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This paper is the last in a set of 13 presented to the 9th ICCRTS by staff of the Defence Scientific and Technical Laboratory (Dstl) and QinetiQ plc, relating to 'command in the network enabled era'. The papers are based on research undertaken for the United Kingdom Ministry of Defence's 'Network Enabled Capability' programme and, unless otherwise stated, are covered in whole or in part by Crown Copyright.

Network Enabled Fires - A NEC/NCW Use Case[1]

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This paper is the last in a set of 13 presented to the 9th ICCRTS by staff of the Defence Scientific and Technical Laboratory (Dstl) and QinetiQ plc, relating to 'command in the network enabled era', based on research undertaken for the United Kingdom Ministry of Defence's 'Network Enabled Capability' programme.

Abstract

Employment of Fires has traditionally been regulated using procedural deconfliction measures. This method is characterised by a lack of flexibility and responsiveness. In addition, the introduction to service of longer range artillery and attack helicopters - at the same time as the rise of the manoeuvrist doctrine - poses significant challenges to the current process. Defining processes that address the challenges will provide a robust, more flexible and efficient means of employing Joint Fires, to Joint ends, across the battlespace.

Applying a practical, pragmatic approach to this problem has provided the necessary insight into this militarily significant 'Use Case'.

The research has shown that central to the successful implementation of a Joint Fires capability is the provision of Joint, real time Situational Awareness (SA). This relates not only to force dispositions but also to the dynamic, continually changing control measures that need to be implemented. This necessitates the provision of an integrated Situational Awareness picture, which we have called a Deep Operations Picture.

The means of producing this Deep Operations Picture (DOP) at the operational level of Command is discussed, along with a limited form of Network Centric behaviour that is likely to emerge when a DOP is fielded.

Results are also presented of both architecture analysis of the impact of including a DOP facility, and also of modelling undertaken to provide a numerical estimate of the benefits to be expected.

Introduction

Revolutionary changes within military organisations can be difficult to achieve at the best of times, given entrenched cultural attitudes. When the need to make best use of limited military resources whilst maintaining operational readiness is added to the mixture, a pragmatic, evolutionary approach becomes unavoidable.

In this same pragmatic spirit, recent research has investigated the application of networked technology to existing force structures and organisations, with the aim of increasing the efficiency and effectiveness of employment of Joint Fires.

The work began by gaining a full appreciation of the scope of the problem, through literature searches and collaboration with current military practitioners. The outcome of this initial analysis identified SA, especially relating to position and intent, as the central component that determines the extent to which all other aspects of Joint Fires employment can be successfully achieved.

A concept for creating and maintaining networked SA was derived. The concept was then analysed, using process and benefits modelling approaches to determine how it would enhance the employment of Joint Fires. The outcome of this analysis showed that some aspects of a Network Enabled Capability can be realised even with modest interventions. This paper indicates some areas where a limited form of NEC-like behaviour would be expected to emerge if the concept was to be implemented.

Joint Fires Challenges

Fires are defined as "the effects of lethal or non-lethal weapons"[2]. Joint Fires is therefore the name of the process responsible for co-ordinating the use of Fires across all domains.

The employment of Joint Fires has traditionally been regulated using pre-planned, procedural deconfliction measures. This arrangement has generally been highly successful in avoiding fratricidal encounters and in providing a well-defined framework within which to conduct operations.

However, the system can also be characterised by a lack of flexibility and responsiveness, especially in the face of unforeseen events. In addition, the introduction into service with land forces of longer range artillery and attack helicopters - at the same time as the rise to prominence of the United Kingdom's doctrine of a manoeuvrist approach to warfighting - poses significant challenges to the current process.

Whether measured by efficient, flexible and agile use of resources, simultaneity of effects or maintenance of operational tempo, the pre-planned or short-notice Joint Fires processes cannot be judged as wholly satisfactory on the contemporary or future battlefield.

The factor which, more than any other, has influenced the need to maintain procedural deconfliction measures is the lack of real time or near real time SA.

A Concept for Cross-Component Situational Awareness

Initial investigations were carried out in conjunction with serving military staff who were chosen for their intimate knowledge of the problems with the current arrangements and came predominantly from artillery, fixed wing ground attack, attack helicopter, intelligence and combat operations backgrounds. Through exploratory discussions, it emerged that the major block on the required co-ordination processes was the requirement to channel all the necessary information through liaison officers. These officers have tended to be equipped with limited inter-component communications

[2] DoD Joint Publication 1-02

capabilities and similarly have had limited access to accurate and timely information on evolving force dispositions and intentions.

Automated position and status information from tactical level units either does, or soon will, flow up to component command level. Examples of this type of information are Blue Force Tracking and Link 16 Precise Participant Location Indicator (PPLI). It was therefore considered most important to concentrate effort on streamlining (through automation) the inter-component data exchange mechanisms.

At this point, it should be clear that the problem requires consideration of interoperability at all levels, from data transfer at the most detailed level to cognitive understanding at the highest level. Digitised links between components are beginning to appear; therefore data transfer is not considered the major issue. From this level upward, however, work is required to establish common data formats, enabling automated processing, through to the establishment of coherent Joint Doctrine, allowing common interpretation and action on information provided.

At the doctrinal level, there has been significant debate regarding whether the future intention should be to integrate or to deconflict Fires. We contend that this debate comes down to semantics. Fires must be integrated, to achieve the desired synergy, flexibility and efficiency of employment. However, deconfliction must still be applied, albeit on much shorter timescales and with much finer granularity than at present, if safety and related operational effectiveness are to be maintained.

The primary requirement for data exchange between components is positional information for tactical units (along with hostile forces, targets and neutral elements), and deconfliction boundaries for effects systems. These then become the main elements for incorporation into a DOP and a coherent picture available to all relevant users.

The Deep Operations Picture

The concept for Cross-Component SA for Joint Fires is therefore quite simple. It involves the transfer of the following information over digitised inter-component links:

- Blue positions
- Red positions (and targets)
- Neutral positions
- Dynamic Control Measures, changing rapidly according to current requirements

Synchronised databases at each component should maintain a consistent picture based on the information passed, and Joint Doctrine should provide the means to interpret the pictures in different components in a consistent and coherent manner. The required data model should consist of a very small number of commonly agreed elements and would most conveniently be captured, stored and manipulated in the form of an XML schema.

A diagrammatic representation of the infrastructure and high-level connectivity required is shown in Figure 1.

A further requirement, implicit in the concept, is the existence of information management personnel equipped to compile, control, fuse, aggregate and share information, electronically. In this way, a coherent picture containing the essential features of the battlespace, with appropriate coverage and currency could be assembled.

We have chosen to call the envisaged picture the 'Deep Operations Picture (DOP)', since this captures its raison d'être as an aid to prosecution of the Deep battle i.e. operations that are, in general, well separated from the majority of Blue force elements. Underlying this restriction on the use of the picture is the assumption that for Close operations the time delays inherent in producing and synchronising the picture at Component Command level would introduce unacceptable latency and therefore inaccuracy into the picture. However, the effects systems that we are considering are generally those which are optimised for Deep operations and which belong directly to formations at, or close to, the Operational level of command.

The DOP is envisaged as a tool that is applicable beyond the operational level headquarters. The picture would also be provided, via digitised links, to Deep effects systems (long range artillery, fixed wing air, attack helicopter, etc.) and relevant ISR assets. For most of these systems the necessary links already exist - procurement and installation of the DOP tool itself is all that is required.

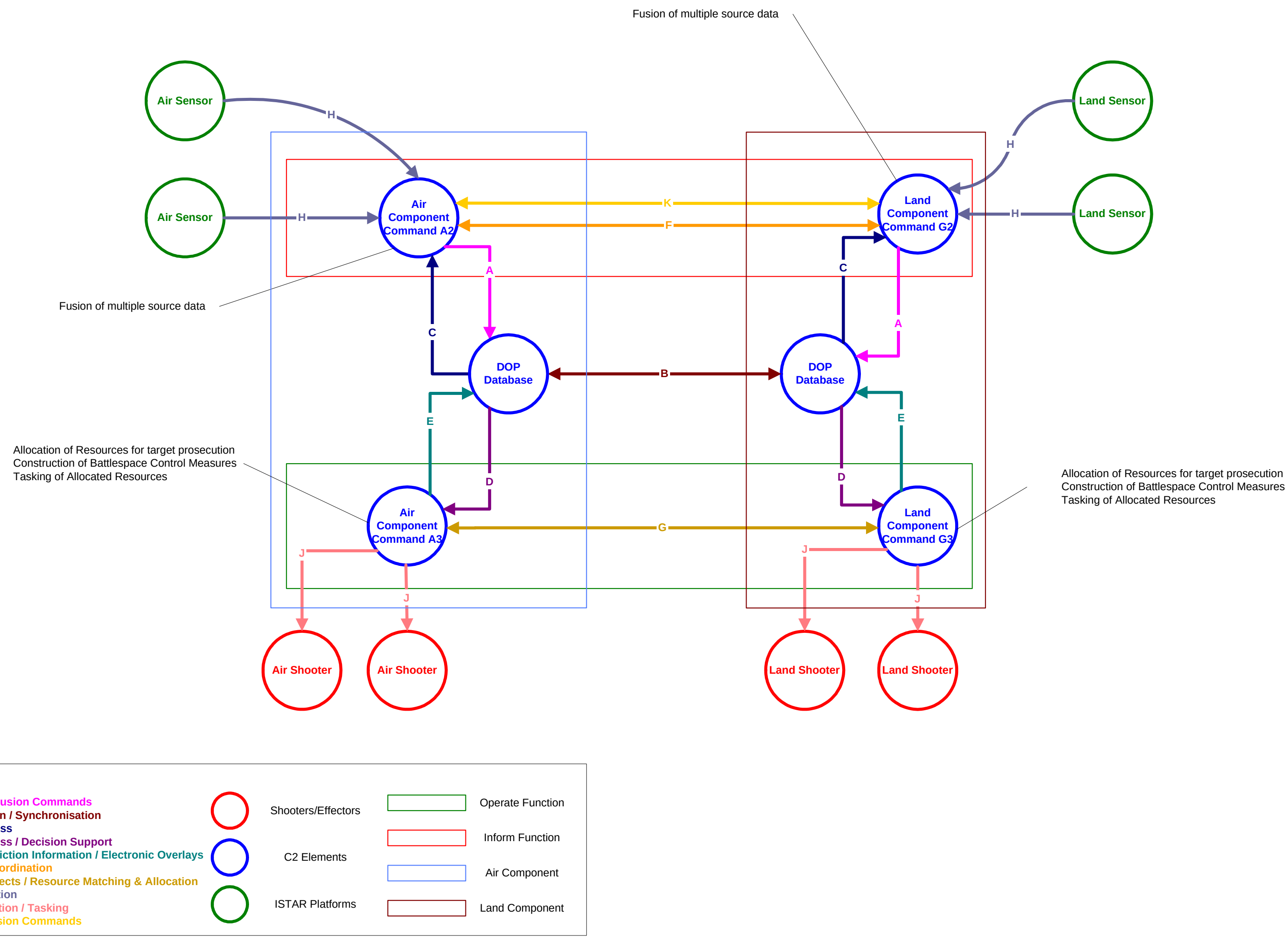

Figure 1 – Information Architecture

Analysis

Having established what we considered necessary as a baseline capability for the successful prosecution of Joint Fires co-ordination in near real time, we moved on to analysing the potential benefits that should flow from the concept. The analysis was undertaken in two main phases, the first being a static analysis of the proposed architecture, including benefits analysis, the second phase using a computer model to assess numerically the expected benefits.

Where possible, the analysis was carried out by analysing generic architecture concepts. However, the more specific analysis and the modelling required the use of a specific use case. For these areas of work, a specific mission chain was used as a yardstick. This mission chain required the detection of two related target types, suppression of these by effectors from two different components, and all events closely synchronised in time.

Architectural Analysis

To allow a comparison to be made when a DOP facility is available, four architecture views were created for both the current organisation (referred to as the Initial architecture) and that expected with a DOP (referred to as the Transitional architecture). These views were based on the DoDAF Architecture and were selected to represent different perspectives of the operation of the system.

The views used were:

- Organisation View (OV-4) which showed at a high level the organisation required to accomplish the relevant benefits.
- Process View (OV-6) which followed from the Organisation view and showed, in the form of a cross-functional flowchart, the order in which processes occur and the interactions between the assets involved.
- Information Exchange Requirements View (SV-6) showed the messages being transmitted between the nodes as defined in the process view and an estimation of the communications requirements to allow these messages to be passed.
- Systems Interface View (SV-3) showed the details of the connectivity between the nodes as well as the applications required by each node. Where applications are required to exchange information electronically, this was also highlighted.

The views were used to capture the operation of the systems at the relevant level of detail to allow analysis to take place. The views could not capture every detail of the mission chain and the ancillary interactions, and did not document every link in the C2 chain. However, the main assets involved in the mission chain and the systems and applications that would be used to prosecute the target were included.

While defining the architecture views, the capabilities and requirements for the DOP were compared to the NEC themes[3]. Table 1 shows these NEC themes with those highlighted which were felt to be required to achieve an architecture including a DOP.

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3. NEC Outline Concept Part 2 – NEC Conceptual Framework Dstl/IMD/SOS/500/2 Issue 2.0 Dated 2 May 2003

NEC Theme	Theme Breakdown
Full information availability	Access to information sources
	Data searching
	Data manipulation
	Data exchange
Shared awareness	Gathering and dissemination information
	Maintaining information
	Presenting information
	Fusing information
Flexible working	Units supporting tasks other than primary roles
	Units working with any other combination of players
	Units working in multiple agile mission groups
	Units moving rapidly between agile mission groups
Agile mission groups	Assembly of capability components for specific operational tasks
Synchronised effects	Dynamic planning
	Dynamic C2 system
	Dynamic, co-ordinated battlespace management
Effects based planning	Tools to allow prediction of effects
	Tools to assess effects of operations across all domains
Resilient information infrastructure	Capability to share information across the battlespace
	Management of information sharing to support operational situation
	Assured end-to-end performance
Fully networked support	Links to OGD's
	Dynamic resourcing to support front-line in theatre
Inclusive flexible acquisition	Co-ordination of equipment definition
	Delivery of coherent packages of military capability

Table 1 – NEC Themes and DOP requirements.

Summary of Architecture Analysis Findings

The main finding from this architecture analysis was that the DOP will allow sensors and effectors to operate with consistent information in near-real time. This information would also be available to the Command elements. Since no change was envisaged to the command structure each component command would be organised as currently, using liaison officers to confirm availability of assets where necessary. Although the assets will be commanded as in the present organisational structure, once the mission has commenced, the assets themselves can use the relevant part of the DOP to allow choices over the course of action to be made (subject to the constraints of the Command authority). The assets involved will also have full view (albeit filtered in geographical, temporal, target type etc.) that the commanders will have.

In terms of the NEC themes, the DOP should allow a limited amount of self-synchronisation. The DOP need not be a global structure, but a relevant portion of it could be made available to service the assets required for a particular mission chain.

Metrics

It is well recognised that understanding and measuring the performance of a C2 system is complex. A great deal of work has been carried out in trying to define and measure the effectiveness of systems, but no successful method has yet been defined.

To be able to assess the benefits of changing the information infrastructure to realise a DOP, a system for estimating the performance of the architecture prior to and following the changes is required. Since the implementation of the changes will impinge on the physical, information and cognitive domains, a method of defining and assessing both metrics and benefits across all of these domains is required.

There are many possible metrics for measuring success – use of resources, attrition, fratricide, etc. However, the chosen metrics need to encompass output measures that can be justified and if possible quantified.

The analysis began by selecting five main attributes that would be expected to improve with the proposed architecture changes, namely:

- Time (T) - defined as the duration of individual processes and the total mission time.
- Flexibility (F) - refers to the degree of choice available for plans, assets etc.
- Co-ordination (C) - measures the ability of people, equipment and information to work together.
- Situational Awareness (SA) – refers to the degree of awareness and understanding of surrounding battlespace.
- Optimality (O) - refers to the best possible use of people, equipment and information.

In order to assess each of these metrics, which may be difficult to quantify as specified above, a further breakdown was made into the physical, information and cognitive domains as shown in Table 2.

This categorisation then helps to define further some of the terms used – e.g. co-ordination can be defined as consisting of collaboration in the cognitive domain, coherence in the information domain and synchronisation in the physical domain. It should then be easier to measure or estimate these separate metrics rather than the higher level attribute ‘co-ordination’.

	Situational Awareness	Time	Co-ordination	Flexibility	Optimality[4]
Cognitive Domain	Understanding	Time to make decision	Collaboration between people	Choice of CoA and problem solving	Ability to make correct decisions
Information Domain	Availability of information	Time to transfer and display information	Coherence of information	Production and flexibility of alternative plans	Selection and filtering of appropriate information
Physical Domain	Presentation of information	Time to move assets	Synchronisation of physical assets	Choice of assets and ability to change team structure	Utilisation of assets

Table 2. Metric Categorisation

This analysis of metrics vs. domains was then used in estimating the values in the benefits modelling and for evaluating the parameters for input to the dynamic modelling.

Benefits Modelling

To extend the qualitative analysis undertaken in terms of the architecture views, an approach was required to assess the usefulness of the DOP concept. A 'Benefits Modelling' approach was used, where subjective judgement was applied in a structured manner to gain sufficient insight for improvements to be analysed, and subsequently used in the simulation (as detailed in section 5.4).

To perform the analysis it was necessary to convert the specific use case processes into a set of generic mission processes. These generic processes were developed using the use case and several other Joint Fires 'mission chains' (including a contemporary Joint Air Attack Team or JAAT). This identified the following generic process elements:

- Communicate
- Collate and create intelligence products
- Disseminate intelligence products
- Assess target and establish required effect
- Decide if ISR or effector required
- Decide which ISR or effector
- Plan and deconflict
- Task ISR or effector
- ISR or effector preparation
- Transit
- Find target and gain ISR

[4] The term Optimality refers to the optimal use of resources across all three domains

- Engage target

Each of these processes needs to be assessed against the defined metrics of Time (T), Flexibility (F), Co-ordination (C), Situational Awareness (SA), Optimality (O), and the overall measure of Mission Success (MS).

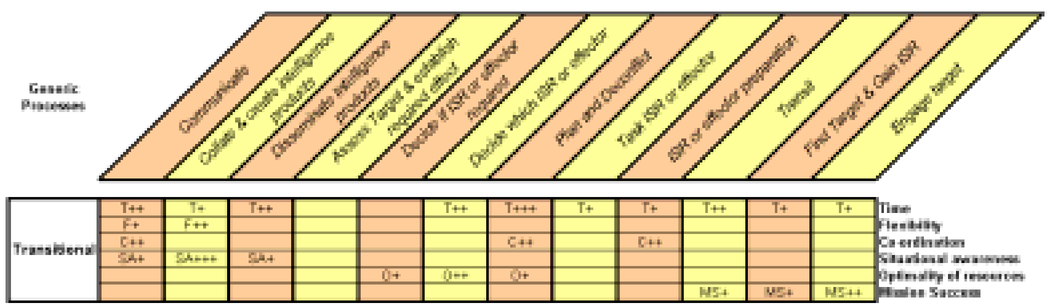
Mission Success is defined as the degree to which the mission objective was achieved.

The Benefits Analysis was carried out in the following manner:

For each generic process:

- The elements of the NEC themes (Table 1) that would impact the generic process were identified.
- Each of these elements was then taken into account when assessing each main metric against the generic process.
- The breakdown of metrics from the Metrics Categorisation (Table 2) was used to identify changes at the detailed level. Any changes[5] were then identified as minor, significant or very significant.
- The overall change to the main metrics for each generic process was then estimated, taking into account all of the changes at the more detailed level and their perceived importance.
- The benefits matrix was then populated with these overall changes to give an estimate of the benefits accrued by each generic process in terms of each of the metrics considered.

This resulted in the following matrix:



Generic Processes	Communicate	Collate & create intelligence products	Disseminate intelligence products	Assess Target & establish required effect	Decide if ISR or effector required	Decide which ISR or effector	Plan and Deconflict	Task ISR or effector	ISR or effector preparation	Transit	Find Target & Gain ISR	Engage target
Transitional: Time	T++	T+	T++			T++	T+++	T+	T+	T++	T+	T+
Flexibility	F+	F++										
Co-ordination	C++						C++		C++			
Situational awareness	SA+	SA+++	SA+									
Optimality of resources					O+	O++	O+					
Mission Success										MS+	MS+	MS++

Figure 2 - Benefits Matrix for the Transitional Architecture

Each cell in the matrix represents a potential area for an improvement or degradation in performance of the specified metric. The signs following the letters within each cell represent the level of expected change (+++ being best, --- being worst). A cell with no entry represents no change from the current situation.

For example, the use of a DOP within the process of planning and deconfliction would result in significantly better co-ordination in the battlespace, as the planners would have an enhanced awareness of current and future missions that may impact their mission and would be able to plan and deconflict accordingly.

[5] I.e. Does the result of carrying out this process increase or decrease the value of the metric?

Summary of the Benefits Analysis Findings

The main conclusions to be drawn from the benefits analysis are:

- Improved information infrastructure (e.g. DOP, communications systems) allows more efficient dissemination of information.
- This directly improves Situational Awareness and Flexibility.
- The improved SA allows better synchronisation and utilisation of assets at decision and planning stages and leads ultimately to an improved mission success.
- Availability of consistent and timely information to effectors and sensors improves synchronisation.
- Improved tools and SA provide time savings in dissemination, planning, tasking and execution processes.

For each of the generic processes that constitute a mission chain, different combinations of metrics were found to have been influenced. These improvements in the metrics were then used to inform the dynamic modelling.

Time related amendments were applied directly to the process times recorded for the Initial mission chain, so that a new overall mission time for the Transitional architecture could be determined to compare with that of the Initial architecture. The +/- changes were assigned a value (such as '+' = 10%, '++' = 30% etc.) for input to the dynamic modelling, to determine the Transitional mission time.

The remaining metric amendments relate to qualitative changes and were, where possible, used primarily to inform the dynamic modelling team, ensuring that these benefits were taken into account of in the model.

Dynamic Modelling

Computer modelling was used to provide a quantifiable method of evaluating both the current architecture and also the capabilities expected to be available from the DOP. This work built on the results from the architecture views and the benefits analysis, and also used the same metrics so that modelling assessment would be in line with those assessments developed in the other aspects of the study.

Specifically two models were developed:

- A single mission chain Monte Carlo spreadsheet model aimed at analysing times and critical paths for the baseline NEF mission chain and any future equivalents. This was developed in Microsoft Excel.
- A multiple mission chain event-based dynamic simulation model, providing a more complex environment which allowed both a wider range of metrics to be assessed and more sophisticated future architectures to be represented. This was developed in Simul8®.

The value of taking both approaches was that while the spreadsheet model allowed specific and detailed focus on the baseline NEF mission chain, the multiple mission chain model had a more holistic and generic view. However, they also complemented each other by providing both a means of validation, and by providing inputs to each other.

Both models concentrate on modelling aspects of the physical domain and the time metric, with less emphasis on the detailed representation of either the cognitive (human-decision making) or information (communications infrastructure) domains. This was due to the lack of verifiable data pertaining to the future systems that would be required to carry out this analysis.

Single Mission Chain Model

The single mission chain model used a Monte Carlo approach to repeatedly generate random process times. These are combined to produce overall mission chain times and critical paths. The process times are modelled using beta distributions, which are configured to be consistent with the judgement of military and technical experts. The times for the current architecture were established using subject matter experts, and the amended times for the architecture including the DOP were estimated using the findings from the benefits analysis.

Multiple Mission Chain Model

The multiple mission chain analysis used an event based model written in Simul8® to simulate the simultaneous execution of a range of mission chains, these all being variants on the original NEF mission chain. Using multiple mission chains allowed a wider range of metrics to be investigated. The process times were again modelled using beta distributions, and configured to be consistent with the single mission chain timings.

The multiple mission chain allowed resources to be limited to more realistically reflect the context of a wider battlespace. Additionally, the software allows more complex and dynamic decision rules to be incorporated into the mission chain, so that events are driven by real time circumstances rather than pre-ordained. Another important benefit is that longer simulations can be run which allows a representative steady state to be reached which is not dependent on specific starting conditions. With the extension of the analysis to this much richer environment, the range of metrics was extended.

The model used an input file containing the control information for a particular run. The range of control extended from basic parameters such as the number of types of assets to be modelled, down to detailed timings. The model allowed targets to be generated, which are all assumed to be targets of opportunity, and are treated as time-sensitive. The runs used for the analysis reported here included five target types. Targets are characterised by attributes such as which component found it, what ISR asset found it, the depth of target, the proximity of sensitive areas, the terrain type, target mobility and dependency (e.g. secondary target to be destroyed first). The generation rate of targets is also set, along with a level of background activity present in the architecture.

The targets are detected by one or more ISR assets, limited here to 8 different types. The program selects a suitable ISR asset using data from the control file, which determines from the target type and characteristics, the most suitable ISR asset. Preference values allow optimum choices to be made between these targets and the assets available.

The simulation was run for the Initial architecture, and for the Transitional architecture, with improvements in parameters taken from the benefits analysis matrix. For example, a T+ benefit was represented by a 10% time reduction, T++ 30% reduction, T+++ 50% reduction.

Modelling Results

Single Mission Chain Results

Following 500 runs of the simulation, the mean time for the execution of the mission chain was reduced by 18.5% between the Initial and Transitional architectures. The largest mean time reductions on the critical path are from the detailed planning and deconfliction tasks. The two major contributors to the critical time (transit and securing data) reduce slightly but remain the dominant processes. However, these conclusions are specific to the assets in the NEF mission chain, most specifically the means of gaining the ISR data.

Multiple Mission Chain Results

A series of runs were carried out using this model and the major results and trends are summarised. They were attempting to compare the Initial architecture with the Transitional architecture over a wider span of the metrics than could be considered with the single mission chain (which focussed only on the time metric). However, the results obtained and the perceived improvements are intended to be indicative of those expected rather than definitive results.

It must also be borne in mind, as mentioned earlier, that these results represent modelling in the physical domain as well as the time metric, and do not include all of the information and cognitive metrics.

The main metrics are examined below in terms of the results from this model:

- Time

  A series of runs was carried out with differing background activity levels. (I.e. the background activity represents the deployment of assets on other tasks and not currently available. Specific asset availability is determined by probabilistic sampling.) With the background activity set to 70%, the overall mission time was improved by 19.0%, which was in close agreement with the value obtained independently in the single mission chain model.

- Mission Success

  There was significantly better access to preferred assets in the Transitional architecture compared to the Initial architecture. Out of all the decision points across all missions, the number of successful first choices increased by 18%. This would have a major bearing on the probability of mission success.

- Flexibility

  The reduction in process times between the architectures led to only very minor changes to the mean number of different asset types available (<3%). This was mainly due to many benefits in the Transitional architecture being associated with planning, deconfliction and decision making processes.

- Optimality

  The term optimality was used to refer to the way in which resources were used in the best possible manner to maximise their effectiveness. Mission success covers some of these issues, and optimality measures focussed on utilisation (the physical domain) and therefore the implied availability of assets. Reductions in utilisation of assets were small but significant, with availability in the

Transitional architecture improving by up to 15% for a few resources. This improvement implies that a smaller force could support the same mission workload without loss of performance from the Initial architecture. However, the overall value taking account of all resources was found to be nearer to 5%.

- Co-ordination

The Transitional architecture reduction in median time between engagement of related targets was 29%. This measure of co-ordination is relevant to the success of achieving effects-based missions.

A summary of these results is shown in Figure 3.

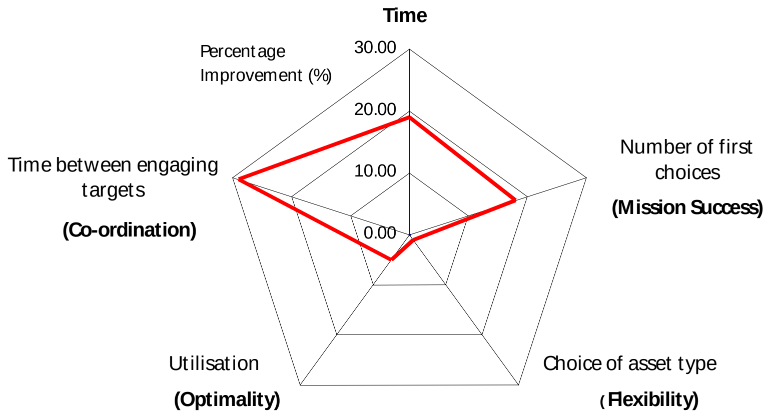


Figure 3 – Summary of metric improvements

These summarised results show that the dominant improvements are time-based (being quicker and more co-ordinated) and success based, by having access to more suitable assets. The changes are specific to a chosen baseline, so the interpretation should be comparative rather than absolute.

Discussion of Results

Modelling assumptions and metrics

The simulations of the single and multiple mission chains are necessarily an abstraction from the real world, and it was decided at an early stage that to model the cognitive domain in detail would not be possible. Hence the decision-making processes are represented by simple but consistent rules which support a comparative rather than absolute analysis. Similarly a detailed representation of the information infrastructure has been eschewed in favour of model elements that capture its implications, especially timing and quality.

The metrics therefore concentrate on the physical domain, and the implications for eventual mission success. Aspects of timings, choice, availability, synchronisation and quality are all directly or indirectly drivers of the probability of the mission meeting its objectives. In the case of this mission chain, the key objective is to successfully destroy the primary target as quickly as possible whilst minimising the risk of collateral damage and losses to enemy action.

Benefits of DOP architecture

The most obvious outcome of moving from the Initial architecture to the Transitional is that there is a potential across a wide variety of processes for doing things quicker (the time metric). The benefits analysis emphasises this, and the simulations, for which time is a major driver, exploit this. Because of the difficulty in representing improvements that are non-numerical (such as the "quality" of SA), the simulation generally has to represent these in a numerical and often time-equivalent manner. However, it has been possible to use mechanisms such as restricting the use of assets in order to represent the constraints due to deficiencies in SA.

As a result of this, the next most obvious outcome of moving to the Transitional architecture is that there is significantly more potential for using the most appropriate asset against each target (mission success metric). Due to better intelligence about the target – using better ISR assets – and having better awareness about the disposition and availability of ones own assets – due to the DOP / GII – leads to better use of effectors against targets and hence improved mission success. It was also clear from the consideration of the decision rules in the simulation, that there is a direct trade-off between time and 'best' asset selection; the emphasis on time sensitivity in the NEF mission chain puts the focus on doing things quickly. However, with the Transitional there will be a greater opportunity in exploiting this trade-off.

Of the other changes between architectures, those focussing on utilisation (optimality metric) and flexibility do not stand out as strongly. This is partly due to the fact that the changes to realise the Transitional architecture do not fully exploit all of the benefits of NEC (Table 1). To realise all, or at least some more of these benefits, would entail a radical change to the command structure. However, a better understanding of what these new structures may be and their interaction would be required before this further analysis could be considered.

The other reason why utilisation and flexibility do not stand out as strongly is that the model emphasises the time effects. For example, it will seek to send assets to engage a target as soon as possible rather than trying to predict the latest point at which they could be employed. This tends to mask the synchronisation metric, although in real life the benefits of better SA and quicker processes could be exploited and traded off against better synchronisation.

Operational Considerations

Agility

Rapid allocation and deallocation of areas for Fires and/or manoeuvre would be the main driver for integration of effects. The effects could even come from different components, such that previously they would never have been considered as viable contenders for co-ordinated Fires towards a common mission aim. The Fires assets may not need to co-ordinate directly between themselves either; they need not necessarily ever be aware that they are participants in a coherent, task oriented grouping. All the necessary co-ordination in compiling the DOP would be likely occur at the operational headquarters level, with the Combat Ops personnel, across all components, making decisions on which targets to strike and with which assets in a flexible, agile manner.

Self-Synchronisation

Creation and dissemination of a DOP would provide effects platforms with levels of Situational Awareness that have previously been unachievable. Provision of this level of SA leads to the possibility that the platforms will become able to make independent decisions regarding the conduct of their mission - this represents, at least, a limited form of Self-Synchronisation.

An example that emerged from the 'mission chain' analysis was that of a fixed wing attack aircraft, requiring Suppression of Enemy Air Defences (SEAD) to be carried out by long range artillery. It was concluded that, as soon as the long range artillery Battle Damage Assessment (BDA) process is complete, the results could be posted on the DOP. The attack assets receiving the DOP could then make the decision to continue with their mission, in alignment with any necessary command authority, which would have been agreed in the pre-mission briefing.

On the other side of this argument, it is considered that Self-Synchronisation (even in this limited form) is only achievable for small, well trained groups who share a high degree of common understanding. In short, our analysis of Joint Fires and the DOP has led us to question "How scalable is the concept of Self Synchronisation?" Clearly, this is another research question, in its own right, and will not be discussed further here.

Command Structure

In the course of the research, we were asked, "What place does 'Functional Command' have in the future prosecution of Joint Fires?" In this context, Functional Command refers to an organisational structure where work groupings are determined by role or function rather than by domain or parentage.

We concluded that for reasons of logistics and basing it would not be appropriate to amalgamate the command elements responsible for operational employment. However, the construction of the DOP was considered a task that would be continuous, providing a constant and relatively well-defined workstream for ISR and Intelligence personnel. For this reason, we believe that the construction of a DOP should be a Joint process at the operational level of command, conducted in close to real time. It would be organised on the basis of the task performed, using personnel from all appropriate services albeit possibly working collaboratively at various distributed locations.

Conclusions

The capability to perform Joint Fires routinely and efficiently is becoming more important with the introduction of systems, across components, with overlapping areas of influence. These systems are relevant mainly to the Deep battle.

Analysis has shown that the most important factor in employing Joint Fires in a safe, efficient and flexible manner is Situational Awareness. The Deep Operations Picture represents an evolutionary concept for providing this SA between component command headquarters without having to make significant, disruptive changes to the existing command structure.

Investigations of the implications of the DOP concept suggest that improvements would be realised at nearly every stage of the Joint Fires process. In addition, some aspects of Network Centric behaviour would begin to emerge, most notably in the areas of Agility and, in some cases, a limited form of Self Synchronisation. Changes in command structures, with an evolutionary shift towards more functionally oriented groupings may also be a consequence of the widespread sharing of information at the Component Command level.