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Technical and Operational Design, Implementation and Execution Results for SINCE Experiment 1

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Abstract

In this paper we describe the design, implementation, and execution results obtained from the SINCE experiment 1b (SINCEx1b) which took place in July, 2004 at the Fort Leavenworth facilities of the US Army 35th ID (Mech). The goals of this experiment were a) to build upon the success of the SINCE Experiment 1a (SINCEx1a), which took place at the MIP facility of WTD-81, Greding, GE in November 2003, by operationalizing the information exchange among all of the US and German systems connected in the experimentation environment, and b) to verify and validate with military users in control that the C2 functionality implemented is well understood and acceptable to support future planned operational experiments such as SINCEx2. Clearly, many compromises had to be made considering the limited resources and budget available. Many trade-offs were made in establishing a balance between a) developing the infrastructure not only for SINCEx1b but for the planned follow-on experiments and b) developing the SINCEx1b configuration that was finally used in the conduct of the actual experiment. The infrastructure concepts illuminated issues pertaining to various bilateral and multilateral coupling mechanisms within each federation of C2 systems, within each federation of combat M&S systems, and within the super-federation of C2 and combat M&S systems.

An integral part of the solution was the establishment of a methodology by which the various information architectures would be harmonized within federations and across federations. The infrastructure for SINCEx1 was embodied in a US Proxy Server, the GE C2Sim Proxy Server and the Coalition Portal as federates that collectively included the various adapters and filters that mediated between the otherwise incompatible heterogeneous interfaces inherent in the selected federate systems using a common domain model encoded as XML schema. The selected federates for the experiment represented the deployment of either a current force, a future force or a mix that is required to be not only network-centric with respect to its own assets but also with respect to other Joint, National and Coalition assets. The SINCEx1b experiment addressed in a more comprehensive manner the main issue for any network-centric architecture: how to establish connectivity, federation, collaboration and operational interoperability in a self organizing way among all elements of the force to include combat (e.g., maneuver), combat support (e.g., maneuver support), combat service support (e.g., maneuver sustainment) and C2 (e.g. battle command) assets. A significant contribution of SINCEx1b was to demonstrate a common information model that provided a “one-to-many” mapping to bridge across several disparate information architectures inherent in the applications and data models pre-existing in the various federates required by the operational user.

Objectives

The objectives of this paper are to describe the SINCE experimentation approach and provide insight from the first experiment. Specific background for this paper may be found in references [1-4]. General background for motivating the SINCE Program is based upon references [5-6]. Multinational issues are addressed from an operational perspective as well as from a technical perspective which are then integrated. Multinational issues impact national issues relevant to Battle Command and therefore they need to be addressed in an integrated approach as well. Specific issues addressed in SINCE involve

(a) automating the federation process among heterogeneous multinational and national C2 systems and modeling and simulation (M&S) systems as a federation of federations, and
(b) conducting multinational, multi-spectrum, multi-modal, multi-session collaborative planning continuously under the stress of execution monitoring and maintaining a multinational Common Operational Picture (COP) in addition to a national COP.

The SINCE Design

Operationally, the SINCE environment is designed to be modular and scalable to support any tactical force represented by a mix of live and constructive operational users. This is exemplified in Figure 1. The live operational user is represented at the two highest echelons of the force referred to as tiers n and n-1. The constructive operational user is simulated at one or more lower echelons referred to as tiers n-2, n-3, …, down to tier n-m which represents the primitive entities of the simulation environment. For SINCEx1, n = brigade (Bde), n-1 = battalion (Bn), n-2 = company(Co), n-3 = platoon (Plt), n-4 = team/crew/platform. The enemy and any other friendly or neutral, military or civilian entity are also represented by the constructive simulation environment. Figure 1 depicts the operational architecture of SINCEx1. Two or more live users represent the Commander (Cdr) and his key staff elements at each tier such as the Intelligence Officer (S2) and Operations Officer (S3). The S2 is responsible for collecting intelligence and preparing Intelligence Preparation of the Battlefield (IPB) products for the Cdr. The S3 is responsible for generating Courses-of-Action (CoAs) and drafting and coordinating Operational Plan (OPLAN) and Operational Order (OPORD) products and related Warning Order (WARNO), and Fragmentary Order (FRAGO) products for approval by the Cdr [6]. At each tier the live operational users are responsible for commanding, controlling, planning and monitoring the execution of their subordinate units. The experiment is designed to enable the assessment of the needs and preferences associated with the supported modalities of collaboration and interoperability between and among the live operational users at tiers n and n-1. These modalities include voice, text and graphics.

Technically, the SINCE environment is also designed to be modular and scalable to support an Open System approach with respect to the interconnection a) between and among national and multinational C2 systems that form the C2 environment, b) between and among national and multinational M&S systems that constitute the M&S environment and c) between the above C2 and M&S environments. Each environment is said to be a federation of systems that must be interconnected in accordance with the rules of the federation and initialized to a common scenario starting point. Each environment is flexible in supporting one or more tiers of federates. For example, the C2 environment may have both national and multinational (coalition) federates. A national or multinational C2 federate may be a service unique (e.g. army, navy, air force, amphibious) or a multi-service (joint) federate. Not all national federates are required to be multinational. The SINCE design supports the use of multiple physical networks to accommodate both access and traffic needs of each environment that must be interconnected and federated to support the user with a common scenario. The M&S environment may also have both national and multinational federates. They can be segregated to support different standards such as the IEEE Distributed Interactive Simulation (DIS) [8] or the IEEE High Level Architecture (HLA) [9]. They can be further segregated within each of these standards to support different DIS Protocol Data Units (PDUs) or HLA Federation Object Models (FOMs).

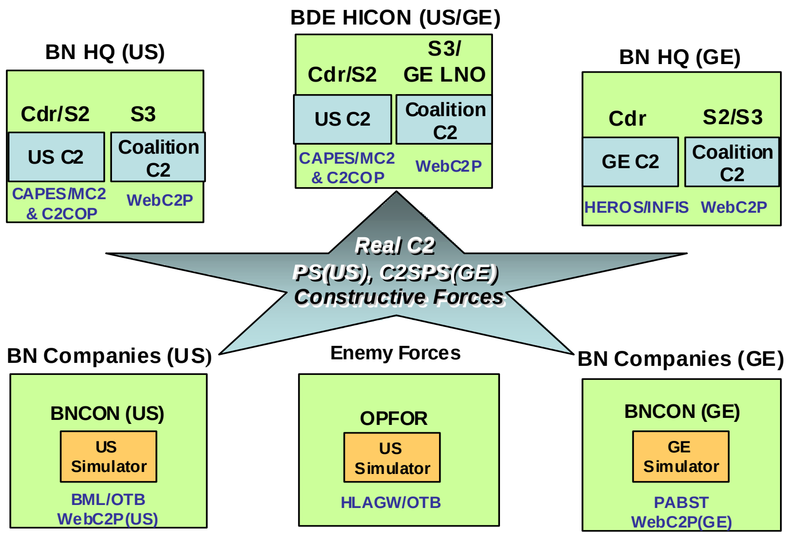


Figure 1. SINCEx1 Multi-National, Multi-Echelon Operational View

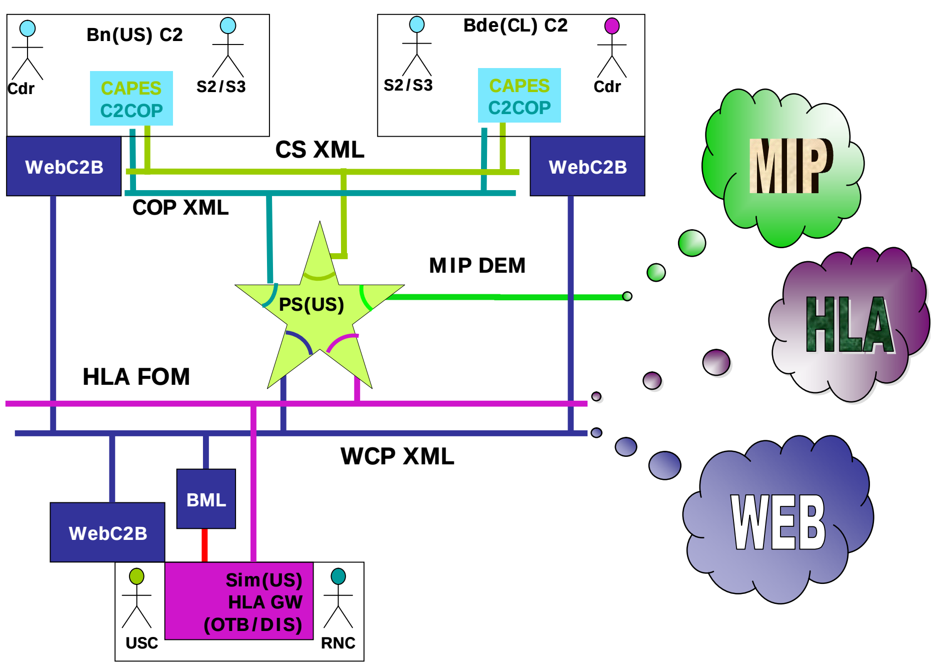


Figure 2. SINCEx1 Open System View from a US perspective

The SINCE environment not only federates within the HLA environment but across DIS federates and C2 national and multinational federates using gateways (GW) and proxy-servers (PS). Considering the Military Decision Making Process (MDMP) [7] two concurrent activities must be accommodated by the total federation: currently executing operations (current Ops) and future planning of operations (future Ops). C2 federates may be involved in one or both types of concurrent activities. M&S federates are typically involved only with the current Ops. A future SINCE design will address the use of M&S federate in future Ops. Once demonstrated, it would be possible in the foreseeable future for a M&S federate to be involved concurrently with both current and future Ops. As shown in Figure 2, the US federates participate in a four-federation environment consisting of a) a national C2 federation of the PS(US), CAPES and C2COP federates, b) a coalition federation of the PS(US), WebC2Portal (WCP), and the Battle Management Language (BML) federates, c) a national DIS M&S federation of One Semi-Automated Force (OneSAF) Test Bed (OTB)[10] and the High Level Architecture Gateway (HLA GW) federates and d) a multinational federation supporting the multinational FOM consisting of the HLA GW and the PS(US) federate. Note that the US C2 national federation may be further treated as two sub-federations segregating planning and execution monitoring functions. The US C2 federates participating in the coalition federation use the Multinational Interoperability Program (MIP) [11] standard for the current Ops and the SINCE XML based Web interface[12] for both current and future Ops. This enables us to assess tradeoffs between the two means of sharing coalition information. As shown in Figure 3, the GE federates are also members of similar federations. The main difference in the design is that the PS(GE) only participates in the GE national C2 federation and the multinational M&S HLA federation. Common to both US and GE designs is the use of three network protocols: a) the MIP standard for multinational current Ops execution monitoring, b) the Web for multinational current Ops execution monitoring and future Ops collaborative planning and c) HLA for multinational current Ops execution. Ultimately, the inherent strength of the SINCE approach is the ability to support different national agendas and designs with a common set of interfaces.

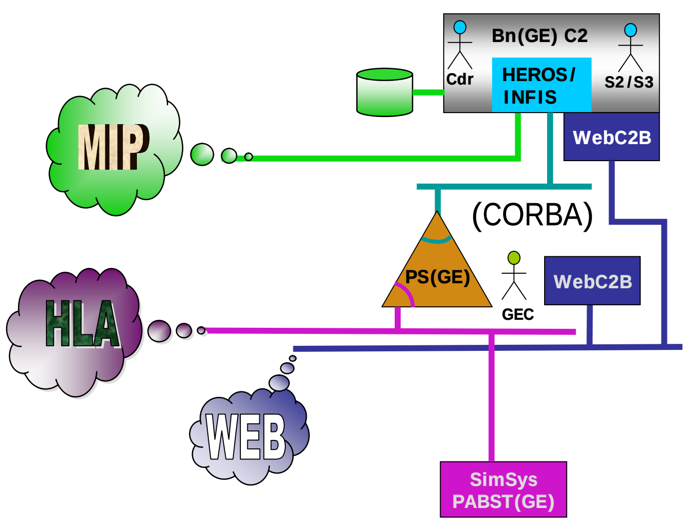


Figure 3. SINCEx1 Open System View from a GE perspective

The SINCE Implementation

Operationally, we adopted and adapted an existing scenario with a broad mission for a multinational brigade size force Bde(MN). The scenario included a US battalion, Bn(US) and a GE battalion, Bn(GE). Thus the live component of our experiment had three headquarters: HQ(Bde, MN), HQ(Bn, US) and HQ(Bn, GE) as shown in Figure 1. The HQ(Bde, MN) was given the mission to secure an objective area to its north while blocking the enemy from threatening to cut off its logistics by attacking its flank from the east as shown in Figure 4. The Bde Cdr had the choice of using any number or combinations of up to 24 tasks selected from the C2 Information Exchange Data Model (C2IEDM) [13] in a) generating his/her concept of operation and course of action and b) tasking his/her subordinate battalions. As a trivial example, the Bde mission could be accomplished by a) tasking HQ(Bn, US) to secure the objective area in the north and tasking the HQ(Bn, GE) to block the enemy threatening to infiltrate from the east or by b) interchanging their tasks. All the tasks implemented in SINCEx1 are standard military tasks also described in MIL-STD 22525B [14] and FM 1-02 [15]. A subset of these tasks are shown in Table 1. Once the battalion orders were coordinated and issued to the constructively simulated subordinate companies, they were recast into the types of commands understood by their respective M&S systems. For US companies, tasks were automatically mapped into OTB commands using the BML and readjusted manually by the OTB operators for any terrain discrepancies. For GE companies, tasks were manually entered into PABST. A future implementation of the C2SPS(GE) will use an extended FOM to command HLA entities in PABST.

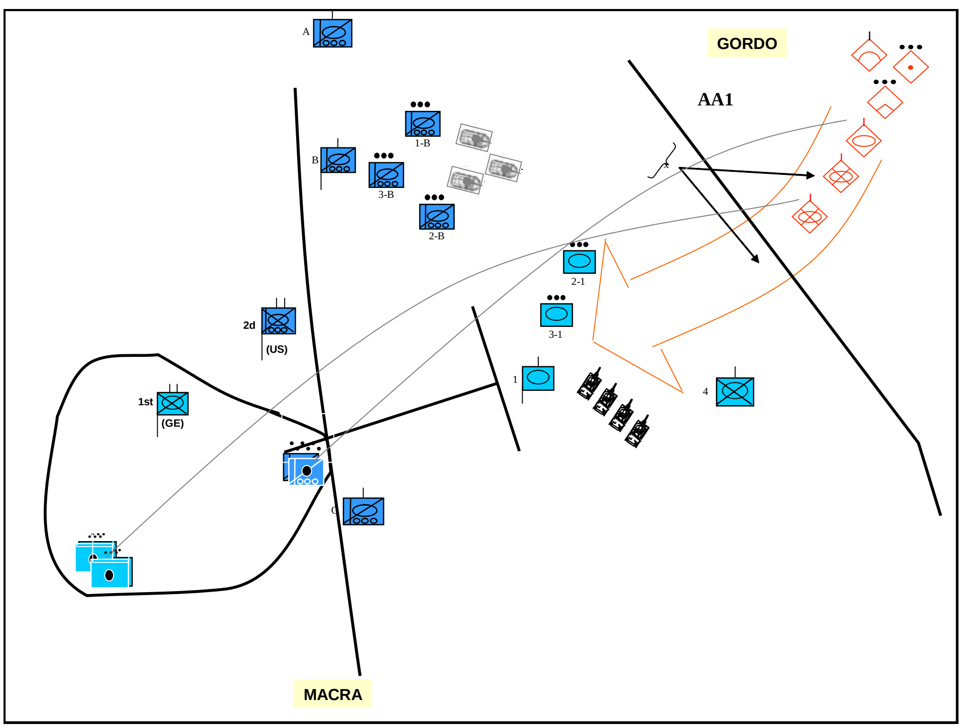
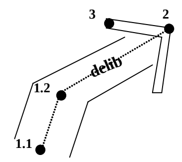
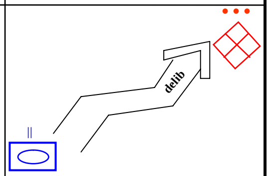
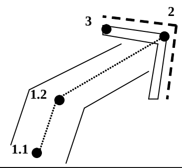
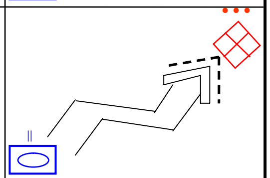
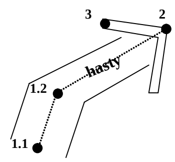
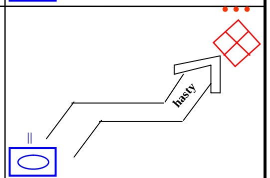
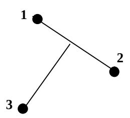
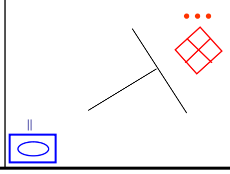


Figure 4. An operational Overlay corresponding to a sample OPORD(Bn)

Table 1. Sample Tasks available to create an operational Overlay for sample OPORD(Bde/Bn)

Action: Comments	**Graphical Representation**	**Example**
Attack, deliberate: Use Axis of Advance (Main Attack) to represent the path for the unit to attack. The word 'delib' is added to denote such action.		
Attack, feint: Use Axis of Advance for feint to represent the path for the unit to attack.		
Attack, hasty: Use Axis of Advance (Main Attack) to represent the path for the unit to attack. The word 'hasty' is added to denote such action.		
Block: Defined in MIL-2525B.		

Technically, at the peak of the experimentation period, the confederation of networked federations of systems totaled 23 computers as shown in Figure 5. All federates were interconnected into a US National Local Area Network (LAN) and a coalition/M&S LAN also shown in Figure 4. Thus for SINCEx1, only two physical networks were implemented. This was due to the fact that available GE computers were only enabled with a single network card. Practically, due to traffic demands and access separation control, three physical networks would be necessary to support the logically distinct National C2, Coalition C2, and M&S federates. This could be implemented in a centralized approach as was chosen by the US Technical Working Group (TWG) or in a decentralized approach as was chosen by the GE TWG. The US design solution as shown in Figure 2 is to provide a single C2SPS(US) computer enabled with three LAN cards and have the Coalition Domain Manager (CDM) component mediate among all three federations. This represents a centralized approach to accommodate the three types of federations. Ideally, using the decentralized GE design, as shown in Figure 3, where the C2SPS(GE) only mediates between national C2 and M&S federations, the C2SPS(GE) should have been enabled by two LAN cards to support the two federations with no traffic interference. The C2SPS(GE), however, was installed on a laptop which could only support access to a single LAN. As a result of this hardware limitation, the M&S traffic shared the same network bandwidth as the Coalition C2 federation. When M&S traffic was low, there was no interference with the C2 traffic. When C2 traffic required priority, the M&S traffic was temporarily suppressed to avoid communications errors. Similarly, the INFIS(GE)/HEROS(GE) C2 systems that are used to mediate between GE national C2 and Coalition C2 were also using a single LAN. Future implementations are anticipated to be enabled by two LAN cards to support greater access separation control between these two C2 federation communities. In SINCEx1, however, this was not an issue for the GE implementation since there was only one C2 system that only represented the GE Coalition C2. In a more elaborate experiment with more than one GE national C2 system this would most likely be a requirement.

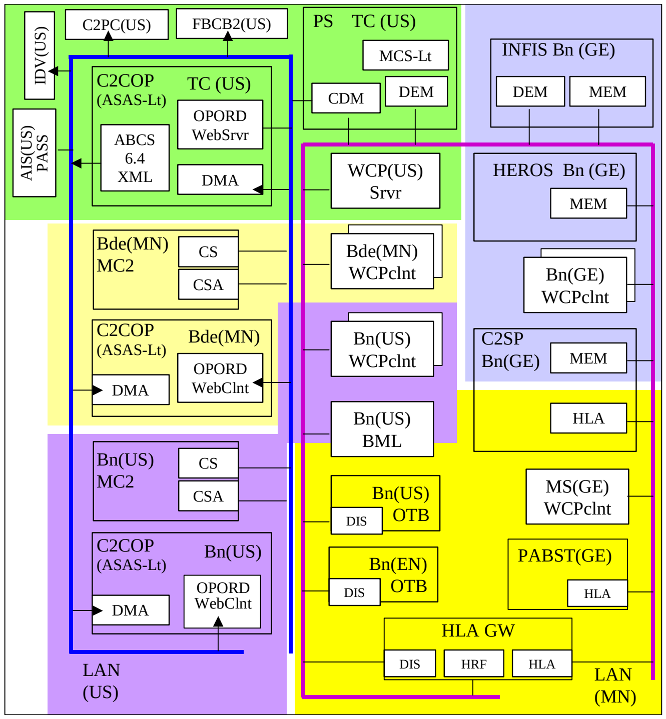


Figure 5. SINCEx1b Coalition Network Connectivity Architecture

The SINCE Execution

The Operational Working Group (OWG) created a number of test cases that were exercised to verify that the implementations were acceptable to the user. For each test case there were three phases: a) initialization, b) planning and c) execution. After each initialization the users at each federate verified that their screens showed only what they would be expected to see. Thus, for example, enemy entities that were out of range of a given GE/US unit would not be observed by a federate that represents the parent GE/US unit. Or similarly, the M&S federate controlling enemy entities, OTB(OPFOR), would only see the friendly entities within its range or if made available by external sources. Once the initialization Common Operational Picture (COP) was agreed upon, the federates moved to the next phase, i.e., the collaborative planning phase. Each HQ was responsible to initiate an OPORD for its subordinates. Thus

a. HQ(Bde, MN) initiated drafting of its OPORD(Bde, MN), then
b. HQ(Bn, US) initiated drafting of its OPORD(Bn, US), and concurrently
c. HQ(Bn, GE) initiated drafting of its OPORD(Bn, GE).

Since the content of the OPORD(Bn, *)[1] depends upon the content of OPORD(Bde), the Bde HQ first initiated a collaboration session and collaborated on its OPORD(Bde) with its subordinate Bn HQs. As part of the collaboration process, each OPORD evolved within their respective collaboration sessions from OPORD(initial, collaborate) state to the OPORD(final, collaborate) state through a series of iterative OPORD(feedback/update, collaborate) states. Once a C2 planning federate issued an OPORD(final, collaborate), its corresponding C2 execution monitoring federate published an OPORD(initial, execution) for analysis, planning and execution by its subordinate C2 planning

[1] * = GE/US

federate. Thus the HQ(Bn, US/GE) initiated OPORD(Bn, *, initial, collaborate) only after it had received OPORD(Bde, MN, initial, execution). Collaboration on FRAGOs was implemented similarly to OPORDs and using the same XML schema. For execution, a FRAGO was represented by OPORD(update, execution). Since each OPORD/FRAGO has a start time and an end time, any OPORD(final, collaborate) that overlaps in time with a previous OPORD(final, collaborate) can be republished as an OPORD(update, execution), otherwise, it would be published as an OPORD(initial, execution). Since the OPORDs are published in XML, They are available for review and analysis and editing both graphically and textually.

Each HQs was enabled to initiate its separate planning session and collaborate to transition a plan to its final state. While in the planning state, M&S federates continuously monitored their environment. OTB(OPFOR) was allowed to execute maneuvers in accordance with guidance from the OWG. OTB(US_BLUFOR) and PABST(GE_BLUFOR) were allowed to report any observations while awaiting their orders. Thus the current situation was allowed to evolve during the planning process and the user was enabled to observe the current situation in one window while collaborating on the three separate plans in their respective planning window. The planning window allowed the user to toggle among each of the ongoing collaboration sessions. Once OPORD(Bn, GE/US) were finalized, OTB(US_BLUFOR) and PABST(GE_BLUFOR) were tasked to perform their combat mission and shared BLUFOR tracking (BFT) of position reports as well as OPFOR SPOT reports. The experiment was paused periodically to determine discrepancies due to time delays, aggregation, filtering and software bugs that were then fixed “on the spot.”

Outcomes

The SINCE Program achieved the project's objectives for Experiment 1 by successfully demonstrating connectivity, federation, collaboration and interoperability in a seamless process among coalition C2 systems, among coalition M&S systems and between a coalition C2 systems and a coalition of M&S systems. Important insights of both technical as well as operational nature were acquired to improve both design and implementation of the next experiment. Furthermore, capabilities of both C2 and M&S systems that need further development were identified to enable future experiments to be conducted with more flexibility and in a more efficient and comprehensive fashion.

From a networking point of view, we observed that for the size of a realistic brigade/battalion scenario of several hundred entities, one should have separate networks to accommodate C2 data and M&S data on a non-interference basis. This is important if one wishes to experiment with continuous planning, i.e., planning a future operation while monitoring a current operation. With a common network, the experiment could still proceed but in a more serial fashion. Since in real operations, there is no on-going simulation traffic, M&S traffic should always be allocated a dedicated network to avoid the artificialities of potential conflict between the two types of traffics.

Minor display discrepancies were observed when comparing the locations of rasterized features used by the C2 systems to the vectorized features used by the M&S environment. These discrepancies were due to the inherent inaccuracies associated with maps of different resolutions. Another possible contributing element to the discrepancies was the fact that not every map background used the same source map. In general, the M&S display did represent the correct relevant terrain features, i.e., mountains, hills, rivers, valleys, urban areas, as encountered on the C2 displays. Only the 2D mode was used in the M&S environment. The 3D mode was not required. Since the M&S systems were required to control platforms, they used maps at the 1:50K scale and since the C2 systems were required to command and control companies and war-game with platoons, an ADRG map at the resolution of 1:250K was adequate. This caused some issues when the C2 system operator tried to create routes for the M&S entities. Considering that the number of entities simulated by the M&S environment did not exceed 600, the M&S workstations ran smoothly without crashing. Since each system was responsible for preprocessing the standard terrain products, such as Digital Terrain Elevation Data (DTED), Digital Feature Attribute Data (DFAD) and Arc Digitized Raster Graphics (ADRG), into its own unique format, it was observed that key locations such as bridges over rivers were not calibrated to the same reference points. These discrepancies should be moot if the entities behave as Semi-Automated Forces (SAFs). A SAF should be able to know automatically how to get around an obstacle and re-route itself to get to an objective. However, since the terrain was abundant with rivers and steep terrain covered much of the conflict area, it seemed that the SAF required a significant amount of intervention from the operator to be made often for even the most rudimentary commands. For example, individual vehicles were not smart enough to cross a river at a "bridge", even when put in a line formation and given a route over the bridge and straight down the center of the bridge. M&S Subject Matter Expert (SME) operators are able overcome such discrepancies by invoking “magical” moves. Consequently, the need for M&S operators will continue to exist into the foreseeable future even once a multi-echelon, multinational BML becomes common to both C2 systems and the M&S environments.

Conclusions

Overall, the US-GE SINCE team considers the conduct of SINCE Experiment 1 a success. The program objectives were effectively addressed by leveraging existing (Current Force) and evolving (Future Force) C2 systems and prototypes as well as existing modeling and simulation systems and prototypes. While some technical integration problems were experienced that resulted from the increase in the scale of the test bed from SINCEx1a to SINCEx1b and the introduction of new capabilities in SINCEx1b (JUL 04, Fort Leavenworth, KS) above those tested out during SINCEx1a (NOV 03, Greding Germany), none of these problems was a “show-stopper” or of major issue. Future SINCE experimentation plans should be adjusted to allow more pre-experiment integration testing both nationally and internationally to maximize the amount of operationally oriented tests. There is little question that the experiment conducted provides significant insight as to how to improve multinational collaboration and achieve semantic interoperability. The SINCE environment provides a cost-effective means to address the numerous issues and enable national, Joint and coalition partners to learn to better understand each other’s “business rules”, concepts of operations, tactics, techniques and procedures.

Acknowledgements

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