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The Knowledge Wall for the Global 2000 War Game: Design Solutions to Match JOC User Requirements

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EXECUTIVE SUMMARY

Previous interviews with Joint Operation Center (JOC) senior staff (Miller & Klein, 1998; Moore & Averett, 1999) have revealed a high-priority need for tools to support shared situation awareness and decision-making in the JOC. A wall-sized shared display—or "Knowledge Wall"—fusing all information relevant to mission status, has been proposed as a solution to this need. A Knowledge Wall is being implemented onboard the USS *Coronado* (AGF 11) and at the Naval War College (NWC) for the Global 2000 War Game. What features and content should this new display possess?

To answer this question, structured interviews were conducted with JOC command elements from Third Fleet, Carrier Group 1, and Carrier Group 3 expected to participate in Global 2000. Fourteen requirements were distilled from the interviews with these potential Knowledge Wall users. The Knowledge Wall must support:

- Shared situation awareness among its JOC users
- The integration of relevant mission status information
- An intuitive graphical interface
- Consistently formatted information
- A tactical focus for the displayed information
- The display of information to supplement tactical data
- The display of mission goals and Commander's Critical Information Requirements (CCIRs)
- The display of summary information provided by "anchor desk" or support staff
- The ability to connect and coordinate or collaborate with others at diverse locations
- A flexible configuration that can easily be changed by users
- The ability to drill-down through displayed information for more detail
- Display of information age and reliability
- Tactical overlays to highlight different types of information

This report presents a Knowledge Wall design capable of meeting these requirements and elaborates its design features from the "ground-up." The advantages and disadvantages of the proposed design solutions are discussed. The proposed design is compared and contrasted to those for other wall-sized displays that are being prototyped for other military command centers and for non-military applications.

We recommend studying the usage of this Knowledge Wall at the Global War Game to evaluate its utility and performance under operational conditions. Future Knowledge Wall research should examine emerging tools (e.g., attention management tools) and alternative operating procedures (e.g., multiple simultaneous users) to facilitate its effective use in modern JOC environments.

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INTRODUCTION

Increasingly, the U.S. Navy conducts a variety of missions outside the bounds of traditional warfare. These missions are often conducted with fewer personnel than in the past, and command and control is more distributed in nature. Such mission characteristics do not always fit well with the methods, technologies, and capabilities of current command, control, communications, computers, and intelligence (C^4I) systems. Improvements in display systems, information management tools, and human–computer interfaces (HCI) are needed to improve situation awareness (SA), facilitate command team collaboration, support command decision processes, and enable the command staff to recognize critical events and manage operations within the rules of engagement. Several research and development projects at the Space and Naval Warfare Systems Center, San Diego (SSC San Diego) are working toward providing such improvements.

A number of previous analyses by SSC San Diego focused on decision-makers in command centers, specifically Battle Watch Captains (BWCs) and other personnel in Joint Operation Centers (JOCs). These analyses identified the existing Concept of Operations (ConOps) for the JOC and revealed a critical need for improved displays and information management systems (Miller & Klein, 1998; Moore & Averett, 1999). The JOC is organized with anchor desk liaison officers (LNOs) who produce a variety of information products for the Commander, his BWCs, and senior JOC staff. These information products are generated and distributed continuously as well as forming the basis for formal briefs that are given at fixed intervals (typically, two or three times a day) for the Commander. BWCs and their Assistants (ABWCs) monitor events primarily by verbally interacting with LNOs and others outside the JOC to maintain awareness of the operational situation. Moore and Averett uncovered a critical JOC need for improved technologies to support BWCs in maintaining SA and for visualizing the "big picture." BWCs find the tasks of gathering, fusing, and disseminating operational information both time-consuming and error-prone. BWCs need better ways of acquiring SA rapidly and then disseminating that awareness to subordinate JOC staff. In addition, senior-level decision-makers in operational command centers require tools to help answer cognitively challenging questions such as:

- "How are we doing?" (with regard to all aspects of the overall mission and current plan)
- "What is our status?" (with regard to force-wide resource management, multi-domain plan implementation, and various timeline issues)
- "What has changed since I was last updated?"
- "Are there coherent patterns in the data that I'm missing?"
- "Am I remembering what led up to this situation correctly?"

One solution envisioned by SSC San Diego for use in the JOC is a "Knowledge Wall" (K-Wall). The K-Wall is a wall-sized shared display consisting of contiguous display windows bringing together information from multiple sources. For illustrative purposes, one vision of a future K-Wall is shown in Figure 1. The idea behind the K-Wall is that providing a processed and fused presentation of the "information space" on a single large display should support human cognitive processes such as data integration, pattern recognition, event memory, and distributed cognition. By making the K-Wall large and sharing it among the users in the JOC, it is expected to promote shared SA among its users.

The K-Wall shown in Figure 1 consists of two large "focus" displays (presenting tactical data in this example), surrounded by supplemental monitors displaying information from selected LNOs (e.g., Intelligence, Current and Future Operations, and Ground Operations), mission planning information,

Commander's Critical Information Requirements (CCIRs), weather and satellite information, etc. The peripheral location of the supplemental monitors provides a natural visual metaphor for the role they play, embedding tactical data in a larger situational context. The K-Wall could have video teleconference (VTC) capabilities and could be augmented with various cognitive tools and tactical overlays (such as the track history information, weapons envelopes, and response planning tools shown). It is envisioned that the K-Wall will be used for a variety of purposes, but primarily for:

- Supporting the rapid development and maintenance of SA
- Providing a "window" into current missions/operations and force resources
- Supporting briefings/updates to senior staff

In addition, the K-Wall is intended to afford several collateral benefits for other JOC staff, such as:

- Aiding watchstanders in quickly developing, maintaining, and sharing SA with other watchstanders
- Facilitating information exchange and fostering collaborative work processes among watchstanders

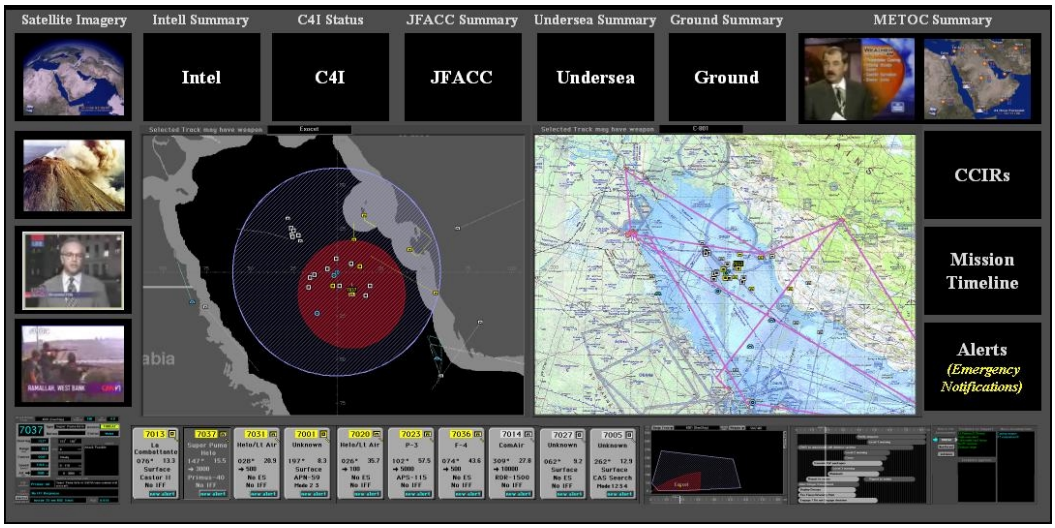

Figure 1. One vision of a future K-Wall.

Other ongoing efforts, both at SSC San Diego and elsewhere, are examining the information requirements for decision-makers in different military command centers. These efforts have identified as general concerns common across different environments both the need to bring multiple sources of information together to support decision-making, and to provide shared SA to multiple users. In attempts to address these needs, others have also suggested large, wall-sized displays, similar to the K-Wall, as a solution. For example, the Air Force is currently developing a multimedia "Interactive Datawall" to provide fused, multi-source information for C^4I environments (Jedrysik et al. 1999).

Another wall-sized display designed to support shared SA and decision support is SSC San Diego's Tactical Situation Awareness Tool (TacSAT) for the U.S. Marine Corps (Proctor et al. 1998). This display was designed to be used in a Marine Combat Operations Center (COC). TacSAT consists of a central tactical display with various overlays that can be superimposed to provide context-dependent situation information. For the U.S. Strategic Command, SSC San Diego is developing a scalable prototype K-Wall-type display to support strategic-level decision-making, involving complex

coordination of distributed forces and requiring powerful cross-echelon communication capabilities[*]. The display features a scalable interface with multi-function thumbnail screens that provide information as well as VTC capabilities to support interaction between the Commander and his specialized experts in each functional or operational domain.

Although these efforts are currently developing similar, wall-sized displays, questions remain regarding the content and the HCI functionality that need to be incorporated into the K-Wall design. The design of a K-Wall must, first, take into account the specific requirements of its users, and then, develop and evaluate solutions to meet these needs. This report describes the first step in an ongoing, iterative process of K-Wall design for users in a JOC at the CJTF level.

In order to elicit input and recommendations from potential JOC K-Wall users, structured interviews and Cognitive Task Analysis (CTA) techniques (Kirwan & Ainsworth, 1992) were employed. Structured interviews were conducted with personnel from Carrier Group 1 (CCG1), Carrier Group 3 (CCG3), and Third Fleet participants in Global 2000 to identify specific user requirements of personnel in the JOC. These interviews focused on specific information needs (content) and the interactive features (HCI tools) that a future K-Wall might possess. In addition, the interviews inquired into the likely context-sensitivity and the cognitive processes underlying their use of the K-Wall. In this report, we document the results of these interviews and present concepts for an initial design of a K-Wall prototype capable of meeting the identified requirements. This initial design is intended to be implemented for use in the Global 2000 wargame. We also indicate the advantages and disadvantages, as well as capabilities and limitations of this proposed design. Finally, we discuss possibilities for future research associated with use of the K-Wall.

[*] Fehér, B. (2000). Personal communication. Please contact authors for further information.

MOTIVATION AND PURPOSE

In order to provide preliminary baseline specifications for an effective K-Wall design, structured interviews were conducted with experts who had operational experience in the JOC and who were familiar with the information exchange and fusion challenges faced by the staff. The focus of the interviews was on the K-Wall in the context of its use by senior staff—i.e., at the BWC-level and above—but an attempt was also made to collect data relevant to how the K-Wall might impact the tasks of other JOC personnel. The interviews had three objectives. They were to determine:

1. The information needs (content) and the interactive features (HCI tools) required of a K-Wall.
2. The cognitive processes underlying the use of a K-Wall.
3. The context-sensitivity of K-Wall use across different types of scenarios (i.e., would use and utility of the K-Wall differ according to the mission type—for example, between a wartime strike mission and a peace-keeping operation).

Considering the many uses and users of the K-Wall in the JOC, interview questions were directed at two broad groups, the first group being information producers (LNOs) and the second being information consumers (Admirals, BWCs).

In order to address objective three above (K-Wall context-sensitivity), two diverse scenarios (a wartime strike planning and execution mission and a peacetime non-combatant evacuation operation) were used as contexts for the interview questions. Within these contexts, K-Wall information producers and consumers were asked to specify desired K-Wall content, uses, features, and interpersonal exchanges that would support their information production or consumption.

METHOD AND APPROACH

DATA COLLECTION TECHNIQUES

The data were collected using formal interviews with potential users of the K-Wall. Due to participant time limitations, it was not possible to schedule individual interviews with participants. Therefore, the interviews took the form of "focus groups" of between 4 and 15 participants led by SSC San Diego interviewers. The interviews lasted approximately 1 hour. All of the interviews took place between 14 April and 3 May 2000.

PARTICIPANTS

Approximately 30 individuals were interviewed in one of four separate 1-hour discussion sessions. Most of the participants had recent operational experience performing the role of BWC, ABWC, or LNO. Many of the participants had been assigned to play one of these roles during the Global 2000 War Game and/or had played one of these roles in a previous war game. The participants included personnel from Third Fleet, CCG1, and CCG3.

INTERVIEW STRUCTURE

Sample interview forms are provided in appendices B and C. Whenever possible, the interviewer adhered to the outlined structure of the interview. However, due to the group nature of the interview sessions, occasional deviations from the structure were necessary.

The basic interview structure was as follows. After a general description of the purpose of the interview, participants were read and given a copy of the K-Wall Vision Statement (see Appendix B), which included a description of the K-Wall concept and the problems it was designed to address. They were asked questions regarding their background and were asked to indicate the degree to which they would be providing information to be displayed on the K-Wall (information producers), or they would be viewing the K-Wall to assimilate information (information consumers), or both. The participants were given a blank template of the K-Wall layout (see Appendix E). They were encouraged to refer to the template during the interview and to make any notes or suggestions on it that they wished.

The interviewer then read a description of a wartime strike planning and execution scenario (see Appendix C) and instructed the participants to answer questions regarding the use of the K-Wall within the context of the scenario. Questions asked included:

- Of the information you listed, which is the most important to you? Please prioritize this information.
- What format should the information take?
- Are there any special features or information tools that you would like to see on the displays of the K-Wall?
- Are there any problems that you now face when monitoring the situation or making decisions that you think the K-Wall might alleviate?

If time permitted, the participants were also provided a Non-combatant Evacuation Operation (NEO) scenario and asked whether they would answer any of the above questions differently, given the context of the new scenario.

RESULTS

BACKGROUND OF EXPERTS

The participants shared a broad range of experience that related to most key roles in the JOC. Most of the participants were senior-level personnel (Admirals, BWCs, ABWCs), but many anchor desk (J2, J3, J6, JAG, etc.) LNOs were also interviewed. Interestingly, despite the fact that many anchor desk personnel were present, most participants identified themselves as either primarily knowledge consumers or as producing and consuming knowledge to an equal degree (only one respondent indicated that he was solely a knowledge producer). This may be indicative of the extent to which junior JOC personnel feel the need for better SA (i.e., that even junior personnel identified themselves as consumers as well as producers may indicate that they require SA-related information to provide a context for their own tasks). Most participants possessed several years of command center experience.

KNOWLEDGE WALL REQUIREMENTS

Answers to the questions and notes taken during general discussion were compiled into a master list. This list was subjected to content analysis from which four categories of user requirements emerged (general, format, content, and feature). Further distillation by content analysis of the requirements within each category led to the identification of 14 user requirements in total. Each of the 14 requirements is discussed below, followed by representative paraphrased responses that indicate or support that requirement. Supporting evidence from previous research or interviews that relate to the specific requirement is also discussed. The requirements are grouped into the four categories, and they are generally ordered from the more general to the more specific.

GENERAL REQUIREMENTS

Shared, Integrated Support for "Instant" SA

A consistent theme running through the discussions was a need to acquire and maintain shared SA quickly. The participants also expressed a desire to see—and then be able to disseminate—critical information integrated together, with responses such as:

- I want to quickly bring the boss's SA up to mine.
- I want to achieve SA in no more than one and a half minutes.
- Everyone should see the same picture because without common SA, mistakes are made.
- There is a need to represent the "big picture" quickly and concisely.
- It's difficult to make a decision when I can't bring all the pictures together.

The problem of poorly shared SA and a lack of understanding of the "big picture" among watchstanders in command centers has been indicated across a variety of military settings in addition to the Navy JOC. For example, the need for shared SA emerged from interviews conducted with watchstanders and senior staff in a Marine Corps COC (Klein et al., 1996; Proctor et al., 1998). The same need (for better shared SA) also emerged from interviews recently conducted with command center staff from the U.S. Strategic Command[*].

[*] Fehér, op. cit.

Of course, the requirement for rapid shared SA can be broken down into two separate, although not entirely unrelated requirements for (1) shared SA, and (2) integrated information.

FORMAT REQUIREMENTS

Intuitive, Easy-to-Use Graphical Format

The participants expressed a desire for data on the K-Wall to be presented in a consistent format that is intuitive and easy-to-use. Further, participants expressed a desire for the graphical presentation of information, when possible. Typical responses that indicated these needs included:

- I need a display that is graphically intuitive and doesn't need to be learned (e.g., 3-D, use of color).
- The lingo specific to particular information domains (e.g., weather, special operations, or strike planning) should be eliminated.
- I need access to Web pages to bring up anchor desk briefs.

Earlier interviews with JOC personnel had revealed that anchor desk personnel spend a great deal of their time working with Microsoft Office to make presentations in PowerPoint (Moore & Averett, 1999). Those interviews suggested a need for tools to facilitate rapid generation of briefings and other information products in a consistent format.

Again, we can usefully break down this formatting requirement such that the format of information, to the extent possible, should be (1) intuitive and graphical, and (2) consistent across all the displays.

CONTENT REQUIREMENTS

Several content requirements emerged when participants were asked to specify and prioritize the information they wanted to see presented on the K-Wall.

Multiple Tactical Displays as Primary Focus

All of the participants identified tactical information as the “key” to acquiring SA and they indicated that it should be the focus of the K-Wall. They indicated that *multiple* views of the tactical picture (e.g., of ground and air, or on multiple scales, or two separate missions) are often necessary and that overlays would be useful additions to the displays. Example responses included:

- A tactical picture has all the information I need. . . . I could build all the other information from the tactical.
- Tactical/Geoplot information is the highest priority information to everyone.

This finding is consistent with those of previous efforts that have also identified tactical displays as providing the most essential information. For example, Moore and Averett (1999) identified a requirement for anchor desk personnel to monitor tactical displays. Further, interviews with elements of the 5th Marine Regiment COC indicated the need for a “map focus” in the COC around a focal, “single situational map” to promote shared SA (Klein et al., 1996; Proctor et al., 1998).

Supplemental Information

The display of supplemental information, beyond the tactical picture, was also indicated as a necessity for the K-Wall. This supplemental information should not be allowed to hide or obscure the

tactical displays, which should remain the focus of the K-Wall. To meet this need, supplemental information could be presented on peripheral windows or monitors, thus surrounding and embedding the tactical displays in a rich context. However, many respondents expressed concerns about the utility of the peripheral displays. For example, they were concerned about the visibility and legibility of information displayed there. Some important issues and recommendations that developed from these concerns were:

- Peripheral information might also serve the purpose of alerting the user of updates or current problems related to non-tactical, supplemental information.
- The data in the supplemental displays must be readable/usable at a distance.
- A picture-in-picture feature might be useful—to provide simultaneous presentation of multiple, supplemental information.

Mission Goals and Objectives

Most participants expressed a desire to see, or be able to easily access, information about mission goals and objectives on the K-Wall. Peripheral (non-tactical) displays should provide current mission plans and operations, as well as information about mission status. Participants specified that they needed to know if events were going according to plan and/or were within mission parameters and, importantly, they wanted to be alerted when events were *not* going according to plan. Participants reported the need for:

- Information to provide a good "intellectual framework" to help recall what was planned.
- Mission statements.
- Commander's guidance and CCIRs.
- Preplanned responses for different situations.
- ROEs (to help "bound the decision space" and inform me about decisions that I can—and cannot—make).
- Decision points (when reached and future).

Other SSC San Diego efforts have also suggested the need for some indication of mission plans and status. Earlier discussions with JOC personnel indicated the need to answer questions, such as "How are we doing?" and "What is our status?" (Miller & Klein, 1998; Moore & Averett, 1999) and revealed problems related to the lack of understanding of assigned tasks. An analysis conducted for the Marine Corps indicated problems related to failures to understand the mission and to visualize its overall goals in the COC (Klein et al., 1996).

Anchor Desk Outputs

Participants also indicated a need to see anchor desk outputs on the peripheral displays of the K-Wall. This information must be presented at the level that is beneficial to all users and should take the form of a summary and/or of detailed information from the anchor desk LNOs, as is appropriate to the situation. Participants recognized the tradeoffs between summary and detailed information. Responses identified a need to see displayed:

- Anchor desk briefs (current status, any important alerts or advisories, supplemental or supporting information, etc.).
- Risk assessment/management (discussion of risks and mitigating options).
- Communication status (related to both verbal and data communications).
- Weather information (primary focus on how weather affects other operations).
- What assets (friendly and enemy) are available?

- Battle damage assessments and effects.

The way that the JOCs currently function relies on briefing products produced by the anchor desks as grist for the briefing process and the maintenance of SA by the BWC (Moore & Averett, 1999). The need to have anchor desk products disseminated to the entire senior staff by being shown on a shared display also emerged from interviews recently conducted with Command Center staff from the U.S. Strategic Command*.

Connectivity, Collaboration, and Coordination

Participants indicated the importance of sharing information collaboratively, both within the team and with remote parties. Participants expressed a desire for real-time, face-to-face communication for collaboration and coordination across a variety of situations. For example, one participant highlighted the need to communicate with the ambassador-in-charge in a NEO context. VTC communication was suggested as a necessary adjunct to voice-only communications because of its ability to provide useful visual information (such as facial expressions and body language). Collaborative tools, such as electronic whiteboards, chat rooms, etc., perhaps overlaid on the tactical displays, were also identified as being essential. Further, participants pointed to the need for systems and connectivity status information. Common responses included:

- For operations such as NEO, we need to have near continuous interagency connectivity.
- We need to bring up pictures and intelligence overlays and share them collaboratively in near real time.
- It would be useful to get real-time, face-to-face communication with other BWCs.
- The JOC is only one portal of information. We need to ensure that information is shared with others.

Interviews in the U.S. Strategic Command corroborate the need for the shared command display to provide integrated VTC capabilities and other collaborative tools for both internal and external collaboration*.

Support for Challenging Cognitive Tasks

The large number of responses that referred to the challenges of decision-making and maintaining SA in the JOC strongly suggests the need for tools that support difficult cognitive processes. Cognitive support tools need to be incorporated into the displays in order to meet the requirements for:

- Directing users' attention to important information and alerting them to important changes in that information.
- Highlighting important information and "decluttering" irrelevant display information.
- Supporting management of planned responses.
- Highlighting potential conflicts between domains, and ambiguous or conflicting information.

Example responses that suggested the need for decision support tools were:

- There should be an alerting mechanism between the anchor desk/cells and the BWC.
- Help us recall what was planned so we can focus on how to deal with what wasn't planned.

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* Fehér, op. cit.

- I need to know about issues that would force a change of plans or that are not in accordance with a set course.

Many previous and current SSC San Diego projects have focused efforts on the development of decision support tools to augment decision-making. For example, the Tactical Decision Making Under Stress (TADMUS) project determined the decision-making principles and information requirements of single ship naval air warfare Tactical Action Officers (TAOs) (see Hutchins, 1996). The capacity-limited, serial nature of human information processing (Simon, 1978) does not lend itself well to time-pressured integration of critical information and decision-making. As part of the TADMUS effort, a Decision Support System (DSS) was developed to support the user's critical information requirements (Kelly, Hutchins & Morrison, 1996). This display was designed to be viewed by a single user or dual users (TAO and Commanding Officer). However, the applicability of tools like the TADMUS DSS to shared displays like the K-Wall that is designed to be viewed by multiple users (perhaps 10 or more) remains an open question.

FEATURE REQUIREMENTS

Flexible Configuration

There was a strong consensus on the need to configure the K-Wall displays according to current information and user needs. Participants indicated a need for flexibility across watches and changing situations. However, they also agreed that some information should be dedicated/constant across situations.

- Information needs change with each watch, so the configuration should be very flexible.
- We need the ability to push and pull information at tactical, operational, and strategic levels.

But . . .

- Some information should be universal or locked-in. What this information is should be determined via usage and will change with subsequent iterations.

A desire for configurable displays to be customizable to fit the needs of different commanders and missions was also expressed in interviews with the 5th Marines (Klein et al., 1996; Proctor et al., 1998). Too much flexibility, however, may provide for less-than-optimal performance with the K-Wall. A previous analysis of JOC personnel, for example, identified problems that were caused by the lack of a standard set-up within the JOC and pointed to a need for some displays to be dedicated to certain information (Moore & Averett, 1999).

Drill-Down

Participant responses also indicated a need to be able to drill-down to get access to more detailed information in briefs and to a finer scale of resolution in tactical displays. Participants also wanted the ability to move between (and laterally across) levels in the hierarchy of information. This navigation must be intuitive and easy to use. Responses that pointed to the need for drill-down and navigation concerned a need for:

- The ability to drill-down from the main displays, both in a temporal sense and for more granularity.
- The same picture at different levels of detail.
- Drill-down if there is a question from the boss, or a particular point I want to make.

The need to be able to drill-down and also to see tactical maps at different resolutions was also articulated by the 5th Marine Regiment (Klein et al., 1996).

Information Status and Update Indicators

A common theme underlying many responses concerned the need for access to information characteristics. For example, participants cited the need to know the "age" of the information being displayed on tactical and peripheral displays and for important changes in this information to be highlighted. A related concern was to know the *normal* update rate of information, and to be alerted of any deviation from it. Respondents also wanted to know the source of the information on displays when these data have been fused or combined from multiple sources (or at least have that information accessible if it is desired).

- We need an indication of the update rates and then an alert if the display will not be updated on this schedule.
- We need real-time data, updated second-to-second for Ops.
- I want the update frequency to be maximally configurable.

Information Reliability and Trust

The source of data on a display is a key piece of information for decision-makers. Before making a decision based on displayed information, the observer must trust the information. An important determinant of this trust is the source of the data, regardless of whether the source is human, an intelligent agent, or a simple system feed. Discussions about information reliability included comments such as:

- I must know how accurate the information is. This is based on my trust of the source of the information.
- The relative confidence of the data should be displayed graphically.
- The anchor desks are the experts and the responsibility for displaying reliable data is at their level.
- I have to assume the data is accurate.

The reliability of information and the source of that information is a central need in naval air warfare. The SSC San Diego Basis for Assessment (BfA) research program that developed out of the TADMUS program identified TAOs' need for the representation of the reliability and the source of track information (e.g., Liebhaber & Smith, 2000). Liebhaber and Smith found that TAOs rely on an array of information from various, potentially unreliable sources, when assigning the threat level of a track.

Tactical Display Overlays

Participants repeatedly expressed the need for customizable displays that integrate various types of data onto geographical space through the use of tactical overlays. There was consensus on the requirement for scalable tactical displays and the ability to filter, add, and augment data. A very common request concerned the need to see historical and projected information for planning purposes. The need for various overlays was repeatedly highlighted in user responses, such as:

- I want to be able to filter the display so I can see just ground or just air tracks.
- I want to know the location of our forces, adversary forces; also neutral forces (often neglected).

- I want to see the tactical picture for the entire region to provide an awareness of theater-wide events.
- I need to see the flow of forces . . . to see the big picture of the world, including movement to and within operations and the time that events occurred.
- For each unit, I need to know: what it can do, what it is doing now, what it has been doing, what it intends to do.
- I want to be able to see projections of future locations and movements. I want to see information such as elliptical data, launch alert, azimuth, and expected area of impact.

Many overlays have been developed in previous projects to meet the recurring need for overlays on military tactical displays. For example, the TacSAT display that was developed to support the Marine COC (Proctor et al., 1998) includes overlays that allow the user to augment the display as is appropriate to the tactical situation. These overlays give the user the ability to add gridlines, weapons envelopes (friendly and enemy), anticipated movement, enemy areas of uncertainty, etc. The earlier TADMUS DSS display (Kelly et al., 1996) included overlays that provide additional track information such as weapons envelopes and history trails. These tools are easily transferable to the K-Wall for use on its tactical focus displays.

DISCUSSION

USER REQUIREMENTS AND PROPOSED K-WALL DESIGN

Fourteen user requirements for the K-Wall were identified in the Results section to be addressed in a K-Wall prototype to be implemented during the Global 2000 War Game. There are many different ways to meet these requirements. This prototype will therefore possess *initial* design solutions to meet the *initially* deduced 14 user requirements. This prototype will be evaluated, based on its usage during the War Game. Future research and development efforts should focus both on identifying further user requirements and on improvements to this initial design.

The fourteen user requirements, and the initial K-Wall design solution for each, are shown in Table 1. The requirements are categorized into General, Format, Content, and Feature requirements, and then they are discussed in turn. The way in which the initial K-Wall design solutions meet each requirement is discussed, and its advantages and disadvantages are outlined. Further, a schematic diagram of the components of the K-Wall prototype is shown as it is constructed from the ground up. Following the elaboration of the initial K-Wall prototype, we present alternate design solutions and directions for future research.

Table 1. Fourteen user requirements and K-Wall design solutions.

User Requirement		Initial K-Wall Design Solution
General	Shared SA	Multiple sources of information on a single, wall-sized display
	Information Integration	
Format	Graphical/Intuitive	Graphical presentation
	Consistent	Consistent format across supplemental displays
Content	Tactical Focus	Two large, side-by-side tactical displays
	Supplemental Information	Smaller peripheral monitors surrounding tactical displays
	Mission Goals and Objectives	CCIRs, mission plans, and related information on supplemental displays
	Anchor Desk Output	Anchor desk summaries on supplemental displays
	Connectivity/Collaboration	VTC capabilities; collaboration software
	Cognitive Support	Cognitive tools and aids
Feature	Flexible Configuration	Both dedicated and configurable displays
	Drill-Down	Multiple scalable views, hyperlinks
	Information Age and Reliability	Data age and source information
	Tactical Overlays	Multiple tactical overlays

GENERAL REQUIREMENTS

General Requirement 1. Support shared SA

The initial K-Wall prototype will address support for shared SA by bringing multiple sources of information together on a single, large (wall-sized) shared display. Because the intent is that all JOC staff should be able to see the content of the K-Wall, the display will be large (approximately 12 feet by 5 feet for Global 2000). The shared nature of the K-Wall should promote shared SA among JOC staff. Integrated summary information from all services about mission status is shown to also support rapid SA.

Two recent SSC San Diego projects working on improving decision-making and shared SA in command centers have also opted for the design solution of a large shared display projected onto the center of a wall. Both the TacSAT display for the Marine COC (Proctor et al., 1998) and the STRATCOM display for the U.S. Strategic Command[*] are shared displays. The Air Force's DataWall prototype is also envisioned as a large shared display (Jedrysik, et al., 1999).

Shared displays, although largely ignored in *non-military* research, have been created for several purposes. For example, the University of Arizona Center for the Management of Information (CMI) created a series of rooms equipped with a Group Decision Support System (GDSS) (Vogel & Nunamaker, 1990). These rooms contained a set of up to 30 networked PCs that shared a display space projected onto a wall in full view of the PC users. This GDSS was used during group meetings for group decision-making. Although they conducted no formal experiments, Vogel and Nunamaker reported that the GDSS led to high satisfaction ratings and subjective reports of rapid cooperative decision-making by participants. However, unlike the envisioned Navy K-Wall, there was a moderator/facilitator present in the GDSS to oversee and coordinate usage of the shared display for decision-making. Of course, decision-making and maintaining shared SA are different tasks with different requirements. However, the question of who moderates, or facilitates, use of the K-Wall remains an issue. In other, more empirical research, two recent studies have found mixed support for the notion that shared displays promote shared SA (Bolstad and Endsley, 1999; Farley et al., 1998). Both studies used pairs of participants sharing or not sharing displays. They found that users of shared displays were slower overall because they spent time making suggestions for how the other users should perform their job.

Shared displays may have other drawbacks for SA. Just because information is shared on a display does not guarantee that everyone *has* shared SA. Endsley (1995) has proposed a well-known three-step model of SA. Successful SA involves perceiving the elements of the current situation (level 1 SA), comprehending how those elements figure into the current situation (level 2 SA), and finally, figuring how the future situation may develop from the present one (level 3 SA). Critical to SA, then, is the *perception* of that of which one is meant to be aware. Information must be visible, legible, and discriminable in order to be perceived. Because the K-Wall prototype will be shared and many JOC members must be seated around it at varying distances, the average viewing distance to the K-Wall may be as much as 15 feet during Global 2000. Because of this, presenting text and graphics on the display large enough to be visible becomes problematic. For example, to be legible, text on the K-Wall will need to be *at least* 0.5 to 0.7 inches tall (Helander, 1987).

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[*] Fehér, op. cit.

General Requirement 2. Show integrated information

The initial K-Wall prototype will address the need to display integrated information by presenting multiple sources of information together in a common format on the large display. The information displayed on the K-Wall will be filtered, synthesized, fused, interpreted, and summarized by specialists on the command staff. The intent is to reduce the amount of information to which the command team must attend to just that which is critical to mission success.

The Proximity Compatibility Principle (PCP) from the human factors literature (Wickens & Carswell, 1995) states that all the information that facilitates task completion should be integrated as much as possible into a coherent display. Thus, according to this principle, tasks that require the user to integrate information are best served by integrated displays. Many of the cognitive tasks performed by personnel in the JOC (e.g., template matching and pattern recognition in complex data sources, data integration, mission monitoring etc.) require decision-makers to combine information quickly from multiple sources. Currently, these sources of information are on separate consoles (anchor desks), distributed spatially within the JOC or at a remote location and monitored individually by different LNOs. In order to acquire and maintain accurate SA, senior staff rely on the LNOs to present them with relevant data, which then requires rapid assimilation to information already possessed. The K-Wall should support these processes by bringing data from multiple sources into a single wall-size information space. The K-Wall should allow users to access various sources quickly, facilitating the information integration that is required to effectively develop and maintain SA.

Although the integration of information has its advantages, there are disadvantages to the K-Wall solution that should be considered. For example, the K-Wall shows *so much* information that attending and determining which subsets of that information are *directly relevant* to task performance may become an issue. Human attention is a notoriously capacity-limited and restricted process that filters incoming information (see Pashler, 1998). It will inevitably serve to filter K-Wall information even further.

A key question remains unanswered. Although all information is integrated, shared, and observable on the K-Wall, do all JOC users need it all the time to do their jobs effectively?

FORMAT REQUIREMENTS

Format Requirement 1: Have graphical support and be intuitive

K-Wall users' preference for graphical presentation is valid, as reflected in studies that reveal graphical presentation generally facilitates rapid assimilation of information, requires less training, and is easier to recognize than text (Camacho, Steiner & Berson, 1990; Wickens, 1992). Of course, not all information can be easily represented graphically, so textual representations of knowledge on the K-Wall prototype are inevitable.

The K-Wall prototype will support the need for graphical displays, using visual metaphors when possible. The two large central displays serve as focus windows in which data from any of the supplemental windows may be displayed. It is anticipated that the focus windows will primarily be used to show the tactical situation with Geoplots (i.e., geographically accurate maps with political boundaries and other features plotted on the map). The smaller peripheral displays support graphical presentation of information through the use of html-formatted summaries that provide further access to additional graphical Web pages via hyperlinks. The intent is to take advantage of the widespread adoption among existing junior JOC staff of the Microsoft Office suite and World Wide Web browser tools (Moore & Averett, 1999).

Moore & Averett (1999) found that LNOs may spend as much as 80% of their time working with Microsoft Office to exchange E-mail, prepare and review reports and logs, develop plans, review resources and assets, and prepare presentations. A significant portion of this time involves searching for or creating suitable maps and graphical objects, and importing, formatting, and reformatting these graphics in an *ad hoc* fashion to produce a variety of information products. To speed the production of tactical graphics, users of the K-Wall were provided a new tool dedicated to supporting the rapid and consistent development of graphical map-based products for tactical briefs and domain specific summaries. This tool, referred to as the Tactical Graphics Application (TacGraph), enables quick and easy construction and publication of tactical briefs to the K-Wall. TacGraph output is in html format, with standard military symbols and capability for annotations (Bank & Moore, 2000). Figure 2 shows the TacGraph tool being used to select the track category of a MIL-STD 2525B symbol (Military Standard 2525B, 1996) for placement on a map to be published for a variety of uses. In this case, a new ground track is being selected by the mouse.

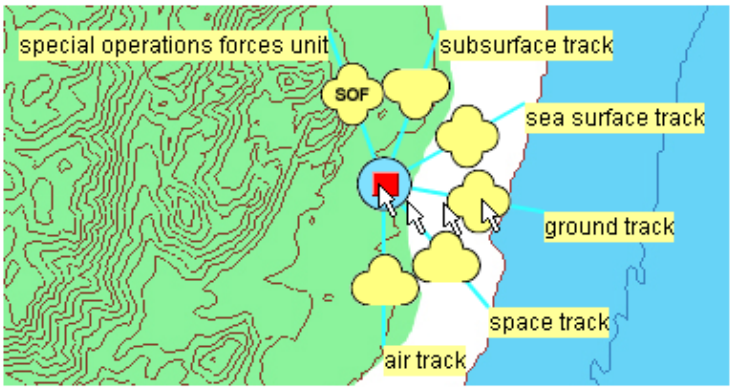


Figure 2. Snapshot of the TacGraph tool (Bank & Moore, 2000).

Format Requirement 2: Support a consistent format

The K-Wall prototype anchor desk summaries will be in the form of consistently formatted html documents. This format is similar to PowerPoint brief summary slides already being produced by JOC personnel. It is intended that these summaries should be familiar to the JOC staff and therefore easily adopted. As previously discussed, JOC staff already use the Microsoft Office suite as the primary briefing preparation toolset (Moore and Averett, 1999); thus the proposed summary displays are intended to leverage the process already in place. The format and layout of information is intended to be consistent across displays from various sources and will include both textual and graphical data (images, bulleted text, links to web pages, etc.).

An example showing the general format of the anchor desk summaries is provided in Figure 3 (example used here is for meteorological and oceanographic [METOC] information). The layout of the summaries will consist of four parts, based on the needs identified by the participants interviewed by Moore & Averett (1999). Each summary includes: (1) color-coded status of short, mid-range, and long-range plans and operations, (2) important alerts and advisories, (3) impacts and implications of status and alerts, and (4) related links. The upper right corner also provides an indication of the age of the summary.

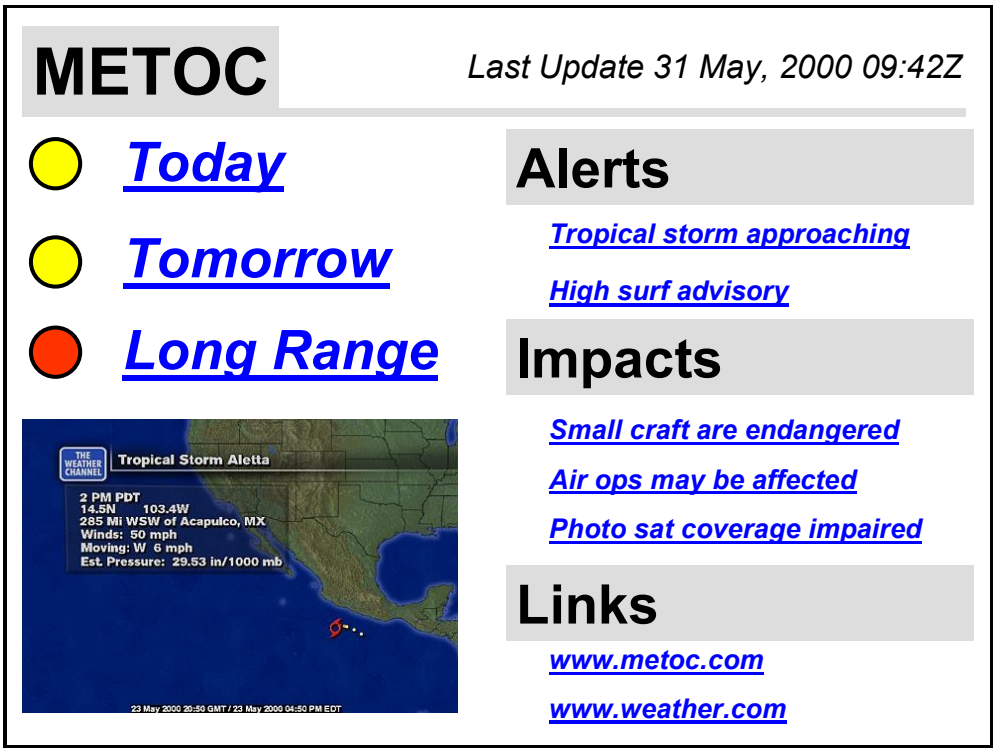


Figure 3. The format for a supplemental display on the K-Wall, in this case METOC.

This summary format implements a basic HCI principle: that the design of various displays be consistent, in terms of the position and format of the displayed information (Mayhew, 1992). This consistent format facilitates both the development and maintenance of an effective mental model of the represented system (Wickens, 1992) and supports optimal use of the displays. Also, for a display as large as the K-Wall (100 degrees of visual angle for a JOC user at 5 feet), consistency enhances learned eye scan-paths around the display, thus enabling more rapid assimilation and monitoring of information (Yarbus, 1967).

CONTENT REQUIREMENTS

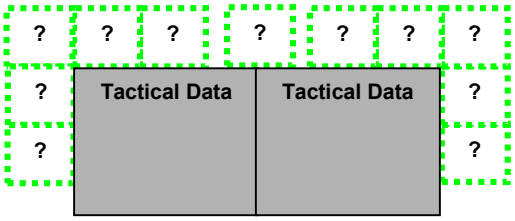
Content Requirement 1: Be focused on tactical data displays

The K-Wall prototype will address the need for information to be provided in the context of tactical data by providing two large, side-by-side focus windows that will, by default, provide tactical displays, around which all the summary displays are positioned. The tactical displays will be generated by Command and Control PC (C2PC) software (currently used by U.S. Marine Corps and various U.S. Military joint organizations). Two tactical displays will be used, rather than one large one, so that either (a) the same tactical situation can be viewed concurrently at two resolutions (e.g., strategic and tactical), or (b) so that two entirely different areas of the theater can be simultaneously viewed. More than two tactical displays will generally not be used because they would take up valuable screen real estate.

The interviews established a critical need for information that maintains a tactical focus, particularly during certain phases of the operation. Therefore, having tactical displays at the center of the

K-Wall, at least during critical phases of the operation, is not at issue. What is more debatable is whether there should be one or two displays—and whether the tactical displays need to be in the focus windows at all times. As mentioned, providing two or more tactical displays offers a number of viewing options. However, in order for summary information to be effectively used it must be easily visible and understandable. If the visibility of summary information on the K-Wall becomes an issue due to excessive viewing distances or window/display size, then perhaps using one large screen display for better visibility of summaries would be a preferable solution.

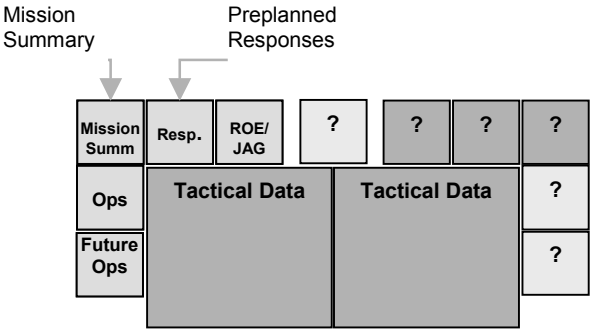
Content Requirement 2: Show supplemental information



Users require other information besides tactical displays. In order to display this information, the K-Wall prototype will include smaller, peripheral monitors surrounding the two focus windows/tactical displays. The supplemental nature of this information relative to the tactical data is reflected in its peripheral location. Further, this design provides the user an intuitive visual metaphor for the role of the supplemental data, which is to embed the tactical data in context.

One potential disadvantage to the use of smaller, peripheral monitors to present supplemental information is that this information may not be legible at a distance and, therefore, not be useful. This concern suggests that the peripheral monitors should serve an alerting function only, and another way of presenting supplemental information, at a higher resolution, might be considered. One alternate way of doing this can be using the "information folder tabs" employed in the TacSAT design (Proctor et al., 1998). This idea is discussed in more detail below (see Alternate Design Solutions).

Content Requirement 3: Display mission goals, objectives, and CCIRs



To meet the need to visualize mission goals, plans, and related information, the K-Wall prototype will make available summaries of the following:

- Mission summaries
- CCIRs
- Planned responses
- Rules of Engagement (ROE)
- Judge Advocate General (JAG) information
- Current and future operational information

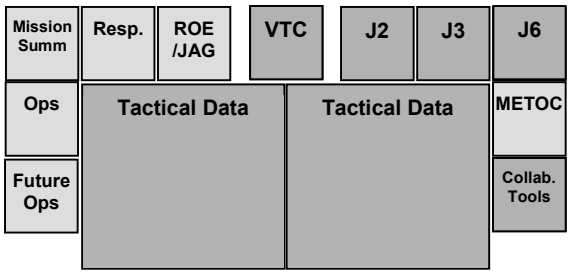
Although this information was consistently requested in the interviews, and also noted by Moore and Averett (1999), there are several important issues concerning its use. For example, since much of this information is static in nature—or at least does not update often, its continuous display on the K-Wall may be problematic. Static mission summaries that are not integrated into the tactical picture may be ignored after a while. On the other hand, if an effective alerting and attention management system were used to present alerts that are integrated with the tactical displays, for example, showing that the mission plan is falling behind, the alerts could provide an excellent answer to the BWC who wants to know "how are we doing?" without tying up valuable screen real estate.

Content Requirement 4: Show anchor desk outputs

The K-Wall prototype will address the requirement to show anchor desk outputs by showing *summary* information from the anchor desks on the peripheral monitors (rather than mirroring the actual anchor desk's display). Because the format of the summaries will be html (see Format Requirement 2, above), these anchor desk summaries will be presented in the form of Web pages. This will allow users to access and drill-down through the information to several levels of detail through html hyperlinks (see the discussion of drill-down features below).

The issues raised above concerning the presentation of mission goals can also be applied to the anchor desk displays. The visibility and legibility of information presented on the supplemental monitors is an issue in common with all the smaller summary displays. An advantage of the K-Wall solution is that the tactical picture remains visually embedded in the context of the various anchor desk summaries.

Content Requirement 5: Enable connectivity, collaboration, and coordination

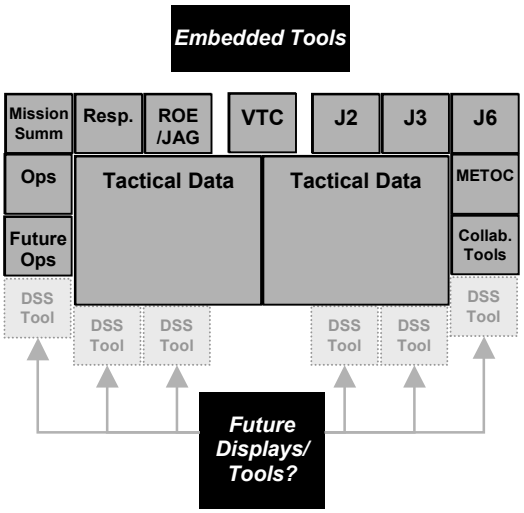


To address connectivity, collaboration, and coordination needs, the initial K-Wall prototype will take advantage of a variety of collaborative and communication technologies. It will also feature links to summary displays produced by J6 personnel. There will be a dedicated VTC window at the top center of the display. The design includes facilities to open three further VTC windows. A supplemental display supports InfoWorkSpace, a web-based bundle of collaborative tools for communication, data access, and knowledge management. InfoWorkSpace can be accessed from either of the large focus windows as well, though this would temporarily make unavailable the tactical data in that window. InfoWorkSpace supports a virtual conference center for online interactive discussions over the Web.

A unique collaborative attribute of the K-Wall concept as it is being implemented by SSC San Diego arises from the existence of duplicate K-Wall systems to be operated during Global 2000 at the Naval War College, aboard USS *Coronado* (AGF 11), and in the K-Wall Lab at SSC San Diego. The existence of duplicate Knowledge Walls, linked together in a wide area network (WAN), is intended to enable long-range shared SA between decision-makers during a Joint Task Force (JTF) mission.

The central issue with regard to real-time collaboration and coordination on a shared display is who gets to use the provided tools, and when and how they use them. The issue is particularly important when there are multiple simultaneous K-Wall users; however, it remains even when one assumes that only one person is involved in the ongoing communications. For example, considering that a VTC must obviously involve auditory communication, will this auditory information interfere with other JOC staff not engaged in the VTC? Auditory information, and particularly the human voice, is notoriously difficult to ignore (Wickens, 1992; Simpson & Williams, 1980). Will activity on the K-Wall interfere with other K-Wall users trying to maintain SA through the monitoring of visual content on the wall?

Content Requirement 6: Support challenging cognitive tasks

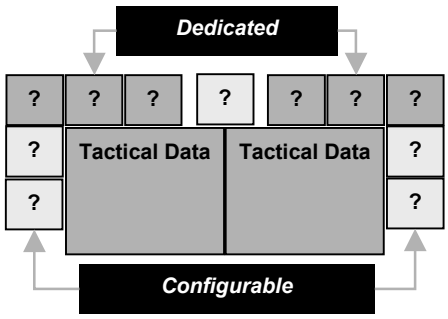


The initial K-Wall prototype includes multiple design solutions intended to support tasks identified as cognitively challenging. The most difficult cognitive task—that of maintaining shared SA—is supported by the display of integrated mission-relevant information on a shared display. The integration of information is intended to augment memory limitations and to facilitate the formations of new and potentially important associations between otherwise disparate data. Other cognitively challenging tasks will be supported by new tools as, and when, they can be transitioned from other research efforts. For example, the CHEX change history tool (Smallman & Oonk, 2000) could be integrated into the K-Wall to support users' attention management and to help answer the otherwise difficult question of "what's changed?" on the display. Response planning can be supported by the integration of Gantt chart-type response managers under development (e.g., St. John et al., 1999).

The main advantages of the K-Wall solution to supporting cognitive tasks are also its disadvantages. As mentioned above, by integrating and showing so much information together, the need for display simplification through techniques such as highlighting, grouping, and attention management becomes critical. Human attentional limitations and bottlenecks are such that only a limited amount of information from even a highly distilled version of the world, as represented on the K-Wall, is likely to be assimilated. Recent perceptual and cognitive research into so-called "attentional blinks" and "change-blindness" has gone even further to highlight just how impoverished the internal perceptual representation of the world is, on a moment-to-moment basis (Rensink et al., 1997). Attention management is complicated enough for a single-user display (see McFarlane, 1997); based on available literature, it would appear that it has not even been investigated for a multi-user shared display.

FEATURE REQUIREMENTS

Feature Requirement 1: Be flexible in configuration



The design solution for the initial K-Wall prototype must address the trade-off between the desire for flexibility and the need for consistency. It will do this by including both dedicated displays (generally above the tactical data) that will always present the same type of information, as well as configurable displays (along the side) which can be moved or changed as the watch, situation, and data needs demand. Users of the K-Wall prototype will also be able to bring information from any of the peripheral displays into the larger workspace on the central tactical displays.

There is a clear trade-off between the need for flexibility and the need for consistency. Too much flexibility may lead to confusion and sub-optimal usage of the K-Wall if the location of information changes from situation to situation or important information is not always displayed. The HCI literature supports this suggestion, indicating that consistency in the placement of information on displays

is necessary to allow users to scan for information most efficiently (see Mayhew, 1992; Wickens, 1992). In JOCs featuring multiple shared display surfaces, varying display and information configurations between shifts (and sometimes many times in the same shift) often create a great deal of confusion among users (Moore & Averett, 1999). On the other hand, task requirements occasionally demand flexibility. For example, tactical displays may be best seen in perspective view (in 3D) for initial orientation to a new scene but then seen in planar view (in 2D) when operated on (St. John, Cowen, Smallman & Oonk, in press). A rigidly inflexible configuration encourages familiarity and well-rehearsed scan-paths, but it is likely to fail under novel situations.

Feature Requirement 2: Enable drill-down through displayed information

The initial K-Wall prototype will address the need for access to more detailed information by providing multiple, scalable views of the tactical data. Further, anchor desk summaries will be in the form of short bulleted lists that include hyperlinks and URLs to more detailed information (as in a Web browser); see Figure 4. Selecting a link will enable drill-down to the contents of that link. Web browsers and Microsoft Office are in such general use that this analogy's familiarity should support its ready adoption.

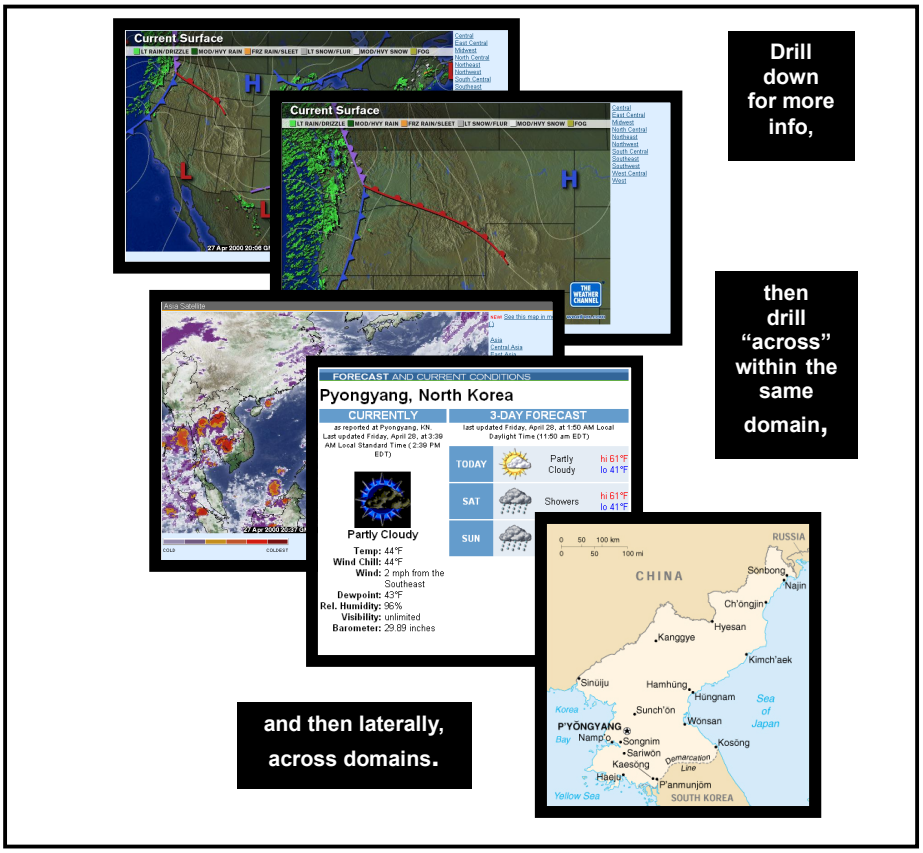


Figure 4. Example of drill-down through a METOC summary.

There are many advantages of being able to drill-down for information mining (see Card, MacKinley & Schneiderman, 1999). However, drilling down too deeply may lead to a great deal of text being displayed, resulting in legibility problems. Further, when drilling both horizontally and

laterally within an information space (see Benjamin & Hollan, 1994), issues associated with loss of semantic orientation and location may result.

Feature Requirement 3: Display information age, status, and reliability

The initial K-Wall prototype will accommodate the need for access to information characteristics through the use of a simple date and time stamp prominently displayed on an anchor desk summary (see Figure 3, top right). Future research must develop methods of presenting the data in a manner that allows users to quickly and reliably assess information age and update rate to answer the question "what's changed on the K-Wall?" Providing the user with reliability information is a difficult challenge. Designers of such technology must take into account such issues as:

- How many levels deep should the reliability be assessed?
- Who trains/certifies the assessors?
- How to rate the rater? (agent or human)

Feature Requirement 4: Allow multiple, flexible overlays on the tactical displays

The initial K-Wall prototype will allow a variety of tactical overlays to be superimposed on the tactical displays. SSC San Diego has developed a range of such overlays, both for the Marine TacSAT display prototype (see Figure 5) and for the TADMUS DSS (Kelly et al., 1996). Additionally, the tactical data program to be used with the K-Wall—C2PC—offers a number of overlays. C2PC will be displayed on the K-Wall and the value and utility of the overlays will be evaluated at Global 2000. Overlays may be used to highlight information related to:

- Gridlines
- Weapons envelopes
- Projected movement
- History trails
- Zones of dispersal
- Scaling
- Population density of noncombatant areas
- Filtering/Decluttering (e.g., air vs. surface tracks)

An advantage to these types of display overlays is that they provide information in a way that is integrated with the system. On the K-Wall, they can be applied as useful highlighting tools to facilitate shared understanding of the situation. However, overlays always involve clutter that may get in the way of information integration, raising the question: Who is to decide which overlays are displayed? (This issue is discussed further in the Future Research section of the Discussion.)

ALTERNATE DESIGN SOLUTIONS

The initial K-Wall prototype outlined above represents just one set of design solutions to meet the requirements identified by JOC personnel. Other solutions should be considered as they may represent superior solutions to meeting these requirements. These solutions, which range from implementing other K-Wall designs to the augmentation of anchor desks *in place of* providing a wall-size display, suggest other avenues of investigation. Several alternative design solutions are discussed below.

Alternate Knowledge Wall Design Focus

One potential problem that was identified by many of the participants of the current interviews relates to the usefulness of the data presented on the peripheral supplemental monitors. These personnel were concerned that the information on these monitors would not be readable at a distance, rendering it useless to viewers of the K-Wall. They suggested that the peripheral monitors could only effectively serve as alerts to changes in the supplemental information they are designed to present. The existence of multiple peripheral information sources also leads to attention management problems. The user is required to filter more information in order to focus on and make sense of the important available data.

The format of the anchor desk summaries (see Figure 3) is designed so that it can serve as a visual alert to problems through the use of color-coded (red, green, and yellow) temporal status dots. These dots give users a quick, rough indication of when problems are likely to occur so that they can focus on more detailed information if necessary. However, as discussed, drilling down to access this information will soon result in legibility issues related to the small size of the supplemental monitors.

An alternative to the use of peripheral monitors to present supplemental information can be seen in the TacSAT display (see Figure 5). TacSAT gives users access to supplemental information (such as ROEs, intel, weather, CCIRs, etc.) by putting it into separate "information folders" and positioning tabs to these folders around the tactical display. Flashing, red tab-text alerts users about any updates of the information in the folders. Clicking on a folder tab brings the information into view to the side of the tactical monitors and users can access up to three folders simultaneously. Because only a subset of the supplemental displays is presented at a time, a larger screen area can be devoted to this information, making it more readable at a distance. This type of feature might prove to be a useful alternative to the multiple peripheral monitors provided in the current K-Wall design.

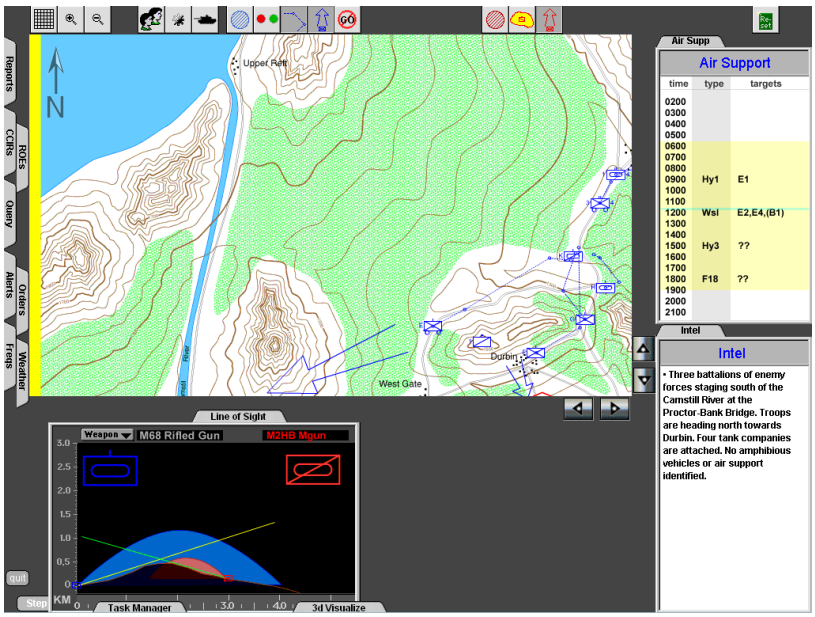


Figure 5. The Marine Corps TacSAT display.

An example of how the K-Wall design might employ this idea is shown in Figure 6. The left configuration shows the design of the initial K-Wall prototype, with two large tactical displays surrounded by multiple supplemental monitors (S1–S11). The right configuration shows tabs to supplemental

information surrounding the tactical displays and two supplemental displays to the side. The supplemental information can be brought into focus on the side displays by accessing the tabs. Red tabs alert users to updated information in that summary. Note that the side displays in the right design are larger than any of the supplemental displays in the current design, on the left.

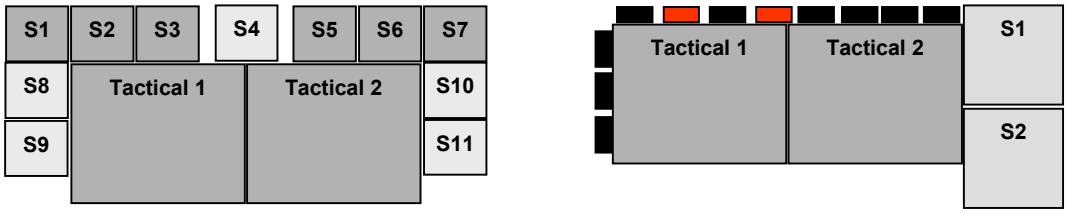


Figure 6. Two possible K-Wall designs.

An advantage of the information folder tab solution to the supplemental data visibility problem, discussed above, is that it allows the supplemental information to be presented at a higher resolution within the context of a shared SA display. A disadvantage to presenting supplemental information in this way, of course, is that it limits the amount of information that can be viewed by K-Wall users at one time. One primary goal of the K-Wall is to bring data from multiple sources into a single location in order to support rapid fusion of this information. Hiding some of the data until the user specifically calls for it may not support the integration required for the rapid acquisition of SA. Further, multiple users will potentially want to see different types of information at the same time, a need that can only be met through the use of multiple peripheral monitors. The tradeoff between the amount of information and the resolution of that information is an important consideration in the K-Wall design.

Anchor Desk Focus

An alternative to building a large shared display is to provide additional tools on the individual consoles of the anchor desk personnel. Many of the requirements identified in the structured interviews can be met by augmenting these displays with, for example, collaboration tools, cognitive support tools, status and update indicators, and tactical display overlays. This solution affords optimal flexibility in display configuration, allowing an LNO to make use of these tools to meet his or her individual information needs, and still facilitates collaboration with other anchor desk personnel. Because the consoles are at a closer viewing distance to the LNOs, this design ensures that they can read and make use of the information.

Figure 7 compares this alternative to the current proposed implementation of the K-Wall. On the left, the K-Wall provides a shared display and is augmented with collaboration, cognitive, and tactical display tools. On the right, the same tools augment individual anchor desk displays without the large, shared K-Wall display.

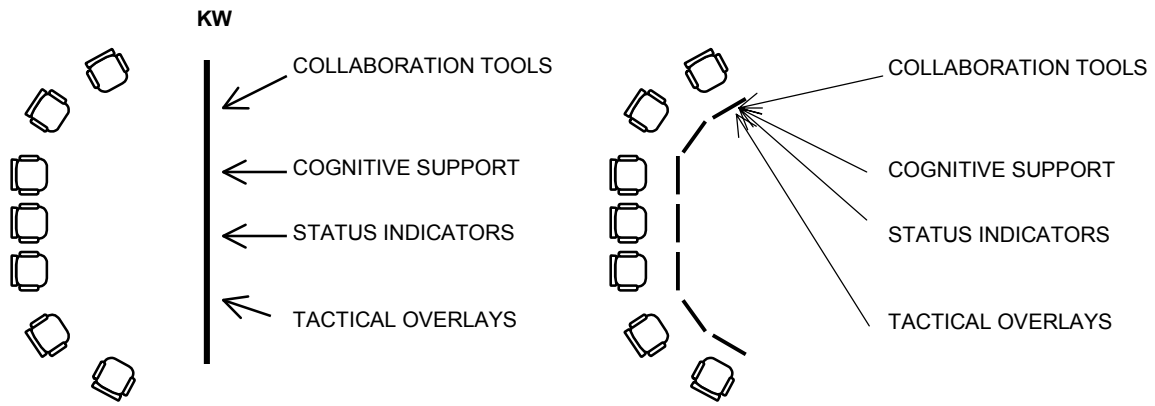


Figure 7. Two ways to provide users with additional display tools.

However, simply improving the anchor desk displays does not support one of the most important requirements identified in the current and previous efforts—the need to integrate multiple sources of information to provide a *shared* understanding of mission objectives and status. The K-Wall facilitates communication, collaboration, and a shared big picture across these personnel in the JOC. Without a K-Wall, these personnel will need to use the means of physical mobility to integrate information across the individual anchor desk displays.

Hybrid Focus

A final alternate solution would involve a hybrid of the K-Wall and anchor desk approaches, in which a miniature K-Wall is made available on each of the anchor desk consoles. This K-Wall miniature could be brought up as a separate window on the individual's displays, allowing all personnel access to an integrated and shared view of the tactical and supplemental information, overlays, alerts etc., through their individual consoles. This would provide JOC personnel collaboration capabilities and give them shared SA (as long as they had a monitor in front of them), and allow them to view the K-Wall information at a much shorter distance and, thus at a higher resolution, than if the K-Wall was presented at distance from them. The STRATCOM display[*], shown in Figure 8, provides one model for this hybrid focus. This display can be resized so that the same information can be displayed on a wall or on a laptop monitor. A major disadvantage to this solution is that the K-Wall would obscure any other information on the anchor desk monitor, making it difficult for users to perform other tasks, including preparation summaries for the K-Wall. Fortunately, because multiple-monitor consoles are quickly becoming the norm, this disadvantage could easily be overcome. Thus, each anchor desk would have simultaneous access to both their task specific monitor and a miniature K-Wall.

[*] Fehér, op. cit.

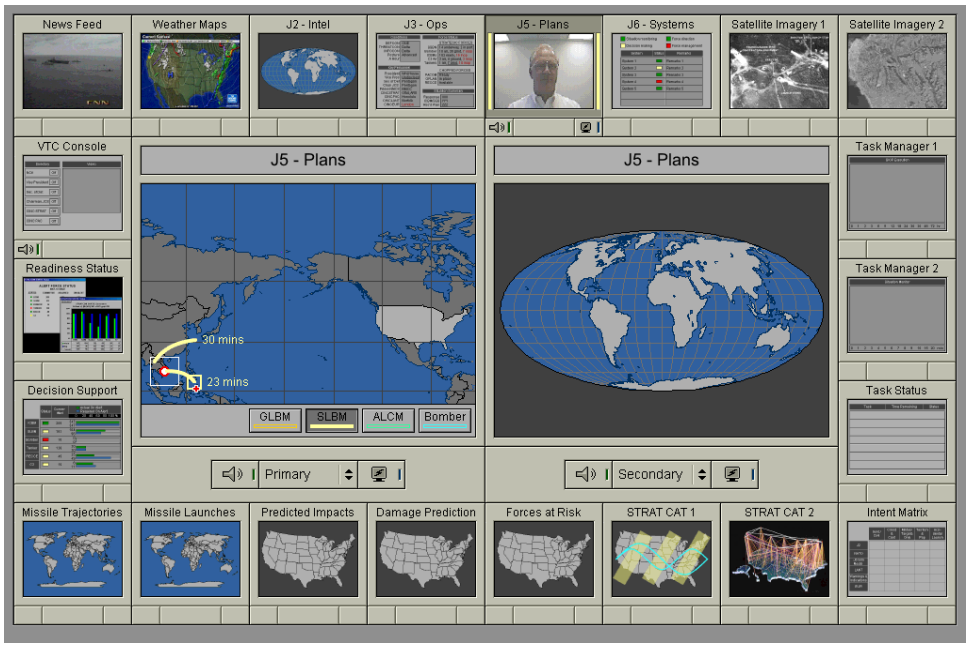


Figure 8. The STRATCOM display concept.

FUTURE RESEARCH

Usage at the Global 2000 War Game

One goal of the current effort is to provide for multiple iterations of the K-Wall design based on its usage and user requirements. The first implementations of the K-Wall will be in the JOC on *Coronado* and in the Joint Command Center (JCC) at the Naval War College (NWC) during the Global 2000 War Game (14–25 August 2000). These implementations will allow the K-Wall designers to observe its usage, conduct interviews with players in the War Game, and answer questions such as:

- Does the K-Wall support shared SA?
- Can information on the K-Wall be seen, understood, and interacted with easily?
- Did the interviews identify the right information requirements?
- Do the K-Wall design solutions support these requirements?
- Are there new requirements that emerge from K-Wall use at Global?

Further development of the K-Wall will be based on the results of these observations and interviews. Some issues that will need to be taken into consideration during this future development are discussed below. Other issues will undoubtedly be identified and will drive future K-Wall development.

Cognitive Support: Attention Management

An important requirement that will still need to be considered in future development of the K-Wall is to support limited perceptual, attentional, and memory capabilities of K-Wall users. The problem of attention is an important and ubiquitous one, and it has already been mentioned, as it relates to specific K-Wall design solutions, in the above discussion.

The K-Wall provides a great deal of important and dynamic information in a single location. Although this information has been processed and filtered and it is presented in a way designed to make it easy to use, viewers must still continuously sample and integrate this information. Users can only fixate, attend to, and process a limited amount of information at a time (Pashler, 1998; Rensink et al., 1997; McFarlane, 1997). From a practical viewing distance (i.e., a distance at which any text on the K-Wall can be read), the information on the K-Wall is spread out over a large area. (For example, from 10 feet away, the width of the K-Wall subtends almost 62 degrees of visual angle. This is equivalent to the width of approximately 1½ 17-inch monitors at a 17-inch viewing distance.) Integrating information across the K-Wall is akin to integrating data from sources spread across a large (26-inch) computer monitor. Making sense of this information requires K-Wall users to make several gaze (eye and head) movements (Robinson, 1979), to hold what was sampled in memory and to integrate this information. This task is made more difficult by the fact that some of the information is changing very rapidly and much of it may be not displayed at a given point in time. Spreading the information over such a large area also makes it difficult to provide alerts to viewers on any of the supplemental monitors. Future research must focus on tools and methods that help:

- Direct user attention to the most important and relevant information on the K-Wall displays
- Highlight important changes in this information
- Represent the history of important changes over time

Information integration problems are exacerbated by the fact that the K-Wall is designed to provide a shared picture to multiple users. At any one point in time, different users will be sampling different information on the K-Wall. In order for the K-Wall to provide a shared understanding of the big picture, tools must be developed that facilitate the task of getting JOC personnel to look at/attend to the same information when necessary, while at the same time allowing them to process information to meet their individual needs.

If the K-Wall is to successfully support the cognitive processes of its users, the focus of much future research needs to be on the incorporation of effective attention management tools. One tool that offers some promise is the CHEX change history tool (Smallman & Oonk, 2000) that highlights and tracks important changes in tactical displays over time.

Integration of Other Tools

Another feature of the K-Wall that should be considered with respect to its future development is how well other software will be integrated into its design. For example, one set of software tools that will be used with the K-Wall for Global 2000 is CAESAR II/EB. CAESAR models changing events during operations and can be applied in the evaluation of courses of action (COAs). Other software, discussed previously, that will be integrated includes C2PC and InfoWorkspace (collaboration software), as well as various tactical overlays developed by TacGraph (tactical visualization software) and other tools and transferred to the K-Wall prototype. The effectiveness of this software within the context of the K-Wall can begin to be evaluated at the Global 2000 War Game.

Interaction with the K-Wall

The current implementation of the K-Wall design (at the Global 2000 War Game) is one in which a single operator controls the interaction with the display. Although this interaction may be at the instruction of several senior JOC personnel, only one individual will perform the actions that control the mouse, move information onto peripheral and focus monitors, drill-down for more information, apply tactical overlays, and so on. An advantage to this implementation is that it supports shared SA

by allowing operators to follow the same “path” when navigating through the K-Wall information. However, it may also cause confusion, if several personnel are instructing the K-Wall operator simultaneously and if these instructions are based on different (but perhaps, complementary) information needs. Further, individual decision-makers may be dissatisfied if they do not have control over access to the information they feel is necessary to perform their tasks.

An alternative is to have several (or all) of the K-Wall users act as the operator(s) of the K-Wall, through multiple control accessibility. This would allow these operators to view the displays and use the K-Wall tools as they deem appropriate. However, it may also lead to new types of confusion if several individuals are making changes to the K-Wall display content or configuration. This in turn may produce a loss of SA or time delays. Future research must examine the costs and benefits of having a single vs. multiple operators of the K-Wall display.

RECOMMENDATIONS

The following recommendations provide a strategy for rational, step-wise development of the K-Wall:

- Implement an initial K-Wall prototype for Global 2000 that incorporates the initial design solutions that meet the 14 user requirements established here;
- Evaluate the usage and performance of this prototype at Global 2000;
- Investigate the development of attention management and other cognitive tools for the K-Wall; and
- Develop methods of effective interaction with future designs of the K-Wall

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APPENDIX A

ACRONYM GLOSSARY

ABWC	Assistant Battle Watch Captain
BfA	Basis for Assessment
BWC	Battle Watch Captain
C^4I	Command, Control, Communications, Computers, and Intelligence
CCG1	Command Carrier Group 1
CCG3	Command Carrier Group 3
CCIR	Commander's Critical Information Requirements
CCOF	Command Center of the Future
CINC	Commander-in-Chief
CMI	Center for the Management of Information
COA	Course of Action
COC	Combat Operations Center
ConOps	Concept of Operations
CTA	Cognitive Task Analysis
DCD	Decision Centered Design
DSS	Decision Support System
GDSS	Group Decision Support System
HCI	Human–Computer Interaction/Human–Computer Interface
HF	Human Factors
JAG	Judge Advocate General
JCC	Joint Command Center
JOC	Joint Operation Center
K-Wall	Knowledge Wall
LNO	Liaison Officer
MMWS	Multi-Modal Watchstation
NEO	Non-combatant Evacuation Operation
NWC	Naval War College
ONR	Office of Naval Research
PCP	Proximity Compatibility Principle
ROE	Rules of Engagement
SA	Situation Awareness
SSC San Diego	Space and Naval Warfare Systems Center, San Diego
STRATCOM	U.S. Strategic Command
TacSAT	Tactical Situation Awareness Tool
TacGraph	Tactical Graphics Application
TADMUS	Tactical Decision-Making Under Stress
VTC	Video Teleconference
WAN	Wide Area Network

APPENDIX B

KNOWLEDGE WALL VISION STATEMENT

Improved information systems and human–computer interfaces are urgently required to address the ever-increasing demands placed upon military decision-makers in a modern C^4I environment. Therefore, scientists and engineers at the Space and Naval Warfare Systems Center, San Diego (SSC San Diego) are currently developing the concept of a "Knowledge Wall"—a wall-sized display meant to impart information and *knowledge* to the user in an intuitive, easy-to-use, and efficient manner.

Current tactical data and information management systems provide the user with enormous amounts of unfiltered and unprocessed data—leaving the user to develop his or her own understanding of the data's meaning and implications. This information often comes from many different systems representing distinct information domains, e.g., strike planning, air defense, logistics, and intelligence. Conversely, the Knowledge Wall concept being developed at SSC San Diego will provide a processed and fused presentation of the "information space" on a single large display designed to facilitate information use across a number of relevant domains. It is envisioned that the Knowledge Wall will be used for a variety of purposes such as quickly developing, maintaining, and sharing situation awareness, providing real-time status of concurrent missions/operations and force resources, facilitating information exchange among watchstanders, and supporting briefings to the senior staff.

As a result, the Knowledge Wall is designed to address:

- Perception of Data Patterns
- Alerting/Attention Management
- Memory for Dynamic Events
- Situation-based Data Fusion
- Adaptive Information Flow and Team Structure
- Distributed Cognition

INTRODUCTION AND PURPOSE OF INTERVIEW

In order to develop an effective Knowledge Wall display that presents information in the most effective and intuitive way, we must determine the information needs of the people who will use it. Therefore, the purpose of today's interview is to determine what specific information should be displayed on the Knowledge Wall just described to you, where that information should be displayed and how it might be used. We are also interested in the mental processes you might be using when interacting and making decisions with the Knowledge Wall and how best to support them. In order to do this, we will be asking you questions related to the type of information and displays you would need to see on the Knowledge Wall when performing certain tasks and how you might use this information.

The interview should last approximately 1 hour. Your answers to the questions in this interview will be kept confidential. Your name will never be connected with these answers in any report or presentation of the results of the interview.

BASIC BACKGROUND INFORMATION COLLECTION

To provide a context for all further discussions, it is necessary to collect some basic background information from you. This information will be kept confidential and your name will not be associated with any report or summary/presentation associated with this interview.

1. What is your name and rank? How can we contact you if there are any follow-up questions after the interview?
   Rank and Name:
   Position:
   Contact information:

E-mail:

2. What job/role do you typically perform in the JOC?

3. What experience do you have in a BG command center? How many years experience?

4. If applicable, what is the job/role that you will be performing during the Global 2000 War Game?

APPENDIX C

DATA COLLECTION FORMS: SCENARIOS

War-time Strike Planning and Execution

Country "X" has attacked country "Y" following a territorial dispute. The US has declared war on country "X" as a result of our long-time alliance with country "Y." Your BG is currently involved in operations to neutralize the enemy's ability to launch short- and intermediate-range ballistic missiles against our ally.

Air Defense (in "hot" and "cold" environments)

"Hot" Environment: Your BG is currently conducting a presence patrol in the vicinity of a country that has previously been hostile to the US. Recent events have led to a serious rise in tensions between our two countries. Intelligence reports indicate that the potentially hostile country has recently upgraded its coastal defenses and maritime strike capabilities. Further, diplomatic communications between the two countries have broken down, and imminent hostilities are expected.

"Cold" Environment: Your BG is currently transiting along the coast of a country neutral to the US. Your current position is well outside territorial waters. Intelligence does not indicate the possibility of any hostile actions by forces in the area.

NEO (Non-combatant Evacuation Operation)

US citizens are trapped in a country currently involved in a bitter civil war. Forces on both sides of the dispute are experiencing heavy losses and analysts expect the conflict to continue for some time. Several US citizens have been killed and wounded as a result of the ongoing violence. Your BG has been ordered to extract the US citizens as quickly as possible while minimizing further casualties and remaining impartial to all of the factions involved.

In order to determine how the Knowledge Wall might be used to present information and support briefings, it is important to understand what type of information should be displayed on the Knowledge Wall and how you might use it. *(Present participants with a layout of the Knowledge Wall. Participants should answer questions relating to location/features of K-Wall by drawing on layout.)*

The following questions were asked in the context of the Strike and NEO scenarios, as time permitted.

For knowledge consumers:

In order to make decisions in the scenario described above:

1. List the *type* of information that you would need to see on the Knowledge Wall.

2. Of the information you listed, which is the most important to you?

3. Who is responsible for providing this information?

4. Where should this information be displayed? (*Indicate on K-Wall template.)*

5. Please prioritize this information. (*Indicate on template.)*

6. What *format* should the information take?

7. How often should this information be updated?

8. Of the information that you just listed as important, which would you need to look at first? Why would you look at this information first?

9. Which would you need to look at most often? Why would you need to look at it most often?

10. Are there any special features or information tools that you would like to see on the displays of the knowledge walls? (Provide them with a list of potential features, if necessary.)

11. How would you use these features?

12. Are there any problems that you now face when monitoring the situation or making decisions that you think the Knowledge Wall might alleviate?

13. How often do you think you would use the Knowledge Wall when making decisions?

14. Who else in the JOC would use the Knowledge Wall? Do you interact with them? How do you interact with them?

15. Specifically, how do you think they will use the Knowledge Wall?

For knowledge producers:

In the context of preparing a briefing for senior staff in the scenario just described :

1. List the *type* of information that should be displayed on the Knowledge Wall.

2. Of the information you listed, which is the most important?

3. For which of this information are *you* responsible?

4. Where should the information that you supply be displayed? (*Indicate on K-Wall template.)*

5. Who else is responsible for important information?

6. Where should the information that these other people supply be displayed?

7. Please prioritize this information. (*Indicate on template.)*

8. What is the *format* that this information should take?

9. How often should you update the information you provide? Is this more or less often than you update information now?

10. Are there any special features or information tools that you think users of the data wall might use? (Provide them with a list of potential features, if necessary.)

11. How might these tools/features be used?

12. Are there any special features or information tools that you think users of the data wall might use? (Provide them with a list of potential features, if necessary.)

13. Who else (besides senior staff) might use the Knowledge Wall?

14. How might these personnel use and interact with it?

APPENDIX D

RESTATEMENT AND WRAP UP

SUMMARY/RESTATEMENT

As I described in the vision statement, the Knowledge Wall will be designed to impart information and knowledge to the user in an intuitive, easy-to-use, and efficient manner. By providing processed and filtered information on a single large display, the hope is that the Knowledge Wall will allow users to quickly and efficiently develop and maintain situation awareness, monitor missions and resources, and allow watchstanders to update and share information with other watchstanders and senior staff. The information that you have just provided will help us to determine how best to represent information on the Knowledge Wall so that it will optimally support the human cognitive processes involved across a variety of situations.

Has our discussion made you think about any K-Wall features that you would like to comment on now?

CLOSE

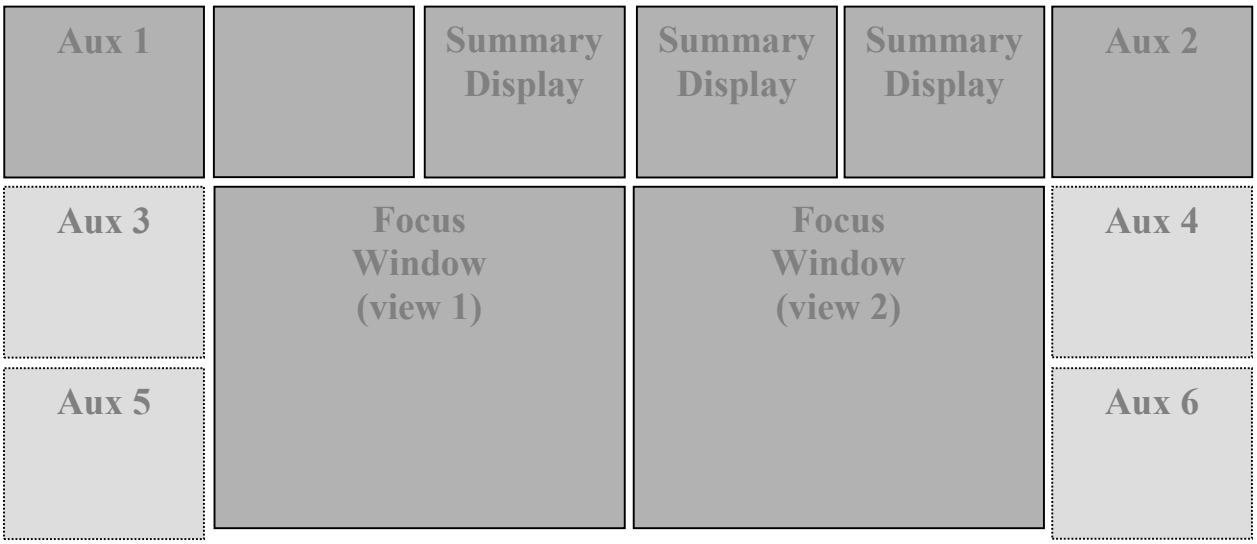
Thank you very much for taking the time to allow us to conduct this interview. Your answers will prove valuable information as we continue to develop our ideas about the specific content and features of the Knowledge Wall. We will continue to keep you informed about these developments. If you have any further comments, questions, or concerns, please feel free ask them now. You may also contact either the interviewers or the sponsor, Dr. Jeff Morrison with any questions or concerns. (*Point out contact information on leave-behind sheet.)*

APPENDIX E

VISUAL AIDS AND HANDOUTS

KNOWLEDGE WALL TEMPLATE

Please draw or describe desired features on template below. Please do not limit yourself to specifying tools or features available in current systems. Likewise, please do not limit yourself to information sources or potential tools/features listed below; they are provided solely as a way to "spark your imagination."



Candidate Information Sources

C2PC, InfoWorkspace, JFLEX, J2, J3, J5, J6

_____

_____

_____

Potential Tools/Features

Task management tools, Visualization tools (overlays, zooming, highlighting etc), Communication tools, Task assignment tools, Presentation/briefing preparation tools, Time management tools, and Collaboration tools

_____

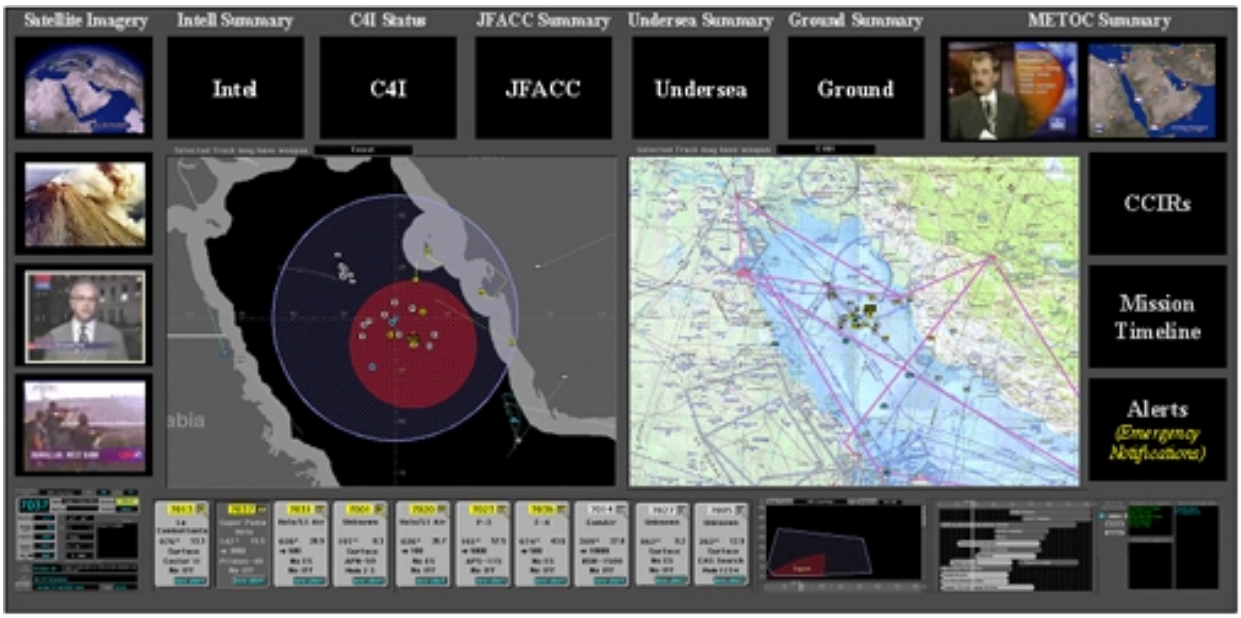
_____

_____

Improved information systems and human–computer interfaces are urgently required to address the ever-increasing demands placed upon military decision makers in a modern C^4I environment. Therefore, scientists and engineers at the Space and Naval Warfare Systems Center, San Diego (SSC San Diego) are currently developing the concept of a "Knowledge Wall"—a wall-sized display meant to impart information and knowledge to the user in an intuitive, easy-to-use, and efficient manner.

Current tactical data and information management systems provide the user with enormous amounts of unfiltered and unprocessed data—leaving the user to develop his or her own understanding of the data's meaning and implications. This information often comes from many different systems representing distinct information domains, e.g., strike planning, air defense, logistics, and intelligence. Conversely, the Knowledge Wall concept being developed at SSC San Diego will provide a processed and fused presentation of the "information space" on a single large display designed to facilitate information use across a number of relevant domains. It is envisioned that the Knowledge Wall will be used for a variety of purposes such as quickly developing, maintaining, and sharing situation awareness, providing real-time status of concurrent missions/ operations and force resources, facilitating information exchange among watchstanders, and supporting briefings to the Senior Staff.

Accordingly, the Knowledge Wall will be designed to address Perception of Data Patterns, Alerting/Attention Management, Memory for Dynamic Events, Situation-based Data Fusion, Adaptive Information Flow and Team Structure, and Distributed Cognition. Presented below is a notional Knowledge Wall, the actual features and functions of which remain to be determined.



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