Lessons Learned From Recent
UK Land Formation C2 Experiments

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Abstract

The UK Ministry of Defence (MoD) is currently embarked upon a programme to digitize the UK Land Forces. This will result in procurement of a complex system-of-systems that will evolve over three stages from a basic capability that automates current Command and Control (C2) processes to an ultimate end state where computer support shapes the battlespace by enabling information superiority to enhance tempo and force simultaneity. The procurement of this complex system-of-systems and the management of the interfaces between evolving components are challenging problems. To aid this process, the UK has created the Land Digitization Test and Prototyping Rig (the Rig) which allows investigation of some of the most pressing development and integration issues. This paper describes two C2 experiments conducted using the Rig during 1999. The paper begins with a description of the Rig, then moves on to describe the set-up and objectives for each experiment. It concludes with a summary of lessons learned, placing particular emphasis on the Symposium theme of "Making Information Superiority Happen".

1. The Digitization Test and Prototyping Rig

1.1 *Background to the Requirement*

In common with other NATO nations, the UK has begun the process of "digitizing" its forces. In the land domain this will be accomplished by a three-phase approach that will successively deliver:

- **Digitization Stage 1–** a basic capability which provides limited support to current C2 functions at formation level (brigade HQ and above);
- **Digitization Stage 2 –** a more comprehensive approach which provides an integrated set of tools designed to provide support tailored to user roles at any echelon in the land hierarchy, but still largely based upon current business processes;

- **Digitization Stage 3 –** which applies business process re-engineering to change the methods of working within the organisation and hence allow the maximum exploitation of the benefits that digitization can offer.

To deliver this programme the MoD has a complex set of linked projects that deliver individual components of the enterprise. These include:

- an underlying communications and computing infrastructure;
- a middleware layer known as the Common Infrastructure for Battlefield Information Systems (CIBIS) which is designed to provide a set of services to application developers that are robust to the hostile environment of the land battlefield;
- Battlefield Information Systems Applications (BISAs) which provide user tools specifically designed to support individual roles at every echelon.

Each of these components represents a complex system and are taxing procurement challenges in their own right. However, it is recognised that management of the interactions between the systems within the overall digitization system-of systems is even more complex. To aid this process, the UK has created a Land Digitization Test and Prototyping Rig (the Rig) which allows early investigation of some of the most pressing development and integration issues.

1.2 *Description of the Rig Facility*

The Rig is based in a self-contained facility at DERA Fort Halstead, near Sevenoaks in Kent.
Figure 1 shows a schematic representation of the major components of the Rig. These are:

- **The system under test.** At the core of any experiment is the system under test. This can vary in complexity and scale from a single application running on a single PC, through a set of applications running in a client/server configuration on a single local area network (LAN) representing a single command node, to a complex configuration of LANs linked via a military wide area network (WAN) that represents a set of linked command posts.
- **A stimulation method.** Most systems-under-test do not exhibit true performance unless stimulated by a realistic set of tasks that stress their underlying behaviour. The rig has a variety of stimulation methods that vary from controlled application of a reproducible load on a single component, through controlled application from a single control point of loads upon a number of components, to free play where components are stimulated in a realistic but unpredictable manner. The stimulation may require human players where decision making or human-computer interactions are important. Where data from a military ground truth are required, the Rig can link to the ABACUS training simulation to provide own and enemy force activity. In the most complex case, a realistic manned exercise, military players man the systems under test and control staff operate the training system to provide a militarily valid exercise context. Stimulation is therefore an essential component and requires significant care to ensure that the correct stimulus is selected to the match test objectives.

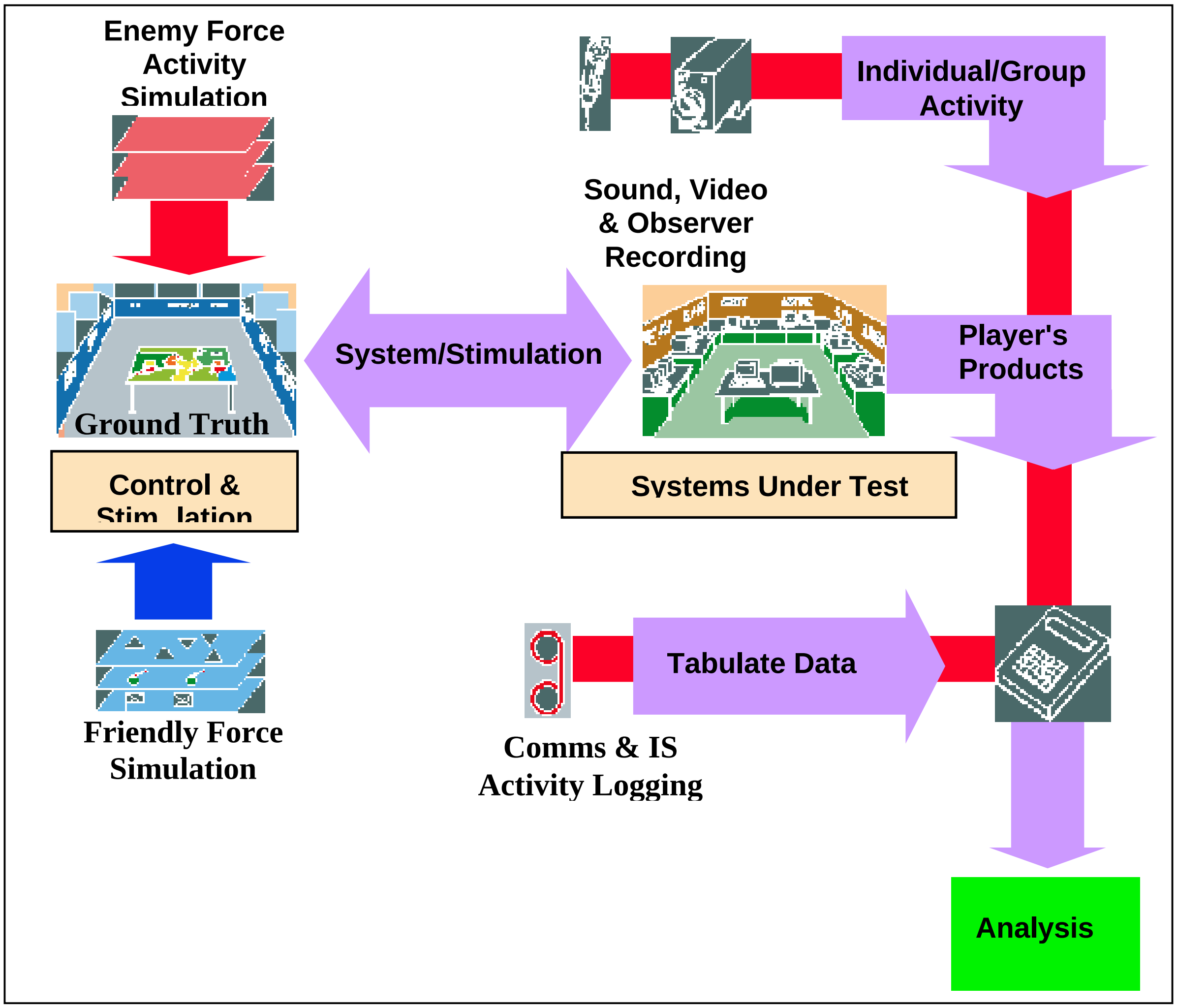

Figure 1. A Schematic Diagram of the Digitization Test and Prototyping Rig

- **Data collection tools.** The Rig also requires a comprehensive suite of data collection and analysis tools to gather performance data that describe the behaviour of the components of the system under test. These include LAN and WAN analysis tools, processor performance monitoring tools and specialised tools that analyse the behaviour of military messaging systems. Up to 9 Gigabytes of data a day have been collected from the Rig. Development of a complete set of tools able to collect data in real time and to process and analyse data rapidly is a continuing research activity.
- **Observer support systems**. Finally, if the Rig is being used with human participants a suite of tools are provided to allow scientific observers to monitor unobtrusively player’s activities. The Rig has a sound and video system and a remote monitoring booth which allows scientific observers to gather essential contextual data: what were the military players doing at any given point in time, relative to the utilisation of the systems under test and the military scenario?

Collectively, these capabilities make the Rig a unique facility in the UK. Although primarily designed for use with military systems, the Rig has also been used for civil applications.

1.3 ***Purpose of the Rig***

The Rig's primary purpose is to conduct experiments to investigate **future concepts** for systems to support the UK's Digitization initiative. This research covers the following areas:

- performance and effectiveness of individual applications;
- performance and effectiveness of the components of the underlying infrastructure;
- interactions between applications and infrastructure;
- performance of overall system of systems that comprises the complete set of applications and infrastructure components;
- investigations into alternative concepts of use, procedures and organisations structures.

Where possible, this research draws upon prototype applications and infrastructure components developed under the MoD's Applied Research Programme. This allows important deductions to be drawn about the performance and behaviour of these prototypes. Ultimately this leads to an enhanced understanding of the true user requirement and the quality of service characteristics that can be expected from technology when it is delivered to the user. Although prototype systems can be unreliable, their limitations can be generally determined in advance and useful experiments can be designed to make best use of their capabilities.

As a complement to the latter, another method is to draw lessons from experiments using systems that are currently about to enter service or that are actually in service. These experiments aim to learn important lessons for the future by extrapolating from a clearly understood baseline system and from current command processes and organisational structures. In the process of conducting such an exercise, additional insights can be gained into the in-service system and data can be gathered that characterises the performance of the system. This represents an additional benefit that further enhances the cost effectiveness of the experiment.

2. **Recent C2 Experiments**

2.1 ***Overview of Exercises conducted***

Two major exercises were conducted using the Rig during 1999. The exercises are reported at References [1,2,3] and were similar, with the following configuration:

- Brigade Headquarters focus, with all major cells manned and with suitable higher/lower control staff;
- Latest in-service UK Army Tactical C2 Infrastructure System (a Windows NT based ruggedised system using TCP/IP protocols for local area networks and links to the UK military Ptarmigan X25 system for wide area networking);
- Development version of the UK Army Command Support Application, which provided support to G2 (intelligence) and G3 (operations) functions;

- Full deployment of LAN and WAN monitoring tools and workstation/server monitoring tools to allow detailed analysis of C2 Information flows and bottlenecks;
- Comprehensive use of the sound and video equipment to allow trained observers to gather military contextual information.

The physical layout for the exercise is shown in Figure 2. This shows the Main HQ area, the major componentsof the system under test, together with the exercise control area that provided the stimulus and the Rig monitoring and observer recording areas.

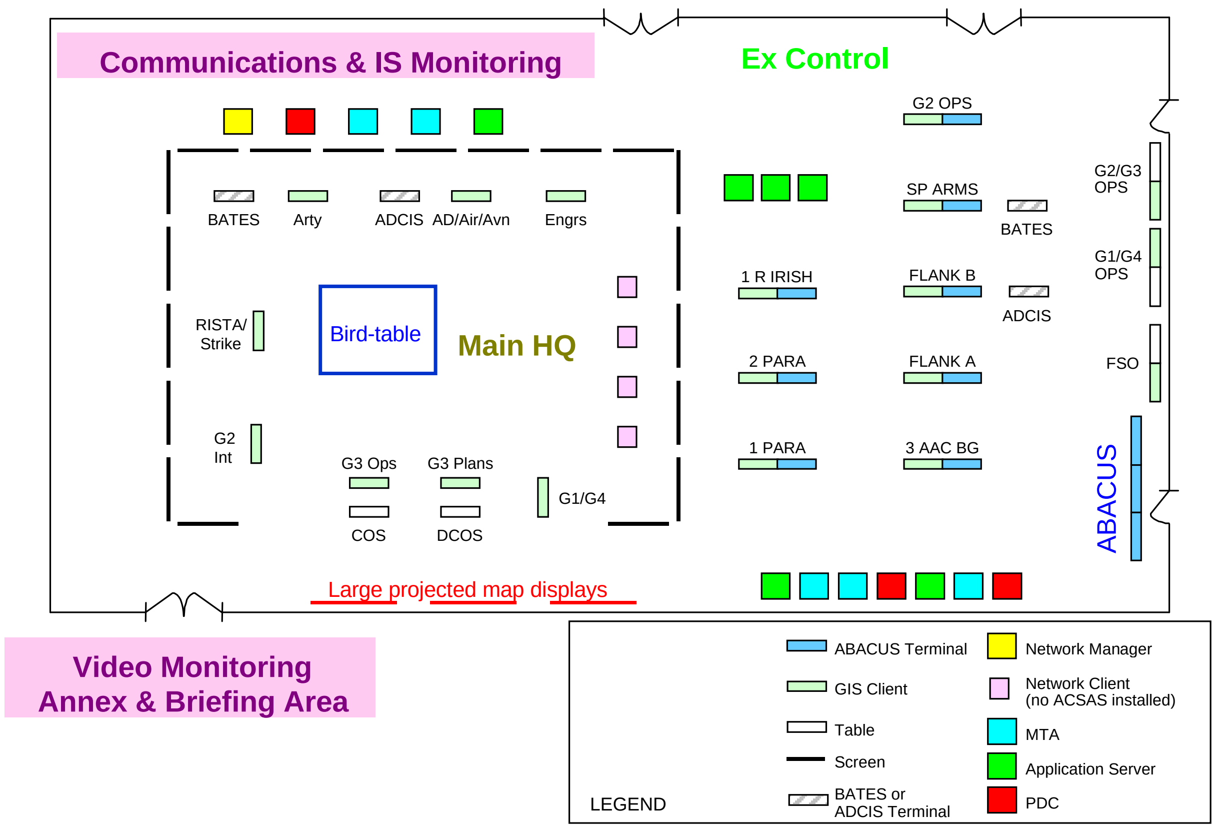

Figure 2: Exercise Configuration for 1999 exercises

2.2 *Experimental Objectives*

The experimental objectives for the exercises were as follows:

- to gather representative performance data that describes the behaviour of the combined infrastructure/application when stimulated by a Brigade HQ exercise;
- to observe the behaviour of the HQ staff when presented with the new tools and to determine changes to processes and standard operating procedures (SOPs).

It is important to note that these trials were the first user based evaluations of the newly integrated application and infrastructure components. The trials were an important opportunity to consider system-of-system performance, component integration and a number of potential weak points in the overall enterprise. The experiments were complicated by teething problems with the systems themselves and in the integration of the application and infrastructure components. Training of military users was also an issue, given the novelty of the systems under evaluation. Although these problems limited the extent to which all of the original objectives could be met, the experiments were highly beneficial.

3. **Lessons Learned for Information Superiority**

3.1 ***Introduction***

To make the lessons learned relevant to a broad audience, they have been abstracted to highlight key enablers for realisation of the ultimate goal of the Land C2 system: making information superiority happen in the land tactical domain. The lessons are presented in three categories:

- system-of-system performance;
- equipment scale of issue;
- usability.

3.2 ***System-of-system performance***

Anecdotal evidence prior to the exercise suggested that the performance of the overall system-of-system enterprise was affecting its military utility. Information known in one HQ could not be passed easily to other lower-echelon HQs. Where was the problem? The first possibility was the LAN. Figure 3 shows an analysis of utilisation of the Brigade HQ LAN.

The graph shows the percentage LAN utilisation, with 30s and 3min moving averages plotted in blue and red. 30% and 60% utilisation levels are also marked: 30% representing an acceptable utilisation and 60% a near saturated utilisation. The data show a small number of short duration utilisation spikes where traffic exceeds the 60% level, but in general the data is typical of a load well matched to the capacity of the LAN. It can be deduced that the LAN was not responsible for any degradation in performance.

Another likely culprit was the wide area network. Analysis of the WAN traffic showed similar trends to the LAN. Utilisation of the military X25 system reached an occasional peak in excess of 50% of the theoretical capacity, but median utilisation was just 5% of the theoretical capacity. The WAN was therefore introducing a delay based upon its bandwidth limitation, but was not operating below expected levels.

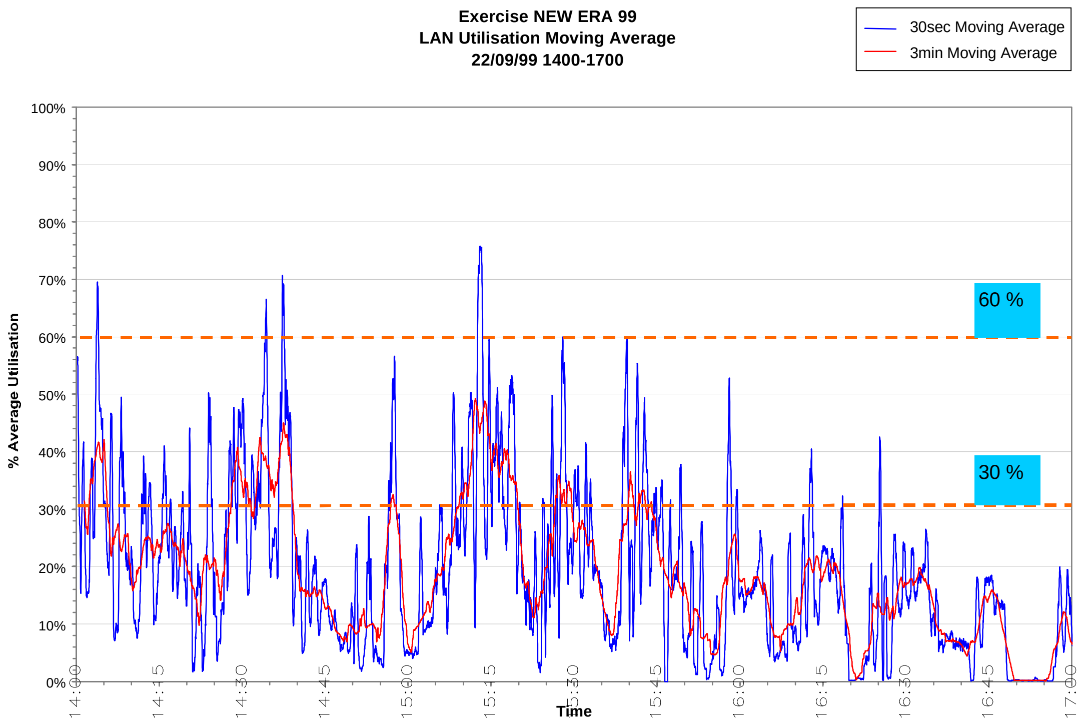

Figure 3: Analysis of LAN Traffic

Attention then passed to key processing nodes – notably the applications server and the Message Transfer Agent (MTA). Were the processors overloaded? Figure 4 shows an analysis of typical CPU utilisation of an applications server.

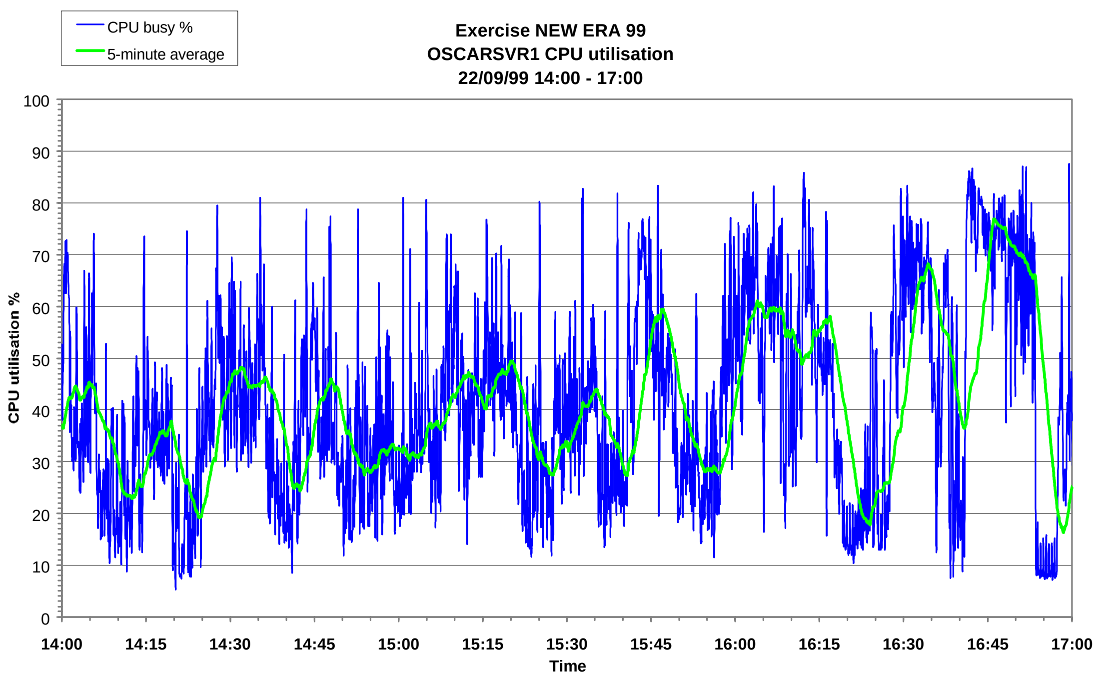

Figure 4: Analysis of an application server CPU utilisation

These data show peaks and troughs of activity that can be correlated with known patterns of utilisation during the exercise. Although peak utilisation of CPU reached 80%, on the whole the graph shows that the processor is well matched to its tasks. Similar trends were found for the MTA processor, and analyses of memory utilisation also showed no significant problems. Processor performance was therefore not causing the problem.

Finally, an analysis of the database performance was conducted. Figure 5 shows data from an analysis of the response times for individual queries against the application database.

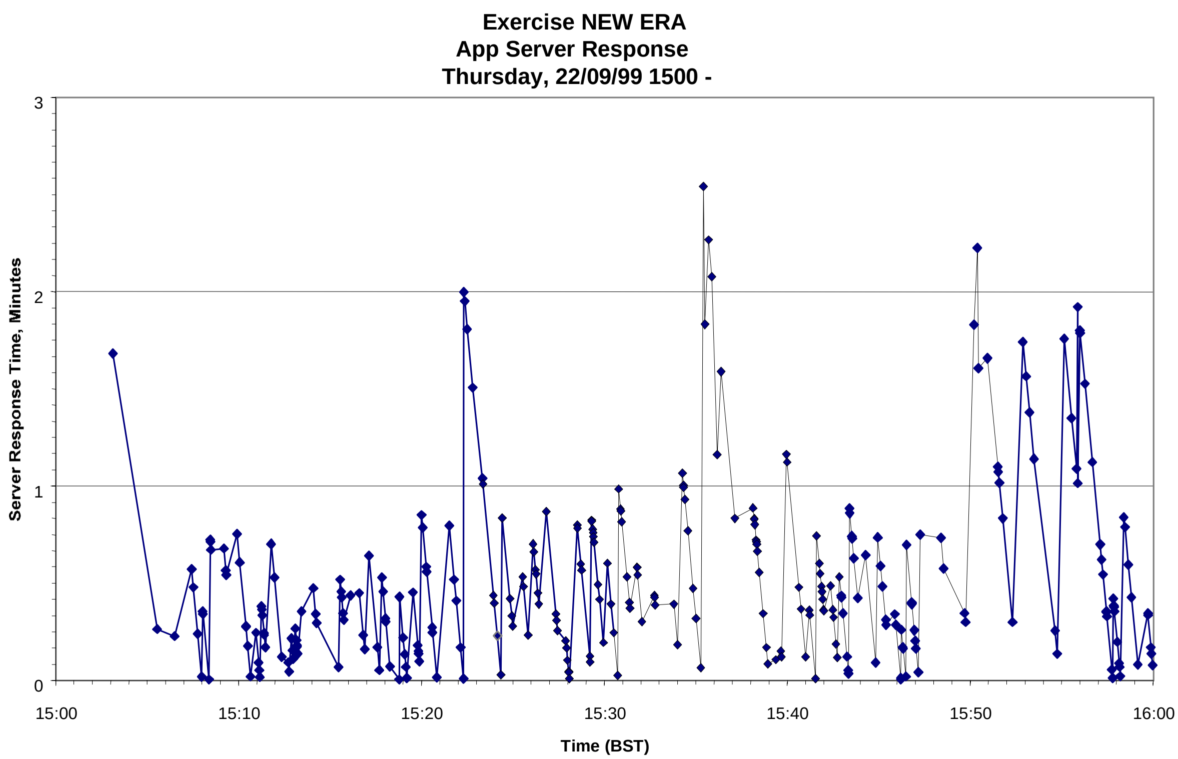

Figure 5: Analysis of database response times

The graph shows that the query-response time varied between 1-2 seconds up to a maximum of 150 seconds. Benchmark performance for a well designed database produce maximum response times of ~10-15 seconds. These data therefore provide quantitative evidence of a component that is significantly under-performing.

These lessons demonstrate that a thorough analysis of the total enterprise is required to fully understand limitations to performance. Impediments to information superiority are just as likely to occur from sub-optimal database queries as from more visible data dissemination bottlenecks.

3.3 ***Scale of issue***

A comprehensive review of the equipment issued to the HQ was conducted during the exercise. Two main types of equipment were assessed:

- The Graphical Information System (GIS) Client computer, which provided a screen just large enough to operate a tactical map display;
- The Network Computer, which provided a more limited display suitable for orders generation, report submission and log-keeping activities.

One GIS and one Network Computer was provided to each cell in the HQ. However, it was observed that two GIS terminals are required in most cells: one to maintain overall situational awareness and monitoring of current operations, the other to facilitate future planning activities. It was also found that two Network Computers are required: the first to enable orders creation and other reports and returns, the second to allow routine watch-keeping duties. The loss of situational awareness from the inability to monitor current operations whilst planning is considered particularly troublesome. Users became engrossed in the planning task and could fail to appreciate significant developments that are clearly shown in situational awareness screens.

However, size and weight issues limit the total numbers of systems deployed just as much as cost/availability. The standard issue equipment is both bulky and heavy and is designed to be carried in large, padded transportation boxes. Without a comprehensive re-design the desired equipment scales are simply impractical. Such a redesign is being actively considered, but is clearly non-trivial.

This lesson demonstrates that impediments to information superiority can occur through limited ability to access information known within the HQ, not just from information not known to that HQ. Even knowing that there is a scale of issue problem does not make it easy to resolve.

3.4 ***Usability***

It is well known that design of a software application requires detailed user involvement, and user review panels were incorporated into the application development cycle. However, this was the first use of the system by a formed group of staff officers executing their normal role as a team. Their use of the facilities differed from that experienced with individual users, and did not always result in the expected patterns of behaviour. As a consequence, user comments on the usability and utility of the C2 applications were, on occasion, unfavourable.

Our findings repeated lessons that are well known in the CIS community, but are sufficiently general that they are worth re-stating here:

- Poorly designed tools can actually increase staff workload, e.g. requiring laborious data entry, and must be designed to maximise benefits relative to effort expended;

- Maintenance of reversionary information in the event of systems failure places too great a burden upon limited staff time, yet staff are generally not confident in system robustness;
- Application functionality has to be tested against real users, operating in their normal roles and with a full command team. Actual methods of working differ significantly from textbook descriptions!

The feedback gained from the two experiments challenged the perceptions of the software developers and will result in changes in the method of delivering key tools and services in the future. These lessons demonstrate that impediments to information superiority can occur through limitations in the ability of the support applications to truly support user processes, despite use of best development practice.

4. **Conclusions**

The UK Land Digitization programme is designed to enable commanders to exploit the opportunities of information superiority to increase operational tempo, lethality and survivability. Information superiority essentially assumes not only that our commanders have an overwhelming advantage in terms of their knowledge of the battlespace, but also that they are able to effectively use this information within and between formation HQs. There are undoubtedly many complex issues that require detailed research before the goal of information superiority is attained. However, our work has shown that there are many seemingly mundane issues that are just as likely to prevent the timely and effective passage of information and its presentation in a meaningful way to commanders and their staff.

The findings from our experiments will influence systems development, future procurement and utilisation of the new systems. However, pressures on budgets and military time mean that future experiments are in jeopardy. Nonetheless, future C2 experimentation with representative military users must be conducted if the goal of information superiority is to be attained.

5. **References**

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DERA Loose Minute DERA/LSB3/19E51/32.1/1.0 dated March 1999.

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[3] A H Smith et al, *Digitization Prototyping and Test Tig: Ex NEW ERA – Final Report*
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