islands. This article, taken from a press release, describes the impact achieved by the provision of engineering skills, leadership and manpower "from the sea".

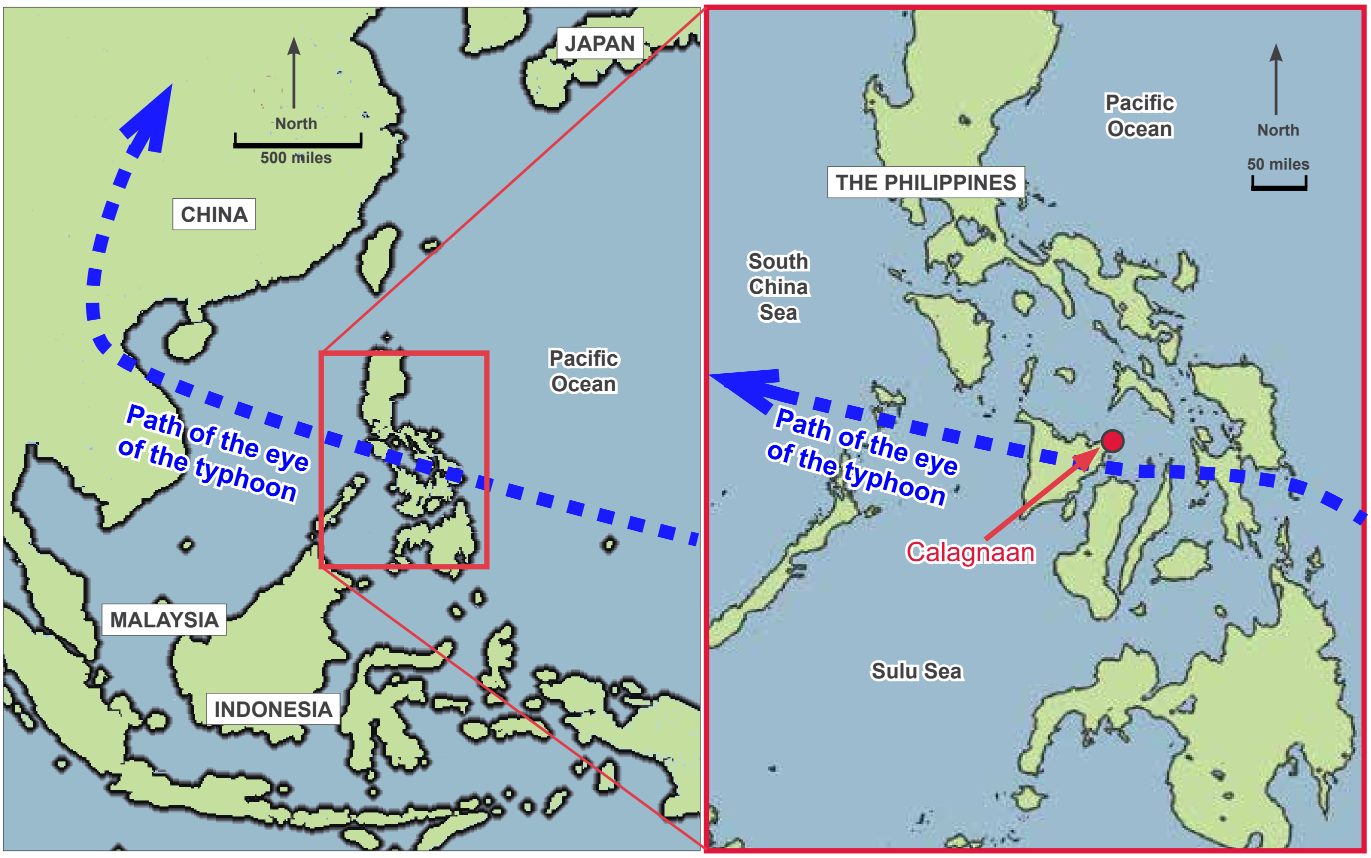
A team of Engineers from HMS Illustrious has rebuilt a school on the island of Calagnaan in the central Philippines to make it safe for the children.

On 7 November 2013, 129 children of the Batuan Primary School were at school when fierce winds from Typhoon Haiyan hit.

Made up of three wooden and two large concrete classrooms, the school is usually well protected. The local villagers used to consider this building as their safe haven but there was no respite this time. In the face of the most powerful storm ever to hit land fall, the wooden structures were completely blown apart. Of most concern, the roof boards of the concrete classrooms were ripped off and the metal framed roof structure collapsed into the building. Thankfully no children were hurt, but the damage was too extensive for other emergency aid teams to deal with.

A metal framed roof is quite rare for this island so the local villagers did not have the expertise or tools to deal with it. They were therefore grateful for the assistance of a specialist engineering team from Illustrious.

Almost half of Illustrious' ship's company are engineers whose skills transfer well from marine,



The island of Calagnaan

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"... a complicated mess"

"... all of the metal from the roof ..."

weapon and aircraft specialisations to domestic and civil engineering. To assist, the ship's company had been bolstered by members of 24 Commando Regiment Royal Engineers and J Company, 42 Commando Royal Marines, bringing with them a lot of additional engineering expertise. Overall, a force to be reckoned with.

The UK Department for International Development (DfID) led the UK disaster relief effort in the Philippines. Aid packages provided by DfID included shelter and debris clearance packs. The latter were made up of useful tools, such as hammers and nails, a wheelbarrow, shovels and other clearance items. These tools were used alongside specialist equipment brought ashore from the ship.

The school roof had twisted as it collapsed and had ended in a complicated mess. Lusty's engineers needed to remove the metal carefully without causing further damage, by cutting the metal into sections with a pneumatic cutter and then hammering and twisting it away from the building. The mechanical cutter struggled with the metal beams, which was a testament to the incredible strength of the winds that struck.

The school-mistress, Marie, stayed at the school for the whole day watching the roof disappear. She said: "*Everyone is so eager to get back to school, but we couldn't have taken this roof off and made it safe ourselves.*"

With an incredible amount of hard work, the engineers removed all of the metal from the roof in just one day.

The school lost almost all of its books and learning materials, but anything that could be salvaged was laid out to dry on the remaining chairs on the hill behind the school. Having cleared out the debris, the team of engineers made a temporary flat roof on one of the buildings out of bamboo and tarpaulin, allowing schooling to resume.

Repair of the school means that life can return to normal. Parents can now concentrate on replanting rice fields or repairing boats and buildings.

Sub Lieutenant Tom Thicknesse, who led the team, felt proud with the achievement. He said: "*It is a very special feeling to be able to come and use our skilled people and specialist equipment to help get the local community back on their feet. All those in my team will be able to go home knowing that they have played a part in rebuilding people's lives and livelihoods – it gives a real sense of purpose to what we do.*"

Tools provided by DfID were left behind for the local villagers to progress the work. The engineers discussed with the head of the school how they should rebuild the roof in order to make it safe and more durable in the future, before leaving for other tasks.

"Salamat", the Filipino word for thank you, was repeated more times than the team could count.

"... anything that could be salvaged was laid out to dry ..."

"... temporary flat roof ... out of bamboo and tarpaulin ..."

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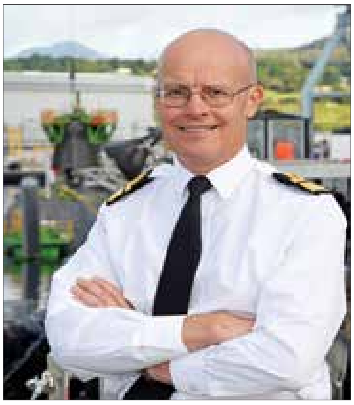
The newest member of the Naval Engineering Board

Rear Admiral Mike Wareham
Director Submarines



Director Submarines (DSM) generates and sustains four SSNs at high readiness and delivers Continuous at Sea Deterrence, by ensuring submarines are fit to fight. It is a 2*-led Operating Centre, the vision of which is a high-performing integrated and enduring enterprise, delivering the Nuclear Submarine Programme demonstrably more efficiently and effectively every year. The Nuclear Submarine Programme comprises submarines in service, in production and future submarines as well as the nuclear propulsion, nuclear warhead and Trident missile programmes.

DSM is responsible for leading the Submarine Operating Centre in the DE&S. DSM is accountable to the Chief of Defence Materiel, though Chief of Materiel (Fleet), for the successful delivery of through-life, integrated and coherent output from projects that comprise the Nuclear Submarine Programme, within agreed envelopes and control totals, including providing the required Force Elements at Readiness and delivery support to current operations. Moreover, ensuring coherence between capability-based sponsor direction and domain-based user requirements, informing trade-offs at capability programme level, particularly for in-service and Astute class submarines, where agreed envelopes will be exceeded and inform Sponsor/User discussion on the balancing of their priorities.

Mike Wareham joined the Royal Navy in 1982. After initial training at BRNC Dartmouth, he read for an honours degree in Marine Engineering at the RN Engineering College at Manadon, Plymouth, specialising as a submarine Marine Engineer Officer. On completion of the Nuclear Reactor Course at RNC Greenwich in 1988, he served in HMS Repulse (Starboard) as Assistant MEO until 1992, when he returned to Greenwich, first for the Initial Staff Course and subsequently to study for an MSc in Reactor Engineering. Following an appointment to HMS Sultan as Apprentices Training Officer, he returned to sea as Deputy MEO of HMS Triumph in 1996 before joining the Director of Nuclear Propulsion at Abbey Wood in the Current Class Safety Section, SM607.

Following promotion to Commander in 1999, he worked in the Naval Bases and Supply Agency at Ensleigh, where he dealt with a range of nuclear issues including the Shiplift Staged Improvement Programme, before moving to Foxhill following the formation of the Warship Support Agency. An appointment in MOD Main Building, in Resources and Plans (Centre), dealing with the DLO programme and the WSA Short Term Plan, was followed by a return to the Nuclear Propulsion Team in Abbey Wood as Head of Primary System Mechanical Projects.

Selected for promotion to Captain in 2005, he joined HM Naval Base Clyde as Director of Safety Assurance, remaining at Clyde as Superintendent Fleet Maintenance until early 2008 when he returned to Main Building in a tri-Service post as Deputy Director Defence Resources and Plans, dealing with defence-wide programming issues in the run up to the Strategic Defence and Security Review. He returned to Abbey Wood in late 2009 as Head of Programmes in the In-Service Submarines Project Team.

Following promotion to Commodore in January 2011, Mike returned to Clyde as Naval Base Commander leading a wide ranging programme which included the outsourcing of Strategic Weapon System activities at Coulport and an extensive infrastructure development programme across both the Faslane and Coulport sites. On promotion to Rear Admiral, Mike became Director Submarines on 7 October 2013.

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18-19 March 2014

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