Title: Creation and Use of a Command and Control Collaboration Testbed

Topics: C2 Architecture, Social Domain Issues, C2 Experimentation

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Abstract

Transformational network-centric warfare concepts rely on providing real-time collaboration among command and control (C2) entities operating in a geographically dispersed and temporally and functionally distributed environment. Collaboration tools help compress the kill chain by improving the shared understanding of potential courses of action. Consequently, understanding underlying collaboration elements is important to improve current capabilities and meet future needs.

Three key elements have been identified within the C2 collaboration domain for study: geospatial, temporal, and process. For example, common collaboration interactions include where things are, when they will arrive/depart, and how close a task is to completion.

An instrumented collaboration testbed was developed that provides three-dimensional (3-D) geographic displays, a geo-referenced whiteboard, and context aware text-chat. The testbed can be deployed on a variety of platforms, including wireless tablets and eventually on Personal Data Assistants (PDAs), allowing one to study the impact of form factor on collaboration.

The testbed will be used in a series of investigations on collaboration within a C2 environment. The first investigation explores the performance ramifications of different chat display configurations and capabilities. The metrics gathered will provide the baseline against which other collaboration mechanisms (such as voice and video) can be compared. The results of this first investigation will be included in the presentation.
1 Introduction

Collaboration is an essential and important part of command and control (C2). Improvement of real-time collaboration is an identified need in the military domain. For example, the Air Force Capability-Based Planning FY08 Command and Control Functional Needs Analysis Report includes the following recommendation: “C2-E-N-08-01 - Improve the capability for real-time collaboration among C2 entities supporting mission execution.” (pg C-42). Real-time collaboration is especially needed for geographically, and possibly temporally, dispersed C2 operations, particularly across echelons and within coalitions.

As the military moves to a net-centric environment, dispersed C2 collaboration will increase and include enhanced capabilities. Such collaboration will involve discussions on where things (e.g., assets, targets, friendly forces, and enemy forces) are, when these things arrived/departed or will arrive/depart, and the state of a current process (e.g., prosecution of a time sensitive target).

In order to meet these collaboration requirements, new collaboration tools are needed. To this end, Johns Hopkins University Applied Physics Laboratory (JHU/APL) is developing a collaboration testbed, CollabSpace, in order to explore advanced collaboration techniques with application to dispersed C2. Three areas of C2 collaboration are being targeted for investigation using this testbed: geographic, temporal, and process monitoring.

The testbed is designed to accommodate these three areas of collaboration and allow for collection of performance data during investigations and experiments. The first section of this paper describes the design of the testbed and provides a description of the current testbed capabilities. The second section of the paper describes the design of the first experiment that will use the testbed. The third and final section provides some final thoughts on the testbed and planned experiment.

2 Description of Collaboration Testbed

The design of CollabSpace is focused on eight requirements. These requirements are listed below:

R1: The testbed must instrument each collaboration feature so that metrics can be collected and post experiment reconstruction can occur.
R2: The testbed must provide a basic geospatial situational awareness display.
R3: The testbed must provide basic presence reporting capability. This is an indicator if collaboration partners are online (e.g., friends list).
R4: The testbed must provide basic single and multi-user chat capability.
R5: The testbed must provide basic “whiteboarding” capability on the geospatial display.
R6: The testbed must provide data import and export capability from other C2 systems through web services as well as traditional methods.
R7: The testbed must be extensible so that new collaboration mechanisms can be added for study.
R8: The testbed must allow for investigation of secure wireless technology and alternative form factors.

These requirements drove the initial technology exploration to find a suitable starting point for development. A decision was made early on that the testbed be based on existing standards. The preference was for platform neutral solutions but an existing geospatial library based on Visual C++ and OpenGL was available. In the hope of reducing development time, work was started with that library to create a geospatial situational awareness display, and Microsoft’s Real-Time Communications API was used for presence awareness and text chat capabilities in the initial technology prototype (see Figure 1).

![Figure 1: Technology Exploration Prototype](image)

This early prototype demonstrated that building the desired components from scratch, while feasible, was cost prohibitive and too time consuming. Therefore, Google Earth (known then as Keyhole) and Environmental Systems Research Institute’s (ESRI) products were evaluated. Both, however, were outside the budget constraints. An open source alternative to Google Earth developed by NASA called NASA World Wind was ultimately selected as the basis of the collaboration testbed. The testbed has been named CollabSpace.
2.1 Geographic Display

NASA World Wind is the basis of CollabSpace’s geospatial situational awareness display (see Figure 2). NASA World Wind contains a rich set of features that could immediately be leveraged and allows for extensions using “Plug-Ins” written in C#, Visual Basic, or Visual C++.

NASA World Wind provided the following important features of the CollabSpace geospatial display:

- 3-D display of imagery and maps
- High resolution Landsat 7, Blue Marble, USGS 1m and .25m imagery
- USGS Topographical Maps
- Digital elevation model based on 30m and 90m Shuttle Radar Topography Mission (SRTM) data
- Streamed imagery and maps
- Icons, Hotspots and other visualization components
- Support for multiple layers of imagery. For example a map layer can be superimposed on top or below satellite imagery.
- Geo-referenced image draping over base imagery. This allows user images to be superimposed above the World Wind base imagery if the geospatial coordinates of the image is known.

In addition to these basic features, the following capabilities were added to meet the geographical situational awareness visualization requirements:

- Retrieval of track data from web service-based data providers and display as MIL-STD 2525B, DHS Emergency Response and other symbololgy in World Wind layers. Limited 3-D icon support is also provided.
- Retrieval of geo-referenced overlay data from web service based data providers and display in World Wind layers.
- Linkage of the MIL-STD 2525B symbols (World Wind icons) to a persistent collaboration environment. The persistent environment is currently implemented as a Wiki page for each object that contains notes, known information from RSS (Really Simple Syndication) feeds and links to additional information.
2.2 Chat and Enhanced Chat

Lessons learned from the initial technology exploration revealed that the Microsoft Real Time Communication Application Program Interface (MS RTC API) would not meet testbed requirements. While the MS tool suite supported single and multi-user chat, it did not provide persistent chat rooms (i.e., chat rooms that exist with or without users), a feature commonly used within the C2 environment. Furthermore, the MS RTC API lacked the data passing mechanisms desired, requiring the implementation of a separate data passing protocol.

The eXtensible Messaging and Presence Protocol (XMPP) chat protocol, also known as Jabber, was selected for the chat client. This protocol interoperates with the MS presence and chat environment as well as other proprietary chat systems used within the C2 community (e.g., Information Work Space (IWS), WebEx, etc). The XMPP standard also contains a publish-subscribe protocol, which may be leveraged to exchange more complex information in future versions of the CollabSpace testbed.

The CollabSpace chat client was built from a purchased C# implementation of the XMPP protocol. The purchased implementation included several libraries, which were used to extend the basic XMPP chat messages for data passing between CollabSpace clients. These enhanced messages allow the exchange of whiteboarding and camera information between chat clients and are automatically time-stamped and logged within the chat server.
After the initial chat client was developed, an enhanced chat client was created to support FY 06 experiments. The enhanced chat client will include the following features:

- **Multi-Channel support:** It was observed that war fighters often monitored multiple channels (also referred to as rooms) in separate chat windows. One planned investigation is to determine if combining these chat windows into a single window has a positive or negative effect on productivity. In a multi-channel window the individual channels are labeled and color-coded for identification.

- **Automatic Ask/Response Support:** Quick exchanges of information where one user would directly ask another user a question within chat were observed in the C2 domain. By holding this dialogue in a chat room, all other chat users could see the answer. The chat convention was to type the name of the user as the first word to indicate a directed question or request.

  When designing the multi-channel support in CollabSpace, a concern was raised that increased scrolling would occur due to the higher combined volume of messages and that these ask/response exchanges might be lost. Consequently, an automatic ask/response feature was created; if the name of a user is the first word in a chat message then the client for that user bolds the message in the window to make it more visible as well as adds it to a list in the chat client (see Figure 3) of both the requestor and respondent. Users asking questions or making the requests would see the message in their Ask List. Users responding would see the message in their Request List. Even if the original request scrolled off the screen while the responding users were busy, they could easily see any queries directed towards them and answer. Their responses would be sent to the entire channel but also be tagged in the asking client’s Ask List so the requestor could see that the request had been answered and retrieve the response.

  There are several potential limits of this feature that need investigation. These limits include the possibility of orphaned Ask requests existing when the respondent answers the question outside the Ask/Response interface, missing Ask requests because the user mistyped the name of the responder, and the possibility that ask/answer pairings are mismatched by the responder clicking (or manually entering the ID for) the wrong Ask list item.

- **Automatic hyperlinking of known objects:** When the unique name or identifier of an object from the geographical display is identified in a chat message, it is automatically hyperlinked to the geographical object. Clicking on the link takes the user to that object on the geographical display.

- **Keyword Highlighting:** This feature will allow the user to define words or short phrases to be highlighted in some manner within the chat dialog. This feature has not yet been implemented.

- **Threaded Chat support:** It was observed that there are threads of conversations within a single channel. In the C2 domain the topics of these threads were targets, objectives, or units. In the particular domains observed, it was noticed that users would often preface a chat message with the topic of the thread. These became
the basis of threaded chat support. When a topic is selected to be the “default” the client would automatically append the topic to the chat message. Messages could be filtered by thread topic so that a user could quickly see all messages pertaining to a particular thread topic. This feature has not yet been implemented.

**Figure 3: Enhanced Text Chat Description**

### 2.3 Geographical Whiteboard

The geographical whiteboard in CollabSpace allows users to exchange user-defined graphical information in addition to chat (see Figure 4). Users can circle areas of interest, draw polygons to indicate airspace control measures, or draw lines to show a desired route directly on the geographical display.

Since each graphical object (e.g., polygon) is geo-referenced and contains the latitude and longitude coordinates for each vertex, these objects may be exported to other C2 systems as overlays or as sets of coordinates.
2.4 Planning and Monitoring Tool

The planning and monitoring tool provides two support capabilities. One capability is a visual timeline of the process being undertaken and the other is the ability to monitor progress through that process by the involved parties.

These features are still in preliminary design in support of FY07 experiments and may change significantly. The visual timeline is envisioned as a GANTT chart. A slider allows the user to see the historical positions of objects (tracks) in the geospatial display as well as projected positions of objects as the plan progresses. Storage of historical positions and computation of future positions are not handled by the CollabSpace environment but by a separate planning service.

The process monitoring visualization tool will provide collaboration members a “dashboard” that indicates the status of the steps within a process. The “dashboard” indicators are colored lights that collaboration members alter throughout the process to show their individual status and the state of a step and will provide more information when clicked on by a user.

2.5 Other Aspects

2.5.1 Data Import from Legacy Systems

One aspect of shared collaboration workspaces that needs exploration is how cross-functional teams collaborate. Each team member has skills, a tool set, and
information that he or she brings to the collaboration environment. In order to study this area, the testbed must support importing information from legacy systems.

One such example is a plug-in developed to import Laurence Livermore National Laboratory HOTSPOT plume data into World Wind (see Figure 5). This data is saved as a CollabSpace whiteboard layer and can be shared with all users within the chat channel. In addition to display, the plume data can also be exported in a web service overlay format for other web-enabled C2 systems to consume. This export capability allows collaboration members with access to particular toolsets to publish their results from that tool to other collaboration partners and the net-centric community.

![Figure 5: HOTSPOT Plume Close-up](image)

3 Enhanced Chat Experiment

JHU/APL will use the CollabSpace testbed to investigate the performance impact of several of the enhanced chat features. Although chat is a popular medium in the military for command and control communications, collaboration, and situation awareness, little significant research on the design of chat user interfaces exists.

This first experiment will focus on investigating the performance impact of a single chat window with color coding to denote separate “rooms”, an ask/request list, and object links. These characteristics will be used at both low and high chat volumes. Activity within the geographical display will be moderate and kept constant across all
experimental sessions. The following sections describe the experimental design, participants and set-up, procedure, measurements, and expected results. (Note: Actual results will be presented at the symposium.)

3.1 Design

The experiment utilizes a $2^4$ factorial experimental design, which is blocked on participants such that one first-order interaction (task list-object links), and two second-order interactions (volume-task list-windows and volume-object links-windows) are confounded with the blocks. This design was considered reasonable since these interactions were not expected to exist or be of interest. The experiment was blocked to keep the requirements of each participant at a reasonable level. The four variables are: volume of chat messages, which can be low (0.1 messages/second) or high (10 messages/second); the presence or absence of a task list; the presence or absence of object links; and the number of windows, which is either single (1) or many (4). The order of the trials will be randomly selected for each participant. The design is shown in Figure 6.

![Figure 6: Experimental design in 4 blocks]

3.2 Participants and Set-up

The 32 participants are Johns Hopkins University students. They will be paid $20 for their participation with an additional $20 going to the participant with the best performance.

The experimental set-up for each participant consists of a desktop computer with a 1280x1024 resolution monitor, keyboard, and mouse. Two participants, in separate experiment rooms will be run simultaneously. There will be no interaction between the participants during the sessions.

3.3 Procedure and Method

Each participant will attend a single two-hour session. During a session, participants will complete training on the experimental set-up, four 15-minute task sessions, and both demographic and opinion surveys. Participants will be separated into four groups: A, B, C, and D. Each group will participate in its own set of task sessions, as depicted in Figure 6.
The task sessions consist of monitoring both the chat and geographical display for tasks that they need to complete. The tasks will be randomly selected from a set of potential tasks using a distribution kept constant across all trials. The tasks to be completed by the participants during the task sessions include: locating and clicking on an icon on the geographical display as instructed from the chat stream, clicking on an icon that has changed state or recently appeared on the geographical display, drawing a polygon on the display as indicated within the chat stream, and providing simple responses (or questions) in chat. The geospatial display will have approximately 100 objects on it at all times and update every second.

### 3.4 Measurements

Measurements will be both subjective and objective. The subjective measures will consist of the participants’ responses on the opinion surveys. The objective measures will consist of task completions, response times, and accuracy. The completions will count the number of times a particular task is completed as directed. The response times will be measured from the time that a chat message arrives or an icon changes state or appears, until the participant appropriately responds. The accuracy will measure the ratio of a participants’ correctly to incorrectly completed tasks.

### 3.5 Expected Results

Several results, which are directly related to the hypotheses, are expected. The hypotheses and results concerning the main effects are explained below:

- **Performance will be negatively impacted by a higher volume of chat messages** – The larger number of chat messages to monitor will raise the participants’ workload. It is expected that all performance measures will be worse; fewer completions, longer response times, and poorer accuracy.

- **Performance will be positively impacted by the presence of the ask/request list** – The ask/request list will help the participants focus on the information that is important to them. At least for the tasks that are requested through chat and placed on the ask/request list, it is anticipated that all performance measures will improve. It is also expected that the ask/request task list will reduce overall workload and, therefore, improve all performance measures for all tasks to some degree.

- **Performance will be positively impacted by the presence of the object links** – The object links will help the participants quickly match chat message content with related icons on the geographical display. For the tasks that are impacted by object links, it is anticipated that all performance measures will improve. It is also expected that the object links will reduce workload over all and, therefore, improve all performance measures for all tasks to some degree.

- **Performance will be negatively impacted by multiple windows** – Multiple windows will split the participants’ attention and cause a higher workload,
making all performance measures worse; fewer completions, longer response times, and poorer accuracy.

Some statistically significant first-order interactions, especially between the volume level and the other main effects, are also expected. Specifically, the impact of the ask/request list, object links and multiple windows will be greatest at higher chat volume levels, whereas at the lower volume level, the impact of the other variables will be less noticeable and potentially not statistically significant. In addition, the presence of an ask/request list and object links may mitigate some of the negative impact of having multiple chat windows open simultaneously. Finally, as mentioned earlier, the first-order interaction of the ask/request list and object links will be confounded with the participant blocks so cannot be examined. However, a significant interaction between these two main effects seems unlikely.

4 Conclusion

CollabSpace is developing into a versatile testbed that will allow for investigations into many advanced command and control collaboration concepts. For example, CollabSpace, with its integration of several collaboration tools, will aid in the exploration of impact of integrated tools on collaboration and mission success. Not only is CollabSpace flexible and amenable to external connections, but it also can record all of the activities that occur within CollabSpace. This feature makes CollabSpace invaluable for evaluating and assessing different collaboration issues and techniques.

The first investigation using CollabSpace will explore how the chat user interface configuration impacts user performance in noticing events that occur in the accompanying geographical display while monitoring four chat rooms. Despite the increasing use of chat in the military, not to mention the civilian uses, surprisingly little research into how the chat user interface impacts performance exists. CollabSpace and the described experiment is a first step in expanding this field of research.

5 References