The Use of a Conceptual Battlespace Architecture to Manage and Exploit Concepts and Doctrine Experimentation

Dr Paul King & David Evans
VEGA Group PLC
Delme Place, Cams Hall Estate
Fareham, Hampshire PO16 8UX
United Kingdom

paul.king@vega.co.uk

david.evans@vega.co.uk

ABSTRACT

Advanced simulation and modelling technology has provided the military establishment with a new and unprecedented opportunity to experiment with concepts and doctrine in a way that today's constraints on cost and resources have made extremely difficult to realise by any other methods. Simulation and modelling technology enables a greater range of options to be explored, the flexible arrangement of real and the simulated participants and the rapid development and demonstration of new concepts, all leading to a powerful capability for shaping the future of military operations. This technology can be used to underpin experimentation which explores and defines concepts and processes for future doctrine such as the United Kingdom (UK)'s Network Enabled Capability (NEC) and Effects Based Operations (EBO).

Without some framework for managing the resulting information and to provide a wider scope for interpretation of results, the full benefit of this type of experimentation can remain unfulfilled. Based on work conducted on behalf of the UK Ministry of Defence (MOD) and the UK NITEworks[1] programme, this paper shows the benefits which have been gained from an architecture framework based model repository to provide a conceptual architecture for managing and exploiting experimental architectures and observations.

1.0 INTRODUCTION

Today's current climate of increased commitments of UK forces, the prominence of homeland security, changing threats coupled with rapidly evolving technology, increased complexity of integration and tighter controlled defence expenditure has lead to experimentation as the means of, providing an effective way to support the definition, development and delivery of Networked Enabled Capability (NEC) [1] and Effects Based Operations (EBO). Not only must this experimentation deal with the development of new capability, but importantly it must concern itself with existing capability as acknowledged by the UK Defence Industry Strategy [2];

> *"..unless systems engineering capability and vital long-term knowledge is maintained, it is little use investing in cutting-edge science. New technologies will have less benefit without knowledge of how they might be exploited and inserted into existing equipment."*[2]

[1] NITEworks is a Registered Trademark®

[2] Defence Industry Strategy, Section B.1 System Engineering, para B.1.4

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Within the UK, a joint MOD–industry experimentation programme known as NITEworks is at the forefront of this effort to deliver an experimentation environment to enable the UK MOD to assess the benefits of NEC and the options for its effective and timely delivery. NITEworks responds to specific issues posed by the UK MOD and uses experimentation to propose solutions in terms of changes to:

- operational development, expressed as changes to concepts and doctrine;
- warfighter development, in terms of how current capability is deployed;
- capability development, whether through enhancement to existing equipment or development of new equipment.

After the completion of several experiments[3] NITEworks recognised that there was potential overlap between experiments and this could be exploited to gain additional insight into the NEC issues that NITEworks addresses. An experiment addresses a set of specific issues raised by the MOD community. The experiment is constructed to reflect a specific operational context and system configuration, and reports specifically on the issues it is addressing. In April 2005 work was started to develop and demonstrate a methodology and process to enable this additional value to be obtained from across a number of experiments and external references. The aim was to find an approach which would enable observations from different experiments to be used to inform common elements from the experiments, and to promote the ability to learn about the general from the specific. This paper describes a process and methodology designed to achieve these aims, and the lessons that have been learnt in developing a conceptual battlespace architecture to realise its value.

2.0 BACKGROUND

2.1 Integration Authority

Within the UK MOD acquisition community, individual Integrated Project Teams (IPTs) are responsible for delivering specific equipment programmes, but in many cases the military capability sought can only be realised through the interoperation of two or more projects. This can only be achieved through the close co-ordination at the planning and design stages, and for the integration and testing of the related equipment before delivery.

The Integration Authority (IA) has been established within the Defence Procurement Agency (DPA) to facilitate these activities to ensure a coherent acquisition of military capability. Part of the IA activity is to provide an architectural centre of excellence; to develop an architecture framework (i.e. MODAF[4]) and develop an architectural representation of the battlespace. In support of these objectives the IA has commissioned the development (by VEGA Group PLC) of the Integration Services Support Environment (ISSE) as a combined MODAF compliant, EA modelling and architecture repository solution.

2.2 NITEworks

NITEworks is an innovative partnership between the UK MOD and Industry to deliver experimentation in support of NEC. NITEworks provides an experimental environment that allows the UK MOD to asses the benefits of NEC and the options for its effective and timely delivery. The partnership arrangement enables the UK MOD and Industry to gain a common understanding of the problems faced by the warfighter, and to work together to identify solutions, drawing on the expertise offered by Industry. NITEworks seeks to [3];

[3] NITEworks refers to an experiment that addresses a set of specific issues as a 'theme'. For the purpose of this paper, the term 'experiment' has been used.

[4] The MOD Architecture Framework (MODAF) is an Architectural Framework which has been designed to meet the specific business and operational needs of the MOD. (see www.modaf.com)

- Gain an understanding of NEC based on the UK MOD's priority issues across all the lines of development;
- Demonstrate the value of experimentations to NEC;
- Identify where innovative technology could be exploited.

The NITEworks team is made up of core personnel from the UK MOD and industry who work as a single, integrated team. The team is supplemented by additional resources to provide specific expertise to support dedicated experiments.

3.0 GENERALISING THE SPECIFIC

Looking at NITEworks as a whole, there are three issues arising from the way experiments are conducted. Firstly, how can the knowledge (which is documented in the form of observations and recommendations, of which there are plenty) acquired during one experiment be meaningfully re-used. Secondly can the observations and recommendations made in the specific context of one experiment be applied to other similar circumstances. And lastly, and to some extent predicated by the first two issues, can the results of previous issues be used to address new issues.

Since NITEworks experiments are conducted to address specific issues within a specific operational and system context, the challenge is to establish a broader environment in which the specific elements of an experiment can be either generalised or related in a meaningful manner to more general concepts. If this is possible it should then be feasible to apply the experimental findings to other specific circumstances identified by the general, or information which is gathered about a number of examples of the general can be used to build evidence for wider recommendations for operational, warfighter or equipment development.

For instance, suppose an experiment makes observations about the targeting process for smart munitions within a Brigade HQ. Then it would be sensible to look how these relate both to HQs in general (that is to the targeting process in a general "Command Node" and also to targeting process for general munitions). This can than be potentially used to make recommendations about other specific "Command Nodes", such as a Combined Air Operations Centre (CAOC).

Of course the notion of generalisation, and analysis of the features of concepts and relationships between them, is the stuff of the related disciplines of "class modelling" and "taxonomy". Through the application of ideas from modelling in general, and taxonomy, the notion of a "conceptual battlespace architecture" grew. There are two types of input to the conceptual battlespace architecture observations and recommendation from experiments, concepts and doctrine. Generalised entities (such as "Command Node") and their features (both properties and behaviours) and relationships were derived both from observations and recommendations, and from concepts and doctrine which were also used to index and classify the resulting conceptual entities.

To sum up the problem in an aphorism, the premise on which the use of conceptual architectural modelling is based is that the sum is greater than that of individual parts. That is, within NITEworks the combination of the results of a number of different experiments, together with information from other sources, should provide a greater understanding of NEC than that could be obtained from a single experiment.

The result was a conceptual battlespace architecture with the following objectives:

- **Improved capability to deliver future experimentation.** Future experiments could identify and reuse existing knowledge to enable an understanding of the problem domain to be achieved quicker and hopefully cheaper and, by drawing on the aggregated knowledge, hopefully better.
- **The provision of derived knowledge from experimentation**. The accumulated and derived knowledge from a number of experiments will provide a better understanding on how to realise NEC. The availability of this derived knowledge can be used to support ongoing issues or may even replace the need for future experimentation into the issue.
- **An enhanced architectural description of the battlespace.** The consistent and coherent incorporation of architectural material from a range of activities will provide an improved architectural description of the battlespace that will support the wider UK MOD community and in particular the IA in developing a battlespace representation.

In order to fully realise the desired benefits of the adopted architectural approach would require the ability to construct queries based on an underlying meta-model which facilitate analysis of complex relationships within the architecture, together with the ability to manage an extensive repository of consistent models. The realisation of this approach was a conceptual battlespace architecture with the key features shown in Figure 1.

Situate experimentation in the Battlespace.	The ability for current and planned experimentation to gain an initial understanding of the problem domain to enable the identification of potential areas of overlap and reuse with existing experimentation and to identify stakeholders.
Carry out semantic searches of Knowledge.	To overcome the inevitable variation in terminology a semantic means to identify potential areas of knowledge for reuse.
Generate Battlespace Templates	The means to reuse architectural understanding in the generation of new experimental architectures through the use of templates and patterns.
Generate Derived knowledge to support both new experimentation and doctrine.	To support the collation of like meaning things to enable an analyst to derive and capture knowledge to support future reuse.

Figure 1 – The 'key' features of the conceptual battlespace architecture.

4.0 THE CONCEPT

4.1 Conceptual Battlespace Architecture

The conceptual battlespace architecture is the elicitation of concepts, patterns and trends from the Battlespace[5] represented in experiments, which are then conceptualised to enable them to be re-applied in different areas of the Battlespace without the need to undertake experimentation. In essence, the aim is to identify the fundamental rules that govern the Battlespace and then represent these as architectural patterns and observations which can then be reused. The approach is analogous to the identification of patterns in software engineering [4], which in turn have been developed from the recognition of the importance of patterns in constructing traditional (building and city) architecture expounded by Christopher Alexander [6].

[5] Within the context of this work the term 'Battlespace' refers to the domains of the experiments, architectural representations and doctrine that have been used as source information.

An overview of the structure of the conceptual battlespace architecture is shown in Figure 2. From a range of source information[6] (that describes the battlespace) a number of entities are derived and classified into an architectural framework. These entities are then abstracted within the framework to identify commonality and to enable aggregation to occur. These 'conceptual entities' represent the conceptual battlespace and are used to support the development of architectural patterns. These patterns are subsequently expanded by observations, and form the building blocks of the whole conceptual architecture.

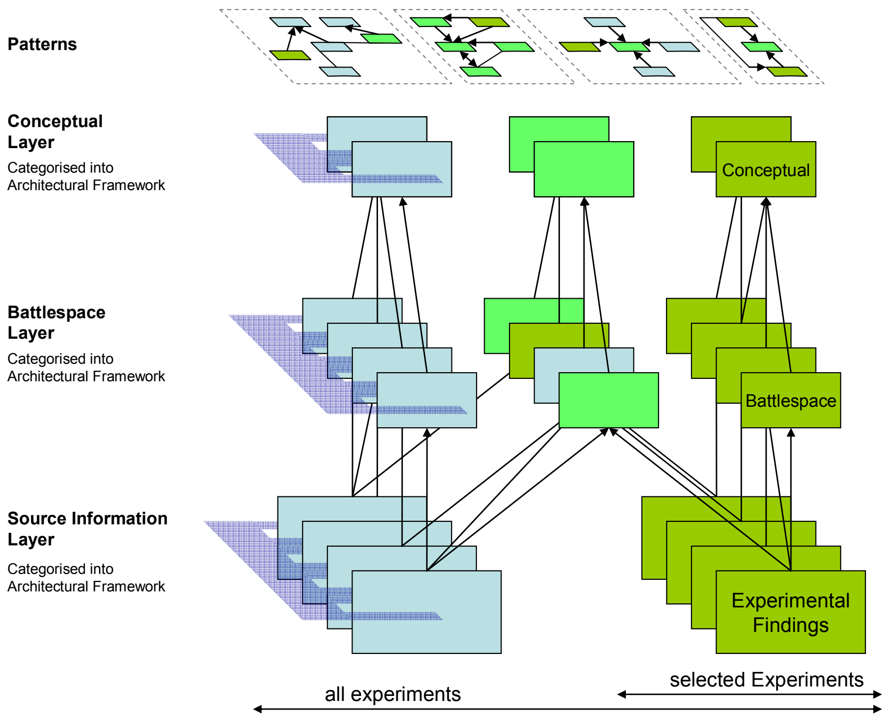

Figure 2 - An overview of the elements of the conceptual battlespace architecture.

4.2 The Need for an Architectural Framework

Within each layer of the architecture a means is required to enable the identification and collation of like entities, and to provide a structure to support the construction and maintenance of the model. An architectural framework is the obvious approach to realise this, and the Zachman Enterprise Framework[7] [4] was adopted. The Zachman Framework is widely used in industry, and unlike other frameworks, it provides a structure, in the form of a matrix, according to which information can be directly classified. Only the top four layers of the Zachman Enterprise Framework were used, as only these layers were warranted by the scope of the available source information. Additionally, in order to provide a reference point for stakeholders, cells within the framework were given a military tag. The adapted Zachman Framework is shown in Figure 3.

[6] For example experimental findings, experimental architecture, doctrine, concepts etc.

[7] The Zachman Framework for Enterprise Architecture™ is a trademark of John A. Zachman and Zachman International

	Data	Function	Network	People	Time	Motivation
Scope	**OPERATIONAL DRIVERS** List of things important to the business	**OPERATIONAL CAPABILITY** List of processes the business performs	**BATTLESPACE/ STRUCTURE** List of Locations in which the business operates	**STAKEHOLDERS** List of Organisations Important to the Business	**PROGRAM** List of Events Significant to the Business	**STRATEGIC EFFECT** List of Business Goals/Strategies
Business Model	**OPERATIONAL INFORMATION** Semantic Model	**OPERATIONAL PROCESS** Business Process Model	**OPERATING ENVIRONMENT** Business Logistics System	**OPERATIONAL ROLE** Work Flow Model	**PROGRAM ACTIVITY** Master Schedule	**OPERATION** Business Plan
System Model	**DATA MODEL** Logical Data Model	**SYSTEM** Application Architecture	**DOMAINS** Distributed System Architecture	**USERS** Human Interface Architecture	Processing Structure	Business Rule Model
Technology Model	Physical Data Model	**IMPLEMENTATION** System Design	**INFRASTRUCTURE** Technology Architecture	Presentation Architecture	Control Structure	Rule Design

Key: **Military Context** Zachman Definition

Figure 3 – The first four layers of the Zachman Enterprise Framework with the addition of contextual named cells.

With the framework in place the source information can be analysed to derive and classify entities about which the experiment deal's with, for example Permanent Joint Head Quarters (PJHQ), Component Command (CC), Air Tasking Order (ATO), and so forth.

4.3 The Conceptual Battlespace versus The Battlespace

These derived entities are abstracted within each cell of the framework to identify common themes or relationships. For example PJHQ and Component Command could be abstracted into a 'Command Node'. These conceptual entities are in the conceptual battlespace layer, and start to enable different sources of information to contribute a common understanding to a similar concept.

For example, if two experiments are dealing with the planning processes in PJHQ and a Maritime Component Command (MCC) respectively, the findings can now be related through a common abstraction called 'Command Node'. This enables the experimental findings relating to planning in PJHQ and Maritime CC from both experiments to be applied to the conceptual 'Command Node'. If appropriate subsequent experiments dealing with planning for example in Joint Force Head Quarters (JFHQ), to identify and reuse these findings through the use of the use of the concept 'Command Node'.

This is obviously a simple example but with multiple abstractions through multiple cells of the framework, connecting a range of experimental findings and by further grouping the abstractions, a more detailed understanding can be reached. Additionally these connections through the layers can be used to start to quantify the synergy between different experiments.

4.4 Architectural Patterns and Aesthetics

A 'pattern' has been identified as "an idea that has been useful in one practical context and will probably be useful in other." [5] . By identifying common concepts across experiments it can be assumed that they will be useful to a future experiment that's dealing with the real world of operational, warfighter and equipment capability. In the context of the conceptual battlespace architecture the attributes, operations and interactions between conceptual entities are used to represent a pattern. Figure 4 shows a simple representation of a pattern for the abstract concept 'command node'.

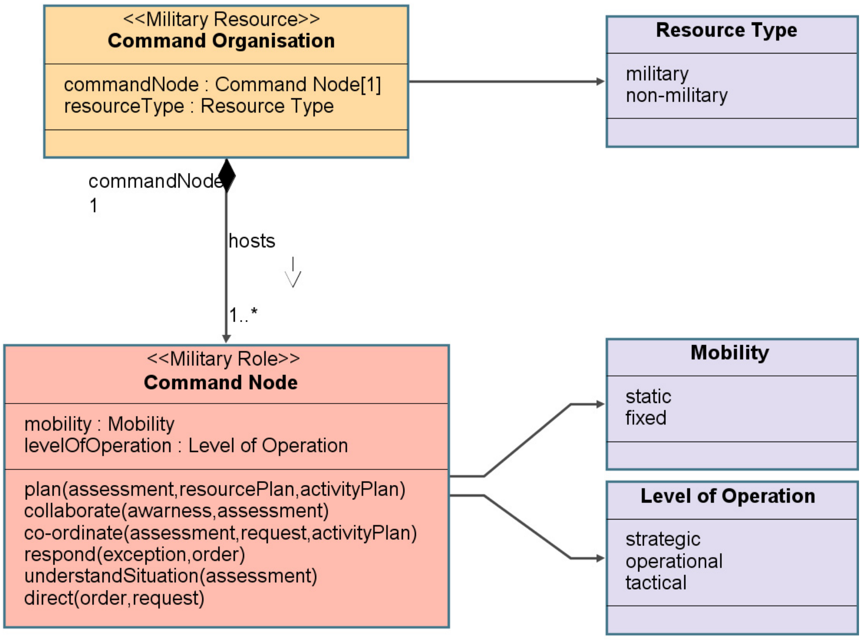

Figure 4 – A simple pattern of the abstract concept 'Command Node' showing the attributions and operations.

A pattern can be created about any aspect of the battlespace, and is not limited by size or complexity. Conceptual entities can feature in multiple patterns which means there is considerable cohesion between patterns. Through these relationships new patterns can build on or redefine existing patterns. Unfortunately these dependencies can cause considerable re-work as a change to one pattern can affect many. In practice it has been found that patterns should exhibit a degree of encapsulation to ensure that the interactions between patterns are manageable.

A pattern has associated with it textual observations that capture features or guiding principles that are taken from the source material and represent the 'softer' aspects of the experimental findings. They are akin to Enterprise Aesthetics [7]. For example, were the planning processes identified by the experiment dealing with PJHQ well formulated or did they have weaknesses.

4.5 An Architectural Frameworks supported by a Meta-Model

The development of the architecture is an iterative activity that continually incorporates new sources of information and develops patterns. Current source information includes;

- Experiment Findings;
- Experiment Architectures;
- Experiment Objectives;
- Concepts and Doctrine;
- MOD Architecture Repository (MODAR).

To ensure that the architecture is developed in a coherent manner a rigorous mechanism of traceability between all the entities needed to be enforced, which both supports configuration control and allows an incremental growth of the architecture both in terms of sophistication and value. This is underpinned by the use of a meta-model which provides the basis for the construction of consistent, coherent and queryable models.

An enterprise meta-model that has been developed by the IA was used in the conceptual battlespace architecture[8]. This meta-model has been implemented in the Integrated Service Support Environment (ISSE)[9] modelling application and was chosen as the modelling application to develop the conceptual battlespace architecture.

5.0 EXPLOITATION OF THE ARCHITECTURE

The basic premise in exploitation of the model is through the query of the relationships within and between layers of the conceptual architecture and the reliance of the adherence of the model to the meta-model. The following sections provide a brief overview of how the model has been exploited to deliver the previously discussed key features. It should be noted, that due to release restrictions, this paper focuses on the exploitation concept rather than on specific outputs.

5.1 Situating Experimentation in the Battlespace

Through the classification of entities within each layer of the model and the way they relate to other layers provides a means to situate the experimentation in the battlespace in terms of impact, coverage and knowledge, see Figure 5.

[8] At the commencement of this piece of work the MODAF meta-model (www.modaf.com) had not been finalised. It is planned that the IA Enterprise Meta-Model will merge with the now published MODAF meta-model.

[9] ISSE is developed by the UK Ministry of Defence's Integration Authority. ISSE itself has been developed as a SysML-based enterprise architecture modelling tool and as a repository of interconnected models of the elements of MoD's enterprise architecture.

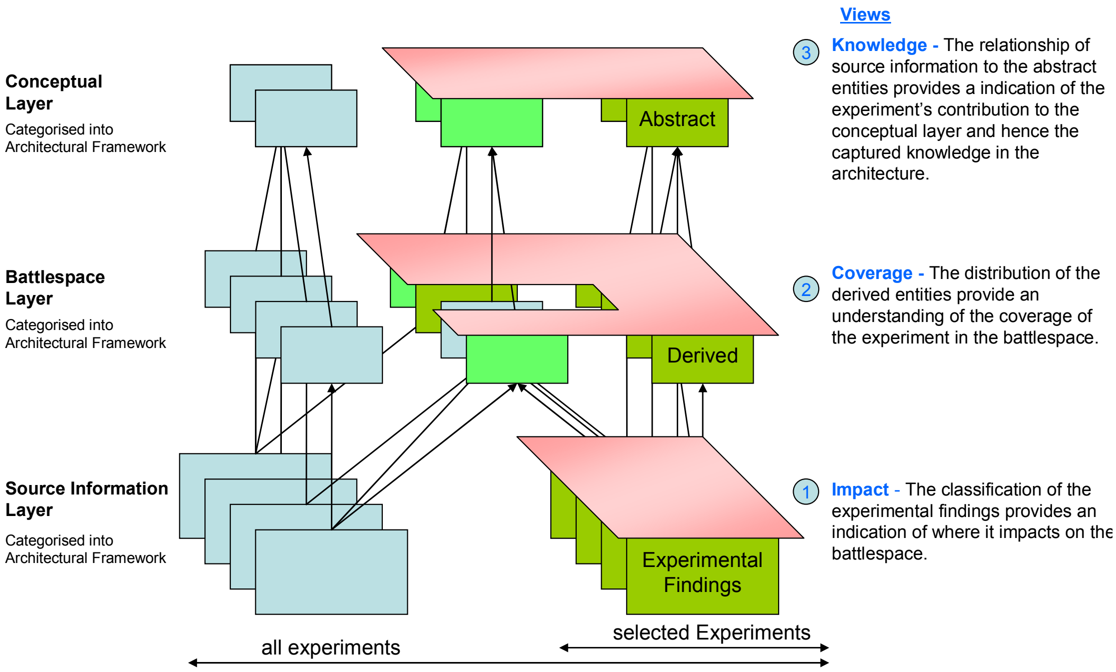

Figure 5 – The different ways experimentation can be situated in Battlespace in terms of Impact, coverage and Knowledge.

The same idea of understanding the relationships from one experiment through the layers of the model can be expanded to gain an understanding of how an experiment relates to other experiments in terms of impact, coverage and knowledge. This supports the identification of communality and trends to enable the generation of new patterns and to reinforce existing patterns. If an experiment can be referenced to another experiment, by the inclusion of alternate frameworks as source information, it follows that any experiment can be referenced against this alternate framework e.g. Defence Capability Framework (DCF), NATO Architecture Framework (NAF). This provides a means to translate concepts from one organisation to another that are using different frameworks. This idea is illustrated in Figure 6.

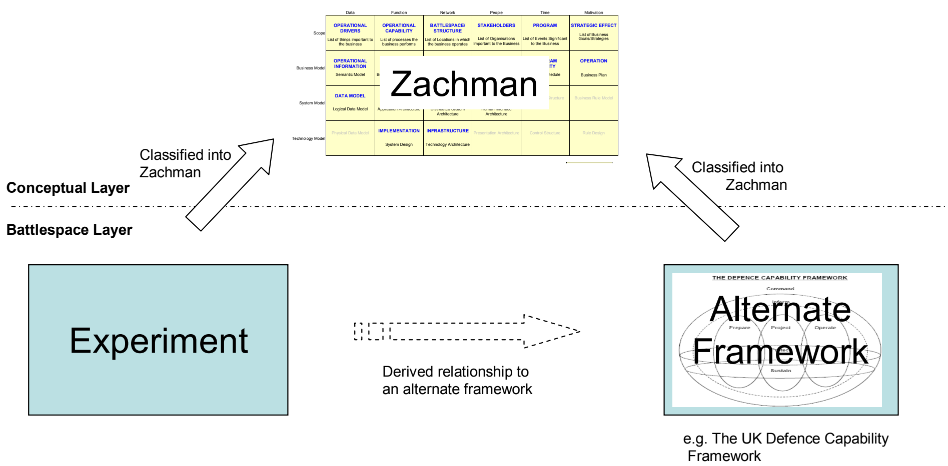

Figure 6 – By the mapping of an alternate framework into the Zachman Framework an experiment can be translated onto this alternate framework.

5.2 Semantic queries

Through the development of the model and the abstraction of commonality between entities within the battlespace to the conceptual layer the basis of taxonomy is formed. Furthermore, within each cell of the framework the conceptual entities are further abstracted to build on this classification. Additionally, the classification of the entities within the Zachman Framework and the meta-model provides additional meaning to the entities. With this understanding of the relationship between entities which in effect represent context, these relationships can be used to support searching by meaning: that is semantic queries. Primarily, this feature was used simply to provide the ability to overcome variation in terminology and interpretation of meaning between experiments.

For example, two experiments one dealing with command processes and the other dealing with logistics could both deal with PJHQ. The first experiment considered PJHQ an operational role that undertakes command processes, the second could consider it a resource that needs to be sustained. In this case PJHQ would be classified as an Operational Node and as an Operational Resource so the findings from each of experiment could be associated to two different representations of PJHQ. Additionally a third experiment could have been dealing with HQs and after investigation it was found that this was a short hand used by the experiment for PJHQ. By building relationships to a common 'Command Node' then subsequent searches from a 'Command Node' would reveal HQ and PJHQ are the same, in this case.

5.3 Generation of Battlespace Templates

In the context of this work, the relationships that have been captured within a pattern are used to generate architectural templates. The basic elements that would appear in a template are again classified into the framework and specialised to the appropriate conceptual entity(s). The relationships and attributes that are inherited by the template entities can be queried to generate architectural products e.g. MODAF views [8]. This is illustrated in Figure 7.

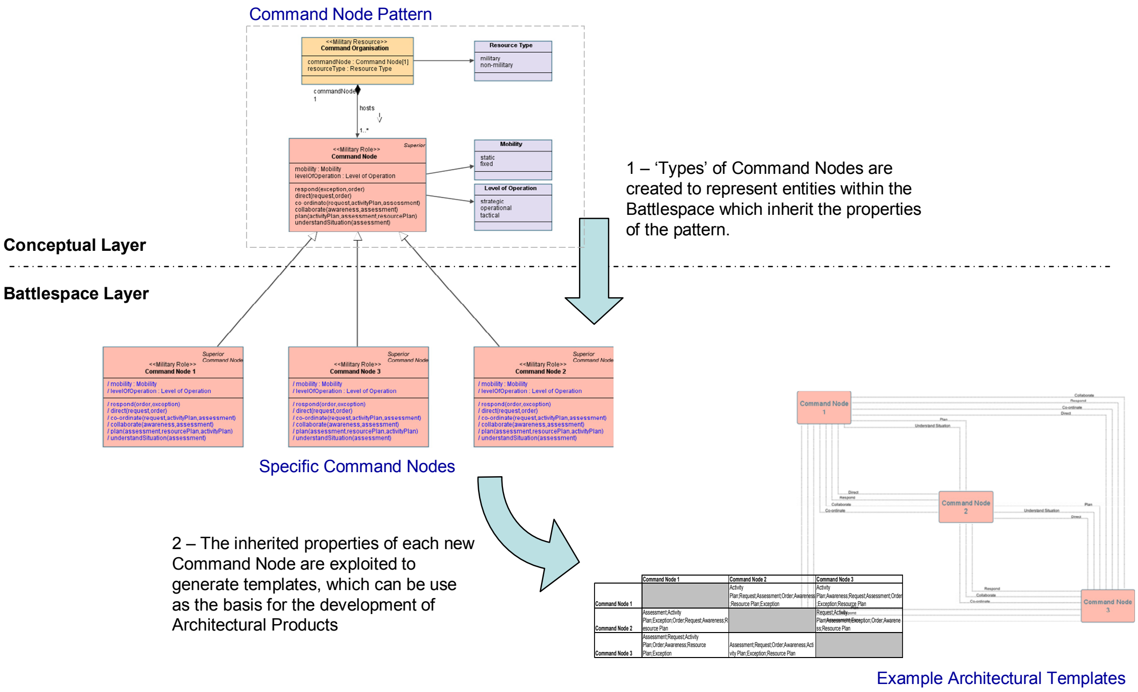

Figure 7 – Illustration of how a 'Command Node' pattern can be used to generate architectural products that contain multiple types of 'Command Nodes.'

5.4 Deriving knowledge to support both new experimentation and doctrine

The derivation of knowledge is from the result of analysis by a user. However the approach supports this analysis by providing the ability to;

- Collate 'like' things to support the identification trends and commonality;
- Manipulate findings into different contexts;
- Compare findings from multiple experiments;
- Relate experimental findings against Doctrine and Concepts;
- Relate experimental findings against an architectural representation of the battlespace;
- Query experimental findings by meanings;
- Act as a single repository of all experimental findings from an organisation.

6.0 LESSONS LEARNT

This work has been ongoing since April 2005 along with a number of activities to explore methods of combining the outputs from multiple experiments. At present the features set out above have successfully been demonstrated with the development of an exploitable architecture based on outputs from a number of experiments[10], doctrine and external architecture material. It has been found that in order to construct a conceptual battlespace architecture which will enable the maximum benefit it must be established at the heart of the experimental regime:

- **Context of Source Information** – The context of experiments must be thoroughly described to enable the source information from the experiment to be incorporated into the conceptual battlespace architecture to be exploited. Importantly, it must be possible to incorporate experimental observations at the appropriate level of abstraction to enable it to be re-applied in a meaningful manner. There is a danger of source information being so specific and de-contextualised as to make it irrelevant outside of the context of the experiment.
- **Depth of Source Information** – A 'critical mass' of information needs to develop to enable the conceptual battlespace architecture to be of value. This is achieved by the capture of source information to a suitable depth that is beyond simply capturing the experimental conclusions and should include the reasoning and justification behind these conclusions. Particularly the descriptions of the architecture used in an experiment provide context and reference to the real battlespace architecture it is addressing.
- **External Reference Material** – The source information derived from experiments needs to be complemented in the conceptual battlespace architecture by external reference material which describes both doctrine and capability architectures. Thus experimental findings to be placed against common frames of reference and be represented in commonly understood military contexts.
- **Generalisation and Classification of the Battlespace** – It is important to the usefulness of future exploitation that the conceptual battlespace architecture is created through a single method of information interpretation and analysis. Consequently the process of classifying and generalising needs to be rigorously controlled through peer review and a clear understanding of the architecture framework.

[10] Approximately the outputs and lessons learnt of 10 NITEworks experiments have been incorporated. A typical NITEworks experiment has duration of about 6 months with a team size of 20 plus people.

The UK MOD IA has established an MOD centre of excellence for architectural modelling which is populating a repository of interconnected architectural models. The repository contains architectural descriptions of doctrine and equipment capabilities. It forms a *defacto* MOD Architectural Repository (MODAR). A corollary of the observations above is that there should be a strong relationship between the information held in the conceptual battlespace architecture created by NITEworks and MODAR (in practice the IA's repository). The IA's repository contains the contextual information necessary for NITEworks experiments; conversely NITEworks experiments make observations about the architectures described in the repository. At the time of publication of this paper, negotiations to create such a relationship are taking place.

7.0 CONCLUSIONS

This paper has discussed an approach that has been used to elicit additional value from a range of experimentation, doctrine, concepts and architectures. The paper has identified a set of features that such an approach should exhibit. These features have been derived from the experience gained during work undertaken on behalf of the UK's NITEworks programme. This work has resulted in the concept of conceptual battlespace architecture and has highlighted the need for an architectural framework and meta-model to ensure the consistent and coherent development of exploitable architectural models based on observations derived from experiments. The paper has described the realisation of a conceptual battlespace architecture using the ISSE toolset, highlighted how the conceptual battlespace architecture can be exploited to achieve the proposed benefits and, on the basis of lessons learnt in realising the conceptual battlespace architecture, identified a number of necessary criteria for ensuring the maximum exploitability of experimental observations beyond the context of the original experiment. Meeting these criteria will ensure that experiments produce information that is re-useable beyond the motivation for the issues which originally led to the experiment.

8.0 REFERENCES

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