MARINE SYSTEM DEVELOPMENT STRATEGY

BY

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ABSTRACT

To enable affordable and technically viable Maritime Platform Capability through coherent research, development and demonstration programmes.

By delivering availability and enabling capability, marine systems are one of the most significant force multipliers available to a Service that continues to contract in terms both of manpower and the number of its hulls. Marine systems enable ships to move, they support their fighting capability and they provide the environment in which our sailors live, work and fight. Without reliable, sustainable and flexible supporting services, the most complex and effective combat system is just so much metal and plastic. Research, development and procurement of high quality, adaptable, supportable and optimised power, propulsion and domestic services is thus vital if the Royal Navy is to continue to have the ships and submarines that it needs to be able to Fight and Win.

This article considers the Marine Engineering Development Strategy of the 1990s and its realisation in the integrated electric propulsion topologies of the recently accepted and current surface ship programmes. It then examines the genesis of the Marine Systems Development Strategy, which builds on the successes of the MEDS and takes the development of marine systems forward into the future. A summary of work currently underway under the auspices of the MSDS is provided along with a brief look at its governance and funding.

Background

It is now more than ten years since the Royal Navy Marine Engineering Development Strategy was produced within the then Naval Support Command. Its aim was to establish a programme to develop the *electric ship* for the Royal Navy. The strategy was primarily the brainchild of the Assistant Director Marine Propulsion Systems, Mr John Simms, though it was largely authored by the Director General Submarines, Vice Admiral Sir Robert Hill.

The aims of the strategy were clear: *to exploit electric propulsion for future surface vessels and to remove the need for distributed high-energy fluid systems through the development of electrically operated auxiliaries for both ships and submarines.*

The aspiration was to maximise the benefits that could be derived from improved fuel efficiency, quieter running, and flexible and survivable power distribution through the design of new platforms with fully integrated electric propulsion systems and wholly electric auxiliaries. This policy marked the beginning of a step change in technology similar to the transition from steam to all gas turbine ships in the 1970s.

Endorsed by the Navy Board, the MEDS had some significant successes, most notably the establishment of the Electric Ship Technology Demonstrator that was built at Converteam's (then Alstom Power Conversion's) test site at Whetstone to derisk technologies for the electric ship. The Electric Ship Propulsion Office was established to manage marine engineering research and development. Funded by the Marine Engineering Development Programme, it enabled a coordinated and coherent approach to R&D in the field of marine systems.

Though considerable progress has been made towards the *electric ship* and most recent surface ship designs feature electric propulsion, the implementation of Integrated Full Electric Propulsion as envisaged in the MEDS is yet to be fully achieved. Current architectures, as exemplified by the Auxiliary Oiler, Landing Platform Dock and Landing Ship Dock Auxiliary, are not only complicated to operate, they are insufficiently resilient to faults and suffer with poor quality of power supplies. IFEP technology will only migrate to smaller surface vessels and submarines when there are improvements in propulsion drive power density and when it can properly integrate with advanced power generation and distribution topologies. Additionally, the benefits of IFEP will only fully be realised when complementary technologies are sufficiently developed to ensure a 'ride through and fight through' capability.

A New Strategy

After extensive consultation, the Director of Equipment Capability (Above Water Effects) gave a new impetus to marine systems R&D by formally endorsing a new strategy in September 2006. Thus, the Marine Systems Development Strategy, addressing all the issues and concerns, proposes clear direction for investment to ensure affordable, unconstrained and flexible operational capability for present and future warships, submarines and auxiliaries.

In simple terms, this new strategy provides a framework for the development of key marine systems and enabling technologies for current and future platforms over the next two decades. Marine systems are taken to include propulsion (excluding nuclear primary systems), power generation and distribution, and ship wide auxiliary systems (including combat systems support and hotel services).

The need is clear: any failure to support the development of marine systems will impact significantly on the warfighting capability of current and future platforms. Adequately funded, high quality targeted development is critical to meeting the needs of a sustainable and flexible Future Navy. Underpinning this requirement is the fact that R&D of marine systems requires significantly fewer resources than for combat systems, yet it delivers a disproportionately higher R&D investment return in terms of improvements to both availability and enabling capability.

Aims and Objectives

The aims of the MSDS have been articulated as follows:

- Deliver the required maritime platform capability;

- Ensure affordability by reducing whole life costs (both unit production and through life costs);

- Deliver equipment and systems at the appropriate technical maturity to meet platform programme requirements;

- Deliver platform strategic reach through unrestricted global access;

- Contribute to the sustainment of key industrial capabilities in accordance with the Defence Industrial Strategy and Coherent Nuclear Equipment Programme.

These aims are expanded through four Strategic Objectives that relate to areas or fields where R&D can be concentrated to achieve the aims of the strategy. These objectives are supported by Key Performance Targets that provide measures of effectiveness against which their delivery can be assessed.

Strategic Objective 1. - Deliver enduring maritime platform capability by adopting upgradable platform systems that allow for:

- Cost effective ‘spiral development’;

- Reduction of bespoke military equipments through the wider use of appropriate Commercial Off-The-Shelf and Military Off-The-Shelf equipments;

- Adoption of common open system architectures for platform systems;

- Enabling the integration of future high-energy electric launchers, sensors and weapons;

- Coherent system solutions that meet the needs of all future maritime platforms.

Strategic Objective 2. - Deliver future technologies that reduce whole life costs via:

- Unit production cost reduction;

- Energy efficiency;

- Increased system automation and consequent (possibilities for) reductions in manpower;

- Improvements in equipment and system availability, reliability and maintainability;

- Improvements in platform utility (encompassing crew rotation, extended running periods and longer platform deployments away from base port assistance);
- Reduction in costs of through life support.

Strategic Objective 3. **-** Deliver platform strategic reach through technologies that enable unrestricted global access by:

- Minimising reliance upon external support infrastructure;
- Ensuring appropriate responses to changing global fuel circumstances;
- Enabling sustained and persistent operation in the littoral;
- Ensuring compliance with current and future safety and environmental legislation and regulations (including the Secretary of State's policy statement that has moved the MoD beyond compliance to embed continuous improvement in safety and environmental compliance).

Strategic Objective 4. **-** Deliver enabling technologies necessary to support surface and sub-surface platform system architectures to:

- Provide increased system resilience;
- Ensure whole platform power and system survivability;
- Develop improved platform, propulsion and power system density to reduce overall platform displacement and increase subsequent efficiency.

The Challenge – What needs to be done

Marine engineering systems have suffered from a lack of investment that has hindered improvements in capability, efficiency, reliability and ease of operation. Developments in submarine propulsion and platform systems, for example, have been stifled through a policy of progressive minimum change that is fast making improvements unaffordable. Without a more enduring submarine system solution we may not be able to overcome obsolescence nor sustain our current industrial base. More importantly, these weaknesses, combined with enduring resource constraints and the tautening environmental and legal context, threaten the operational capability and the worldwide persistent presence of warships.

What is Currently being done and why

Advanced Power Systems

Advanced power systems that provide the aforementioned 'ride through and fight through' capability are being developed in partnership with Industry and Academia. In parallel with this, we are funding research and development to utilise embedded power electronics for the protection of advanced power systems. Robust and enduring power generation and distribution architectures are being developed for future surface and submarine platforms in the areas of DC zonal distribution, energy storage systems and advanced power electronics. Power dense variable speed drives are now being developed, utilising COTS components for system simplification.

Hybrid propulsion drives are being developed for future submarine and surface ship applications. Examples include cruise electrical propulsion for the Astute Class submarines and for the potential mid-life update for Type 23 Frigates. Industry has been engaged to ensure that opportunities for exploiting the commercial development of high temperature super-conducting motors are maximised. Programmes are also in hand to develop advanced induction motors and integrated propulsion drives for future surface ships and submarines.

Open System Architectures

Acquisition practice is moving towards a policy of incremental acquisition that allows a ship's capability to be updated and upgraded throughout its life. The MSDS has to anticipate this so that, for example, a ship can cope with the developments in the field of high-energy weapons and sensors. For incremental acquisition to succeed, that ship will require both the appropriate margins (space, weight, electrical power etc) and architectures that are suitable for supporting the new capability. To this end, funding is being sought to develop coherent platform open-system architectures that permit improved modular construction and commissioning and provide for cost-effective upgrades and updates.

Reducing the Vulnerability of High Energy Fluid Systems

High-pressure fluid systems are widely used to provide power and services to dispersed equipment throughout the ships of the current Fleet and they feature in the designs for future platforms. Eliminating them through the electrification of auxiliaries offers benefits in terms of improved reliability, optimised maintenance and reduced vulnerability. Platform electrification also facilitates cost-effective modular construction and commissioning. Electrically actuated stabilisers are currently undergoing trials in HMS ST ALBANS and the results to date are generally encouraging. A further programme to develop electric actuation for hydrodynamic control surfaces for submarines is now under consideration. Electro-magnetic valve actuation for submarine hull valves is under development in partnership with Industry, whilst COTS electric valve actuators are currently being shock qualified to ensure suitability for future classes of submarine.

Ship wide fluid systems, whether high or low pressure, are inherently vulnerable to damage. The use of intelligent control and smart valves in, for example, chilled water systems, can, however, substantially reduce the effects of breaches to them. The shock policy adopted for the future carrier relies heavily on the ship wide distribution of critical components to provide a degree of survivability in the event of underwater shock. Fitting smart valves and intelligent control to the CVF's CW system could significantly improve its recoverability in the event of damage, and is being seriously considered by the Alliance. To assist in derisking this technology, an intelligent fluid system demonstration rig is being developed in partnership with Industry. Additionally, the potential use of smart technology for submarine hull valves is being developed in conjunction with the electro-magnetic valve actuation work.

Unconstrained Global Access

During Operation TELIC, the invasion of Iraq, a warship was taken off task to escort and protect the 'gash barge' as it collected solid waste from ships in the Task Group. Apart from wasting a valuable asset, there is a real need to remove the reliance that ships have on such facilities. Therefore advanced incineration and pyrolysis plant are being developed at QinetiQ, Haslar, to process solid waste on board. HMS ILLUSTRIOUS is already operating advanced cyclonic incinerators whilst the first marinised pyrolysis plant should be installed in HMS OCEAN in 2007.

Sewage disposal is another mission disabler as ships with collect, hold and transfer sewage systems can only operate within the 12-mile limit (or in 'special areas') for approximately three days before proceeding to sea (off station) to discharge sewage. IMO compliant Membrane BioReactor sewage treatment plant has now been developed to overcome this problem in surface vessels. Once fitted they will be able to achieve the Defence Planning Assumption of 28 days on station without host nation support, even when operating in the littoral. A pre-production version was successfully trialled at sea in HMS GRAFTON and the first production installation is planned for HMS ST ALBANS in 2007. Though MBRs are not suitable for submarines owing to the high airflow required, Catalytic Wet Air Oxidation plants are being developed to meet this requirement, subject to funding.

For fresh water production, ships with Reverse Osmosis plants are severely constrained in their ability to make water close to shore owing to the presence of pollution and silt. This could largely be resolved by reducing the amount of clean feed water required by developing systems that recycle grey water (wash water drains) as feed for RO plant. A number of studies have been completed and, again dependent upon funding, it is planned to conduct trials to derisk this technology for use afloat.

The carriage of petrol in ships and submarines will be phased out by 2015 in line with the single fuel policy for land equipments. This is bring done to overcome logistical issues involved with delivering adequate quantities of petrol from ships, and to reduce the hazards inherent in the carriage of very low flashpoint fuels. The most pressing requirement is to replace the 50 HP outboards used by the Royal Marines who are by far the most significant users of petrol. There is also a need to produce a non-magnetic version for MCMVs, 30 and 200 HP variants for the Special Forces and a non-petrol-burning outboard for the Army. Development and trials of non-petrol burning outboards are generally proceeding well with a limited minor trial of the 50 HP engine underway in 539 Assault Squadron, Royal Marines. The Royal Engineers at Chatham are also trialling a new engine for the Army, which may also have potential to be developed as a non-magnetic variant.

Optimising Fleet Fuel Usage

The ever-increasing pressure on the Fleet fuel budget caused by spiralling world fuel prices means that the need to optimise fuel usage has never been greater. Work is underway to ensure that the benefits of introducing electric propulsion can fully be realised in future platforms whilst other technologies are being developed that have the potential to deliver considerable fuel savings. A simple transom flap is being fitted to all Type 23s after trials showed that it delivers up to 10% reduction in fuel usage and the concomitant production of carbon dioxide. Encouraged by this, the Type 42 destroyer HMS MANCHESTER now sports a transom flap and early indications are that similar benefits are being achieved. The previously inconclusive cost benefits analysis for Type 22 frigates is being revisited and the development of a design for a transom flap for CVS is underway at QinetiQ Haslar.

New approaches to the problems of hull fouling are being investigated and the development of advanced underwater coatings is being monitored.

Beyond Compliance – the Environmental Challenge

Both MBR and CWAO are capable of processing sewage and grey water. This is good news as discharging grey water to shore reception facilities is expensive, manpower intensive, inherently unhygienic, and unreliable. Whilst grey water discharge is not currently included in MARPOL 73/78 legislation, an increasing number of ports have adopted more stringent local legislation and prohibit the discharge of all untreated waste, including grey water.

IMO regulations prohibit the discharge of sullage containing hydrocarbons at more than fifteen parts per million (roughly the smallest concentration that can be seen with the naked eye). Bilge Water Separators have long been fitted to ships and submarines but have often proved unreliable and of dubious serviceability. Particular problems are being felt by Vanguard class submarines, Type 23 frigates and even the Astute class hulls number one to three that are still in the construction hall in Barrow-in-Furness. BWS technology suitable for use in submarines is currently being competitively tendered, with shore trials expected before March 2007. For Type 23s, a replacement ceramic membrane BWS has been trialled successfully ashore and at sea in HMS RICHMOND and a programme is underway to retrofit the rest of the class.

Type 22 frigates and Type 42 destroyers are constrained in their ability for unrestricted global operation owing to their water compensated fuel systems (although less constraining, submarine dieso systems are also water compensated). Compensating water discharges need to be compliant both in terms of oil content (below 15 ppm) and to meet the requirements of the IMO Ballast Water Convention MEPC-49. Ballast water discharges also need to comply with MEPC-49, necessitating the development of technologies that are likely to centre on the treatment of the water as it is embarked to kill micro-organisms and as it is discharged to remove oil.

Diesel engine and incinerator exhaust emissions are increasingly subject to the regulations contained in MARPOL 73/78 Annex VI and to local rules. Whilst compliance with legislation for diesels is likely to be demonstrated through configuration control and quality assurance, the local rules may lead to a requirement to monitor, and even treat, exhaust emissions if global access is to remain unconstrained. Problems encountered with emission quality from the advanced cyclonic incinerators fitted in HMS ILLUSTRIOUS led to the units that were procured for ARK ROYAL being shore tested at QinetiQ Haslar prior to installation.

Firefighting and Damage Control

Although warships qualify for 'Critical Use' status with regard to the continuing use of halons for fire fighting (in accordance with EU Regulation 2037 / 2000 Annex VII) this is unlikely to be sustainable in the long-term. The hazards inherent in the use of the CO_2 systems in Type 45 and RFAs mean that carbon dioxide is not an entirely suitable replacement for halon. Therefore trials to develop a satisfactory alternative to Halon are currently underway at the Horsea Island test facility. These trials are mainly focussed on fine water spray systems and other media, including gaseous substitutes.

Current firefighting techniques are extremely manpower intensive, physically demanding and no longer reflect 'best practice' as people dressed in cumbersome fearnaught clothing struggle with the pressurised hoses and awkward nozzles that are associated with current wet firefighting techniques. A wide range of alternative equipment and techniques are being trialled at Horsea Island although it is widely recognised that more work is required to ensure that the MoD makes optimum use of manpower and continues to meet its 'duty of care.'

Governance

The one-star led Marine Systems Development Steering Group oversees the management and direction of R&D in the field of Marine Systems. Capability Working Groups analyse shortfalls in current capability (as identified by the Capability Audit) and determine further development needs and tasking. On a day-to-day basis, the MSD Management Board then prioritises development effort against these shortfalls in order to deliver maritime capability and provides the horsepower for actually implementing the strategy. Focus Groups monitor the progress of multiple development programmes that are related to a particular requirement, future capability or field of technologies, and formulate a technological vision to identify new lines of development that can address specific technical issues. They are also responsible for ensuring that individual programmes of work meet the required Technology Readiness Level for Future Platform exploitation.

Co-ordination of development work and management of the MEDP is conducted through the Marine Systems Development Office, which is part of the DPA's Future Business Group (and rose from the ashes of the former ESPO). The prioritisation of research effort within and by the ME equipment Integrated Project Teams is the responsibility of DLogME[1] and is delegated to his Chief Marine Engineers.

Funding

There are a number of sources for R&D funding under the auspices of the MSDS, all of which are under significant pressure and this presents a considerable challenge to the successful implementation of the Strategy. First and foremost is the MEDP itself, which has its own P9 line within the Equipment Programme. This funding has been steadily eroded over recent years and even the relatively modest amount that remains is under threat as the pressure to reduce costs continues to increase. Nonetheless, the MEDP is managed directly by the MSDO and as it funds the whole range of R&D within the field of marine systems without caveat or limitation, it is probably the most useful and flexible source of funding we have.

Individual marine equipment and platform IPTs also fund R&D through their STP. This is particularly useful as it enables subject matter experts to target identified shortfalls directly and, in many instances, it meets a similar need to that satisfied by the MEDP. This funding, however, has to compete with other support and administrative costs within the IPT and, as a direct result, less and less research is being directly funded year-on-year by the IPTs.

On a more positive note, as well as exploiting the output of research conducted through the MEDP and by the DLO IPTs, the DPA platform IPTs also fund R&D to support their particular projects. The Director General (Nuclear), in whose area the Nuclear Propulsion and Submarine IPTs reside, has recently released a limited amount of funding which the MSDO can use to support submarine-related R&D. A large amount of research is also funded through the Research Programme, the scope of which is prioritised by the DSTL[2] Capability Advisors who work within the Directorates of Equipment Capability. The RP is divided into seven research outputs, six of which are managed by the Research Acquisition Organisation. The exception, Output 6 – Technology in the Supplier Base, is funded and administered through the FBG. All of the projects compete for funding, on merit, with Combat System R&D, some of which is very costly indeed.

Summary

The MSDS has been written and endorsed to build on the strengths of the original MEDS and remedy its shortfalls. It will ensure that marine systems R&D is managed in a coherent and coordinated manner towards the achievement of clearly defined aims and objectives. A formal system of governance has been set up to ensure that the strategy delivers. Providing funding can be made available, MSDS promises to deliver solutions to the shortfalls in current capability identified by the Capability Audit and introduce technologies that are capable of supporting our future maritime platforms.

Conclusion

By delivering availability and enabling capability, marine systems are one of the most significant force multipliers available to a Service that continues to contract both manpower and the number of its hulls. To maximise the military effects to which marine systems contribute, the MSDS is the means by which:

- Capability shortfalls in the field of marine systems can be overcome in the short term;

- The designs for future maritime platforms can be optimised in the medium term; and

- New technologies can be exploited in the long term.

For these aspirations to be realised, however, funding must be made available now.

GLOSSARY OF TERMS

BWS	Bilge Water Separator
COTS	Commercial Off The Shelf
CWAO	Catalytic Wet Air Oxidation
CVF	Future (Aircraft) Carrier
DEC	Director Equipment Capability
DLO	Defence Logistics Organisation
DPA	Defence Procurement Agency
ECC	Equipment Capability Customer
EM	Electro-Magnetic
ESPO	Electric Ship Propulsion Office
FBG	Future Business Group (of the DPA)
IA	Incremental Acquisition
IFEP	Integrated Full Electric Propulsion
IMO	International Maritime Organisation
IPT	Integrated Project Team
MARPOL	International Convention for the Prevention of Pollution from Ships
MBR	Membrane Bio-Reactor
MEDP	Marine Engineering Development Programme
MEDS	Marine Engineering Development Strategy
MOTS	Military Off The Shelf
MSDO	Marine Systems Development Office
MSDS	Marine Systems Development Strategy
R&D	Research and Development
RO	Reverse Osmosis
RP	Research Programme
STP	Short Term Plan

References

1. Director Logistics Maritime Equipment.

2. Defence Science and Technology Laboratory.