Applying Distributed Simulation to Understand Dynamic Planning and Decision Making Processes in Command and Control

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Abstract

Connecting related sets of Command and Control (C2) applications to a synthetic battlespace environment allows their relationships to one another and their supporting roles in integrated C2 operations to be recreated and examined. A team of research engineers at the MITRE Corporation in Bedford, Massachusetts is creating just such an environment in support of the Air Force Electronic Systems Center (ESC). The development of this proof-of-concept testbed involves four steps: (1) stimulating multiple C2 applications within a single simulated battle, (2) connecting "commander-in-the-loop" applications to the synthetic battlespace, (3) forming backlinks into the synthetic battlespace to realistically portray the effect of C2 operations on the battle, and (4) configuring a central demonstration facility for visualizing data flow and decision processes associated with this distributed set of simulation and C2 applications. This paper presents the motivation behind each of these steps, then uses the details of the ESC work plan to further illustrate the process. The examples presented in this paper focus on the dynamic planning and time critical targeting aspects of C2. However, many other facets of C2—some service-specific, others concerning integrated Joint operations—could also benefit from closer examination within a synthetic battlespace environment.

1. Introduction

Warfighting trends are toward seamless interaction between the joint services to support increasingly time-critical operations. To meet these needs, command and control systems and the warfighters who operate them must continue to push the envelopes of information interoperability and effective decision-making. Current Command and Control (C2) support systems must be integrated to facilitate the flow of information between them, and this information must be presented to the warfighter in a timely and meaningful manner. The processes that warfighters follow to fit the information provided them into their mental model of the battle must be understood and evaluated. Where appropriate, decision support tools can assist in the warfighter's understanding of the options available to him in time-critical situations.

To work toward these objectives, synthetic battle environments are needed so that interplay between C2 systems and operators can be exercised within complex battle situations in an affordable manner. System developers, those who fund system development, and end users can come together within the context of simulated battle scenarios to visualize and form a common understanding of the challenges that lay ahead.

A team of research engineers at the MITRE Corporation in Bedford, Massachusetts is creating just such an environment in support of the Air Force Electronic Systems Center (ESC). The process includes:

(1) stimulating multiple C2 applications within a single simulated battle,
(2) connecting "commander-in-the-loop" applications to the synthetic battlespace,
(3) accurately portraying C2 operations and the effect of the resulting information and decisions on the battle by forming backlinks into the synthetic battlespace, and
(4) configuring a central demonstration facility for visualizing data flow and decision processes associated with this distributed set of simulation and C2 applications.

This paper presents the motivation behind each of these steps, then uses the details of the ESC work plan to further illustrate the process.

2. A First Step: Stimulating Multiple C2 Applications within a Single Simulated Battle

There are other methods for obtaining this information; certainly, lessons learned from actual conflicts are invaluable. Thankfully, we have very little historical conflict data that remains relevant in the face of today's warfighting conditions. "Live fly" exercises can be staged; but there again, the lessons learned are limited to the specific conflict conditions presented. Synthetic battlespaces offer the potential for an affordable, flexible, and scalable alternative for placing systems in battle context with one another to examine interoperability issues.

At ESC we are beginning a small research project to explore this hypothesis by setting up a synthetic battlespace testbed of our own. Working within tight budget constraints, we are seeking out existing C2 applications that can be included in our project that minimize the need for costly hardware purchases and software (interface) development. A number of candidate C2 applications exist in a variety of labs both at MITRE and on the Hanscom AFB. In addition, we have access to battle simulations being used for a variety of purposes by ESC's Modeling, Analysis, and Simulation Center (MASC).

As we select applications for our testbed, many logistical and technical issues are surfacing. A few C2 applications have existing simulation interfaces that we can reuse with minimal effort. Of the remaining applications, newer designs tend toward open architectures that are easier to penetrate with simulated inputs than older, more "stovepiped" designs. Some applications are only available to us on a limited basis due to tight proprietary restrictions or disinterest on the part of the sponsoring organizations. With other applications, we are strongly encouraged to experiment and in some cases even permitted to modify source code.

We decided on an initial application set that includes Airborne Warning and Control System (AWACS)-related applications and a set of Ground Moving Target Indication (GMTI) emulation applications driven by a simulated time critical targeting scenario. Figure 1 is a connectivity diagram of this distributed applications set. Our initial synthetic battlespace consists of a High Level Architecture (HLA)-compatible, mission-level battle simulation. The decision to employ the DoD-standard HLA [DMSO, 1999] as the cornerstone of our data exchange architecture is generating many benefits that we will note in context throughout this paper. The AWACS applications include a set of sensor models, a tracker, and a display emulator that share an open, Common Object Request Broker Architecture (CORBA)-based interface architecture. The GMTI applications include the Joint Surveillance and Target Attack Radar System (Joint STARS) Transportable Emulator (JSTE) and an Unmanned Air Vehicle (UAV) Model. Both GMTI emulators feature realistic operator display capabilities and existing simulation input interfaces via the Distributed Interactive Simulation (DIS) protocol. In the case of the JSTE, we have the additional advantages of (1) access to the source code if we wish to modify the software, and (2) an X-Windows-based display that can be viewed remotely for demonstration purposes. We will discuss the value of remote execution and display capabilities later in this paper when we present our plans for a centralized demonstration facility.

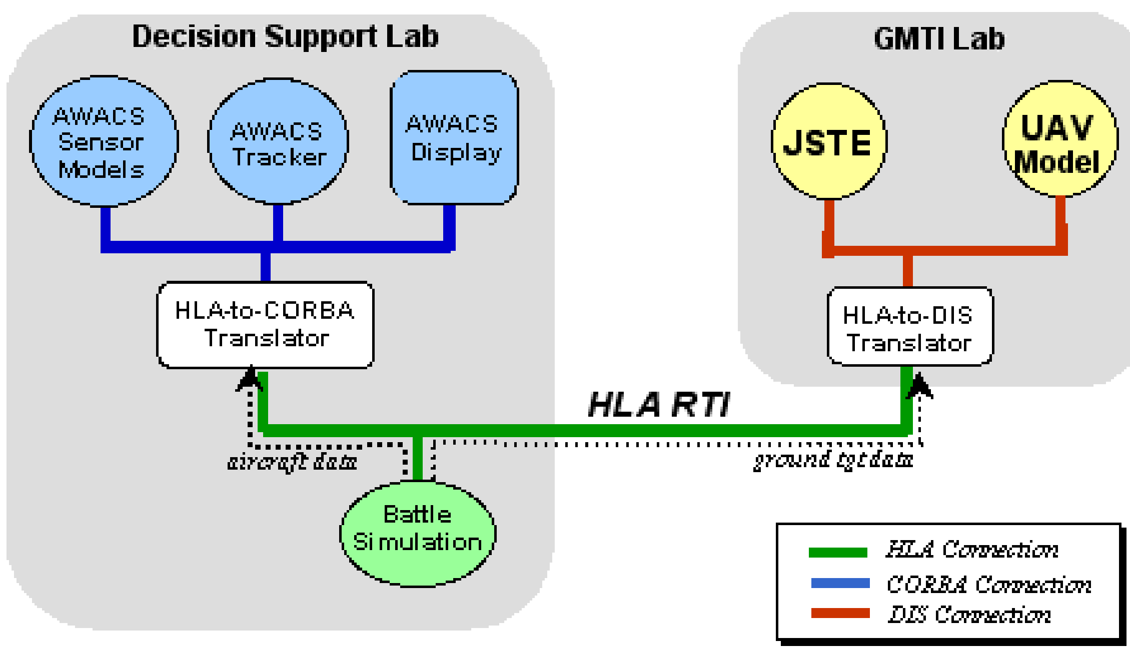

Figure 1. Connectivity Diagram for Initial Application Set

We chose MITRE's Decision Support Laboratory to be "home base" for our battle simulation. We will collocate the AWACS applications in the Decision Support Lab and use an HLA-to-CORBA translator to reformat simulated aircraft truth data to comply with existing interfaces. Our approach to the GMTI applications is a bit different; we chose to connect to the GMTI applications where they resided, in the GMTI Lab, to avoid disruption to existing hardware and ongoing project work. We are taking advantage of our High Level Architecture (HLA) infrastructure's built-in Wide Area Network (WAN) connection capabilities to route the necessary data feeds from the simulated battle to the GMTI Lab. At that point an HLA-to-DIS translator application performs the rest of the task of mating the simulated data to the DIS interface requirements of the GMTI application.

In our initial demonstration scenario, friendly air assets detect a potential threat. Commanders look for additional surveillance data from a Joint STARS aircraft to identify the threat. Once identified with adequate confidence, the commanders, working with data from an AWACS aircraft and an Army Corps Tactical Operations Center (CTOC), assess the suitability and availability of strike assets. The decision is made to prosecute the target with the Army's (Advanced) Tactical Missile System (ATACMS) and air-to-ground missiles from an F-15 fighter aircraft.

3. Connecting "Commander-in-the-Loop" Consoles into the Battlespace

In the initial prototype described above, all processing of battle data leading toward decisions to prosecute time critical targets takes place within the battle simulation. If control of these processes can be handed off to an external console that can realistically support "commander-in-the-loop" activities, then the effects of altering:

(1) the availability and presentation of data,
(2) the going-in mindset or command style of the decision-maker, and/or
(3) the governing rules of engagement

can be assessed.

In order to add such a commander-in-the-loop console to our initial AWACS/GMTI battlespace, we plan to develop the software and interfaces necessary to incorporate an unclassified version of Motorola's Time Critical Targeting Aid (TCTA) application. As shown in Figure 2, we plan to establish a GMTI data input connection to the TCTA. In all likelihood we will use an existing TCTA workstation that is installed on yet a third MITRE laboratory Local Area Network (LAN), again taking advantage of the HLA's WAN connection features and the TCTA's existing DIS interface.

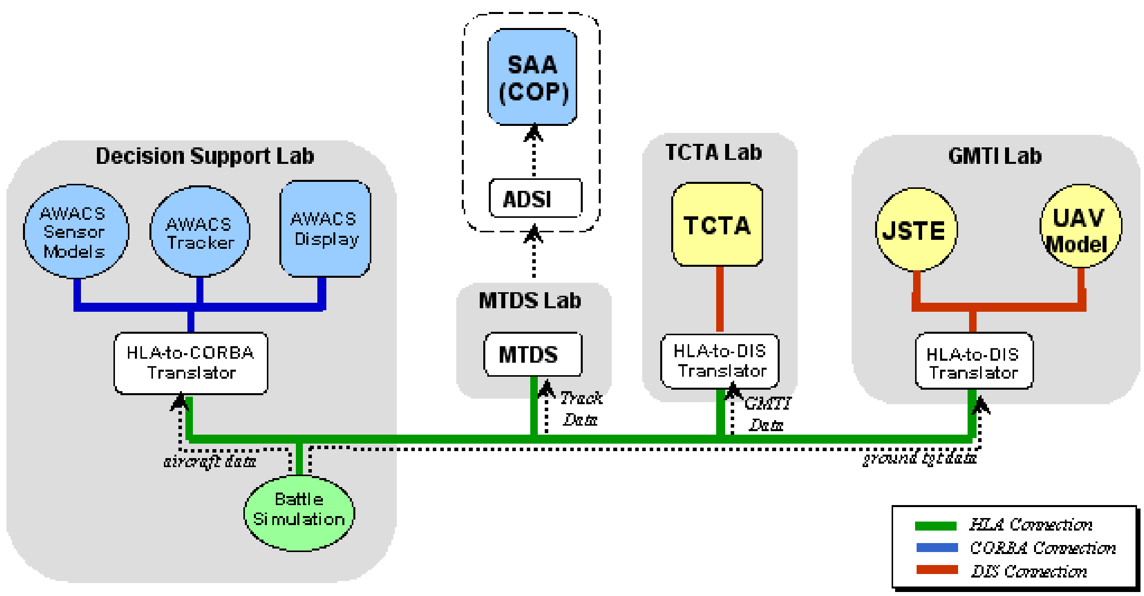

Figure 2. Connecting Commander-in-the-Loop Consoles

In addition, we plan to add an air track data "feed" from the synthetic battlespace to a Common Operation Picture (COP) console. The version of the COP we plan to incorporate is the Theater Battle Management Core Systems (TBMCS) Situational Awareness Aid (SAA). Our initial connection to the SAA will be accomplished by leveraging two existing translation applications, the Multi-Tactical Display System (MTDS) and the Air Defense Systems Integrator (ADSI). The MTDS is capable of sending TADIL-J messages to an ADSI, which in turns sends the data as JTIDS tracks to the SAA. We will work with the MITRE group responsible for MTDS enhancements to develop an HLA simulation input interface to the MTDS.

For security reasons we can only exercise the SAA connection as far as the MTDS on the MITRE WAN with the other applications mentioned so far in this paper. Connections to the ADSI and the SAA can only be made within a more secure network environment. However the MTDS itself can serve as a surrogate COP for our initial unclassified environment since it features a situation display of its own. Furthermore, because the MTDS display is based on the X-Windows graphical standard, it can be remotely executed and projected from anywhere within the MITRE WAN. This feature will prove useful for demonstrating our distributed synthetic battlespace in a centralized location, as is discussed later in this paper.

4. Forming Backlinks from C2 Applications into the Simulated Battle

Feeding simulated data into tracker applications, emulators, and command consoles is a significant step toward a useful battlespace for understanding C2. However, the full potential of the synthetic battlespace as a context for understanding C2 processes can only be realized by *creating an interactive, 2-way flow of data between the simulated battle and C2 system components*. This involves generating data exchange paths into the simulated battle or "backlinks" that represent the tracks, command decisions, and other actions entered on the actual C2 consoles. The synthetic environment then responds to these backlinks from the C2 systems by influencing the play of the battle accordingly (flying out selected missions, processing more realistic tracks from actual tracker applications, etc.). In this manner the effects of the different roles and relationships between the C2 systems can truly be brought to light [Flournoy and Providakes, 2000].

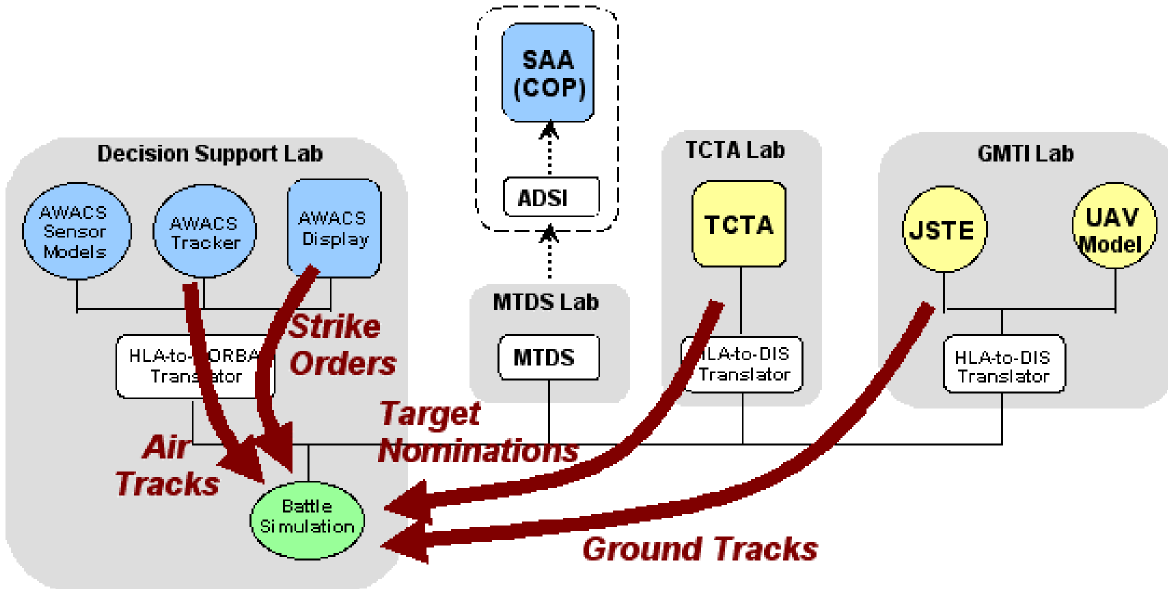

Figure 3: Backlinks Into the Simulated Battle

Figure 3 shows four such backlinks that we plan to build into our synthetic battlespace testbed. We discuss them in left-to-right order as they appear in the figure:

- *Air tracks from the AWACS tracker application represented within the battle simulation.* The battle simulation includes its own representation of air tracks; however, use of the tracks generated by algorithms and user actions more closely representing "real" battle operations greatly enhances the air picture within the synthetic battlespace.
- *Strike orders from the AWACS display emulator processed by the battle simulation, resulting in execution of the attack aircraft missions as directed by a "commander-in-the-loop."* Instead of relying on the battle simulation's inherent strike operations algorithms and their simplifying assumptions, an AWACS operator can be inserted into the battlespace to provide more realistic situational assessments and strike order timing/content.
- *Target Nominations generated by operators at the TCTA console providing more realistic triggers for ground strike operations.* Again, the battle simulation has its own set of assumptions and algorithms for elevating ground tracks for attack. However, the capability to substitute humans at an operational console playing within a simulated battle is invaluable for understanding the complex data and decision points involved in the target nomination process.
- *Ground tracks from the Joint STARS emulator represented within the battle simulation.* Once again, the ability to have a human operator determining tracks from GMTI data on a situation display can be an invaluable replacement for a simulation's inherent algorithms when it comes to understanding the target identification and tracking processes.

5. A Central Demonstration Facility for Visualizing C2 Data Flows and Decision Processes

A synthetic environment that allows commander-in-the-loop consoles and other C2 applications to be "played" interactively in a simulated battle provides a powerful capability to understand existing decision processes and test new roles and concepts. However for this capability to reach its potential as a tool for increasing understanding among the C2 community, there must be a mechanism for effective demonstration of the simulated data flows and decision processes as the develop. Diverse groups of C2 professionals may find it challenging to come to a common understanding of a battle situation if they must do so by visiting multiple computer labs and viewing detailed data on small workstation monitors. A centralized demonstration facility is required where C2 consoles can be viewed remotely via enlarged screen projections while the battle progresses. If this facility includes the capability to manage execution of all the piece-parts of the distributed applications set, the battle can be halted if desired to discuss key decision points. The capability to fast-forward through less critical parts of a battle scenario could even be implemented to the extent that the applications can support faster-than-real-time operations.

MITRE, in support of ESC, is developing such a central demonstration facility. This facility is on the MITRE unclassified WAN; therefore, it can achieve network connectivity with every as shown in Figure 4. Called the C2 Vision Center, this facility is based on personal computers (PCs) supplying images and other multimedia data to eight large projector screens in a single demonstration room. Although a limited amount of software and hardware physically exist in this room, network connectivity allows additional applications throughout the MITRE network, including all the unclassified applications within our synthetic battlespace testbed to be run remotely from the Vision Center PCs. For those applications that have X-Windows-based graphical displays, these images can then be projected onto the eight screens. Such an environment is a critical capability for portraying the sharing and presentation of data among C2 nodes under simulated battle conditions. Without this type of facility, demonstration of these concepts would be fragmented at best using small workstation monitors and requiring the audience to shuttle between the various computer laboratories. Within the demonstration room all the components of the battle-in-process can be viewed simultaneously on screens of ample size for a medium-sized group of onlookers. This allows varied audiences including C2 subject matter experts, analysts, and system development engineers to view situations together so that all may gain fuller understanding of dynamic planning processes and how automation can be used to best support these processes [MITRE, 1999].

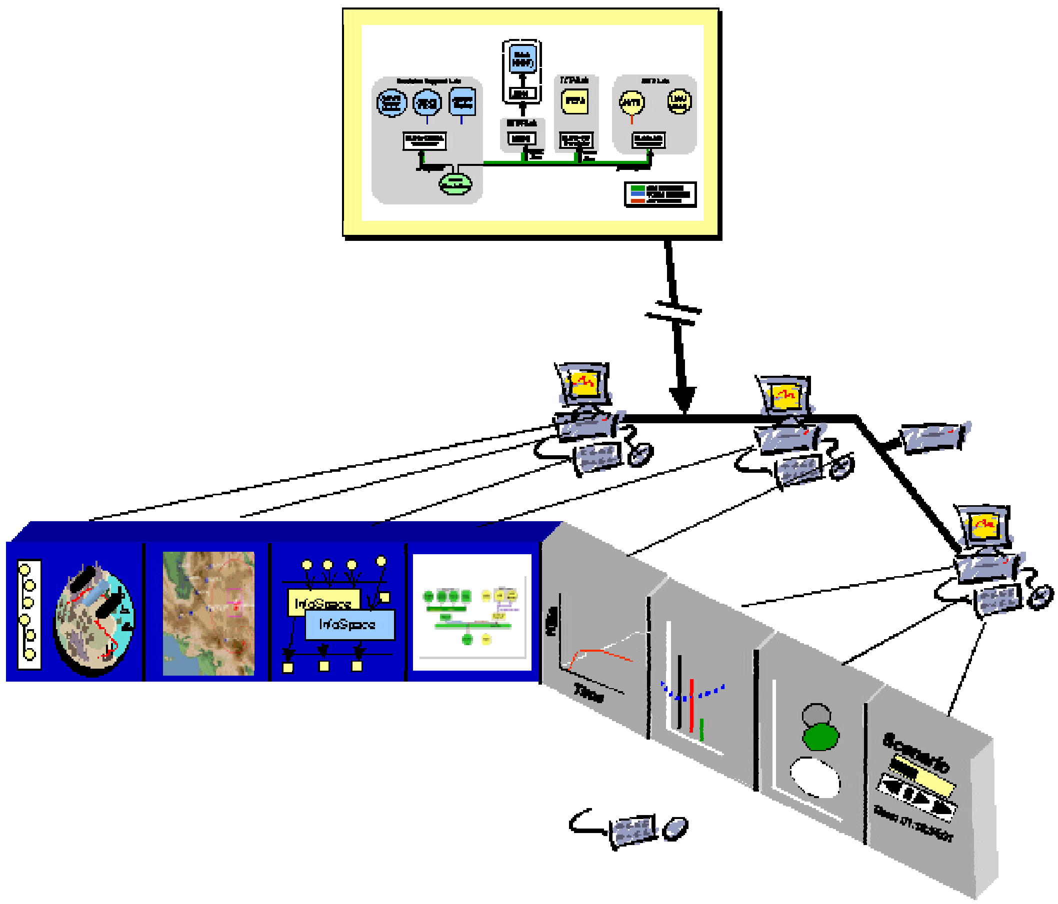

Figure 4: Central Demonstration Facility

6. Current Status of ESC Research

As this paper goes to press, we have demonstrated our battle simulation driving the AWACS applications and GMTI applications from the same battle scenario. We are waiting on funds to purchase hardware to host the AWACS applications in the Decision Support Lab in order to achieve simultaneous connectivity between all the players in the initial application set. We are also awaiting resources to continue with our plan as outlined in this report, with the next steps being to develop interfaces to the TCTA and MTDS applications.

As mentioned earlier in the paper, the majority of our work to date and near-term plans are targeted for an unclassified environment. We have found working at the unclassified level adequate for "proof-of-concept" prototyping—that is, demonstrating the premise that valuable insight can be gained by exercising C2 systems interactively within a distributed synthetic environment. Obviously, a more secure environment is necessary to gain meaningful insights into particular operational issues. In weighing the pros and cons of switching to a classified environment for our research, we found that a more secure environment would allow us to work with a wider variety of operational systems and issues. However, transitioning to a more secure capability presents network challenges and requires significant facility upgrades to our demonstration room. These costs are beyond the reach of our small research project, but will be well worth bearing when the results of this work are applied to specific operational issues.

7. Summary

Synthetic battlespaces potentially offer an affordable, flexible, and scalable approach for placing systems in battle context with one another to examine interoperability issues. Connecting related sets of C2 applications to a single simulated battle allows their relationships to one another and their roles in supporting the flow of battle information to be recreated. In particular, stimulation of "commander-in-the-loop" consoles can provide a mechanism for gaining valuable insight into C2 data presentation and decision processes. The realism of a C2 system's interplay within a synthetic battlespace is greatly enhanced by creating the proper return data paths or "backlinks" into the simulated battle. A central demonstration room that facilitates discussion and understanding can be configured affordably. Existing network connections can be leveraged that allow local display of remotely executed C2 applications in other laboratories.

Although this paper presents a plan for visualizing and understanding specific processes involving dynamic planning and time critical targeting, the paradigm of C2 systems operating within a synthetic battlespace in tandem with a central demonstration facility can be used to gain insight into other areas of C2 as well. Combat support for an Expeditionary Air Force is a critical focus area that depends on a successful coming together and common understanding of problems between the logistics and combat operations communities. Increased collaboration and understanding between the intelligence and combat operations communities could also lead to breakthroughs in the way we maintain information superiority in battle. These are just two examples of the many facets of C2—some service-specific, many others concerning integrated Joint operations—that could benefit from closer examination within a synthetic battlespace environment.

8. References

[DMSO, 1999] Defense Modeling and Simulation Office. HLA Overview from Web Site *http://hla.dmso.mil*, March 1999.

[Flournoy and Providakes, 2000] R. Douglas Flournoy and Dr. George F. Providakes. A Synthetic Environment for C2 System Integration Based On Emerging Infrastructure Standards, The MITRE Corporation, February 2000.

[MITRE, 1999] The MITRE Corporation. *MITRE Debuts Command and Control Vision Center*, MITRE Matters, October 1999, p. 4,5.