Integration of CCTT and JCATS in an LVC Exercise

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Keywords:
LVC Training Systems; Virtual-Constructive

ABSTRACT: *The Joint Training Experimentation Program (JTEP) is a multiphase, multiyear effort to develop a distributed training capability for the California National Guard (CANG) that combines live, virtual, and constructive (LVC) simulations to support multiechelon training. The second JTEP demonstration was a battalion-level exercise conducted in December 2003. This demonstration linked the Joint Combat and Tactical Simulation (JCATS), a constructive simulation, the Close Combat Tactical Trainer (CCTT), a virtual simulation, and the Deployable Force-on-Force Instrumented Range System (DFIRST™), a live instrumented training system. JCATS and CCTT were located at Camp San Luis Obispo, California, with DFIRST at Camp Roberts, California.*

A significant aspect of the overall success of this exercise was the integration of the CCTT (version 10.0) and JCATS (version 4.1) simulation systems. During this demonstration, JTEP cross-attached CCTT and JCATS entities into realistic task forces that engaged a JCATS-based OPFOR. JCATS-based OPFOR also engaged Live DFIRST entities on the same overall battlespace, i.e., "GrafenBob"—a fictitious area in Germany created by stitching a portion of the CCTT Grafenfels (P6) terrain to geospecific Camp Roberts terrain.

The creation of GrafenBob and its correlation to the CCTT P6 terrain was a key technical enabler for successful integration of JCATS and CCTT. As a result of its significance to the overall JTEP effort, the development of GrafenBob is the subject of a separate companion paper submitted for this workshop. This paper documents the impact of a JCATS-CCTT-correlated GrafenBob terrain and other issues that required resolution before this virtual-constructive integration could be deemed a success. These issues include the effects of entity state update rates, enumerations, and integrating the DIS radio network used by CCTT with that used by the other JTEP federates. This paper describes how JCATS and CCTT entities were task organized, presents an overview of the technical issues identified above, describes how these issues were addressed, and suggests issues for further study.

1. Introduction

1.1 JTEP overview

The Joint Training Experimentation Program (JTEP) is a National Guard Bureau project managed by the California National Guard (CANG). The Guard currently uses advanced live, virtual, and constructive (LVC) systems to support training, but each system is used standalone. JTEP is intended to bring to the Guard the benefits of integrating existing or readily available training environments, and to enable LVC interaction over nondedicated wide-area networks (WANs).

JTEP started with an initial study to determine which candidate systems and integration mechanisms would achieve the greatest training impact. After the initial study, the first demonstration, linking live and constructive training systems, was conducted in May 2003 [1]. The second demonstration, conducted on 11 December 2003, was a complete LVC integration. This was a battalion-sized demonstration with approximately 125 total live and simulated entities. An overview of the JTEP LVC Demo, [2], includes a discussion of innovative features such as a virtual Unmanned Air Vehicle (UAV) for reconnaissance and the use of pop-up gunnery targets to facilitate Live-Constructive engagements. The latest JTEP information is online at http://www.jtepforguard.com.

1.2 Goal of this paper

This paper describes how the "V" and the "C" pieces of the JTEP LVC Demo were integrated. The virtual simulation was the Close Combat Tactical Trainer (CCTT) and the constructive simulation was the Joint Combat and Tactical Simulation (JCATS). The live element, the Deployable Force-on-Force Instrumented Range System (DFIRST), and the Tactical Operations Center (TOC), are not addressed in significant depth in this paper. Additional detailed information about the JTEP LVC Demo is presented in companion papers [3] and [4].

This paper is directed to a large cross-section of the distributed simulation community. Our goal is to cover the key aspects of configuring CCTT and JCATS for successful interoperation and to describe the qualitative nature of that interoperation during the actual LVC demo. Further, while an exhaustive technical description is not within the scope of this paper, we hope that readers with more in-depth knowledge of JCATS and CCTT can use this information to help them develop or improve their own CCTT-JCATS exercises. If additional detail is desired, readers should not hesitate to contact the lead author for more information.

The rest of this paper is divided into the following sections: (2) JTEP Simulation Resources, (3) Data Exchange, (4) Correlated Terrain, (5) Results, (6) Next Steps, (7) Summary and Conclusions, (8) Acknowledgements and (9) References.

2. JTEP Simulation Resources

The CANG has access to a set of four CCTT M1A1 virtual trainers. These trainers, each with realistic M1A1 crew stations for four soldiers each, are packaged in two semitrailers and supplemented with a trailer containing after action review (AAR), operator, and observer-controller terminals. The third trailer also contains CCTT Semi-Automated Forces (SAF) host machines, which provide additional computer-generated CCTT entities during training exercises. A fourth trailer provides electrical power to the other three, making the system completely standalone and transportable. This CCTT mobile set was used in the JTEP LVC Demo. The set ran CCTT software version 10.0 on AIX workstations connected to a Fiber Distributed Data Interface (FDDI) LAN. The CCTT trailers are shown in Figure 1. The CCTT AAR area, with its 3-D (upper) and 2-D (lower)

Figure 1. California CCTT Mobile Units

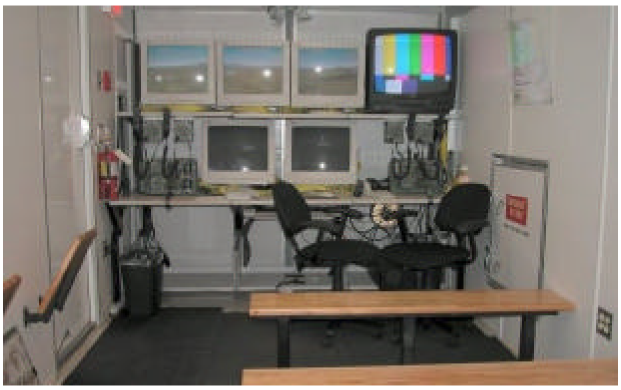

Figure 2. Mobile CCTT AAR Area

Figure 3 JCATS Station

viewing monitors, is shown in Figure 2.

JCATS version 4.1, running on Red Hat Linux 7.3, was used for the JTEP LVC Demo. Pentium-4-class desktops and laptops were utilized as the JCATS server, backup server and operator workstations. These machines all had 1 GB of memory and ran at a nominal 2.4 GHz. All JCATS machines were connected to an Ethernet LAN. Figure 3 shows one of the JCATS operator stations in use during the demonstration.

Although JCATS and CCTT systems would normally be located at different geographical sites in a JTEP exercise, for purposes of the December demo, they were co-located at Camp San Luis Obispo, California, and were connected by a 120-ft Category-5 network cable. These systems were linked for nine days of testing and rehearsal prior to the actual demonstration event. The DFIRST live simulation was located 45 miles north at Camp Roberts. The three systems were connected via a Virtual Private Network (VPN) running over the California Army National Guard (CA-ARNG) network.

3. Data Exchange

3.1 JCATS Configuration

JCATS must be configured to send and receive DIS PDUs on the exercise network to interoperate with CCTT or any other external DIS-enabled simulation. The JCATS DIS Bridge is designed for this purpose. The graphical user interface (GUI) for configuring the JCATS 4.1 DIS Bridge is shown in Figure 4. We specified that the DIS Bridge operate with DIS version 4 and with a one-second Entity State PDU heartbeat interval.

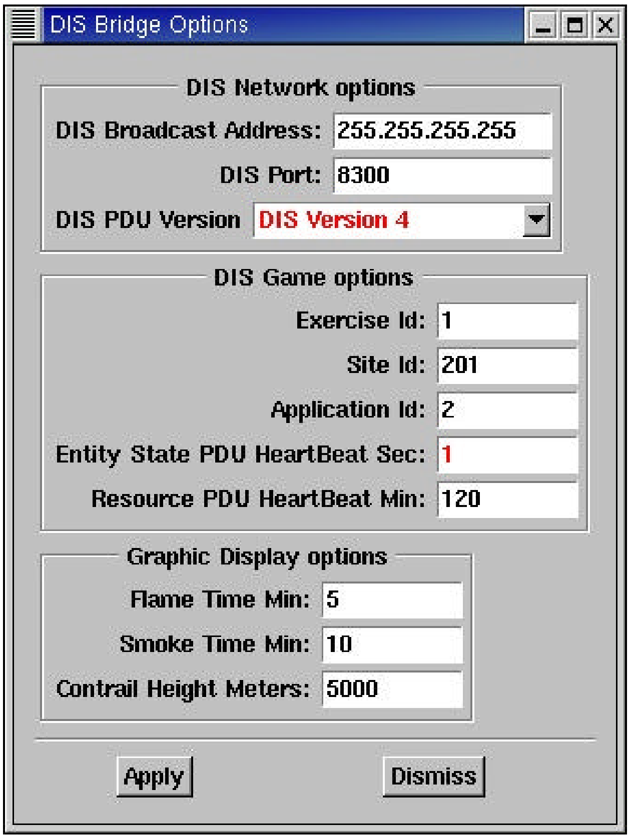

Figure 4 JCATS 4.1 DIS Bridge Options

Other DIS versions may have worked with CCTT 10.0 but we did not test them. The heartbeat interval, which is much shorter than the 180 s default value, was chosen to help smooth out the motion of JCATS entities when displayed on CCTT 3-D terminals.

The JCATS DIS Bridge and the CCTT Gateway are depicted schematically in Figure 5.

3.2 CCTT Gateway

The CCTT Gateway software runs on a CCTT host machine (running AIX in this case) containing both FDDI and Ethernet interface cards. The Gateway provides four important services for connecting CCTT to an external DIS simulation. These services are: (1) an *electromechanical bridge* between the FDDI network and an external Ethernet network; (2) an ability to *filter* both inbound and outbound DIS PDUs; (3) an ability to *map* DIS external enumerations into enumerations that CCTT understands; and (4) *ground clamping* of external DIS entities to the CCTT terrain, if desired.

DIS Enumerations. CCTT operates on a subset of the possible DIS enumerations. This subset of 600+ entity

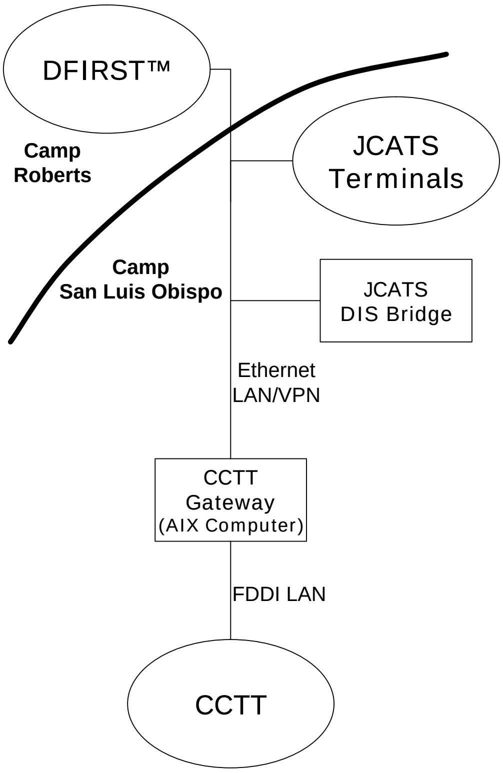

Figure 5 Simplified JTEP VPN Schematic

types is defined in the CCTT *entity_type_values* file. For JTEP we were careful to specify that all DIS enumerations used in JCATS and DFIRST were taken from this list. This was done as much as possible in advance, but some "unknown" enumerations were still caught and fixed in the field during the exercise rehearsal period. This approach freed us from needing to use the mapping capability of the CCTT Gateway software, saving some Gateway processing time. This uniform treatment of DIS enumerations across JCATS and CCTT is strongly advised in [5].

Ground Clamping. Another Gateway feature we did not need or utilize was ground clamping. Ground clamping can be computationally intensive for the Gateway but was unnecessary in this demo since we ran both simulations on correlated terrain (see Section 4 below).

Radio Data. The CCTT Gateway filter parameters must be configured properly to allow DIS radio data to pass into and out of CCTT. While this was not required for the CCTT-JCATS interoperation discussed in this paper, it was required for CCTT-TOC interaction. We found that the following settings were needed in the CCTT Gateway to allow two-way radio traffic:

```
## FDDI Filtering Parameters
export FDDI_RECEIVE_RECEIVER_PDU=TRUE
export FDDI_RECEIVE_SIGNAL_PDU=TRUE
export FDDI_RECEIVE_TRANSMITTER_PDU=TRUE
export FDDI_RECEIVE_VOICE=TRUE

## Ethernet Filtering Parameters
export ETHERNET_RECEIVE_RECEIVER_PDU=TRUE
export ETHERNET_RECEIVE_SIGNAL_PDU=TRUE
export ETHERNET_RECEIVE_TRANSMITTER_PDU=TRUE
export ETHERNET_RECEIVE_VOICE=TRUE
```

CCTT uses a hardware-based continuously variable slope delta (CVSD) modulation for DIS radio encoding. For compatibility, the other JTEP federates needed to switch from μ-Law encoding to CVSD.

We observed that in our battalion-sized scenario, peak radio traffic used 80 percent or more of the available exercise network bandwidth (nominally three-fourths of the T-1 connecting Camp Roberts and Camp San Luis Obispo), and that heavy radio traffic can degrade the performance of the CCTT Gateway. DIS radio issues will be challenges for JTEP engineers as we grow exercises beyond the battalion level.

4. Correlated Terrain

The use of correlated terrain in the two systems was absolutely critical to the success of CCTT-JCATS interoperation. A detailed explanation of the technology used to create the correlated terrain products for the JTEP LVC Demo is available in a companion paper [6]. This paper mentions only the high-level characteristics of this terrain.

Within the context of the JTEP JCATS-CCTT integration, an effective working definition of *correlated terrain* is "a set of two or more terrain databases that provide a computationally equivalent description of the common exercise playbox." Since DIS was our simulation protocol, and DIS utilizes the WGS-84 geocentric Cartesian coordinate system, in practice the three geocentric coordinate values of a ground surface feature in one simulation must match the three coordinates of the same feature in the other simulation.

As of this writing, we have not yet had the chance to rigorously compare our terrain sets, but quantitative spot checks and qualitative observations indicate that our terrain sets were correlated to within 1 m.

This type of correlation addresses the basic "shape of the dirt" that the simulation is played on as well as "ground-hugging" surface features such as roads, pavement, rivers, and lakes. It does not address above-

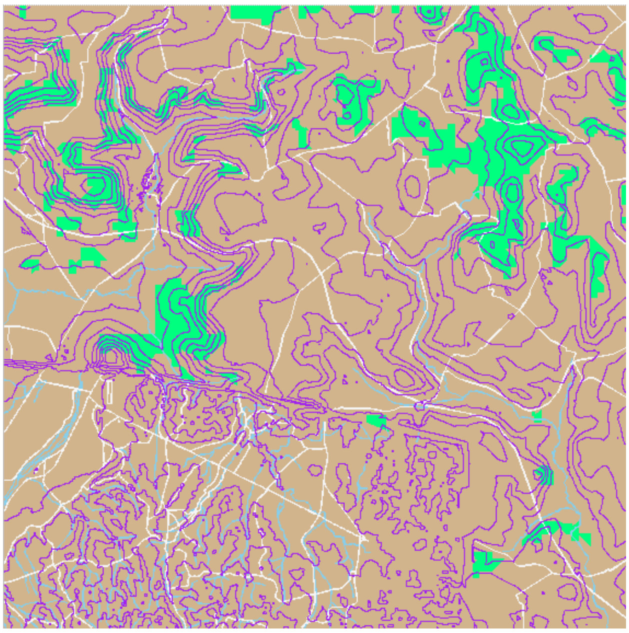

Figure 6 JCATS Terrain for the JTEP LVC Demo

surface features such as trees and buildings. Since these are obviously important to target acquisition and entity movement, they will be investigated and addressed in a future JTEP evolution. For the December 2003 demo, precise “tree-and-structure” correlation was not attempted.

4.1 Terrain characteristics

The playbox for the JTEP LVC Demo was a square region 12 km on a side; the JCATS map is shown in Figure 6. The southwestern region of the playbox is a portion of Camp Roberts that was “stitched” to a portion of the CCTT Grafenfels (P6) terrain. This stitched terrain was dubbed “GrafenBob” by the JTEP team. Computationally, the entire playbox is within Military Grid Reference System (MGRS) Zone 32 in Germany. Position data from the live player instrumentation in the “Bob” (Camp Roberts) region of the playbox was translated in the DFIRST Base Station to Zone 32 coordinates.

The Grafenfels portion of the GrafenBob terrain was generated from the SEDRIS Transmittal Format (STF) of the CCTT P6 terrain. The availability of P6 in STF was the primary driver for selecting Grafenfels for the V-C interactions.

The JCATS GrafenBob terrain, in the form of a *.DAF file, had the resolution of 10 m post spacing for a total of 1.44 million posts and a total file size of 11 MB in ASCII format.

Paper maps of GrafenBob at 1:24,000 scale were also produced for use by the exercise commanders in the TOC and by all other participants in the exercise.

The CCTT mobile system did not have a view into the Camp Roberts portion of the playbox since it was impractical to modify the fielded CCTT P6 terrain databases. This was not a practical concern, however, since the scenario was designed to keep CCTT vehicles separate from live vehicles. If CCTT virtual players had been allowed to come within engagement range of the DFIRST live players, the fight would have been unfair because the virtual players would have been able to engage the live players, but the live players would not have been able to see the CCTT units.

4.2 Problems with uncorrelated terrain

Prior to the production of the correlated GrafenBob terrain we conducted JCATS-CCTT interoperability testing in our JTEP Testbed laboratory. Since we did not have easy, regular access to the actual CCTT mobile units we used the Standalone CCTT-SAF from Scientific Applications International Corporation (SAIC) as a CCTT surrogate. The version of the program we used was derived by SAIC from the CCTT 9.x Linux codebase to run on Red Hat 7.3.

When we ran tests using uncorrelated terrain, it was observed qualitatively that one system typically had an advantage over the other due to terrain mismatches. Since our correlated terrain was in production, in-depth and quantitative analysis of these mismatches was not needed. Entities from one system were perceived as floating or flying in the other system and were therefore easy targets. (We used DIS network diagnostic tools to help verify these elevation discrepancies.) Conversely, from the other system’s point of view, entities external to that system were underground and difficult or impossible to acquire. It is important to note that neither JCATS nor CCTT had any permanent, built-in advantage over the other, since it was the nature of the terrain mismatches that dictated the characteristics of the system interactions. Later, when using our correlated GrafenBob terrain, we no longer observed these discrepancies.

5 Results

5.1 Participant impressions

The JTEP LVC Demo was just that—a demonstration. Most of our effort was expended on the technical areas required for basic interoperation. Nevertheless, CANG participant soldiers felt that the training value was quite high, with several commenting that the demo provided the best training they had ever received in the Guard.

A key benefit from the participants' point of view was the cross-attaching of JCATS elements with CCTT elements to create a realistic BLUFOR task organization. In fact, the Battalion Commander requested such an improved reorganization of elements (in the field, just hours before we were to enter our rehearsal phase), and we were able to accommodate his request.

We jointly created a Mechanized Team composed of a CCTT M1A1 platoon and a company of ten JCATS M2A2s. The M1A1 platoon was made up of one manned module and three tethered CCTT-SAF tanks. The M2A2s consisted of two platoons, a company commander vehicle and an XO vehicle. This entire cross-attached team was commanded by a captain who did his own JCATS "puckstering" and also provided radio commands to the CCTT manned module crew. The tank commander in the CCTT manned module commented that it was particularly satisfying to have the M2A2s be under "man-in-the-loop" JCATS control as opposed to being under automated SAF control.

The three remaining CCTT modules formed a separate Armor Company Team with a company commander (including a tethered CCTT-SAF XO tank) and two CCTT platoons, each with platoon leaders in manned modules. The team also included four CCTT-SAF tethered M2A2s.

OPFOR vehicles were all simulated in JCATS and consisted primarily of BMP2s, BDRM2s, and T72s.

The soldiers in the CCTT manned modules reported that acquisition, engagement and probability of hit/probability of kill (PHPK) behavior was realistic when the CCTT BLUFOR engaged the JCATS OPFOR. This result was somewhat serendipitous because we did not systematically evaluate or adjust the JCATS acquisition or PHPK data for this "experimental" demonstration exercise.

5.2 3-D display

Although apparently not a distraction to the crews in the manned modules, JCATS entities understandably exhibited some visual artifacts when displayed on CCTT 3-D terminals. Most notably, the update rates were not frequent enough for JCATS vehicles to travel smoothly in CCTT 3-D views. Note that we set the JCATS DIS Bridge heartbeat rate to once per second per entity, the most rapid heartbeat setting permitted by the DIS Bridge configuration GUI. While this heartbeat rate is more than satisfactory for a 2-D plan view display, it results in jerkiness when the simulations is viewed in 3-D. Between heartbeats, JCATS vehicles would occasionally "lift off" or "burrow" up to 0.5 meters above or into the CCTT terrain surface. (Remember that we were using correlated terrain in both simulations with grand clamping turned off.) Also, when a JCATS entity encountered a waypoint in its travel path, the vehicle would typically overshoot the waypoint and then snap back to its correct, new heading when the next heartbeat was received.

While we would like to emphasize that we did not receive a single negative comment about this behavior from the exercise participants, we are not satisfied with these artifacts, and we hope to be able to investigate this issue by consulting with both CCTT and JCATS engineers in the future.

6. Next Steps

JTEP has two major areas of focus: (1) Combat JTEP, or training for combined arms exercises and (2) Military Support for Civil Authority (MSCA) JTEP, or training for the Guard's mission supporting civil authority in natural disasters and for homeland defense. For Combat JTEP, the next demonstration, currently envisioned for fall 2004, will expand the training to encompass a brigade-level exercise. The principal extensions will be the addition of LVC component federates and the expansion and enhancement of the communications networks. JTEP is investigating the addition of Air Guard and Marine Reserve units to make the exercise truly joint. Additionally, the third demonstration is likely to bring in at least one long-haul link to connect participants in other states and satisfy one of JTEP's key programmatic goals.

At the time this paper was prepared we had not had a chance to prioritize our research and development tasks related to JCATS-CCTT interoperation. Much of our work needs to move beyond "basic" fair fight interoperability and on to ensuring a precise fair fight between entities in these systems. Some of the tasks ahead of us are as follows:

- Work to correlate our terrain further, if possible, verifying less than 0.5 meter differences throughout.

- Explore "tree-and-structure" terrain correlation in the two systems. JCATS and CCTT have fundamentally different mechanisms for describing above-surface features, so it may be particularly challenging to develop terrain databases that will permit a truly fair fight in all situations.

- Study the compatibility of the target acquisition models in the two systems. The JCATS database can be tuned to more closely match the CCTT model if incompatibilities are discovered, as discussed in [5].

- Study the PHPK models in the two systems. As with acquisition, JCATS can be tuned to better match CCTT, if necessary.

- Consult with CCTT and JCATS engineers to develop approaches to smoothing the motion of JCATS entities viewed on CCTT 3-D displays.

7. Summary and Conclusions

The second JTEP demonstration, an integrated LVC exercise, was conducted on 11 December 2003 at Camps Roberts and San Luis Obispo in California. This demonstration successfully integrated live, instrumented systems with CCTT virtual trainers and the JCATS constructive system, providing a seamless LVC battlespace. This paper described the key features behind the successful Virtual-Constructive interoperation, the most important being the use of carefully correlated GrafenBob terrain in the two systems.

8. Acknowledgements

We would like to thank Peter McHale and Bob Callahan of PEOSTRI/CCTT and Lou Duet and his team with the California CCTT Mobile units for their support.

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Author Biographies

MARK JOHNSON, Senior Software Engineer at SRI International, has over 20 years of experience in engineering and simulation and is a member of SRI's Software Engineering and Development Program. On the JTEP project he concentrates on JCATS, CCTT and the interoperation of these systems.

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