Identifying Decision Maker Information Requirements For Knowledge-Centric Information Systems

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Abstract

How can the Navy best meet the C^2 needs of decision makers in command centers? The Navy's Command 21 program is working to support decision makers through the joint development of Web-architectures and integrated support applications. A functioning prototype system was created for the Global 2000 War Game. Building on an earlier cognitive task analysis (CTA) conducted on Joint Operation Center (JOC) personnel (Moore & Averett, 1999), structured interviews were conducted with potential Global prototype users to identify their information requirements for this new prototype. Participants reported difficulty quickly developing, maintaining and sharing situation awareness (SA) with other staff. They also reported difficulty exchanging information and fostering collaborative work processes with others. From a master list of comments and answers to questions, four categories of user requirement emerged (general, format, content, and feature) that could be directly related to the prototype design. Further distillation led to the identification of a total of 14 key user requirements. How design solutions for support of these 14 requirements led to the initial specifications for a wall-sized shared display - or "Knowledge Wall" - fusing all information relevant to mission status are elaborated.

1. Introduction

A recent Chief of Naval Operations Strategic Studies Group report noted that the speed of command is compromised by fleet decision makers being faced with too much data and not enough information (Wagoner et al., 1997). The Navy's Command 21 program is working to Web-enable command centers to deliver Knowledge Management tools and a new Concept of Operations (ConOps) to address this problem. As part of this effort, a fully functional prototype system - or "Knowledge Wall" (KW) - was created for Global 2000. Global 2000 is a War Game where potential high technology solutions for future naval needs are débuted. To determine the specific tools and features that this prototype should possess, a cognitive task analysis (CTA) was conducted to determine the specific information needs of the users of the KW prototype at Global 2000.

Previous CTAs conducted in the JOC identified the existing ConOps and revealed an important need for improved displays and information management systems (Miller & Klein, 1998; Moore & Averett, 1999). The JOC is organized with anchor desk liaison officers (LNOs) producing a variety of information products for senior staff, the Admiral and Battle Watch Captains (BWCs) and JOC staff. These information products are generated and distributed continuously, as well as forming the basis for formal briefs for the Admiral that are given at fixed intervals (typically, three times a day). Between briefs, BWCs and their assistants (ABWCs) monitor events primarily by verbally interacting with LNOs and others outside the JOC to remain constantly apprised 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?" and "what is our mission status?".

The Command 21 program envisions a new Web-centric ConOps for command centers where the punctuated briefing cycle is replaced with one where information products are published in HTML format and continuously updated to populate a Knowledge Web. Continuous mission state could then be displayed in the JOC on various display surfaces, the first of which would be the KW. In order to elicit input and recommendations from potential JOC KW users, structured interviews and CTA (Kirwan & Ainsworth, 1992) were employed with potential users of the KW.

2. Method and Approach

Data collection techniques

The data were collected using structured interviews with potential users of the KW. 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 four and 15 participants led by interviewers.

Participants

Approximately 30 individuals were interviewed in one of four separate one hour, focus groups. 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 Global 2000 and/or had played one of these roles in a previous war game. The participants included personnel from C3F and Command Carrier Groups one and three (CCG1 and CCG3).

Interview Structure

Whenever possible, the interviewer adhered to the following structure of the interview. However, due to the group nature of the interview sessions, occasional deviations from the structure were necessary.

After a general description of the purpose of the interview, participants were read and given a description of the KW 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 KW (information producers), or they would be viewing the KW to assimilate information (information consumers), or both. The participants were given a blank template of the KW layout. 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 and instructed the participants to answer questions regarding the use of the KW within the context of the scenario. Questions asked included:

- List the type of information that you would need to see on the KW.
- 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 KW?
- Are there any problems that you now face when monitoring the situation or making decisions that you think the KW might alleviate?

3. 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. Most participants possessed several years of command center experience.

User requirements and Knowledge Wall design solutions

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 requirement emerged (general, format, content, and feature). Further distillation of the requirements within each category led to the identification of 14 user requirements in total. The requirements are listed in the left column of Table 1.

Each of the 14 requirements had to be supported by the KW design. There were many different ways to meet these requirements. Given that there was only three months to build a functioning prototype for Global 2000 after the interviews, the prototype should be seen as an initial attempt to meet the requirements. Future research and development efforts will focus both on identifying further user requirements and on improvements to this initial design.

The design solutions that were chosen are listed in the right column of Table 1. Each requirement is discussed below, followed by representative paraphrased responses that indicate or support that requirement and by a discussion of the design solution. In

general, to better conceive of its design, the KW design is elaborated from the 'ground-up' from the need for a display to a fully-populated and functional KW. Further details can be found in Smallman, Oonk & Moore (2000).

User Requirement		KW design capability
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 list
	Anchor Desk Output	Summary pages with links to more information
	Connectivity/Collaboration	Collaboration tools (*InfoWorkSpace*)
	Cognitive Support	Restricted set of stand-alone tools
Feature	Flexible Configuration	Any pages viewable in any display
	Drill-Down	Multiple scalable views, links to more info
	Information Age and Reliability	Text date stamp
	Tactical Overlays	Various software for tactical graphic presentation

Table 1. The 14 JOC user requirements and the design capabilities provided to meet them with the prototype KW for Global 2000.

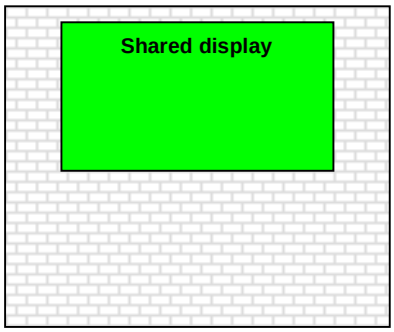
1. General Requirement: Shared SA

A consistent theme running through the discussions was a need to acquire and maintain shared SA quickly, with responses such as:

- I want to quickly bring the boss's SA up to mine.
- Everyone should see the same picture because without common SA, mistakes are made.

The problem of poor support for shared SA 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 USMC Combat Operations Center (COC) (Klein, Schmitt, McCloskey, Heaton, Klinger, & Wolf, 1996; Proctor, St. John, Callan & Holste, 1998).

Design Solution: Large shared display



The initial prototype addressed support for shared SA by bringing multiple sources of information together on a singleshared display, or KW. Because the intent is that all JOC staff should be able to see the content of the KW, the display was large (wall-sized -approximately 12' by 5' for Global 2000).

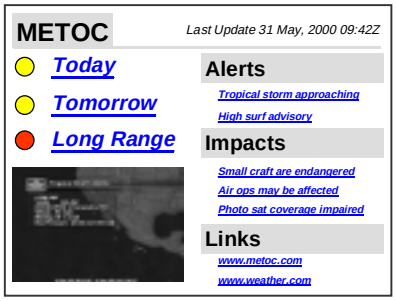
Shared SA displays are also being developed for the U.S. Marine Corps COC (Proctor et al., 1998) and for Air Force command centers (Jedrysik, Moore, Brykowytch, & Sweed, 1999). How well shared displays promote shared SA, *per se,* is an open question; there is a mixed literature on the topic (Farley et al., 1998; Bolstad & Endsley, 1999). However, given the time constraints of the prototype development effort it was decided that this was the obvious first solution to the requirement.

2. General Requirement: Integrated information

A related need to that for shared SA was to be presented integrated information instead of 'data'. Participants expressed this need with responses such as:

- It's difficult to make a decision when I can't bring all the pictures together.
- There is a need to represent the "big picture" quickly and concisely.

Design Solution: Co-located Summary Pages and other information



The Global 2000 prototype integrated information by co-locating it on the KW. Further, the KW was populated with an array of 'Summary Pages'. Summary pages are distilled representations of the state of an entire 'functional area' (a functionally-related collection of LNOs). A different Summary Page was created for each functional area. An example of a METOC Summary Page is shown below on the right. Summary Pages were created with a new authoring program, *SumMaker* (Averett & Moore, 2000) that was created for this purpose. Having all of the Summary Pages located together was intended to facilitate 'getting the big picture'. Integrating information together is known to be facilitate integrated decision-making tasks (Wickens & Carswell, 1995).

3. Format Requirement: Intuitive graphical interface

Participants consistently expressed a desire that the interface of the KW and the support applications have an intuitive graphical interface, with responses such as:

- I need a display that is graphically intuitive
- The lingo specific to particular information domains (e.g., weather, special operations, or strike planning) should be eliminated.

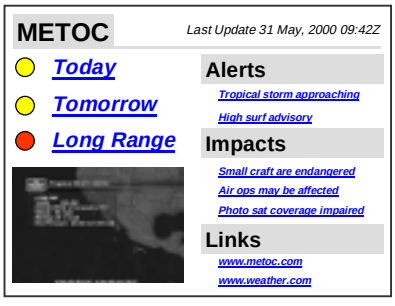
Design Solution: Graphical presentation when possible

The KW could be conceived as a multi-window Web browser. It was populated with graphical Hyperlinked Web pages, both to support the rapid production of the Knowledge Web and also to provide an intuitive familiar graphical interface to its users. The use of commercial off the shelf (COTS) software (e.g. Web browsers) and hardware (PCs) was intended to reinforce familiarity. To further enhance graphical presentation, information producers were encouraged to create at least one summary graphic on each of their Summary Pages. These summary graphics were created with another support application that was created expressly for purpose called *TacGraph* (Bank & Moore, 2000). *TacGraph* enabled tactical briefs to very quickly be put together and published on the KW in HTML format. The figure to the right above shows the tool being used to select the track category of a new MIL-STD-2525B symbol (US DoD, 1996). In this case, a new ground track is being selected with a mouse. *TacGraph* is discussed further in relation to requirement #14, below.

4. Format Requirement: Consistency

Earlier interviews with JOC personnel had revealed a need for consistency on both the information production and consumption end. On the production end, LNOs spent a great deal of their time (maybe 80%) 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. On the consumption end, BWCs expressed frustration at have to integrate information products given them in diverse formats and at different levels of detail. The current interviews found the same need for consistency.

Design Solution: Consistent format of Summary Pages



Summary Pages were designed to impose a consistency on the production of information products. All functional areas produced Pages in the same format and layout using *SumMaker*. Each Summary Page included, (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, (4) related links, and (5) a summary graphic. Also provided was an indication of

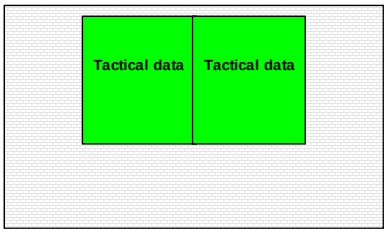
the age of the information being provided. This consistent format was intended to both facilitate the task of information producers and to improve assimilation by information consumers.

5. Content Requirement: Tactical 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 KW. 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.

Design Solution: Multiple tactical displays accessible



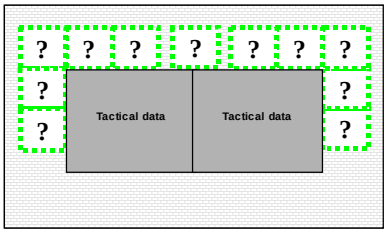
The initial KW prototype addressed this need by providing two large, side-by-side focus windows. These windows provided, by default, tactical displays as the focus of the KW, around which all other displays were positioned. Two tactical displays were used, rather than one large one, so that either, (a) the same tactical situation could be viewed concurrently at two resolutions (e.g. strategic and tactical), or (b) so that two entirely different theater operations could be simultaneously viewed. The tactical displays were generated by *C2PC* software.

6. Content Requirement: Supplemental information

The display of supplemental information, beyond the tactical picture, was indicated as a necessity. 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.

Design Solution: Show supplemental information



In order to display both tactical and supplemental information, the initial KW prototype possessed smaller, peripheral monitors surrounding the two focus windows / tactical displays. The supplemental nature of this information relative to the tactical data was reflected in its peripheral location. Further, this design provided the user an intuitive visual metaphor for the role of the supplemental data, which was to embed the tactical data in context. When turned on, the initial KW configuration showed a different Summary Page in each peripheral monitor.

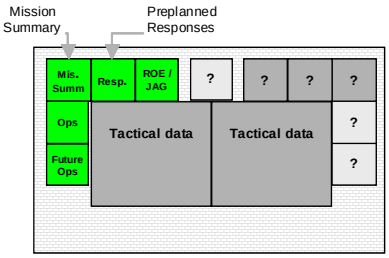
7. Content Requirement: Mission goals and objectives

Most participants expressed a desire to see, or be able to easily access information about mission goals and objectives on the KW. 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.
- Pre-planned 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).

Design Solution: Display goals, objectives and CCIRs

To meet the need to visualize mission goals, plans, and related information, the initial KW prototype made available summaries of the following:



- Mission summaries
- CCIRs
- Planned responses
- ROE
- JAG information
- Current and future operational information

These were all in text format. They could be pulled into a focus area to be read. In addition, (1) status information was shown graphically on the Summary Pages to rapidly convey whether that area was proceeding to plan, and (2) certain Summary Pages provided links to *JFLEX* (planning) and *TAPS* (effects evaluation) tools.

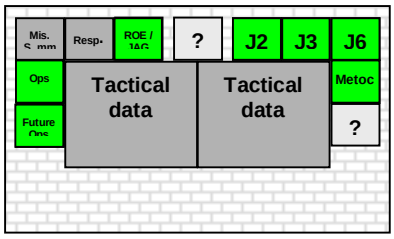
8. Content Requirement: Anchor desk outputs

Participants indicated a need to see anchor desk outputs on the peripheral displays of the KW. 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 effects other operations)
- What assets (friendly and enemy) are available
- Battle damage assessments and effects.

Design Solution: Summary Pages with links to more information

The KW was populated with Summary Pages on the supplemental displays. These both summarized the entire status of a functional area and provided Hyperlinks to other information products produced by LNOs.

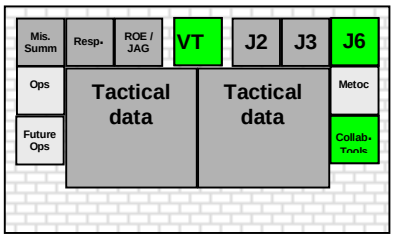


9. Content Requirement: Connectivity, collaboration, and coordination

Participants indicated the importance of sharing information collaboratively, both within the team and to 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. Video-teleconferencing (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. 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

Design Solution: Collaboration tools



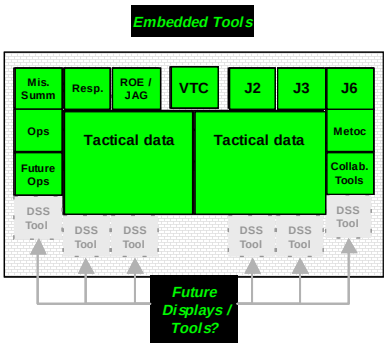
The need for support for collaboration is addressed at several levels in the design. First, Summary Pages create a compelling new coordinating representation (Alterman and Garland, 2001) to facilitate collaboration between junior and senior staff. Second, the initial KW prototype possessed a dedicated VTC window at the center top of the display. Third, supplemental displays could support *InfoWorkSpace (IWS)*, a Web-based bundle of collaborative tools for communication, data access, and Knowledge Management. Finally, a unique collaborative attribute of the KW concept arises from the ability of duplicate KWs, linked together in a wide area network (WAN), enabling long-range shared SA between decision-makers during a Joint Task Force (JTF) mission (say, between the NWC and a deployed TF).

10. Content Requirement: Cognitive Support

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 challenging cognitive processes. Example responses that suggested the need for decision support tools were:

- Help us recall what was planned so we can focus on … what wasn't planned.
- I need to know about issues that would force a change of plans

Design Solution: Stand-alone tools



The initial KW prototype included multiple design solutions intended to support tasks identified as cognitively challenging; some were more developed than others. The most difficult cognitive task – that of maintaining shared SA – was supported by the display of integrated mission-relevant information on a shared display. Rudimentary attention management was provided by the graphical color-coded status lights on the Summary Pages. Other decision aids were supported. For example, course of action analysis was supported by being able to view the output of the *CAESAR* modeling tool (Levis, 2000; Wagenhals, Shin & Levis, 1998). Currently, this is a stand-alone application. Future development of the KW will incorporate and integrate more sophisticated modeling tools as they mature.

11. Feature Requirement: Flexible configuration

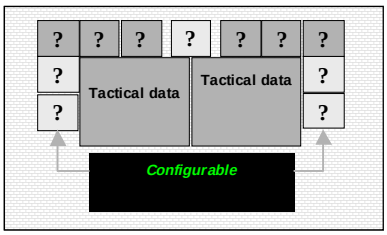
There was consensus on the need to configure the KW displays according to current information and user needs. Participants indicated a need for flexibility across watches and changing situations. However, they also agreed that some information should be dedicated / constant across situations.

- The 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.

Design Solution: Any page viewable in any display



The initial KW prototype addressed the trade-off between the desire for flexibility and the need for consistency in the following way. It enabled flexibility by allowing any Knowledge Web page to be viewed in any display. Generally, users will want to bring information from any of the peripheral displays into focus on the central tactical displays. It imposes some consistency by loading in a default configuration with the Summary Pages surrounding the tactical displays.

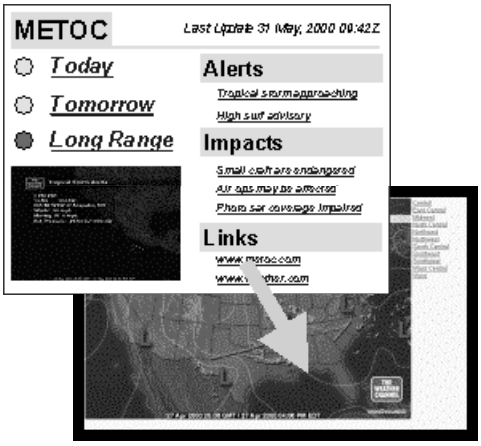
12. Feature Requirement: Drill-down

Participant responses 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.

Design Solution: Multiple-scalable views with Hyperlinks

The initial KW prototype addressed the need for access to more detailed information by being a Web-browser. It supported multiple scalable views of tactical data. Summary Pages were populated with Hyperlinks to more detailed information. Selecting a link enabled 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.



13. Feature Requirement: Information age and reliability

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). Comments included,

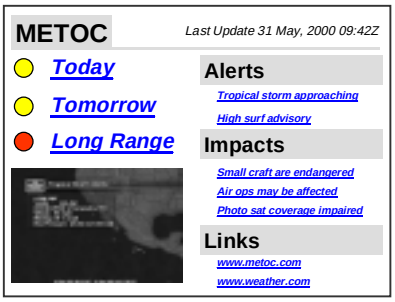
- We need an indication of the update rates and then an alert if the display will not be updated on this schedule.
- We need real-time data, updated second-to-second for Ops.
- I want the update frequency to be maximally configurable.

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 first trust the information. An important determinant of this trust is 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.
- I have to assume the data is accurate.

Design Solution: Text date stamp

Time pressure in the development and design cycle forced a simple accommodation of these needs with a simple date and time stamp prominently displayed on an anchor desk Summary Page and information products.

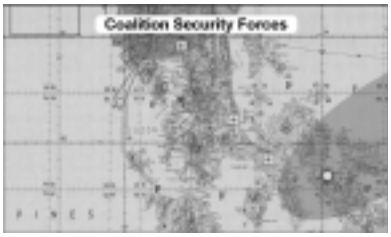


14. Feature Requirement: Tactical overlays

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 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.

Design Solution: Software for tactical graphics presentation (TacGraph)



As mentioned above, the *TacGraph* support application (Bank & Moore, 2000) was created to enable LNOs to rapidly create and edit tactical graphics. TacGraph graphics could be published in html format. This enabled them to possess embedded links to other information – a particularly powerful capability. In this way, LNOs could create sophisticated graphical presentations and link them to their other briefing products. *TacGraph* supported a wide variety of overlay features, some of which are show in the graphic on the right.

4. Discussion

A needs assessment was conducted on potential users of a new Web-centric system to support JOC decision makers. This assessment revealed 14 key requirements that the KW prototype must possess. Design solutions to meet each of these requirements were outlined for the prototype created for the Global 2000 War Game.

The resulting KW radically changed the ConOps in the JOC. It provided, on a large shared display, a continuously updated and integrated status summary for senior decision makers. A key development was the creation of the Summary Page. Although at first sight a relatively innocuous invention, the Summary Page may represent a significant advance. It fulfills many roles. It transforms LNO-assimilated data into knowledge decision makers can use. It forms the entry-point for drill-down to more detailed

information. As such, it organizes and imposes structure on the Knowledge Web for both information producers and consumers. It acts as a template for LNOs to structure their information. It imposes a consistency on diverse sources to facilitate rapid assimilation by decision makers. Perhaps most importantly, it acts as an extremely effective 'coordinating representation' (Alterman & Garland, 2001) to structure the unique discourse and asynchronous collaboration requirements of hierarchically-organized military decision makers.

The KW prototype was developed extremely rapidly – there were three months from needs assessment to implementation at Global 2000. Inevitably, some of the design solutions performed better than others. How the KW was specifically implemented for Global 2000 and what was discovered about its usage, utility and usability are discussed in the next two presentations (Moore & Averett, 2001; Oonk, Smallman & Moore, 2001).

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