The dissemination and fusion of geographical data to provide distributed decision making in a Network-Centric environment

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Simon Snell
Principal Systems Engineer
QinetiQ
Intelligence Systems
Darenth House
84 Main Road
Sundridge
Nr Sevenoaks
Kent
United Kingdom
Tel: 01959 54 7419
Fax:01959 54 7499
E-mail: shsnell@QinetiQ.com

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Simon Snell
QinetiQ
Darenth House, Sundridge Business Park, 84 Main Road, Sundridge,
Nr. Sevenoaks, Kent TN14 6ER, United Kingdom
Tel +44 (0)1959 54 7419, Fax +44 (0)1959 54 7571
shsnell@qinetiq.com

Abstract

Network Enabled Capability (NEC) provides a conceptual framework to generate new perspectives, approaches and solutions to military missions, operations and organisations. The key principle is to enhance military capability through the power of information. Distributed information will empower all the decision makers in the battlespace rather than just a few. Core NEC themes such as Agile Mission Groups, Synchronised Effects and Effects based planning will be dependent on increased situational awareness, more collaboration and the sharing of data. Decision makers at lower levels of command will require an understanding of both the big picture and the local situation. This shift in Command and Control principles will fuel the demand for geospatial data across the battlespace and specialist applications will be required to provide geospatial decision support for dynamic decision making on the front line. This paper considers geographical data, which is currently the domain of the specialist spatial data providers and is not freely accessible to the decision makers. At present, crucial geographical analysis is separated from the decision makers resulting in a fragmented information flow that prevents a genuine problem solving environment.

Introduction

> *"NEC allows platforms and C2 capabilities to exploit shared awareness and collaborative planning, to communicate and understand command intent, and to enable seamless battlespace management in order to create* ***decision*** *superiority and the delivery of synchronised effects in the joint and multi-national battlespace."*[1]

This paper will concentrate on the decision aspects of this statement and will consider some of the decision support applications required to aid complex geographical and location based decision making to create decision superiority. Decision support applications will be dependent on the sharing and dissemination of standard military geographical products and geo-referenced intelligence overlays.

[1] Major General R Fulton Capability Manager (Information Superiority) 30 April 2002

The UK Ministry Of Defence (MOD) has stated that the move to a Network Enabled Capability (NEC) is to be central to the definition and operation of its future equipment capability.[2] NEC has adopted many US Department Of Defense (DoD) Network Centric Warfare (NCW) principles based on the following tenets.

- Information is shared
- Situational awareness and commander's intent is available to all levels
- Operations are effects based and synchronised
- Decisions should be collaborative

At the core of NEC are the concepts of Agile Mission Groups (AMG), Effect Synchronisation (ES) and Effects Based Planning (EBP).

> *'Enabling the dynamic creation and configuration of Mission Groups that share awareness and that co-ordinate and employ a wide range of systems for a specific mission.'* [3]

The formation of AMG will support the employment of rapid effects within a flexible and dynamic organisation. This supports the NEC concept of a network-centric force composed of capability components brought together to form AMG to undertake specific operational tasks. Once a mission is complete the components will disband to their original structure. AMG will require a high level of shared awareness to synchronise planning and exert effect within the battlespace. The synchronisation of effects is achieved within and between Mission Groups by co-ordinating the most appropriate assets available in the battlespace through dynamic distributed planning and execution. The battlespace will contain many separate and distributed planning teams and EBP and synchronisation will be realised by the integration and synchronisation of planning processes to provide purpose behind the formation of an AMG.

In the UK, Mission Command is an established principle where the Commander's intention is pushed down to subordinates, enabling them to carry out missions with the maximum freedom of action and appropriate resources. As this style of command implies a shift from centralised control to delegated control, the structure behind AMG will become increasingly about self-organisation. Mission Command also relies on the dissemination of up-to-date information to be effective.

Delegated control means delegated decision making which requires access to information and data. Commanders need full access to the situational awareness which needs to be distributed in a timely manner through the Command and Control (C2) system in order to make the best possible command decisions. An understanding of the Commander's Intent and shared situational awareness are required across the battlespace to allow AMG to deliver synchronised effects.

The management and distribution of information to enable NEC is the subject of much current research, the focus in this paper is on the dissemination and application of digital mapping, geo-spatial data and overlay based information to facilitate analysis and decision

[2] NEC Core Capabilities, DSTL 23 October 2002
[3] NEC Core Capabilities, DSTL 23 October 2002

making at lower levels of command. This is in contrast to the current process of providing information in the form of a hard copy overlay, such as the Intelligence Preparation of the Battlefield (IPB). AMG will need to plan their own operations and effects and will therefore require specialist tools and applications to ensure that the decision makers can carry out their own analysis.

Shared Awareness

Shared awareness is a core theme of NEC and is an extension of the concept of situational awareness. Shared awareness aspires to achieve a common state of understanding within a group through the exchange of data and information. During the course of previous MOD research, situational awareness has been defined as:

> *'Situational awareness is the assimilation of current and historical information to form a mental model of what is going on and what is likely to happen in the future in order to support timely decision making'.*[4]

Access to, and common understanding of Commander's Intent is essential to achieve shared awareness. Without accurate and common understanding of Commander's Intent, the ability to conduct dynamic collaborative interworking and form AMG to deliver synchronised effects will be diminished. Commander's Intent needs to be replicated in full to all those who require access. Information systems need to be developed to aid understanding of Commander's Intent so that it can considered alongside other information and data in a decision support context.

Shared awareness will need to enable users to identify what capabilities or effects are required and how those effects might be delivered. Apart from Commander's Intent, shared awareness needs to convey an understanding of the interpretation of the situation by other battlespace users and an appreciation of how other battlespace users will react to changes in circumstances. Initially this is achieved by providing the intentions of friendly forces, and their potential Courses Of Action (COA). Shared awareness is not simply achieved by the provision of appropriate information because it exists primarily in the cognitive domain. This makes awareness an individual state where others factors such as the environment, fatigue and time pressures will affect an individuals perception of the situation. The challenge to attain shared awareness will be to present the information in a suitable form for the user to assimilate it quickly and accurately. The application of technology alone cannot provide shared awareness as it can only provide the information that a user requires in a way that they find easy to assimilate. Shared awareness at a group, unit or individual level is developed over time. To reduce the time taken to reach an acceptable level of shared awareness, decision support software will be required to enable manipulation and analysis of the information alongside other forms of intelligence. These should be provided in a systems environment that allows the user to explore, research, formulate and share situational awareness.

Intelligence Preparation of the Battlefield

The geographical environment, in particular terrain, on which ground-based operations are conducted is a key factor in determining the type of operation and potential movement of

[4] MOD ARP 13 Project 17

both friendly and enemy forces. The study and analysis of terrain and other effects of the environment is called the Intelligence Preparation of the Battlefield (IPB). IPB is a process that starts in advance of operations and continues during operations planning and execution. It provides the guidelines for the gathering, analysis, and organisation of information for the intelligence estimate. The purpose of IPB is to support a commander's decision process to identify critical battlefield Decision Points (DP), from which their staff can firstly deduce the information that their commander will need to support those decisions and, secondly, to recommend how best to employ Intelligence Surveillance Target Acquisition and Reconnaissance (ISTAR) assets. IPB is also the foundation for the targeting process. The resulting products of IPB are identification of various areas of the battlefield that affect COAs. Such distinctive areas include engagement areas, battle positions, avenues of approach, targets and areas of interest. Identifying these areas allows the Commander to make inferences about possible enemy COAs and the degree of vulnerability or 'threat' of his own force to enemy attacks.

In addition to basic infrastructure data (roads, urban areas, forest, obstacles etc) and weather patterns, IPB requires population information including: refugee movement patterns; ethnic boundaries; protected or sacred areas and areas of humanitarian concern. This data must be collected prior to the operation to provide the data needed to develop COAs. At present, IPB is developed manually by intelligence officers with support from geographic engineers using hardcopy maps on which they notate various significant areas, such as DPs, Main Supply Routes (MSR) and defensible terrain. This manual and non-digitised process suffers from a number of disadvantages:

i) Fixed level of detail – no zooming in to detailed mapping or imagery
ii) No control over what is displayed
iii) Manually annotating the map is time consuming
iv) Annotation overlay is difficult to reproduce and is hard to copy electronically
v) Maps soon get cluttered and information easily misread or disregarded
vi) There is a limit to the information that can be added.
vii) Not designed for dissemination from main HQ

Despite these disadvantages the IPB process has established a robust, well defined methodology with a predictive analytical approach which provides a foundation for disseminated decision making.

While the IPB process is sequential, it is also continuous and cyclical. It must be conducted before, during, and after an operation, while planning for and executing other contingencies as they arise. As new information is supplied, intelligence staff modify their assessments of the battlespace and assess further potential COAs. The dynamic nature of IPB will be critical to the success of AMG operations and an essential component to effect based operations.

The targeting process

Targeting is defined as:

> *"the process of selecting targets and matching the appropriate response to them taking account of operational requirements and capabilities".*[5]

[5] AAP-6(V), NATO Glossary of Terms and Definition, 1998 Edition

The targeting process is based on the Commander and his staff continuously performing a cycle of four functions known as decide, detect and track, deliver, and assess. The process is designed to establish key targeting requirements and to ascertain and match the best method of attack and effect. The decide function is key and requires close interaction between the Commander and the intelligence, plans and operations cells. The staffs must clearly understand:

1) The mission
2) The commander's intent and concept of operations, including his schemes of manoeuvre and fire
3) The commander's initial planning guidance

The IPB overlay is the main component in this process along with Target Value Analysis (TVA) and the intelligence estimate. At higher levels of command (typically divisional level and above) operations, intelligence and offensive support staff participate in war gaming and develop the products of the decide function.

The end products of the IPB and the targeting processes are the Decision Support Overlay (DSO) and a collection of targeting information specifying high priority and value targets. The DSO is effectively a combined intelligence and operations estimate in graphic hard copy form representing a record of wargaming. It depicts Target Areas of Interest (TAIs) and associated DPs which reflect the expected enemy COAs.

Dissemination of information

Within the context of NEC the delegation of planning and filtering down of the IPB is unclear. Mission command doctrine dictates that a mission, resources and minimum constraints on time or action are passed down to the subordinate. This is the freest style of command currently practised but the introduction of networked AGM will add extra dimensions of self-organisation and self-synchronisation. In order to achieve this, information has to be pushed down and configured to support co-ordinated planning activity within the AGM. Alongside the Commander's Intent the IPB and DSO provide a good representation of the planned COAs, threat, terrain limitations and targeting information. Extra information such as the Surveillance Target Acquisition (STA) Plan matrix could be fused with the Named Areas of Interest (NAIs) depicted on the DSO. This would provide surveillance indicators to support the allotment of suitable STA assets at mission group level.

The DSO in its current hardcopy format is difficult to reproduce and distribute. It can only be manually copied by tracing but generally it is carried between different planning cells or remains on the operations birdtable. NEC will dictate that such valuable information is shared and disseminated to all relevant users on the digitised network for use in distributed and collaborative planning processes.

There is often a misunderstanding of the concept of digital overlays and the belief that they represent merely digital scans of hardcopy overlays. Digital overlays are compiled using vector geometry which allows for the attachment of attributes and information to geographical features, locations or other symbolic entities such as units.

Vector data

Geographical Information Systems (GIS) allow the computer based visualisation and manipulation of geographical or spatial data. Standard digital maps are stored in a format known as raster data. Raster data represents an image of a map and are useful for providing the mapping backdrop on which vector data sets are overlaid. Vector data comes in the form of points, lines and polygons that are geometrically and mathematically associated. Points are stored using the co-ordinates, for example, a two-dimensional point is stored as (x, y). Lines are stored as a series of point pairs, where each pair represents a straight line segment, for example, (x1, y1) and (x2, y2) indicating a line from (x1, y1) to (x2, y2). The points themselves are encoded with a pair of numbers giving the X and Y co-ordinates in systems such as latitude/longitude or Universal Transverse Mercator grid co-ordinates.

- *Points*
  These are the basic building block and may also represent individual features such as a unit, a target or decision point.

- *Lines*
  These are sets of points that represent linear features such as obstacles, movement corridors, boundaries or phase lines.

- *Polygons or areas*
  Consist of a set of lines used to represent closed areas such as TAIs, NAIs, no go, and terrain features.

Vector data is often considered as 'intelligent data' due to its association with attribute tables. This means that the spatial element of the data can be queried and sorted through its attributes i.e. just show DPs connected with a certain TAI. It is also connected with the overlaying of features so it is possible to have a vector overlay dedicated to a single theme that can be toggled on or off in a GIS. This allows a layered approach to building a DSO that could consist of individual overlays for going, terrain analysis, different COA and friendly/enemy forces. The system user then has the option to view only the features they are interested in. Attaching attributes to geographical objects such as NAIs allows the addition of other information such as the Surveillance Target Acquisition Plan (STAP) matrix where observation times, indicators and other tasking data can become available to all users in a mission group.

Vector data also allows more spatial intelligence to be added in the form of a topological data structure. Topology describes the connectivity, adjacency and containment of a line or polygon vector data structure allowing queries such as: 'what is next to…?'; 'how far is the road from…?'; 'what is inside that area? This is crucial to many forms of spatial analysis where real world features such as a road network need to be accurately modelled. This makes it ideal for more advanced decision support applications.

The vector data structure produces small files as only point co-ordinates that are stored with their associated attributes. Manipulation of vector data is usually more precise and robust than other types of geographical data, such as raster mapping. Changing a co-ordinate system or map projection of a vector data set involves the mathematical transformation of every point which can be done 'on the fly' by most standard processors.

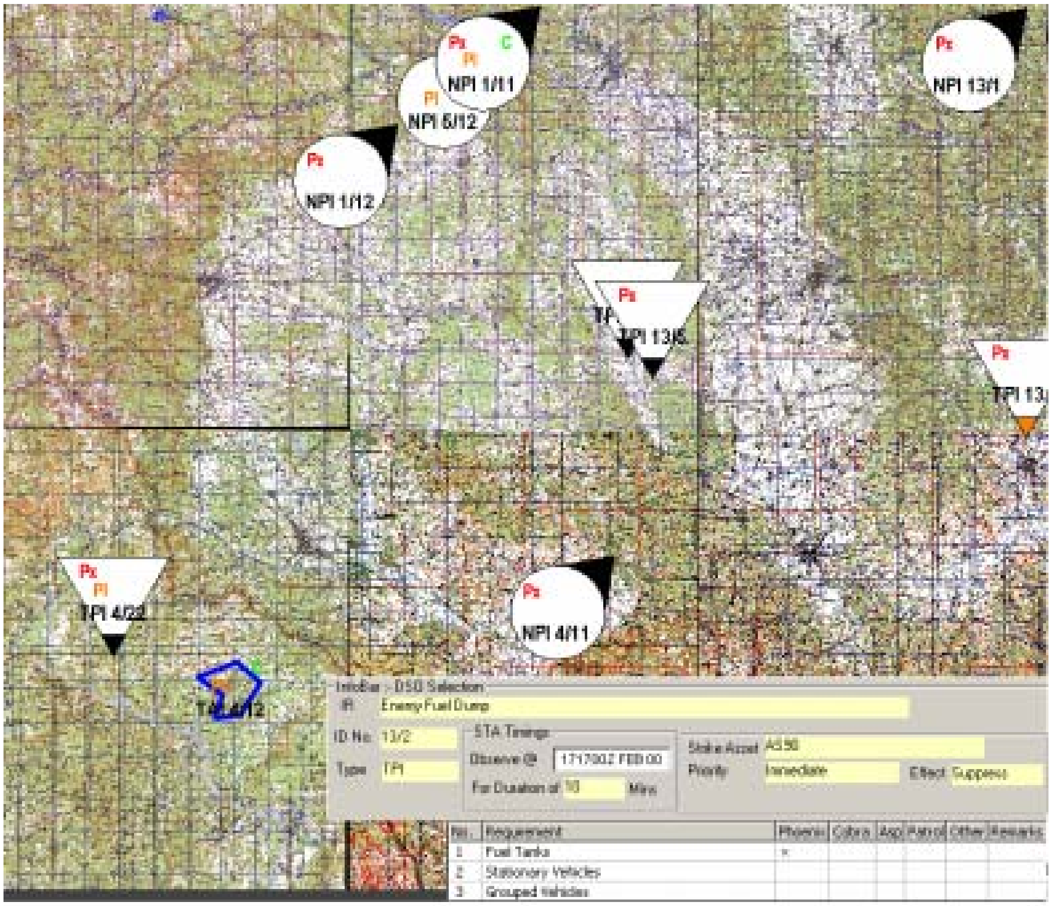

Figure 1: Representation of the DSO showing Target Points and Named Points of Interest. The DSO is a vector overlay displayed on a raster map. Targeting and surveillance information are stored as attributes of the DSO and displayed when a DSO object is selected.

Geographic Support

The Defence Geographic Imagery and Intelligence Agency (DGIA) is responsible for all aspects of geographical policy, plans, standards, requirements and supply/dissemination for the MOD. During an operation, the Geographical Engineer Group (GEG) provides deployable geographical capability. Field deployable geographical support is provided to meet the following requirements:

- i) Provision of geographic advice
- ii) Management and provision of geospatial data
- iii) Terrain analysis input to IPB
- iv) Provision of standard geographic products

In the network-centric battlespace many disparate planning systems will have some form of map interface and be dependent on the provision of geographical data. The role of geographic support will evolve into the integration of geographical data into decision support systems combining planning processes with analytical geographic decision making. Currently, the level of expertise required in geographical data manipulation limits access to all forms of GIS that provide geographical analysis. Many staff who make critical geographical based decisions in a C2 context have been unable to benefit from GIS.

The concept of Geospatial Decision Support (GDS) is to place the capability of GIS into the hands of a wider range of decision makers. At present, the planning activities are removed from the geographical analysis, so if an STA planner is looking for a good location for a radar platform they pass a candidate location on to the geographic engineer who will provide some terrain assessment and a line-of-sight overlay. If the STA planner had dynamic decision support tools at his fingertip providing not only line-of-sight information but also complex terrain suitability assessments for radar location, then the analysis and planning would become integrated. In this way the planner is combining his expert knowledge, intuition and experience with decision support tools that are providing an instant response to his queries. The planning process becomes rapid, accurate, efficient and more effective than having geographic analysis ten steps away.

The future role of GEG will be to continue as the expert providers of spatial data and maintainers of spatial data integrity. However, the role of geographic support will change with the introduction of GDS systems. GDS will enable rapid decision making by including processes that automate complex geographical analysis. The geographic data will be embedded into the system which will be finely tuned to provide decision support without the complexities of managing geo-spatial data. Geographic engineers will be required to manage this data, maintain its integrity and support and service GDS systems for the end user. Geographic analysis should be placed the in the hands of the decision maker using an appropriate GDS system.

Examples of geospatial support

- Visibility/line-of-sight analysis
- Sensor footprint
- De-confliction of complex three-dimensional scenarios
- Shared environmental picture
- Deployment routing
- Routing analysis and movement timing
- Terrain analysis
- Ballistic trajectory analysis and de-confliction
- Effect planning
- Asset management and scheduling

Spatial Data

To remove the requirement for the user to have detailed understanding of spatial data, GDS requires such data to be embedded into the system. The decision maker should not be required to input or manipulate the raw data and this should be done by geospatial specialists before the operation or upgraded during. To support most decision support models a combination of geographical data is required and should include:

- Raster data

  Data is stored in a grid system e.g. scanned images of existing paper maps provide an excellent interface for GDS.
- Vector data

  Data is stored as point, line and polygon representations of features. Highly effective for describing certain features, such as urban areas and road networks.
- Digital Elevation Models (DEM)

A 3D representation of terrain, essential for analytical models such as line-of-sight analysis, gradient and terrain analysis and artillery cresting models.

- Imagery

  Can enhance the visualisation aspects of GDS. Although currently none of our GDS models work directly from image analysis, future systems could extract features using multi or hyper-spectral analysis and potentially DEMs could be computed 'on-the-fly' from raw satellite imagery.

A core level of geographic data at AMG level should be available, either pre-loaded on systems or via the GEG. Data storage solutions are rapidly advancing and PC hard drives are already available with one terabyte capacity (>1000 gigabytes). This would be large enough to cover mapping and elevation data for most of the world. This data could be disseminated throughout the battlespace before deployment on a small hard drive device similar to an Apple iPod e.g. regarded as just another resource like food or munitions.

Conclusions

Battlespace planning involves dynamic situations that consist of complex systems of changing problems that interact with each other. Commanders are rarely confronted with isolated problems that are independent of other aspects of the battlespace. It is not possible to sum the optimal solutions to individual problems to find an optimal solution to the whole problem. To find the most satisfactory solution to individual problems within the context of the whole battlespace, the wider picture needs to be considered and de-conflicted subject to specific constraints. Shared Awareness seeks to achieve this but the challenge is to define the information and data provided from current processes and move them into the NEC arena.

NEC aspires to allow disparate groups to work closely together using shared information to develop and execute plans. Decision making will have to be both synchronous and asynchronous to cope with location and time differences between the group components. Common data sets and collaborative planning applications providing decision support will be key enablers to collaborative working and shared understanding within distributed teams such as AMG.

Fusing the DSO with other matrices and data from intelligence and targeting processes provides a graphic representation of the current situation. Multiple attributes can be associated with battlespace geometry that can be contained in an efficient spatial message for dissemination to suitable users. This digital overlay can be sorted and manipulated accordingly in systems to provide geospatial support.

Traditionally geographic and spatial data is in the domain of the specialist military spatial data providers and the geographic engineers. It is not generally not accessible to the decision makers who have to refer to the engineers for geographical advice. This means that crucial geographical analysis is separated from the decision makers resulting in a fragmented information flow that prevents a genuine problem solving environment. GDS is aimed at users who are expert planners in their own fields but not in GIS. The user is not expected to be an expert in geographical data nor an expert in computer simulation and modelling. The aim of GDS is to provide support to the user by relieving them of the skilled knowledge required for standard GIS operations. The end result is that the decision maker is free to apply their particular knowledge to solving the problem in hand using simple 'point and click' methods on a map based environment.

References

Shared Situational Awareness in the Context of Network Enabled Capability
QinetiQ/KI/INTSYS/CR030191 dated January 2003.

Impact of NEC on the Dissemination of Commander's Intent
QinetiQ/KI/INTSYS/WP040300 dated January 2004.

Artillery Training Volume 1 Artillery in Battle, Pamphlet no.3
The Targeting Process, MOD dated November 2000.

QinetiQ