On the Use of Synthetic Environments for the Through Life Delivery of Capability

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ABSTRACT

The paper explores the relationship of Systems Engineering and Synthetic Environments to the delivery of Capability, particularly Military Capability. This relationship is explored from a through life perspective.

The development of Capability trade spaces, their definition, visualisation and exploration is considered. Importantly, the paper addresses the need for measurement within these trade spaces and how that overarching system evaluation can support 'Management by Maturity' concepts based upon the Lines of Development – including the non-equipment Lines of Development. This leads to the development of conceptual and Operational Analysis styles of operation that act, and lead naturally, to the modelling and simulation processes for system development, measurement and evaluation of effectiveness and performance. The impact of these ideas upon the execution of Systems Engineering processes and process lifecycles, and the role of Synthetic Environments, is reviewed. This leads to consideration of a 'new' Systems Engineering Process Lifecycle that offers significant opportunities for cohesive Through Life Management.

The major theme of System Evaluation and Measurement is developed through the critical role identified for Synthetic Environments. This is developed further through a delivery mechanism – the '5 Column Model' – that enables a consistent' whole life' programme perspective to be articulated within the TLMP. This perspective engenders an integrated view of all aspects of the programme – rather than solely the product – based upon continuous and developing system evaluation. Further, this framework is developed and executed on behalf of all system stakeholders, across all Lines of Development and thence supports the overall delivery of military capability in a structured, defined and manageable fashion.

The 'Transformation' theme is considered throughout the paper via a series of comparisons, and the discussion considers the impact of and investment necessary to implement the proposed new processes, the process lifecycle etc. on the ease with which these changes – many of which are cultural – may be achieved.

INTRODUCTION

'"Transformation" is the process of changing form, nature or function.' So suggests the USJFCOM home page [Ref. 1: www.jfcom.mil/about/transform.html], which goes on to indicate the implications of transformation upon;

- military forces

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- military culture and doctrine supporting the forces
- war-fighting functions to meet the complexities of new threats et al.

In a much broader sense however, transformation can be applied to a large spread of activities within the defence environment. A longer, but still incomplete, list of activities that have to be 'transformed' or where 'transformation' occurs can be expressed as:

- Equipment performance *to* Military Capability ensuring operational capability as a recognised output
- Platform centric perspectives *to* network centric and beyond to service centric
- Attrition based planning *to* a broader effects based planning perspective
- Stand alone *to* integrated to interoperable
- Requirements *to* specifications (in a capability focused acquisition process)
- Analogue *to* digital
- Bespoke *to* commercial
- UPC focused procurement *to* integrated through life capability management focused acquisition
- Confrontational contracting *to* partnering.

This paper considers a small, related number of these transformation areas and considers the role of measurement and evaluation in order to establish the value and focus of the transformation. The thread chosen for this paper through these themes explicitly includes the Capability Definition problems, the move from standalone systems to integrated and thence offers a view of the move from an UPC focused world to an integrated capability based through life perspective. Along the way, many of the other transformation topics are noted.

Clearly these transformation issues have different perspectives depending upon whether the observer is in Ministry – buying – space, or industrial – selling – space, and indeed the bulleted list above could be ordered to reflect those differing views. However ultimately the views must be symbiotic, i.e. mutually beneficial, so that the buyers have something to buy, and the sellers understand what must be produced.

WHAT IS CAPABILITY?

Modern defence acquisition is today expressed less in terms of items of equipment and more from a 'capability' perspective. This move from the tangible to the abstract gives rise to several issues and conflicts – not least of which is one of definition. Ref. 2, [Daw A, 'New Process and Structure Thinking for Capability Development' 9th International CCRP Symposium Sept 04 Copenhagen] highlights issues arising from the differences between the customer and supplier definitions of capability in the (UK) defence domain. A précis of that discussion is presented here.

In the UK, the Joint Doctrine and Concepts Centre offers a framework (Figure 1) in which 7 'capabilities' are defined as the primary goals of the military domain and they are expressed as verbs; Command, Inform, Prepare, Project, Protect, Sustain and Operate [Ref. 3: JDCC Joint Concepts Paper www.mod.uk/jdcc/concepts.htm]. This so-called Defence Capability Framework represents a 'Customer' perspective of Capability, and to express these capability needs in terms of a satisfactory implementation whereby solution options may be discussed, requires further analysis and breakdown.

The industrial perspective however is generally constructed around the 5 elements of People, Process, Product, Access to Technology and Facilities (as represented in Figure 2). The relationship between these tangible assets is also clearer cut than definitions expressed in abstract terms, as each offers some contribution to the development and subsequent sale of product – the product is the focus of the Industrial capability definition.

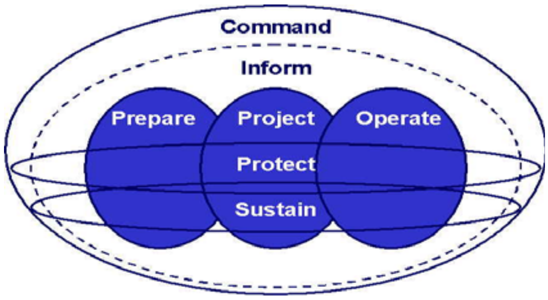

Figure 1: UK Joint Doctrine and Concepts Centre 'Defence Capability Framework', expressing the 7 'verbs' of Operational Capability.

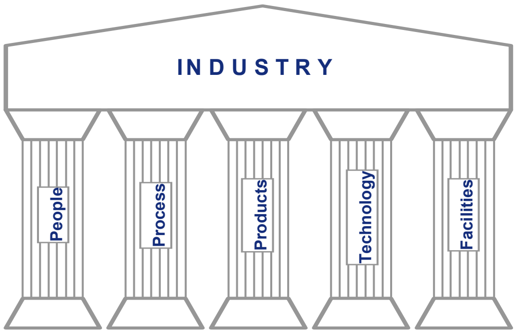

Figure 2: The 5 Resource classes of the Industrial Definition of Capability.

Clearly, without some degree of effort, these perspectives are not compatible (indeed in some circumstances they are in conflict) and a middle ground must be sought if Capability-based acquisition is to be a reality.

In the UK, an approach to this middle ground is found within the concept of the Line of Development (LoD). Originally structured from military operations, the LoD concept has offered a third interpretation of capability and comprises currently 8 elements – the Training, Equipment, People, Information, (Tactics and) Doctrine, Organisation (Force Structure), Infrastructure and Logistics (giving rise to the acronym TEPID OIL). From these components capability is 'derived' by having the;

'right equipment and information, operated to known rules of operation by trained personnel who are supported in theatre within a recognised and known organisation and environment'.

[NB: It is appreciated that much current thinking [Ref. 4: Unpublished research and study activity for the UK MoD Equipment Capability Group (Michael Collins, Andrew Daw, Richard Westgarth)] defines a 9th Line of Development as Industrial Readiness. As this construct has not been recognised formally, it is not included in this analysis, although such a development line adds considerable weight to the proposed hypothesis.]

Each of these interpretations is appropriate for a particular audience and perspective. A primary issue is the reconciliation and combination of these perspectives so that an appropriate customer – supplier – user relationship can be established for the mutual benefit of the contributing parties. If the LoD concept and structure does represent the middle ground, bridging the gap between Customers and Suppliers, the 8 constructs form the implementation mechanisms for the delivery of capability, rather than an explicit definition. If capability delivery is to be achieved from the design of a system solution that 'integrates' the 8 Lines of Development, a comprehensive overarching view of the system to ensure that the emergent properties and system trades are managed is essential.

The operational environment in which these perspectives must be reconciled is also 'transforming'. Today the concepts of Network Enabled Capability or Network Centric Warfare are central to the defence domain and the 7 UK Capability verbs must apply within such an operational environment. Thus the ideas and issues of Network Enabled Command or Sustainment or Projection must be considered within the design solution and concept thinking and then implemented.

A primary transformation therefore is one between 'verbs' and 'nouns' and the overall integration and evaluation of the outputs to establish the resultant capability (as expressed through the aggregation of contributions from each of the Lines of Development).

THE 'VERBS' TO 'NOUNS' TRANSFORMATION THROUGH SYSTEMS ENGINEERING?

The traditional process for Systems Engineering and the development of products is the 'V' model as illustrated in Fig 3 with particular emphasis upon the left hand side of the 'V'. This has served well in various implementations for some time – particularly through the formal processes of Requirements Engineering, System Analysis and Systems Design.

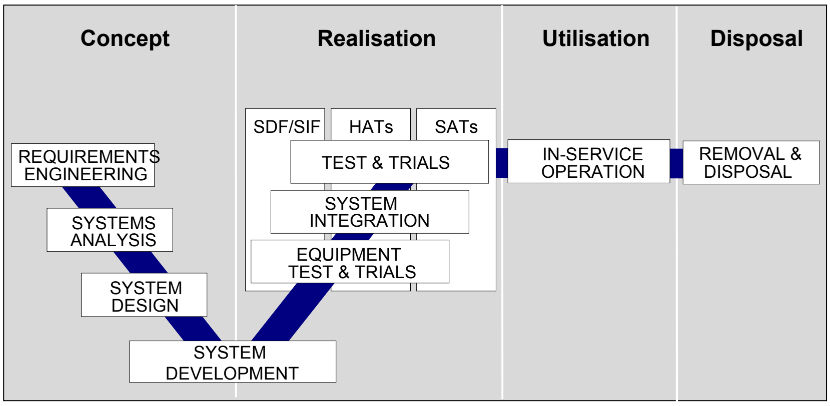

Figure 3: Traditional 'V' Diagram Systems Engineering Process Lifecycle.

The right hand side of the 'V' offers Test Acceptance and Integration – each of which enables validation and verification of the design and product. But it is product based. How do the complex inter-system reactions take place and get valued within this structure? It is postulated that this type of 'sequential' process is inadequate and ill posed for the much broader canvas that is required when considering capability.

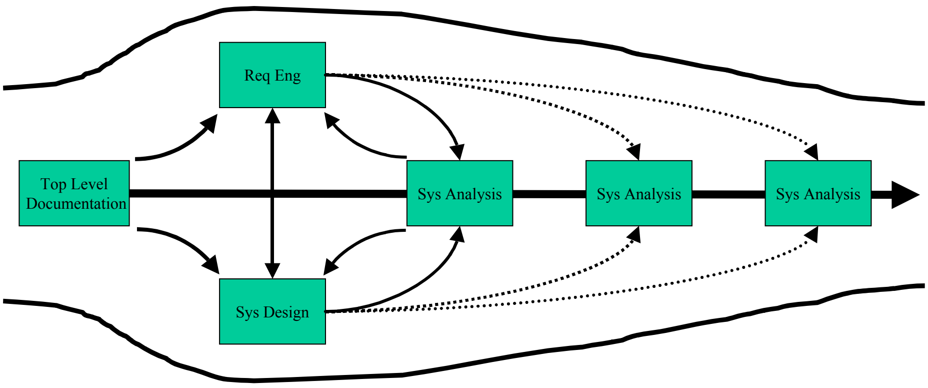

Figure 4: Reaction Chamber Systems Engineering Process Lifecycle (Adapted from Price and John [Ref. 5]).

A new model of the Systems Engineering Process Lifecycle has been proposed [Ref. 5; Price S.N & John P. The Status of Models in Systems Engineering IFORS 2002, RMCS Shrivenham], illustrated at Figure 4, and nicknamed 'The Reaction Chamber'. Ref. 2 presents a more detailed comparison of the traditional

'V' model with this new 'Reaction Chamber' representation, and also describes a number of extensions to that original model that offer the required articulation of capability development.

Together with a formal recognition that certain aspects of those activities must occur in parallel, the new model places Systems Analysis processes in a much more dominant and important role, as the continuous, through life tail of the process lifecycle. This tail now enables a more defined and coherent through life management policy to be adopted as each of the systems analysis activities offers the opportunity for a measurable system delivery.

An immediate extension of the model is to map the capability definitions noted above to this model (as indicated in Figure 5). The conceptual definitions offered by the 7 verbs of Command, Inform, Prepare, Project, Protect, Sustain and Operate form the requirement and sit in the upper half of the model – this is the 'what is required'. The Industrial definition sits in the lower half – the 'how' it will be delivered.

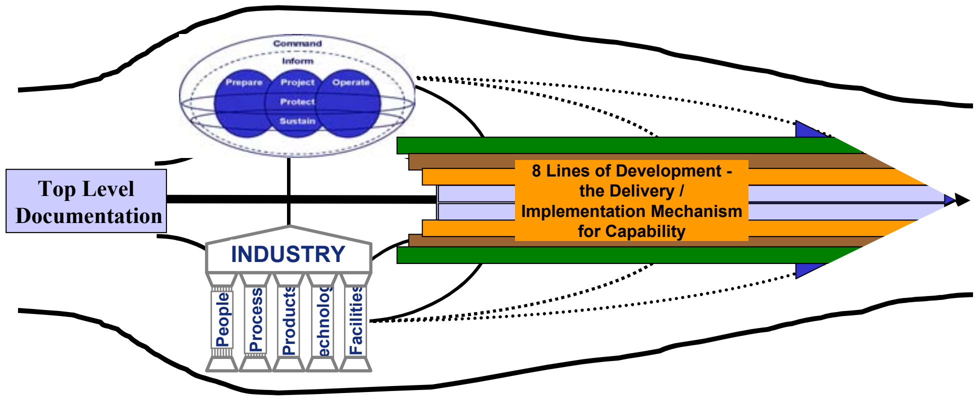

Figure 5: Capability Mapping to Reaction Chamber Process Lifecycle.

The Lines of Development – as implementation and delivery mechanisms – then represent the tail of the model reflecting the overall system analysis activities. It is through the interactions and interplays of all these 'development lines' that the capability is delivered, the iteration and balancing of the system is achieved and the overall management of the capability is effected. The issues associated with the delivery of capability through these types of construct are not just technical – commercial and financial issues are just as important to the ultimate success, as the overall integration of the design problem can only be achieved through a comprehensive partnering arrangement that brings all parties together in a supportive and beneficial way.

An important aspect of the mapping is the 'position' of the implementation mechanisms. In this mapping, the Lines of Development overlay the systems analysis activities and extend those activities through life. They sit along the 'operational shaft' of the model linking the Top Level Documentation – supported as it is by the broad raft of Operational Analysis and assessments – to the detailed system measurement and evaluation activities associated with the solution i.e. the analysis issues of effectiveness and performance. Through this positioning, analysis across all aspects of the enterprise forms an essential element in the delivery of capability, as implemented by the components identified as Lines of Development. If the Industrial Line of Development is also included in this model, then clearly the concepts of measurement and evaluation can be applied to the concerns of research and focused investment as industry considers the support of a capability throughout its service life.

Such a mapping also enables a much more coherent ability to address the management of change – customer needs both increase and decrease – and the ability to accommodate and manage the effects of change is vital in circumstances of limited procurement / acquisition budgets, timescales etc.

Some Impacts and Implications of the 'New' Model

A detailed discussion of this new model is available at Ref. 2 concerning the implications of 'above' and 'below' the line formed by the central shaft moving from left to right in the diagram. The issues detailed below are concerned with the detailed interactions of the processes within the model as applied to the delivery of capability. The discussion concentrates upon the issues arising from Trade Space definition and evaluation, the management of capability acquisition programmes in part through the required maturity of the Lines of Development and finally the development, management and support of the capability through life, via an integrated, capability-based Through Life Management Plan.

The Parallel Execution of Requirements Engineering and System Design – The Trade Space

The formal link illustrated between the requirements engineering and system design processes must not be taken as an opportunity to limit or mitigate the requirement through the application of reality. The need remains the need – which of course should be justified and supported through analysis, experience etc. The link expresses an opportunity to allow the two processes to interact and be cognisant of the activities of each other. The link supports the definition of a range of interaction activities such as trade space analysis and evaluation. Within this model, this crucial activity is undertaken in a fashion that is fully supported by the development and interpretation of various top level policy, environmental constraints, operational boundaries, all expressed within a measurable and measured framework. Thus the trade space definition work seeks to articulate the requirement and at the same time illustrate the physical space – as described through system characteristics – to provide visibility and visualisation of the solution opportunities without prescribing the solution specification. The line represents the debate between the requirement and the state of the currently achievable, which is then developed through life to be appropriately compliant. This enables the definition of the trade space.

Currently significant work is under way between the UK Ministry of Defence and Industry (through the Equipment Capability Group (ECG)) to develop processes and opportunities for debate that will enable a coherent definition of this trade space. A set of processes and schematics has been defined that enables the constraints of the system solution to be expressed and the resulting trade space visualised. A simplified schematic is offered at Figure 6.

The objective of the trade space identification and analysis is to determine the solution volume in which a viable / feasible solution may sit. It is NOT about determining the exact solution. The trade space is defined in terms of solution attributes and characteristics that any solution must exhibit in order to be compliant. A range of factors including policy, industrial constraints, performance issues, financial constraints, the scenarios of operation, the tactics doctrine and policy of use, inter alia will bound this trade space. The contention is that each of these issues can be expressed in a numerate fashion and then represented upon a graphic, in generic terms. Further the trade space expresses compliance against a range of parameters – not just the more obvious and straightforward traditional equipment performance parameters.

The volume that is contained by these constraints and issues is then the trade space in which it is viable to seek the most cost effective solution. If a number of generic programme attributes are identified (such as numbers of platforms to be procured, or their size or their payload opportunities), many of the constraining issues can be expressed within the graphic.

Using a naval example, in size terms a maximum vessel size (tonnage) can be assessed from the perspectives of industrial build capacity and / or the ability to sustain that size of vessel in both maintenance and husbandry terms in service and dockyard / berthing support. Thus a maximum limit can be identified. Conversely the minimum size can be debated and identified through consideration of the operational scenario (Sea State 8 or 9 in the South China Sea is likely to preclude a rowing boat / OPV) or through discussion about the minimum payload that would be worthwhile. Similarly in 'numbers' terms the minimum number constraint represents a view of the smallest numbers of a project that it is viable to buy, whilst the maximum represents the outcome of the detailed OA work and (ministry / military) capability gap analysis.

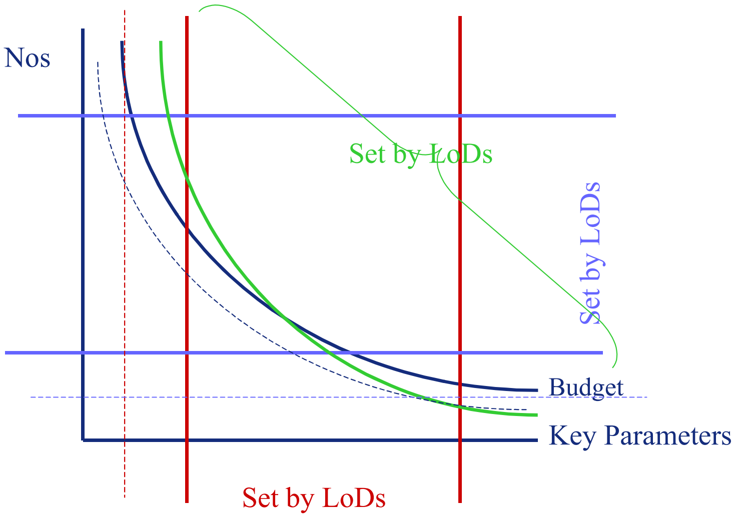

Figure 6: Trade Space Identification highlighting boundary constraints formed by policy and Lines of Development.

Other forms of constraint such as manning and training may place additional profiles upon the programme, such as having sufficient numbers of ships to maintain a particular manning development policy, or the recruitment profile expected through life. Similarly a profile of possible budget constraints might conclude that the finances available would allow only limited numbers of the largest possible solution size, whilst permitting the procurement of sufficient smaller vessels.

This type of diagram also permits the broad analysis of trends and initiatives enabling informed views to be taken of force structure issues, initiatives such as NEC / NCW etc.

The process of development of such a diagram is also informative. Initial views of the trade space can be derived from simple analysis of current policy and constraints, national interests, resource / asset limitations etc. The debate can then be expanded to include discussion of the 'what if' questions, such as;

- Relaxation of the constraints
- Investment in particular resources (such as infrastructure)
- Adjustment of operational needs and commitments

A Management Opportunity of Programme Integration through the Lines of Development

Figure 7 illustrates a means of establishing programme management mechanisms from the Lines of Development. Currently readiness levels are applied only to equipments (through the ideas of TRLs) and to some extent of systems through System Readiness Levels (SRLs) and System integration Readiness Levels (SiRLs). By developing equivalent measures and metrics for the non-equipment Lines of Development the opportunity exists to determine the evolving maturity of the proposed capability solution.

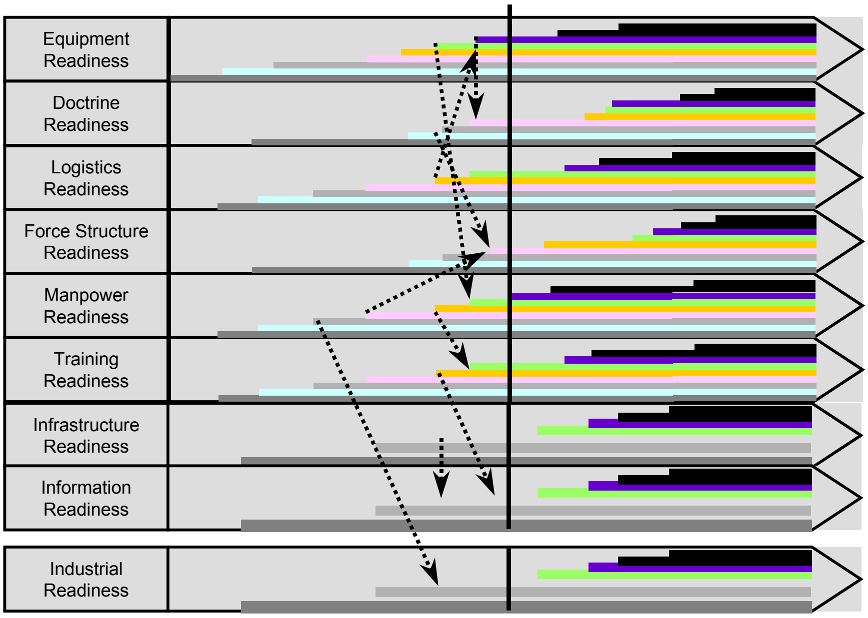

Figure 7: Programme Management via Lines of Development Maturity and Readiness (inc. Industrial contribution) illustrating programme dependency identification.

Using the schematic of Figure 7, it is possible to consider a range of programme attributes, such as:

- Programme dependencies across the LoDs
- The wide variation in development timescales of the individual LoDs – long lead items could now be equally as applicable to non-equipment issues (such as manning (through recruitment)) as to equipments
- Programme risk through schedule delay, programme opportunity through acceleration

Recognising these issues and opportunities as being directly pertinent to the ongoing management, these LoD perspectives can also support major changes in business process through cultural adjustments. To achieve this consider the construction of the trade space:

- The trade space 'contains' the desired solution at ISD, so define LoD targets for ISD across all LoDs; as noted above establishing targets and readiness levels for non-equipment LoDs
- Mentally consider ISD and look back – what has to do be done to get here. This enables the establishment of the inter-LoD programme relationships and dependencies and leads to the identification of appropriate programme review opportunities – based on expected / required LoD maturity issues (and others). This is Initial Gate and Main Gate in the UK acquisition process
- These activities will also be instructive and key to looking forward from ISD using the Through Life Management Plan. The techniques adopted here (i.e. readiness levels and maturity for all LoDs) enable the definition of a Through Life Management Plan that fully considers changing requirements, developing technical issues and the non-technical issues of cost and schedule etc. This style of ongoing capability development supports Management of Change activity.

To achieve all this however – no matter how many LoDs are formally defined – there is a need to consider and define an Industrial Line of Development. Unless Industry is involved and established within the programme there can be no guarantee that the resources can be found to design build and deliver the required equipment, training, sustainment packages etc.

The Development of an Integrated Capability-based Through Life Management Plan

One of the primary outputs from the Reaction Chamber Model is the development of an integrated, capability-based Through Life Management Plan (TLMP). Currently these plans – where they exist – are equipment / system based with a primary view of cost. This is not sufficient to provide appropriate detail for planning purposes in capability terms when considering the timescales and timeframes of the component parts (e.g. recruitment, training).

Consider a simple construct for the definition of the TLMP; the customer has an important System Measure of Interest which traditionally is required to improve over time to cope with increasing threats, improved performance etc. Consider also (as in Smart Acquisition) the opportunity to deliver 80 - 85% of the required capability quickly supported by a series of increments to the solution over time. The resulting staircase could look as shown in figure 8a.

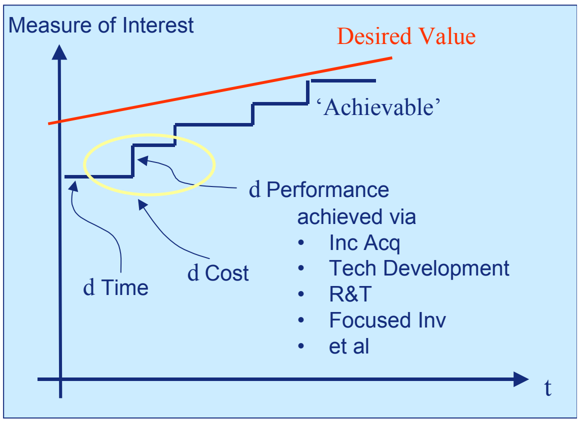

Figure 8a: Staircase Model of Through Life Acquisition.

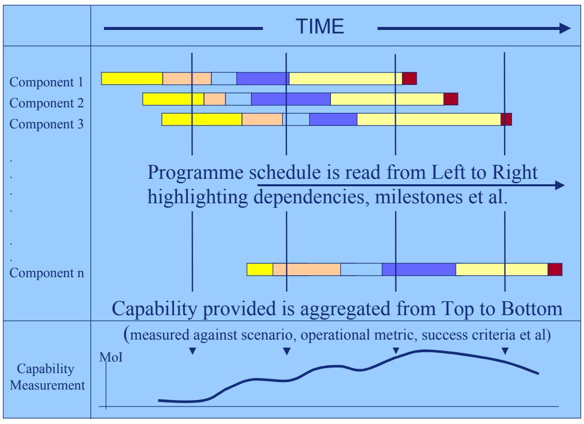

Figure 8b: Combined Gantt and Aggregation TLMP Representation.

The tread of the staircase is time, the pitch the expected capability increase wrt the Measure of Interest. To achieve this a programme must be established which can be costed / is costable. Hence the Cost Time 'Performance' trio of the UK Procurement Agency can be determined. The increase in capability is achieved across the LoDs through the standards tenets of Smart Acquisition (such as Incremental Acquisition and Technology Insertion) etc. but also through pull through of research, development, focused investment etc.

There are many additional elements that can be derived from such a representation but a key benefit is one of flexibility, particularly of industry to respond to radical changes in the measure of interest. A properly managed and contracted staircase offers considerable openness and visibility to the Ministry for planning purposes (both long term and short term), and to Industry who – in some cases – could be competed and judged not just upon the initial product but also on the quality and confidence of the supporting TLMP.

Schematically the TLMP can be represented as a typical Gantt Chart (figure 8b). At the highest level the rows of the Gantt chart represent not programme activities but components and their associated LoDs that comprise the capability solution system. Reading from left to right therefore provides a clear view of the schedule and interactions / dependencies between the component lifecycles – offering views of proposed in service, out of service dates, spend peaks in demonstration / manufacture, even start dates for future programmes to support an enduring capability need. This view is simply an extension of standard Project Management. Reading from top to bottom however affords the opportunity to 'sum' / aggregate the contributions to capability provided by the individual components at any one time and thence through life, and the simple graphic at the bottom of the chart represents some presentation method against a particular measure of interest from the customer. This can be established wrt scenarios, operational metrics (casualties e.g.), success criteria etc.

In these circumstances the TLMP now offers a consolidated view of the management of the Capability, not just the cost function of a particular piece of equipment or system as is currently the case. Such a Plan is predicated upon the ability to measure and evaluate the system and to understand the value or worth of an activity. It is in this context that System Analysis plays such a major role in supporting the transformation opportunities noted above.

IMPLEMENTATION SUPPORT – THE ROLE OF ANALYSIS

To implement the concepts presented herein requires particular emphasis on coherent and continued analysis. This analysis is a broader construct than that traditionally associated with Systems Analysis in the Systems Engineering Process Lifecycle and reflects the ability to seamlessly drive the Reaction Chamber model from the Top Level Documentation to the Effectiveness and Performance representations of the model tail. It reflects the need to evaluate and analyse options across multiple disciplines and techniques, building a coherent picture that combines the measurable objective technical parameters with the less tangible more subjective – so-called soft – parameters of the system. Further, the analysis must encompass a much more significant temporal representation – time is the primary parameter along the axis of the model. Thus in the environment of transformation, analysis is a fundamental tool in its achievement.

Integrated systems to deliver capability are now achieved not only internally within the equipment components but also across the LoDs and hence system measurement and evaluation must be extended across the LoDs and the value of their contribution, the relative importance and weighting of their effects must be assessed and incorporated into the overall capability calculation. The range of scenarios, operational contexts etc. must also be weighed and balanced – and balance here is the key. Given the current operational financial political economic conditions it is pointless optimising system solutions – system balance is crucial (expressed in some sense by the MoD as flexibility and agility). The balance of the system is achieved and must be understood through the overall integration of the Lines of Development, the policy and constraints placed upon the system – as expressed through a maintained Trade Space representation and TLMP.

In this transformational context, support to decision making is vital. Hence a primary output of all analysis is support of decision making. Analysis provides the evidenced information to support the ongoing development processes and system balances that provide cost effective long-term solutions to the capability needs. The traceability of decision making – based on a broad range of analysis techniques executed across the lifecycle – also provides a major component of the flexibility necessary to accommodate change. An underpinning feature of the integrated TLMP advocated here is the flexibility offered to pro-actively manage change through the lifecycle.

Thus, analysis spans the entire product lifecycle in support of such areas as:

- Requirements Definition, Articulation and Enumeration
- Trade Space identification and evaluation
- Assessing non-equipment Lines of Development contributions
- Concept Option evaluation and comparison enabling system balancing
- Integration and Acceptance
- Through Life Management
- Decision Making

Overall, the evaluation requirements are extensive, and need to be inclusive of a wide range of parameters and system attributes. The ability to evaluate and measure the constraints that are placed upon the designer in terms of safety, security and legislative requirements exacerbate the design problem and extenuate the difficulty of providing the appropriate performance elements that can be integrated to provide the required capability. The difficulty in 'thinking through' the transition from Platform-centric views through Network centric to Service centric is matched only by the difficulty in organising, in an optimum balanced fashion, the vast range of assets available. The development of multiple system representations, within an environment that enables the integration and evaluation of those views may enable such complexity management to be achieved. The ‘5 Column Model’ represents an opportunity to develop an embracing development environment for the optimisation of resources and the delivery of complex systems.

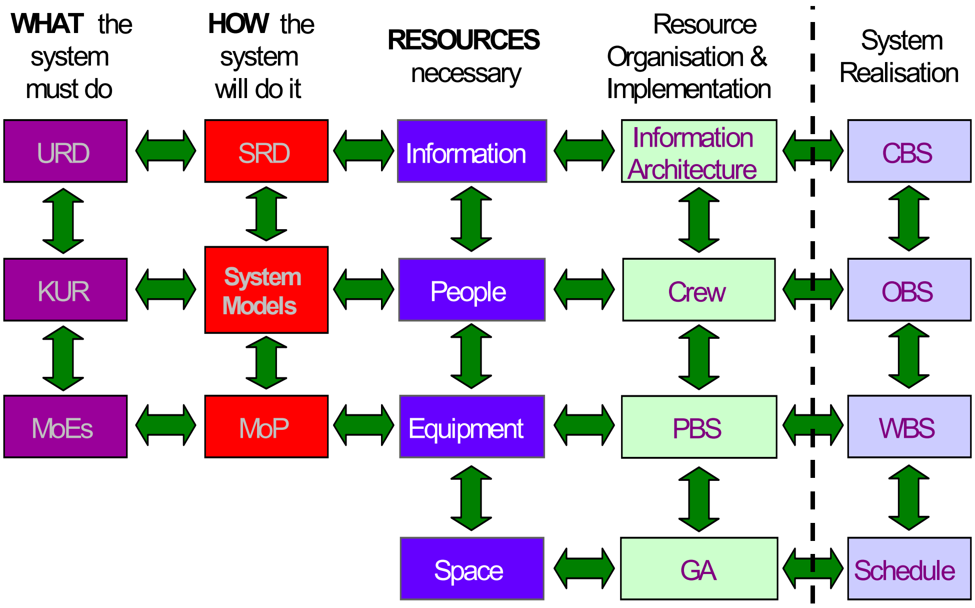

Figure 9: The 5 Column Model, illustrating the components of an over-arching development environment for system design.

[NB: This is a schematic representation of the links, offered for simplicity rather than exact detail. The important element of the diagram is the overall connectivity, rather than any individual ‘row based’ connectivity.]

Each of the columns represents a distinct view of the system to be addressed. Reading from left to right;

- 'What the system must do' expresses the key user requirements and capability needs as expressed in the top level documentation
- 'How the system will do it' contains multiple system representations where a range of techniques, such as functional modelling and business process modelling, address individual component performance, maturity and readiness issues
- the 'Resources Necessary' details those artefacts of the real world that are required to populate the execution elements of the system (the functions)
- whilst the Resource Organisation and Implementation column indicates how the necessary real world resources may be organised to achieve the required functionality and performance and thence the capabilities.

Each of the boxes in this model must be connected. The relationship of one element to those on its left, right, above and below illustrates a different perspective of the whole system. In the full population of this representation, the opportunity exists to ask 'what if' questions at any point, of any point within the system and derive a consistent coherent response for all stakeholders. Thus the model expressed here represents the overall System and Programme Synthetic Environment where the opportunities to interrogate the requirement, the design, the implementation etc. are brought together.

The 1st and 2nd columns provide the fundamental statement of the problem (the Customer stakeholder) and a source of system description via the 'System Models' box. This area of the environment contains a wide range of system representations to enable an inclusive view for all stakeholders. A key component of this area is the functional model of the system, recognising that the functions of war-fighting as expressed by the highest definitions of capability and military effect are unchanging; this system model represents the detail of what has to be accomplished. It is solution independent and hence makes no assumptions about the groupings or organisation of functions, of people, or other components of the world.

Having established the set of required functions and their associated attributes, constraints of the real world can be applied – this is the beginning of the definition of the system architecture. The 3rd and 4th columns articulate this initial physical world debate by identifying the resources and their organisational opportunities that are available (or need to be developed) for the solution system. The decomposition of the functional view offers the designer, the system procurer and the system user several key inputs to the achievement of capability. The 'organisation' of the functions initiates debate about the overall system architecture – at which point a range of activities can be brought together to establish system balance and understanding. From a design perspective, the groupings of various functions enables a detailed engineering view of manufacture and produceability. The interfaces defined by the functional groupings can be considered from a 'who does what perspective'; i.e. they offer opportunities to establish the human-machine interface (HMI) and its information exchange demands and identifies those aspects of system operation that are expected of the user (if any). Finally, the user can begin to understand more fully his position within the system and the demands to be placed upon him as an operator, maintainer etc. Thus the organisation of resources enables an inclusive view of the overall need and of the potential solution opportunities.

Clearly the investigation and generation of system balance can be considered at all levels. For the purposes of example, consider the 4th column – that of System Architectures and Implementation. This column represents the organisation of the fundamental system components;

- the information required,
- the people required,
- the products offered as putative solutions,
- and the environment in which they will operate (the physical General Arrangement of the solution).

These components represent stakeholders in the solution space and in UK capability terms form part of the 8 Lines of Development that comprise the capability delivery mechanisms. The requirements and associated need are expressed, the functional characteristics addressed and a potential set of resources necessary to implement them identified. How then are they to be organised in the most effective way? Addressing the issues vertically offers the opportunity to balance automation against people, products against space in the environment (with all the attendant safety issues) etc. Addressing the organisation horizontally, the system balance can consider the mappings of products to functions to cost, of people to training to performance, of information needs to usage and so on.

Within these connections and balances lies the need for performance. The 2 left-hand columns contain all the non-functional performance parameters of the system (the performance, capacity, timeliness, periodicity, reliance and reliability). As the high-level capability needs are decomposed and placed in context, individual measures of effectiveness and thence solution artefact performance can be derived.

Furthermore, such a view also enables and initiates a structured view of through life planning for not only the components of the system but also the capability required to meet the changing demands of the military environment, whether that change is initiated by a change, inter alia, in threat, demography, political intent.

The 5th column of this model actually represents the activities of a Prime Contractor in that his management view of the system is reflected in the Cost, Organisational, Work and Schedule breakdowns of delivery of the programme.

Model Application

The 5 Column Model operates well within the current UK Smart Acquisition initiative in that it enables a measured response and understanding to the problems of through life management not only of equipment but also of capability and thence for transformation. With its intimate support of Systems Engineering process development, the outputs from this model in terms of performance measures, capability statements etc. enable a through life view to be taken of the changing requirements in terms of the threat, the constraints of operations, of support and manning etc. Most importantly, each of these components can be measured and the overall integration of a system, through its many associated 'organisations of resource' can be achieved. The achievement of measurement enables debate upon value and priority and hence provides a framework in which informed trade-off activities and debates can be sponsored.

Any value and priority debate however must be inclusive of system stakeholders including procurers, suppliers, users, maintainers etc. Such debate must be undertaken in the framework of an informed partnership supporting appropriate understanding. The flexibility, adaptability and versatility demanded of national assets within the current war-fighting environments requires coherent and consistent application of development processes and implementation to ensure the correct overall system balance in capability and performance terms.

This is a Programme Synthetic Environment for the delivery of Integrated Capability.

CONCLUSIONS

The transformation activities currently underway within the defence environment are numerous and inter-related. A major initiative is the development of concepts based on capability rather than simple equipment views. The provision of military capability requires a coherent and consistent environment in which all stakeholders can participate and contribute. The current set of capability definitions gives rise to conflicting views and understanding, where the military customer requires action (through verbs) whilst industry has resources (expressed as nouns) and reconciliation of these views is suggested through the UK construct of Lines of Development.

The Lines of Development are the implementation mechanisms for capability, where each of the 'Lines' offers a component and contribution to the mix of delivery. Thus the achievement of a balanced solution to the capability need requires all the artefacts of the solution – the contributing components – to be measured and balanced across all the components. It is proposed that in this context, the traditional Systems Engineering 'V' process model is inappropriate / inapplicable and that a broader more inclusive lifecycle process model is required – the Reaction Chamber Model.

This model reflects a formal recognition of parallel activity between Requirements Engineering and Systems Design, and uses the Lines of Development to reflect the enduring processes of Systems Analysis as the 'tail' of the model. This model demands detailed Systems Analysis techniques and system representations through life. The shaft of this model is the system measurement and analysis techniques that span from the Operational Analysis and assessment supporting the Top Level Documentation to the effectiveness and performance modelling associated with individual component measures. Additionally the ability to measure the system non-functional and constraint issues, such as safety and security, is enabled in a coherent and consistent fashion.

Using this style of process execution and activity, the development of an integrated capability based Through Life Management Plan is achievable. This in turn enables a more flexible and agile set of mechanisms for the through life management of capability where issues of Incremental Development and Acquisition become viable with measured and understood changes to the delivered system pertinent to the changing requirement or technology of the solution. Further, it provides an opportunity to manage change pro-actively, identify pertinent research and development pull through, and direct investment to best effect.

To achieve this however comprehensive measurement

- of hard technical equipment performance issues
- of softer subjective human related activity and performance
- of baselines and the value of increments
- of the overall effect that is achieved in context by the solution

is essential. A model of system development appropriate to the scale of the problem facing designers is proposed in the 5 Column Model, where the whole acts as an over-arching synthetic environment enabling the development of architectures – organisations of resource – that are inclusive of all the pertinent components. Such a model enables a view to be taken by all stakeholders to the problem of the entire problem from capability need to solution implementation in a way that enables their position in the system to be well defined, the interactions and interfaces to be well specified and the appropriate resource organisations initiated. In addition, the model also enables the supplier – for example in the form of a Prime Contractor – to recognise his position and responsibilities in the development cycle. The overarching system views enabled by such an environment offer opportunities for:

- detailed traceability and design justification
- visibility of trade off opportunities across all areas of the solution provision space
- underpinning and traceable information for consistent and coherent capability development
- coherent requirement – design – acceptance information for all activities within the life cycle.

The combination of the Reaction Chamber Model and a 5-Column Model Programme Synthetic Environment provides a complementary suite of tools and processes essential to support the wide range of 'transformation' opportunities and perspectives noted above. The constructs enable;

- Informed decision making through justified / justifiable evidenced information
- Inclusivity of stakeholder, system perspective and development opportunities
- Integration, capability acceptance / assurance
- Support to flexibility and the management of change
- Enables a focused investment and identified opportunities for research pull-through

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