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ARCHITECTING A 21ST CENTURY SYSTEM AND ITS ENTERPRISE

BY

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SYNOPSIS

Technical architectures are crucial in delivering key properties required of complex systems such as surface combatant combat systems. Increased modularity and openness are seen as being important in reducing combat system costs and delivering additional benefits including capability and acquisition agility, and reduced supplier incumbency. However technical architectures alone can provide only limited gain and must be coupled with enterprise change if full benefits are to be realised. The devising of (1) a technical architecture which maximises the potential benefit and supports enterprise change together with (2) an aligned enterprise architecture which fully exploits the technical architecture are key to achieving the required benefits. Both should be 'architected' and in a coherent manner. A technical architecture capable of achieving the required objectives together with issues of enterprise alignment and exploitation are outlined in this paper.

INTRODUCTION

After outlining the MOSA programme, this paper describes a new system architecture for UK Royal Navy warship combat systems. It also describes the process of devising it and the relationship between this Technical architecture and the corresponding Enterprise architecture.

Authors' Biographies:

Tim Rabbets is a Research Fellow in Maritime Systems Engineering at QinetiQ Ltd. Since graduating from the University of Oxford in 1982 he has worked as a systems engineer in the aerospace and shipbuilding industries before joining DERA, now QinetiQ, as a researcher. Most recently he has been the Technical Leader of the Technical Architecture on the MOSA Research Study.

Dr Richard Smith is currently Chief Systems Engineer, Architectures at MBDA UK Ltd. Since 1973, after studying at the University of Exeter, he has worked in System Engineering with MBDA and predecessor companies, particularly on

development of the Rapier Air Defence system. Since the mid-1990s he has focussed on Future Systems, most recently taking the MBDA Technical lead within the MOSA Research Study.

The MOSA Programme, Objectives and Scope

The MOSA (Modular Open Systems Architecture) study is a significant MoD-funded R&D programme which is intended to transform surface warship combat systems [1]. MOSA comprises 2 parallel study contracts. The major one is centred on devising the Technical architecture and a parallel study is addressing enterprise issues. It has been conducted by a consortium of industrial companies, MOSAic, supported by dstl on behalf of MoD's Defence Technology and Innovation Centre (DTIC) and Director Equipment Capability (Above Water Effects). Phase 2 of the study completes mid-2009, having determined the Technical architecture, confirmed characteristics required of the enterprise, and devised a migration strategy. This paper is based on work undertaken as part of this Technical contract.

Objectives

The primary objective of the MOSA programme is to devise a new architecture for major RN surface warship combat systems exploiting the properties of modularity and openness. Architecture is recognised as being crucial in determining key properties both of technical solutions, that is combat systems, and of the enterprise which delivers and supports them. In this context we understand an architecture to be the system structure of components, their interconnectivity and key properties.

The MOSA architecture is a 'target architecture' intended to be applicable across the surface fleet, with combat systems based on it able to meet capability needs both now and in the future. Basing architectures fleet-wide on a common modular and open architecture is considered as the best way of delivering combat capability at reduced whole life cost. It will allow the extensive use of COTS technologies and, through adherence to open standards, technological refresh will be eased. Using common components will ease logistics and training requirements.

The final key objective is to promote the retention of a viable and sustainable UK sovereign capability for maritime combat systems, in at least those technical areas required by Government policy.

Scope

The MOSA Technical contract covers three areas:

- the derivation of a target architecture for future maritime combat systems;
- a migration strategy to influence projects prior to full realisation of the envisaged target architecture;

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[1] It should not be confused with the US Modular Open Systems Approach which is an approach mandated by the 'Open Systems Joint Task Force' of the US Department of Defence

- support to the Enterprise-focussed study.

Concentrating on the technical architecture, its scope is naval combat systems and it focuses on those elements which can be implemented using general purpose computing and communications technologies, as shown in Figure 1. That is it addresses command and control functions and much of the sensor, effector and other subsystem software-intensive functionality.

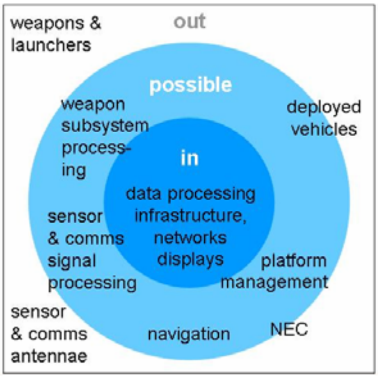

FIG.1 - SCOPE OF THE MOSA TECHNICAL ARCHITECTURE

This constitutes a broad range of complex system functionality which is compounded by non-functional characteristics of varying levels of severity. Security is a particularly demanding example of such Non-Functional Requirement (NFR).

THE MOSA TECHNICAL ARCHITECTURE

This section describes the technical architecture – what it is intended to achieve, the architecting process and its overall form. Determining the appropriate technical architecture is key to delivering the required system characteristics and handling complex problem spaces such as are encountered in naval combat systems. It is also crucial in delivering technical, non-functional, requirements such as security, safety, performance and availability.

There are several drivers for the study and its technical architecture, as shown in Figure 2 below.

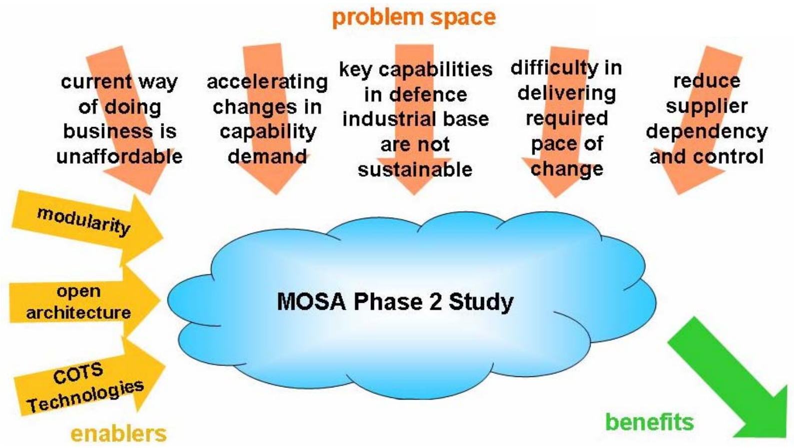

FIG.2 - DRIVERS FOR THE STUDY AND ITS TECHNICAL ARCHITECTURE

Drivers for change are both problem space difficulties, and enablers through modern approaches and new technologies. Particular problem space difficulties are:

- affording the current way of doing business, and sustaining critical industrial capabilities;
- rapidly delivering change, particularly as the rate of capability changes increases; and
- MoD's wish to reduce supplier dependency and control.

Key enablers include modularity and the opportunity to employ increasingly capable Commercial Off-The-Shelf (COTS) technologies, which are very much cheaper in initial procurement cost but are shorter lived by almost an order of magnitude. Open architectures have the potential to counter the short life of COTS by facilitating technology refresh.

The benefits sought from the new technical architecture and associated enterprise are largely the negations of the identified problem space issues.

The Architecting Process Adopted

Figure 3 shows the key elements of the architecting process adopted. This is driven by a number of factors including (1) the customer user and system requirements for combat systems, and (2) architectural principles, elicited from a variety of sources.

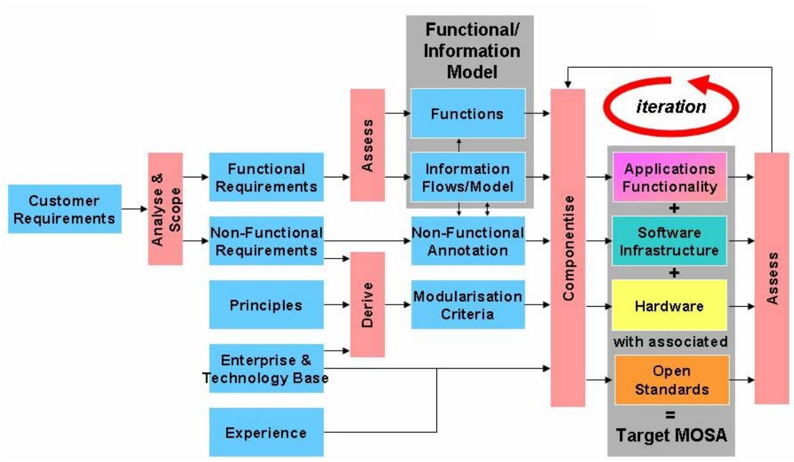

FIG.3 - THE ARCHITECTING PROCESS ADOPTED

A generic yet future-looking combat system functional model was devised together with an information model. These were derived from a superset of all envisaged functional requirements and combat system processes. This model was annotated with relevant NFRs such as performance, safety, security and reliability.

Compartmentalisation of functionality was conducted iteratively, using the annotated functional model as a key input and by applying formalised modularisation criteria together with enterprise and technology considerations and experience. The resulting architecture comprises applications, software infrastructure and hardware components.

Several iterations have taken place resulting in a formalised modularisation of the architecture which is aligned with applicable open standards to allow for commercial sourcing and future technological migration.

This architecting approach and the resultant architecture are focussed on our specific domain. However the process is more generally applicable and by tailoring its elements it can be used to derive architectures appropriate for other military and civilian domains. For example, the functional and information model could be replaced and appropriate NFRs, modularisation criteria and open standards applied.

The Architecture and a Typical Component

The MOSA architecture has been conceived as a comprising 3 major facets, or types of components, as shown in Figure 4, namely:

- applications functionality;
- software infrastructure; and
- hardware.

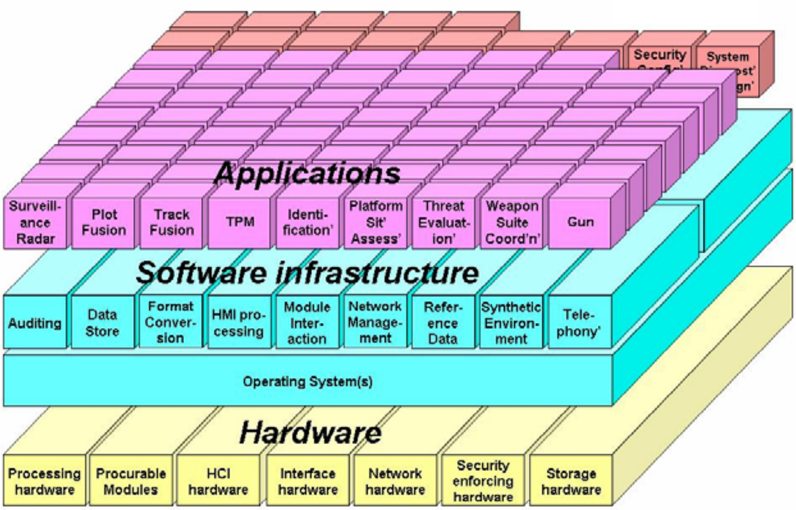

FIG.4 - A SCHEMATIC VIEW OF THE OVERALL ARCHITECTURE

A number of the identified components within each of these layers are also indicated. For example, 84 operational and support applications have been identified and defined to date. Each component is aligned with existing and anticipated open standards thereby aiding technology refresh and evolution.

Components in the lower layers of software infrastructure and hardware are largely commercially sourceable. In any given instantiation, vertical segments – not shown in this diagram – can be created to deliver appropriate levels of non-functional requirement (NFR) attributes. A key feature of the architecture is its ability to meet a stringent security requirement. Details of this are not shown due to its potential sensitivity.

Combat systems employing the architecture can be assembled from the defined components several ways. One would be as traditionally procured stovepipe equipments comprising applications functionality and supporting software infrastructure and hardware. Alternatively a system-wide computing platform could be assembled on to which applications components are progressively integrated.

Figure 5 shows the scope of each of the identified architectural components. Specifically this one is an operational application component that is a functional part of the combat system 'business logic'.

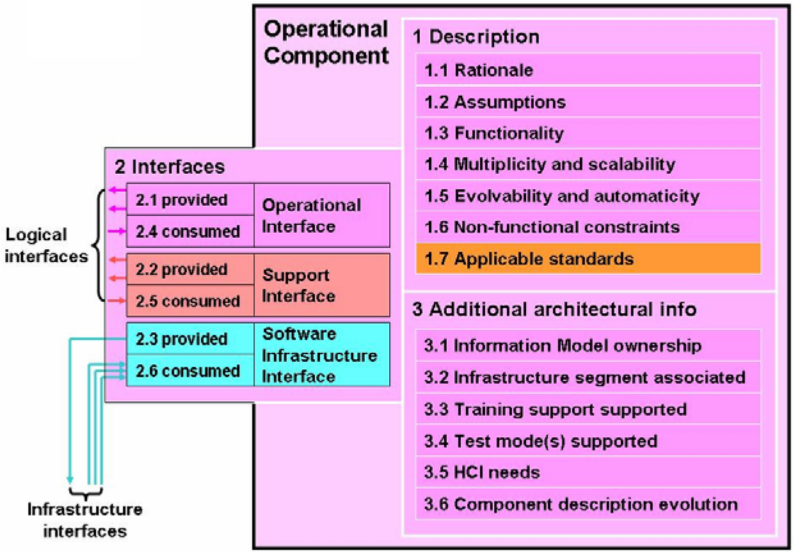

FIG.5 - THE CONTENT OF A COMPONENT DESCRIPTION

Each component is defined in terms of 3 main areas, namely:

1. A high-level description describing key aspects of the component including variants and tailoring, non-functional constraints and applicable standards;
2. An interface section identifying provided and consumed interfaces with other components, both peer level and enabling;
3. Additional information including ownership of information, applicable infrastructure segments and other characteristics.

Components were initially described textually and subsequently were developed using UML [2] notations in a CASE [3] tool.

THE COMBAT SYSTEMS DELIVERY AND SUPPORT ENTERPRISE

This section describes the current combat systems delivery and support enterprise and identifies the changes required to achieve the MOSA objectives.

It is acknowledged that a technical architecture is a necessary but insufficient enabler of the required objectives and to achieve all the benefits desired by MoD (and industry) the enterprise must change too.

Our 'Enterprise of Interest' (depicted in Figure 6) is the 'Maritime Combat Systems Capability Delivery and Sustainment Enterprise'. This comprises the customer and supplier organisations contributing to the enterprise objective, together with their associated information, processes, resources, skills and facilities.

[2] Unified Modelling Language
[3] Computer-Aided Systems (or Software) Engineering

FIG.6 - KEY ELEMENTS OF THE COMBAT SYSTEM DELIVERY AND SUPPORT ENTERPRISE

Combat systems are generally procured as key elements of host warship platforms. The industrial element of the enterprise includes the shipbuilder, the combat system designer and suppliers, the integrator and tester, installer and support provider. It extends down the supply chain to include system module suppliers and specialist contractors. It also includes those contributing to the non-equipment lines of development such as training and support.

It is difficult to characterise an enterprise as complex as that concerning the delivery and sustainment of naval combat systems. The Enterprise of Interest is related to a number of other enterprises – in other words it is part of an 'Enterprise of Enterprises'. It is closely related to the wider enterprise concerned with the delivery and sustainment of warships.

Figure 7 is a simplified characterisation of some of the types of organisations responsible for key activities related to the delivery and sustainment of a combat system, typically as fitted to a single class of warship. Combat system acquisition is warship-based and project-centric.

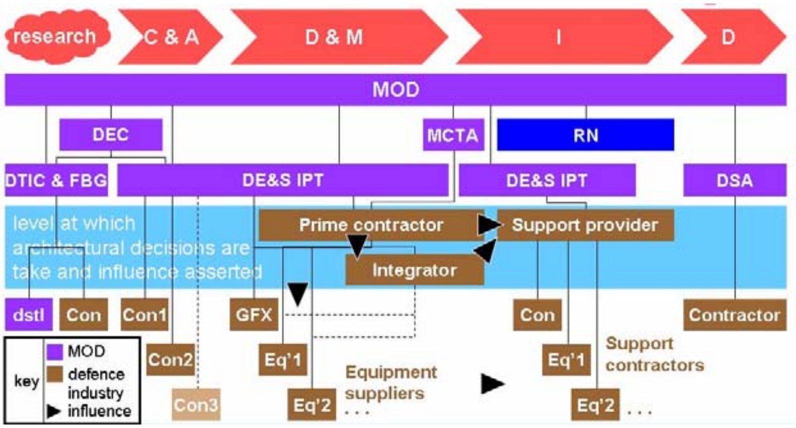

FIG.7 - THE 'AS-IS' PLATFORM-CENTRIC ENTERPRISE

The standard MoD CADMID [4] Smart Acquisition project life cycle is shown at the top of the figure. Indicated in purple in the graphic are the various parts of MoD which are responsible as the customer and acquirer of the combat system with certain MoD organisations being responsible at different stages of the life cycle and for certain specific functions such as research, capability delivery, system acceptance and disposal.

Indicated in brown are typical industrial parties responsible for undertaking studies, delivering system elements and sustaining the system in service. Key amongst these is the prime contractor, who defines and controls the overall system architecture and often conducts initial in-service support. System integration may be undertaken by one of a number of parties such as the prime or by a separate organisation. As is indicated by the solid arrowheads, a prime contractor is able to dominate the industrial supply chain, including integration, support and even equipment selection. Similarly, equipment suppliers may have a dominant position in the provision of equipment support including post design services. Such dominance is recognised as not necessarily being in MoD's best interest.

Desired Outcomes from Enterprise Change

Whilst the current acquisition approach can deliver effective systems, the Enterprise is not financially sustainable and can't match the increasingly rapid evolution in capability which is required.

Current system contracting models such as prime contracting and lead systems integrator result in too much control of the system and its sustainment and evolution by the original supplier. So MoD is changing its relationship with industry such as by taking architectural control back in-house or forming an alliance.

Given the increasingly fast evolution of required capability and of the obsolescence of current technology, acquisition agility is increasingly important - system changes must be fieldable in shorter timeframes than in the past.

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[4] Concept Assessment Demonstration Manufacture In-Service Disposal

Operationally and financially the Navy would benefit from fleet-wide commonality - but Project-based acquisition has resulted in dissimilar combat system solutions across the Fleet. This is due to contractors optimising solutions on a project-by-project basis with different contractors being selected to deliver equipments against similar requirements, or just as likely against inadvertently different requirements. This results in logistics and training problems for MoD and the RN.

Finally, the enterprise should allow more commercial sourcing of combat system components and encourage the UK defence industrial base to concentrate on those key military capabilities which need to be retained. Such key industrial capabilities will need to be sustained through predictable and regular work.

How the 'To Be' Enterprise is Developing its Alignment with The Technical Architecture

Figure 8 shows how enterprise change can be realised through exploiting opportunities created by the technical architecture. The centre column in shows Approaches aimed at satisfying the desired outcomes through Enterprise change, and on the right are desired features of the 'To be' Enterprise.

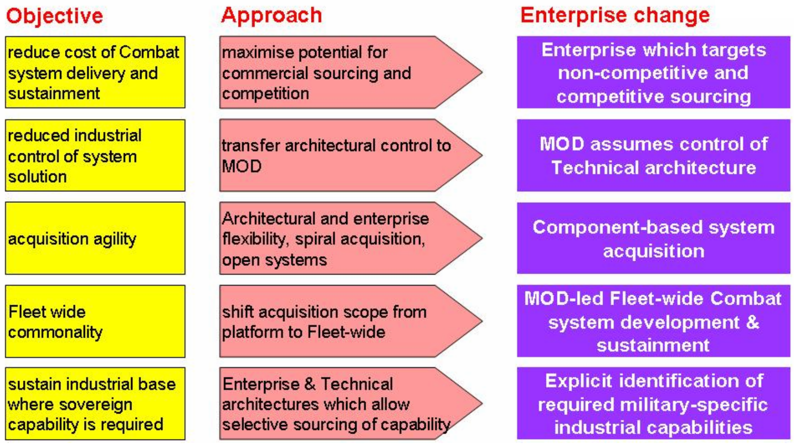

FIG.8 - REALISATION OF ENTERPRISE CHANGE

Reduction in the cost of Combat systems is considered to be best realised through a number of measures including making them 'as commercial as possible and only as military as necessary' and by increasing their commonality.

MoD also sees it as essential that the industrial control of the Combat system solution is reduced. Presently this control can result in the initial system being compromised and its through-life sustainment and evolution being further impeded. It is therefore considered desirable for architectural control to be vested in MoD.

Enterprise considerations will stimulate a rationalising and re-structuring of the UK defence industrial base as it withdraws from enterprise areas which are sourced from the non-defence sector. It is imperative that those military-specific capabilities required to be sustained are explicitly identified and their continued viability is determined. This will require consideration of adequate financial and human resources, relevant activities and other factors.

The 'to-be' Enterprise

It is difficult if not impossible to depict the 'To Be' Enterprise in a similar graphic to that for the 'As is' Enterprise. This is particularly as a result of the cross-fleet and through life span, in contrast to the single platform 'CADMID' lifecycle. Also, certain features are beyond the scope and even influence of the MOSA study. This section therefore emphasises features which relate to technical architectural considerations. Figure 9 identifies which enterprise activities are best undertaken by MoD, traditional defence industry companies, by commercial suppliers or by joint contributors.

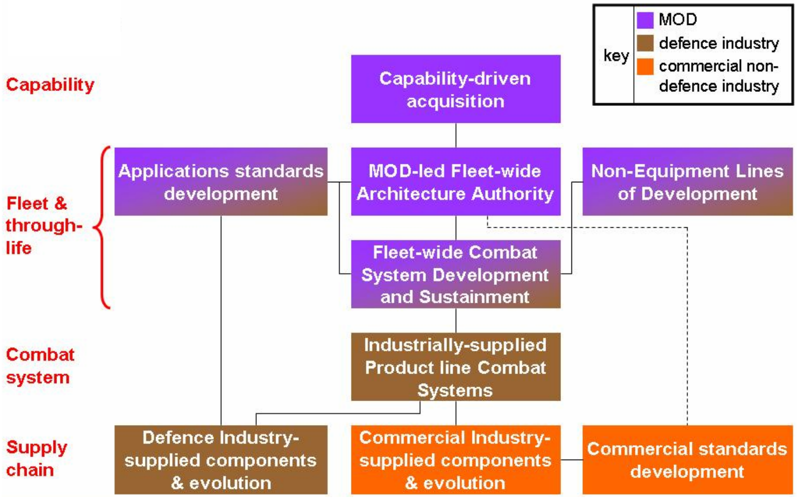

FIG.9 - ESSENTIAL FEATURES OF THE 'TO BE' ENTERPRISE

Within the context of capability-based defence delivery, it is essential that architectural control is raised from the platform-level to being Fleet-wide, and control is exercised by MoD rather than specific suppliers. This eliminates the through-life design control which an industrial prime and/or systems integrator can impose on a particular platform combat system. Architectural control should be supported by the development of open applications-level standards by MoD and industry, preferably on an international basis.

The development and sustainment of Combat systems should also be managed on a Fleet-wide and on a longer term basis than the service lives of individual warship platforms if the benefits of increased system commonality are to be realised. Consideration is extended from the usual equipment focus to include non-equipment line of development. Logistics and Training are conspicuous as needing cross-fleet and through life co-ordination.

Industry will develop, integrate, supply and sustain individual Combat systems for specific warship platforms and classes using 'product line' techniques. They will be composed largely from MOSA-defined components and will have increased commercial content as a result of:

- the fine grain componentisation of the MOSA architecture;
- the extensive commercial availability of many such components.

System evolution will largely be accommodated by component evolution and is facilitated through the adoption of open standards.

So far we have really taken a product-centric view of what architecture can deliver. Technical architecture can also deliver process change within the enterprise as is indicated in Figure 10.

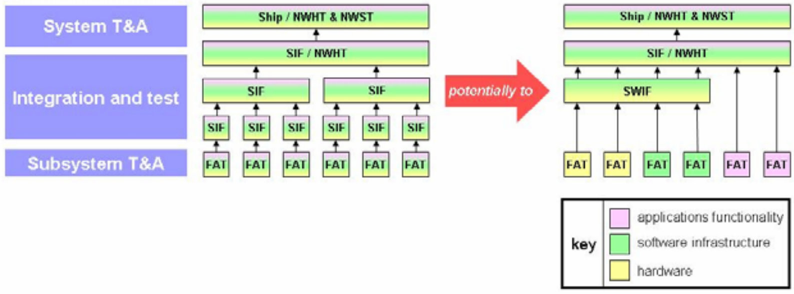

FIG.10 - AN EXAMPLE OF POTENTIAL PROCESS CHANGE ENABLED BY THE TECHNICAL ARCHITECTURE

For example, as is indicated in the graphic on the left in Figure 10, the current 'hierarchically-based' integration and test is based around equipment federates each comprising mixtures of applications functionality, software infrastructure and hardware. System-wide consideration of an architecture founded on layering can support a rationalised integration and test process, reducing the total effort required. This is indicated in the graphic on the right.

The 'to be' enterprise should identify organisational interfaces which match product (i.e. combat system) and process interfaces.

WAY AHEAD FOR THE MOSA PROGRAMME

As the study concludes, the consortium is consolidating its view on the Technical architecture and is keen that this should be realised. However, 'Big bang' adoption of MOSA is seen as too great a risk for MoD and a more gradual approach will be required. Emphasis will be placed on proving the architecture, probably in the form of progressive demonstration within a subsystem or equipment context. The first whole scale adoption of a MOSA combat system is likely on the RN's next major frigate platform, the Future Surface Combatant which has a projected in service date of about 2019.

In parallel with this industry has the opportunity to re-engineer 'legacy' equipments as and when they are the subject to technology refresh and/or capability upgrade. But, without co-ordination, convergence to a common system infrastructure will not happen. Cross-fleet coordination means Enterprise change, and this is now required to realise the MOSA vision.

RETROSPECTIVE ANALYSIS OF THE STUDY

Technical architectures play a key role in delivering required system capabilities. There is no universally optimal architecture but the most appropriate form depends upon factors such as:

- customer priorities, including NFRs;
- the technological base and likely developments;
- industrial base;
- the ease of migration from existing systems.

We have found that devising an appropriate Technical architecture is a highly complex endeavour, and the MOSA programme has proven to be extremely challenging both technically and culturally.

The MOSA Technical architecture is capable of meeting MoD’s and industry’s needs and is encouraging Enterprise change.

A Technical architecture alone can deliver technical benefits, but in order to deliver substantial benefits it requires some Enterprise change including a willingness to impose it or adopt it. However, the current Enterprise does not include decision makers at the right levels to achieve this, so further Enterprise change is required. It is beyond the remit of the MOSAic team to propose a full Enterprise solution, however we are able to highlight key characteristics we think are required of the Enterprise.

It is this combination of the Technical architecture with an exploiting Enterprise which offers the best prospect for reducing the overall cost of delivering and evolving naval combat capability and meeting other stakeholder objectives.

CONCLUSIONS

The MOSA programme has devised a Technical architecture exploiting modularity and open systems principles which meets customer and industry objectives. Enterprise studies are serving as a catalyst leading to the re-shaping of the UK naval combat systems industrial base.

MOSA must deliver tangible benefit near term and beyond. Near term work will concentrate on Technical architecture demonstration and exploitation. Re-shaping of the combat systems enterprise will continue with a fleet-wide MoD combat systems organisation already emerging. An industrial team, perhaps based along similar lines to Team Complex Weapons, is a likely prospect.

Enterprise considerations will stimulate a rationalising and re-structuring of the UK defence industrial base in this sector encouraging it to concentrate on those capabilities which cannot be sourced commercially and are important to retain nationally.

Some further technical work will also be required, for example (1) to set up an architecture authority/standards body and intervene in open standards formulation, especially as concern applications functionality, (2) to address issues such as integration, test and acceptance, and (3) to refine the architecture and resolve outstanding issues such as the quantification of its overall cost-benefit. This further work will reduce remaining risks to an acceptable level.

ACKNOWLEDGEMENTS

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