Using Large Group Displays to Support Intensive Team Activities in C2

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Abstract

The use of Large Group Displays (LGDs) is becoming widespread in Command and Control (C2) facilities to support teams involved in the conduct and planning of operations. They should, in theory, provide significant benefits to C2 teams, particularly in situations where they are engaged in intense collaborative tasks to support coordinated decision-making, collaborative planning and synchronized action. There are several documented examples of how LGDs have been deployed and used, both within defense and non-defense environments. Much of the focus has been on the use of LGDs for shared situation awareness, particularly in relation to providing a *picture* of the external or target environment. However, there is significant scope for extending their usage to support new modes of awareness, interaction, and collaboration. This paper draws from an extensive base of knowledge generated and consolidated across the USA, UK, Canada, and Australia which was used to develop considerations and guidelines for the design, development and use of LGDs in C2. In this article, we draw on this work to consider how LGDs might best be incorporated and used in future C2 facilities to support highly dynamic situations involving high levels of interaction between team members, rapidly changing and evolving information needs, and situations where teams may not be geographically collocated.

Introduction

As operational situations become more complex, dynamic, and time critical C2 teams need additional support to achieve their goals. For example, new approaches are needed to aid collaborative activities through the provision of enhanced awareness, improved methods of communication (particularly for geographically distributed teams), and new interactive methods to support teamwork. The introduction of Large Group Displays (LGDs) into command facilities provide a very visible *contribution* for addressing many of the challenges being faced by C2 teams. But are LGDs proving effective or are they just another technology that provides a *wow* factor and an impression of progress? How might they be most appropriately integrated into the workings of modern C2?

Figure 1. An Example of the use of Large Group Displays for C2

One of the main reasons for using LGDs in C2 has been to provide shared situation awareness of the external threat environment. This type of awareness is often provided as a map with overlays showing the placement of adversaries in relation to one's own forces—generally referred to as the Common Operating Picture (COP). LGDs provide a large display area and so can be used to display a range of additional and related information. Figure 1 shows an example of how LGDs are being used in modern C2 centers, in this case at the Prince Sultan Air Base Air Operating Center. In this example, multiple LGDs are being used to provide a range of information about the operational setting including the operating picture, video feeds from airborne assets and the provision of weather conditions in the area of interest.

But how do we go about ensuring that LGD capabilities are developed to most effectively support C2 teams? There is a considerable amount of material available to those responsible for the design and development of LGD capabilities. For example, this paper draws from an extensive base of knowledge and experience consolidated and generated by The Technical Cooperation Program (TTCP 2010) to provide guidelines for the design, deployment and use of LGDs in command environments. The Technical Panel on Command Information Interfaces (TP2) of the Command, Control, Communications, and Information (C3I) Group has undertaken a range of activities in this area, including a Knowledge Integration Task (KnowIT) (Vernik et al. 2006), and a workshop session involving defense scientists from the USA, Canada, the UK, and Australia (Bowman et al. 2006). This work brought together and analyzed collective knowledge about currently available large screen technologies, future display technologies, defense use of Large Group Displays for C2, and information on related non-defense implementations. Importantly, the work undertaken by TP2 resulted in the capture, consolidation, and generation of a host of guidelines and lessons learned based on experiences and evaluations of actual C2 systems. These activities culminated into the development of a comprehensive reference document to be used by national Defense staff

and contractors involved in acquiring, developing, using, and evaluating LGD capabilities (Gouin et al. 2010). There is also a substantial body of information in texts such as the "Handbook of Control Room Design" (Ivergard and Hunt 2009) and various defense and commercial standards—MIL-STD-1472F (DoD1999a), MIL-sTD-2525B (DoD1999b), AS 3590.1-1990 (AS1990)—which deal with a range of important issues, particularly in relation to human perceptual attributes and their impact on the readability and use of large displays.

In the development of the TTCP materials it became evident that there was a broader range of issues that need to be addressed in relation to the use of LGDs for collaborative working, where shared situation awareness of the type described above is but one aspect. This article focuses on this broader context which includes the use of LGDs in C2 environments that comprise multiple integrated LGDs, for dynamic situations requiring the information displayed to be adapted to team needs, and for situations that involve geographically distributed teams. We consider these in line with the evolving nature of C2, where teams are required to increasingly cope with highly dynamic, time-critical, and uncertain situations.

We begin our discussion by defining a contextual basis for the paper by providing background information on collaborative working and teams in C2, with a particular focus on intense collaborative activities. We then provide a set of examples of where LGDs have been used in practice and highlight some of the challenges that have been recorded. The remaining sections then focus on four key areas that we believe need to be considered when introducing LGDs to support a broad spectrum of intense collaborative activities in C2. These are: Information Content (what needs to be displayed when, and how?); Content and Display Management (how should the displays be dynamically arranged and managed?); and Integration (how should LGDs be integrated into C2 facilities) and Interaction (what modes of interaction should they support?).

Context and Background

A significant amount of research has been undertaken to provide a theoretic basis for teamwork including the science of teams in C2, team cognition, and macrocognition (Rosen et al. 2008; Letsky et al. 2008). This work can help ground some of our thinking in terms of how we might best use LGDs to support the collaborative working of C2 teams. For example, the notion of *team* is explicitly defined as "a set of two or more individuals interacting dynamically and adaptively through specific roles while striving towards a common and valued goal" (Rosen et al. 2008). There is a spectrum of collaborative activities that C2 teams must perform to achieve common goals. Some of the work involves low-intensity activities where procedural processes can be enacted and where team members can work largely independently. However, C2 contexts are becoming more complex due to the more dynamic, and time-critical nature of military operations. In response, C2 teams are faced with situations where they must quickly assimilate information, coordinate and synchronize their activities within their own team and with other stakeholders, and react within ever shorter time frames. These types of intense team collaborations are the focus of this report.

Kumar, van Fenema, and Von Glinow (2005) describe intense collaboration in terms of: "the level and frequency of interactions needed for initiating and sustaining joint action and mutual awareness of the members of the team, the flux of activities in teamwork; the evolving work-object, and the context of the collaboration situation." They propose a model with four dimensions to help characterize intense collaborative activities. These dimensions refer to the temporal arrangements of work, the ease of sharing work, the tightness of work coupling, and the uncertainty of work. Bowman et al. (2009) draws on and extends from the work of Kumar et al., to define a contextual basis for Intense Collaboration in Command and Control. They extend the contextual model of to include considerations defined by Alberts and Hayes (2006) in their work on C2 in the 21st century which highlights three factors that define the

essence of transformed C2: "allocation of decision rights, patterns of interaction among the actors, and distribution of information." Access to and use of information is an important dimension of intense collaboration and one that has been of prime concern for the use of LGD in C2 environments: the need to support Shared Situation Awareness.

Shared Situation Awareness

The underlying goals for C2 teams typically involve undertaking operations within a particular geographic area; the common goal being to defeat an adversary. As such, shared awareness of the external or threat environment becomes an important enabler.

There are many potential benefits of using LGDs for shared situation awareness. For example, a report by McLeod (1997) suggests that LGDs may support team working when "operators require concurrent use of information, they have shared tasks and where there are non-conflicting task needs." The report also suggests that LGDs may be important where there are common information needs, feedback is required to be given to whole team, tasks require a common frame of reference, and high-level summary or overview of information needs to be provided. LGDs can also provide an *orientating* type of capability by providing a way of getting a quick update and appreciation of the overall situation, either for one operation or across a range of operations.

There are many examples of how LGDs have been used to provide shared situation awareness and there are a range of considerations and guidelines that can aid in the design and development of these types of capabilities (Gouin et al. 2009). These cover important areas such as the readability of displays, information content, and display management. Ensuing sections of this article will discuss many of these within the context of actual examples.

Broader Usage Contexts

Much of the work to date has focused on the use of LGDs to provide shared situational awareness for collocated teams based on largely static display layouts and limited interaction capabilities. This section establishes the context for an expanded discussion on the use of LGDs in C2, both in collocated and distributed environments.

The results of the Integrated Command Environment (ICE) study at the Naval Surface Warfare Center (Dugger and Barley 2000) provide some insights into these broader requirements. For example, although the more traditional notion of support for shared situation awareness featured prominently, some of the requirements focused more on the internal working of the team. The work showed that, in addition to using LGDs as an information display, LGDs could be also be used as a common *walk-up* workspace to support briefings and g*roup work*. Moreover, the work proposed a broader notion of shared situation awareness. For example, in addition to providing information on the external situation, they highlighted a need to provide awareness of the workings of the team and the systems that they are using; commonly called internal situation awareness.

Modern C2 facilities are being developed to include a host of technologies to support collaborative working such as electronic chat, video teleconferencing, groupware applications, electronic whiteboards, and LGDs. Rather than providing a set of individual technologies that work independently, consideration needs to be given to providing an integrated capability to more effectively support C2 teams. For example, in situations where the team is distributed, it may be important to display video teleconference sessions on the LGDs so that the entire team can be briefed at once and to support ensuing discussions. In these situations, internal situation awareness for the team becomes an important consideration to ensure that the entire team has received the required information and that there is consensus as to the goals and courses of action.

In this article we provide examples and challenges for developing these types of integrated capabilities. Considerations for use of LGDs in supporting both collocated and geographically distributed teams are also addressed.

Examples and Challenges

Although Large Group Displays have proliferated in many areas, including defense and non-defense, these technologies are often not exploited to their full potential. Large Group Displays are often simply used to conduct presentations, show TV news channels or display a static view of the operational environment. Why might this be? In many cases, insufficient time is devoted to the broader design considerations. The important questions, such as: *who* are the LGDs intended for?, *what* information should be displayed?, and *how* is the information shown controlled?, are not addressed. Another problem is that technology is often too complex to be used by most users and so only rudimentary features are used.

There are many examples of where LGDs have been used in C2 facilities but few deployed systems that have been evaluated. In this section we have chosen four systems which have undergone significant evaluation to provide examples and hence support the discussion in this paper. They show a spectrum of capabilities covering a range of challenges facing C2 teams with increasing levels of support for intense collaborative activities, ranging from the provision of shared awareness of the external situation through to highly integrated multi LGD environments. The intent of this section is to introduce the systems to the reader together with a set of broad challenges that the systems were designed to address. This material then provides a point of reference for the more specific discussions provided in later sections of this paper covering some of the key areas that we believe need to be addressed in the design, development and use of future C2 environments that make use of large displays.

K-Wall

The Space and Naval Warfare Systems Center (SPAWAR) center has developed Knowledge Wall (K-Wall) concepts to support shared situational awareness and decision-making in joint operation centers. The purpose of the K-Wall was to foster shared situation awareness, permit continuous updating of the military situation, and enhance the senior staff's ability to interact with supporting information systems. Specifically, it was to help Battle Watch Captains maintain situation awareness through the use of various information products produced daily and to maintain their understanding of the "Big Picture." K-Wall was to help senior-level decision makers answer cognitively challenging questions such as: *how* are we doing? (with respect to all aspects of the overall mission and current plan); *what* is our status? (with regard to force-wide resource management, multi-domain implementation, and various timeline issues); *what* has changed since I was last updated?; *what* coherent patterns in the data may be missing?; and *what* led up to this situation correctly? (Smallman et al. 2001).

Figure 2. K-Wall

The K-Wall used a wall-sized shared display to fuse all information relevant to mission status and to replace the traditional situation maps that were ubiquitous in operations centers. It provides a good

example of how support for shared situation awareness can be provided on a LGD. Some of the features and contributions that this system makes include:

- Information Integration. Bringing multiple sources of information together on a large shared display.

- Summary Information. The use of novel graphical and drill-down approaches for providing mission and anchor desk summaries.

- Reducing the briefing cycle. Eradicating the need for a traditional 8-hour briefing cycle by using a continuous situation awareness and assessment approach.

- Information Quality. Providing indicators of information age.

The Knowledge Wall was deployed on the USS Coronado and at the Naval War College for the Global 2000 War Game and evaluated against 14 key user requirements (Oonk et al. 2001). A range of issues and considerations were recorded including limitations in being able to support interactions with, and visibility of, information. Some broader team-based collaboration issues were also identified such as the need to provide tools and business processes to support improved multi-tiered collaboration. These will be discussed in more detail within the appropriate sections of this paper and in relation to approaches used by other example systems.

The results from the Global 2000 War Game helped in the development of a modified design for the K-Wall which was used and evaluated in the Global 2001 War Game (Oonk et al. 2002). The new design used 3 large display panels. In addition, smaller "K-Desks" were provided to the various Component Commanders for use in information production and monitoring. The layout of the workspace was redesigned to provide users with better viewing of the large displays. There were mixed results in that many of the

complexities inherent in providing integrated workplaces now came into play such as the management and interaction with multiple displays, attention direction, and the workplace layout.

Interactive DataWall

A similar approach to the SPAWAR K-Wall, called the *DataWall*, was evaluated during the USAF JEFX-2004 exercises at Nellis Air Operations Center (Darling and Means 2005). This work echoes many of the considerations and challenges of using LGDs to support shared situational awareness as were reported in the K-Wall deployments and evaluations including the need to understand information requirements, the ability to support content and display management, and the need to provide integration of information. The requirement to be able to interact with the information on the displays was also highlighted. In terms of broader contexts for collaborative working, the evaluations highlighted the need to support distributed collaboration, the need for flexible systems that can be adapted to team needs and the importance of providing internal awareness of team activities and processes.

The Interactive DataWall developed by the US Air Force Rome Laboratories provides an example of how interaction capabilities can be provided for LGDs. The system allows multi-modal interaction through speaker-independent voice activation and a wireless pointing device using camera tracked laser pointers. The system provides both conventional computer mouse functionality and electronic grease pencil capability to interact with a high-resolution display. Three horizontally tiled video projectors allow a combined resolution of 3840 x 1024 pixels across a 12' x 3' screen area. Examples of data display elements include detailed terrain, land route maps, real-time audio/video communications, airborne surveillance and intelligence information, archived geographic database information, and modeling and simulation capability for sortie generation exercises (Jedrysik et al. 1999).

Figure 3. The Interactive DataWall

As shown in Figure 3, interaction and collaboration often go hand in hand. In this case, local collaboration is being supported. Distributed collaboration through LGDs is often more problematic. In these situations, many of the mechanisms that people use to communicate and collaborate, such as gestures, are not supported.

LiveSpaces

This next example shows an approach for addressing some of the challenges of integrating LGDs into team workplaces and the challenges of supporting the interactions between people, the technologies and information they use, and with their environments. The LiveSpaces approach also looks at the challenges of distributed collaboration.

The LiveSpaces approach (Vernik et al. 2003; Vernik et al., 2004) supports the development of highly integrated collaboration environments. The LiveSpace Operating Environment and related applications (Phillips 2008) provides a means of controlling and coordinating all aspects of the environment to help people work together. LiveSpaces allows the seamless integration of various technologies, including LGDs, into a supporting system that becomes a part of the background environment rather than the more common situation

where these technologies appear as a set of disparate, idiosyncratic and quirky hardware gadgets and software applications, each with their own modes of operation and interfaces.

Figure 4. One of the 10 federated LiveSpaces in use at the Australian Defence Force Warfare Centre

Figure 4 shows a LiveSpaces environment in use at the Australian Defence Force Warfare Centre. In this case, in addition to having access to their own personal displays, the users have access to a range of shared displays including LGDs and a number of smaller displays used to provide ambient information and for activities such as video teleconferencing. The underlying LiveSpaces infrastructure supports various ways of managing, controlling, and interacting with the shared displays. For example, the LiveSpaces automation system can allow autonomous control of the displays to rapidly configure the displays with required information for the task at hand. A LiveSpaces application called Ignite can be used to reconfigure

displays, either from a touch screen located near the front door or from individual's workstation. Individuals can interact with the shared displays by simply moving the mouse cursor from their own screen onto the shared screens. Users can also easily share the information on their own screens with others. The LiveSpaces infrastructure supports the federation of sets of LiveSpace environments to provide support for distributed collaborative work.

The LiveSpaces baseline has been deployed to several defense sites around Australia, three installations have been established by Defence R&D Canada, and setups have been taken in the USA to support work being undertaken by the USAF in the design of future Air Operations Centers. In addition to studies being undertaken on a national basis, the TTCP C3I TP2 panel has been using LiveSpaces to support such studies across member nations. LiveSpaces has also been used to support an Australian national research project called HxI Braccetto (Vernik et al. 2006) which focused on new rapidly composable and deployable collaboration systems. A significant amount of exploration and evaluation has been undertaken in areas such as workspace awareness (Gutwin and Greenburg 2002). A key issue relates to the layout of team workspaces. LiveSpaces does not presuppose the layout or configuration of a team environment. The various team environments developed using the LiveSpaces approach and technologies have been arranged in a variety of ways with different numbers of LGDs. But, what is the optimum number of LGDs for particular team situations and where should they be positioned?

ICE Lab

Naval Surface Warfare Center Dahlgren Division developed and Integrated Command Environment (ICE) Laboratory to explore the possibilities for an innovative naval command center where control of a ship's systems (e.g., weapons, navigation, and damage control) could be centrally maintained and communication between the

operators controlling these systems could be optimized (Dugger and Barley 2000). Of particular interest for this article were the results that provide insights into the use of multiple LGDs within a C2 facility.

As shown in Figure 5, eight watch stations were surrounded by ten large screen displays. Each operator had a multimodal watch station console with three upright monitors and one desktop embedded monitor. The setup differs from *traditional* control rooms, where operators generally face one direction and all view the same LGD(s). The rectangular layout was selected to facilitate face-to-face interaction and minimize shipboard fatigue by aligning operators with one of the ship's principal axes.

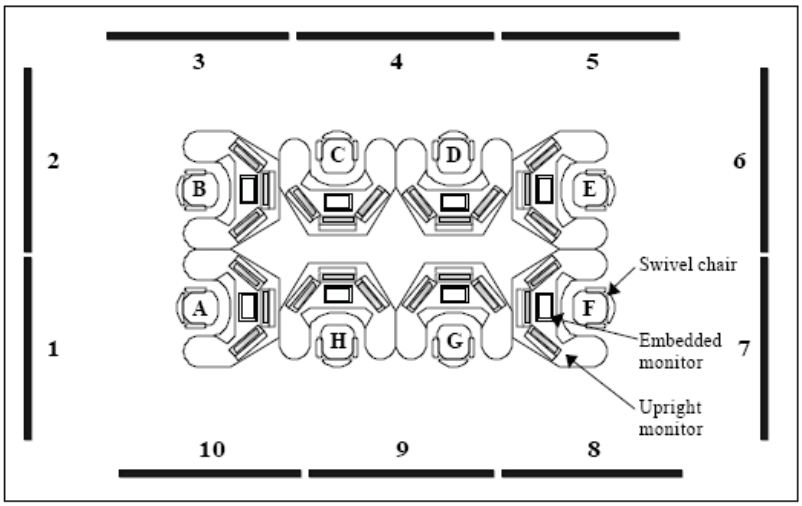

Figure 5. The Configuration of the ICE Lab. Eight Operators Surrounded by ten LGDs (from Dugger and Barley [2000])

The ICE Lab was used to measure the impact of viewing distances, viewing angles and text size on the readability. In particular, this work provides important data to support workplace layout design and display management strategies. For example, determining the

required head rotation and viewing angle of the operators when they are using the LGDs, permits analysis of the useful operator/LGD combinations and provides insights into which screens, if any, should display redundant information. Research of this type is particularly important to help in the layout and design of future C2 collaborative workplaces.

Information Content

We now turn our attention to the three key areas that we believe need further attention when considering broader contexts of using LGDs to support intense collaborative activities within future C2 facilities. This section covers the first and most fundamental of these: information content. A range of questions need to be answered such as: what should be displayed, why is it needed and when should it be provided? There are also questions related to how the information should be provided. This includes the use of video, sound and speech, graphical representations, text, and combinations of these. The usability of content is of particular importance, such as the size, format and legibility of text and graphics. We will not discuss this aspect in any detail in this article, and refer readers to Gouin et al. (2009) for a comprehensive set of guidelines.

As discussed previously, there is a need to provide information on the external or operational situation. This area has been the focus of significant amounts of research and much has been written about this type of Shared Situation Awareness (Endsley 1995). However, an important aspect that needs to be considered relates to highly dynamic situations, where teams involved in intense collaborative activities require awareness of the internal workings of the team, and the systems and information that they use. For example, the DataWall evaluations (Darling and Means 2005) highlighted the need to use the displays to: "provide activity awareness to show the current state of tasks, check lists, and/or operations." In relation to systems status, the LiveSpaces main interface application, called

Ignite, was designed to provide up-to-date feedback on the availability of particular facilities and applications, and faults that might impact on the team activities (Bright and Vernik 2004). Information about the content itself also needs to be provided, such as the age of the information and its reliability. Few of the systems surveyed provide this type of information.

LGDs can show so much information that it may be difficult to determine which subsets of that information are directly relevant to the current task. Also, some of the information on LGDs may be static by their nature, such as mission summaries. Often large amounts of disparate data is drawn together from different sources and displayed on an LGD. Display simplification techniques such as providing summary information, highlighting, grouping and attention management becomes critical if the information is to be used effectively. The summary displays shown on the K-Wall (Figure 2) provides a good example of how these types of issues might be addressed. In this case, in addition to the more traditional COP displays, summary information is provided on important aspects in areas such as weather. Importantly, a system of graphical indicators is used to highlight the criticality of the information and provides information on the situation now and as anticipated tomorrow, or in the longer term.

Content and Display Management

The arrangement and management of content on displays is also an important consideration if required information is to be made available to teams at the right place and time. This becomes problematic in situations where multiple large display surfaces are used to support teams engaged in highly dynamic situations.

Experimentation undertaken as part of the LiveSpace's AUSPLANS project (Evdokiou et al. 2004) showed that team members can innovate and adapt work practices to provide highly effective approaches

for content and display management when environments provide mechanisms to allow for rapid access to required information and highly integrated socio-technical capabilities such as are provided in ubiquitous workspaces (Vernik 2011). However, this relies heavily on the particular skills and abilities of the team members and team dynamics.

Dugger and Barley (2000) provide several useful insights into the use of automated content control in relation to their ICE lab investigations. They suggest that consideration needs to be given to the "advantages and disadvantages of both manual and automatic control, along with possible hybrids." They highlight a number of possible disadvantages of manual control including increased operator workload/stress, degradation of primary task performance, and operator annoyance experienced when completing the repetitive task. Automated control may prove beneficial but there can be a number of down sides including "reliability problems such as might be experienced when the system alters the display to show information that is deemed less important."

The management and control of content displayed on a LGD was investigated as part of the SIDEView system developed at MITRE (Mulgund et al. 2005). This system was used to study how content might be best provided and managed on LGDs to achieve shared situation awareness. In this system, users did not directly control and manage the information on the display. Rather, all interaction was through a display management process using a publish/subscribe mechanism. This allowed information from multiple different users to be fused into a common view on the large screen or for particular information to be displayed in a separate view and tiled on the display. The approach allowed for direct and mediated interaction by the users. In a mediated mode, an information manager can activate *view filters* which control who can place information on the displays and can decide on how the views will be arranged.

Content and display management is a critical aspect in the development of LGD capabilities to support the activities of C2 teams. Some work has been done in this area but more work is needed on areas such as attention direction (Oonk et al. 2002) understanding the tradeoffs between manual and automated control, and considerations for aspects such as redundancy of information on displays based on the layout of team workplaces.

Integration and Interaction

We now turn to the broader aspects of how LGDs might be integrated into C2 facilities and the modes of interaction that they should support. Interaction covers a variety of areas. For example, in conducting intense collaborative tasks, people need to interact with the information on the LGDs to, for example, drill down on information to get more detail. They also need to interact with the LGD capability to arrange views on the screen, change volume and screen settings, and move information between screens in situations where multiple LGDs are in use. They also use LGDs to interact at a human level though the use of approaches such as video teleconferencing and when using the displays as an electronic whiteboard. However, LDGs are but one capability within modern C2 facilities. Individuals often have access to their own displays and information and they use a range of electronic collaboration tools such as chat and groupware applications. The cognitive overheads of having to understand a range of interaction methods and protocols can have a significant impact of the effectiveness of teams.

Several approaches have been developed and deployed for providing multiple LGDs into a fully integrated C2 environment. For example, the second iteration of the K-Wall R&D looked at how 3 LGDs could be used in conjunction with K-desks that provided users with their own displays and information (Oonk et al. 2002). The ICE lab investigations looked at layouts which incorporated 10 LGDs. The LiveSpaces approach uses ubiquitous computing approaches

(Weiser 1991) to provide highly integrated workplaces and to address many of the socio-technical challenges facing C2 teams. Each of these initiatives has highlighted a range of challenges that will need to be addressed in the future. For example, Darling and Mears (2005) report on the need to support distributed collaboration. They argue that there is a need to provide tools and business processes to support improved multi-tiered collaboration, including feedback, and guidance for information providers. Dugger and Barley (2000) show the impact of layout in terms of team interactions and the need to consider aspects such as the redundancy of information on displays.

Conclusion

In this article, we have discussed a range of issues that need to be addressed in relation to the use of LGDs for collaborative working, particularly for C2 teams engaged in intense collaborative activities. In particular, we focused on situations which employ multiple integrated LGDs for dynamic situations requiring the information displayed to be adapted to team needs, and for situations that involve geographically distributed teams.

We defined a contextual basis for the paper by providing background on collaborative working and teams in C2, with a particular focus on intense collaborative activities. We drew from a set of examples, considerations and guidelines for the design and development and use of LGDs in C2. This material resulted from TTCP collaborative activities undertaken across the USA, UK, Canada and Australia. Analysis of this information identified three main inter-related challenge areas that need to be addressed by future R&D: Information Content, Content and Display Management, and Integration and Interaction. We discussed these in relation to four main example deployments of LGDs and the socio-technical and the emerging operational challenges that will be faced by C2 teams in the future.

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