NAVAL MARINE ENGINEERING THE CHALLENGES AND OPPORTUNITIES A PERSONAL PERSPECTIVE

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ABSTRACT

The reality of the Electric Ship has left Marine Engineering without a clear technology driven 'headmark' with the levels of investment that have supported the introduction of the Electric Ship in part no longer sustainable; Marine Engineering is clearly at a decision point. As we look to the future, we must clearly meet the availability and affordability challenges of an ageing Fleet whilst derisking the enablers for the Fleet of the Future, set in the context of ever diminishing investment, the challenge of a diverse range of operational scenarios, ever more burdensome legislative constraints and smart acquisition. This paper provides a personal view of Naval Marine Engineering – the challenges faced and associated opportunities that such challenges present to the Naval community, looking at how a commercial operator's approach could reap significant rewards in terms of affordability, commonality and supportability. Themes include:

- Building on the introduction of Electric Ship, where next.
- An overview of operational drivers and constraints, including the impact of legislation.
- The role of Maritime Platform Characteristics, technical assurance, and design standards – how prescriptive can the MoD afford (or not) to be.
- Key enabling technologies to meet the challenges.
- Manpower issues, including training.

Introduction

The Electric Ship has been the headmark for marine engineering investment since 1996 under the auspices of the Marine Engineering Development Programme (MEDP). Much has been written documenting the successes and early operating experiences of the Electric Ship, notably the Electric Warship papers (Reference 1), but anything more than a passing reference is clearly outwith the scope of this paper. That said, much of what set the original headmark is useful in providing context for Naval Marine Engineering challenges and opportunities. Driven by the need to break the tyranny of Cost of Ownership (COO), investment in the key enablers for the Electric Ship centred on the three key strands: advanced cycle gas turbines; propulsion systems (motors and converters); and, wider electrification of auxiliaries – all set in background of a vigorous commercial market. Whilst predominantly driven by cost (balance of investment), the secondary benefits of the Electric Ship including operability and survivability have served to underpin continued investment.

However, the changing face procurement, notably the move to Smart Acquisition (SA) has moved the emphasis away from the 'technology push', so much the driver MEDP. Requirements led acquisition, transfer of Design Authority and Risk adversity have all served to challenge MEDP, with the emphasis now almost exclusively

CONTEXT – REDEFINING THE HEADMARK

The operational context is the most important element for the future of Naval Marine Engineering, notably in defining the characteristics of the platforms: to meet worldwide operations: with the ability to deploy and sustain worldwide; to undergo unrestricted operations in the littoral; and, deliver the key tenets of the Future Maritime Operational Concept (FMOC).

The challenge is how to achieve current levels of deployability, force generation and readiness, sustainability and survivability with an ageing legacy Fleet with a mind to how to improve these key aspects in new platforms. The link between the operational context and marine engineering is important and a number of key themes emerge:

- Maritime Strike and Littoral Manoeuvre. The platform is a key enabler for the delivery of maritime capability, combat system and sensors of the future likely to make ever more demands on platform systems.
- Worldwide Deployability. The ability to deploy both as a part of a task group and on dispersed unsupported operations requires endurance, the ability to replenish and increasingly, particularly for strategic lift, a potential requirement for speed.
- Littoral Operations. The ability to operate for extended periods in the littoral is a key capability, but with it comes a number of issues notably environmental compliance and fresh water production.
- Survivability. Survivability of maritime platforms is linked closely with marine engineering, with the resilience, vulnerability and recoverability of equipment and systems key components.

Drawing the above together, the headmark for the future, in terms of delivering enduring capability in legacy platforms and new capability in the platforms of the future is clearly going to be driven by affordability, but within this the key themes will be environmental legislation, littoral operations, and deployability. The MoD has a number of challenges within this new context to delivering available and capable platforms in the future, amongst which are assurance, enabling technologies, manpower and support.

CHALLENGES AND OPPORTUNITES

Assurance

Assurance continued to challenge the Ministry of Defence, notably how to achieve acceptable levels of design assurance within the Smart Acquisition construct, without imposing an affordability burden or creating an unmanageable assurance framework. In discussing this it is worth reflecting on the transition in recent years from a process with the Design Authority vested in the MoD with an expansive framework of Defence Standards (Def Stans), formerly Naval Engineering Standards (NES), to a new era of Naval Class and devolved Design Authority in a Requirements led Process. The move from Def Stans has been predicted on affordability of standards often thought to be 'gold plated', and in the most part the burden of their maintenance left many of the standards obsolete.

Def Stans reflected best practice and lessons learned (often the hard way) and were an extremely important part of the acquisition and support processes, providing the 'Owner's Requirements' to maintain effective integration, coherence, minimum design standards and minimum characteristics of Defence Systems. The move to Smarter processes has removed a significant amount of over-regulation in the specification, design and acceptance of maritime platforms, with the trend away from Def Stans. Def Stans had over time become a mixture of standards, advice and guidance, often without sponsors and in need of review and it was generally accepted that the blanket application of standards was unaffordable. However the move towards Requirements led acquisition has been accompanied with a move towards Naval Class and supporting Naval Rules. Unlike the Commercial Sector, where the Requirements process and Owner's Requirement are well-established, early experiences have shown the Class cannot provide the necessary assurance in Naval equipment and systems in isolation of a set of Naval Owner's Requirements. Indeed the recent problems experienced with the introduction of the LPD serve as a good example of how JSP430 Safety Case and Class failed to provide the necessary assurance for High Voltage in a Naval environment.

There are two aspects that need to be developed, broadly a better framed performance requirement (platform characteristic) and Naval Owner's requirement to set the 'Owner's' context for the performance requirements. To achieve this the MoD has, under the auspices of the Warship Engineering Management Guide, sought to provide a framework within which key Lines of Development (LoD) can be developed together with smart requirements, a central element of which are the User and System Requirements and Acceptable Criteria. The emphasis of current work is to establish a set of Warship Characteristics (Warship Characteristics include: adaptability; deployability; habitability; interoperability; mobility; operability; safety; supportability; and, survivability) that either drive the performance of the design or place constraints on the design, in part setting the Requirements, both System (SRD) and User (URD) which in turn will frame the engineering solution. This will in turn ensure that common characteristics are established and with it commonality of solution.

Naval Owner's Requirements are the standards which provide the Naval context to Class and in doing so draw together good practice that has been proven operationally, compatibility (Fleet Coherence) and safety. It is these Owner's Requirements, which when combined with the Warship Characteristics and Class provide the framework within which Assurance (Technical and Safety Assurance ensures: that the design complies with agreed standards; the materials and equipment used are acceptable; and the warship is properly constructed and set to work) can be achieved.

Within this assurance framework there are a number of challenges:

- Improved MoD and Industry behaviours to achieve more coherent approach.
- An agreed process by which the assurance framework and the constituent parts can be mandated across all platforms and adopted by both MoD and Industry.
- Ensure that lessons are learned across both MoD and Industry, noting that currently we do not have a process by which we can translate the many and in some cases obvious lessons – without which we are unlikely to achieve the necessary levels of assurance.
- Adopt a progressive, incremental and continuous approach to acquisition, challenge the almost monolithic approach of step changes in platform capability and timescales.
- Focus on Cost of Ownership and not initial purchase costs, with realistic levels of 'up front' investment and derisking.
- Commonality of solution and reduction in supply base – utilising standard ranges, within and across Platform Types where COO benefits are clear.
- Translating the current plethora of sources of standards (Including Defence Standards, Books of Reference (BR), Joint Service Publications (JSP), Classification Society Rules, NATO Standard Agreements (STANAG), Statutory Legislation, British and International Standards) into a single General Naval Engineering Specification (GNES).
- Maintaining a 'Corporate' knowledge base and pan-MoD/Industry Naval Authorities.

Assurance need not be difficult but requires MoD and Industry to agree a framework within which 'goodness of design' can be achieved and within which MoD can discharge its role as an Owner with confidence without imposing an affordability burden on either legacy or new systems and equipments.

Enabling technologies

The MoD, as a technology 'venture capitalist', still has a key role to play in ensuring the key enabling technologies are available to meet the operational challenges, and in doing so share the burden of risk with industry.

Looking back, much has been learnt from the introduction of IEP into warships, from the partial integration in the Type 23 and SRMH to the AO and LPD. The success has been not only in the enabling technologies but also in the process by which technology has been developed across a broad front, in support of the Electric Ship and other key enabling technologies such as environmental compliance and heat management. In identifying the key drivers for the future platform designers of future systems those with Design Authority for legacy platforms must address strengths and shortcomings identified from recent surface ship projects, operational experience through Fleet readiness and availability data, and lessons from the Electric Ship Technology Demonstrator (ESTD).

In terms of likely focus of future marine engineering investment, the following Marine Engineering equipment and system issues are and will continue to have a direct impact upon platform availability, capability and affordability.

- Environmental compliance, including waste handling, black, grey water, ballast water processing, oil, exhaust emissions etc
- Heat Management, notably the inability to operate in extremes of environment due to poor Chilled Water Plant performance, HVAC, refrigeration, and, main and auxiliary machinery cooling requirements. There is an overly restrictive reliance on liquid cooling systems and a need to reduce overall cooling requirements.
- Tyranny of the Electric Ship (Volumetric and gravimetric power density, system integration, heat management, system integration and IP ratings).
- Resilience as a function of vulnerability and recoverability.
- Fresh water production.
- Ship husbandry.
- Combat and sensor system enablers.
- Long term fuel availability.

Looking at the top three, which are very likely to frame MoD's investment priorities in the near and medium term:

- Environmental Compliance. Probably the most significant challenge faced by the legacy and future platforms is that of environmental compliance, driven in part by sustained operations in the littoral but also for unrestricted operations worldwide. As such the priority is to articulate the likely environmental challenges, understand current and future shortfalls, and identify what enabling technologies will meet the challenges. Those familiar with the subject will be aware of a range of reactive solutions, not always successful, that have been introduced by the RN in recent years. Recent investment is developing some of the key elements of the system (Advanced Incinerator, Pyrolysis, and Membrane Bioreactor), the focus for which is how the enabling technologies can be harnessed to meet the very stringent environmental targets of the future. Key challenges include successful integration into the platform and the robust waste management processes (Reduced packaging, separation and sorting facilities and waste management). The future presents challenges yet to be resolved, which includes ballast water and food waste management.

- Heat Management. Currently a severe limitation for legacy Ships deployed to extremes of environment with Sea Water temperatures in excess 38°C and air temperatures above 45°C, together with an increasing number of heat sources, numerous cooling mediums and extensive (geographically displaced) systems. The challenge is how to reduce the heat burden in the most cost effective manner, mindful of the need to avoid system interdependencies and single point failures. By the way of example, the LPD uses HP and LPSW, de-ionised water, chilled water, and LP air to name but a few to meet the heat management challenge. The problem is further exacerbated in Type 45 where we are approaching the limit for conventional cooling. Plainly, the problem can be mitigated by improving conversion and system efficiencies, or indeed looking to remove conversion at higher powers (QE2) but realistically this needs to be accompanied by more novel approaches to cooling.
- Tyranny of the Electric Ship. It is perhaps overly emotive to term it as a 'Tyranny' but clearly we have come only part of the way towards realising the full potential of IEP and there are aspects that if resolved would result in significant improvements in operability, resilience and COO. Having removed the tyranny of the shaft line we are now beholden to the electrical cabinet and issues such as volumetric power density and IP rating, both of which impact on system operation (LPD(R) IP and Cubicle experiences). ESTD has demonstrated that there are a multitude of combinations which are now open to us; it has just wetted our appetite and certainly not allowed us to explore all possibilities. A mature debate is now required to look at which options provide the best solutions from a technical and practical operator's perspective. So where are we likely to see improvements that could unlock the Electric Ship fully, mindful of the previously discussed fiscal pressures:

    - In the short term the system is likely to comprise an AC propulsion bus and an AC ring or tree distribution system. Variable Voltage Variable Frequency on the propulsion bus offers some significant advantages in systems where the large prime movers have an extended time lag in response to major system disturbances but this would rule out rotating converters or transformers as the link between the propulsion bus and the distributing system. Given some of the problems experienced with QPS in recent platforms and the results at ESTD, static converters, subject to cost, weight and space considerations (harmonic filters will not be required), may be an attractive solution.

- It is also vital to reduce to a minimum any system dependencies. For instance all auxiliary power supplies for each converter should come off the same breaker or switchboard, not from disparate locations around the ship.

- There may also be numerous auxiliary systems which, should they trip, cause the drive to shut down. There should, at the very least, be a system override, permitting the MEOOW1 to take an informed decision on the relative risk to ship and propulsion system.

- IP ratings for HV equipment in main machinery space should be IP 56 or better.

- Lastly we must ensure that the drives are designed to accept seawater cooling which may be as high as 40 degrees Centigrade.

Manpower

There are many challenges to manning of the future Royal Navy, including levels of automation, sustainable branch structures, recruitment and retention, the need to reduce manpower costs, coherence between MoD and Industry, and training. The priority is to maintain Suitably Qualified and Experienced Personnel (SQEP) in a structure that is both sustainable and offers an attractive career. Looking to the key manpower challenges:

- Many new platform projects have been set headcount reductions for ships companies which result in automation instead of people. Unfortunately the easy solution is to cut numbers of Junior Rates by increasing automation. This leaves the RN with unsustainable branch structures in the long term. Recent experience with Warfare Branch Development and the Engineering Branch Development has demonstrated yet again that if we are not careful we will end up with unsustainable structures and we are having to add bunks back to T23 Frigates to accommodate Junior Rates not included in the build scheme of Complement (SOC). New platform projects must recognise that billets at sea drive the sustainability of out branches and hence must reflect a realistic ratio between ranks and rates irrespective of any automation they wish to use.

- Our ability to grow personnel for each rank or rate is predominantly based around the platforms we operate as we funnel most officers and ratings through the first sea drafts or appointments. Fundamentally the ability to grow personnel is based upon the number of first sea appointments or drafts, the length of the appointment of draft and the time in the rank or rate. This is a critical factor and any attempt to restructure manpower cannot be taken in isolation of the need to 'grow' people. We must however adopt more novel approaches to manning, recognising sideways entry and short term directed recruiting as key levers to achieving a balanced manpower plot.
- A interesting dynamic is that of coherence between MoD's future manning ambitions and Industry's perceived cost effective technical solutions. The MoD cannot afford to set manning priorities and structures in isolation of technology debate – an optimum solution to the manning conundrum can only be achieved if MoD and Industry work closely together. Superimposing new structures and manning initiatives into new platform programmes without significant dialogue between MoD/Industry will not deliver an effective manning/technology balance.
- Training requirements are usually derived from the introduction of a new capability via the Training Needs Analysis (TNA) process, a change in capability (equipment updates and modifications), new or changed doctrine or a change in structures (new specialisations). Training is continuously monitored by the Future Training (FT) cells within the lead schools. These groups are tasked with ensuring that the training delivered reflects emerging technologies and is efficient and appropriate. It is this group that most likely to drive a change in emphasis within career training and has indeed recently made such a proposal for HV training. Once a new training requirement is identified the FT cells endeavour to establish a business case to support the inclusion of the revised training which among other issues will include the most effective means of delivery. These business cases are often difficult to substantiate based upon a single class and the MoD needs to make investment decisions on a pan platform basis (The case for HV training could not be supported for LPD alone, however had the potential applicability in AO, T45, LSD(A) and CVF been factored into IA the case would have been far more compelling; this would however have required an improved mechanism for making pan platform investment decisions).

The Royal Navy has embarked on a range of initiatives to meet these challenges to deliver the 'person', the most recent of which is the Navy Board Personnel Change Programme (NBPCP) which amongst other initiatives, particularly in the Warfare Branch, has provided the development of the Engineer Technician and is assessing future Engineer Officer structures.

- The number of technical Senior Rates was and still is falling at an alarming rate causing severe gapping in key posts. There are many contributory factors, a pause in recruiting mid 1990s, too many leaving, no junior rate structure, hence no growth path for weapon engineers and a front loaded training programme which did not encourage retention in the longer term. All these have forced a radical design of the technical branch structures. Gone is the Artificer and in is the Engineer Technician, now providing Weapon engineer junior rates and a growth path for Senior Rates and appropriate training delivered at each rate commensurate with the level of knowledge required in each job. The academic qualifications will also be delivered over a longer period.
- With reducing number of hulls and hence first sea appointments, the current structure for engineers already shows a long term shortfall against the requirement. Should this be accepted as realism? What perhaps needs to be challenged is the shore requirement, particularly in the DPA, DLO, DCSA, etc…and bring the requirement down to the projected bearing. Future Officer Corps modelling across all branches is needed now, particularly in light of reducing sea appointments, shore requirements, NEC requirements of the future, etc…and may lead to a solution at sea such as shown in Figure 1. Once modelling has been completed and a requirement for change identified, various options for manning may be explored before we embark on a solution from which there may be no way back.

Current	MEO	WEO	CISO	PWO(C)	PWOs	BRIDGE TEAM	LO
Future	PEO	CNSEO		BRIDGE/OPS TEAM			LO

MEO	Marine Engineer Officer
WEO	Weapon Engineer Officer
CISO	Communications and Information Systems Officer
PWO(C)	Principal Warfare Officer (Communications)
LO	Logistics Officer
PEO	Platform Engineer Officer
CNSEO	Combat and Networked Systems Engineer Officer

Fig. 1 Future Officer Corps Structure

Support

The move away form the MoD as a DA coupled with not unfounded perceptions that the traditional support solution was unaffordable has potentially left a void in the support framework; the bespoke support solution having been replaced by a mixed economy of solutions. Whilst is principle this approach offers headline savings it is questioned whether it is sustainable and the real costs (and risks) are understood; as an owner can the MoD afford a multitude of support solutions and how does this sit alongside the existence of support IPTs. Again the MoD's inability to view support solutions on a pan platform basis makes a coherent solution difficult to achieve. The DLO's Transformation Programme includes a number of significant initiatives, including:

- Transformation Staircase.
- Support Options Matrix.
- Contracting for Availability.
- Contracting for Capability.
- CLS contracts.
- Supply Chain improvements.
- Lean techniques in equipment overhaul.
- Lean techniques in platform support.

Conclusion – A Personal Perspective

In this paper we have exposed a number of challenges and opportunities but what does it mean:

- The MoD must be a responsible and informed Owner, and assurance will be an essential element if we are to ensure 'goodness of design' but perhaps more importantly achieve the required levels of operability and affordability. The MoD must not be overly sensitive to being more prescriptive and must seek mechanisms by which coherence can be achieved pan-platform.
- Unless there is a compelling case (benefit and need) and clear exploitation, the MoD and Industry must be realistic with Research and Development, and Technology Management. Of course, we must not constrain the blue sky thinking but the MoD must be realistic in its aspirations for novel and advanced technologies. An early BoI and decision points are essential elements of technology development, alongside clear exploitation mechanisms and opportunities.
- Manpower will remain a significant factor, it is unlikely that automation will result in the oft quoted unmanned platforms and therefore we must continue to focus on optimising manning structures if we are to achieve sustainable levels of SQEP. Key to this is coherence between the MoD's strategic View and that of Industry.
- As the Maritime Industrial Strategy develops a coherent and affordable support solution needs to be developed across all platforms which dovetails with the other environments and allows MoD and Industry to work in partnership.

References

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