C2-Simulation Interoperability Benefits

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ABSTRACT

Force readiness, support to operations and capabilities development heavily lean on C2 to Simulation interoperability. Developing standards that define common interfaces for the exchange of military information among C2 and simulation systems can lead to significant cost-reduction and greatly facilitates systems' integration.

1.0 PROBLEM SPACE

1.1 Definitions

C2 (Command and Control) systems ease the commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission via situational awareness and shared common operational pictures. They provide a bi-directional flow of information between a commanding officer and subordinate military units. Without effective command and control systems, combat units had to be operated "the old way", relying on slow and unreliable voice communication and hand drawn maps.

Interoperability is defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged. The simulation community has established general simulation to simulation standards like DIS[1] (based on formatted messages) and HLA[2] (based on publish-subscribe model) and the C2 community has defined information exchange standards like ADatP-3 [3](based on formatted messages) and MIP[4] (based on database replication).

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

A **Model** is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

1.2 Flow of Information

Large organisations, such as the armed forces, cannot function without the availability of accurate, timely, complete and consistent information. The quality of every decision that is made depends largely on the

[1] DIS: Distributed

[2] HLA: High Level Architecture

[3] ADatP-3: Allied Data Publication 3

[4] MIP: Multilateral Interoperability Programme

quality of the information which the decision is based. This makes information essential resource for any organisation that must be managed carefully.

The need to share information between a commander and its subordinates translates directly to the requirement that information be exchanged between their command & control (C2) systems. For this to be possible, the systems must agree to exchange and interpret information in a standardised known (unambiguous) way. In other words: the systems must be interoperable.

Interoperability, as showed in Figure 1-1, means that for one system (the provider) to successfully transfer information to another (the receiver), agreements must be made at various levels. First, they must agree upon a medium of communication. Second, they must agree upon a language. It deals with vocabularies and meaning for the words. Finally, they must agree upon a common communication procedure.

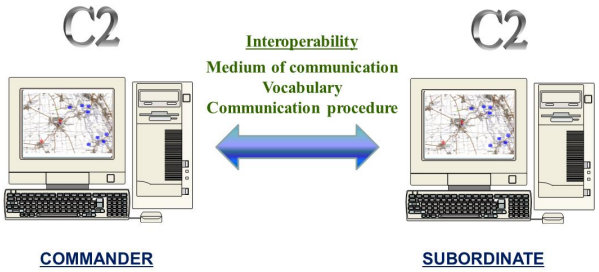

Figure 1-1: C2 systems interoperability between Commander and Subordinate.

Work to establish standards for C2-simulation (C2SIM) interoperability has been limited. As a result, almost every simulation has a unique C2 interface which is standardized with the C2 system exchanging information protocol.

Figure 1-2: C2-Simulation interoperability.

Currently, there is a need for a common approach to address C2SIM Interoperability. The issue is to provide an international standard that is acceptable by both the M&S [5]and C2 domains in order to address the overall problem space dealing with different stakeholders, targeted applications and requirements.

[5] M&S: Modelling and Simulation

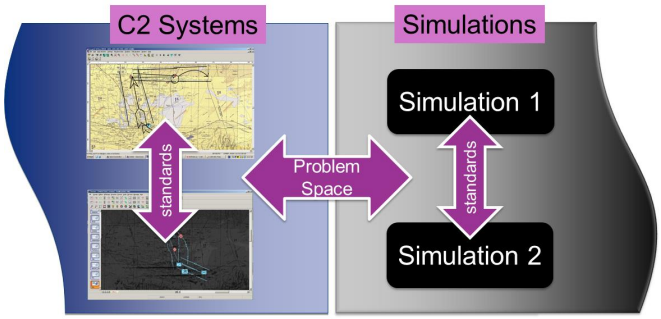

Figure 1-3: C2SIM Problem space.

1.3 Information to Exchange

It is critical the C2SIM mechanism to perform the automatic exchange (without swivel chair) of the full kind of digitized military information that is used between C2 and simulation systems during execution. It deals with orders, reports and requests.

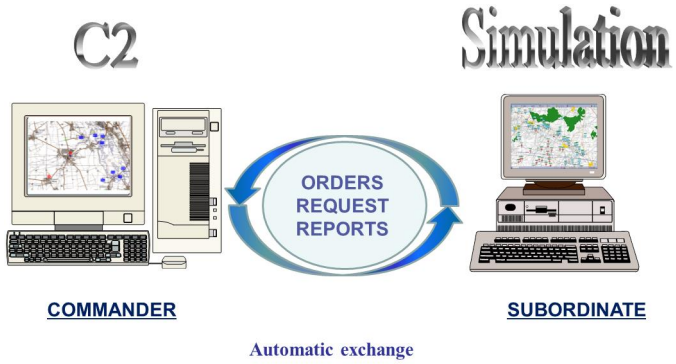

Figure 1-4: C2SIM exchange of Information.

In addition, most of the information is not only exchanged during system execution but also during the initialization phase. It addresses both persistent and non-persistent data. A persistent data is information that is not likely to be modified. A non-persistent data may change over the time due to upcoming events.

Persistent data deals mainly with the definition of the OOB[6] which encompasses forces structure, size, weapon systems and other information about terrain, weather, military boundaries as limits and phase lines and sometimes mission & plan.

Non-persistent data provide information as initial forces location, status, logistics loads (ammunition, fuel, water, human resource).

Data to exchange may also ease functioning of the federation of systems. It provides information about time management, systems capability to publish-subscribe, to execute a dedicated list of orders or required data to perform actions.

The C2SIM technical reference model, depicted in Figure 1-5 summarizes the need of exchange when C2 and simulation systems have to be coupled.

[6] OOB: Order of Battle

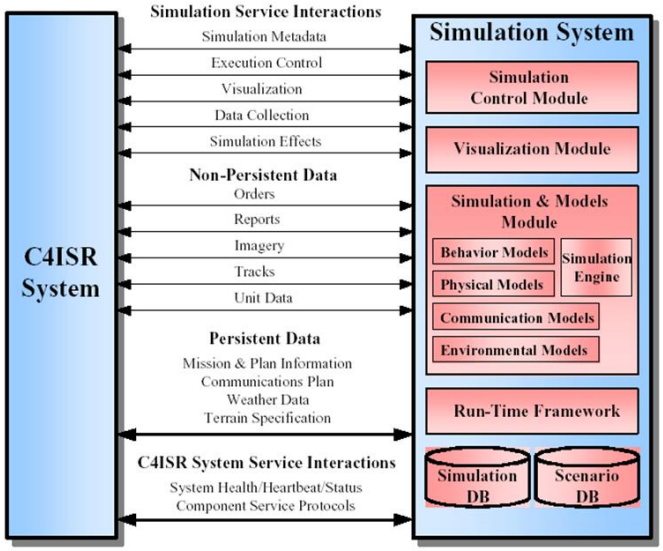

Figure 1-5: C2SIM Technical Reference Model.

1.4 C2SIM Standards at a Glance

The MSDL[7] and C-BML[8] standards have been developed by SISO to support scenario initialisation and scenario execution, respectively.

MSDL approved in November 2008 by SISO[9] is intended to reduce scenario development time and cost by enabling creation of a separable simulation independent military scenario format, focusing on real-world military scenario aspects, using the industry standard data model definition XML[10] that can easily and dependably be consumed by current and evolving simulations.

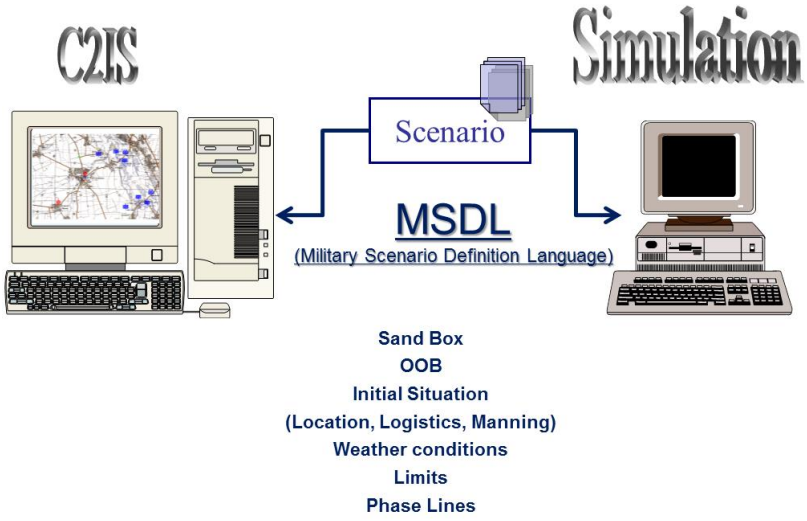

Figure 1-6: MSDL Scenario contents.

[7] MSDL: Military Scenario Definition Language

[8] C-BML: Coalition Battle Management Language

[9] SISO: Simulation Interoperability Standard Organization

[10] XML: eXtensible Markup Language

C-BML approved in April 2014 by SISO is intended to be an unambiguous, formal, language for the exchange of digitized military information among C2 and simulation systems. In general terms, C-BML expressions are communicated using the XML syntax according to a dedicated grammar based on a set of rules that dictate what valid sentences or expressions (i.e. combinations of lexical elements) can be constructed.

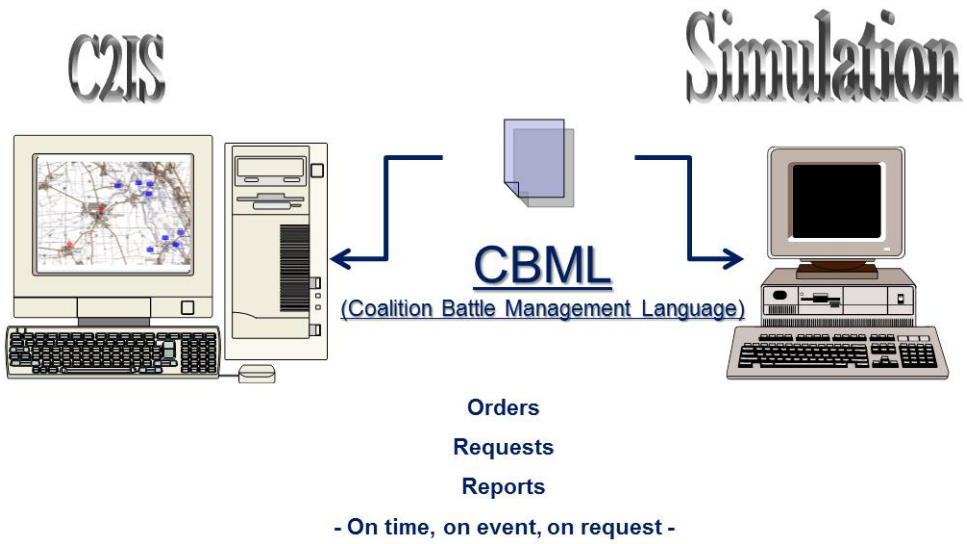

Figure 1-7: C-BML data type exchange.

2.0 RATIONALES

Initializing and executing operational scenarios are important parts of military enterprise activities of interest. For each of them, as showed in Figure 2-1, possible applications are foreseen which drive different interoperability requirements (e.g. time, accuracy …).

Policy & Procedures	• Doctrine • Tactics, Techniques & Procedures • Rules of Engagement • CONOPS
Acquisition	• System Development • Test & Evaluation • Verification, Validation & Accreditation
Training	• C2IS Operator Training • Robotic System Operator Training • Command & Staff Training
Mission Rehearsal	• Force, Service Level • Coalition
Planning	• Course of Action Development • Course of Action Evaluation
Mission Execution	• Situation Awareness • Tasking • Decision Support Systems • Planning during operations
After Action Review	• Training • Mission Debrief • Doctrine Evaluation • COA Analysis

Figure 2-1: C2SIM application' domains.

2.1 C2SIM Objectives

Whatever the C2SIM application to address, the goals for C2SIM interoperability are to develop a mechanism by which the connection between C2 and simulation systems becomes:

- Automated or semi-Automated;
- Unambiguous;
- Easy to sustain;
- Independent of applications;
- Expandable to include new domains;
- Available in Theatre;
- Persistent low cost; and
- Applicable to different levels of command.

These requirements are the drivers for the continuous development of C2SIM standards.

2.2 C2SIM Values

Whatever the targeted application, an efficient way to connect C2 and simulation systems provides the following benefits:

- Enhance realism & overall effectiveness;
- Decrease cost and risk;
- Reduce preparation and response time; and
- Refine requirements and statement of needs.

2.2.1 Enhance Realism and Overall Effectiveness

This is achieved by faster and more consistent information exchange among systems.

The values are the following:

- Faster restart/backup system of systems;
- Increase realism by approaching real life;
- Better consistency of information between systems; and
- Reduce risk of mistakes: Automatic validation of messages according to receiver capabilities/ format.

2.2.2 Decrease Cost and Risk

This is achieved by reducing manual input and the reduced number of supporting personnel and equipment.

The values deal with the saving of:

- Resources with an automatic swivel Chair;
- Resources by reducing workload of required operators; and
- Development and maintenance of gateways.

2.2.3 Reduce Preparation and Response Time

This is achieved with rapid configuration, initialization of systems and validation of scenario.

It provides the following values:

- Reduce time to feed systems with initial data (Theatre/Battlefield);
- Faster validation of scenario to meet training objectives; and
- Offer a flexible process to back and forth information from systems to systems.

2.2.4 Refine Requirements and Statement of Needs

The use of M&S in the acquisition process is a new paradigm called SBA[11]. The acquisition community tends to better integrate the use of M&S throughout all phases of the acquisition cycle to deliver fielded systems within imposed constraints such as budget, schedule and technical complexity and critical performance.

It provides the following profits:

- Continuous evaluation of system development;
- Rapid evaluation of concept design;
- Reduce and delay need for physical prototype;
- Facilitate continuous user participation in development process;
- Efficient development/evaluation of manufacturing plans;
- Reuse of system software and hardware in training simulators; and
- Ability to test proposed system at sub-component, component, and system level.

The C2SIM interoperability may provide during the acquisition process the following values:

- Develop C2 surrogate fed with simulation data;
- Experiment new capabilities with end-users in the loop;
- Assess different tactics and procedures with legacy systems in the loop; and
- Capitalize scenarios for further use during the CADMID[12] V cycle acquisition process.

2.3 Additional C2SIM Requirements

The former benefits lead to enrich the list of C2SIM requirements:

- Be routed via radio devices on the field; and
- Compliant with military standards, procedures and CP[13] organization.

In addition, VV&A process could be more efficient if one common language (e.g. C2SIM standard) is used for military experts to understand model's behaviour based on formal inputs and outputs.

[11] SBA: Simulation Based Acquisition

[12] CADMID: Concept, Assessment, Demonstration, Manufacture, In service, Disposal,

[13] CP: Command Post

3.0 USE-CASES

This section intends to provide several examples where C2SIM interoperability improves current military activities. It addresses the following application domains:

- Forces Readiness: Command Post Training and Fault Tolerance;
- Support to Operations: Briefing, Planning, Back-Brief and Mission rehearsal; and
- Simulation based acquisition: Assess new C2 capabilities and procedures.

3.1 Forces Readiness

3.1.1 Command Post Training

The aim of an exercise is to immerse the TA[14] in a realistic environment. The directing staff should be able to control the exercise execution in order for the trainees to reach their objectives. The organization of the systems is depicted in Figure 3-1 as a function of the different user and supporting groups

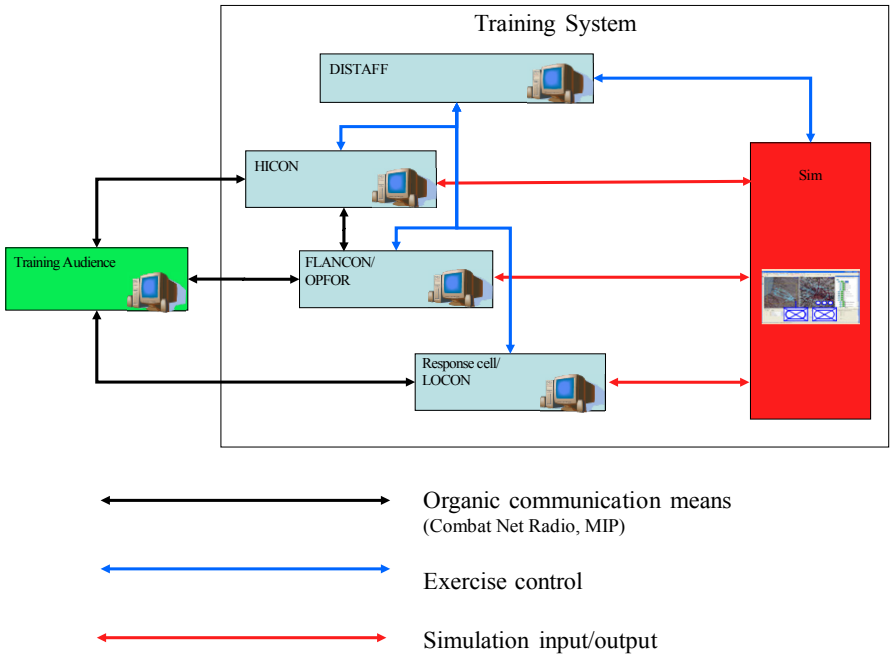

Figure 3-1: General layout of the current CP training environment.

The TA plans and executes orders using its fielded operational systems; commands and controls subordinates in the Response Cell and/or LOCON[15] cell. The TA composition obviously depends on the level that is trained, which can be Brigade, Battalion or Company.

The training organization is comprised of:

- EXDIR[16] with his DISTAFF[17]: EXDIR is responsible for setting training goals and managing the training, using his Monitor Staff that is comprised of HICON[18], FLANCON[19], LOCON, OPFOR[20] and White Cell. EXDIR is also responsible for AAR[21];

[14] TA: Training Audience

[15] LOCON: Lower Control

- HICON: plays the role of the trainees' commanders and is under control of DISTAFF;
- FLANCON: The Flanking (Neighboring) Forces of the Trainees (under control of DISTAFF);
- LOCON: provides the interface between the response cell and the simulation. LOCON receives orders sent by the response cell and translates them into commands for the simulated forces. In addition, LOCON dynamically reports simulation results to the response cell. LOCON is under control of TA and DISTAFF for exercise control;
- OPFOR: simulates the enemy during the training exercise; and
- White Cell is comprised of role players that play all incidents or events that are not handled by the Simulator (under control of DISTAFF).

Until recently, the use of simulation systems for training did not have a direct C2SIM coupling. All of the interfacing between the simulator and the C2 systems was done via human intervention using the so-called "swivel chair interface". The Orders were sent by the Combat Net Radio system between the different levels of command (Brigade, Battalion, Company) and when an order had to be simulated, it was displayed on the C2 system of the LOCON Operator[22] who, using this simulator interface entered the order into the simulation, as shown in Figure 3-2.

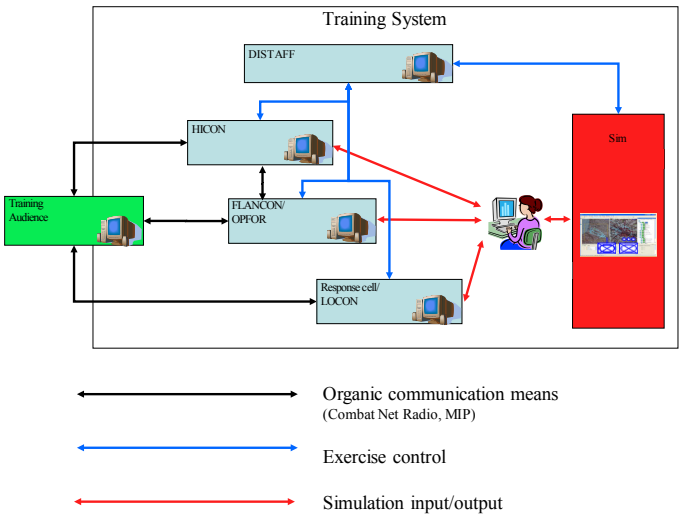

Figure 3.2: Manual "Swivel-chair Interface".

Using C2SIM coupling standards, the swivel-chair is completely removed allowing simulation outputs (i.e. Reports) to be reported automatically to the C2 systems and also orders to be sent from the C2 systems to the simulation, as shown in Figure 3-3.

[16] EXDIR: Exercise Director

[17] DISTAFF: Directing Staff

[18] HICON: High Controller

[19] FLACON: Flanking Controller

[20] OPFOR: Opposing Force

[21] AAR: After Action review

[22] NB: this is depicted as only one operator, but obviously, in reality this will be comprised of multiple operators, involved in the different cells.

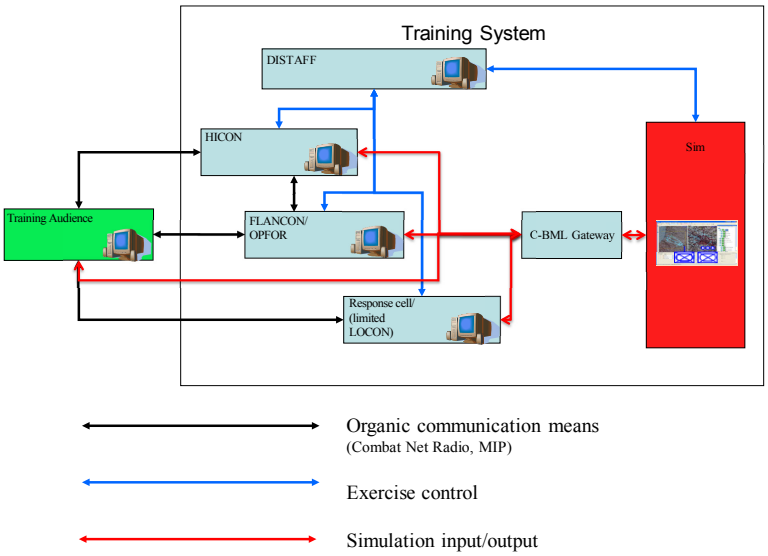

Figure 3-3: Automated Interface for Reports and Orders.

3.1.2 Fault Tolerance

Simulation applications being software, risks of crash may not be ignored. Currently, most of the simulations provide recovering capabilities. Nevertheless, it doesn't address the federation of systems which needs to restart sharing the same initial situation. MSDL standard may provide a flexible mechanism to save at some points the overall situation which may be used for federation re-initialization. The figure 3-4 shows the sequence of MSDL storages that could solve existing issues.

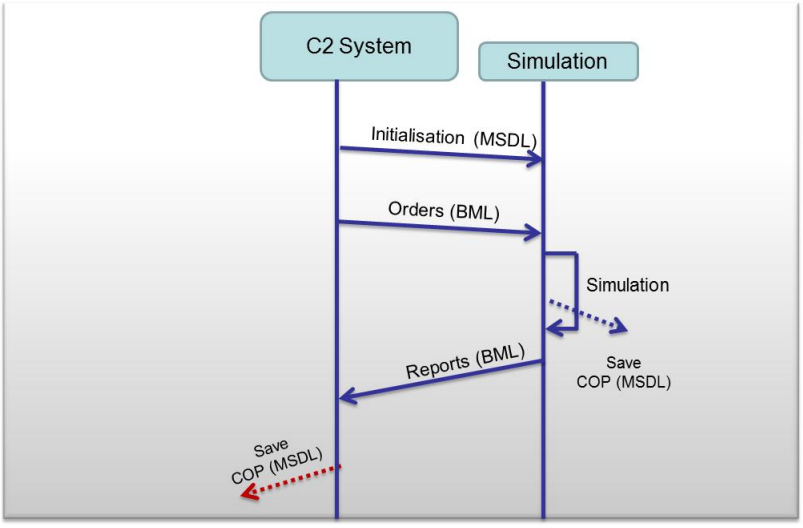

Figure 3-4: Use of MSDL to restore operational situation.

3.2 Support to Operations

Currently, there is no easy, flexible, cost-effective way to support with simulation the MDMP[23] steps described below:

1. Receipt of mission and mission analysis
   - Briefing:
     The higher commander briefs the subordinate explaining what is expected for the mission after the subordinate has received the order. The commander describes the idea of the manoeuvre considering the "major effect", the constraints (environment, time, resources) and imperatives, the threat, the risks, and the possible OPFOR manoeuvre. The subordinate exchanges ideas with the higher command to clarify any points, as required, and to avoid any ambiguity.
   - Back-Brief:
     The subordinates explain to the commander what they understood from the commander's order. The commander provides advice and guidelines, and questions the subordinate leaders to assess the consistency of their manoeuvre.

2. COA[24] development, analysis, comparison and approval:
   - War-gaming for COA development:
     Initial COA are designed by the subordinate (e.g. a friendly COA developed by the G5[25] or an enemy COA developed by the G2[26]).
   - COA analysis and comparison:
     The subordinate uses a process to judge the effectiveness of the COAs. Traditionally this is done by a human giving his expert judgment. Simulation may provide more in-depth insight.
   - War-gaming for Order enhancement:
     Following the COA development/analysis/comparison process, the order is chosen by the subordinate and mission rehearsal is performed. Again, traditionally expert judgments and labour intensive processes involving simulators may be required.

3. Orders production:
   - The order is put into a formal format.

4. Mission Rehearsal:
   - The Order is played (using expert judgment or by labour-intensive simulation processes).

5. Execution:
   - Assessment:
     The current situation is checked against the planned situation. There is a constant comparison between the current situation sent by the subordinates in the field to the Command Post (G3 cell) with the initial plan. Based on this comparison, the subordinate can decide to change the plan and send a FRAGO to their subordinates.
   - Re-planning:
     A new plan/order of FRAGO is constructed based on the assessment.

[23] MDMP: Military Decision Making Process

[24] COA: Course Of Action

[25] G5: Execution cell

[26] G2: Intelligence cell

In the near future, each of the MDMP steps would benefit with the tremendous increasing use of simulation. To make it happens, it is mandatory to achieve the close coupling of both C2 systems and simulation. This would lean on the use of C2SIM standards.

3.2.1 Briefing

When the commander sends his order to the subordinate units, simulation is used to execute the order. Each subordinate may display on his own C2 system the dynamics of his own mission to get a clear understanding regarding the desired outcomes of the commander. This is achieved via C2SIM reports feeding the C2 system of the subordinate.

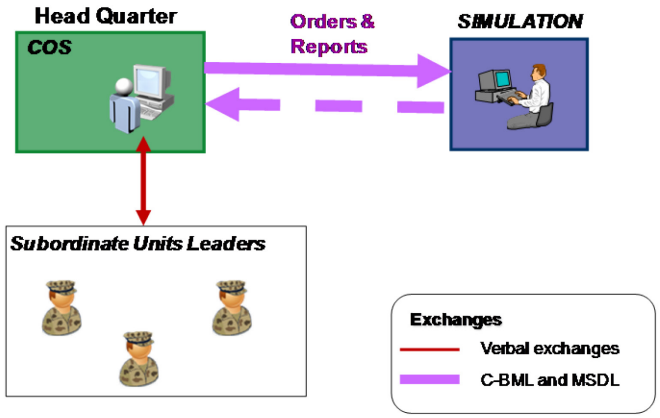

Figure 3-5: General layout for Briefing.

3.2.2 Back-Brief

Each subordinate idea of maneuver is expressed within an order that is run independently by the simulation. The commander displays on his own C2 system the dynamics of each subordinate mission to check if his plan is well understood. This is achieved via C2SIM reports feeding the C2 system of the commander.

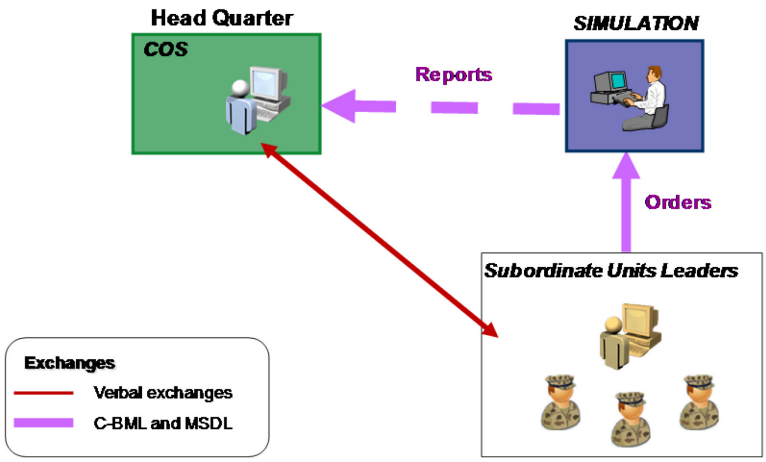

Figure 3-6: General layout for Back-brief.

3.2.3 Mission Rehearsal

Every subordinate' orders are run by the simulation. The commander and his subordinates display the order execution on their C2 devices. This is achieved via C2SIM reports feeding the C2 system of each stakeholder. This simulation session helps the commander to synchronize the overall action and may highlight weak points that require further support during the real maneuver execution.

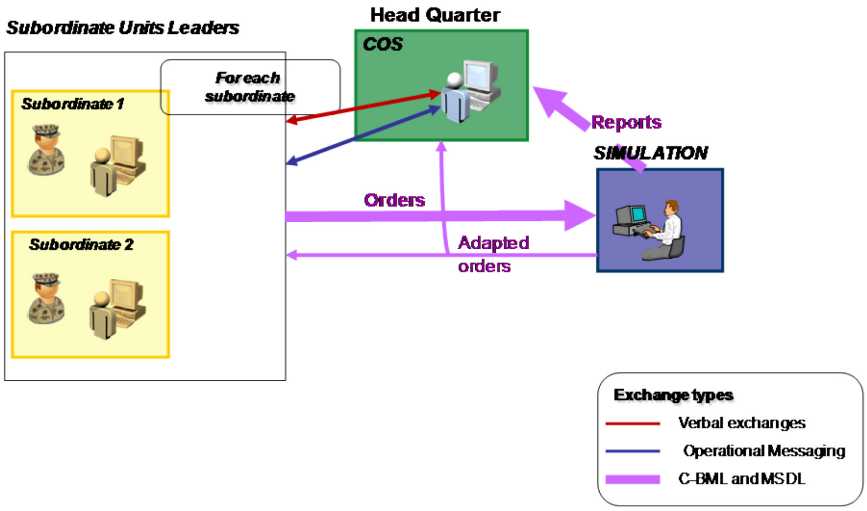

Figure 3-7: General layout for Mission rehearsal.

3.3 Simulation-Based Acquisition

To determine what to buy, it is currently mandatory to place considerable emphasis on a "system-of-systems" decision-making approach. The goal is to select the most cost-effective mix of individual systems for development and fielding. Trade-offs between existing systems and future capabilities are being considered and evaluated under simulated combat conditions. In order to execute such work, extensive use of constructive models for these system-of-systems evaluations is foreseen.

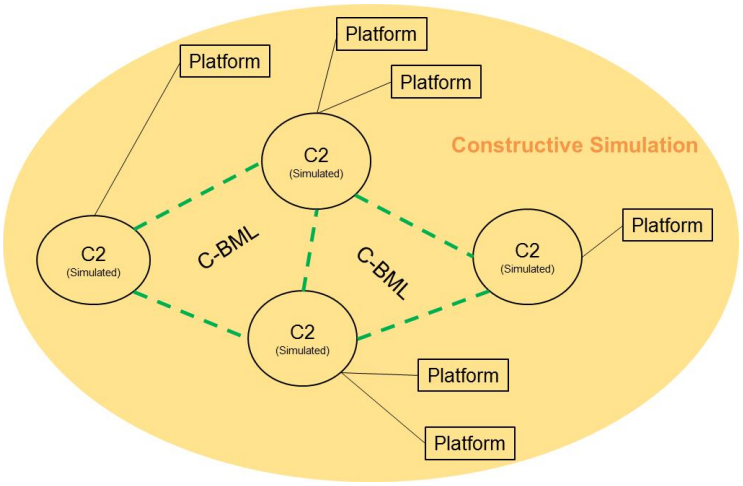

Figure 3-8: Simulation of System of systems architecture.

It is proposed within simulation to model the expected exchange of information between systems using C2SIM standards as shown in Figure 3-8.

This would ease the integration of virtual prototypes, real systems and components operated on synthetic battlefields for simulation-based system evaluations in a simulated combat environment to assess the performance of alternative designs and concepts. This is shown in figure 3-9.

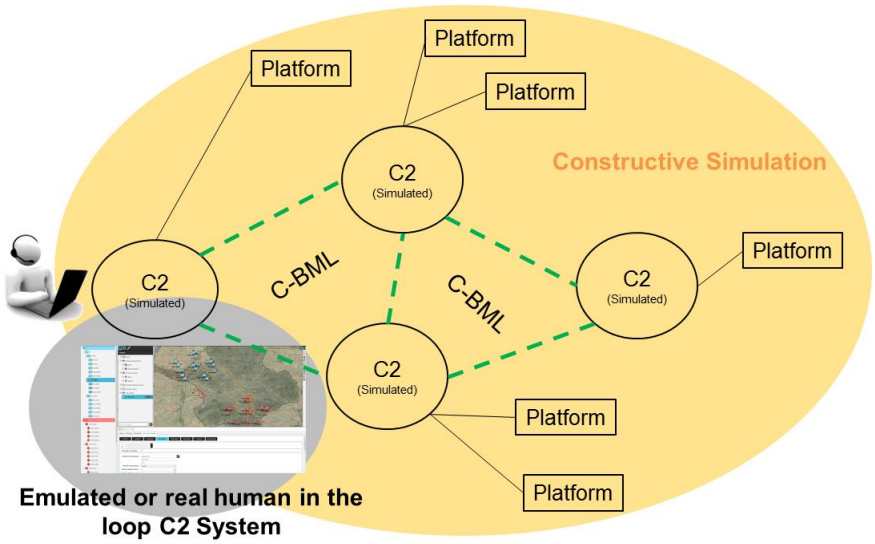

Figure 3-9: Integration of a virtual prototype within the simulated System of systems architecture.