23ISMOR, 29th August –1st September 2006

OR: Making an Impact in a Systems Engineering Environment

Jenny Young

Head of Operational Analysis, MBDA

PB76a, MBDA, Six Hills Way, Stevenage SG1 2DA

Abstract

MBDA is a prime contractor for Guided Weapon Systems and maintains a relatively small, but growing group of operational analysts to support the company business. This paper will highlight the ways in which OA is used within the business, and the types of impact that it is able to achieve. The spectrum of tools and techniques that are used will also be identified.

In recent years, emphasis has moved away from the analysis of individual weapon systems, towards the analysis of weapon systems operating as part of a Network Enabled Capability. A key enabler of such analysis has been the use of MODAF and DODAF type techniques (Architectural Frameworks) to define the systems of interest and their interactions. Case studies will be presented to show the practical application of such techniques, and will illustrate the impact that can be achieved when OA is conducted as part of a multi-disciplinary team. Frequently the OA discipline merges seamlessly with high-level systems engineering to provide the operational context within which more detailed engineering can progress effectively.

This paper is concerned with how OA can make an impact in a systems engineering environment.

The author's background is working in Industry, in the UK, where she is employed by MBDA, currently leading an OA group. MBDA is a leading prime contractor for missiles and missile systems, with operations in the UK, France, Italy, Germany and US. MBDA has 45 products in service and 30 products in development, with extensive experience of international programmes. Currently, the three main international programmes are: Storm Shadow, PAAMS with the Aster missile, and Meteor.

Within the UK the OA team consists of 14 people, who contribute to a wide range of activities all across the company business, from research programmes and concept studies through to providing support to development contracts and export sales campaigns. Members of the OA group regularly work as part of multi-disciplinary, multi-company teams, but by remaining a group are able to share experience and knowledge. OA is firmly part of the systems engineering culture, and this paper gives some examples of how OA is able to make a difference.

This paper will first outline the typical tasks that the OA group conducts and the range of tools and techniques that are employed. Examples of where OA makes an impact will then be given, focusing on working with capability level requirements, system boundaries and system architectures.

The nature of the company business means that the effort of the OA group is concentrated on weapon systems and weapon command and control systems. The emphasis is therefore on 'systems' – their definition, assessment and their potential use. The majority of the work is focused on future weapon system concepts, typically in the 2015-2020 timeframe.

The main areas of activity for the OA team are therefore:

- Analysis and capture of User Requirements, where we are asking *'what does the user need the system to do ?''*
- Defining System Architectures, typically using MODAF Operational Views, where we must ask how the system might work, how it could interact with other entities, how will it be commanded, and who will make the decisions?
- Developing an outline CONcept of EMPloyment (CONEMP), where we are trying to identify how the system will be used. The CONEMP will impact both the requirements, the system architecture and the operational effectiveness studies
- Quantitative and qualitative evaluation of Operational Effectiveness, where we may use quantitative and qualitative measures of

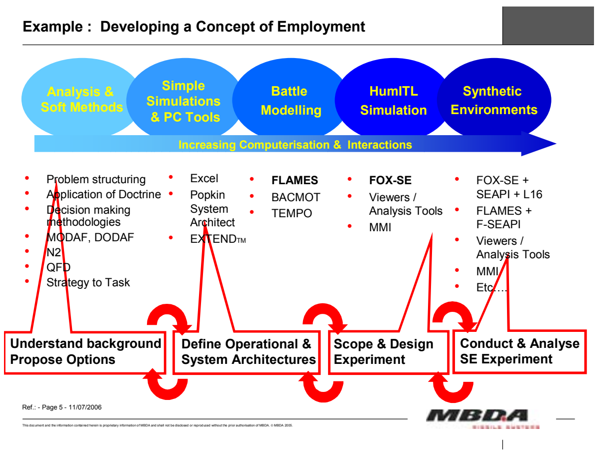
effectiveness. At concept stage we may wish to use these measures to compare the system of interest to other potential options, or possibly competitor products. Later in development measures can be used to help refine the system design.

- The final area is where we provide Cost-Effectiveness studies and support to Business Cases. We must assess whether or not systems are cost-effective, and we may be required to conduct a balance of investment between different types of solution.

We have a range of tools and techniques available to study these themes, which can be summarized as:

- Analysis and Soft Methods
- Simple PC based tools
- Battle Modelling
- Human-in-the-loop Simulation
- Synthetic Environments

Specific examples of some of the tools we use are shown below. Our two main computerised tools are: FLAMES a mission level battle model, and FOX-SE, a Human In the Loop (HumITL) air-air and air-surface simulator. Both of these tools can be integrated into a broader synthetic environment when required.



In principle any of these 5 methods might be employed for any task. However, the selection of the type of method must always be fit-for-purpose, and will inevitably depend on the maturity of the project, and the time and money available for the study.

Often we can start by analyzing a problem with soft methods and then progress to simulation in later phases of study, as shown in the figure. In this example we are developing a concept of employment for a system in a number of steps. We start with paper studies thinking through the options and defining the different elements of the system and how they interact. We can then use performance models and simple simulations as a first test of the viability of the system. At each stage, options may prove to be unworkable or physically impossible, and military input can be sought. Finally we might want to conduct human-in-the-loop experiments to try out our main options. In this way we can progress iteratively and be sure we are directing simulation effort at the most worthwhile areas of the problem space. We can also be sure that the systems we are attempting to simulate are adequately defined, albeit still conceptual. By using synthetic environments we can enable the military user to interact with the system at the earliest possible stage of design, and provide feedback to the design team.

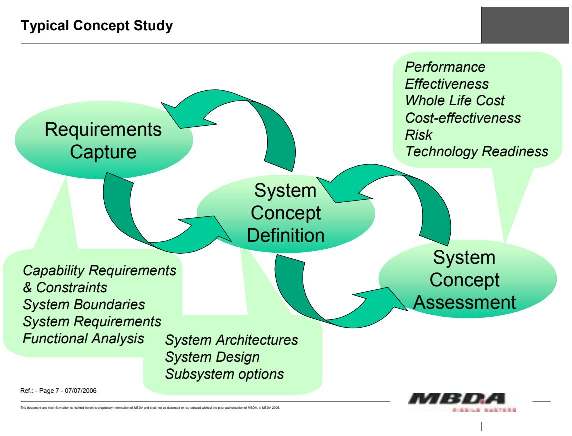
The remainder of this paper will concentrate on two areas, where the link between OA and systems engineering is strongest:

- Analysis and capture of User Requirements
- Defining System Architectures (MODAF Operational Views)

In all the activities, the OA group are generally working as part of a multi-disciplinary team which may consist of systems engineers, technical experts, military advisors, simulation and human factors specialists and cost estimators.

User Requirements

Much of our work is concerned with the development and assessment of system concepts. Concept studies are often conducted before a User Requirement Document or URD is formally issued – indeed the concept study itself is often conducted to give customers an idea of the ‘art of the possible’ in terms of time, cost and performance. It is only by developing a system concept that performance and effectiveness can be calculated, whole life costs can be estimated, and candidate technologies identified. A typical study cycle is shown here. There are usually three main phases of activity: requirement capture, system concept definition and assessment. Operational analysts contribute to all three phases and are able to use their operational insight to make a valuable contribution to the generation of system concepts.



Often, the first job for the operational analyst is to capture and analyse User Requirements or capability level requirements as we sometimes call them. These requirements can then be discussed with the customer, prioritised and if appropriate, endorsed for use on a specific study.

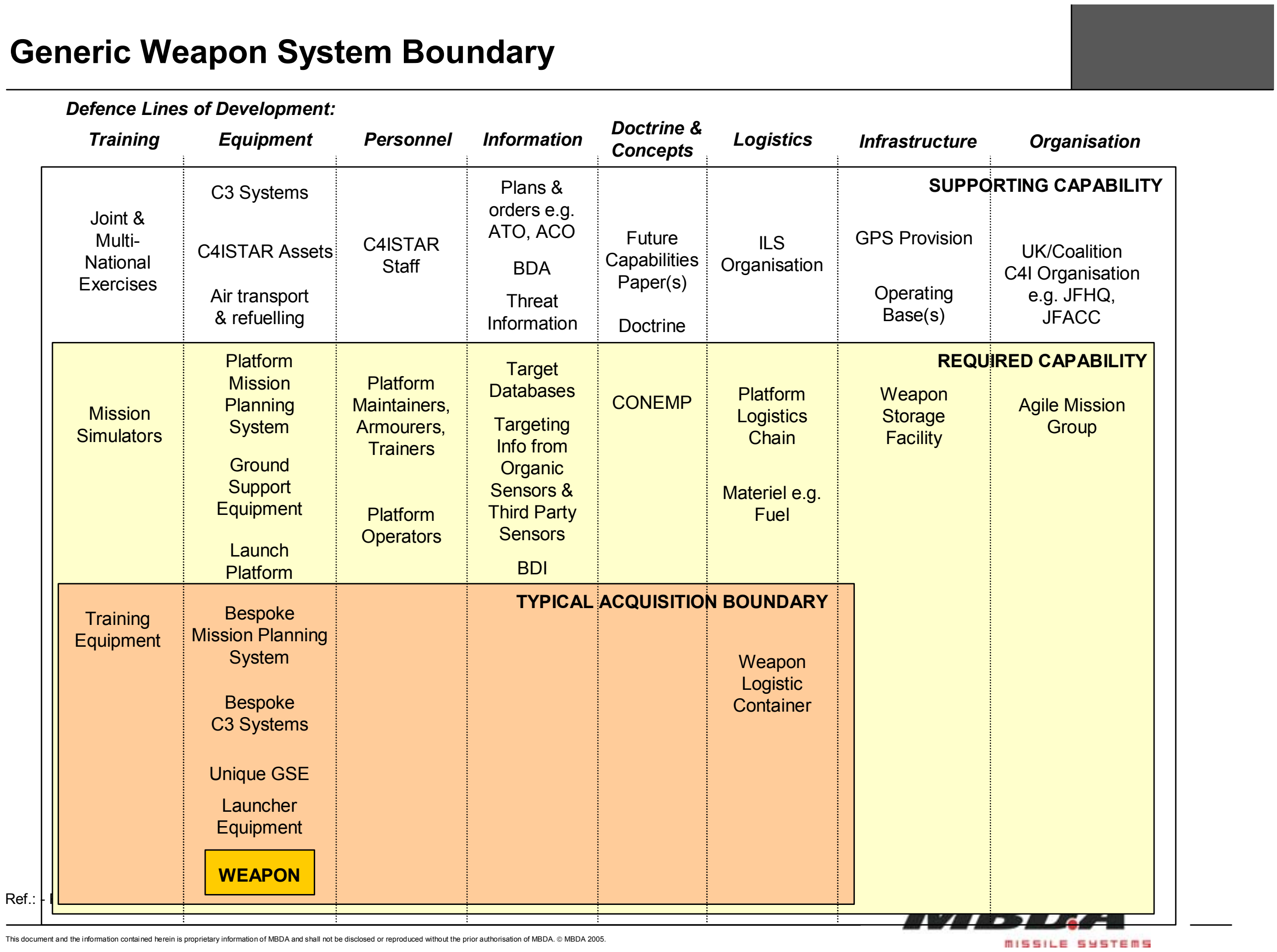
Frequently we are asked to contribute to multi-national studies, where there are potentially several customers and a spectrum of requirements. In this case we must analyse where the national requirements are complementary or conflicting – an important first step that could lead to a multi-national programme. We must also think about what can be done in system concept terms to converge the requirements, or encompass the divergence.

When working with user requirements, it is always important to explore and hopefully establish the boundary of the potential system. The new capability that is required will almost certainly be dependent on other systems and equipment, and this is particularly true for weapon systems, where targeting information may be provided by a third party. Within MBDA we have developed a technique for analysing system boundaries using the Defence Lines of Development (DLOD). The DLOD define the different aspects that must be considered to provide an operational capability and are summarised as Training, Equipment, Personnel, Information, Doctrine and Concepts, Organisation, Infrastructure and Logistics.

The example below shows an example for a generic weapon system. As you can see the weapon itself is just one item under equipment, but a much wider range of equipment (and non-equipment) items need to be in place to provide the required capability. Some of these items are likely to be acquired with the weapon, others are not, so we can start to build a picture of the acquisition boundary for the System. This may also help us trade-off alternative procurement strategies. The required capability is also dependent on a much wider range of capabilities, stretching across all the DLOD, and will in turn also be dependent on a range of supporting assets.

Using this format we can also highlight the components that must come together during a mission creating another boundary, potentially one that we might be able to call an agile mission group.

This method gives us a way of articulating the system boundary, and identifying interfaces to other systems. By identifying an acquisition boundary we have also started to make assumptions that will start to define the whole life cost of our solution.



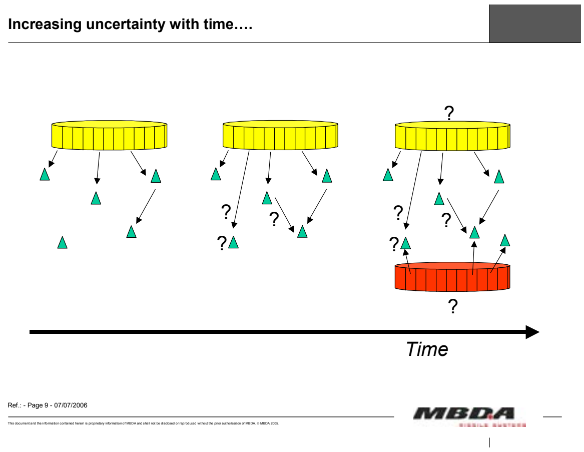
System Architectures

One of the biggest changes to our work over the last few years has been the customer's aspiration for a Network Enabled Capability.

We no longer study weapon systems in isolation, but they must be part of a larger, more complex system. We must consider the possibility that targeting data for the weapon system could be provided by a third party, and that the weapon itself may have valuable information to contribute to the network.

The availability of datalinks to weapons also gives us the option to communicate with the weapon in flight. This open up a range of new capabilities including target confirmation, re-targeting, collateral damage avoidance, loitering and weapon abort. Capabilities will inevitably depend on the latency and bandwidth of the available datalinks.

When we are dealing with future systems, there is often much uncertainty – within our system architecture we may have a launch platform, multiple targeting platforms, several datalink options, and a command and control platform. Each of these components may be subject to their own upgrade path over the next 10 to 15 years, adding to the complexity of what the future system architecture, or architectures, may be and creating a lot of uncertainty.

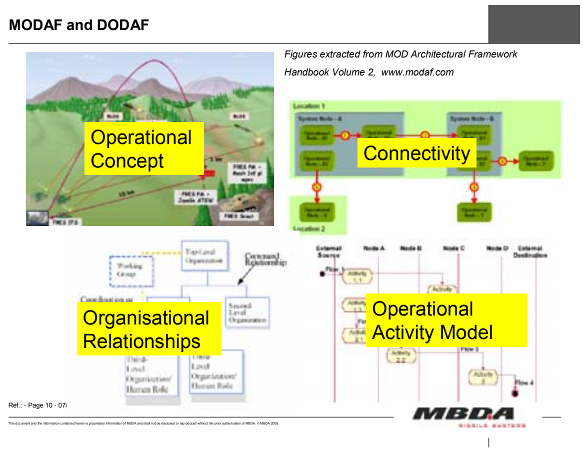


Fortunately we have a new tool in our armoury – the DOD and MOD Architecture Frameworks (MODAF and DODAF). These frameworks define a standard method by which a system architecture can be defined and documented. The operational views are of primary interest to the operational analyst, and we can use these to define how we think the system might operate, and to facilitate dialogue with the operational user. MODAF also facilitates dialogue within the concept team and during a concept study, this can be a much needed form of communication and documentation, ensuring that a common view is held of the systems that are being defined, and the potential options that may exist.

The operational views that have proven most useful to us are the OV-1, OV-2, OV-4 and OV-5. In summary these capture the high level operational concept, system connectivity, organisational relationships and an operational activity model. Considering the command structure (using the organisational relationships diagram) early in the lifecycle is particularly important. It helps to identify where the decision makers sit in the system, and the type of information they will need to have access to, to make those decisions. If an activity requires the use of battle modelling or SE, these MODAF views also provide a good way of defining the systems that need to be modelled, their functionality and the interactions that occur between them.

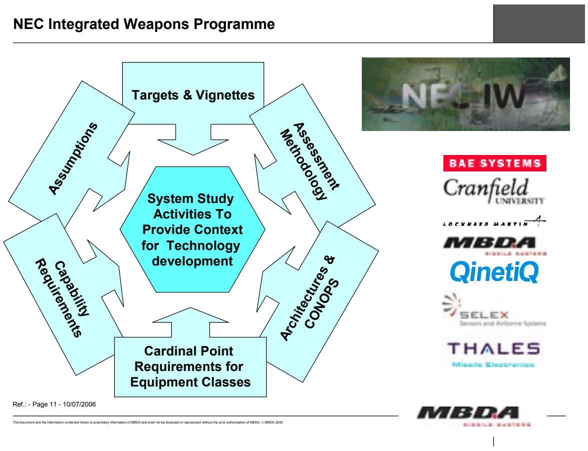
To give you an idea of how powerful these diagrams can be, virtually every major task conducted by my group in the last year has used MODAF to some extent. Not because I have been telling them to use it, but because everyone finds them useful.

It is not my intention to provide a tutorial on MODAF in this paper, but further information may be obtained from www.MODAF.com.



One of the problems of defining system architectures at concept stage is managing the uncertainty, and the sheer number of options this can produce.

The example I would like to present to you is from work undertaken as part of the NEC Integrated Weapons research programme. This is a 2 year research programme for UK MOD, primed by MBDA and active involvement from a UK industry team. The NEC Integrated Weapons programme covers the assessment, development and risk reduction of interacting sub-systems technologies that are required for future weapon systems operating within a NEC environment. Overall the programme considers the ways in which network information can be used by the weapon system, and how the weapon system might provide useful information back to the network. Technology development is progressed through four main themes, known an Integrated Technology Concepts, as well as a number of smaller risk reduction activities.



To provide context for these detailed technology activities the programme has also included system studies where capability and system requirements have been captured and system architectures developed. These activities provide an important link between the overall requirement and the technology development, and ensure the relevance of the technology and its exploitation.

A large number of potential architectures exist which reflect the potential launch platforms, targeting options, data links and weapon candidates. This presented far too many options for study within the programme. So, rather than develop dozens of specific architectures, we have taken the approach of developing a set of generic architectures that reflect the needs of the programme.

After some deep thought about the potential system architectures we concluded that there were only two aspects that made a difference from the perspective of the weapon system: The source of the targeting data and the way in which command and control is exercised over the weapon in flight.

Taking first, the source of the targeting data, we were able to summarise this with 3 options:

- targeting solely from the Fast Jet (FJ) organic sensors, or
- targeting based solely from one or more third party sources, or
- targeting using a combination of the two.

Similarly we can reduce the way in which command and control is exercised over the weapon in flight also to 3 options:

- An autonomous weapon (no datalink),
- Datalink(s) from/to the FJ launch aircraft
- Datalink(s) from/to third party assets

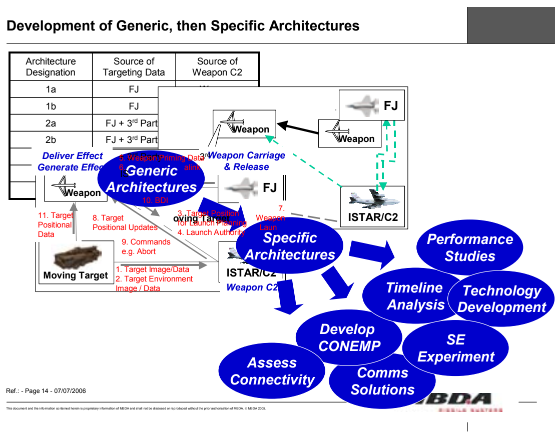
By combining these options in a logical manner we arrive at seven architecture options that summarise the different ways in which the weapon system might operate. The options are summarised in the following table, and summarise all the ways in which a network enabled weapon might operate.

Summary of NEC IW Architecture Options

Architecture Designation	Source of Targeting Data	Source of Weapon C2
1a	FJ	Weapon
1b	FJ	FJ
2a	FJ + 3rd Party	Weapon
2b	FJ + 3rd Party	FJ
2c	FJ + 3rd Party	3rd Party
3a	ISTAR	Weapon
3b	ISTAR	ISTAR

Ref.: - Page 13 - 07/07/2006

Individual architectures were then developed in their generic form, using MODAF operational views. When we have a need to, we can populate one or more architectures with the details of specific systems. For example as operational analysts we may be requested to analyse engagement timelines, or conduct a synthetic environment experiment to investigate the concept of employment for a given architecture. The wider systems engineering team may need to assess connectivity, conduct performance studies, define communication solutions, or develop or integrate relevant technologies.



However, whatever is required, we are now able to do the work with a greater understanding of the total solution space that enables us to relate one specific architecture to another, and add structure to our analysis. We can avoid selecting architectures for study on an arbitrary basis, and manage the complexity of the problem by only adding detail when we need it. The architectures also provide a framework within which the value of the technology developments can be assessed, and keep as many options open for as long as possible.

Conclusions

Two examples have been presented that show how operational analysts have an important role to play in the capture and analysis of user requirements and the development of system architectures. Key skills are problem structuring and operational understanding and these can be readily employed in high level systems engineering, to the benefit of all concerned in a seamless way.

System concept studies typically include three main areas: requirement capture, architecture definition and concept assessment. OA has a role to play in all three areas, and analysts will play a central role in the decision making of the concepts team.

Most impact is obtained where operational analysts are working in a multi-disciplinary team. They are able to provide broad operational thinking, to provide context to tasks such as technology development, and problem structuring to assist with complex issues. By also remaining part of an OA group they are able share their knowledge and skills and develop best practice.