

Evaluating the Usage, Utility and Usability of Web-Technologies to Facilitate Knowledge Sharing

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Abstract

In order to facilitate knowledge sharing in military command centers, the Command 21 research program has created a large shared display – a “Knowledge Wall” (KW) – that brings together mission relevant information on a shared display. An initial KW prototype was implemented for senior staff during the Global 2000 War Game. In order to assess how well this prototype performed, a usage, utility, and usability evaluation of the KW was performed as it was employed at Global 2000. Data was collected in a minimally-invasive fashion. It included informal observations of KW user behaviors and comments. Further, data was collected automatically by the KW application software. The results of the evaluation suggested that the initial KW prototype adequately supported most of the 14 user requirements identified in a previous cognitive task analysis (Smallman, Oonk & Moore, 2001) and that users preferred it to other that was made available to them in the past. The information products provided the KW users with an integrated summary of the operational picture and allowed them to navigate through the knowledge web to get more detailed information. However, several issues were identified, including those related to usability of the KW and providing cognitive support to users, which need be addressed by in future KW designs.

1. Introduction

The Navy’s Command 21 project is directed at supporting the needs of senior decision makers and support staff in military command centers. As part of that effort, a prototype wall-sized shared display – or “Knowledge Wall” (KW) - that fused mission-relevant information was created to support shared situation awareness (SA), to facilitate group interaction and to augment the decision-making capabilities of senior staff. The prototype KW was designed to meet 14 user requirements that we had identified with a previous cognitive task analysis of potential KW users (Smallman, Oonk & Moore, 2001). Prototype KWs were implemented ashore in the Joint Command Center of the Naval War College (NWC) and in the Command 21 Laboratory of SPAWAR Systems Center, San Diego, and on-board the USS Coronado for the Global 2000 War Game. The implementation of Summary Pages’ shown on the KW was intended to provide users high level summarized views of the operational picture and a means to easily navigate through the ‘Knowledge Web’ to get more detailed information (Moore & Averett, 2001).

The Global 2000 War Game was played over a period of two weeks, including six days of operational play. The game consisted of three operational phases: a pre-hostilities phase (Phase 1), a hostilities phase (Phase 2) and a post-hostilities phase (Phase 3). The command structure consisted of a Commander Joint Task Force (CJTF), a Commander in Chief (CINC) and a National Command Authority (NCA) supported by the component commanders and personnel assigned to one of 13 functional areas. The KW prototype provided the operational picture to the CJTF and CINC staff by displaying information products produced by the anchor desks elements making up these functional areas. The information products were continually updated over time during game play, multiple times every hour.

The Global War Game provides a venue for debuting potential high technology solutions for future naval needs. As such, Global 2000 afforded an invaluable opportunity to observe the prototype KW undergoing extensive real-time usage in an operationally-realistic setting by exactly the sort of experienced real Navy users for which it was intended. To facilitate a usage, utility, and usability evaluation of the KW, a research plan was developed before the Game to ensure a minimally-invasive presence during the operational usage. This plan called for the gathering of both observational and automated data.

2. Method and Approach

2.1 Data Collection Plan

The data collection effort was very focused in scope and centered primarily on the usage of the KW in the JCC at the NWC. The data collection had several purposes. It attempted to determine whether:

- The KW design solutions supported the 14 user requirements identified in the previous interviews and whether there were additional requirements that could be supported by new KW design features and content.
- The information products (Summary Pages and others) met the information requirements of KW users. In particular, whether the content and format of the Summary Pages provided the KW users a consistent, intuitive representation of status across the different functional areas that could be easily fused to provide an integrated picture of the operational situation.
- There were usability or ergonomic issues related to KW use or operation.

2.2 Data Collection Techniques

The data collection techniques employed during Global 2000 were restricted to passive observation and automated data collection. Because of the free flow and continuous nature of the game, no questionnaires that would disrupt play were given and direct questioning of players was limited.

2.3 Automated Data Collection

Automated data was collected in order to track Universal Resource Location (URL) access and changes in the configuration of displays of the KW. Two types of automated data collection were implemented. Logs of the usage on each display of the KW were

created at the beginning of each day and updated any time a change was made. These logs included the address of the Web pages that were displayed on the KW, when the URLs to these pages were accessed and on which KW monitor they were displayed. The usage logs were also updated every time a KW operation was performed. The usage logs did not include information about other tools or software that was displayed on the KW, unless they were accessed via the KW application (i.e. via a URL). The second type of automatically collected data came from screen captures of the entire KW, which provided insights into its usage by showing actual content and configuration. These were also time stamped and they were taken automatically every five minutes.

2.4 Observational Data Collection

Much of the data collection was informal and observational: this was inevitable, given the need to collect data non-invasively in a real-world, operational setting. Observational data collected during the game related to several different aspects of the KW. These included (a) Critical events and situations, which allowed the other data to be put into a context over time. Critical events were broken down into those events that caused a modification in the usage pattern of the KW, and those events that were determined to be mission-critical based on observer comments, (b) KW usage patterns, including which tools and URLs KW users accessed and how the KW displays were configured (c) User preferences, in terms of how much users liked or disliked the KW and its features (d) KW usability, including issues related to the ease and intuitiveness of interacting with the KW (e) Suggestions for new requirements, in terms of the content, features and tools of the KW and (f) Visibility issues, including the legibility of text and graphics on the KW.

The observational data collected came predominantly from the primary KW users (JCC staff). However, observations of and comments made by other game players, including the functional area Commanders, functional area anchor desk personnel (i.e. the information producers to KW), and visitors to the JCC were also collected when available. Sources of data also included comments made during discussions with the Knowledge Managers (KMs), a team of personnel that was given the role of supporting and evaluating knowledge management. One of the responsibilities of this role included supporting players in the effective use of the tools made available to them during the game.

3. Results

Several themes emerged from analyses of the automated and observational data that was collected during the Global 2000 War Game. These themes, which are discussed below, concerned:

- The initial requirements identified in previous interviews and which the KW was designed to meet.
- The design, content and tools of the Summary Pages.
- Usability and usage of the KW.

3.1 Information Requirements

The initial implementation of the KW was intended to address the 14 requirements identified by previous interviews with potential KW users (Smallman et al., 2001). Each requirement is discussed below, followed by representative paraphrased responses and / or analysis of automated data that document how well the KW design met the requirement.

3.1.1. General Requirement: Shared SA

The KW attempted to meet users' need for shared SA by bringing multiple sources of information together on a single shared display. Unfortunately, due to constraints imposed on the data collection procedures used, no formal measures of SA could be taken during Global 2000. However, users' perceptions of how well SA was supported can be discerned from the observed comments of JCC staff. All of these comments should be considered in light of the fact that there was a limited number of tools available to the game players which they could take advantage of to acquire and maintain SA. In general, most of the relevant comments made by KW users suggested that they believed that the KW was the best tool available to them for the acquisition of SA and that it provided support for SA reasonably well. In particular, the comments reflect the perception that personnel who had access to the KW were able to acquire SA more easily than those who did not have this access. Typical comments included:

- SA increased in the CJTF but not component commands.
- The speed of command was increased by the improved SA of the CJTF. The KW was a factor in terms of improved speed of command.
- The KW is valuable in giving all a sense of what's going on, especially the CJTF and the CINC.
- We need a common picture that gives instant SA to the commander when they walk into the room... this is a pretty interesting first step.

3.1.2. General Requirement: Integrated information

Another general requirement that the KW was designed to meet was the need to display integrated information. Again, the design of the KW addressed this need by bringing multiple sources of information together on a single display. Further, the KW was populated with an array of Summary Pages. The observed comments made by KW users suggest that they believed that displaying information typically distributed across multiple systems simultaneously, in a single display, was a step toward providing integration of the information provided by the different functional areas. However, the comments also reflect the feeling that it was still difficult to fuse the information that was displayed on the KW to form a sufficiently integrated picture of the operational situation across functional areas. Comments related to this issue included:

- Only the CJTF can look at all the screens at the same time. [Those without a KW can not...]
- I see this as valuable because we can put different formats up there to discuss things.

- The KW was a good first step. We need better integration... it was hard to see everything....
- The information presented on the wall was not fused from relevant functional areas. However, it gave the false impression that it was...

3.1.3. and 3.1.4. Format Requirements: Intuitive Graphical interface and Consistency

The interviews revealed a need for the information presented on the KW to be in a consistent format that was intuitive and graphical. In order to meet this need, information producers were trained to populate the KW with Summary Pages, HTML pages that had a predetermined layout and format. In order to support graphical information on the KW, the functional area anchor desk personnel were encouraged to use graphical representations of information when possible. They were also provided with the *TacGraph* tool (Bank & Moore, 2000) with which they could provide graphical tactical information to be published on the KW. The comments regarding the format of the KW suggest that, although the format of the KW was “fairly” intuitive, there were problems with consistency that were not resolved during the game. These problems stemmed from a lack of standardization of the representation of information on the KW, especially across the different military forces. Representative comments included:

- The technology, a lot of it being the KW, was fairly intuitive...
- There is no way to have one metric for all the functional areas... If we were together for a longer time, a metric would develop.
- We need standards of use (e.g., colors used, processes completed, level of detail, purposes, etc.) ...

3.1.5 Content Requirement: Tactical focus

A desire expressed by users in the interviews was for multiple tactical displays as the focus of the KW. The KW provided two large, side-by-side focus monitors that were intended to meet the need for a tactical focus. The primary software used to generate detailed tactical information during Global 2000 was *C2PC*. Another common way that information producers represented tactical information was to link pictures produced using the *TacGraph* tool to the functional area Summary Pages.

Figure 1 shows the percent of time that *C2PC* was running or a Summary Page link containing a *TacGraph* picture was being displayed on one or both of the Focus monitors as a function of the operational phase of the game. Tactical information was included in the focus of the KW for a significant proportion of the game. Analysis of the screen captures of the KW revealed that tactical information provided by

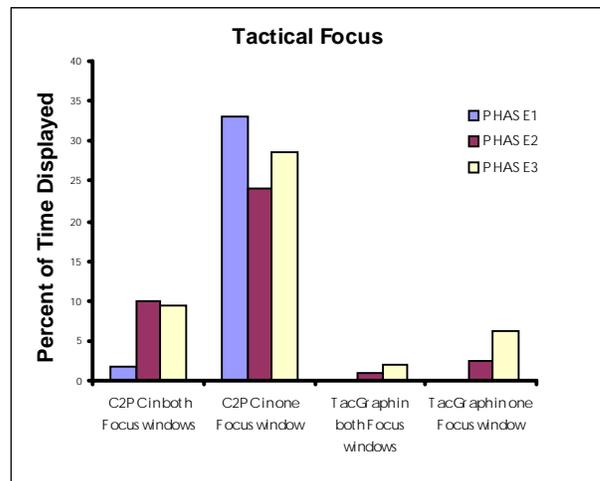


Figure 1. The percentage of time that tactical information was displayed in one or both of the KW focus displays (Monitors 9 and 10) as a function of format of information and operational phase.

C2PC or *TacGraph* was displayed on at least one of the KW focus monitors 34% of the time. However, tactical data was rarely the *only* focus of the KW - *both* focus monitors contained tactical information only 8% of the time.

3.1.6 Content Requirement: Supplemental information

In order to display other information besides tactical, the KW design provided ten small, peripheral monitors surrounding the two big focus monitors. The observed behavior of the KW users demonstrated both confirmation of the need for this information and a potential design problem with KW layout. Although the information on these monitors was frequently viewed or discussed, it was almost always brought into focus on one of the larger central monitors in order for KW users to be able to read it. This was especially the case when any links from the Summary Pages were being viewed. This behavior suggests, that although users were *very* interested in seeing non-tactical information on the KW, the small peripheral monitors only provided some information (such as changes in the color of the status indicators or in the color of the links text), and that they were not sufficiently large to provide the information that users wanted to see and read (see also the discussion in *Usability*, below).

3.1.7 Content Requirement: Mission goals and objectives

A requirement identified in the interviews was for the KW to provide access to mission goals and objectives. A goal of the KW design was to meet the need to visualize goals, plans, and mission status, however no single monitor or location was dedicated to provide this information. The information producers did make this type of information available in links from the functional area Summary Pages and there were also separate Summary Pages for the Theater Assessment Profiling System (*TAPS*), which provided effects-based assessment of the operational system and the Joint Force Level Execution Monitoring and Re-planning Software (*JFLEX*), a mission planning and monitoring tool tools, which provide mission planning and effects evaluation. Further, the CJTF staff developed their own Summary Page that was intended to provide this sort of information to both the CINC / NCA and functional area component commanders. Comments made by the KW users, however, reflect a perception that the KW did not sufficiently support communication of mission goals and objectives. These comments include:

- It did not provide the commander's intent to me
- The CJTF level did not feel comfortable... with no way to sync with higher and lower levels – no way to push information or convey needs / plans / intentions.
- The overall battle plan is not really reflected on the KW...

3.1.8 Content Requirement: Anchor desk outputs

Previous interviews indicated that KW users needed to see output from anchor desks on the supplemental monitors of the KW. Analysis of the screen captures revealed that information produced by the anchor desks from the 13 functional areas was the primary information presented on the peripheral monitors of the KW. Figure 2 (top panel) shows the percentage of time that a Summary Page was displayed on the KW displays. Even though many types information and tools were available to be displayed on the KW, Figure 2 reveals that the Summary Pages were by far the most commonly displayed information products (86%, averaged across all monitors).

The KW data logs also indicated that information products from these anchor desks were the most commonly accessed information on the KW monitors. Figure 3 shows the number (per hour) of Summary Pages and other information products (i.e. links from the Summary Pages) produced by the functional areas that were accessed as a function of operational phase. As can be seen, over time, as the KW users and information producers became more familiar with the technology, as evidenced by their increasing access of KW information products.

3.1.9 Content Requirement: Connectivity, collaboration, and coordination

During Global 2000, several collaboration tools were made available to players. The primary tool provided was InfoWorkSpace (*IWS*), a bundle of collaborative tools for communication and data access. KW users who had access to *IWS*, however, tended to use their *IWS* on the laptops provided on the command table. The KW did provide a dedicated VTC window (on a thirteenth monitor) but this was not used for this purpose. Finally, the implementation ability of multiple KWs (one at the NWC and one on the USS Coronado), to be linked together in a wide area network (WAN), enabled long-range

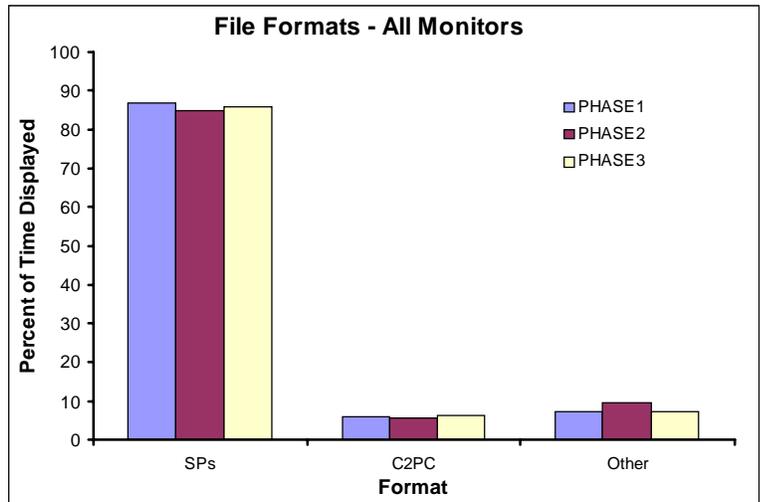


Figure 2. Percentage of time that a Summary Page was displayed on the KW displays, averaged across all monitors.

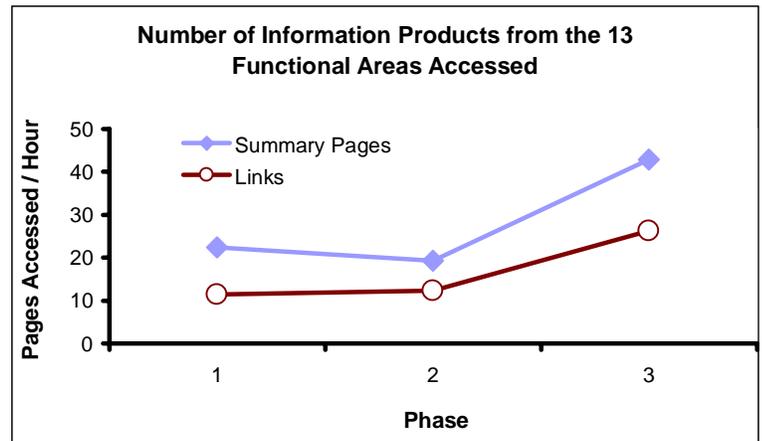


Figure 3. The number of Summary Pages and other information products (i.e. links) from the 13 functional areas that were accessed via the KW, as a function of operational phase.

communication and collaboration between decision-makers. Finally, the Summary Pages supported collaboration by providing an effective means of communication between the functional areas and the CJTF. Comments that related to collaboration and connectivity during the game in general were:

- Groups that were on *IWS* did use chat for collaboration
- There was a need for better shared awareness/collaboration
- The VTC was worthless, actually negative because poor execution made it a distraction... maybe they thought they were sharing information but they weren't.

3.1.10 Content Requirement: Cognitive Support

The KW itself did not provide integrated cognitive support tools. Therefore, most comments related to cognitive tools focused around the need for such tools on the KW in general or the on the Summary Pages (see discussion of *Summary Pages: Tools*, below).

The output (in the form of Summary Pages created for this purpose during the game) from a limited number of *nonintegrated* cognitive support tools could be displayed on the KW. These tools were (a) *TAPS* (b) *JFLEX* (c) Computer Aided Evaluation of System Architectures (*CAESAR*), a course of action visualization support tool (Levis, 2000; Wagenhals, Shin & Levis, 1998).

When they were accessed, these tools or their outputs were most often displayed on one of the focus monitors of the KW. Figure 4 shows the percentage of time that the output from one of these cognitive support tools was displayed on one of the KW focus monitors. As can be seen, KW users rarely viewed the output of these tools – the most often accessed tool was *TAPS* which was displayed on the KW for only 3.6% of the time during the game (averaged across all three phases).

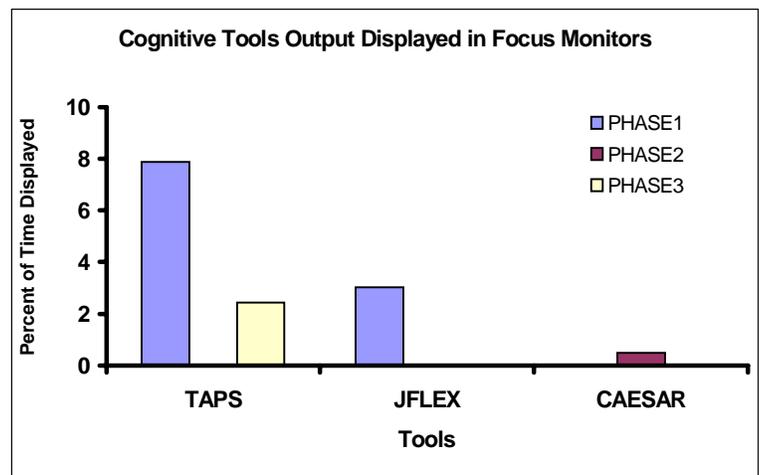


Figure 4. The percent of time that output of the few cognitive tools was displayed on one of the KW focus monitors

Suggestions for several new KW tools were made throughout the course of the game. Tools for the KW in general that were requested were those that provided (a) *Alerting* – tools that allowed the KW users to alert others about information and to be alerted about changes, especially in information not displayed on the KW (b) *Attention management* (pointers etc)- tools to direct KW users attention to relevant information, especially in the context of discussion / collaboration using the KW (c) *Other tools* – included chat capability with information producers.

3.1.11 Feature Requirement: Flexible configuration

The KW provided flexibility in the configuration of the displays by allowing users to easily move the contents of the KW monitors and bring up new information as necessary. It enabled flexibility by allowing any Knowledge Web page to be viewed in any display. Users could easily bring information on the peripheral displays into focus on the central tactical displays

The comments and behaviors of the KW users reflected two contexts within which the need for configurable displays must be met. First, the KW must be configurable to support a change in the operational situation. During Global 2000, KW users were observed to reconfigure the KW displays to meet this need. For example, they changed which Summary Pages were presented in the peripheral monitors following a change in operational phase. Second, the configuration of the KW must be flexible enough to meet the demands of different users. Much discussion revolved around this requirement for user-defined KW configuration. However, the fact that the KW was used by only two groups during Global 2000 made it difficult to collect data relating to this requirement. At the NWC, the KW was configured to meet the information requirements of the CJTF and JCC staff. Although the CINC *could have* configured the duplicate KW aboard the USS Coronado differently, a comparison of the typical configurations of these two KWs revealed that they were configured quite similarly. Representative comments included:

- Now that we are no longer in [Phase 1] and in [Phase 2], I need to see information relevant to that... only certain pages.
- Whose tool is it? If three groups can see a KW they need to see different information...One KW glove does not fit all - there needs to be tailorable information...

3.1.12 Feature Requirement: Drill-down

The Web-based KW application and the Summary Pages produced by the functional area information producers were designed to support drill-down to more detailed information. The intent of this design was to enable information producers to use the bulleted text of the Summary Pages (status alerts, alerts, impacts, links) as Hyperlinks to other information products such as other Web pages, briefs, and other documents. As the game progressed and information producers became more adept at posting to the KW and updating Summary Pages, the number of the links increased, content of these links became more detailed and the relationship between

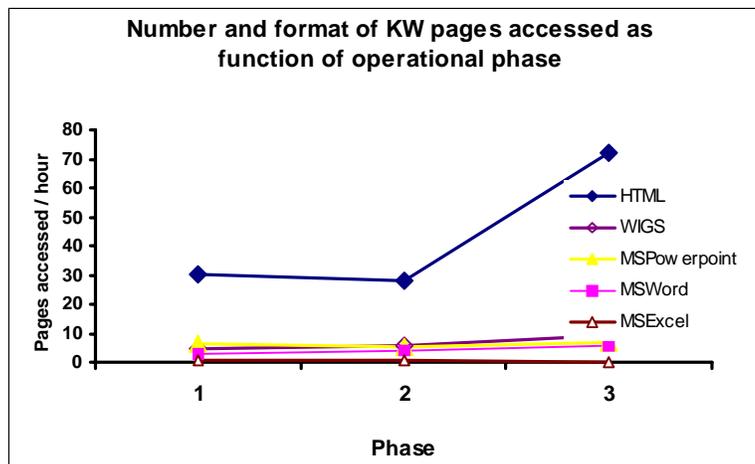


Figure 5. The number of links accessed per hour of game play via the KW as a function of format and operational phase.

links increased, content of these links became more detailed and the relationship between

linked products became more complex. This is reflected in the KW data logs, which automatically recorded the path of every link accessed through the KW application, from which can be extracted both the source and format of these links. Figure 5 shows the content and format of the pages accessed as functions of the operational phase of the game. As can be seen, the majority of these pages were Web pages, in HTML format.

3.1.13 Feature Requirement: Information age and reliability

The KW provided information age, in terms of the last update time of the Summary Page, using a simple time and date stamp. Some comments reflected that KW users wanted a better indication of the age of information products presented on the KW. More importantly, however, were comments suggesting that users were not happy with the *rate* at which the KW was being displayed which is related to the age of the information on the KW. -Representative comments included:

- One thing we've heard about the KW is 'how current is the information?'
- A lot of these things don't have times on them so we don't know old they are
- Currency of information is a big issue with the wall, in terms of how long it takes to produce products

3.1.14 Feature Requirement: Tactical overlays

The main tactical tool used on the KW, *C2PC*, provided a number of overlays that were used frequently throughout the game. Further, users of *TacGraph* could show filtered (de-cluttered) representations and include objects such as arrows, shapes, etc. to graphically represent things such as projected movement, zones of interest, etc. Comments related to the *TacGraph* tool were made by both users of the KW and the information producers. These comments suggested that both of these groups believed it be a good tool for creating useful graphics to represent the operational picture. Information producers found the software easy to interact with to rapidly build effective graphics. The output of *TacGraph* is in HTML format and information producers took advantage of this, sometimes producing interactive graphics Hyperlinked to multiple levels of drill-down. KW users expressed the desire to see the *TacGraph* pictures linked to *C2PC* data. Representative comments related to *C2PC* and *TacGraph* included:

- I believe this is a fantastic tool, which was brought too late in the game. Its graphics are outstanding and bandwidth is conserved when docs published in JPEG format
- Clearly tools like *TacGraph* are great for rapidly building a picture that can express info concisely and rapidly.....
- It [*TacGraph*] needs to be integrated with *C2PC*

Issues Related to Summary Pages

A great deal of discussion focused around the content, layout and format of the Summary Pages. This is not surprising since the Summary Pages were the most common format of the information displayed on the KW and they served as entry points into the Knowledge Web of anchor desk information products. The current data collection effort attempted to evaluate the design of the Summary Pages and answer questions such as:

- Did the Summary Pages (and their links) have the right content?
- Did the Summary Pages (and their links) have the right format?
- How can the Summary Pages be improved?

3.2.1 Summary Page and Links: Content

A great deal of discussion was focused around the content and features of the Summary Pages. Most of the discussion related to how to define specific content, who should define it and how to maintain consistency across Summary Pages. This suggests that, in general, the content categories (status, alerts, links, etc.) met the information requirements of the KW users. The discussion of the content of the links pages suggested, not surprisingly, that the links should provide information directly related to the information on the Summary Page. For example, a link from the alert text for Today, should provide detail about today's status and indicate why the alert was the color it was. The need was also expressed to display a clear indication of the source of a link. Representative comments were:

- It's important to communicate and have a common understanding of what should be on the wall.
- When you change the color of the alert, we need to know why the alert changed.
- That's what we want to see: what they're planning to do today, what are their intentions for tomorrow....

3.2.2 Summary Page and Links: Format

The most prevalent suggestion with respect to the Summary Page format was to dedicate more room to graphical information and less room to text information. This represents both the acknowledgement of the usefulness in representing information in a graphical format (as expressed in requirement #3, see above) as well as the difficulty in reading the text on the Summary Pages (see usability discussion below). The comments relating to the format of the links from the Summary Pages reflected the same acknowledgement and stressed the need to 'keep it simple'. KW users explicitly requested that graphics be used as much as possible and when not possible, simple, large black and white text be presented.

3.2.3 Summary Pages: Tools

3.2.3.1 Alerting change to Summary Pages. One of the most pressing needs that emerged from the observational data was for tools that alerted the user to changes to the Summary Pages. KW users had great difficulty detecting when changes occurred to information on the Summary Pages and, when they did, determining specifically what information changed and how important the change was. The need for a change alerting system was underscored by the many 'fixes' that were improvised and implemented to alleviate this

problem. Because the Summary Pages were not originally designed to provide a mechanism for alerting change to KW users, these users and information producers introduced business rules and took advantage of the coding used by HTML to indicate 'visited' links to help them become apprised of changed information. Comments and observations relating to this need for alerting change included:

- Change the stop lights so they flash when changed....
- I'm looking for blue text as an indication of new information...

3.2.3.2 Feedback to Information Producers. Also emerging as a related needed tool for KW users, is one that would enable them to inform information producers that a particular page or link had been accessed, and convey their information needs. This tool would clearly benefit the information producers since they would know when their information had been viewed, and their comments reflected this need. Providing this type of feedback might also improve the update rate of the KW since the information producers would become more aware of how often their products were being used.

- We need a way for KW users to convey desires / disseminate information "down" to anchor desks and lower echelons.
- There needs to be automatic feedback that the page has been read.

3.3 Usage, Usability and User Preference

3.3.1 Usage.

The KW was used in a variety of contexts during Global 2000. The most common way in which it was used was as a 'situation assessment' tool. JCC staff (and others) continuously viewed the KW throughout the game to maintain SA and to discuss information with each other. Many user comments reflected this and also highlighted its importance in eliminating the need for these personnel to be briefed daily by the component commanders. The KW was also used as a briefing tool, especially during the transition between operational phases of the game. Observations and example user comments included:

- The KW was used for briefing, discussion of information without having to stop the war.
- We didn't do a briefing at 8 o'clock, 1 o'clock... we didn't need to be brought up to date because we were always up to date... we didn't have to go off for 2 hours and prepare a brief.

3.3.2 Usability

Although, in general, the KW operators and viewers found the KW easy to use, several usage problems were identified based on observed behaviors and comments. KW operators complained that accessing information that was found in locations other than the displayed Summary Pages or their links was difficult because it involved many steps. The fact that input to the KW came from two sets of mouse and keyboard controls plus the touch screens caused some confusion when more than one person attempted to operate the KW simultaneously. Confusion also arose because only the focus monitors

had touch screens. Users were observed attempting to use the screens of the peripheral monitors as if they were touch screen-capable. Another commonly observed problem was the tendency for KW users to lose the mouse cursor in so much screen real estate – especially after looking away from, and then returning their view to the display.

Many user comments concerned the difficulty that KW users had in seeing information on the KW. These comments primarily reflected problems in reading the text and small objects and controls displayed on the smaller peripheral monitors. This difficulty was also reflected by the fact that the KW operator typically brought information from the peripheral monitors into focus on one of the focus areas in order to read it. However, even the information on the focus areas was sometimes found to be difficult to read when it was too small or when other KW users were obscuring the view of the monitors. An assessment of the difficulty that KW users had at reading information on the Summary Pages indicated that identification accuracy for the smallest text (used for the bulleted links) was as low as 61% and only approached 100 % for the larger font sizes (the text used for the title and status indicators)

3.3.3 User Preference. In general, KW user comments suggest that they liked the KW, though users believed that there were problems that needed to be addressed and various improvements that could be made to its design. When comparing the KW to the tools they currently had available to them, they expressed a preference for the KW. Representative comments were:

- This is much better than what we had before, better than a stickpin in a map...
- The KW was a hit...
- [The KW] is a good idea but it needs some tweaking...
- The KW was a good first step...
- Life would have been miserable if I didn't have this...

4. Discussion

The initial implementation of the KW for Global 2000 was intended to address the 14 user requirements identified by previous interviews with potential KW users (Smallman et al., 2001). The KW was generally considered to be a success in terms of meeting – at least to some reasonable extent – the 14 identified requirements. This assessment is borne out in both user comments and in the results of the data analysis. Of course, certain characteristics of the wall were judged more successful than others. In general, both the automated and observational data suggest that the KW was ‘a good first step.’ A summary of the 14 user requirements, the KW design capability intended to meet them and an evaluation of whether or not the KW met each design requirement is shown in Table 1.

Summary pages from the 13 functional areas (and links from them to other information products) were the most commonly displayed information sources on the KW. Tactical information and other software were also displayed as needed, especially on the large central focus monitors. The Summary Pages were designed to provide users a means to

rapidly acquire and integrate information by providing them with a high-level, intuitively presented summary from the various functional areas. They provided a window into the “Knowledge Web” (the entire constellation of Summary Pages and Hyperlinked information products) and a means to easily navigate through it, via links to more detailed information. Several issues were identified, however, regarding the Summary Pages and the information that they linked to that must be addressed in the future design of Summary Pages.

Table 1. How the results bear on the success (or failure) of meeting the 14 user requirements with the prototype KW design.

User Requirement		KW prototype design capability	Requirement met?
General	Shared SA	Shared display	✓
	Integrated Information	Co-located Summary Pages	~
Format	Intuitive Graphical Interface	Graphical presentation when possible	✓
	Consistency	Consistent format Summary Pages	✓
Content	Tactical Focus	Ability to view multiple tactical displays	✓
	Supplemental Information	Summary pages on peripheral displays	✓
	Mission goals and objectives	Text document	~
	Anchor Desk Output	Summary pages with links to more info	✓
	Connectivity/Collaboration	Collaboration tools (<i>IWS</i>)	~
	Cognitive Support	Limited output from nonintegrated cognitive support tools	~
Feature	Flexible Configuration	Any pages viewable in any display	✓ / ~ contexts / users
	Drill-Down	Multiple scalable views, links to more info	✓
	Information Age and Reliability	Text-based time stamp	~
	Tactical Overlays	Various software for tactical graphic presentation	✓

The data and observations collected during the Global 2000 War Game point to specific needs that must be met by future Command 21 research and development efforts. These needs include (a) Cognitive tools to support attention management and change detection, including tools facilitating navigation to changed pages in the Knowledge Web. (b) Tools and improved business processes to support multi-tiered collaboration, including feedback and guidance for information producers on content access of their pages. (c) Design layouts to support improved text legibility. (d) Information integration *across* functional areas – preferably integration that is graphical in nature. (e) Information age and source information on the summary pages. Overall, the usage, usability and utility

evaluation of the KW at Global 2000 provided an important error signal that will drive future KW design and development.

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