A Proposed Process and Toolset for Developing Standardized C2-to-Simulation Interoperability Solutions

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ABSTRACT

The Military Scenario Definition Language (MSDL) and the Coalition Battle Management Language (C-BML) are open standards that have been developed for military scenario initialization and run-time exchange of digitized military information among command and control (C2), simulation and autonomous systems by the Simulation Interoperability Standards Organization (SISO). Initial versions of MSDL and C-BML have been released by SISO and recent activity has begun toward merging MSDL and C-BML into a unified C2-to-Simulation (C2SIM) standard.

The NATO Modeling and Simulation Group 085 (MSG-085) Technical Activity was kicked off in 2010 and has worked in the area of Standardization for C2SIM Interoperation for the past four years. More recently, a sub-group of MSG-085 has developed an engineering process and prototype toolset for the development and maintenance of a unified C2SIM Scenario INitialization and EXecution (SINEX) Model. SINEX is an engineering process and toolset that uses a Model Driven Architecture (MDA) approach and builds upon existing tools and models from the Multilateral Interoperability Programme (MIP). As part of this activity, the group also developed a draft C2SIM Distributed Simulation Engineering and Execution Process (DSEEP) Overlay for the development of federations comprised of simulation and C2 systems. The current paper reports on these activities and provides recommendations for the adoption of the SINEX Process for the development of the unified C2SIM interoperability standard currently being proposed by SISO.

The SINEX process and toolset allow for the management of requirements as per system engineering best practices while ensuring traceability to the model elements that are defined as part of the process. Automated tools produce UML models, diagrams and documentation based on a set of model definition files. It also is possible to automatically produce model representations such as eXtensible Markup Language (XML) schemas using available model transformations. This process and toolset could be employed to facilitate the alignment and convergence of the MSDL and C-BML toward the goal of a unified C2SIM model. This model then can be utilized as one of the inputs into the C2SIM Federation development process as specified in the C2SIM DSEEP overlay.

1.0 INTRODUCTION

The NATO MSG-085 Technical Activity formed a series of Common Interest Groups (CIG) in early 2012 to address domain-specific issues for the Air, Land and Maritime domains. The Requirements, Recommendations and Specifications (2RS) CIG was formed to explore the viability of the SINEX approach with the objectives of documenting a formal process and creating a prototype production chain based primarily on existing COTS tools and those made available by the Multilateral Interoperability Programme (MIP) Block 4 Working Group. An additional objective of this CIG was to create a draft version of a DSEEP Overlay to guide the use of the derived products for C2-to-Simulation (C2SIM) Federation development.

Following this introduction, Section 2 describes the SINEX approach and the results of the 2RS CIG. Section 3 describes the C2SIM DSEEP Overlay drafted by the 2RS CIG. Section 4 proposes a set of recommendations for future work, as well as recommendations for the standardization bodies. Section 5 concludes the paper.

2.0 SINEX APPROACH

This section provides recommendations for the standardization of the Scenario INitialization and EXecution (SINEX) initiative based on the work conducted by the MSG-085 2RS Common Interest Group. In related previous work, the SINEX approach has been proposed as a means to unify the SISO Military Scenario Definition Language (MSDL) and the Coalition Battle Management Language (C-BML) into one common standard based on Systems Engineering best practices and Model-Driven Architecture (MDA) tools developed in collaboration with the Multilateral Interoperability Programme (MIP) [1]. The SINEX approach is consistent with the recommendations of the SISO C2SIM Interoperability Tiger Team Final Report [2].

SINEX is for the development and maintenance of interoperability standards based on the *Standard Development Framework* [3], and can be described as:

1. A formal process that guides the standard development [4]; and
2. A highly automated production chain to facilitate the elaboration of standards products based on the re-use of existing tools developed by the MIP [5].

SINEX addresses the issues and challenges related to developing and evolving technical interoperability standards in general, and specifically for C2SIM interoperability [6]. The main output of the SINEX approach is the creation of a Logical Data Model (LDM) that is largely based on the re-use of existing model elements such as classes, enumerations and associations from the MIP Information Model (MIM). The MIM is the successor to the Joint Command & Control Consultation Information Exchange Data Model (JC3IEDM). From the LDM, or Platform Independent Model (PIM) in MDA terminology, Platform Specific Models (PSM) (e.g. eXtensible Markup Language (XML) Schemas, HLA FOMs, DIS PDUs etc…) can be generated using MDA transforms.

The SINEX approach provides several advantages compared to maintaining a monolithic model using an XML Schema-based interface. First, SINEX is based on the MIP modular *sub-view* approach and thus allows for building models with small footprints to meet only the C2SIM interoperability requirements needed for a specific use case. Second, this allows for maintaining interoperability with other systems since it involves the use of a common base model – the MIP Information Model (MIM). Finally, the fact that MIM and SINEX are based on MDA makes the C2SIM interoperability neutral to specific interoperability technologies. Thus, it allows for using technologies such as HLA and JSON.

The work of the 2RS CIG has focused on finalizing the approach and defining the process. Also, a prototype production chain has been developed and already provides a powerful capability and shows much promise for continued use in future related technical activities.

2.1 Background

The SINEX initiative draws from two bodies of work: 1) The MIP Modular Enterprise Architecture Interoperability Solution as described by Lang et al [7]; and 2) the Standards Development Framework for M&S standards elaborated by Gupton and Heffner [3] that build upon the work done by the US Intelligence community in defining a standard for information storage and retrieval [8].

The MIP solution leverages the Model Driven Architecture (MDA) approach and focuses on the creation, evolution and exploitation of a PIM that is a formal Logical Data Model (LDM). Lang et al [7] also recognize the need to maintain modularity at all costs and thus offer the capability to those wishing to reutilize the existing MIP model, by reusing only the model elements that they need by creating “capability packages” or “model sub-views”.

Heffner and Gupton [6] describe a holistic process that also centers on the LDM while maintaining a strong connection with stakeholder requirements. Consistent with the MDA approach, transforms are used to derive products from the SINEX LDM in order to meet implementation needs. At the same time, this approach emphasizes the need for extensibility. Arguably the strongest link between these two efforts is the underlying requirement for SISO C-BML to utilize the MIM as the first and primary source of vocabulary.

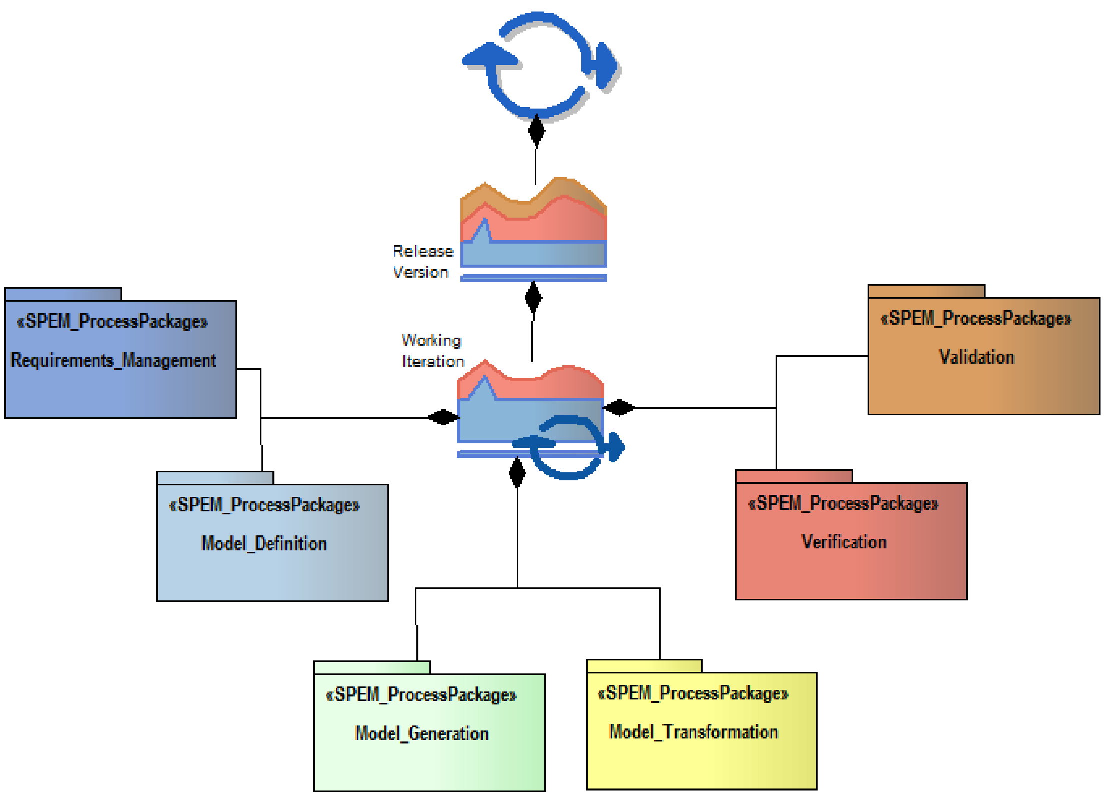

Figure 1: SINEX Process Overview

2.2 SINEX Process

The SINEX process is based on the Systems Engineering iterative Vee-model adapted for the development of technical interoperability standards, described in reference [4]. The strong emphasis on requirements management is consistent with the goal of achieving traceability.

The *model definition*, *model generation* and *model transformation* processes correspond to MDA constructs, while the *verification* process links the user and derived requirements to the model and derived products. The *validation* process is intended to ensure that stakeholder requirements have been successfully captured and implemented. This may require a dedicated test environment and target test scenarios and is an area of future work. An overview of the SINEX process is shown in Figure 1.

2.3 SINEX Production Chain Prototype

One of the main ideas in developing the SINEX production chain was to make maximum re-use of existing tools and in particular, those provided by the MIP Block 4 Working Group associated with the development of the MIM, the latest MIP model. The MIM is the proposed successor of the JC3IEDM. Based on the MIP tools, the SINEX production chain also utilizes the Unified Modeling Language (UML) editing tool Sparx System Enterprise Architect™ (EA) to specify, manipulate and transform the model. EA also has features for requirements management and automatic document generation.

The SINEX production chain is implemented as an environment that allows for the collaboration of various actors with different backgrounds and roles, contributing from different locations. Figure 2 is an overview of the SINEX workspace and shows the primary workflows. Figure 3 is a screenshot of the main menu of the prototype that was developed as a first implementation of the SINEX process and which enables the work flows that are identified in Figure 2. Table 1 provides a brief description of the components that enable the workflows identified in Figure 3. In December 2013, demonstrations of the SINEX process and prototype toolset were given 2013 as part of the NATO Modelling and Simulation Group activities during Interservice Industry Training Simulation and Education Conference (I/ITSEC).

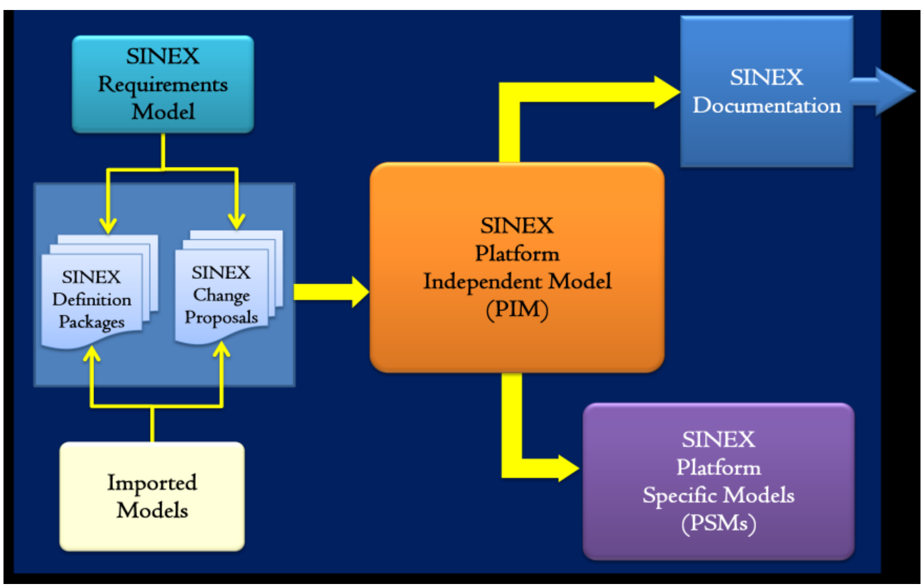

Figure 2: SINEX Workspace Overview

The demonstration included the *requirements definition* step for a C2SIM interoperation sub-model to communicate an obstacle report, followed the *model definition* of a sub-model based on existing model elements from the MIM (e.g. types, enumerations, associations etc.). Also, additional model elements were defined and added to the model as per the requirements. As part of the model definition process, a *drag-and-drop* functionality allowed to create links between requirements and the specified model elements, thus allowing for traceability of requirements. Then a UML model was created as part of the *model generation*, including automatically generated UML diagrams. In the next step, *model transformation*, an XML schema was created using a fully automated UML transform. The *verification* step allows for the user to rapidly determine *which* requirements have been satisfied and by *which* model elements. Also, developers can access the requirements associated with a specific model elements and derived products such as XML schemas and thus are better able to understand the intended use and limitations of these products.

Figure 3: SINEX PROTOTYPE MAIN MENU

This demonstration highlighted an important aspect of the SINEX approach in that the user is not required to have any UML experience. The tools present an interface that is intended for a broad range of users and therefore requires limited prior knowledge. At the same time, advanced users can access the UML workspace for greater detail concerning the models. However, data modeling is a difficult task and therefore performing the model definition step should be restricted to a limited set of users. Nonetheless, minor modifications to existing models can be introduced by any user.

Table 1: SINEX PRODUCTION CHAIN COMPONENT SUMMARY

COMPONENT	DESCRIPTION
Requirements Editor	Allows user to enter requirements into a workspace as per SINEX Requirements Management Process, based on the NATO Architecture Framework (NAF). Requirements can reference external sources or other requirements. Requirements have unique ID used for traceability purposes.
Model **Editor**	Allows the user to generate or revise Model Definition Packages (for Major Model Revisions) and also to generate Change Proposals (for Minor Model Revisions). The outputs of the editor are XML files that are used as inputs for the fully automated *Model Processor*. The editor also can generate RTF and HTML documents for Model Definition Packages and Change Proposal to facilitate the review process.
Model **Processor**	The *Model Processor* has two modes: 1) model creation mode; and 2) model revision mode. Model creation mode requires a model definition package that may reference a model that has been imported. The output of the Model Processor is a SINEX LDM. Model revision mode requires an existing SINEX LDM and a set of Change Proposals.
Model **Importer**	The Model Importer can import OWL Ontologies, XML Schemas and UML models such that they can be referenced by the requirements interface and/or by the model editor. This allows for re-use of existing models in several manners: 1) direct re-use of data elements as part of SINEX LDM; 2) reference to existing data element for the purposes of subsequent translation and mapping.
Document Generator	Allows for the automatic creation of documents based on the SINEX Workspace Package Structure. Document generation formats include HTML, RTF and PDF. Document content is based on information and diagrams comprising the SINEX Requirements Model and LDM, including inputs entered using the Requirements Interface and the Model Editor.
Model **Exporter**	The *Model Exporter* is based on the Model Driven Architecture approach and consists of a set of Model Transforms: In the short term: 1) UML→XSD; 2) UML→HLA-FOM; and subject to future research: 3) UML→ JSON ; 4) UML→ OWL; 5) UML→ EBNF. The Model Export ensures that the various SINEX outputs or PSM representations are consistent and that they readily can be generated following a SINEX LDM major or minor revision.

3.0 C2SIM DSEEP OVERLAY[1]

Interoperability between Command and Control (C2) and simulation systems involves bridging two separate worlds. The simulation community uses mature standards for building simulation federations, such as High Level Architecture (HLA) and Distributed Interactive Simulation (DIS). The C2 community interacts within operational environments and uses a variety of standards such as formatted messages such as NATO Allied Data Publication 3 (ADatP-3), tactical data links (e.g. Link 16), information exchange data models such as the JC3IEDM and different kinds of transport mechanisms according to operational requirements.

Thus, a C2SIM environment or federation requires bridging several environments and architectures. Figure 4 shows a typical architecture used by MSG-085, involving both C2 and simulation systems interoperating using C-BML. Note that C-BML does not prescribe a specific middleware or transport mechanism to implement communication among the systems. The integration of simulation systems in a C2 environment represents additional challenges. C2 systems are typically designed to operate in a real-time environment with limited information available (e.g. reports from subordinates). Constructive simulations can generate a lot of information not available in a real tactical environment and can run faster than real-time. Another important topic that needs consideration is the common initialization of C2 systems and simulations, e.g. using MSDL.

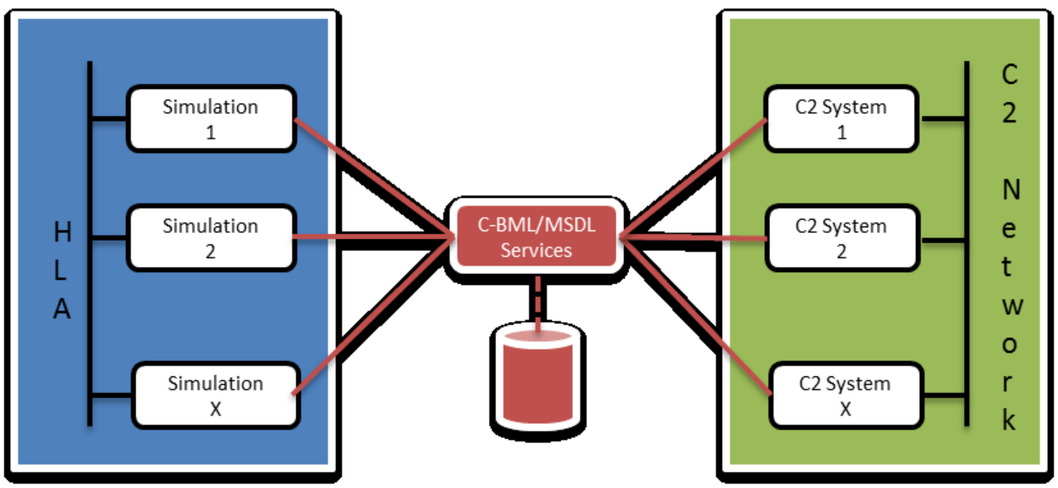

Figure 4: Notional C2SIM Architecture

3.1 DSEEP Overview and Terminology

SISO and IEEE have developed a set of recommended practices for developing distributed simulation environments comprised of systems that may use different simulation protocols. The DSEEP, shown in Figure 5, provides a framework for defining, constructing and executing distributed simulation environments.

[1] The authors would like to thank Robert Siegfried, member of *MSG- 086 Simulation Interoperability*, who reviewed the paper and provided input for this section.

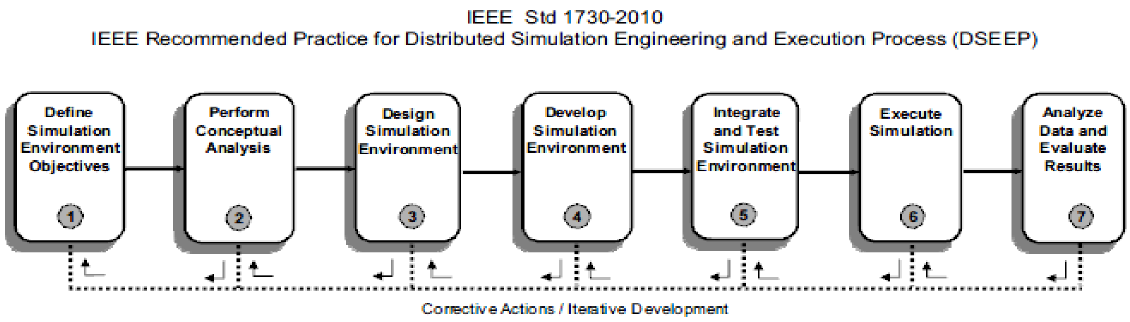

Figure 5: DSEEP Top-level Process Flow View (Taken from [IEEE 1730™ 2010])

To tailor the DSEEP for specific applications or use cases DSEEP overlays are defined. Basic overlays that map the architecture-neutral DSEEP to specific simulation architectures (HLA, DIS, TENA) are provided by the DSEEP [9].

The DSEEP Multi-Architecture Overlay (DMAO) [10] provides additional information and guidance for simulation environments that use more than one simulation architecture (e.g., HLA and DIS).

NATO MSG-086 has drafted a “Guideline on Scenario Development for (Distributed) Simulation Environments” as DSEEP overlay [11]. This guideline document is currently being transferred to SISO with the objective of producing an official SISO product.

NATO MSG-106 is currently working on AMSP-03, “M&S standard profile for NATO and Multinational Computer Assisted eXercises with Distributed Simulation”[12]. Since CAX use C2 Simulation Interoperability concepts, part of this work is similar to what is described in the C2SIM DSEEP overlay.

3.2 C2SIM DSEEP Overlay: Overview and Terminology

The C2SIM DSEEP Overlay is intended to help the user community better understand how C2SIM interoperability standards should be used to support (distributed) simulation environments that are connected to or a part of a larger C2SIM federation. The C2SIM DSEEP Overlay describes recommended practices for applying DSEEP to the development and execution of distributed simulation environments that involve one or more C2 systems used to command and control autonomous and simulated entities.

The two main contributions of the C2SIM DSEEP Overlay are:

- A description of issues and recommendations related to the definition, development and execution of a federation of C2 and simulation systems.
- A description of the additional inputs, tasks and outcomes for each of the seven DSEEP steps [9].

Figure 6 depicts a typical training system that is comprised of several cells (LOCON, Training Audience and HICON)[2] equipped with C2 systems and one (or more) simulation system(s).

[2] Low Control; High Control;

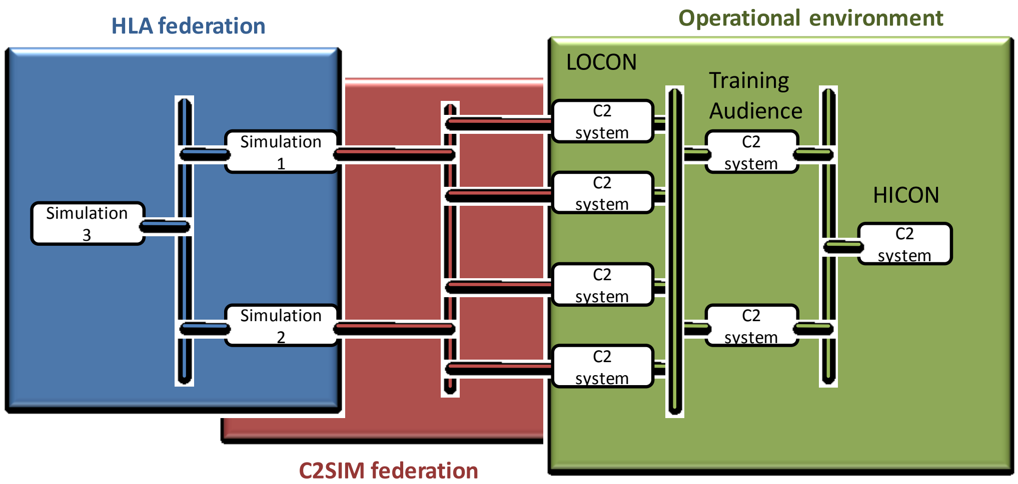

Figure 6: Notional Training System Architecture

For the C2SIM DSEEP Overlay, the following terms are defined:

- Simulation environment: generic term as defined in references [9] and [10], it includes LVC simulations including all Live assets which are connected together with a common Simulation Data Exchange Model (SDEM);
- C2SIM federation: a simulation environment that contains at least one C2 system, and that uses a C2SIM data exchange model as the SDEM;
- Operational environment: a set of connected C2 systems that exchange operational data.

The C2SIM federation defines the system boundary for the C2SIM DSEEP Overlay. The C2SIM federation also can be combined with other simulation environments, as required. The architecture shown in Figure 6 also is an example of a Distributed Multi-Architecture (DMA) and the corresponding overlay or DMAO as specified in reference [10] should be used in conjunction with the C2SIM DSEEP overlay.

The C2SIM DSEEP Overlay deals only with the practices relevant to the development and execution of a C2SIM federation, and not with concerns related to a C2SIM federation combined with other simulation architectures such as HLA or DIS; these cases should be considered in the DMAO. The DMAO is already applicable to C2SIM federations since the combination of C2 and simulation systems raises multi-architecture issues. All DSEEP steps containing “simulation environment” (or “simulation”) are thus renamed “C2SIM federation” (or “C2SIM”) for the purpose of the C2SIM DSEEP overlay, to avoid confusion with other simulation environments.

3.3 Issues[3]

The list of major issues identified is as follows:

- Stakeholders include individuals from both C2 and simulation communities
- Initialization of systems
- Time management
- End-users' perception of federation execution
  - Report processing
  - Order processing

Some of the major issues are further described in the following sections but due to space limitations other major issues that have been addressed as part of this work are not reported in this paper, such as: the preparation of scenario to initialize the federation (e.g. objects, events and terrain); security of C2 systems; C2SIM architecture, infrastructure services and data exchange model. An extensive investigation of issues that limit simulation interoperability, including C2SIM issues, has also been done by NATO MSG-086 [13].

Reference [14] proposes a web-based coordination system for monitoring and control of both the initialization and execution of C2SIM federations. Recognizing that there may be several sources of initialization data, Pullen et al describe a concept where several MSDL files are merged by a server before distributed to the participating systems [15].

3.3.1 Stakeholders include individuals from both C2 and simulation communities

The DSEEP process involves two communities of stakeholders: C2 stakeholders and simulation stakeholders. The involvement of both communities throughout the process is mandatory to meet the end-users needs.

Because of the operational constraints, the potentially limited availability of valuable C2 system resources should be considered as part of the C2SIM federation planning. For example, the availability of C2 systems experts and other subject matter experts (SME) should be taken into account when the work breakdown structure is developed within Activity 1.3: Conduct initial planning (e.g. design, install, configuration and operators). The same applies to the availability of the C2 systems themselves. Also, some contingency plans could be prepared to reduce risks.

3.3.2 Time management

What distinguishes simulation systems from most other types of systems is the necessity to manipulate and manage time. This is a challenge when integrating with systems that are designed to use only wall-clock time. To address this issue, two categories of use cases are considered:

- Training use cases, which mainly involve real-time (RT) simulations;
- Planning use cases (e.g. course of action (CoA) analysis), which mainly involve faster than real-time (FTRT) simulations.

[3] *Issue*: a concern, such as a situation within a development process or a technical element of an architecture, from which obstacles to achieving the objectives of the simulation environment may arise [10].

In training use cases, end-users use the C2 systems to monitor and control an ongoing (simulated) operation. This involves exchanging messages for situation awareness and to issue orders and requests. Usually C2 systems make assumptions about the time specified in messages, and may refuse to process data time stamped with a future time. In a C2SIM federation, the current tactical situation is computed by a simulation, but the logical time may be different than the wall-clock time. Normally, for the purposes of training, RT simulations are used, but FTRT simulation also can be used, (e.g. to focus on specific phases of an operation). As a consequence, training use cases will require synchronization of time among systems of the C2SIM federation.

In planning use cases, simulations are used in several ways:

- The end user observes the simulated tactical picture as it unfolds on his C2 system;
- The end user brings up the tactical picture on a C2 system for a specific point in time;
- The simulated tactical picture is not displayed on the C2 system; the end user uses analysis tools of the simulation system.

The last case doesn't require exchange of reports between C2 system and simulations. The two first require that reports are properly time-stamped. As a consequence, planning use cases might not require synchronization of time among systems across the C2SIM federation, but may only require that messages and data exchanged are properly time-stamped.

From a system perspective, time management is different for C2 and simulation systems. Usually, C2 systems are locked to the current real-world time, whereas simulation systems manipulate time as a variable.

Most C2 systems can manage several tactical pictures simultaneously. But it is generally not possible to display data for events occurring in the future and that result from a CoA analysis or mission rehearsal. As a consequence, a message generated by a simulation and retrieved by a C2 system may be processed differently depending on the purpose.

The objectives (Activity 1.2: Develop objectives) and the simulation environment requirements (Activity 2.3: Develop C2SIM environment requirements) differ according to the end user needs and use case category. It is also possible that some end user needs might require both categories of use cases (e.g. planning during training). The objectives need to take into account the constraints and capabilities of the systems involved (mainly end users' C2 systems), and possible adaptations or extensions.

For training use cases, the following questions may help to define the time management objectives and requirements and to assess their feasibility:

- Will the exercise time be less or equal to the real-world time (e.g. 24/7 training)?
- During training, how will it be possible to *pause* the exercise or at other times to *accelerate* the scenario execution?
- How will one manage the need to reset one or more simulation system(s), C2 system(s) or the entire C2SIM federation?
- How does the C2 system build its current situation and manage time?
    - Are data / messages verified against computer time?
    - Is old information recorded (and used for later playback), or is only the last known information recorded?

For planning use cases, the following questions may help to define the time management objectives, requirements and assess their feasibility:

- Is the C2 system able to:
  - store and display a snapshot of a future tactical picture ?
  - store and display a future simulated tactical picture as it unfolds ?
- Is there a need to execute an order several times, e.g. evaluation of different CoAs or evaluation of different aspects of the same CoA?

In the two DSEEP activities (Activity 1.2: Develop objectives) and (Activity 2.3: Develop C2SIM federation requirements) distinguishing the following options may be helpful.

Present day solution (training use cases only):

A common time reference should be decided before the execution of the use case. In this case, no modification of the C2 system is required, but it should be configured properly. It can be assumed that the simulated time will never be greater than the C2 system time. If the simulation is paused, the C2 systems will receive information in the past, and the end user might modify some filtering options to display older information on its C2 system.

Short term solution (training use cases only):

Time translation can be managed by the infrastructure. The data generated by a simulation (at a time T_{sim}) can be modified before it is received by the C2 systems ($T_{C2} = T_{sim} + \Delta t$), so that T_{C2} is equal to the system time in the C2 environment. Δt could be managed by the infrastructure and most likely automatically. But during the execution of such a federation, all people should be well aware of the Δt and its modifications.

Long term solution:

The C2 systems should be modified to manage for example a Nominal mode (for live operations), a Training mode and a Planning mode, each one managing the time of incoming messages differently. On the C2 system, the main difference between the Nominal mode and the Training mode is the management of the time of the operation (locked to the C2 system time, or controlled by the C2SIM federation). Infrastructure should then implement common time coordination services across both C2 and simulation systems.

3.3.3 End-users' perception of federation execution

This section describes issues related to the processing and display of information from the simulation environment on the end-users' C2 systems and thus of the messages and data exchanged during C2SIM federation execution. The issues concern various DSEEP activities from scenario definition to scenario execution involving a C2SIM federation.

Message Processing: Reports

There are several issues related to the flow of information included in reports sent from simulations to C2 systems:

- *Level of detail required by end-user and/or C2 system*: For instance, a simulation can generate observation reports about aggregated platoons, whereas the trainees, e.g. at the battalion level should receive individual vehicles reports. This can occur when a simulation designed to train brigades is also requested and used to train battalions (battalions being the first level of command with an intelligence cell, they receive vehicles reports, merge them, and send platoons reports).

- *Simulation information filtering*: Simulations are capable of generating a wide range of information. However, the C2 systems may only need a subset of this information, depending on their role and capabilities. Thus C2 systems or gateways should only process reports that are required for a specific function or purpose. This may require, for instance, a filtering mechanism:
  - A C2 system attached to a particular unit should only process reports that are sent to this unit;
  - A C2 system used as by EXCON[4] to have a "God's-eye view" of the situation needs to be capable of managing several information layers or tactical pictures simultaneously.
- *Ground truth and Perceived truth*: Simulations are capable of generating information dealing with both ground truth and perceived truth, while for C2 systems, information requirements depend on the application. For example, C2 system used for training should only receive information derived from the perceived truth, i.e. from measurements of the real world (sometimes, e.g. in the case of blue force tracking, in a very simple model of the real world ground truth can be used as an approximation of GPS measurements). For the purposes of mission planning, both ground truth and perceived truth are relevant.
- *Simulation information overload*: The rate of messages produced by simulations can be much greater than typical message exchanges occurring within the operational environment. Therefore, it may be required to apply limits and to restrict the rate at which reports are exchanged since C2 systems may not always be able to process and display all of the information produced by simulations. Two options to address this issue are:
  - Infrastructure or gateways can perform filtering by limiting report rates or by creating aggregate reports that include several single unit reports.
  - The simulation can be modified to restrict the flow of reports.

<u>Message Processing: Orders and Requests</u>
Similar to the processing of reports, there are several issues related to the flow of information included in orders and requests sent from C2 systems to simulations:

- Orders and tasks generated by C2 systems may not be executable by simulations because they may require behaviours that are not available in the simulation models. In addition, simulations may require a specific set of parameters for a given task (e.g. a route or a phase line). To resolve this issue, it is possible to extend simulation interfaces or to adapt behaviour models. Alternatively, one may constrain the orders produced by C2 systems in order to be consistent with simulation requirements.
- Orders generated by a C2 system reflect specific doctrine that may or may not be consistent with simulation behaviours.

To address the issues described above, the authors propose the following recommendations:

- *System Capabilities Descriptions*: C2 systems, simulations, gateways … should provide their capabilities using a common format and make this available through a M&S repository (e.g. simulation behaviours, C2SIM information exchange capabilities, C2 system report consumption limits, etc…).

[4] Exercise Controller

- *System Interface Descriptions*: Each C2SIM federate interface should provide a description of its information exchange capabilities. For example, the interface description could specify the unit types that can manage a specific task along with a set of parameters, (e.g. location, boundaries, objectives, phase lines, supporting unit…).
- *System Mediation*: Gateways could be used to satisfy requirements for aggregation and disaggregation of reports and controlling message exchange rates.

4.0 RECOMMENDATIONS

4.1 Use of SINEX Process for Technical Interoperability Standard Development

The SINEX initiative has produced a draft process for the standardization of C2SIM interoperation for initialization and execution of C2SIM federations. This process addresses the issues and challenges that have been identified by previous technical standard interoperability efforts, and proposes a means to maintain the link between stakeholders and standard developers. SINEX proposes an *iterative* process and is based on systems engineering best practices. It includes the means to ensure traceability of requirements for the benefit of both those issuing the requirements and those implementing the standard. This aspect has been identified as essential for developing, evolving and applying technical interoperability standards for the C2SIM interoperation as well as other domains.

4.2 Use of SINEX for C2SIM Interoperability Standard Development

Based on the work presented in this paper and consistent with the SISO C2SIM Tiger Team Recommendations Report, the authors make the following recommendations:

- Consistent with recent C2SIM Tiger Team Report [2] and the initial SISO product nomination for C-BML [16], the C-BML and MSDL standards should be merged into a unified standard;
- This unified standard should be developed and maintained using a formal process such as proposed SINEX Process;
- The unified standard should be based on a formal model;
- Consistent with the C-BML product nomination and the use of the JC3IEDM in existing MSDL and C-BML standards, the model should be built upon the MIM, as the principal source of vocabulary;
- The model should be built using a highly automated production chain to accelerate the development and subsequent evolution of standards products while avoiding human-induced errors;
- The production chain should reuse the MIP tools as much as possible;
- The development of the unified standard should be grounded in user requirements and these must be traceable throughout the standard development process.

NATO Science and Technology Organization Technical Activities such as MSG-048, MSG-085 and MSG-106 have played a key role in evaluating standards and providing feedback to the standards development communities. Therefore, the further development of the unified standard should include continued involvement of NATO technical activities and thus pave the way for adoption of the unified standard as a NATO STAndardized AGreement (STANAG). A draft proposal for a follow-on technical activity to MSG-085 to *operationalize* C2SIM interoperation has been made and is currently being reviewed by NATO nations.

As part of this activity the SINEX process and tools could be used as a means to contribute to the establishment of a unified model and operationally relevant, usable, technically sound C2SIM interoperability standard.

4.3 Future Work

4.3.1 SINEX

The SINEX Initiative has made significant progress under the MSG-085 Technical Activity, however work remains to finalize the process and to complete the tool set. The process must be reviewed by a broader community and possibly refined to meet organizational requirements such as those for the recently formed SISO C2SIM Product Development Group (PDG) from a merging of the MSDL and C-BML PDG.

Although an initial set of requirements for C2SIM interoperability has been proposed, these requirements should be reviewed, refined and complemented, as required.

Recently, the MIP has developed a tool called the *Message Builder* that allows the user to quickly develop XML schemata for messages constructed from existing model elements. The *Message Builder* is consistent with the initial vision of the Message Framework as reported by Heffner & Gupton [6]. This tool complements the current SINEX tool chain and thus should be considered for future versions of SINEX.

As per the C-BML product nomination [16], future applications of a unified C2SIM interoperability standard likely will require the exchange of *semantics* associated with the data elements of the information products that are exchanged (i.e. messages). This will require the development of ontology products such as Web Ontology Language (OWL) modules as part of the standard development process. Initial work in this area already has been conducted in collaboration with the MIP, but more work is needed.

4.3.2 DSEEP Overlay Future Work

The MSG-085 2RS CIG has made an initial effort for a C2SIM DSEEP Overlay. Additional *work is required and should be extended to the larger community that could include* participation from NATO and SISO:

- Elaborate on the issues that have been identified; provide additional details concerning the C2SIM DSEEP steps (e.g. activity inputs, tasks and outcomes);
- Further address C2SIM federation initialization issues;
- Define a C2SIM reference architecture;
- Produce a SISO product

5.0 CONCLUSIONS

The results and findings of the MSG-085 technical activity have allowed for significant progress in establishing a sustainable means for developing and evolving a C2-Simulation Interoperability standard for sharing military information across C2 and simulation systems for various military enterprise activities.

The initial C2SIM DSEEP Overlay that has been drafted captures the experience and lessons learned from experimentation activities that included building and executing C2SIM federations. The SINEX draft process and prototype, along with the initial C2SIM DSEEP Overlay form a strong foundation for guiding future C2SIM interoperability standardization activities within NATO and SISO.

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