Developing a System Using the MOD Architecture Framework – a Case Study

Systems Engineering can be regarded as the process of defining a system's boundaries and performance requirements, of partitioning the system into appropriate sub-systems for ease of implementation and of integrating them after manufacture into a working entity that fully meets the specified performance.

"Developers of government systems face the same challenges as product developers in the commercial world – increased capability at reduced costs in rapidly decreasing time periods."[1]

This article presents a Model-Based Systems Engineering (MBSE) case study where the MOD Architecture Framework (MODAF) has been successfully applied to baseline a new equipment to support UK ground forces. Within four months the work provided an Invitation to Tender (ITT) to allow early teaming with industry.

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Background

In recent times the demands placed on the suppliers to UK's Land Forces have increased substantially. UK's Land Forces' requirements have evolved significantly since moving from historic theatres of operation in Europe and homeland UK. Traditionally, military equipment has been developed as a standalone capability with limited compatibility and integration with other deployed equipments. Predominantly mission driven, equipments today have largely evolved as fragmented solutions to specific needs, with diverse logistic requirements in today's environment [2]. Many equipments are now considered essential "green army" components, so a new approach is required to provide a capability for wider operational use that (as a minimum):

- supports theatres world-wide
- minimises user overheads
- is modular, scalable and readily upgraded
- accommodates technology insertion and integration of Commercial-Off-The-Shelf (COTS) elements
- is interoperable with other UK and Allies' equipments
- fulfils the needs of each Defence Line of Development (DLOD).

Introduction

The development of complex systems requires the rigorous application of systems-engineering techniques in order to fully define and then implement a workable solution that fulfils the users' requirement and which can be delivered on time and to budget. These techniques help manage this complexity and allow a holistic approach to be taken from the initial concept through to its implementation and, eventually, its disposal.

One such technique is enterprise modelling. Enterprise modelling captures the many aspects, or views, that can be taken of an organisation, its people, its processes and the systems and data that support that organisation, and establishes a basis from which to apply Model-Based Systems Engineering (MBSE) in the synthesis of the product. For the UK defence domain it is the MOD Architecture Framework (MODAF) that defines the framework within which the MOD can state its enterprise-level requirements and organise its people, processes and systems to meet those requirements. It also facilitates the planning of future procurements so that capability levels can be maintained or enhanced by presenting the information required to make planning decisions in a simple, easily understood format.

This article presents a MBSE case study where MODAF has been successfully applied to baseline a new generation of protection equipment for ground forces. The work has been carried out at Dstl Fort Halstead by the Systems and Integration Team during 2007/08.

The programme

Initially championed by the Department's Chief Technologist, the Security Sciences Department at Dstl Fort Halstead commenced the Concepts and Architectures study [3] to address the question "Given a fresh start, what capability should we be aiming to provide in five to ten years time to enable UK Land Forces to carry out military tasks safely?"

The Systems Engineering study applied an adaptation of the 6σ (Six Sigma) interpretation of the Taguchi Viewpoint analysis to identify:

- bounding functional requirements
- non-bounding constraints [2].

6σ is a management strategy that seeks to identify and remove the causes of errors in business processes [4]. Taguchi Viewpoint analysis allows the collation of a set of requirements from every aspect of the system, providing a requirements baseline to which all future developments can be traced. It became apparent that the presentation of these aspects of the system would significantly benefit from the use of a coherent, cohesive, holistic model. The evolution of the resultant architecture model was subsequently championed by the (then) newly formed MOD Counter Terrorism Science and Technology Centre (CTS&TC).

Model Based Systems Engineering (MBSE)

MBSE is a recent initiative, sponsored by the International Council on Systems Engineering (INCOSE) [1] as an enabler for capability-based architecting for today's System-of-Systems and Family-of-Systems acquisitions [5].

In the United States (US), MBSE is applied during project development using the Department of Defense Architecture Framework (DODAF) whilst in the UK it is MODAF that is used with an aim to deliver needed insight into the requirements and analysis phase of a military project.

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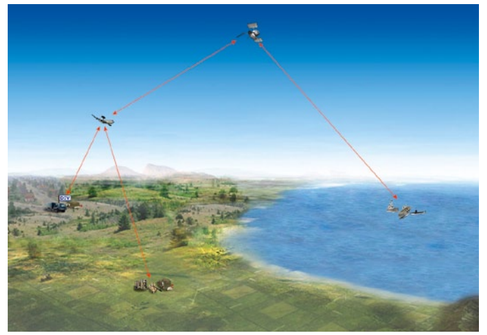

An example MODAF Operational View (OV-1a).

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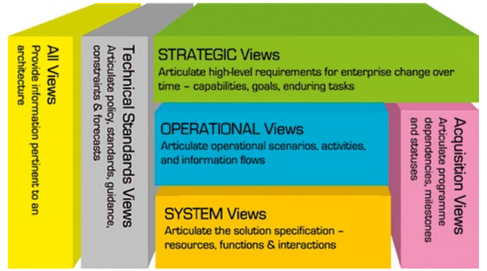

MODAF version 1.1.

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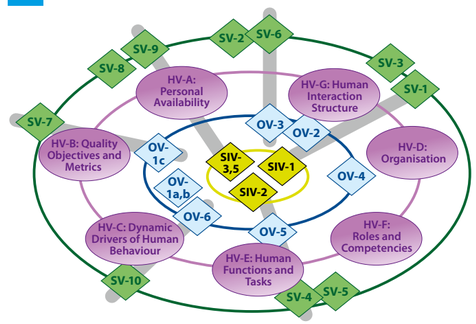

Human Factors (HF) views.

The MOD Architecture Framework (MODAF) model

MODAF provides semantic rigour for defining an architecture via meta-model "Views" that allow the expression of:

- the 'why' – the strategy
- what the solution is required to do – the operational need
- how it is going to be constructed – the technical system aspects
- when is it to be done – the programmatics.

The views provided by MODAF are:

- Strategic Views (StV) – to assist with capability planning
- Operational Views (OV) (Figure 1) – to describe the conduct of operations and present user requirements
- System Views (SV) – to present the system requirement or solution
- Technical Views (TV) – to present applicable standards used, or to be used in the architecture
- Acquisition Views (AcV) – programmatic details of the architectural elements
- All Views (AV) – Overview and summary information.

The new architecture requirement was modelled in version 1.1 of MODAF (Figure 2), but with the introduction of version 1.2, MODAF now has Service Views to facilitate the development of service-oriented architectures.

Another advance since the development of this new architecture is the release of the Views for Human Factors. Although not currently part of the core set of MODAF Views these incorporate Human Factors analysis into the overall architecture to ensure that it is considered at an early stage. Via liaison with the Dstl Human Factors experts, these views are to be incorporated into the new Land Forces' equipment description in later revisions of the architecture (Figure 3).

The Strategic Views for the new capability were presented using terms from existing doctrine so as to be familiar to both the military and industry. However, without an endorsed set of capabilities – the capability taxonomy – there is a risk that each architecture that incorporates Strategic Views will use a different source reference or make up its own, creating confusion and causing an additional overhead where architectures are linked together or merged. It is possible that the terms used for the new system Strategic Views may also not be accepted as recognised capabilities for this reason.

The Operational Views showed that taking an abstract, high-level view successfully stripped away the unnecessary complexity that can clutter the presentation of the core requirement. The maintenance and support requirements were also modelled in the Operational Views, an aspect that is often overlooked.

As the programme was still in the concept stage, the System and Technical Views were used to represent the user requirement and example configurations that may satisfy the operational requirement shown in the Operational Views. They depicted potential deployments and showed which existing systems could be used as a system-of-systems to provide the required information management and communications.

The Acquisition Views are easily understood Gantt-style diagrams that give an immediate indication of programme interactions and potential scheduling problems. For the new system, the platforms that were going out of service were quickly identified so that their replacement could be identified and informed of the new requirement. It also highlighted that some platforms would be scheduled for the fitting of legacy equipment at a time when the later system should be considered as the correct fit.

The complete set of MODAF views [6] selected for the new capability comprises:

- All Views AV-1 & AV-2
- Strategic Views StV-1, 4 & 6
- Operational Views OV-1a, 1b, 2,3, 4, 5, 6a, 6b
- System Views SV-1, 3 , 4[7], 5, 6, 7 , 9, 10a, 10b
- Technical View TV-1
- Acquisition View AcV-2.

Results

This project has demonstrated that the MBSE approach using MODAF:

- enhances communications across multiple teams
- provides a basis to manage critical risks and resolve issues (including those associated with emergent behaviour, budget and resources) as they arise. As each user need is traceable to a stakeholder, any future issues can be resolved by consultation with the owners of the relevant requirements
- enables effective management of the interfaces (including strategic reallocation of capability). Early consideration of the Human Factors aspects of the system ensures that required involvement of any user does not compromise the system's effectiveness in service
- ensures consistency from the initial phases of system definition whilst supporting change impact analysis and technology insertion.

For the Land Forces' equipment programme in Dstl's Security Sciences Department, MODAF has thus established a basis for the expression of the user requirement and system documentation in a way that facilitates their capture in more traditional textual tools such as DOORS™ (Dynamic Object Orientated Requirements System – a proprietary requirements management tool) [8].

Advantages gained

Distinct advantages have been gained from the MBSE approach using MODAF:

1. A cohesive and holistic representation of the needs of all stakeholders is provided, that allows the architecture to be presented from many aspects.

2. It is a truly top-down set of views allowing a clear definition of the key customer needs to be identified quite readily. The analysis is devoid of any preconceptions of what a solution might be, so unnecessary implementation constraints on the system's key requirements are avoided.

3. The system concept was defined very efficiently in a short time (the modelling commenced in April 2008 and resulted in an ITT for Industrial involvement in June 2008) because:
   - having evolved from a stakeholder analysis, as the implementation progresses every requirement is traceable back to its source
   - the process benefited from the clarity of thought derived from 1 above
   - it was possible to evolve the model, the Concept of Operations and User Requirement Document (URD) concurrently (Figure 4) so that they remained consistent with the:
     - functional requirements
     - non-functional requirements (system constraints)
     - compliance with all appropriate standards.

4. This approach provides a common (graphical) engineering language that was shown to be understood by:
   - sponsors
   - users
   - industrial partners
   - supporters
   - reviewers.

5. The MBSE Views of the model are not isolated representations (as alternative design/requirement diagrams would be) – the tool in which the model resides provides for direct, bi-directional translation into:
   - requirements documentation systems such as DOORS™
   - tools providing mass analysis
   - tools providing thermal analysis
   - tools for representing behavioural or functional characteristics
   - logistic analysis packages
   - statistically based manufacturing packages such as the six sigma Minitab™.

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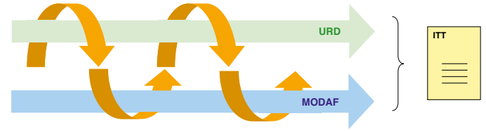

Process illustration. URD – User Requirement Document, ITT – Invitation to Tender.

Future work

The scheduled in-service date for the new equipment is 2014, at which time a functional capability is planned for brigade operation. In preparation, the project is already following the CADMID/T (Concept / Architecture / Design / Manufacture / In-Service / Decommission / Terminate) project life-cycle specified in the MOD Acquisition Operational Framework (AOF) [9].

With increasing support from industrial partners:

1. The MODAF model will be developed to support the required Initial Gate and Main Gate acquisition milestones.
   The only outstanding view required to meet this objective is the SV-2c which requires a clearer definition of the system communications. This will be achieved later when the architecture definition has been established.

2. The System Requirement Document that builds upon the user requirements, architecture and framework will be produced and published in DOORS™ by mid 2010.

3. In concert with the system's System Requirement Document, the system Interface Control Document, sub-system design requirements and interface requirements will be developed to establish a baseline against which:
   - concept demonstrators can be produced
   - equipment procurement specifications can be developed
   - test, evaluation and integration planning can be carried out.

4. The full CADMID/T life-cycle can be evoked efficiently and effectively so that:
   - the logistic supply and support services can be in place to effect a smooth transition into service
   - effective and efficient performance can be provided during service
   - an uneventful withdrawal from service can be achieved when the time comes.

This programme, having successfully applied MBSE to define the baseline for this new generation of system, continues to explore innovations in MBSE such as the latest concepts in the MODAF Human Factors Views. These Views were first presented at the INCOSE international conference in Utrecht in June 2008 and will be evaluated as part of the model produced for this new system.

The authors of this article presented this work at the INCOSE spring conference in March 2009 where it stimulated much interest.

Conclusions

This article describes the innovative MBSE work of the Systems and Integration Team at Dstl Fort Halstead and itemises the advantages of the MODAF modelling developed for one new capability.

The model has established a firm foundation for effective, efficient, timely achievement of the required project milestones to forecast with minimum risk.

This new system will significantly enhance the inventory of programmes already supported by Dstl out of the Systems and Integration Team. As a full procurement programme (unlike many that have been procured as Urgent Operational Requirements) this programme will follow the full CADMID/T cycle as defined in the MOD AOF which the Dstl workforce is ideally placed to support in partnership with industry.

So far, indications are that the achievements are very encouraging:

- Accolades have already been received from the sponsors [10] who have requested support of this approach for other programmes
- Industrial suppliers have acknowledged the clarity of the user requirements
- The programme continues to act as a platform for evaluation of the newly specified Human Factors Views.

The Systems and Integration Team members look forward to pursuing the progress of the MODAF model into representations for evaluation of the various future phases of the programme.

References

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