Experimenting with C2 Applications and Federated Infrastructures for Integrated Full-Spectrum Operational Environments in Support of Collaborative Planning and Interoperable Execution

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Abstract

In this paper we describe the design, implementation, and execution of and the results obtained from the SINCE experiment 1a (SINCEx1a) [1]. The goals of this experiment were (a) to test and verify the information exchange among all of the US and German systems connected in the experimentation environment, and (b) to demonstrate and validate with military user participation that the C2 functionality implemented was adequate to support future planned operational experiment, SINCEx1b. SINCEx1a implementation followed, adopted and adapted a code of best practice approach for experimentation [3]. Both adopted features and adapted elements are summarized herein. 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 SINCEx1a but for the planned follow-on experiments and b) developing the SINCEx1a experimental configuration that was finally used in the conduct of the actual experiment. The infrastructure concepts addressed design 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 [2]. An integral part of the solution was the establishment of the methodology by which the various information architectures would be harmonized within federations and across federations. The infrastructure for SINCEx1a was embodied in a Proxy Server (PS) and Portal that included the various adapters and filters that mediated between the various incompatible heterogeneous interfaces inherent in the selected federate systems using a common domain model (CDM) [4] encoded in XML. The selected federates for the experiments represented the deployments of future forces that are required to be not only network-centric with respect to their own assets but also with respect to other Joint, National and Coalition assets. The SINCEx1a addressed the main issue for any network-centric architecture which is the establishment of connectivity, federation, collaboration and interoperability in a self organizing way among all elements of the force to include combat (e.g. maneuver), combat support (maneuver support), combat service support (e.g. maneuver sustainment) and C2 (e.g. battle command) assets. A significant contribution of SINCEx1a was to establish a solid foundation for future experimentation which would identify and reduce the gaps in the information architectures as required by the user through the operational scenario and the information models [4] supported by the various federates.

Objective

The first goal of the technical SINCEx1a was to test and verify the technical approach to enabling information exchanges for collaborative planning and interoperable execution in accordance with multinational user requirements across US and German data boundaries in a single integrated experimentation environment. Such boundaries exist between C2 systems, between modeling and simulation (M&S) systems and between C2 and M&S systems. The second goal was to lay the foundations for a follow-up experiment, SINCEx1b, by demonstrating and validating, with military user participation, the adequacy of the implemented C2 functionality to support a more operationally oriented experiment. In addition, an important goal for SINCEx1a was to establish a baseline for the functionality and performance required for similarly configured national experimentation and future international SINCE experiments.
**Experimenting with C2 Applications and Federated Infrastructures for Integrated Full-Spectrum Operational Environments in Support of Collaborative Planning and Interoperable Execution**

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**The original document contains color images.**
Introduction

The SINCE experiment 1a (SINCEx1) took place at the MIP facility of WTD-81, Greding, GE on 10-21 November, 2003. Over thirty representatives from the US and German technical and military user communities (USA CERDEC IBCD, USA TRADOC and CALL, German BWB and HeeresAmt (Army Office) plus supporting US and German contractor teams) participated in this experiment. SINCEx1a is the first in a series of experiments being carried out as part of the SINCE Program initiated to enable the conduct of multinational C2 experiments supported by C2 and modeling and simulation (M&S) systems designed to address the transformation of collaborative planning and interoperable execution in a coalition environment. On the US side we used the ASAS Lite systems to automatically collect, develop and disseminate the HICON and US Battalion and below operations centers User-Defined C2 Common Operating Picture (C2COP). The US COP was maintained by ASAS-Lite in a JCDB [11] surrogate. We used the CAPES/MC2 systems to support the conduct of real-time collaborative mission planning and unit tasking of the simulated US forces playing in the SINCE experiment operational scenario. We used the OTB systems [8] to simulate the operational play of the US Blue, and enemy Red forces required to stimulate the users and generate appropriate Situation Awareness (SA) reports to the US C2 Systems. On the GE side, we used the PABST system to simulate the operational play of German Blue forces and generated SA reports on their movement. The German INFIS system enabled the exchange of COP information with the German HEROS C2 system via the Multilateral Interoperability Programme (MIP) Data Exchange Mechanism (DEM) protocol [6,12]. The WebC2P enabled coalition force planners to view the real-time coalition User Defined Operation Picture (UDOP) and also provided an interactive capability to view and modify different aspects of an electronic representation of the coalition OPORD/OPLAN. As depicted in Figure 1, the US Proxy Server provided the automatic information routing and data format/protocol adaptation/conversion processing required to seamlessly exchange real-time COP and OPORD/OPLAN change information between all to these systems. The MCS Lite system is part of the US MIP solution and was embedded as part of the US Proxy Server to support the monitoring and direct display the information that passed across this server.

![Figure 1: Simplified SINCEx1a Information Flow Diagram](image-url)
A key technical feature that was implemented and demonstrated was the use of a common XML schema to represent the various C2 products that embodied the information exchange requirements (IERs). C2 products included a mix of messages represented by friendly position reports (positionRpt) and observations of enemy units called SPOT reports as well as operational orders [13] (OPORDs), fragmentary orders, (FRAGO), operational plans (OPLANs), and warning orders (WARNOs). The common schema for SINCEx1a was developed as a W3C XML schema [9] that enabled all instances of information exchange to be checked for being well-formed as well as for being valid. This common schema was used to generate all instances of IER in all phases of SINCEx1a. Publish and subscribe (P&S) mechanisms were also a major feature implemented for both C2 systems as well as for M&S systems and for their cross coupling. The C2 system exchanged Java objects within the framework of the Java Message System (JMS) topics and the M&S systems exchanged Realtime Platform Reports within the framework of the High Level Architecture (HLA) Federation Object Model (RPR FOM) [7]. This enabled a highly flexible and upgradeable filtering mechanism for information that needed to take place to appropriately support effective collaboration and interoperability as well as for stimulating the exchange via combat simulations. Filtering is possible based upon classification, source, content, time and location as basic criteria. SINCEx1a was limited to unclassified coalition data. To facilitate collaboration between current and future allies with disparate means for collaboration, we’ve found it both necessary and convenient to provide Web services that include a Web C2 Portal (WebC2P) via a standard browser that enables the sharing of coalition domain items such as the user-definable coalition COP initialization and updates and the coalition plans and orders. We have also initiated the representation of the architecture of this experimentation environment in UML [10] and identified key use cases and issues for each of the four phases essential for network-centric C2 system of systems (SoS) integration: inter-connection, inter-federation, inter-collaboration and inter-operation.

<table>
<thead>
<tr>
<th>SINCE Proxy Server (PS) Actors</th>
<th>SINCE Proxy Server (PS) Use Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federate systems: WebC2P, CAPES, C2COP, MIP(AL), OTB</td>
<td>Initialize Federate</td>
</tr>
<tr>
<td>USC (info officer/X6)</td>
<td>Interconnect System</td>
</tr>
<tr>
<td>(AL – Ally)</td>
<td>Federate System</td>
</tr>
<tr>
<td>(X0/X2/X3 – Cdr/Intel/Ops officers)</td>
<td>Stimulate Federate</td>
</tr>
<tr>
<td></td>
<td>Interoperate with Coalition Federate (to Monitor Execution)</td>
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</table>

<table>
<thead>
<tr>
<th>CAPES Actors</th>
<th>CAPES Use Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP_CS</td>
<td>Retrieve COP</td>
</tr>
<tr>
<td>User(US):X0/X2/X3</td>
<td>PLAN Operations</td>
</tr>
<tr>
<td>CAPES(Higher, Lower and Peer Echelons)</td>
<td>Collaborate on Plan</td>
</tr>
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<table>
<thead>
<tr>
<th>C2COP Actors</th>
<th>C2COP Use Cases</th>
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</thead>
<tbody>
<tr>
<td>PS_DMA</td>
<td>Monitor Execution</td>
</tr>
<tr>
<td>User(US):X0/X2/X3</td>
<td>Manage US DB</td>
</tr>
<tr>
<td>C2COP(Higher, Lower and Peer Echelons)</td>
<td>Manage Coalition DB</td>
</tr>
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<table>
<thead>
<tr>
<th>WebC2P Actors</th>
<th>WebC2P Use Cases</th>
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</thead>
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<tr>
<td>PS_IPS</td>
<td>Collaborate on Plan</td>
</tr>
<tr>
<td>OTB</td>
<td>View Coalition COP</td>
</tr>
<tr>
<td>User:X0/X2/X3 (AL/Liaison)</td>
<td></td>
</tr>
<tr>
<td>MSC(US/AL)</td>
<td></td>
</tr>
<tr>
<td>C2COP(Higher, Lower and Peer Echelons)</td>
<td></td>
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<table>
<thead>
<tr>
<th>OTB Actors</th>
<th>OTB Use Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>(US) MSC(US):(Red/White/Blue)</td>
<td>Generate Ground Truth</td>
</tr>
<tr>
<td>M&amp;S Federate (AL)</td>
<td>Generate Enemy Reports (Red, White)</td>
</tr>
<tr>
<td>PS_HRF</td>
<td>Generate Friendly Reports (Blue, White)</td>
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<table>
<thead>
<tr>
<th>MIP Actors</th>
<th>MIP Use Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS_DEM</td>
<td>Report Coalition Situation</td>
</tr>
<tr>
<td>C2 System(AL)</td>
<td>Report Coalition Execution</td>
</tr>
<tr>
<td></td>
<td>Report Coalition Enemy</td>
</tr>
</tbody>
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Table 1. SINCE System Level Federates, Their Actors (External Interfaces) and Use Cases (Functionality)[1]
Background

In previous papers [1,2] we described the detailed goals and objectives of the U.S. and German Simulation and C2 Information Systems Connectivity Experiments (SINCE) Program. In summary, SINCE is implementing a reusable experimentation environment specifically tailored to support the conduct of Coalition and Joint Warfighter experimentation across the full spectrum of technical and operational needs. Under the US SINCE effort, evolving C2 and Modeling and Simulation (M&S) systems are being networked and integrated into a flexible testing environment that will allow both the technical and operational communities to experiment with and evaluate concepts for implementing and conducting collaborative military operations in a network-centric coalition force operational environment. The Federal Republic of Germany is also implementing a similar networked environment of C2 systems and M&S system which is linked to the US SINCE environment during the conduct of joint US and German coalition C2 experiments. The primary focus of SINCE experimentation is on exploring concepts, defining technical requirements and evaluating operational utility of real-time collaboration capabilities and information exchange interoperability as needed to support the conduct of coalition and joint operations. SINCE echelon of concentration are Future Force operations at the battalion and below level, operating in highly mobile and dynamically changing battlefield scenarios. Under SINCE, the US and Germany plan to conduct three coalition experiments, each increasing in levels of complexity and operational scale. The conduct of each of these experiments will be partitioned into two distinct parts, a Technical Experiment part and an Operational Experiment part. The rationale for conducting a separate technical experiment is simply to assure that all the technical functionality needed to support the conduct of a planned operational experiment is indeed in place, working as required, and adequately scaled to support the envisioned complexity of the operational experiment.

Experimentation Design and Approach

SINCEx1a was the first of three planned coalition experiments, each with increased level of technical and operational complexity and scale. The conduct of each of these experiments is partitioned into two distinct parts, Technical and Operational. The conduct of a separate technical experiment is essential to assure that all the technical functionality needed to support the conduct of a planned operational experiment is indeed in place, working as required, and adequately scaled to support the envisioned complexity of the operational experiment. The first week of the two-week experimentation period was dedicated to the technical setup and the system of system integration, performance testing and debugging of the combined US and German SINCE experimentation environment. This is the first time that most of these systems were ever networked under a common environment. The second week of the experimentation period was devoted to exercising the technical and operation capabilities implemented, with the participation of operational users, in a dry run of the operational scenario that would be played out in greater detail and complexity in the planned, future SINCE Operational Experiment 1b (SINCEx1b).

Using the teambuilding paradigm [1] we phased the experiment in accordance with the four phases as shown in Figure 2. These phases characterize the entire SINCE test bed as well as individual federates and user operations. The capability is provided to filter information/reports based upon pre-established criteria: (s)single, (a)aggregated, (c)coalition, (ca)aggregated & coalition. Collaboration on Operational Order (OPORD) was enabled through a flexible cycle of initial draft (i), feedback(fb), update (ud) and final(f). A user issuing an OPORD or any part of it as a C2 product (prdC2), may indicate in the header the level of collaboration desired. By issuing a prdC2(i), no further collaboration is warranted. By issuing a prdC2(i/ud), prdC2(fb) are solicited. The changes were accepted both graphically and textually. The SINCE program is not intended to be a vehicle for enhancing C2 applications or M&S functionality beyond their current capabilities. Our approach is to identify deficiencies and bring them to the attention of the specific system developers. For example, we adjusted the scenario to ensure that only entities whose behavior is already defined by the M&S systems would be called upon to support the experiment. The current version of the applications used (CAPES and WebC2P) did not enable the user to concurrently open and update OPORDs from two different Sources, e.g., Bde/Bn or Bn/Bn. Therefore, collaboration was done sequentially, first on the Bde OPORD, then on each of the Bn OPORDs one at a time. The other two types of IERs implemented to enable situation awareness were prdC2 = positionRpt (Friendly Force Position Report) and prdC2 = SPOTrpt (Enemy Force Position Report). These were generated by the M&S systems.
Each state has its corresponding UML use cases which were tested using three test cases as shown in Figure 3. Since basic networking connectivity was not a major issue for SINCEx1a we addressed the connectivity state and the federation state in a single integrated test case called Initialization. Technical and operational initialization of this network of C2 and M&S systems and subsequent real-time information exchange, was started by electronically publishing an Xml-structured OPORD/OPLAN document from the CAPES/MC2 system to all of the participating systems via the US Proxy Server. The US Proxy Server automatically adapted and distributed this initialization data into the structural formats and protocols required by the participating systems i.e.- US C2 systems USCOP database updates, German C2 system MIP database updates, US and German M&S systems HLA PDUs exchanges/updates.
**Experimentation**

Figure 4 provides a high level approximate view of the physical arrangement of the experiment. All the federate systems, US and GE, were connected via a high speed LAN using TCP/IP and HTTP so that we could focus on the C2 and M&S issues at the transport, session, presentation and application layers. Clearly future experiments will have to contend with less robust means of networking. In addition, the scenario was unclassified and all systems operated using unclassified data. Clearly future experiments will require firewalls and other security measures as required by the scenario. All systems were numbered as well as all logical grouping of IERs as shown in tables 1-3.

Each of the federate systems indicated in Figure 1, had a specific role in the experiment that was characterized by its use cases (The use cases as well as the associated actors for each system level federate are listed in Table 1.) The Actor-Use case dependency is associated with one or more IERs. The Use Cases were implemented to enable each federate to interact with its federated actor systems as shown in the sequence diagrams of Figures 5-7. The IERs were grouped in accordance with the 3 Test Cases. Going through all three Test Cases constituted a single Test Pass, regardless of how long one would dwell within each Test Case. Initial passes were conducted to ensure completeness and accuracy of the information exchanged, subsequent passes were conducted to assess performance under various scenario loads. A simple experiment Test Report was generated and distributed to allow each experiment participant (a federate operator or user) to document and detail observations and findings. Each Test Report was identified with a number, a subject, and as a type (Outcome, Timing, Deficiency, Incompatibility, Limitation, Recommendation). Operators/observers were assigned to each federate and asked to monitor each IER as anticipated in accordance with the sequence diagrams shown if Figures 5-7. In addition each report was judged as to its criticality, and enabled the recording of the context by providing the date and time, federates involved, IERs involved, supporting screen capture, database snapshot and short narrative of the problem and or recommended solution. In SINCEx1a, logging was done in ad hoc manner. Because of display resolution limitations and symbology differences, especially when comparing M&S displays with C2IS displays, it was hard to correlate quickly specific units across displays. This caused the experiment to be slower than anticipated. The lessons learned with respect to data collection procedures, should make SINCEx1b much more rigorous in that regard.
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<td>1</td>
<td>InitialC2Entities</td>
<td>IERprdC2exeOPORD1stBCT(US).xml</td>
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<tr>
<td>2a</td>
<td>cCOP(i)</td>
<td>initial coalition situation, TO, BG</td>
</tr>
<tr>
<td>2b</td>
<td>geCOP(i)</td>
<td>initial GE situation, TO, BG</td>
</tr>
<tr>
<td>2c</td>
<td>usCOP(i)</td>
<td>initial US situation, TO, BG</td>
</tr>
<tr>
<td>2d</td>
<td>geTO(i)</td>
<td>PABST initialization (1st Bn GE TO)</td>
</tr>
<tr>
<td>2e</td>
<td>usTO(i)+redTO(i)</td>
<td>initial Bn US TO + red TO</td>
</tr>
<tr>
<td>2f</td>
<td>filtered (2e)</td>
<td>OTB initialization (2nd Bn US + red TO)</td>
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Table 2. IER Reference Table for Test Case 1a - Scenario Initialization

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<td></td>
<td>IERprdC2exeOPORD1stBn(GE)word/xml</td>
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<td>8a</td>
<td>OPORD(i)</td>
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<tr>
<td></td>
<td></td>
<td>IERprdC2exeOPORD1stBn(GE)word/xml</td>
</tr>
<tr>
<td>8b</td>
<td>OPORD(i)</td>
<td>IERprdC2exeOPORD1stBCT(US)word/xml</td>
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<td></td>
<td></td>
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<td>9a</td>
<td>OPORD(fb)</td>
<td>feedback on Bde OPORD(i)</td>
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<tr>
<td>9b</td>
<td>OPORD(fb)</td>
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<td></td>
<td></td>
<td>final Bde OPORD for execution by BNs</td>
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</tr>
<tr>
<td>11a</td>
<td>OPORD(f)</td>
<td>final Bde OPORD for execution by BNs</td>
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<td>12a</td>
<td>OPORD(fb)</td>
<td>feedback on 2ndBn(US) OPORD(i)</td>
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<tr>
<td>12b</td>
<td>OPORD(fb)</td>
<td>feedback on 2ndBn(US) OPORD(i)</td>
</tr>
<tr>
<td>13a</td>
<td>OPORD(ud/f)</td>
<td>update to 2ndBn(US) OPORD(fb)</td>
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<td></td>
<td></td>
<td>final 2ndBn(US) OPORD for execution by 2ndBn(US) Companies</td>
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<td>OPORD(ud/f)</td>
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<td>OPORD(f)</td>
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<td>OPORD(f)</td>
<td>final 1stBn(GE) OPORD for execution by 1stBn(GE) Companies</td>
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Table 3. IER Reference Table for Test Case 2a – Collaborative Planning

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<tr>
<td>3a</td>
<td>GEsCOP(r)</td>
<td>GEunits Ground Truth HLA</td>
</tr>
<tr>
<td>3b</td>
<td>GEsCOP(r)</td>
<td>GEunits Ground Truth DIS</td>
</tr>
<tr>
<td>4a</td>
<td>UssCOP(r)</td>
<td>GEunits Ground Truth DIS</td>
</tr>
<tr>
<td>4b</td>
<td>UssCOP(r)</td>
<td>GEunits Ground Truth HLA</td>
</tr>
<tr>
<td>5</td>
<td>sCOP(r)</td>
<td>positionRPT.xml,SPOTrpt.xml</td>
</tr>
<tr>
<td>6a</td>
<td>cCOP(f)</td>
<td>Updated positionRPT.xml,SPOTrpt.xml</td>
</tr>
<tr>
<td>6b</td>
<td>geCOP(f)</td>
<td>friend/foe MIP updates</td>
</tr>
<tr>
<td>6c</td>
<td>usCOP(i)</td>
<td>Updated positionRPT.xml,SPOTrpt.xml</td>
</tr>
</tbody>
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Table 4. IER Reference Table for Test Case 3a – Interoperable Execution
Figure 5. IERs (in Yellow) for Test Case 1a: Initialization. M&S federates on Left, C2IS federates on right.

Figure 6. IERs (in Yellow) for Test Case 2a: Collaboration of OPORDs. M&S federates on Left, C2IS federates on right.
Experimental Results

The automatic initialization of all these C2 and M&S systems and confirmation that they could all display the same starting, Common Operating Picture (COP), i.e.- Blue and Red Force Unit locations and appropriated BDE and BN level OPORD/OPLAN mission tasking was demonstrated and is viewed as a significant accomplishment. This initialization process was completed by all systems in approximately 5 minutes and validated for correctness by military users from TRADOC, CALL and the German HeeresAmt (Army Office). The second accomplishment demonstrated that simulated Blue and Red Force movement, and associated position updates generated in either the ONESAF or PABST M&S systems could be published to and viewed in real-time on the displays of all the US & German C2 systems, the WC2P and on US and German M&S systems. Real-time Blue and Red Force COP tracking and synchronization between C2 and M&S systems was successfully demonstrated to approximately the 600-entity level for the current implemented coalition experimentation environment. The third accomplishment demonstrated in this experiment was a capability enabling coalition force commanders to collaboratively plan, modify plans and synchronize coalition force operations via use of the WebC2P interactive, XML-based OPORD/OPLAN information exchange mechanisms. Both TRADOC and HeeresAmt military users evaluated and positively praised the value of this evolving capability. Key to the success of this SINCE experiment was the implementation of common XML-based information exchange mechanisms that supported real-time interoperability between all the systems playing in the experiment. The publish and subscribe information exchange mechanisms implemented in the US Proxy Server automatically mapped and translated all of these XML-based data exchanges into the formats required by the real C2 and M&S systems, and vice versa. The key technology enabling the demonstrated SINCE interoperability capabilities is the implementation of a common, consistent XML-based OPORD/OPLAN representation to which all information exchanges can be consistently referenced into and out of, without loss of traceability. The US and German military user community participating in this experiment indicated that SINCE had successfully demonstrated the linking of real C2 and M&S systems thereby opening the potential for future use of real-world warfighter C2 systems in simulation-based training exercises.
Experimenting with Coalition Liaison

One important operational hypothesis that we began to address is the impact of collaborative technology on the role of the liaison officer. With the advent of decision support, collaborative planning, and situation awareness technologies, the need for continuous liaison presence for face-to-face discussions may become unnecessary and even a waste. What we have begun to observe and hope to pursue with more scrutiny in SINCEx1b is that for the given level of complexity of the scenario used in this experiment, there did not appear to be a need for a liaison officer to continuously monitor and assist in the collaborative planning part. Each planning cell respected the role of their counterpart and was able to monitor collaborative drafts, feedback and updates on their own and made recommendations that were understood by and minimized the impact on their coalition partners. This observation is highly subjective and is not meant to imply that periodic face-to-face contact may be totally eliminated. It is certainly important to ensure, as per STANAG 2101 [5], cooperation and understanding between units that are working together, and to establish tactical unity and mutual support of adjacent units. But as the commander and staff engage each other across coalition data boundaries using the functionality provided by collaborative tools, the role the liaison is reduced and possible transformed by the capability of collaboration.

Summarizing Conclusion

Overall, SINCEx1a provides a repeatable baseline from which to grow a test bed environment suitable for supporting a broad range of coalition C2 technical and operational experimentation activities directed at defining, developing, evaluating and demonstrating improved, collaborative coalition force command and control while operating in highly dynamic and mobile military operational environments. In addition, the SINCEx1a provides a repeatable baseline within which one may readily demonstrate the importance of being able to adopt and adapt evolving mechanisms to assure interoperability between multinational C2 systems stimulated as a direct result of events generated in real-time by the M&S systems. This is key to driving and evolving a combat situation represented by a user definable/common operational picture (UDOP/COP) that provides context to these experiments from a technical as well as an operational perspective. Results of SINCEx1a should prove to be invaluable not only to future SINCE experiments but to support other related efforts. Initial experimental results obtained from SINCEx1a show significant promise in being able to address not only technical issues but operational ones as well. SINCEx1a is a significant step towards developing and establishing a comprehensive international R&D program to support transformation to FF and transition to MIP. The use of UML to design the experimental architecture has proven invaluable. The use of XML to provide a common coalition domain model is facilitating integration and bridging between disparate data models. By leveraging existing C2 prototypes for planning and execution monitoring and coupling them to existing M&S systems to provide a dynamic operational environment we are able to provide valuable feedback for enhancements. Our first experiment with Germany has met all expectations and set the stage for SINCEx1b scheduled for implementation in July 2004. Both countries are continuing to collaborate on a common scenario, hypotheses, and establishing mechanisms to couple complementary C2 systems to national M&S systems.

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Experimenting with C2 Applications and Federated Infrastructures for Integrated Full-Spectrum Operational Environments in Support of Collaborative Planning and Interoperable Execution

Command & Control Directorate

Communications Electronics Research, Development and Engineering Center (CERDEC)

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Why is it needed?

- Need to integrate a diverse set of technologies addressing abroad problem space into an appropriate comprehensive capability
- Army is transitioning from a self-centered C2 environment to a network-centric system
- Operational emphasis is on use of real-time Situation Awareness (SA) and Collaboration in execution Future Operations
- Need an experimentation environment that
  - Allows us to see how things fit together and work before investing in expensive system solutions
  - Enables operational users to experiment with new technology and operational concepts, tactics and procedures
- To test and evaluate technical and operational interoperability interfaces with US Joint and Coalition Partners
- Required to support Network Enabled Battle Command effort and future C4ISR experimentation activities
The C2 Integration Problem Space

**Conduct of Experiment**
- Integration & Test
  - Implementation of components & interfaces
  - Communication, States & Dataflow
  - Definition of Data Model & Dataflow
    - Design of XML Schema
    - Messages & Documents
    - Laying out Systems, Components, Modules, Interfaces
    - Extending of Data Exchange & Mediation
    - Analyzing Existing Data Models

**Definition of Experiment Systems Architecture**
- Defining Actors, Use Cases, States, Interactions, Sequences
- Laying out Systems, Components, Modules, Interfaces
- Designing a scalable, flexible, maintainable & incremental model & architecture

**Understanding Problem Domain**
- Scope of Experimentation
- Analyzing Operational Scenario
- Layout of Experiment

**Subject Areas we Know About**
- C2 Information Systems (C2IS)
- Unified Modeling Language (UML)
- Extensible Markup Language (XML)
- Data Modeling
- Interoperability & Collaboration
- Modeling & Simulation (M&S)
- Software & Systems Engineering
- Army Doctrine & Warfare
Link C2IS with M&S to support
• Joint and International Warfighter Experiments
• Technical System of System Testing and Evaluation
• Simulation Based Acquisition
Supports Joint & Coalition Force Interoperability & Collaboration Experiments

C² Domain

Army (Land & Air)

- Army C² Process of Planning, Decision Making and Execution, Monitoring
- Peer-to-Peer Collaboration & Semantic Interoperability (Shared Situation Understanding)

Other US Joint & Coalition

- Partner C² Process of Planning, Decision Making and Execution, Monitoring

C² Integration Test Bed

- Providing Observed Truth & Stimulation

Common Operational Pictures
Planning & Decision Support Capabilities
Message & Order Processing
Common Languages & Data Models

Peacekeeping and Traditional Operations
Joint and Coalition Force Structures (Units and Assets)
Scalable Experimentation Environment using standard C², Information Exchange & M&S Technologies

Virtual 3D-Environment
Operational Picture
Federated War Game
Federated Synthetic Environment (HLA)

Federated Synthetic Environment (HLA)

Constructive Simulation 1
Constructive Simulation 2
Constructive or virtual Simulation n

Ground Truth within M&S Federation
All entities are to be simulated & ghosted
Rehearsal, Evaluation & Training

Modeling & Simulation Domain

All entities are to be simulated & ghosted
Rehearsal, Evaluation & Training
C2Sim Proxy Server – Key Interoperability Agent

**Collaborative Decision Making Products Interface**
- Currently based on CERDEC CAPES/MC2 collaborative Mission Planning and Execution Mgmt. SW
- Interface to Defense Collaboration Tool Set (DCTS) and other products planned

**Coalition C2 Sys Interoperability Interface**
- Automated exchange of Coalition Common Operating Picture (CCOP) & SA
- Based on Multilateral Interoperability Program (MIP) C2 Information Exchange Data Model (C2IEDM)

**Existing & Evolving Army C2 Sys Interface**
- Supports ASAS Lite and MCS Lite via legacy Joint Common Data Base (JCDB) information exchange mechanisms
- Also supports national C2 Sys Message Exchange via use of US CMP

**Future Army C2 Info Exch will be via C2IEDM and XML mechanisms**

**Web-based C2 Collaboration Portal (WCP)**
- Supports real-time viewing of CCOP
- Supports Collaborative Planning & Decision Making Activities between Army and Joint/Coalition partners
- Implements Digitized, XML-based OPORD and OPLAN info exchange mechanisms

**Simulation Sys Interoperability Interface**
- Automated exchange of simulated Unit location, state & control information between simulator and C2 systems
- Based on HLA Federated Object Model data exchange mechanisms (IEEE Std.)

**Coalition C2 Sys Interoperability Interface**
- Automated exchange of Coalition Common Operating Picture (CCOP) & SA
- Based on Multilateral Interoperability Program (MIP) C2 Information Exchange Data Model (C2IEDM)

**Web Service Implementation for Global Information Grid/DCTS Enterprise Environments**
Other C2Sim Proxy Server Features

- Implemented as a loose federation of external enterprise system interface ports and data adaptor/translation services.
- These system/data adaptor services are Web-based service request oriented agents/clients.
- These data adaptor services automatically map information from external system unique formats and data representations into a common digitized OPORD/OPLAN XML-based representation and vice versa. (One to “n” solution)
- C2Sim Proxy Server implements information exchange between system ports via a rule-based controlled Publish and Subscribe data exchange mechanism.
- Designed to manage and control flow of trusted information between ports/users.
- Also provides selected Information Aggregation and filtering services.
Current US SINCE Test Bed Implementation

Simulation & C2 Info Sys Connectivity Experiments (SINCE)

US Execution Monitoring
- Tactical Picture & Execution Alerts
- Monitor Joint DB for Plan Contingencies

US Planning System
Automated Reasoning & Decision Support Tools
- Mission Analyze
- COA Dev.
- COA Analysis
- COA Compare
- COA Approval
- Orders Gen.

US C2COP

Collaborative Decision Making

C2Sim Proxy Server

Coalition COP Data Exchange

C2IEDM DB

OneSAF Test Bed Simulation System

Visualization & Collaboration

MIP Data Replication Interface
To GE Coalition Partner C2 Sys

Coalition COP Data Exchange

Web-Based Portal

COALITION PLANNING
- Digitized, XML OPORD/OPLAN
- Web-based Coalition COP Display
- Web Collaboration Interface

Other HLA M&S Sys.

SINCE HLA Gateway

HLA GW

GE PABST M&S

OTB

Web-Based Portal

Mission Analyze
- COA Dev.
- COA Analysis
- COA Compare
- COA Approval
- Orders Gen.

Web Collaboration Interface
The Web-based C2 Portal & Common XML Information Model

- Gateway between National & Coalition C2 Planning Systems
- Displays, Sees and Operates on only Coalition C2IEDM based Information
- Standard user interfaces & Common Info Battle Mgmt. Language (BML), Graphics, Xml-based representations for exchange of planning Info
- Interactive OPORD building and Info Exchange

Typical OPORD/OPLAN Text Parsed by W6H Rules

On order IBCT deploys to MACRAN REPUBLIC and moves immediately to Kazar to secure the KACANIC CORRIDOR, PRISTINA Airfield, and PRISTINA, and to establish a US presence throughout the zone. IBCT cooperates with KAF to defeat GSPF elements in zone and deter a Serbian attack on Kazar. If deterrence fails, IBCT defends in order to defeat GAP; attack and to restore Kazar's territorial integrity.

OPORD Text represented in XML
C2 COP Domains

\[ s\text{COP} = s\text{COP}(c) \cup s\text{COP}(g) \]

\[ c\text{COP} = \text{usCOP} \cap \text{geCOP} \]

\[ \text{usCOP} = \{A, B, C, D, E, G, N, H, K, F, M, I\} \]

\[ \text{geCOP} = \{F, H, I, J, K, L, M, E, N, C, D, G\} \]

\[ \text{cCOP} = \{E, C, D, G, H, K, F, N, M, I\} \]
Simulation COP Domains

cCOP = usCOP(c) ∩ geCOP(c)

sCOP = sCOP(c) U sCOP(g)

USsCOP(c) = {A, B, C, D, E, G, N}
USsCOP(g) = {F, H, K}, USsCOP(-g) = {M, I, J, L}
GEsCOP(c) = {F, H, I, J, K, L, M}
GEsCOP(g) = {E, N, C}, GEsCOP(-g) = {A, B, D, G}
SINCEx1a Test Bed Configuration

- US C2Sim Proxy Server
- Tech Experiment IMO
- BDE - CJTF (HICON)
- Bde Cdr
- Bde S2/S3
- HEROS
- WebC2P
- CAPES/MC2
- C2COP
- US Battalion & Below
- Tech
- WebC2P
- OTB
- Soldier/Cdr
- CAPES/MC2
- INFIS
- Soldier/Cdr
- PABST
- WebC2P
- WebC2P
- HEROS

Tech
OTB

Soldier/Cdr

Tech

Tech

Tech

Tech

Tech

Tech
## Experiment / Test Report

**Report #** ________  **Report Subject:** ______________________________________

<table>
<thead>
<tr>
<th>Report Type:</th>
<th>Outcome</th>
<th>Timing</th>
<th>Deficiency</th>
<th>Incompatibility</th>
<th>Limitation</th>
<th>Recommendation</th>
</tr>
</thead>
</table>

Report Criticality ________  Date ________  Time ________

Phase I, II, III, IV  Pass 1, 2, 3, 4

Federate Name ____________________, Federate # ________  IER # ________

Screen Capture File name: __________________________________________

Database Snapshot File name: ________________________________________

Description/Comment/Solution:

---
State Diagram of SINCE PS (US) & Federates

Off

startSession

endSession

On

standFed, fedReady, setContract

startSession

connect

federate

collaborate

execute

prepare

(s/a/c/ca) positionRpt (US/GE)

(s/a/c/ca) SPOTrpt (US/GE)

Federation

contractSet

Collaboration

OPORDdraft, OPORDfb, OPORD(update,final)

Connection

Federation

Interoperation

stand-Alone

(s/a/c/ca) positionRpt (US/GE)

(s/a/c/ca) SPOTrpt (US/GE)
SINCE Test Cases & Use Cases

Test Case 1a (Initialization)
- COP(@ t = t₀) & draft OPORDs
- COP(@ t = t₀)

Test Case 2a (Planning for t > H > t₀)
- Collaborate with Coalition Federate (to Plan operation)
- Interconnect System
- Federate System
  - Initialize Federate

Test Case 3a (Execution @ t > t₀)
- Stimulate Federate
- Interoperate with Coalition Federate (to Monitor Execution)
- Interconnect System
- Federate System
  - Initialize Federate
Test Case #1a (COP Initialization)

COP – Common Operational Picture
ge / GE - Germany,
us / US – United States of America
c – coalition, s – simulation
(i) – initial, (f) – final
(c) – controlled, (g) – ghosted, (r) – reported
OPORD – Operational Order
ge / GE – Germany,
us / US – United States of America
(i) – initial, (f) – final
(fb) – feedback, (ud) – update
Test Case #3a (COP Execution)

COP – Common Operational Picture
ge / GE – Germany,
gs / US – United States of America
c – coalition, s – simulation
(i) – initial, (f) – final
(c) – controlled, (g) – ghosted, (r) – reported
SINCE Experiment 1a Results

• SINCE Experiment 1a demonstrated **New Information Exchange Interoperability and Collaboration Capabilities** between US/German C2I and M&S Systems
  
• Demonstrated **automatic initialization** of all Test Bed C2 and M&S systems and confirmed *that all displayed the same starting*
  
  – **Common Operating Picture (COP)**, i.e.- Blue and Red Force Unit locations
  
  – Appropriate BDE and BN level OPORD/OPLAN **mission and unit tasking**
  
  – **Initialization process** was **completed in approximately 5 minutes** and validated for correctness by military users

• Demonstrated that **simulated Blue and Red Force movement** generated by ONESAF Test Bed or PABST M&S systems could be **displayed in real-time** on all US & German C2 systems, the WC2P and M&S systems
  
  – Real-time Blue and Red Force **COP tracking and synchronization** between C2 and M&S systems **demonstrated to approximately the 600-entity level**

• Demonstrated **interactive Web Portals enabling** coalition force **commanders to collaboratively plan, modify and synchronize OPS** via use of XML-based, OPORD/OPLAN information exchange mechanisms.
  
  – US/GE military users positively praised the value of this **evolving capability**

• The US and GE military users indicated that **SINCE successfully demonstrated the linking of real C2 and M&S systems** thereby opening potential for use of real-world warfighter C2 systems in simulation-based training exercise