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Visible Battle Rhythm

Topics: C2 Concepts and Organizations, C2 Experimentation, C2 Architecture

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Abstract

Battle rhythms are ubiquitous in military operations, but current methods for implementing them have not kept pace with the changes affecting military organizations. Visual Battle Rhythm (VBR) is a software prototype which updates the battle rhythm process with modern technology and careful information design to improve the synchronization, situational awareness and decision making ability of commanders. Key improvements over current methods include faster coordination across commands crucial for joint and coalition operations, easy distributed editing capabilities, instantaneous updates and saved time. VBR was demonstrated at Joint Warrior Interoperability Demonstration (JWID) 2004 and exercised by the Canadian Joint Operations Group (JOG). Training required less than one hour and in both cases it received excellent evaluations. This paper describes the context and use of VBR and its potential as a deployed operational system.

1. Introduction

A battle rhythm is a 'process where the commander and his staff synchronize the daily operating tempo within the planning, decision, execution and assessment (PDE&A) cycle to allow the commander to make timely decisions' [4]. Battle rhythms are ubiquitous in military operations, but current methods for implementing them have not kept pace with the changes affecting military organizations and technologies.

2. Project Background and Context

In order to improve situational awareness and coalition common operating picture (COP) the US, Canada, UK and Australia formed Coalition CINC 21 (C-CINC 21). Recognizing the importance of information design and presentation, Visualization Services is one of the six focus areas of C-CINC 21. [5]. Canada's contribution to C-CINC 21 was the Common Operational Picture 21st Century Technology Demonstration (COP 21 TD). One of the information visualization projects undertaken was the enhancement of VBR.

2.1. Need for Improved Battle Rhythm

The trend towards Network Centric Warfare (NCW) principles in order to maintain information superiority is effecting major changes in military command and control. The tempo of operations and need for rapid response is increasing, command is being dispersed across geographic locations, and decision making is being pushed down the command hierarchy. All of these changes require improved situational awareness and remote collaboration abilities throughout the military organization in order to be successful [1, 8].

Further, as joint and coalition operations become more common, the need to coordinate across commands and with allies is becoming more prominent. Combined with the movement to effects-based and stability operations, collaborations are extending beyond the military to other government agencies and civilian non-governmental organizations (NGO's). These coalitions often form rapidly as situations develop, demanding tools that can integrate heterogeneous systems on an ad-hoc basis [2]. Traditional paper-based systems, or their slightly more modern PowerPoint offspring, do not meet these challenges.

2.2. Current systems and tools

Before commencing work on VBR, structured interviews were held with commanders in order to understand their current working practices and requirements. Current systems tended to be static tables or charts, made in a software package such as PowerPoint, Word or Excel, usually depicting a single day of operations. Charts typically consisted of timelines with key daily events anchored to them in callout boxes. These documents were created and revised by a single designated document owner and then emailed, printed or presented at briefings. Depending on the complexity and rate of change of the schedule, it is not uncommon for revising the schedule graphics to be a fulltime job for a staff member.

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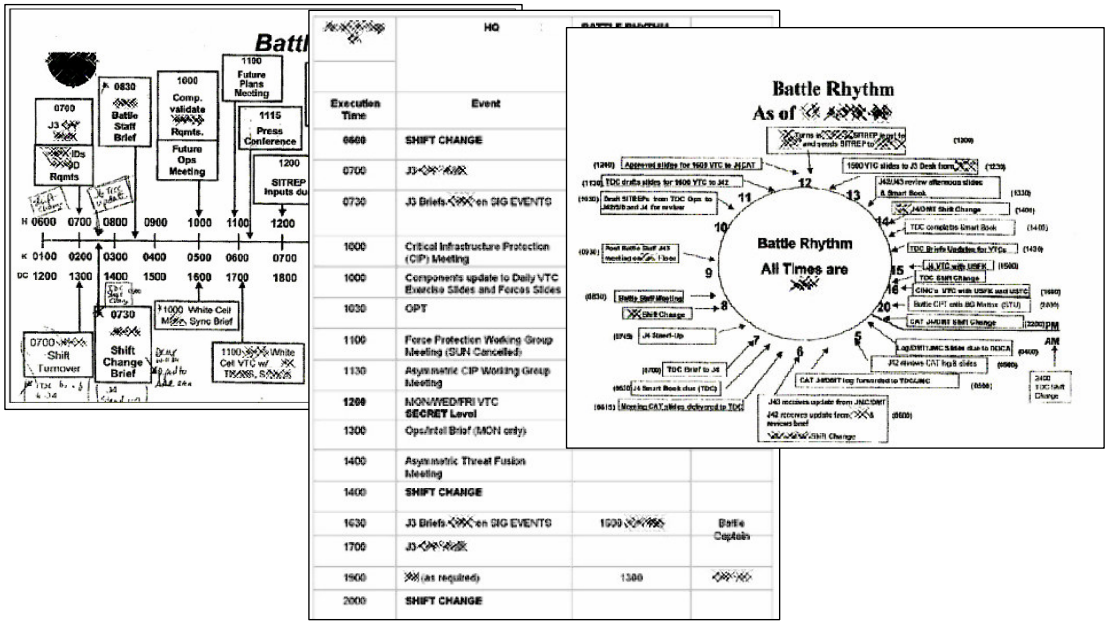

Figure 1: Existing battle rhythms tend to be difficult to read, maintain and distribute.

When discussing commanders' wishes for what a new battle rhythm tool should provide, a number of key points were raised repeatedly:

- *"Battle Rhythm is the most significant thing you do … the trick is to marry the cycles."*
- *"The ability to synchronize BR with other commands would be very helpful, particularly if collaboration is necessary."*
- *"The Commander has four or five hard points each day … and needs to see interdependencies."*
- *"Excellence in BR is marked by flexibility, adaptability of BR."*
- *"Many of the current frustrations with BR derive from its static nature. If it were more dynamic, particularly if tied to decision points and CCIRs, it would be used more often."*
- *"Allow variable display arrangements so that different users could reconfigure the BR to suit their preferences and needs."*

2.3. Design Criteria and Goals

These structured interviews formed the basis for the establishment of design criteria and issues to address:

- **Increased information availability:** improved situational awareness is dependent on users having access to more and better quality information in a useful format;
- **Improved information understanding and decision making:** careful information visualization design can greatly increase the amount of the information that users are able to assimilate and act upon, while reducing operator errors;
- **Dynamic/"live" documents:** information must be continuously editable and updatable to reflect the current situation;

- **Coordination across levels of command:** for all operations, and especially joint and coalition operations, tight synchronization among separate command and control hierarchies must be provided;
- **Multiple timeframes:** a single 24 hour timeframe is insufficient for commands distributed across multiple time zones and for operations that extend over many days. The old manual edit templates and update frequency should not limit the time horizon visibility;
- **Visible interdependencies:** constraints must be made explicit, both within and between commands;
- **Intuitive and easy to use:** many staff complained of complex systems that tried to do too much (e.g. Microsoft Project), or the difficulty of trying to create schedules in tools not designed for the job, such as PowerPoint or Excel. Acceptance of the software depends on it being fast and easy to use. Joint operations and crisis situations can involve non-routine users of VBR who must be able to pick up the tool and be productive without time for training;
- **Distributed access:** users need access to situational awareness information from wherever they are; this includes multiple fixed sites, as well as in the field;
- **Reconfigurable:** coalition and third-party information must be easily incorporated;
- **Open standards infrastructure:** the software must rely on open standards that will allow easy integration with current and future systems.

Most of these criteria are the direct result of moving the standard battle rhythm into the context of NCW. Top-down creation/distribution of single-command battle rhythms fail to provide the common operating picture necessary for operating in a networked environment or joint operations. Live documents allow all commands to see changes immediately and respond and adapt by updating their own rhythms appropriately. Modern joint and coalition operations further extend coordination requirements, creating a need to incorporate information on an ad-hoc basis and extend the system through intuitive integration points.

Animated computer graphics can be extremely expressive. With the correct approach to the visual design of the layout and the objects, large amounts of information can be quickly and easily comprehended by a human observer. Visualization is an external mental aid that enhances cognitive abilities [3]. When information is presented visually, efficient innate human capabilities can be used to perceive and process data. Orders of magnitude more information can be seen and understood in a few minutes. Information visualization techniques amplify cognition by increasing human mental resources, reducing search times, improving recognition of patterns, increasing inference making, and increasing monitoring scope [3, 10]. These benefits translate into system and task related performance factors, for individuals and groups, which affect the completion of analysis, decision-making and communication tasks. The time, effort and number of work products required to do these types of tasks are reduced [11]. An important goal for VBR was to employ the advantages of visualization to achieve an order of magnitude improvement over current Battle Rhythm tools and methods.

3. Related Work

VBR uses the basic principles of Gantt chart design to organize events along a horizontal timeline. This layout is similar to well known project management software packages such as Microsoft Project, however the differences in application domains and usage scenarios result in very different tools. Kullberg's Dynamic Timelines [6] explored using timelines in an interactive 3D space for viewing historical database information. Mackinlay et al. explored a number of time and calendar visualizations [7] which share some interactive similarities to aspects of VBR. The adaptation of their Perspective Wall visualizer provided focus plus context for viewing timelines. Their Time Lattice visualization constructed a 3D model of schedules using people, time and dates as the axes. Translucent projections through this model provide overviews of relationships along two of those axes. Similar to the Time Lattice, VBR employs translucency as a means of showing overall level of activity within a command. In relation to these designs, VBR uses a

simple 2D rather than 3D layout, and focuses on user creation and modification of the underlying data, and representation of relationships amongst events. A key differentiator between VBR and these other systems is the intended domain of use. In the same domain as VBR, Duffy et al. proposed a battle rhythm visualization consisting of a series of waveforms depicting information flow per command. This visualization provides an interesting view of the overall level of activity within and across commands over time, but does not allow drill-down into individual tasks [4].

4. VBR Concept

In response to the design criteria a prototype VBR software application has been designed, implemented and tested. The software allows users to log into the system through a web browser, choose organizational units of interest and view their current battle rhythms. Events, critical points (decision or decisive points) and dependencies between them are all represented. Multiple schedules may be opened at once and compared side by side in their respective time zones at variable time scales. If the user has sufficient privileges, they may create, delete or edit the information. All changes are published to a central server which in turn distributes them to all other users who see them immediately.

The following sections present the system architecture underlying VBR, the information design and interaction design elements employed, and feedback and results to date. Areas of possible future development and improvement are also identified.

5. System Architecture

The VBR software utilizes a three-layer client-server architecture. The client is a Java applet presented in a web browser. The backend is comprised of an SQL database and a Java servlet engine responding to client requests. All communication with the client is composed of XML messages sent over HTTP connections. The servlet engine provides session management with HTTP cookies. A separate administration console is also provided via servlets for configuring users, passwords and permission settings.

5.1. Distribution and Synchronization

The ability for multiple users to simultaneously modify shared battle rhythms necessitates synchronization of data between clients and the server. When designing the synchronization mechanisms for VBR, existing libraries such as SyncML [9], were investigated, but none were found suitable due to technical capabilities, cost, download size and licensing constraints. Instead a custom solution tailored to the specifics of VBR data was created.

Clients maintain their own data and synchronization states, and as is common with web applications, all data transfers are initiated by clients (pull model). Synchronization typically occurs on a regular basis (e.g. every 30 seconds), but this frequency can be tuned, or turned off and only run manually. The synchronization process consists of a sequence of exchanges in which the client sends all pending changes made by the local user, and requests all relevant remote changes made after the last synchronization. Individual objects typically serialize to messages of a couple hundred bytes. The size of entire message payloads thus ranges from a few bytes (no data) to tens of kilobytes depending on the number items sent. The server database maintains timestamps indicating the last modification time for every item and every response from the server includes a timestamp of the current server time. Clients use this timestamp as a way of requesting only changes since their last response from the server. In the case of simultaneous changes to an item by multiple users, only the last committed change is retained and distributed to all users.

5.2. Data Model

The VBR data model is comprised of five simple object types: organizations, events, links, users and permissions. Organizations are represented by a tree structure through parent references, and are comprised of a name, time zone and parent organization. Events are associated with a single organization and have a start time, duration (a duration of zero indicates a point in time such as a decision point), organization,

notes and status of confirmed or tentative. Links join two events and have a start event, end event and link type. Users and permissions are discussed in detail in the next section.

5.3. Users and Permissions

Users and permissions are unique amongst the data types in that they can only be created, modified or deleted from a separate administration console which requires a separate server administrator login to access. User objects are also unique in not being required on the client at all. Instead, users log in with a username and password and the server returns an HTTP cookie associating that user with that particular session.

Each user is assigned a set of permissions describing their privileges when using the client. Each permission associates a user with a privilege for a particular organization. There are three types of privileges: *read* allows the user to view the events and links for a given organization; *write* allows the user to modify these events and links; *admin* allows the user to modify the organization itself by changing the name, time zone, deleting it, or creating new child organizations. Each permission also has a flag indicating whether it applies solely to the indicated organization or also to all descendant organizations within the organizational hierarchy. This flag allows users to have a default level of privileges for entire sub-trees of the hierarchy, without requiring maintaining large sets of permission objects for each user as the hierarchy or their privileges change over time. A typical set of permissions might give a user read permission on all organizations, and read/write permission on all organizations they are a member of.

Finally, a special '*all permission*' can also be granted to an administrator giving them full read/write/admin privileges to all items.

6. Information Design & Interaction

Information visualization is the careful organization and presentation of information as an external mental aid [3]. By taking advantage of innate human perceptual abilities, it is possible to process and understand orders of magnitude more information in the same amount of time. When applied to a domain such as battle rhythm, this can result in task performance improvements through improved analysis, decision making and reduced time requirements. Two key design criteria for VBR were to improve situational awareness and make the software intuitive and easy to use. To achieve these goals careful attention was paid to information visualization and human information interaction (HII) within the application.

After logging in, users are presented with the main VBR interface. The basic layout presents the organization hierarchy in a tree on the left, timelines in the centre, and a toolbar along the top edge. The following sections explore the information design and interaction aspects of the application.

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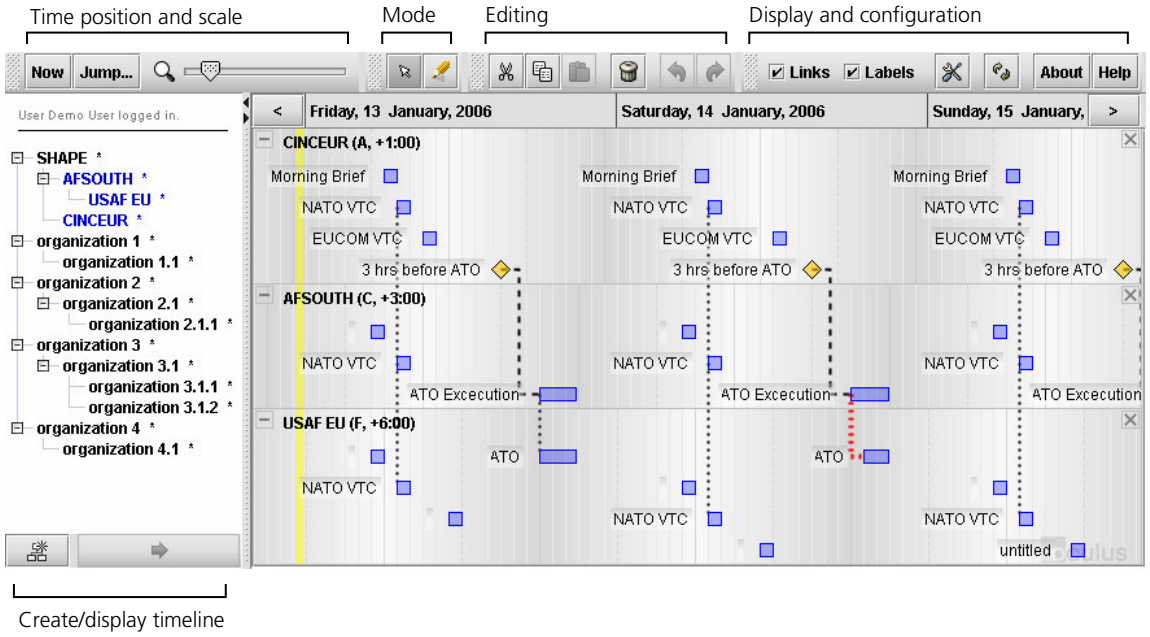


Figure 2: Overview. Screenshot of VBR with labeled control groups.

6.1. Timelines & Temporal Navigation

The organizational hierarchy is shown on the left in a standard tree control. To show an organization's timeline, users select the organization in the tree view on the left and click the 'show timeline' button. If the user lacks sufficient permissions, the entry in the tree will be grayed out and the button disabled. Assuming sufficient permissions, the timeline then appears to the right below any already open timelines.

Above the timelines is a header bar indicating the time range being viewed. The scale of displayed time is altered through a slider in the toolbar, allowing time scales ranging from portions of a day to approximately 4 months (depending on the size of the screen and thus the pixels available for the timelines). As the scale is changed, the divisions and labels in the header bar adapt by abbreviating the labels to fit within the available space and switching the label frequency from daily to weekly. The labels always indicate time in UTC regardless of the local time zones of the open timelines allowing easy comparison to a known default time offset.

Each timeline indicates the organization name and local military time zone in its top row. Hours are drawn as subtle vertical lines indicating the time scale. The local time of day is indicated by a subtle grey (nighttime) to white (daytime) gradient and inverted hour lines for midnight and noon. The current time is drawn as a yellow vertical line extending through all open timelines. The 6am and 6pm divisions are dashed, leaving only six hours between markers and making it easy to eyeball times on the display. All division markers are subtle so as not to interfere with perception of the events. When greater precision is required, hovering the mouse over a timeline produces a tooltip displaying the local time at the position of the mouse cursor.

Navigation through time is accomplished in a number of ways. A 'jump' dialog accessed via a toolbar button allows moving to an arbitrary past or future date. Relative temporal motion is accomplished by either dragging the timelines with the middle mouse button, or clicking the left and right arrows in the corners of the timeline header bar. The amount of time moved by clicking the arrow buttons depends on the scale of time shown in the timelines, moving in increments of hours when only a portion of a single day is

displayed, to weeks when months are displayed. Continuous animation of the relative time movement and time scale changes provides a smooth transition between views and prevents disorientation.

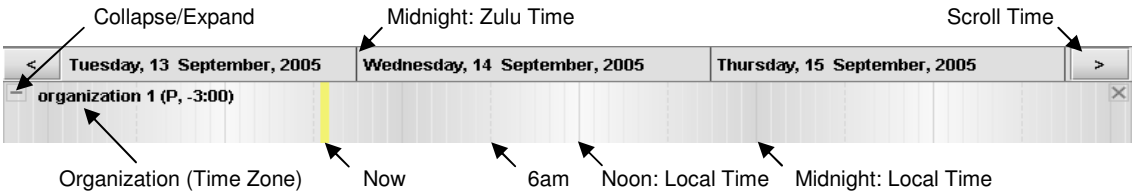


Figure 3: Local time zone timeline and Zulu time zone header bar design.

6.2. Create/edit mode

When interacting with information in the timelines with the mouse, the software can be in either edit mode or create mode. In both cases the design aims to allow direct interaction with the depicted information and thus minimize and simplify the interface controls. In edit mode the mouse is used to alter existing schedule items. In create mode the mouse is used to 'draw' new events and dependencies into the timelines. To avoid confusion, the mouse cursor, the focus of attention when interacting with events, changes depending on the current mode. In edit mode the cursor is a standard arrow cursor, while in create mode a pencil (implying the draw operation) is shown. If, in create mode, the mouse is moved over a timeline the user does not have write permission for, the pencil cursor is grayed out, providing intuitive feedback that the operation is not available.

Select/Edit cursor	Create cursor	Create cursor when placed over an organization which the user is not allowed to edit

Table 1: Cursors indicate the possible operations a user may perform depending on their permissions.

6.3. Events

Events fall into two categories depending on their duration. An event with zero-duration denotes a point in time (e.g. a decision point) and is displayed as a diamond. An event with non-zero duration is displayed as a translucent bar. The name of an event is displayed in an editable text field to the left of the icon allowing direct modification of the event name without need for cumbersome dialog boxes. An option to flag events as tentative is available through a context menu and results in the icons being drawn with de-saturated colors.

Moving the mouse over an event displays a popup window containing the event information (name, start time, duration, and notes). Selecting an event by clicking it highlights it and displays an arrow to its right. Dragging the arrow stretches the end time of the event. Dragging the event itself moves the start time. In both cases the user operates directly on the displayed information, and receives immediate and intuitive feedback on the results of their actions. A configuration option will snap the start time and duration times to round numbers depending on the current viewing time scale, ranging from increments of five minutes to whole days. When greater precision is required, double-clicking an event opens a dialog with options for specifying the exact start and end times, as well as adding textual notes to the event.

Figure 4: Event depiction. Events are shown as bars or diamonds depending on their duration. Both may be in a tentative state in which case they are drawn with de-saturated colors (shown only for a bar). Moving the mouse over an event displays a pop-up window with detailed information.

The current method of placing events is in horizontal rows starting at the top of the timeline at the start of each day in local time. This layout was found effective for the original time scales of hours to a few days. However, after the ability to scale time to view months was added it was discovered that the labels overlap preceding events making the interface difficult to interpret. An option to hide all labels is available in the toolbar, but improved layout algorithms will be considered for future versions.

A collapse button on each timeline overrides the normal layout by overlapping all events on a single row. This view provides an overview of the organization's schedule, clearly showing busy and free times at a glance. By taking advantage of the translucency of the events, times when multiple events are occurring simultaneously appear as darker shades of blue, indicating the level of activity of the team.

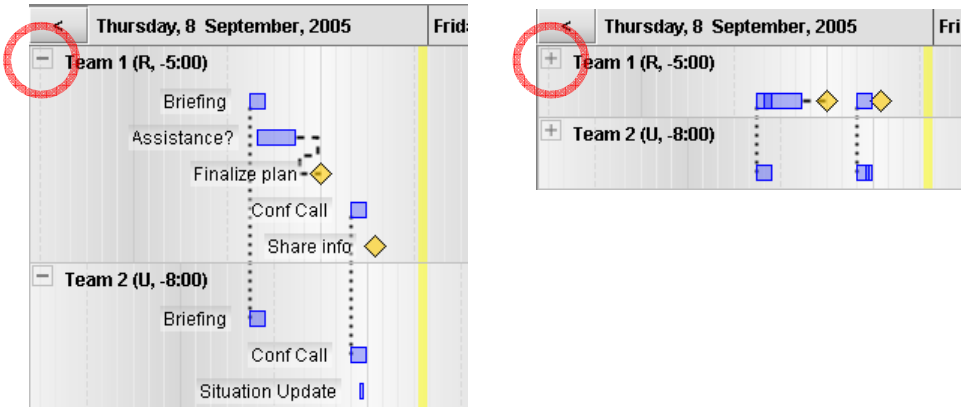


Figure 5: Summary View. Collapsing a timeline by clicking the +/- buttons (circled) provides a summary of the level of activity within a command. Translucent bars produce darker overlays when more activities occur simultaneously.

6.4. Links

Links indicate constrained relationships between two events. There are currently two types of link constraints, sequential and synchronized. Sequential links require the second event to start after the first has finished and connects the right edge of the first event to the left edge of the second. Synchronized links require both events to start simultaneously and connect the left edges of the events. Different dashed line styles help to visually differentiate the two types. If the constraint on a link is violated, the link is drawn bold and red, attracting the user's attention to the problem.

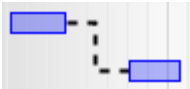
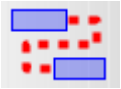
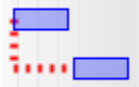
	Constraints satisfied	Constraints violated
Sequential Links:		
Synchronized Links:		

Table 2: Types of links and their constraints.

Similarly to how users interact with events, interaction with links is performed directly on their visual representations. In create mode, links are drawn by dragging from one event to another. Right clicking on a link displays a popup menu allowing the link type to be selected.

7. Evaluation

The VBR prototype was demonstrated at the Joint Warrior Interoperability Demonstration 2004 (JWID'04) and at the Canadian Joint Operations Group (JOG) headquarters in 2005. In both cases, users were introduced to the software with a brief overview and hands-on training session lasting less than hour. The JWID exercise was carefully scripted such that users were required to complete specific tasks with VBR. These tasks had been selected to utilize as many features and use cases as possible. The JOG session, by contrast, was much more spontaneous, allowing many people with widely varying positions to be introduced to the software and provide their opinions on how it would suit their roles.

Both exercises of VBR received excellent feedback. People found the software to be very easy to use and were comfortable with it after only 15 minutes of training, and had become experts after an hour. Staff expressed strong approval of the software, with comments such as "I would use it right now if I had it at my desk." At the conclusion of their exercise, the JOG issued a statement of unanimous support for continued development of the software leading to deployment.

Through discussions with exercise participants a number of interesting observations regarding the role and use of VBR were made. Many of these relate to the second order effects of how a tool such as VBR will influence users' workflow in daily operations. Traditional battle rhythms are very mission-oriented, however staff also spend time between operations and desire a single set of tools that will transition seamlessly as they move between roles. Much of this demand is currently met by Calendaring tools such as Outlook, so attention to how these tools interact and integrate will be necessary. Another interesting observation was the interest in VBR from non-traditional battle rhythm users. For example, planning staff complained of the time spent re-jigging timelines made by coloring spreadsheet cells. They realized the potential of being able to create plans, potentially with all events marked tentative, and then hand them off to operational staff through a simple cut and paste operation, thus retaining links to the reasoning and rationale behind the plan. That these people would feel comfortable with VBR after only a very brief introduction to it and see it as a positive addition to or replacement of other tools in their workflow is, we feel, a testament to its overall appropriateness for military use.

8. Future Work

The next stage in the development of VBR is to transition it from being an advanced prototype into a deployable application. This work involves increasing its robustness and scalability while adding new functionality. The robustness work will entail re-implementing the server portion of VBR on more advanced database software and ensuring all data backup and administration needs are met. Although the current level of functionality is sufficient for most operational requirements a number of potential new features have been identified and need to be prioritized.

Interest in using VBR in non-traditional battle rhythm roles creates a demand for new functionality specific to those roles. Every new feature adds complexity and size to the software, which must be balanced against the new functionality provided. To maintain ease of use, general-purpose features with wide applicability are generally favored over those specific to individual tasks or roles.

Potential new functionality can be divided into a few broad categories. A number of improvements to the semantics of events and links have been discussed. Specific event features include being able to categorize them, group them, add hyperlinks to external content, and specify recurrences. Links could be elaborated with new types of constraints (e.g. at least four hours later), and descriptions.

A number of workflow features have been discussed, some of general use and some specific to military operations. User settings can be stored on the server, allowing users to open VBR and immediately be presented with a familiar layout and the information they are interested in. Change awareness, the ability to tell what has changed since a prior time, could be improved by providing visual markers around modified items. Tied in with stored user settings, this will provide shift workers an intuitive update since their last shift. Other workflow features such as transferring command control by changing the organizational hierarchy can be added to integrate with military procedure.

Additional deployment scenarios have been considered including very low bandwidth or intermittent server communication as might occur with units in the field. One possible design involves remotely deployed servers to provide local support and occasionally synchronize with the main server are a possibility. Schemes to reduce client-server bandwidth requirements have also been discussed.

Finally, functionality to integrate VBR with existing systems can be created. A good candidate for such integration is existing Microsoft Outlook/Exchange installations. Such integrations can be done as needed depending on an organization's software environment.

9. Conclusions

The VBR prototype has demonstrated significant improvements to current operating procedure by providing continuous, distributed control of temporal events throughout the organizational hierarchy. Careful attention to information design principles has resulted in a system that is powerful, quick and easy to use. Feedback from evaluations of the software with potential users has been very positive, with a strong desire for implementation of the software within their units.

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