# THE REALITY OF SBA – HOW SIMULATION CAN AND CANNOT INFORM THE ACQUISITION PROCESS

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## ABSTRACT

*This paper will consider what we can and cannot expect from Simulation Based Acquisition (SBA) type initiatives such as those implemented in the US and UK. This paper will consider the acquisition process in the widest sense; that is the entire system engineering process from user requirement through to disposal. This might be termed a whole life system. We take the cycle of weapon useful-life identified by Simpkin as a baseline against which to investigate the introduction and effective utilisation of new weapons systems. We consider, using a historical example, how an understanding of effective employment of weapon systems develops over time and within the context in which they are used. We argue that simulation techniques judiciously employed during the acquisition of new weapon systems can reduce time into service and system costs while increasing confidence that the capability gap will be met. Further, we argue that the process can inform the development of doctrine and concepts allowing the system to be integrated into a whole defence capability in the most effective manner. In essence, we argue that simulation offers a useful view onto the early stages of the Simpkin cycle. However we caution against unrealistic expectations of the process. Simulation can hasten the introduction of systems and assist in their rapid integration into existing capability. But innovative use of systems rather than the systems themselves will continue to win wars, and we argue that simulation cannot foresee these capabilities in any meaningful way. Rather we need to continue to develop systems with flexibility, robustness and redundancy in mind in order that their employment can adapt effectively as the need arises or the opportunity allows.*

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## INTRODUCTION

Across the defence world considerable efforts are being made to leverage the maximum benefits from modelling and simulation (M&S) methods, applications and technologies in order to better support the acquisition, development and integration of defence capability (DC). This paper will outline what the authors believe are realistic expectations of Simulation and Synthetic Environments Based Acquisition (SBA and SeBA respectively) type initiatives such as those implemented in the US and UK[1]. We will do so through a consideration of the systems engineering process, and the role of M&S within it, through the whole system lifecycle. We will illustrate our beliefs though the use of a case study. Whilst much of the paper is set in the UK defence context, we believe that the observations can be applied to similar processes in different countries.

The aim of the acquisition process (in the UK known as "Smart Acquisition") is to "enhance defence capability by acquiring and supporting equipment more effectively in terms of time, cost and performance[2]". This will hopefully encompass a process that commences with the definition of a desired national capability, the identification of some capability gap, and the determination of how best to fill that gap. It will continue with the development and procurement of a systems solution, its integration into existing DC, its support and utilisation and ultimately its removal from service. This paper will thus consider the acquisition process in the widest sense; that is the entire systems engineering process from the definition of user requirements through to disposal. This might be termed a whole life system. Smart Acquisition is thus summed up by the mantra reproduced in Figure 1[3].

***Acquisition = Requirements + Procurement + Support + Disposal***

**Figure 1 Smart Acquisition**

An aspiration of "smart" defence management is to overmatch the enemy in capability, not platforms. It is perceived that a capability-centric view offers flexibility above the traditional platform-centric view. This is particularly important in a

[1] SBA and SeBA are, in essence, the same thing. We will hence refer to SBA throughout the remainder of this paper.

[2] MoD Smart Procurement Implementation Team, The Acquisition Handbook.

[3] Ibid.

world that is less "threat-based" (as was true, for example during the cold war) and more "capability-based". Thus objectives and expectations are now expressed not in terms of achieving a working technological system, but in terms of delivering a capability when the developed solution is introduced into the real world. This makes the systems engineering challenge a very open-ended problem and demands an approach that is much more focused on understanding the real world situation, proposing and exploring candidate system concepts, boundaries and behaviours based on coherent views of problem and system architecture.

Within the context of the process of the acquisition of capability, SBA is seen as a key enabler. SBA involves the integration of M&S and synthetic environments[4] (SE) into all aspects of the acquisition process. It demands the full, integrated and intelligent use of M&S technologies throughout the whole life of a system lifecycle, from concepts to disposal. SBA is, in essence, the extensive use of M&S in support of decision-making in all parts of the acquisition process. Thus SBA can address the totality of capability related issues. It is currently hypothesised that SBA will allow the accelerated development of equipment and capability whilst reducing costs and time-into-service. There is some evidence that this may be the case, but there are few examples of SBA through life to draw upon.

It is generally accepted that the dramatic increase in computing and communications technologies in recent years, and their application to the creation and use of M&S, offers potentially powerful and cost-effective means of simulating equipment, scenarios and environments in a highly integrated and visible way, including the interaction with, and involvement of, people. These M&S have wide potential application, including equipment design and development and upgrade throughout the whole life of that equipment, doctrine development, mission planning and rehearsal, and individual and collective training. They provide opportunities for sustainability models of military materiel and reserves; and if worked together in a federation could be used to assist in force mix, force generation and deployment decisions.

The management of Defence is a complicated process. Hitherto M&S have been used to address individual problem areas. It is an aspiration that SBA will allow coherence across the process in a way that has not been possible with traditional use of M&S. Further, this coherence is not necessarily achieved by "hard-wiring" M&S together, but is a more philosophical approach to the combined and coordinated use of M&S. Part of the great strength of M&S is that they allow concurrent observation of different stages of the capability lifecycle. Whilst this has been possible in the past, the power of being able to link these simulations, integrating assumptions and outputs, offers a "joined-up" view on the whole life of the system that was previously impossible. Thus the vision for SBA is that it offers a degree of coherence through and across equipment programmes that has not been possible in the past.

Central to the argument of this paper is that sensible use of M&S is the "workbench" that systems engineering requires in order to deliver defence capability as envisaged. We term this integrated view "SE+SE" to emphasise the important synergy that can potentially allow us to deliver the right capability in the right timeframe at an acceptable cost. Defence problems are systems problems – that is, we believe that we should take a systems view of defence that demands a coherent approach to their solution. We are optimistic that "SE+SE" offers such an approach. However we counsel that the adoption of a systems engineering process in itself does not guarantee results – it needs to be applied based on a thorough systemic consideration and in an imaginative and insightful way.

## THE NATURE OF DEFENCE SYSTEMS CHALLENGES

A system can be defined as "an interacting combination of elements to accomplish a defined objective. These include hardware, software, firmware, people, information, techniques, facilities, services, and other support elements".[5] Systems engineering is the discipline that enables the development of designed systems and can be seen as "an interdisciplinary approach and means to enable the realization of successful systems"[6]. It covers a broad spectrum of activities, ranging from the production of a single component to the integration and management of complex systems of systems. Systems engineering for defence (SED) embraces all these activities, which are required for the most effective and efficient delivery of DC. It demands holistic views to be taken at every stage of the acquisition process and, in particular, a sharp focus to be applied to the iterative stages of the requirements capture process. SED is therefore a combination of both soft and hard systems engineering. It is the application of the rigours and disciplines of each in such a way that DC can be delivered against constantly changing circumstances. The definition of SED currently in use and approved by the UK MOD Deputy Chief of Defence Staff (Equipment Capability) is that "set of activities which control the overall design, implementation and integration of a complex set of interacting components or systems in order to meet the needs of all users and other stakeholders within the constraints arising from the system's operational and developmental environments".

Systems considerations pervade defence. In order to sensibly address these problems we hence need to be cogniscent of the types of systems that we find in defence and their nature. On the one hand, modern systems tend to be highly integrated, complex beasts. The advent of the information age, the growth in integration across and between systems and the increasing constraints on time, cost and personnel has had a

[4] Henceforth we will use the abbreviation M&S to refer to all models, simulations and synthetic environments.

[5] SE Handbook Working Group, **Systems Engineering Handbook**, 10

[6] Ibid.

very significant combined impact on the approach needed to manage complex systems within a changing world. These complex systems problems require us to think in different, innovative ways by applying a whole system, through-life approach to solving problems. Defence systems can no longer be seen as ad-hoc arrangements of platforms and people, but need to be viewed as complex interdependencies involving equipment, manpower, training, support, command and control and a raft of other aspects that cannot be considered in isolation. On the other hand, there is an enduring nature to systems, particularly those seen in defence. The systems that we create exist within wider, extant systems comprising such things as strategy, doctrine and existing views on weapons systems and types. Thus the challenge is often more correctly identified as systems integration, as the context in which the developed system will sit is often well-defined. Further, military organisations are hierarchical and political, often to the extent of this being a problem. They, despite what they would really like to think, are rarely dynamic, except in times of war. The notion of enduring "patterns" is ingrained in military organisations. These "patterns" are protected and maintained by command structures that mean all commissioned (and hence decision-making) ranks must start at essentially the same place in the structure and learn the system as then espoused.

A "pattern[7]" can be seen as an existing view of the underlying structure of some system, and is a property common to most if not all systems. Thus we can see that, whilst there are great differences between an F-16 fighter aircraft and the Wright brothers' first aircraft, the underlying "pattern" comprising the structure and (some of) the relationships are much the same. They both are recognisable as a type of aircraft, have wings, a fuselage, a means of propulsion, steering mechanisms, etc. We can see Organisational Design, Doctrine, Tactics, Techniques and Procedures (Process), System Architecture, notions of threat and even individual "worldviews" in terms of existing "patterns" that are passed from generation to generation, and rarely challenged. Thus it is a military truism that "we train for the last war", encapsulating the idea that experiences gained under fire quickly permeate the system but take time to disperse in peacetime. That this should be true in defence is no surprise – it is true in virtually every other walk of life. For example, in his book "The Structure of Scientific Revolution[8]" T. S. Kuhn introduced the term "paradigm shift" and suggested that science makes progress through periodic changes in viewpoint. This corresponds to a change of "pattern" of view. The new "pattern" is then explored until it fails to account for reality in some way, at which point the "pattern" requires changing.

There are two key points to be drawn out when referring to paradigm shifts in defence. The first is that it is generally agreed that that winning of wars is dependant on innovation rather than the reinforcement of existing ideas. Hence, whilst we are actually quite good at introducing improvements into existing "patterns", generating new ones, confidently and in a timely fashion, is something that we have little experience of. Secondly, and in contrast, whilst the worst thing that can happen to a scientist whose ideas are revised due to a paradigm shift is that he loses face, the consequences of a paradigm shift in warfare can mean national failure, even destruction, and the loss of life. It can hence be argued that the stakes are much higher and therefore resistance to change much greater. These two observations are in conflict, and there is a necessity to identify the paradigm shift, but to do so in a way that allows us to be confident that its adoption will be a success. We believe that sensible use of M&S (and realistic SBA) can enable this process.

## THE SIMPKIN CYCLE

In order to address the issues of "paradigm shift" in the defence environment, we have referred to the work of Simpkin, who introduced the notion of the 50-year cycle[9] in his book "Race to the Swift". In that book he stated that "time and again, where a radical change in equipment, doctrine or force structure is concerned, one finds a gestation period of between 30 and 50 years or more between the technique becoming feasible, or the need for change apparent, and full-scale adoption of the innovation. This delay varies somewhat with time and place only because of variations in the factor that governs it - the career span of an officer rising to the highest rank".[10] Based on historical analysis, Simpkin identified the various generations of weapon system that existed with a number of key "patterns". He found that that the "usefulness" of those generations could be usefully graphed against time and against other system "patterns", hence the 50-year cycle. His schematic to illustrate the principle of the fifty-year cycle is shown in Figure 2. We identify three periods within the life of a particular generation of weapon system, which we identify as introduction, dominance and decline:

- ***Introduction***. The period during which the weapon system is in ascendance but is under utilised, based on a lack of understanding, trained manpower or availability.
- ***Dominance***. The period where the system is well understood, widely available and integrated into the wider DC in a synergetic manner
- ***Decline***. The period where the system is in decline, due either to its age or to the fact that a counter-system had been developed.

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[7] These ideas due to Prof P John, QinetiQ Professor of Systems Engineering, Cranfield University, as yet unpublished, taken from his inaugural lecture – "The Systems Century: change, complexity … and complacency – 20 Mar 2002.

[8] Kuhn, **The Structure of Scientific Revolution**.

[9] Simpkin, **Race to the Swift**.

[10] Ibid, 5

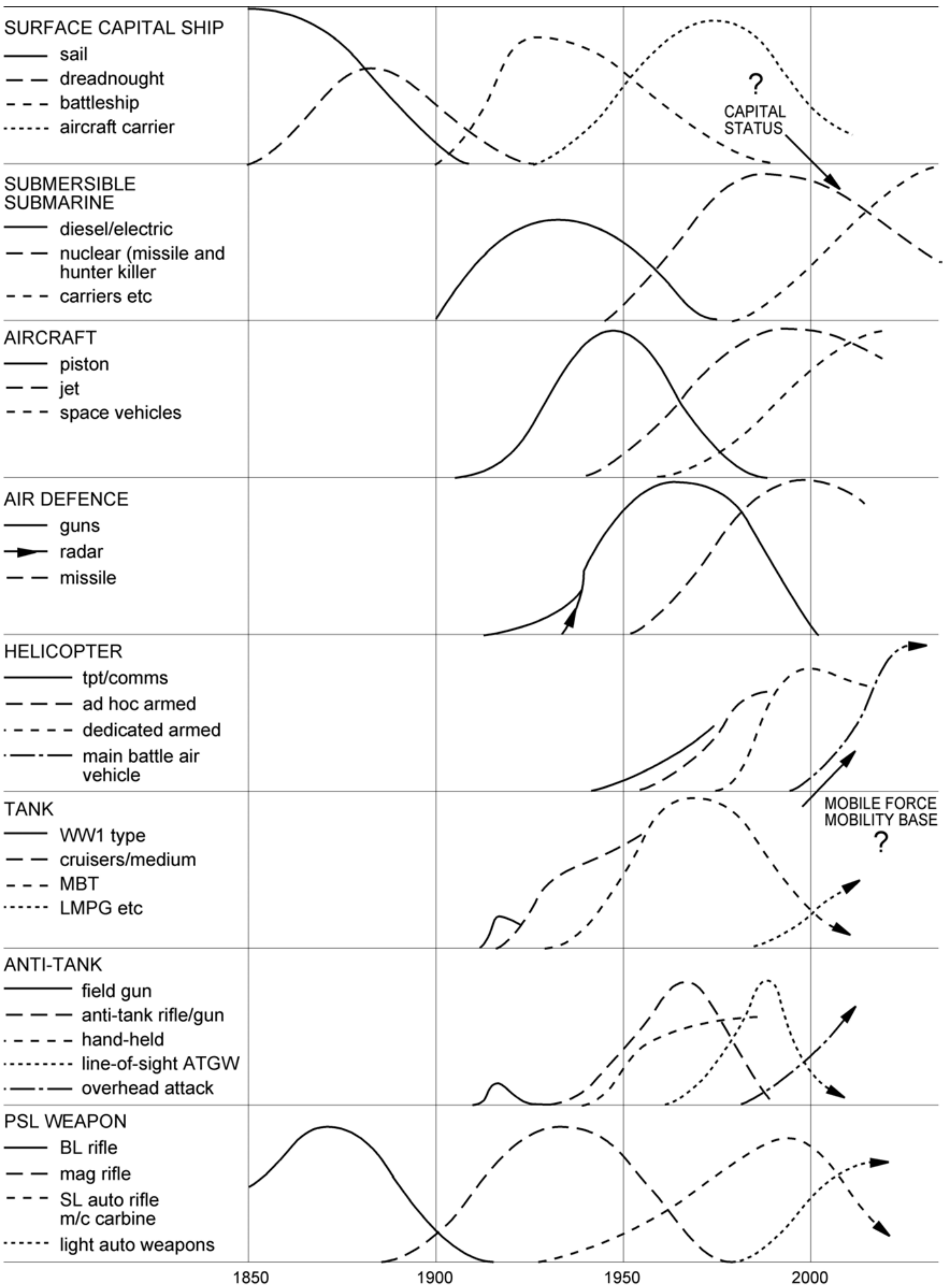


**Figure 2 The 50 Year Cycle[11]**

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[11] Figure 2, The Fifty Year Cycle, is taken from Simpkin, **Race to the Swift**, where it is discussed in great detail. Sufficient for our purposes here is to note that each of the rows represents a new "pattern" of weapon system that enables a "paradigm shift" in defence thought. Progress along the rows tends to be by technology insertion, with the goal of "shoring up" existing patterns through superior technology. It is interesting to note how weapon "patterns" are introduced to counter existing threats, hence linking all the rows into an evolving view of warfare. It is also important to note that the Figure was developed in the early 1980s, so represents a "futuristic view" of the current position. With this caveat the Figure is a helpful illustration of the evolution of the useful life of various "patterns" of weapon system and the phases of evolution that they go through.

Simpkin found that these individual cycles were related in a way that showed how the dominance of different weapon system "patterns" changed over time.

There are many reasons why this pattern has proliferated in the past, and a good number to believe that it may continue to do so in the future. Simpkin identified 6 key reasons, which are discussed below.

**The Career Span Factor**

The "Career Span" is the length of time that it takes for a person to rise from the point at which he can, first hand, observe the power or potential of a weapon system to the point at which he can influence procurement, doctrine or force structuring. An example might be someone like the German tank commander Major General Heinz Guderian, who had served as a signals captain in the First World War, and had hence seen the potential of combinations of armour and aircraft using radio communications to enable command and control at first hand. He was thus able to exploit these ideas in what became known as "Blitzkrieg", essentially a new "pattern" of waging war.

**Increasing Complexity**

As equipment becomes increasingly complex, the familiarisation and training demands increase rather than decrease. This problem is exacerbated with the advent of even more highly integrated systems.

**Costs**

Unit costs of complex modern systems are increasingly great, and there is a political requirement to get maximum useful life out of systems to justify investment. Thus the UK's Puma medium lift transport helicopter is scheduled to be in service until 2018 on current estimates, although the airframes are already 30 years old. This retention, despite official protestations, is unlikely to be due to its suitability, much more likely to be due to a lack of funding for a suitable replacement. Thus we pay in the future for what we need today, which is rarely sustainable.

**Development Time**

Development time of capability solutions, especially complex, highly integrated modern systems, is generally seen as increasing rather than (despite best efforts) decreasing. Constantly we hear of major overruns in defence projects. 20 years ago it was generally recognised that R&D cycles were lengthening rather than shortening. Despite a radical overhaul of the Acquisition System, major defence projects in the UK continue to overrun against their original planned In Service Dates.

**Introduction of Capability**

Additionally, we have the problems associated with the introduction of the equipment/capability itself. In the past, accompanying doctrine or organisational change has rarely preceded the advent of new equipment. In essence, it has taken time and experimentation to integrate the new capability into the existing DC. An example of this is the introduction of the UK's WARRIOR IFV. When the system was first introduced into service, there were various problems in terms of weapon integration (the unfortunate fact that vehicle vibration tended to set off the LAW 84 hand-held anti-tank system that the infantry dismounts carried) and utilisation (no doctrine existed for it on introduction, so, despite its fundamental difference from its predecessor, the AFV 432, which had no offensive capability, it was used it in essentially the same way until exercise experience allowed the development of a useful doctrine).

**The Nature of Peacetime Armies**

Combine this list with the observation that, in peacetime, most armies are extremely resistant to change and it can be seen that weapon systems have a useful life that is often only a fraction of their whole life. As Simpkin observed, "(I)n every field, the peacetime first-line service life of a given generation of major equipment tends to be ten times that of its wartime life - say 20 years as opposed to 2"[12].

We can thus see that there are a number of reasons why weapon lifetimes tend to exhibit this "pattern". Hence the motivating question, and the theme of this paper, becomes:

*What benefits can SBA initiatives, combined with sound systems engineering practice, provide in*

- *The more timely development of desired defence capability*
- *The rapid introduction and integration of this capability*
- *Lengthening the useful life of the capability*

*across the whole life of the system?*

## VISUALISING THE LIFECYCLE OF SYSTEMS

Despite the fact that people have been engineering systems for thousands of years, systems engineering is a relatively new discipline[13]. For example, it is only in the last 10 years that an international professional society has been set up to provide a forum for discussion of systems engineering issues. In the UK there is no single body for the accreditation of systems engineering courses in higher education. However, work is afoot on the development of an international standard in the discipline, and ISO 15288 "Systems Engineering - System Life Cycle Processes"[14] is currently at the Final Committee Draft stage. This document identifies 6 stages in the systems engineering lifecycle. They are:

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[12] Simpkin, **Race to the Swift**, 6

[13] Indeed, there is not general agreement that it is a discipline separate from sound engineering design within the "mature" (civil, mechanical, electrical, etc.) engineering disciplines at all.

[14] Joint Technical Committee ISO/IEC JTC 1, **ISO 15288 Systems Engineering - System Life Cycle**.

- Concept
- Development
- Production
- Utilization
- Support
- Retirement

This lifecycle is chosen for consideration here over the several that are recognised by the UK MOD, US DOD, etc, as an emerging international standard. Figure 3 illustrates these stages, and identifies the purpose that underlies each. We now discuss each stage in more detail, bringing out the real military considerations that pervade it.

<table>
<tr><td>Lifecycle Stage</td><td>Purpose</td><td>Decision Gates</td></tr>
<tr><td>Concept</td><td>Identify Stakeholders Needs<br>Explore concepts<br>Propose feasible solutions</td><td rowspan="6">Decision options:<br><br>- Execute next stage<br>- Continue this stage<br>- Go to previous stage<br>- Hold project activity<br>- Terminate project</td></tr>
<tr><td>Development</td><td>Refine system requirements<br>Create solution description<br>Build system<br>Verify and validate system</td></tr>
<tr><td>Production</td><td>Mass produce system<br>Inspect and test</td></tr>
<tr><td>Utilization</td><td>Operate system to satisfy users' needs</td></tr>
<tr><td>Support</td><td>Provide sustained system capability</td></tr>
<tr><td>Retirement</td><td>Store, archive or dispose of system</td></tr>
</table>

**Figure 3 The Systems Engineering Lifecycle**[15]

**Concept**

The concept phase is where the users key requirements are identified. This will involve the identification of a gap in existing or projected capability, identify concept solution classes and identify which options should be considered further. In UK "Smart Acquisition" this process ends with a "decision gate[16]" where the project is approved for investment and time, cost and performance boundaries are declared.

[15] Taken form Joint Technical Committee ISO/IEC JTC 1, **ISO 15288 Systems Engineering - System Life Cycle**.

[16] Known in UK "Smart Acquisition" as Initial Gate.

**Development**

The development stage will take the concept solution classes and develop each of them to ensure that they are useful and viable - technically or otherwise. A process of down-selection to a single preferred option will then take place. This option will then be "demonstrated" to show that it is achievable and offers a suitable solution to the capability gap problem. The user will validate that the solution meets their requirements. This stage will culminate in the decision[17] to continue the investment and produce the capability in sufficient quantity to meet user requirements.

**Production**

This stage involves the production of the system in sufficient numbers, to an acceptable standard and in the appropriate timeframe to meet the needs of the user. In the defence environment this will often require integration into existing systems (such as a communications fit into an armoured vehicle). The stage culminates with the system as produced being declared fit for purpose by the user or his acceptance authority and authorised for introduction into service.

**Utilisation**

The system is then introduced into service and used, hopefully as envisaged, by the user. This stage will hence involve the agreement and acceptance of concepts of use (doctrine, tactics, techniques and procedures) or their development and is likely to involve final agreement on integration with other systems.

**Support**

During its useful life the system will need to be supported. This will involve the training and management of operators and commanders, the logistic support and sustainment of the system as required, its physical maintenance, and the training and management of supporting staff.

**Retirement**

At the end of its useful life the system will need to be removed from the wider DC in a timely, safe and effective manner, requiring minimum ongoing investment and posing little or no environmental (physical or social) hazard. This will inevitably involve consideration of replacement capability, if appropriate.

## SIMULATION

"Let the imagination go, guiding it by judgment and principle, but holding it in and directing it by experiment".

Michael Faraday

M&S offer a powerful full working laboratory to the system designer. In particular they offer

[17] Known in UK "Smart Acquisition" as Main Gate.

- A microscope
- A window
- A macroscope

onto and into the model world through which we can investigate the consequences of our designs and decisions. Simulation thus allows

- ***downward*** consideration, in that we conduct system analysis, investigating the consequences of system design in order to inform this process. Hence we may investigate the implications of a vehicle design using CAD/CAM tools and mannequin human modelling tools.
- ***outward*** consideration in that we can visualise concepts and designs and familiarise users with them before they exist in the real world. Thus users can be involved in assessing whether concept system solutions meet their requirements and can train on mock-ups in appropriate environments.
- ***upward*** consideration, in that we can visualise and explore the interactions of multiple systems; integrate with other systems, existing or planned; develop concepts of operational use; conduct wargames and force-mix experiments; and investigate support, maintenance and training requirements.

However, at best simulation is an experiment with a model, and that model is necessarily a simplification of the real world. Thus any conclusions that we draw from simulation will be conclusions about the model rather than about the modelled world. As has been stated elsewhere, "perhaps the key philosophical question regarding the nature of models concerns their connection to concrete physical systems and the degree to which they enable us to draw conclusions about these systems"[18]. Thus it is key that we understand that a confidence judgement must be made on the applicability of any information gathered from simulation experiments. Hence the processes of verification and validation (V&V) will remain essential if we are to have any confidence in the output of modelling activities.

SBA mandates the "joined-up" use of M&S across all stages of the system lifecycle, and across multiple projects. We can consider the computer as battle-lab that allows us to play out our ideas, conduct validation[19] of user requirements and verification of solutions against them. This, in turn, allows us to reduce development time of systems, essentially allowing the concept and development stages of the lifecycle to be reduced in duration. This is encapsulated in the phrase "Model – Verify – Model", illustrating the fact that most of the "hard" decisions can be taken before any metal is cut. This is the essence of collaborative virtual prototyping.

In turn this allows reduced early-stage costs. Design changes can made early in the acquisition process when (1) they are possible and not constrained by other decisions and (2) they are less expensive. Whether SBA enables reduced whole-life costs is a moot point and one that is currently unsupported by objective evidence.

Similarly, the use of SBA processes can increase confidence in the resulting system. Whilst, of course, this is an issue closely linked to the validity of M&S, there is general acceptance that the insight gained in conducting a modelling exercise is the product of the modelling exercise itself rather than any model that may exist at the end of it. This can be encapsulated in the phrase "the answer is the process". It is our view (and the subject of an ongoing research project[20]) that validity cannot be "proven" in a formal mathematical sense, but that by ensuring that we have "thought of everything" through the parallel approaches of a sound systematic process combined with a thorough systemic consideration we can gain confidence that the model is fit for the purpose that it was designed for.

Further, simulation allows, potentially at least, the identification of unseen system emergent properties in the designed system that may be undesirable. One useful definition of systems engineering is "the structured and ordered creation of a System that achieves the required Emergent Properties[21]". Implicit in this is that the process minimises undesired emergent properties. Simulation allows the investigation of system models such as designs and embedded software in order to identify these. For example, modelling of the F-16, including the embedded software, allowed designers to establish that the aircraft would have "flipped" on crossing the equator due to a code error. Simulation allows potentially fatal errors such as this to be rectified early in the systems engineering process.

But of course we can also fail to identify these undesirable emergent properties if, for some reason, our models do not capture them. Indeed, as systems become more highly integrated, with complex, dynamic interdependencies, it is often difficult (indeed impossible) to identify the modes in which the system may fail. Hence there is a continuing need for sound V&V practices, combined with an acceptance that fitness for purpose represents a decision, and, as such can be wrong. The term "Normal Accidents[22]" has been used to label the concept that

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[18] Morrison, Models as Autonomous Agents, 38

[19] Note the terms verification and validation are used here in the sense normally attributed to them in systems engineering.

[20] Price S N et al., The Validation of SEs for SEBA.

[21] Hitchins, **Guide to the Practice of Systems Engineering**

[22] Perrow, **Normal Accidents**.

failures often occur “because systems complexity makes failures inevitable”. This can equally well be applied to complex M&S, which are of course themselves systems.

Simulation can also assist with the integration of new or planned capability with existing capability during the actual development process. Thus we are able to address key questions such as"(W)hat is the effect of the new devices on existing methods, and how can the devices best be put to use?"[23]. Thus the development of doctrine and concepts, conducted by users, can be conducted concurrently with the actual system development rather than subsequent to it. This allows consideration of the whole DC as the wider system during development. It is enabled by the use of shared data environments, links to other programmes and the involvement of **all** stakeholders and the consideration of **all** stages of the system lifecycle at **every** stage of system development.

But it is important to note that this process can only allow system integration into existing or foreseen patterns, or in foreseen contexts. In particular, simulation does not allow us to “look into the future” in any meaningful way. We illustrate this through the use of a historical case study in the next section.

## CASE STUDIES

We will illustrate the utility of SBA type initiatives through the use of a thought experiment. In this way we hope to consider how the introduction of new capability could (or did) force a change in existing “patterns” of thought. Critically, we will postulate how a simulation-based approach could have assisted the process. As we have identified above, at a particular moment in history armies tend to have very fixed ideas about how weapon systems and capability can and should be used. Thus, at the beginning of the First World War a senior British General famously said that "I hope that none of you gentlemen is so foolish as to think that aeroplanes will be usefully employed for reconnaissance from the air. There is only one way for a commander to get information by reconnaissance and that is by the use of cavalry[24]". At around the same time a British engineer was advocating the use of air power in the coming war as the “The Fourth Arm” where Aircraft, Infantry, Cavalry and Artillery would be integrated to provide an overall defence capability that would allow the prosecution of a new type of warfare[25]. Our point is not to belittle or praise our forbears; rather it is to point out that (1) generally people make good decisions in the context of the day (i.e. the existing “patterns”) and the light of their (perceived) requirements and (2) it takes ingenuity (even genius) to see how new “patterns” can be created before the advent and development of understanding of the technology. Yet hindsight can throw a very different “spin” on things. It is common for us to criticise a “lack of ingenuity” on the part of our forbears when in fact the context in which they were working appeared very different at the time.

In 1915 the Western Front was stuck in defensive quagmire. In essence, it was the superiority of the defence over the offence that brought this stalemate about. Whilst there was an initial dynamic German plan[26] for the rapid defeat of the French and British Forces, these plans were unable to be exercised at sufficient speed, leading to a deadlock. Neither side could create a decisive advantage, and, as time wore on, both sides were able to develop substantial defensive networks that propounded the problem. The essential requirement for either side was hence to break through the opposing defensive system. This was the context in which the concept of a tank developed as a vehicle that could “crush obstacles, cross trenches and convey its armament under bullet-proof protection into the very midst of the enemy, where it could annihilate the otherwise almost invulnerable machine-guns, and enable one’s own infantry to pass open ground without incurring intolerable casualties[27]”. The original concept was that tanks should hence be “landships” – vehicles designed to cross trenches, barbed-wire and defensive positions in order to allow the prosecution of a mobile battle.

Initial concepts of what this “landship” should look like were driven by the Key User Requirements of the day – an ability to transport men across No-Man’s Land and over the enemy defensive positions in order to allow a breakout. System development proceeded in a conventional manner, and, after a few initial failures, in 1915 what was to become known as the Mark V Tank “demonstrated its ability to cross 9-foot wide trenches. The army ordered 100 of them, describing them as water tanks for security reasons. The name stuck”[28]. The tank was introduced onto the Western Front for the first time and first saw service at the battle of Cambrai in 1917. In that battle it achieved great surprise, but was “penny-packeted” and achieved no lasting success, despite the sound plans of tank advocates such as (then) Maj JFC Fuller[29]. Other British

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[23] Van Creveld, **Command in War**, 2

[24] Sir Douglas Haig, addressing the Staff College, July 1914.

[25] Lanchester, Aircraft in warfare. This work summarises and develops many articles written prior to the outbreak of the First World War.

[26] The Schliefen Plan (after Von Schliefen, German Chief of Staff in 1905), an attempt to ensure that Germany did not have to fight a war on two fronts at once through ensuring a rapid and decisive victory in the West. The plan envisaged a 6 week offensive through Belgium and France to secure the West before a general attack was made on Russia.

[27] Guderian, **Achtung - Panzer!**, p.48.

[28] Deighton, **Blitzkrieg**, 152

[29] "What ended up as the 'battle of Cambrai' was originally envisaged by Major Fuller as a tank raid upon the head-quarters of Crown Prince Rupprecht of Bavaria some miles behind the German lines. The tanks were to strike at one of the most vital communication centres in the German rear and retire after 12 hours". Deighton, **Blitzkrieg**, 154

officers saw great potential for this novel weapon system, and envisaged a paradigm shift in the conduct of warfare. However, senior decision-makers were less keen. For example, “Colonel Swinton remained the most important protagonist of the tank. He saw its value as a surprise weapon and was convinced that it could deal a swift and mortal blow to the Germans. But the higher commanders disagreed. Sir Douglas Haig, C in C of the British Army in France, told the Tank Supply Committee in August 1917, '[The] tank at any rate in its present state of development, can only be regarded as a minor factor ... an adjunct to infantry and guns ..'. For Lord Kitchener, Secretary of State for War, the tank was no more than a 'pretty mechanical toy' ”.[30]

However, it is probably fair to say that, over the remaining years of the war, the integration of the tank into existing DC did take place, and the potential of the tank for waging a new kind of war was accepted by many influential thinkers. So much so that "...acceptance of the "Fuller plan" (for the use of tanks in deep penetration) as the "basis of tactics" for 1919 shows that, after 3 1/2 years and, this time, millions of wasted lives, the Allied high command had finally started to think in terms of manoeuvre. And thanks to Foch's change of heart these ideas did carry some influence in the postwar French Army. But in Britain they were not so much discarded as buried in quicklime; and in the United States Army the tank arm was disbanded and responsibility for the tank given to the infantry. Admittedly "armoured" thought was reinstated in both armies after 25 years rather than 50. But the timing and extent of this swing was dictated partly by the circumstances of the North African Campaign, mainly by the German armoured threat as a whole". Thus wartime conditions and necessities had produced innovation based on understanding of the capability of a weapon system, whereas a reversion to peace led to stagnation of these ideas and a return to the previous "pattern". It was only in the mid-1930s that these ideas returned when a group of young officers who had seen the potential first-hand were in positions of power and influence to drive these ideas.

Thus, the tank “pattern” as we know it today was developed in 1915. In the intervening 87 years the actual system architecture and technical concept has changed little. Of course there have been great advances in armour and defensive aid suites, firepower, mobility and command and control, yet the architecture is still essentially the same. These represent “technology insertion” improvements to the existing “pattern”. Yet the tank is used for a very different thing today than it was designed for. The initial Key User Requirement was to move men in relative safety across a defensive battlefield. One could argue that the tank itself was integrated into the existing cavalry “pattern” of massed “shock” action. It hence subsequently formed the basis for Blitzkrieg warfare (1939) and, arguably, Manoeuvre Warfare (1980s), but as such was designed for neither.

Now imagine that the British High Command had access to the kind of advanced M&S that we have today. What would SBA have thrown up had it been available in 1915? It is our view that SBA would have

- Allowed the exploration of user requirements, that is the crossing of defensive positions, involving the user at all stages;
- Allowed the virtual, rapid, iterative development of concept solutions that could be further tested by users and verified against requirements in a virtual world;
- Allowed the development of designs that could lead to the more rapid development of the tank itself;
- Allowed consideration of related system and wider system issues such as logistics, command and control, doctrine and deployment.

Thus, we would suggest, SBA would have allowed a workable solution to be deployed earlier and with greater confidence that it would meet the requirements that had been set. However, it is our view that SBA would have

- Enabled, but not guaranteed, the exploration of novel concepts of use (“paradigm shifts”). The development of these concepts is a fundamentally human, creative process that can be explored using M&S but not developed by them (in that it is the output of the model). So a few individuals thought of novel concepts of use but were unable to persuade the powers of the day that they were sensible. It is our view that M&S may have allowed the investigation of these novel concepts by people like Fuller and Swinton and their subsequent communication to senior decision makers. Thus the M&S become a laboratory for the development of and demonstration of the paradigm shift. It is in this sense, to paraphrase Faraday, that we see simulation as enabling imagination and innovation rather than replacing it.
- Allowed an only an “initial life view” to be taken, but not a “whole life view”, because so many of the whole life issues are determined by the context in which the system is used. Thus SBA would have allowed rapid system development, and a transition into the Introduction stage of the Simpkin Cycle, but would not directly led to a transition to the Dominance stage. That transition requires human innovation and a systemic consideration, which can be enabled by SBA, but is not a direct consequence of it.

Hence we see that M&S (and hence SBA) can enable a systematic process of system development, but, for that system to fulfil its “capacity” this must be accompanied by a systemic consideration of the whole problem. This is unachievable by M&S alone but can be enabled by them. This should be no surprise. In essence, we are advocating the use of M&S as “tools for thinking with”. Simulation together with imagination allows innovation. Simulation without

[30] Deighton, **Blitzkrieg**

imagination merely generates data that reflects the consequences of the model. Thus M&S can enable the exploration of the paradigm shift when combined with imagination.

There are numerous relevant modern examples that we could draw upon to illustrate our ideas. We choose the advent of digitisation, precisely because it seems at the moment to offer a "paradigm shift" in the way that war can be waged. Digitisation is defined as "exploiting information opportunities offered by digital technology to improve operational capability"[31]. As such, digitisation offers an integrated battlespace that will allow the prosecution of rapid, co-ordinated operations. It will be enabled by a set of solutions, technological, organisational and conceptual, that will allow the storage and dissemination of the right information to the right person at the right time. But, at its simplest, digitisation can be seen as an enabling information system (IS), and, as has recently been observed, the introduction of IS inevitably changes the nature of the system being supported[32]. Thus we believe that, based on the thought experiment above, we can

- Utilise M&S and SBA to ensure that we have captured the Key User Requirements;
- Investigate a number of concept solutions;
- Enable a decision-making process that allows trade-offs to be made between solutions and components of solutions;
- Integrate a better system into the wider system sooner and with a greater understanding of the likely effects of that integration.

But how the developed system will form part of a digitised DC in more than, say, 5 years time is anybody's guess. A "paradigm shift" opportunity such as the advent of digitisation allows human innovation to flourish. M&S can enable and support this, but only that – they cannot be relied upon to generate it.

Thus we can utilise SBA to enable us to design now for current requirements based on current views of the lifecycle. However, the process cannot be used for prediction beyond a sensible timeframe, so whole life issues such as whole life cost can really not be considered in any meaningful way. We should hence be sure to design for robustness and flexibility in order to ensure that the system can mature as the context of use and requirements change.

## REALISTIC SBA

We would thus suggest that SBA realistically allows:

- All parts of DC to be investigated in a coherent fashion;
- Risk Management, in that risks are exposed sooner in the process and that their potential implications are considered, rather than laying undiscovered until too late;
- Increased confidence that requirements will be captured and met through the use of models as a communications medium involving user, developer and other stakeholders;
- Effective trade-offs to be made between performance, cost and time;

However, we would suggest that SBA does not allow:

- Answering the unasked question. The M&S can only be used to address problems as stated. Too often the question asked is not really the one that we want an answer to;
- Prediction of the future. When we are talking about the future, all we can do is estimate out to a certain (unclear) point. Further than that (1) we don't know what the system is supposed to do (in that its context of use will be unclear) and (2) we don't know whether we will need it (in that it may be redundant). Hence there is only a certain "threshold" out to which it is sensible to use M&S to inform, which we suggest tentatively is around 5 years. This raises fundamental difficulties when we try to consider issues such as whole-life system costs. We hence need to ensure a more reactive process that allows change in relatively short time-frames;

In line with these observations, we believe that we should use SBA to allow us to design for:

- **Flexibility**. When we were interested in platform-based requirements, we often found that we got "hidden" capabilities. With capability based requirements it is no longer clear that this is the case. In considering capability, are we losing redundancy and flexibility?
- **Robustness**. In line with the above, we need to develop robust solutions that are adaptable and can be relied upon to meet most circumstances in which they will be used.
- **Redundancy**. It is our view that designing for robustness and flexibility requires us to consider building redundancy in to solutions. One of the problems with an ability to investigate and communicate requirements in great detail is that it is possible to "over-specify" systems. As has been stated elsewhere – "be careful what you ask for – you might just get it!"

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[31] UK Director Land Digitisation (DLD) definition.

[32] Checkland, P and Holwell, S., **Information, Systems and Information Systems**.

- **Innovative Use**. Where possible we need to consider that an ability to support innovative use is a desirable characteristic.

- **Longevity**. Increasingly systems are required to last longer than designed. We need to be cogniscent of this at the front end of the process.

In essence, we see that SBA allows us a good view onto the early stages of the Simpkin Cycle, and can help us "reach the potential" of the system earlier. But it cannot predict how the system will be used and in what context in any meaningful way, so is essentially useless beyond a certain "threshold". The mantra of Total Quality Management (TQM) is "right first time". Perhaps the mantra for SBA should be to "get it wrong early, learn and understand, get it right". But, this should be seen as being "right" in the context of the day, and we should not expect that solution to be enduring beyond a sensible timeframe.

## CONCLUSIONS

We believe that SBA is an enormously powerful philosophy that has the potential to deliver great benefits to the delivery of DC. It allows more rational, reactive decisions to be made and justified. It provides a powerful medium for communication between all system stakeholders. It enables the connection of all aspects of capability in a way that was hitherto impossible. It allows us to explore "what ifs?" to ensure flexibility and robustness are built in to solutions, hence increasing confidence in the result. Further, we believe that, when combined with human imagination and innovation, it enables the exploration of the paradigm shift, if it has been identified.

However, we counsel against unrealistic expectations of the process. There would appear to be a misplaced confidence that SBA taken with a systems engineering process is somehow "guaranteed" to deliver results. SBA does not allow prediction of the future, nor does any simulation. We estimate that it has a "useful view" out to about 5 years, but is unable to offer insight into whole-life issues beyond that. SBA cannot predict paradigm shifts, it can only enable their consideration once identified. In particular, M&S themselves cannot predict innovative ways of doing things, they can only allow a human to experiment with his or her ideas. They cannot really reflect the nature of combat in a meaningful sense. And finally, they cannot be relied upon in any sense whatsoever unless they have gone through a rigorous process of V&V.

It is our contention that innovative use of technology, rather than technology itself, will continue to win wars. As has been stated elsewhere, "(S)ince a decisive technological advantage is a fairly rare and always temporary phenomenon, victory often depends not so much on having superior technology at hand as on understanding the limits of any given technology, and on finding a way around these limitations"[33]. SBA allows consideration of these issues in a novel and "joined-up" way.

But if we treat it as a process alone we will inevitably fail in our endeavour to deliver DC. It needs to be seen as a systematic process enabled by a systemic consideration, thus enabling the human to use it to generate insight rather than treating it as a black box that generates answers. Simulation can support the imagination and hence enable innovation, but not replace it. SBA is a powerful approach as long as we are aware of its limitations.

## REFERENCES


Checkland, & Holwell (1998). **Information, Systems, and Information Systems: Making Sense of the Field**, Chichester: Wiley.

Deighton (1979). **Blitzkrieg**. Reading: Jonathan Cape.

Defence Procurement Agency Website, http://www.mod.uk/dpa/index.html

Guderian, Maj. Gen. **Achtung - Panzer!** (Translated by Christopher Duffy). Originally published in Germany (1937). Reprint Arms and Armour Press (1992)

Hitchins, D. (Pamphlet). (June 1999). **Guide to the Practice of Systems Engineering**. Structured Software Systems.

Joint Technical Committee ISO/IEC JTC 1, Information Technology, Subcommittee SC 7, Software and Systems Engineering. (International Standard). (22 Jul 2001). **ISO 15288 Systems Engineering - System Life Cycle Processes** (Final Committee Draft).

Kuhn, T. (1962). **The Structure of Scientific Revolution**. University of Chicago Press.

Lanchester, F. (1916). **Aircraft in Warfare: the Dawn of the Fourth Arm**. London: Constable & Co.

MoD Smart Procurement Implementation Team. (June 2000). **The Acquisition Handbook**, ( Edition 3).

Morrison (1999). Models as Autonomous Agents. In **Models as Mediators**, (38-65). Cambridge: Cambridge University Press.

Perrow (1999). **Normal Accidents** (2nd Edn). Chichester: Princeton University Press.

Price, John, & Miller (Oct 01). **The Validation of SEs for SEBA**. Proceedings of the 4th International Synthetic Environment Symposium Shrivenham.

SE Handbook Working Group, INCOSE. (July 2000). **Systems Engineering Handbook** (Version 2).

Simpkin, R. (1994). **Race to the Swift: Thoughts on Twenty-First Century Warfare**. London: Brassey's.

Van Creveld, Martin L. (1985). **Command in War**. Cambridge, MA: Harvard University Press.


[33] Van Creveld, **Command in War**, 231

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