A Virtual Collaboration Testbed for C2

Sheldon Gardner
Code 8110
Naval Research Laboratory
4555 Overlook Ave., S.W.
Washington, DC 20375-5326
(202) 767-5652 Voice
(202) 404-7234 Fax
gardner2@ccsalpha2.nrl.navy.mil

Lawrence Filippelli
Ball Aerospace & Technologies Corporation
8381 Old Courthouse Road, Suite 340
Vienna, Virginia 22182
(703) 917-9125 Voice
(724) 917-9129 Fax
lfilippe@ball.com

Abstract

Next generation information warfare will require seamless architecture and systems integration to effectively integrate and improve interoperability with allied and coalition mission planning partners. Collaboration of experts from different domains has always posed logistical and knowledge management challenges to managers and members of the collaboration. Responsive information collection, processing and dissemination require a common operational picture, precise battlespace knowledge, and enhanced command and control (C2) systems. To be effective in future Network Centric Warfare (NCW), mission planners will need to operate in a virtual environment with seamless sharing and collaboration among participants and the resources they use to do work. Advances in information technology have made it easier to communicate to solve, or at least mitigate, some of these problems using e-mail, audio conferencing, and database management software, but a great deal of human intervention is still required to make these collaborations operate smoothly. Over the past ten years enterprises have come to require more than just total asset visibility and human communication capabilities. To plan more effectively and for less cost more human creativity and energy must be focused on the planning products and less on the operation of the planning collaboration. The collaborative environment solutions of the future must not only provide the communication and knowledge management that exists today, but also provide seamless access to resources and information, product and process modeling and the advanced decision support that results from the availability of necessary resources and information. In this paper we discuss a collaboration framework, called Collaborative Enterprise Environment (CEE) which is being implemented in several facilities including the Air Force Research Lab (AFRL) and the Naval Research Laboratory (NRL). At NRL, CEE will be used to study and develop tools and techniques for effective mission planning.

1 Overview of Collaborative Environment Technology

Over the past several years, multiple definitions of collaboration and collaborative environments have emerged. The following definitions are representative of the community's perception of what collaboration is:

> *People using computer-based tools to share information, communicate, and collaborate across geographic and temporal boundaries.* [Mitre Corp. Feb 00]

> *The right tools, the right institutionalized processes and the right environment to enable people to rapidly and freely exchange ideas, move information and manage knowledge.* [International Institute for Collaborative Enterprises, Feb 00]

> *The application of advanced distributed simulation, information technology, and engineering tools, including virtual testbeds, in an integrated environment to support cross domain technology development and sharing; system design; performance, cost and producibility trade-off analyses; test and evaluation; and distributed mission training.* [Air Force Research Laboratory, Nov 99]

Clearly, these are three very different definitions of Collaborative Environments. Each is valid in its own right. This variance in definition has led to the realization that there are different categories or levels of collaboration. For example, based on the first definition, collaborative environments are focused solely on providing human-to-human information sharing and interaction using some computer-based tools. The second definition is similar to the first but introduces the ideas of *process* and *knowledge management*. The third definition is significantly more involved than the first two and introduces the ideas of *resource integration (simulation, engineering tools, virtual testbeds, etc.), integrated environments*, and *cross-domain collaboration*.

These different definitions, coupled with the evolution of the *Collaboration Marketplace* over the past 8 – 10 years and the maturation of collaboration technologies have resulted in the emergence of three different types or levels of collaboration. While varying terminology is used to describe the three different types of collaboration much of the literature has converged on two similar ways to describe them: Asynchronous and/or Standalone, Synchronous & Federated, and Integrated & Framework. Regardless of the naming convention one chooses, it is important to recognize there is a continuum of collaborative environment capabilities as shown in Figure 1.

1.1 Asynchronous/Standalone Solutions

Developed over the past 8 – 10 years, Asynchronous/Standalone collaboration solutions focus primarily on human-to-human collaboration and interaction. These *state of the practice* solutions allow humans to communicate and interact across distributed operations. Typical collaboration solutions include email, bulletin boards, shared calendars, web-based document sharing and management, news groups, chat rooms and web "transactions".

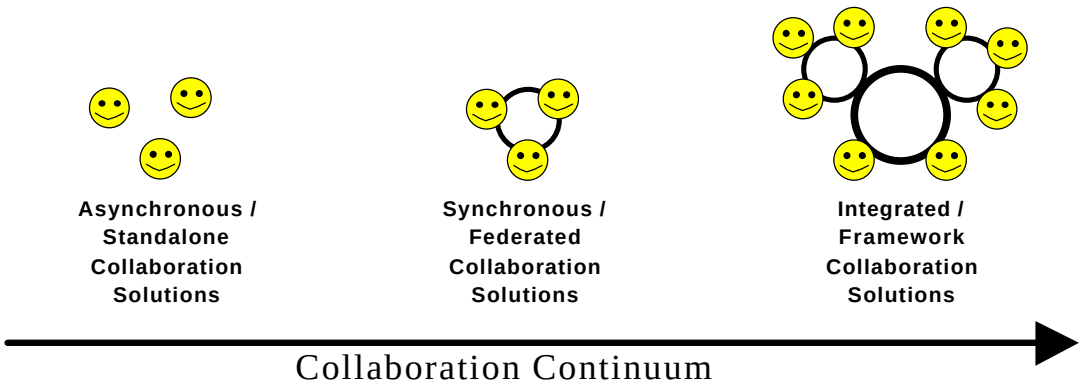

Figure 1 - Collaborative Solutions Continuum

Because there are .no temporal relationships between the collaborants' interactions this class of collaboration solutions is labeled asynchronous. A sender provides information to a receiver (or set of receivers) using one of these collaboration solutions and gets a response back *sometime*, if and when the receiver gets the information and decides to respond.

Because each solution is an independently executing application that is not integrated into or interfaced with other collaboration solutions, this class of collaboration solutions is labeled standalone. An email solution allows users to send and receive email messages but there is no way to automatically feed email information into a shared calendar or shared document management system.

Asynchronous/Standalone systems offer point solutions consisting of individual tools with different user interfaces. The tools are not usually intended to be integrated with other tools and the lifecycle of these tools is very short (12-18 months).

1.2 Synchronous/Federated Solutions

Synchronous/Federated collaboration solutions are *state-of-the-art* in today's collaboration marketplace. Like Asynchronous/Standalone solutions, these solutions also focus primarily on human-to-human collaboration and interaction. However, they differ from asynchronous/standalone collaboration solutions because there *are* temporal relationship(s) among the collaborants. Typical collaboration solutions include video tele-conferencing (VTC), text chatter, shared whiteboards, application and screen sharing, meeting sessions, workflow, and process driven resource management and control.

This class of collaboration solution is labeled synchronous because the temporal dependencies that exist among the collaborants require a synchronized relationship among the participants as providers and consumers of data and information. For example, VTC and audio conferencing allow persons to interact and collaborate in "real-time". All participants are aware of each other's presence (either visually or audibly). They expect to interact as if there was no geographical separation between them and can easily recognize latency issues associated with transmission

delays (out of synch audio and video, jerky video, etc.) if the collaboration solution doesn't support the expected real-time interaction.

Synchronous collaboration solutions are also labeled federated for two reasons. The first reason arises from the associations and relationships that exist between members of the collaboration. By definition, people that are collaborating using these types of solutions are formed into independent groups (federations). Members of the group are aware of the other members collaborating within the group, but are not aware of any other asynchronous or synchronous collaboration activities that may be taking place outside of the group. The second reason involves collaboration solutions employing workflow- and process-driven control of the resources an enterprise uses to develop or produce the "product" they are in business to sell. This type of collaboration forms a well-defined, yet independent group of users and resources that interact with each other within their federation.

Today, there are several vendors with products that provide collaboration solutions of this type, with more continuing to appear as the need and desire to increase collaboration capability continues to increase (move farther to the right along the collaboration continuum). These collaboration solutions come as bundled toolsets that are tightly integrated by the vendor providing limited tool integration by the end user. While these bundled solutions normally provide "out of the box" installation and setup, they often duplicate existing functionality and services. Synchronous/Federated collaboration solutions have a typical lifecycle of 18-36 months.

1.3 Integrated/Framework

Pushing the state-of-the-art in today's Collaboration Marketplace, Integrated/Framework collaboration solutions focus on the entire continuum of collaboration solutions. Although not available today, they are planned to include the ability to support the interaction of asynchronous and synchronous collaboration activities, as well as large-scale collaboration environments that allow hundreds and thousands of users and resources to collaborate. These types of collaboration solutions have to address issues of 24/7 operations, fault tolerance, persistence, scalability, security and other "robust system" requirements. Additionally, these types of collaboration solutions must support enhanced decision support and knowledge generation involving the multi-disciplinary interaction of domain experts. This includes the use of modeling and simulation to support enterprise modeling and predictive hypothesis formulation and testing as well as robust enterprise production resource management and control.

This class of collaboration solution is labeled integrated because that is the word that best describes what these collaboration solutions are required to do … they must integrate all other collaboration solutions together into a seamless, integrated environment that allows users to make better, faster decisions *and* implement those decisions in the most efficient manner possible in order to achieve *better, faster, cheaper* product development.

Integrated framework solutions are so labeled because *framework* is a more descriptive word for defining the overall capabilities these collaboration solutions must provide. Many people view an "integrated" solution as a closed system that is bound and constrained by the components it has

integrated together. Adding other components to the integrated solution is not necessarily viewed as easy. Frameworks, on the other hand, tend to imply a more open systems approach that is not tightly coupled or bound to a specific set of components. Instead, frameworks can support varying configurations of components and the dynamic re-configuration of components based on user need as the product evolves.

Typical lifecycle timeframes for integrated/framework collaboration solutions are expected to be very long, (10-20 years). Marketplace predictions for the availability of these types of collaboration solutions range from 6 to 18 months from now.

2 Advanced Distributed Systems– An Integrated/Framework Approach to Collaboration

Advanced Distributed Systems (ADS), a Ball Systems Engineering Services (BSES) initiative, is the result of an effort to develop a Collaborative Enterprise Environment (CEE) under a Defense Advanced Research Projects Agency (DARPA) - Air Force Research Laboratory (AFRL) Dual Use Application Program (DUAP) contract. BSES has focused on developing an application independent framework that supports the robust use of virtual prototyping in support of multi-disciplinary research and product development. Based on the previous definitions, CEE is an Integrated/Framework collaboration solution. The work has resulted in a framework that is currently being used to conduct business at Ball Aerospace & Technologies Corp. as well as by two different organizations within AFRL. It may soon be the collaboration backbone for the Aeronautical Systems Center (ASC) at Wright-Patterson AFB, OH. CEE is currently being configured at the Naval Research Laboratory to be a Virtual Collaboration Testbed (VCT) for Mission Planning.

Figure 2 shows the basic components and architecture of the CEE-Integrated/Framework collaboration solution BSES is developing and fielding at AFRL and NRL.

2.1 Advanced Distributed System Collaborative Environment Framework

While pushing the state-of-the-art of collaboration solutions, the ADS initiative is designing and integrating the human collaboration and resource management components that currently define collaboration in the marketplace. Just as Microsoft Office integrated its word processing, spreadsheet and database capabilities into one office environment, CEE integrates the communication and resource management components into one collaborative environment.

The CEE collaboration framework uses the Common Object Request Broker Architecture (CORBA) to form the underlying data communication and object management layer. Java 2 Enterprise Edition (J2EE), which operates on top of CORBA, provides the basis for industrial strength services such as persistence, security and transaction processing. J2EE allows ADS to capitalize on commercially available services to provide a robust, scalable architecture.

2.2 Collaborative Environment Components

A collaborative environment framework is the backbone that enables users to interact with the tools and resources they need do work. The CEE framework includes the asynchronous and synchronous level collaboration tools for human collaboration, document management, and

resource management and workflow. This framework supports the human collaborants by giving them the tools they need to focus on what they do best: create, innovate and make decisions. The automated systems take care of coordination, search and retrieval and persistence and sharing of the artifacts of the process. We describe those components in the following paragraphs.

2.2.1 Asynchronous and Synchronous Components

In the current state of the practice, the asynchronous and synchronous human-to-human communication tools, resource management, and total asset visibility define collaboration. This section describes the CEE Human Collaboration tools and Document Management facility.

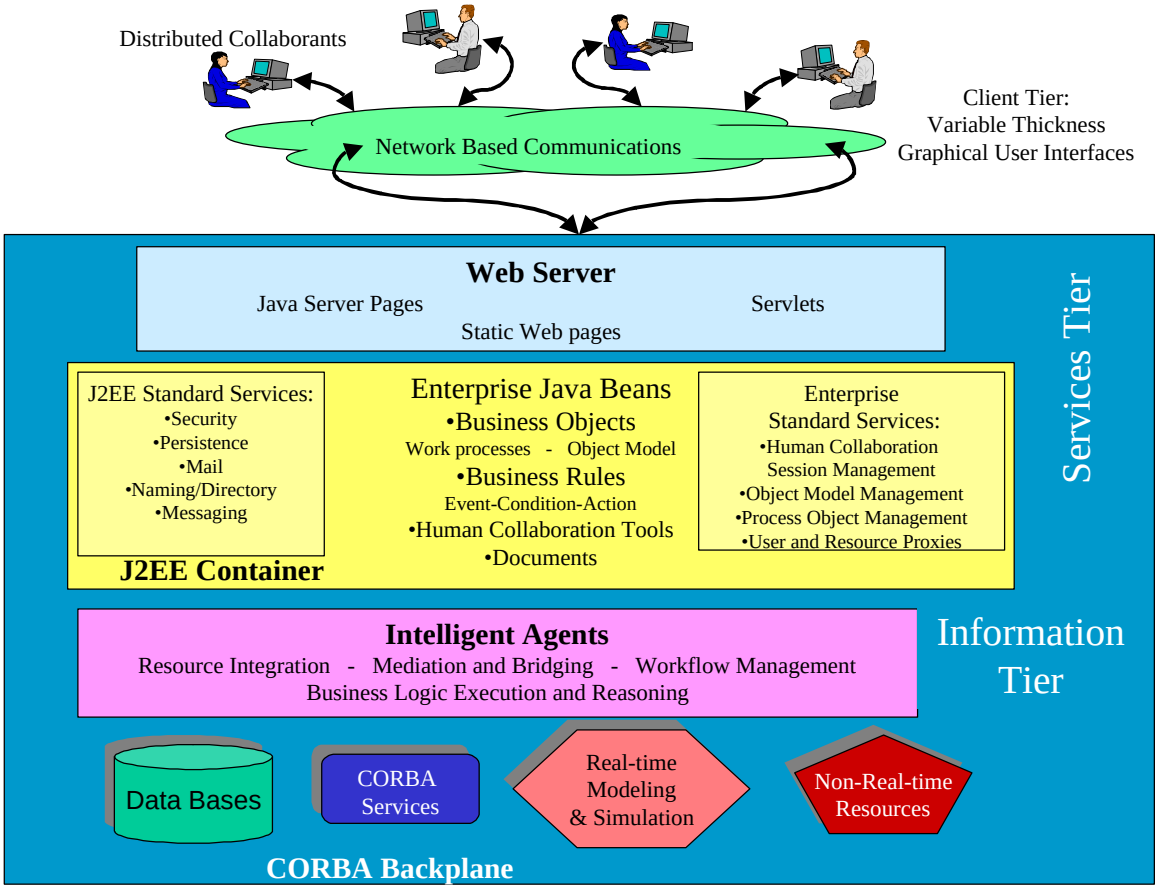

Figure 2 - CEE-An Integrated Collaboration Framework & Associated Collaboration Toolset

2.2.1.1 Human Collaboration

The CEE human collaboration tools let users employ integrated e-mail, shared applications and whiteboards, online chat and audio conferencing. Using the primary web-browser based user interface to the enterprise, users can choose from a menu of these communication options. A session manager coordinates the collaborative activities and works with the Document Management system to record the proceedings.

2.2.1.2 Document Management

The Bookshelf supplies the document management services for CEE. The user interface, based on file cabinets and folders, lets users file and retrieve a variety of enterprise documents that are the artifacts of the collaborative process. The Document Management system also has a powerful search engine to let enterprise users locate information using document metadata or keywords.

2.2.1.3 Resource Management and Workflow

CEE resource management components operate based on carefully designed workflows that result from up-front planning by enterprise managers and decision makers. They represent the plan for creating the product as a process model using the CEE Workflow Toolkit. The association of real resources allows managers to activate, monitor and control the execution of those resources throughout the development process.

2.2.2 Advanced Resource Integration and Product Modeling Components

The ability to control enterprise resources from the process model is not the only advanced feature of the CEE collaboration framework. Resource integration using intelligent agent technology allows integration of one-of-a-kind and legacy resources into a collaborative environment while protecting the proprietary nature of the way those resources produce results. The Workflow Toolkit provides the ability to model and control the enterprise's work processes. Modeling of the product itself is the function of the Smart Enterprise Common Object Model (SECOM) that includes not only the product model, but also the data management and data persistence services for the enterprise.

2.2.2.1 Resource Integration and Intelligent Agents

The Intelligent Agent is the primary software component of the CEE architecture for performing work (tasks). These tasks may be performed autonomously utilizing artificial intelligence concepts or in conjunction with a user that interacts with the agent. The CEE Intelligent Agent is based on The Object Management Group [Object Management Group] (OMG) definition for agents. As prescribed by the OMG, the agents are defined by the "services" that users select during configuration. These services include reasoning, application, security, communication, capability notification, and event notification.

These agents, capable of autonomous behavior, perform tasks based on knowledge supplied to them by the enterprise product and process models, and the specific role the agent was designed to fulfill. Specific agents, known as resource agents, adapt, control and manage legacy resources so they can be used by the collaboration. The CEE framework includes special adapters for resources that must interoperate in hard real time including those that are compliant with the Distributed Interactive Simulation protocols and the High Level Architecture defined by the Defense Modeling and Simulation Organization.

Intelligent Agents also supply a variety of other services to the collaboration including resource bridging, data mediation, user interface and component management.

2.2.2.2 Product Modeling

The intelligent agents derive some part of their intelligence from the enterprise product model maintained in the Smart Enterprise Common Object Model (SECOM). This dynamic model of the product being produced is developed early in the life of the collaboration and represents the product's state at any given time. Drawings, specifications, outlines and all the other data and information about the product/plan are available to the collaborative environment users and resources. Since the SECOM is the central repository for the enterprise data it is scalable, fault tolerant and has rule based reasoning capability to determine when changes must be made to the enterprise data.

The SECOM makes use of Event-Condition-Action (ECA) triplets to couple object-related events to associated actions. When an event occurs, the SECOM ECA agent evaluates the associated condition, and if true, executes the designated action. This allows for such uses as notifying the owner of a document or software module when the document has been read or modified.

3 Advanced Decision Support in a Mission Planning Context

A collaboration environment must provide support for Network Centric Warfare (NCW) in a mission-planning context for the land-sea-air battlespace. As such, the collaboration environment has to provide the community with the following critical capabilities:

- Full suite of human-to-human interaction utilities with low latency including audio teleconferencing, chatting, and whiteboarding
- Rapid collection, integration and sharing among the collaborants of timely and mission critical situation updates
- Effective management and control of historical information contained in databases and documents
- Access control for dissemination and sharing of the objects involved in the planning process
- Mobile intelligent agents that can dynamically allocate and control resources while effectively using available processing and communications infrastructure (bandwidth)
- Support mobile warfighting elements and command posts
- Support multiple coalition partners
- Interoperable over different command echelons
- Support coordination at specific combat element levels – e.g., air and ground forces

The Virtual Collaboration Testbed at NRL will make use of emerging technologies to investigate how a collaboration environment can satisfy these requirements. The NRL VCT will be based on the BSES CEE framework. CEE's set of integrated components combine to provide mission-planning decision-makers with the information they need, in forms they can use, to make the best possible situation-aware tactical plans. The CEE process and product models and other information and knowledge available within the enterprise will exist in a shared environment that supports rapid exchange of ideas. Within the mission-planning context, this framework provides the distributed planning community with a collection of tools and comprehensive historical and situational knowledge as a fully integrated enterprise.

Intelligent decision making for mission planning involves the aggregation of a vast amount of background information related to the land, air and sea assets involved in the plan coupled with the knowledge of the current tactical situation with its accompanying amounts of uncertainty. The decision makers join forces as representatives from a variety of planning specialties and domain experts. The components of the ADS framework enable effective interaction and interoperation of the human participants with the computer-based resources that support the process.

3.1 Human Collaboration Components

The very obvious use of Human Collaboration utilities is to bring people together across limitless geographical expanses. As long as there is a network available, the people can participate in synchronized sessions through chatting and audio conferencing while sharing views of the information and knowledge that support their decision context. For example, using the whiteboard utility, collaborating planners will concurrently review shared Geographic Information System (GIS) based views of current imagery with overlays of strategic targets. They will also have access to historical databases that provide parametric and analytical information about the targets. They will discuss the view using audio teleconferencing or record comments for use in reports using the chatting utility.

Using the Document Management facilities planners gain access to the shared mission planning artifacts that represent historical and anecdotal knowledge as well as the current intelligence that contributes to situational awareness. This includes other imagery, past plans and after action reviews. From these, collaborants can initiate new documents, modify works in progress and trigger pre-engineered processes that perform the automated work of the enterprise. This could include execution of detailed war-fighting simulations using current situational information from intelligence databases to predict the outcome of the battle represented by the mission plan.

On log in using standard web browsers, remote collaborants will join the discussions or check on status of tasks. Planners will retrieve and perform assigned tasking, make queries of databases, and review the documents under development or already posted in the Document Management system. Even if away from their normal place of work, managers will initiate new tasks and register events for email notification.

3.2 Resource Integration and Product Modeling

Less obvious to the collaborants but equally important is the “behind-the-scenes” activities that result in process synchronization and access to the resources that do work. The Resource Agents adapt and control the resources and provide intelligent access to the databases and modeling tools that support the work of the federated enterprise. Using the Resource Agent, the workflow processes can employ real-time simulations, feeding them the data they need from plans in Document Management and real-world objects in SECOM, orchestrating their execution, and on completion of the simulated exercise, collect the important effectiveness measurement data for analysis. The human collaborants continue to interact to review results, modify the plan and eventually agree to issue tasking orders to begin the mission. The sharing environment provides immediate access to simulation results, weather information, and the current intelligence that determines how and when to proceed.

As the plan evolves, the SECOM advances its representation of the collaborated product: group decisions, warfighter state and the plan itself. From these objects comes the real product, the orders that document the mission, its execution and the air, ground and sea forces, armaments and avionics needed for effective results.

Intelligent Agents provide the ability to control resources and assets remotely. While able to respond to tasking through the workflow system, agents will monitor the state of their part of product and the state of the computing resources and react to ensure effective completion of their tasks while minimizing their use of CPU and communications bandwidth. Since they are mobile, agents will relocate to appropriate mission resources to reduce latency and bandwidth. Using secure wireless networking capabilities the warfighter can contribute current situational assessments, battlespace observations and lessons learned as contributions to the next-mission plan.

Finally, Intelligent Agents that perform mediation will perform translation and transformations that enable interoperation among coalition partners. Future capabilities will support language translation and understanding. Similarly, mediation agents allow information from resources with disparate object models to be shared within the common model structure.

Bridging agents will perform aggregation to share knowledge up the chain of command where detail may not be as important or useful as the aggregated analytical assessment of a larger tactical picture. In this way, each echelon of command forms its own enterprise with shared knowledge appropriate to its level of fidelity while contributing to the needs of higher echelons to support their decision-making process.

The CEE framework and integrated components are pushing the state of the art to provide mission planning enterprises with the necessary capabilities to communicate and provide decision support, to model products and processes, and to manage and control resources, in a seamless, automated environment that uses computer and human power to their best advantage.

4 References

1. [Mitre Corp. Feb 00] briefing on “Collaboration Technologies Tutorial: The Promise and Reality of Collaborative Computing”
2. [International Institute for Collaborative Enterprises, Feb 00] briefing on “Collaboration in Air Operations”
3. [Air Force Research Laboratory, Nov 99], briefing on “AFRL Collaborative Environment”, Nov 99
4. [Object Management Group] 250 First Avenue, Needham, MA 02494 USA (http://www.omg.org)