Benefits, Experiences and Challenges in applying GSD Approach

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ABSTRACT

Military Scenarios, also called Operational Scenarios, are usually defined in using different ways and domain-specific terminology which mainly do not express operational background.
Executable Scenarios are machine readable files to set up the components of the simulated environment. They are customized (terrain, order of battle, task organization, …) to allow the execution of the scenarios by the different components involved within the technical architecture.
The Conceptual Scenarios are bridging the gap between Operational and Executable Scenarios and provides a description of the scenario that may improve the reuse, ease the understanding by both SMEs and Modeling and Simulation (M&S expert), solve the ambiguities and provide better mastering of interoperability.

This paper highlights several experiences performed by Direction Générale de l'Armement (DGA) since 2015 in order to move ahead the transition from system engineering to simulation. The Guideline for Scenario Development (GSD) approach initiated under the umbrella of the MSG-086, "Simulation Interoperability", provided the foundations to clarify how to express a conceptual scenario in using the NATO Architecture Framework (NAF). This was first assessed during the preparation of the international operational exercise called "Bold Quest". Due to the unambiguous description of the scenario capturing the operational needs, it was committed to check its relevance for air, ground and maritime scenarios. For this purpose, a scenario named "TRITON" was defined and appropriate NAF Views proved that it is effective to adopt such approach for any kind of scenarios. The conceptual scenario description as a bridge between operational and executable scenario, the MSG-145, "Operationalization of Standardized C2-Simulation Interoperability", decided to experiment this approach in order to master systems interoperability with the goal to provide suitable C2SIM extensions. This leads to an experiment involving Tactical Data Link (TDL) actors, real and simulated, who during the scenario execution required to exchange operational information. The benefits encouraged DGA to develop a guide to master interoperability in a simulated based environment whatever the standards are. It recommends to apply GSD approach and to use NAF Views to describe conceptual scenario. Nowadays, the current works deal with the automatic set up and execution of simulation based on standardized scenario description. This is a critical challenge to really take advantage of the overall approach.

1. CONCEPTUAL SCENARIO DESCRIPTION

1.1 Bold Quest Exercise

Close Air Support (CAS) is a complex, joint military operation in which aircraft engage ground targets identified by a Forward Air Controller (FAC). The difficulty in organizing CAS training activities in live conditions is to find large military venues where staffs, units and their weapons systems can come together to train in a coalition context. For this reason, simulation provides an efficient way to support CAS training because it offers a secure, distributed virtual environment where trainees can operate together from home station. This benefit was illustrated in September 2015 during the multinational event Bold Quest 2015.

The innovation was the methodology used to define a common scenario which should be usable for the military staff to define, in advance, all operations to be performed, and also for the technical staff to set all data exchanges required between the involved systems.

1.2 Operational requirements collection process

It is critical for M&S experts to capture and to share a common understanding of military requirements. In order to develop a structured specification of simulation environment, it is important to understand the objectives and the scope of training audience, through the support of subject matter experts (SMEs). To achieve such well-structured specification, a new approach based on scenario definition was executed with success.

Three steps were needed to form the scenarios:

- <u>Identification of scenario participants</u>: Every stakeholder within the scenario must be clearly stated, regardless of their position.
- <u>Elaboration of vignettes</u>: The scenario must be divided into different parts, and treated independently. Each of them describes the relationships between the participants and the dialogue goals in sequence.
- <u>Definition of information exchange</u>: Each relationship between participants must be unambiguously expressed. This includes the communication device used to communicate and the content of the information that is shared among the participants.

When the process started the main question was how to define the best way to capture and assess the expected information collected as an output of each step. Hence, the SMEs were requested to express end-user requirements using Microsoft Power-Point diagrams, as shown in Figure 1.1.

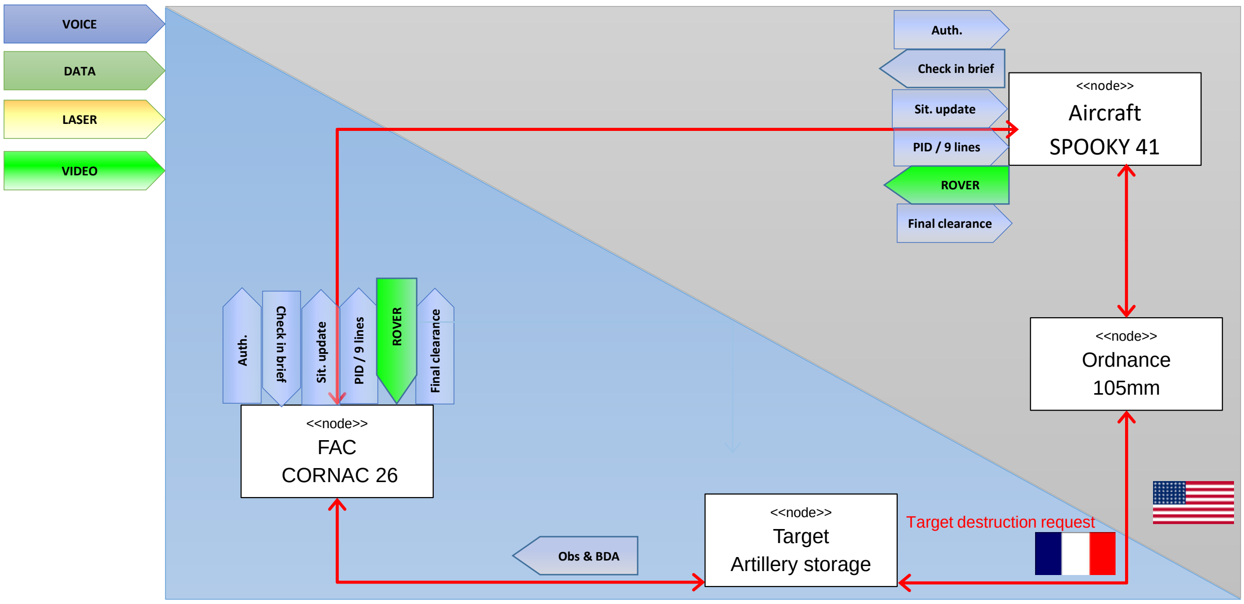


Figure 1.1: End-user requirements capture

This diagram was translated by M&S experts into NATO Architecture Framework (NAF) - Operational View (NOV) for further exploitation. The figure 1.2 depicts such transformation and highlights the first step of the process “Identification of scenario participants”.

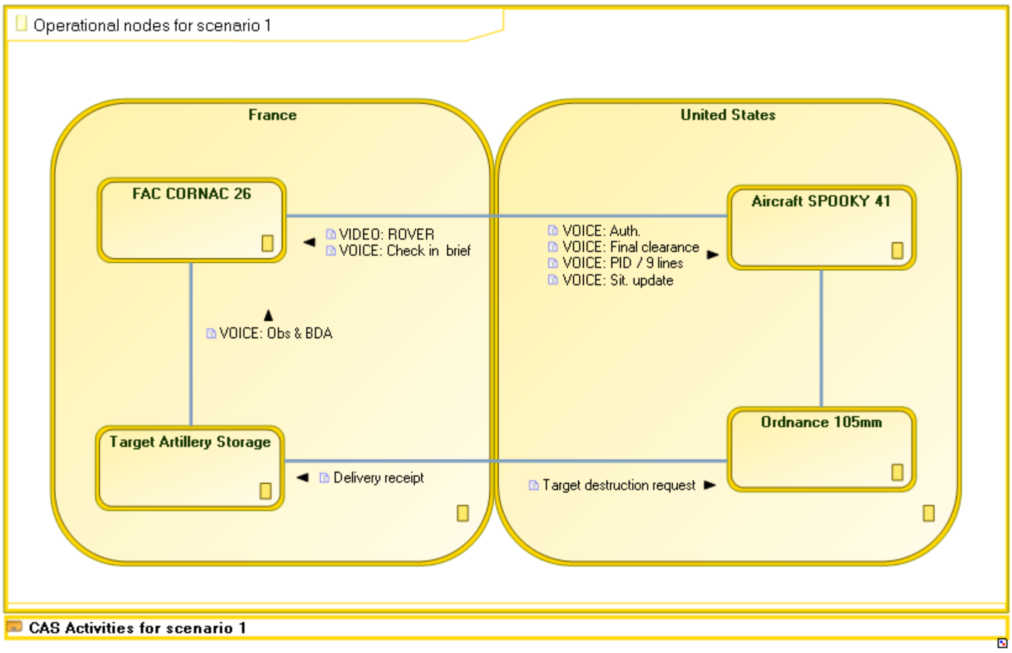


Figure 1.2: NOV-2 Operational Nodes

The NOV-2 also describes the scenario's operational entities and their relationships, in terms of interactions. It refines the rational of each interaction and the means used to convey the information. This figure addresses the last step of the process “Definition of information exchange”.

The "Elaboration of vignettes" assembled together in sequence to build the scenario captures the military procedure or tactic. It depicts the operational knowledge and activities end-users may have to perform during scenario execution. The NOV-5 activity diagram, as shown in figure 1.3, shows the two vignettes to achieve a CAS, from the FAC point of View.

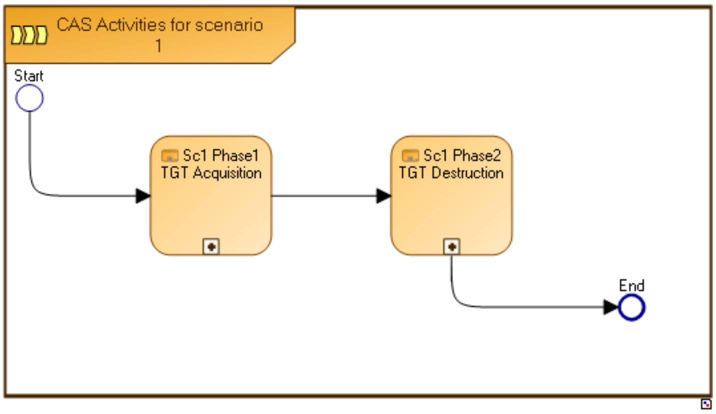


Figure 1.3: NOV-5 Close Air Support Activities

Each vignette must be detailed for each participant. The sequence of actions each operational node needs to execute is clearly stated. The Figure 1.4 below depicts the first vignette.

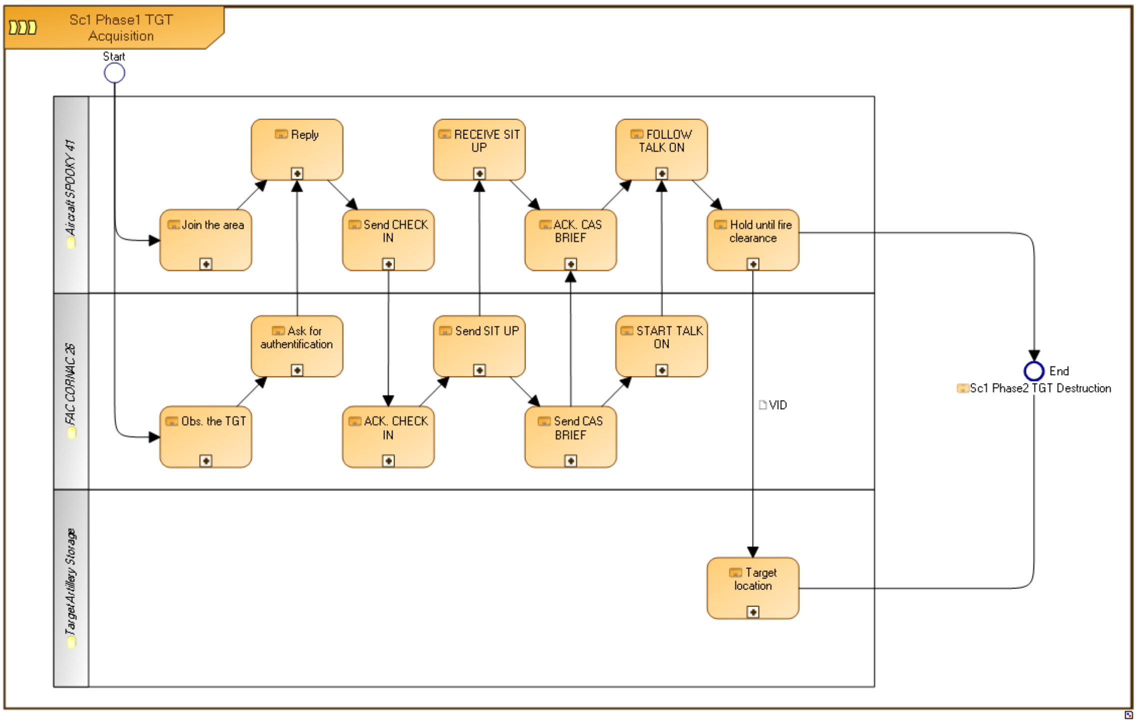


Figure 1.4: NOV-5 CAS TGT Acquisition

The Figure 1.5, which pinpoints the second vignette, introduces an operational node which was not mentioned in the first vignette. It deals with the 105mm canon device which has to fire on the target.

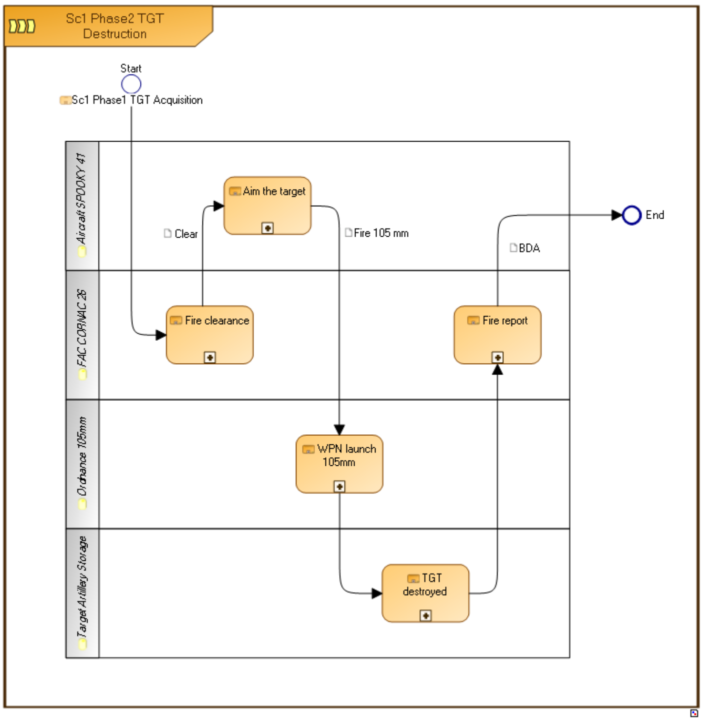


Figure 1.5: NOV-5 CAS TGT Destruction

1.3 Lessons learned and way ahead

The military requirements capture process experienced during Bold Quest event preparation led to collect and transform the operational scenario into a conceptual scenario. This work was necessary to understand the event expectations from the end-users' perspective, in order to develop and provide the suitable simulation environment.

Nevertheless, it was also beneficial to:

- Identify the interoperability requirements: objects and interactions to publish;
- Highlight technical gaps: interactions are missing in using off the shelves products;
- Achieve event capability: propose workaround solutions to overcome technical gaps or when change was not possible, convince the end-user to change the scenario accordingly;
- Monitor the event execution: for the first time, technical staff were able to easily monitor the scenario execution and therefore provide a better technical assessment.

This Operational requirements collection process being so effective, it was used again for the next Bold Quest exercise. Each vignettes were captured in defining NAF Views using MEGA HOPEX.

2. EXTENDING THE CONCEPTUAL SCENARIO DESCRIPTION

Operational scenarios are described in terms the user is familiar with. They are documented in any format. It is often a combination of a graphical and a textual description human readable like Overlay Order (OVO), Operational Order (OPO), Concept of Operations (CONOPS) or Exercise Book.

The conceptual scenario derived from the operational scenario has the objective to capture the main operational features to provide the military desired end state without any details about the military operation context. It has to be generic in order to foster reuse mainly to generate similar military operations but within a different environment.

2.1 Conceptual Scenario Requirements

According to this new perspective, the conceptual scenario is basically an abstraction of an operational scenario. It may be perceived more or less as the script of an operational scenario.

The conceptual scenario mainly contains:

- the units (actors – who?) of the operational scenario,
- a high level description of the missions (what?) they have to perform,
- the status they have to reach to produce the desired effect.

Unlike the operational scenario, the conceptual scenario does not content any precise information about the area of operation (terrain, weather, etc.) and is time information free. The conceptual scenario tells the nowhere and "no when" story included in the operational scenario. Hence, the conceptual scenario is closed to the definition of the vignette proposed within the GSD. Even more, it can be built "from scratch", without any operational scenario.

The conceptual scenario is independent from any simulation environment. Nevertheless, it remains a step on the way to develop the executable scenario.

The M&S experts are in charge to develop the conceptual scenario. Since they are usually not NAF-aware system architects, they must handle few concepts (diagrams). Furthermore, a conceptual scenario creating process is needed to ease the development of conceptual scenarios.

2.2 Conceptual Scenario Basics

The relevant units of the operational scenario are actors performing a role. They belong to an organization such as battalion, company, platoon, Composite air fleet or navy fleet, etc. In general, single human actors are not introduced unless they can be considered as "operational node" interacting within the overall scenario (e.g. Search and rescue operations involve military personnel equipped with a distress beacon).

The generic structure of organizations can be modeled by an entity–relationship or class diagrams. Cardinality and associated rules are used to express the organization flexibility (e.g. the ability to tune the organization into modular units according to their mission).

Missions are triggered by orders from a command unit to its subordinates. Conversely, the subordinates produce reports towards their command unit, at least at the achievement of their mission.

The inner information flows inside an organization (between the command unit and its subordinates) can also be represented within a generic exchange diagram (data flow diagram, entity-relation diagram or class diagram).

Reusable objects already defined in legacy libraries (units, missions, orders and reports) may ease to produce diagrams without a deep military knowledge.

<u>Organization configuration diagram</u>

The structure of a modular organization is clearly linked with the objective assignment and the desired end-state. Since missions being strongly connected with dedicated units multiple configurations of organization may exist within a same scenario.

The objectives of the unit configuration diagram are to:

- Define the various configurations of an organization within a scenario. Each must be compliant with the cardinalities and their associated rules.
- Map the missions assigned to the units belonging to each configuration within a scenario.

Mission process diagram

Any mission assigned to a given unit can be efficiently modeled by a kind of process diagram.

A lane is allocated to each unit of an organization. Crossing over the lanes, phases are introduced in order to express sequences that could be seen as decisive points to reach for the success of the expected end-state to achieve. Units and phase lanes generate a grid on the process diagram. At the intersections missions are allocated to units according to their ability to execute the task. Control assignment is led via a drag and drop mechanism which is based on a legacy library of missions. Finally, the diagram is enriched with mission orders and reports.

Extra non-standard process modeling artifacts can be laid down on the process diagram:

- Phase constrain (pre, post condition),
- Unit state,
- External units who play a significant role (e.g. air support fleet who does not belong to the organization)

Mission exchange diagram

The information flows (mission orders and reports) exchanged between the units belonging to a given organization can be summarized in a flow diagram. The synthesis is automatically generated from the mission process diagram because it contains the critical information of the conceptual scenario.

The mission exchange diagram looks like a generic exchange diagram.

Conceptual scenario heritage

The conceptual scenario generation process may be applied for each of the units belonging to an organization. Hence, each unit becomes an organization. The following 3 steps process is therefore ran down in sequence:

1. Identify the organization and its configurations according to the mission it has to perform (configuration entity diagram),
2. Model the mission assigned to the unit (mission process diagram),
3. Assign orders and reports in order to provide resulting information exchanges (mission exchange diagram).

For each mission of a given unit, the process generates a triplet {the organization configuration diagram; mission process diagram; mission exchange diagram}. This process can be applied to every command level either from top to bottom and vice versa:

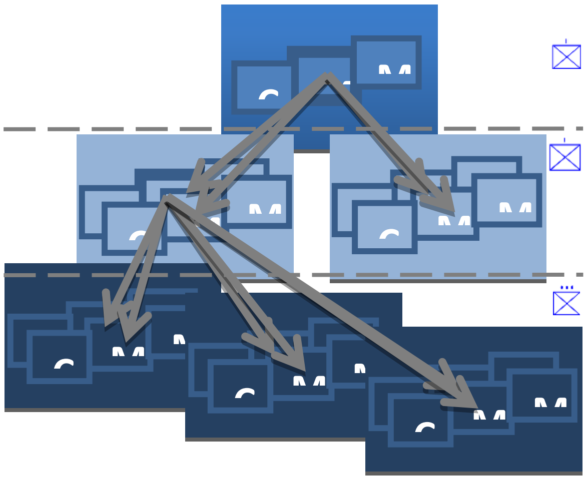


Figure 2.1: Conceptual scenario heritage

As a result, a conceptual scenario is made of a collection of diagram triplets {organization configuration diagram, mission process diagram, mission exchange diagram}.

To be as much effective, this process must be supported by a tool. The M&S experts should be able to:

- Navigate up and down between different command levels,
- At a given level, navigate between the views within a triplet,
- Focus on specific viewpoints (phase, entity, flows, etc) by means of filters due to the wealth of the mission process diagram.

Furthermore, the supporting tool should ease conceptual scenario reuse and should release the M&S experts of non-productive value actions.

Toward NAF views

It may be useful to produce these diagrams using NAF views as GSD identifies NAF as a standard that could be effective for conceptual scenario specifications.

It is believed the translation of a diagram triplet should produce a set of NAF views from a unique level, NATO operational Views (NOV). NAF provides several advantages. The main one is the possibility to later link the NOV with NATO System Views (NSV). It will allow further to detail the conceptual scenario as appropriate.

2.3 Effective Approach

The conceptual scenario making process was assessed according to an operational scenario designed for purpose by French army together with DGA experts from naval and air domains. A mock-up of a tool has been developed in order to demonstrate the concept of Conceptual scenario generation and its use.

2.3.1 Operational scenario

The objective of the joint operation “Triton” scenario is to evacuate nationals, refugees and civilians from a state weakened by the presence of militia, insurgent groups and pirates along the coasts. The overall task force combines different branches of the armed forces. Triton scenario is a joint-forces operation which would address the overall complexity to develop conceptual scenario.

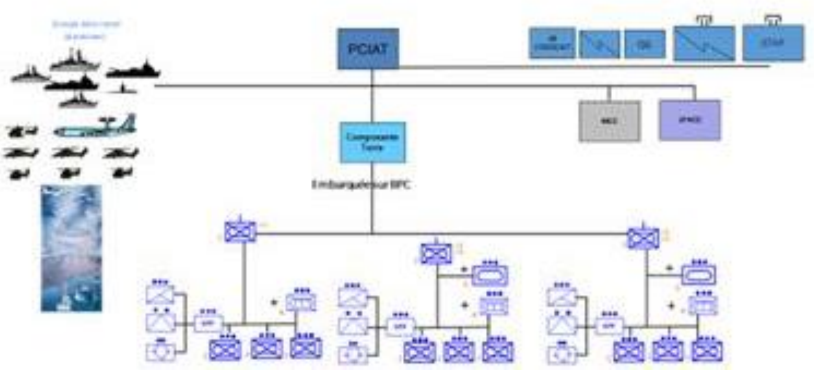


Figure 2.2: TRITON order of battle

Army forces are made of 3 Battle Groups (reinforced company). The operation is divided into 3 phases:

- Joint maritime and amphibious (landing) operation,
- Area control,
- Population recovery.

The following scenario use-cases or vignettes are extracted from the TRITON scenario.

2.3.2 Army Operation

One of the three Battle Groups is assigned to control an area. The conceptual scenario is basically fed by the Battle Group OPORD describing mission's infantry platoons must execute.

Step 1: Organization configuration diagram

The Figure below depicts the generic structure of the Infantry Battle Group as defined by the French doctrine. The cardinalities and the associated rules indicate that a Battle Group:

- Always contains one Command Unit,
- Include zero or one Joint Tactical Air Control (JTAC) team,
- Nominally includes 3 infantry platoons. The Battle Group can be reinforced (+) or reduced down to 1 infantry platoon, etc.

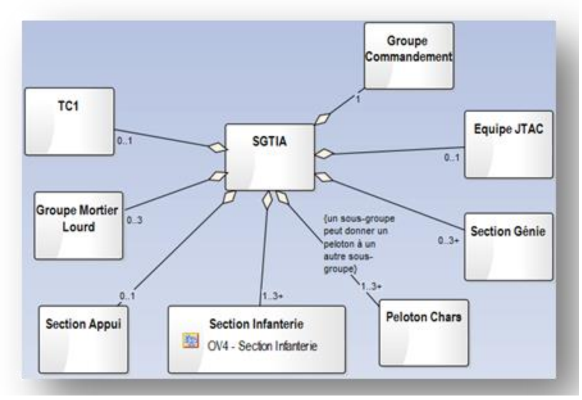


Figure 2.3: Battle Group's class unit diagram

In the context of the operational scenario, the Battle Group's current configuration for the mission control an area is made of the following subordinated entities:

- 2 infantry platoons (named bleu1, bleu2),
- 1 armor platoon (bleu3),
- 1 combat support platoon (bleu4),
- 1engineer platoon (bleu5).

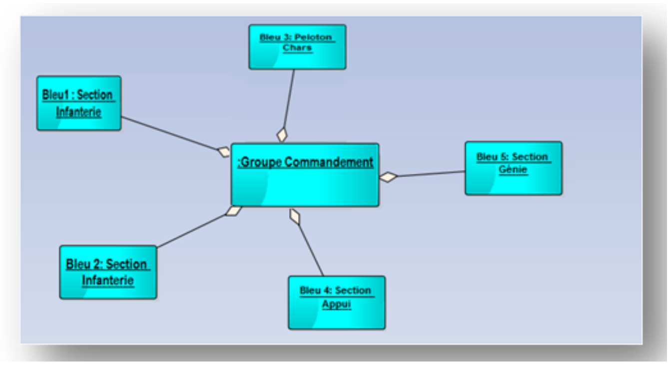


Figure 2.4: Battle Group's Organization configuration diagram

Step 2: Mission process diagram

Once the organization configuration is defined, the mission process diagram is initialized:

- A horizontal lane is generated for each entity. For convenience, the upper lane is dedicated to the command unit,
- The start event of the mission process is linked to the triggering mission order the command unit receives from its own higher command unit,
- The end event matches with the final mission report the command unit generates to its commander.

Then come the mission phases which are represented by vertical lanes, orthogonal to the unit's lanes. According to the French doctrine, land missions are divided into 4 phases:

1. Prepare the desired effect,
2. Generate the effect,
3. Exploit the effect,
4. Prepare the next mission.

Afterwards, the M&S expert drags and drops onto the cells formed at the intersection of each unit and phase lanes the missions each unit has to perform (See Figure 8). In order to execute such work, the M&S expert may pick up appropriate missions from the legacy mission library.

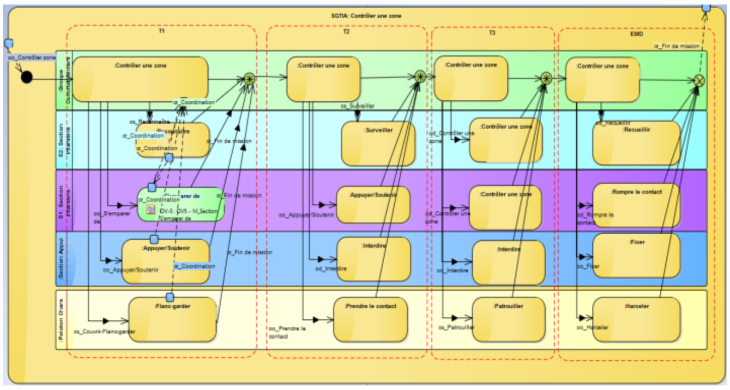


Figure 2.5: Battle Group mission process diagram for control an Area

Finally, the M&S expert adds on the diagram:

- Flows (black lines) to and from any mission (mission orders and final reports),
- Synchronization points at the end of each phase, meaning that the next phase must start only if each unit has achieved its mission within the current phase.

Additional flows (blue lines) can be added to model specific exchanges between entities during the execution of their mission.

Step 3: Mission exchange diagram

Figure below summarizes the exchanges between the Battle Group's units performing the mission control an area. It is a static diagram automatically built showing the semantic of the mission orders and reports. Since the conceptual scenario is not time stamped there is no need for a sequence diagram.

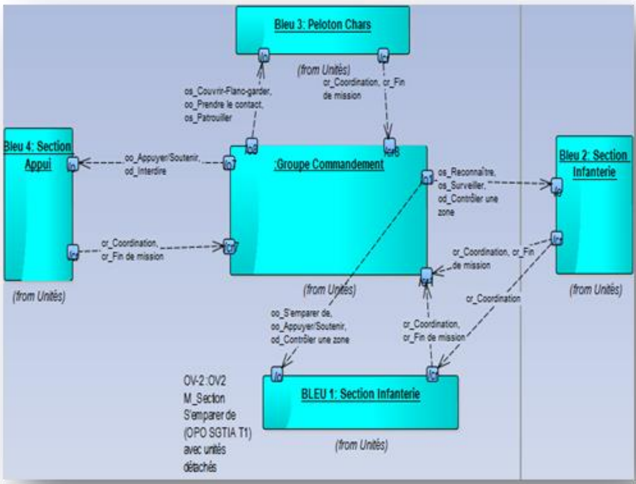


Figure 2.6: Battle Group exchange diagram

2.3.3 Air and Naval Operations

The Operational Order provides a propitious frame to apply the conceptual scenario making process to model land missions. The application of this process for air, maritime and even enemy missions introduces some enrichment to the approach. For sake of simplicity, only the mission process diagrams are discussed in the following study cases.

The use-case of air vignette TRITON scenario deals with an air to air refueling of the fighters. When developing the conceptual scenario, it is obvious that the missions of the fighters and the tanker aircraft do not share the same phases. There is indeed a need to separate the phases between the units as shown in Figure below.

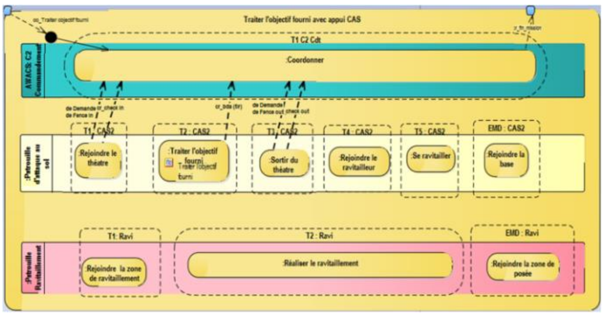


Figure 2.7: CAS mission process diagram

The TRITON operation also includes a naval blockage mission which in turn includes a ship immobilization sub-mission. Due to the various degree of collaboration of the target vessel, the mission can be achieved through many paths. Conditions are added to the mission process diagram to take into account the behavior of the target vessel.

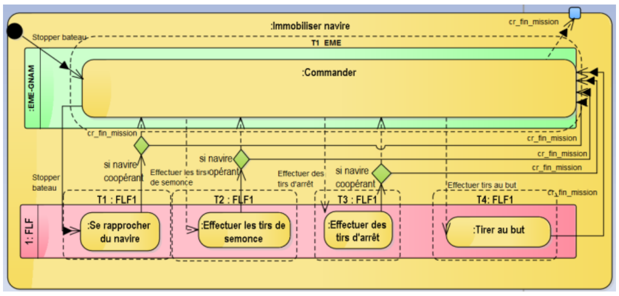


Figure 2.8: Ship immobilization mission process diagram

The opposite scenario (a guerrilla performing terrorist attacks) introduces the need to add on the mission process diagram the state a unit must have when achieving its mission. It is assumed that the enemy unit may be fully reduced at some point.

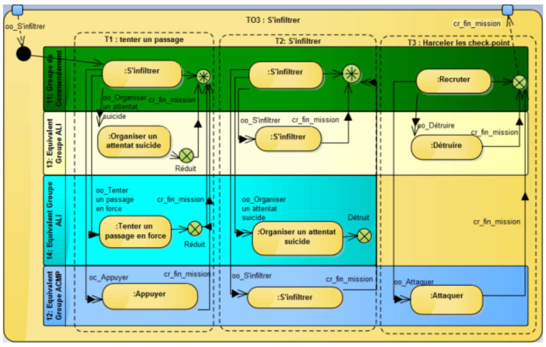


Figure 2.9: Infiltration mission process diagram

2.3.4 Reuse

Reuse of vignette is well suited to build joint conceptual scenarios as showed in the following example.

Figure below zooms into the previous CAS process diagram regarding the mission at phase 2 of the attack patrol.

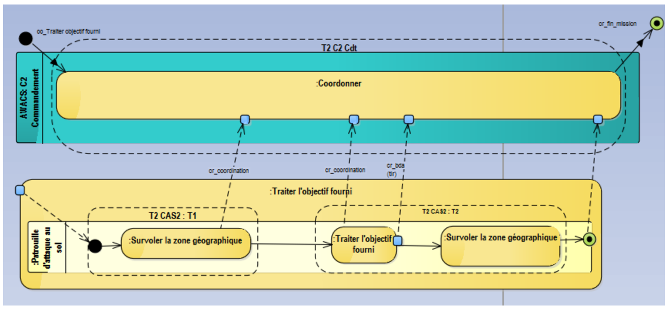


Figure 1: CAS mission process diagram (continued)

The intended target location is supposed to be specified in the air task order (ATO) of the fighters. Hence there is no target designation flow on the mission process diagram.

A variant of the mission could be created for which the intended target location is given by a platoon command group acting as a forward air controller (FAC). The supporting tool should enable the M&S expert to:

- Search in the tool workspace vignettes of interest,
- Merge the selected vignettes,
- Modify the resulting vignette.

The figure below depicts the resulting mission process diagram:

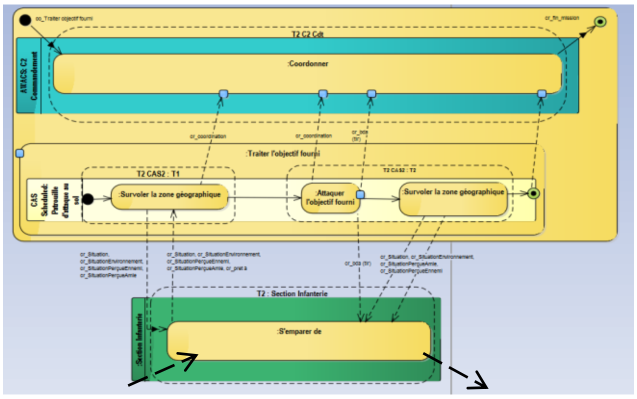


Figure 2.11: CAS mission process diagram (variant)

In the previous example, the platoon is considered as an external unit. Since external unit are not subordinated to the command unit, the lane of the platoon entity is put down outside the pool of the airborne patrol. The M&S expert has to add on the resulting process diagram the information flows (orders and situation assessment reports) to model the synchronization between the supporting and the supported units.

2.3.5 Transition to Executable scenario

The conceptual scenario when fully defined needs to be transformed into an executable scenario. This latter is produced in introducing a specific and unique context that is well described within the operational scenario and authoritative sources. Hence, the executable scenario improves the conceptual scenario with information required to configure simulation environment.

Such information is related to paragraphs “Situation” and “Execution” of the OPORD (Operation Order):

- Area of operations
- Task Organization (Order of Battle)
- Opposing and Friendly Forces Situation
- Naming of operational Units
- Phase Line and Units boundaries
- Rules of engagement
- Timeline
- Coordinating Instructions
- Environment: weather …

They are usually captured in using a Tactical Scenario Editor. No automatic process allows the transformation of the military source of information in order to generate the executable scenario. Nevertheless, the tasks to subordinated units are a matrix that is provided by the conceptual scenario. This matrix is enriched at this stage with the former information such as Timeline and Coordinating instructions. Furthermore, the operational nodes are mapped with Order Of Battle (OOB) and named accordingly. They are detailed with military devices, resources and initial location.

When ready the executable scenario is produced and transmitted in a format that is readable by simulation environment. Currently, the initialization format used is called MSDL (Military Scenario Definition Language). During simulation execution, the scenario management scheduler may provide tasks for units in producing CBML (Coalition Battle Management Language) format orders. In the future the unified format will be C2SIM Initialize and C2SIM Tasking/Reporting.

2.4 Lessons learned and way forward

Most important for Governmental Acquisition Organization is to better capture knowledge and manage it efficiently in order not to reinvent twice or more what already exists. Hence, the conceptual scenario approach may ease reuse of existing scenarios whatever the targeted application (Experimentation, Test & Evaluation, and Analysis) and users are. Also, it may help organization to size its own patrimony and develop metrics to assess the actual benefits of sharing existing valuable components.

The scenario generation process is a theoretical approach. It requires to be tested along the three stages previously defined. In order to do so, suitable tools have to be developed or adapted and used to generate conceptual scenario and to produce executable scenario.

A Meta model could be developed to customize MEGA NAF. This would ease the capture of conceptual scenario. A C2SIM translator between MEGA NAF and a Tactical Scenario Editor could also be specified to setup additional information required to execute simulation. In a near future, it is envisioned that the French Enterprise Data Service (EDS), called DIEDRES, to be populated with a conceptual scenario library in order to foster reuse.

3. GSD TO SUPPORT C2SIM EXTENSION GENERATION

Tactical Data Link (TDL) are a set of standards for Command and Control (C2) Systems to continuously exchange operational situations, orders and reports with other C2 or TDL enabled platforms such as fighters or ships.

It is proposed to develop a C2SIM TDL extension to own a standard and straightforward way of exchanging TDL messages between simulation / simulators and C2 systems. It relies on the ongoing work made by the C2SIM Product Development Group (PDG) of the Simulation Interoperability Standards Organization (SISO). C2SIM standard which is under development aims to ease C2 and Simulation interoperability improving both the previous SISO-STD-007-2008 Standard for Military Standard Definition Language (MSDL) and the SISO-STD-011-2015 Standard for Coalition Battle Management Language (C-BML).

Such an extension is intended to focus on TDL functions and not to detail technical mechanisms of real TDL implementations. The purpose is to make it accessible without a significant technical TDL knowledge.

3.1 Data Model development process

The development of LinkX data model is based on GSD approach. In order to define the C2SIM extension iteratively, an engineering process supported by the selection of the NATO Architecture Framework (NAF) and UML Views was chosen. The process presented below was adopted mainly for two reasons:

- Challenging initial LinkX implementation with a strict engineering process based on various set of operational scenarios;
- Adopting an iterative process in order to successively improve and refine the LinkX definition as new operational scenarios are developed.

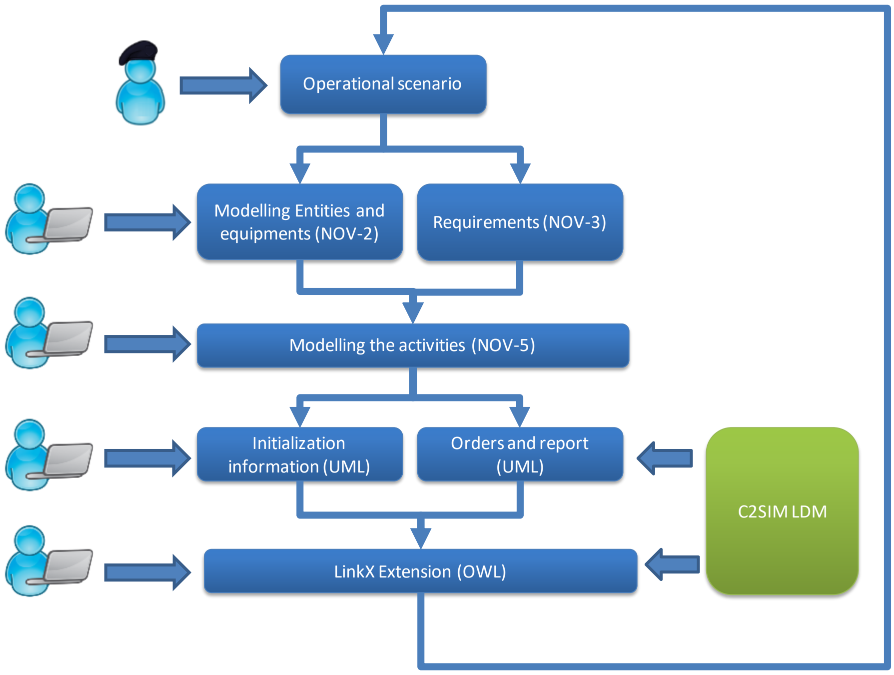


Figure 3.1: Engineering process for the LinkX C2SIM extension design

3.2 Operational scenario

The operational scenario is made of 6 vignettes to execute in sequence as depicted in figure below.

- Vignette 1:
  - PPLI broadcasted by friend fighters with J2.2 messages.
  - PPLI broadcasted by the Aircraft Carrier with J2.3 messages.
- Vignette 2:
  - Detection of an hostile fighter by the Aircraft Carrier, the message J3.2 is sent by the Aircraft Carrier to a friendly fighter and other C2 units over the Link 16 Network.
- Vignette 3:
  - The Aircraft Carrier takes control the friendly fighter with a J12.4 message.
  - The Aircraft Carrier broadcasts to other C2 units that he has the friendly fighter under control with a J10.5 message.
  - The Aircraft Carrier sends a Mission Assignment Discrete message, J12.0, to the friendly fighter to assign a Visual identification of the hostile fighter.
  - The Aircraft Carrier broadcasts to other C2 units the Weapon Engagement Status of his

friendly fighter under control in function of the previous mission assignment with a J10.2 message.

- Vignette 4:
  - The friendly fighter detects the hostile fighter with his own sensor and sends a J12.6 message to the Aircraft Carrier.
- Vignette 5:
  - The Aircraft Carrier correlates the friendly fighter detection with his own detection and sends a J12.5, correlation message, to the friendly fighter.
- Vignette 6:
  - The Aircraft Carrier sends a new MAD, J12.0, Return to Base to the friendly fighter.
  - The Aircraft Carrier terminates the control with a J12.4.
  - The Aircraft Carrier broadcasts to the other C2 units the end of the control of the friendly Fighter.

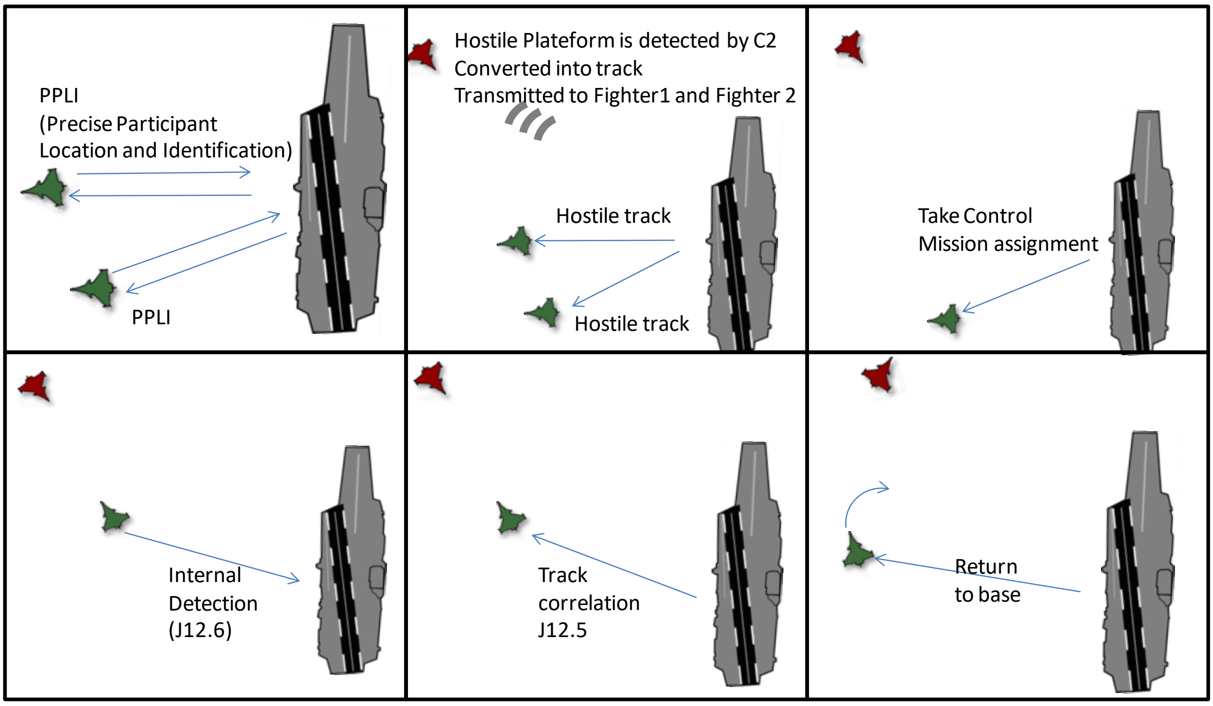


Figure 3.2: Vignettes describing the operational scenario

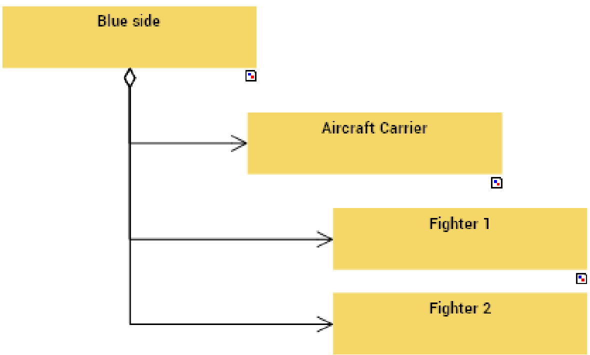
3.3 Conceptual scenario

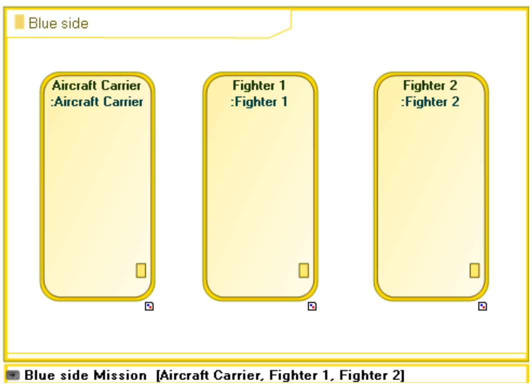
The conceptual scenario development approach requires to produce the NAF Views as depicted in the figure below.

STEPS	Tools / Methods
Operational Scenario	NOV-1 + Powerpoint
Description of nodes structure (entities, equipments)	NOV-2
Description of connectivity	NOV-2
Description of Operation information requirements	NOV-3
Description of activities	NOV-5
Logical Information (Initialization and Tasking/Reporting)	NOV-7
Identify what can be reuse from LDM	NOV-7 => UML/ OWL
Description of extensions	UML / OWL

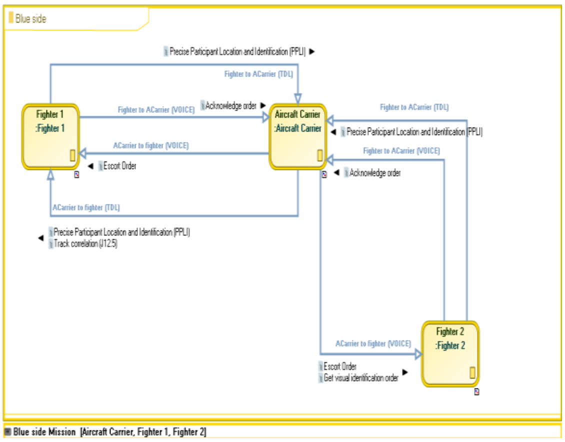
Figure 3.3: NAF Views production for TDL C2SIM extension

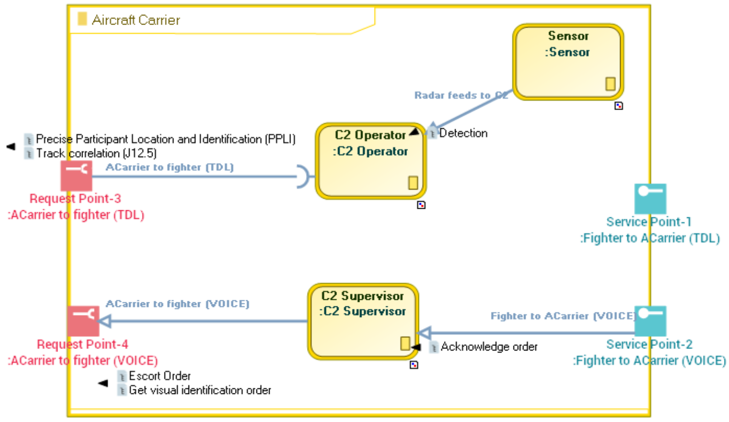
<u>Description of nodes structure</u>





Description of connectivity

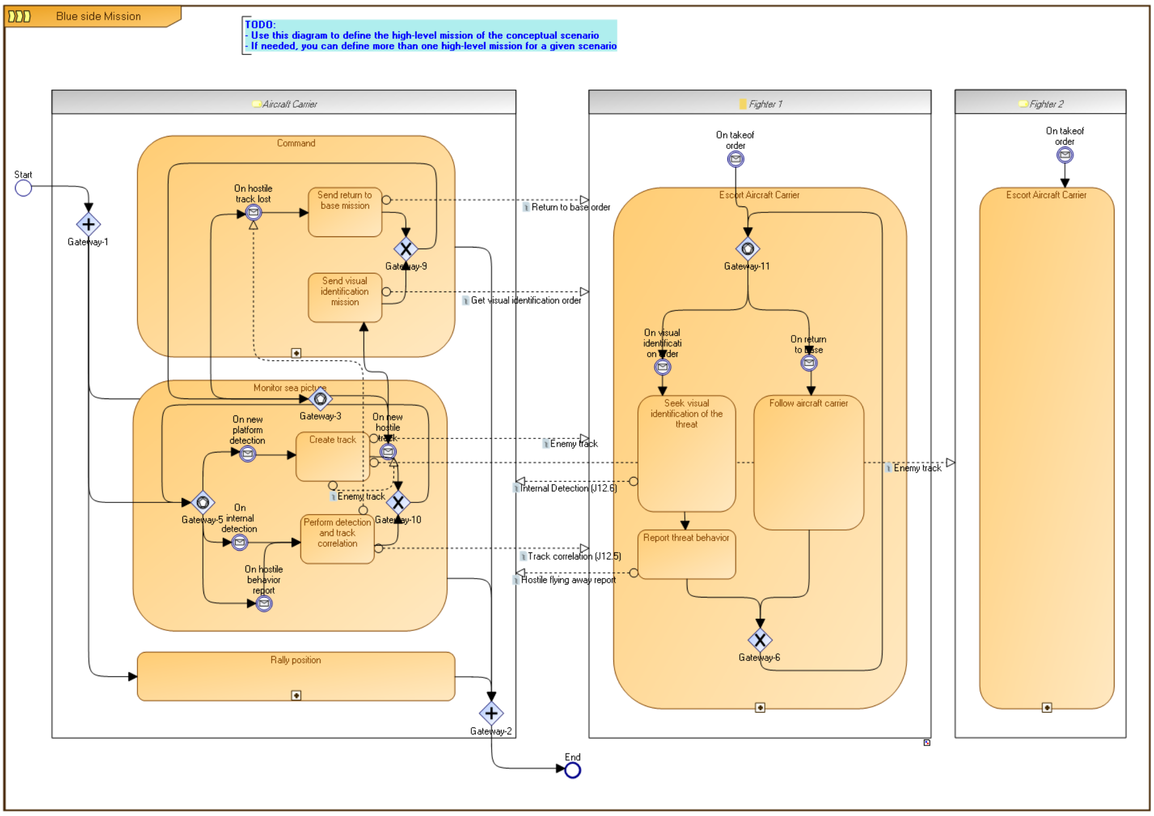




Description of Operation information requirements

Supported Operational Task	Operational Elements Involved		Description of Information	Typical Required Information Exchange Attributes			
Specific Mission, Functions or Activities	Information Consuming Node	Information Producing Node	Element of Warfighter Information	Média (text, video, voice, data, etc)	Quality (Frequency, timeliness, security, etc.)	Quantity (Volume, speed, etc.)	Capabilities (comms, processing, display, etc.)
Command / Send return to base mission	Fighter	Air Carrrier	MAD order (Return to base)	data	on demand		
Command / Send visual identification mission	Fighter	Air Carrrier	MAD order (Get visual ID)	data	on demand		
Monitor Picture / Send Track	Fighter	Air Carrrier	Track (internal detection)	data			
Monitor Picture / Perform detection and track correlation	Fighter	Air Carrrier	Track correlation J12.5	data			
Seek visual identification of the threat/ Send Track	Air Carrier	Fighter	Track (internal detection)	data			
Report threat behaviour	Air Carrier	Fighter	Hostile flying away	voice			
Report PPLI	Air Carrier	Fighter	PPLI	data	every 12 s		
Report PPLI	Fighter	Air Carrier	PPLI	data	every 12 s		
Command / Cease mission	Fighter	Air Carrier	MAD Order (Cease mission)	data			
Control / Take Control	Fighter	Air Carrier	Take Control	data			
Acknowledgement	Air Carrier	Fighter	Acknowledgement	data			can process or can't process

Description of activities



Conceptual Data Model Design

Initialization

Entity or equipement	fields/values	basic type
NC2 TDL Unit	NetworkID	string
	Own PPLI number	DataLinkTrackNumber
	Delta position	double
	Delta speed	double
	Delta altitude	double
C2 TDL Unit	NetworkID	string
	OWN PPLI number	DataLinkTrackNumber
	Delta position	double
	Delta speed	double
	Delta altitude	double
	Min track quality	integer

Tasking/Reporting

PPLI	Position
	Speed
	Environment
	Platform
	VoiceCallSign
	LeaderTN
	C2

InternalDetection	ID
	Position
	Speed
	Environment
	Platform
	Classification
	Force
	FiredTrack
	PositionIncertitude
	AltitudeIncertitude
	RealTime

MissionAssignment	TNTarget
	TypeOfMission
	PositionTarget
	TargetType
	AttackAxis
	ClearanceAxis
	LaserCode
	ResponseRequired
	Armament
	Time

ControlChange	Order
	TN

Correlation	Order
	TN
	IN

RemoteTransmission	TN
	Position
	Speed
	Environment
	Platform
	Classification
	Force
	TrackQuality
	TrackOrPoint
	Exercise

3.4 Lessons learned and way forward

This professional approach identifying required information for setting up the environment and for tasking/reporting was fruitful to generate the targeted TDL extension:

- PPLI PPLI transmissions (C2SIM Report)
- C2 sends track to fighter 2 (C2SIM Report)
- C2 « takes control » on fighter 2 (C2SIM Request)
- Fighter 2 acknowledgement (C2SIM Acknowlege Request)
- C2 sends « Identification » mission to fighter (C2SIM Order)
- Fighter 2 acknowledgement (C2SIM Acknowlege)
- Transmission of local detection to C2 (C2SIM Report)
- C2 sends « Correlation » (C2SIM Order)
- C2 sends « return to base » to fighter 2 (C2SIM Order)

The scenario execution was successfully demonstrated during I/ITSEC 2017 as a prove of the effectiveness and relevance of the approach to fully master the interoperability in producing customized C2SIM extension.

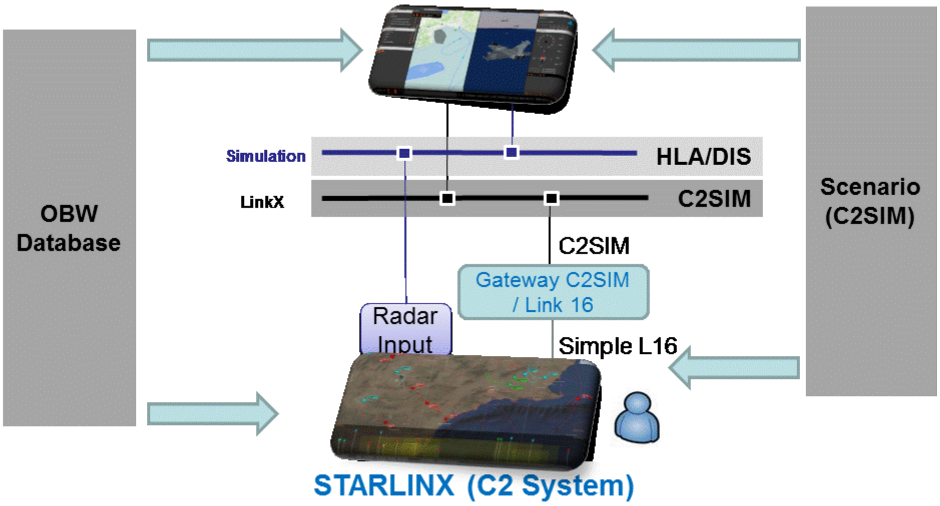


Figure 3.4: TDL C2SIM extension Demonstration at I/ITSEC 2017

4. GSD CONCEPTS AND GUIDELINES TO MASTER INTEROPERABILITY

DGA has produced in 2017 a “Guide for developing simulation based environment”. This is a French improvement of the Simulation Interoperability Standard Organization (SISO) product “Distributed Simulation Engineering and Execution Process (DSEEP)”. Following this initiative, a guide to master interoperability when developing a simulation based environment was produced in 2018. This guide provides a methodology to ease and secure during the specification and the design of the targeted simulation based environment the unambiguous capture and fulfillment of operational requirements. It promotes and details the GSD approach and recommends to address the technical architecture in using NATO System Views. Connection between NATO Operational Views and System Views are critical to guarantee components to fulfill end user requirements expressed within an Operational Scenario. In addition, interoperability between components of the technical architecture are better justified against operational objectives to achieve. In case of any interoperability issues, the consequences regarding the operational scenario execution are quickly assessed.

4.1 Operational requirements

During this first stage, information needed to build the model traceability are collected. Information gathers main actors and expected goals.

The operational scenario is depicted according to:

- A picture highlighting the actors located in the area of operation (NOV-1)
- Macro Objectives and Capabilities as an inventory of operational inputs (NCV-2)

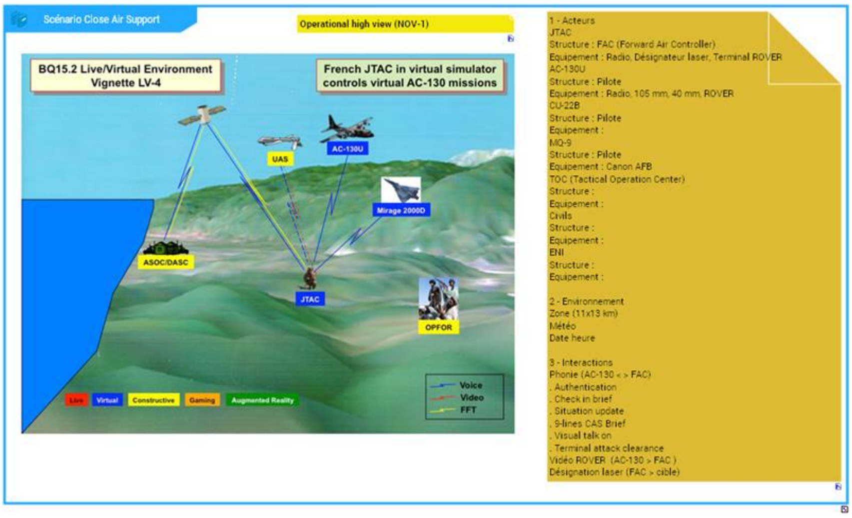


Figure 4.1: Operational Scenario (NOV-1)

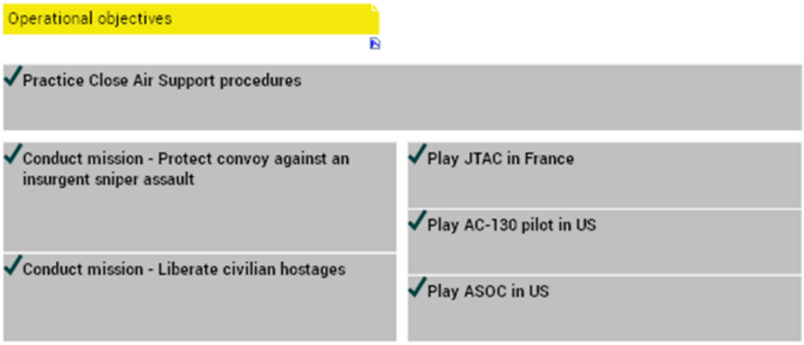


Figure 4.2: Operational Scenario objectives

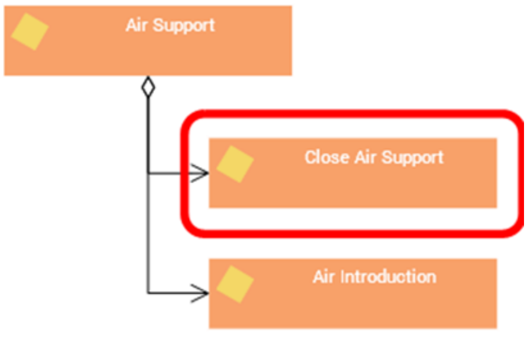


Figure 4.3: NCV-2

4.2 Simulation based environment Specifications

4.2.1 Conceptual Scenario

The conceptual Views can be perceived as an enrichment of the Operational scenario where information is introduced in a non-structured way.

Nodes and operational exchange

The operational nodes gather the roles player. It can be part of an organization, a system, a group of people. They will produce and consume information:

- Communication: formal messages, informal mail exchange (radio procedures);
- Interaction: events triggered under condition (detection);
- Environment: change of the state within the environment.

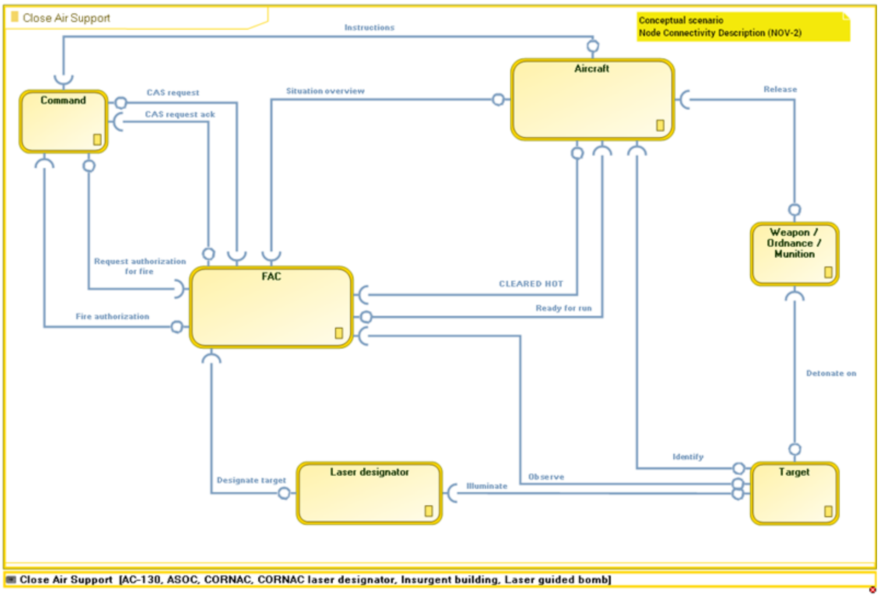


Figure 4.4: Nodes and operational exchange (NOV-2)

Activities and exchange between activities

The architecture modelling is enriched introducing the activities and the required exchanges between them as depicted in the figure below.

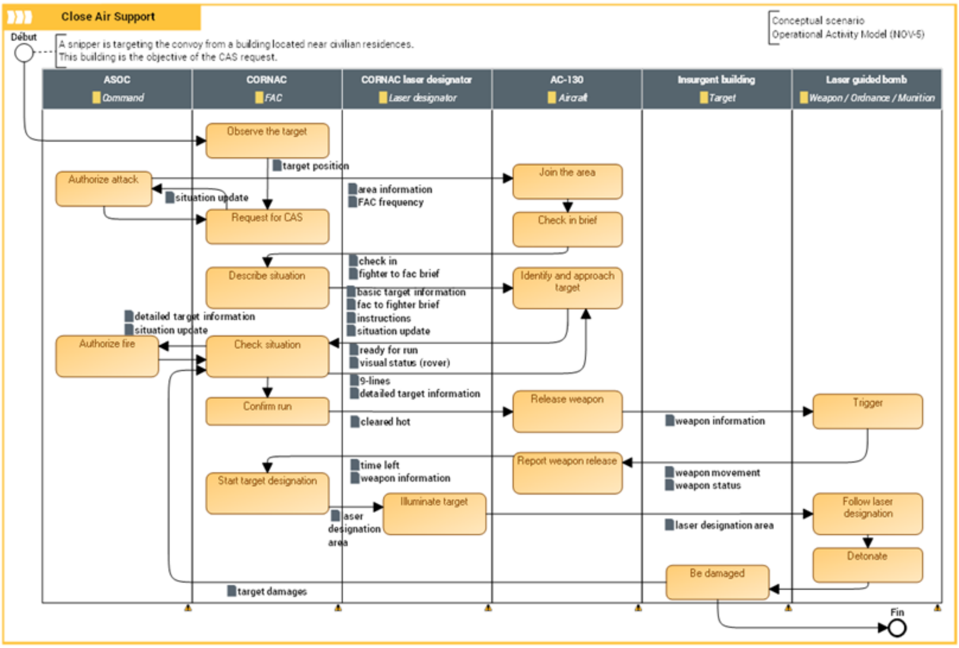


Figure 4.5: Activities and exchange between Activities (NOV-5)

Traceability

Different matrix can be produced to inform and to check the scenario completeness:

- Connection between Nodes an Operational Scenario objectives
- List of information exchange between Nodes
- List of information exchange between Activities

4.2.2 Functional Architecture

The functional analysis tends to gather activities linked to the same functional area into a unique function. It does not concern the technical architecture which will be addressed later.

Functions regarding the overall architecture and not only the goals expected by the players are added such as the exercise control. Therefore, it is quite right that some functions are not connected with activities listed in NOV-5.

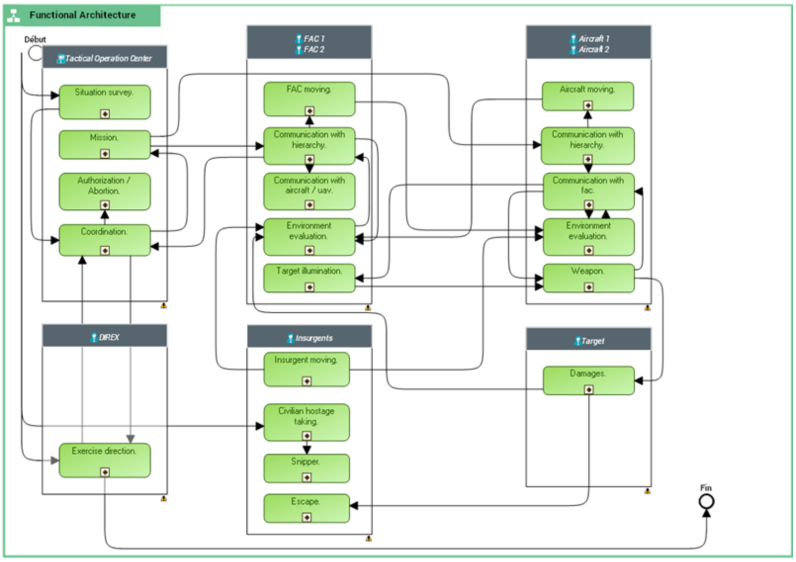


Figure 4.6: Architecture fonctionnelle (NSV-4)

The exchange analysis between functions eases to perform an additional reasoning regarding the information to exchange. They can be refined and improved, such as:

- FAC location;
- Aircraft location;
- Enemy location.

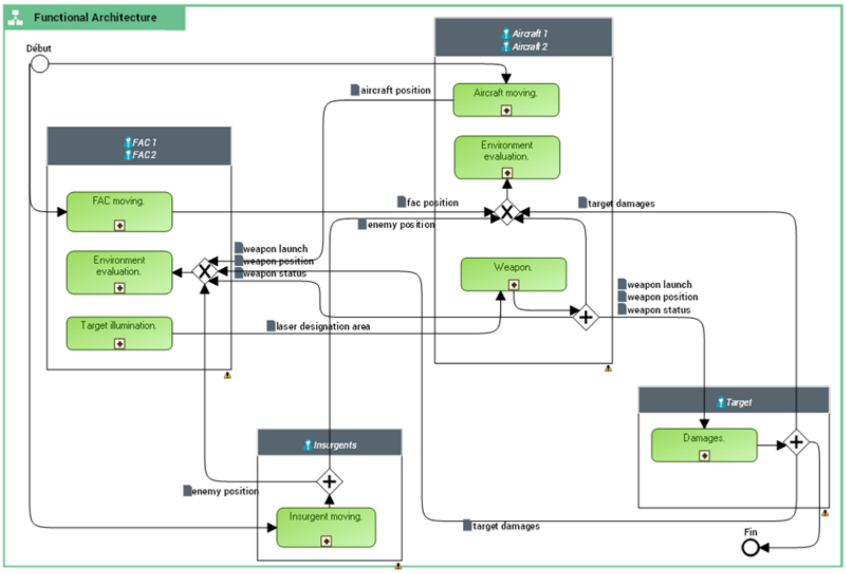


Figure 4.7: Focus on Functional exchanges (NSV-4)

Different matrix can be produced to check the functional modelling before moving ahead:

- Connection between Functions and Nodes;
- Connection between Functions and Activities;
- List of additional functional exchanges;
- List of functional exchanges produced and consumed by Activities.

4.3 Simulation based environment Design

4.3.1 Technical Architecture

Even if several technical architectures can meet the needs, the one which was selected will be depicted in using three different NSV-1 Views:

- Technical Architecture;

  This figure depicts the main systems required to manufacture the simulation based environment. Each system addresses one or several nodes detailed within the conceptual scenario and hosts one or several functions.

- Systems Connectivity;

  Systems can be connected together to vehicle information exchanges previously identified. The objective is to check that the architecture supports the expected exchange of information.

- Interfaces between components;

  A system being made of components, it is relevant to identify the components to connect between systems. It will ease to define what interfaces are needed and how to share information exchange requirements per interface.

It is recommended to apply this approach for each of the systems identified as a building block of the technical architecture. Each interface can support a standard and a different information exchange data model.

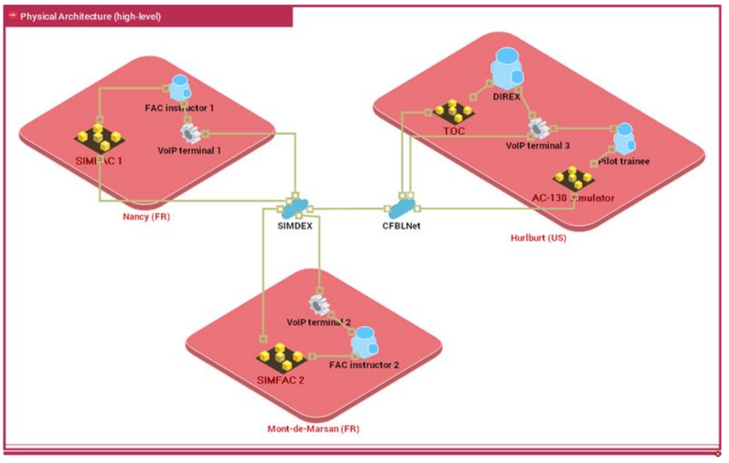


Figure 4.8: Technical Architecture (NSV-1)

An « AssetType » property enriches each resource belonging to the architecture. It pinpoints if the resource is:

- Real, the IP phone for example;
- Simulated, le AC-130 simulator for example ;
- Or if it is a human resource like the FAC instructor.

This information is critical to set up the tractability matrix.

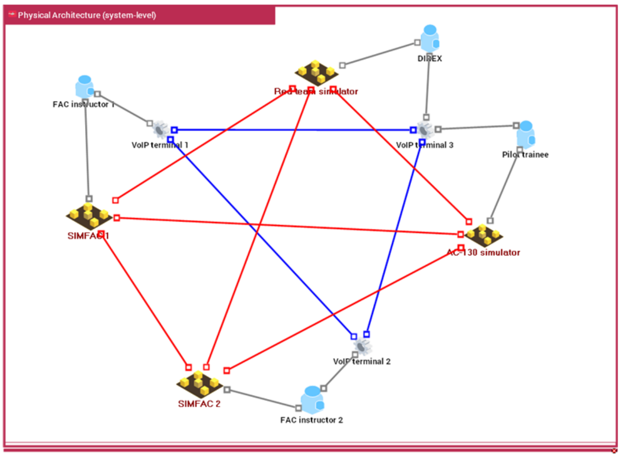


Figure 4.9: Systems Connectivity Architecture (NSV-2)

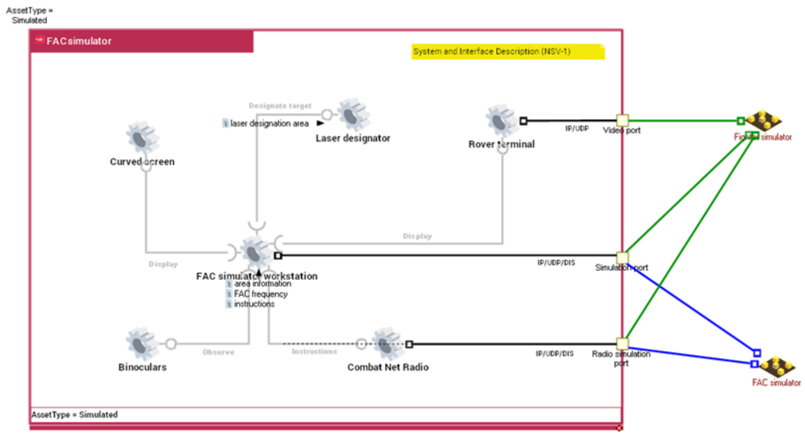


Figure 4.10: Architecture and interfaces between components (NSV-1, NSV-2)

Each information exchange previously identified within the conceptual scenario is linked with a communication channel that is an interface of the system. Hence, the information to exchange for each interface can easily be listed.

When implementing an interface does not require a specific data model, the process can end at this step. This is the case regarding the video.

Different matrix can be produced to check the technical architecture before addressing interoperability issues:

- Connection between Components and Functions;
- Connection between Components and Nodes;
- Connection between Components and Activities;
- List of information exchange interaction per interface;
- List of information exchange object per interface.

4.3.2 Interoperability Model

The objective is to structure the information to exchange between components within a data model. Each information to exchange identified all along the process (operational, between activities, functional) is related to an object or an interaction within the data model. The entities can be references between them, per heritage, per association (e.g. a detonation can be associated with a fire or not) or per aggregation (e.g. ammunition location and speed is also needed).

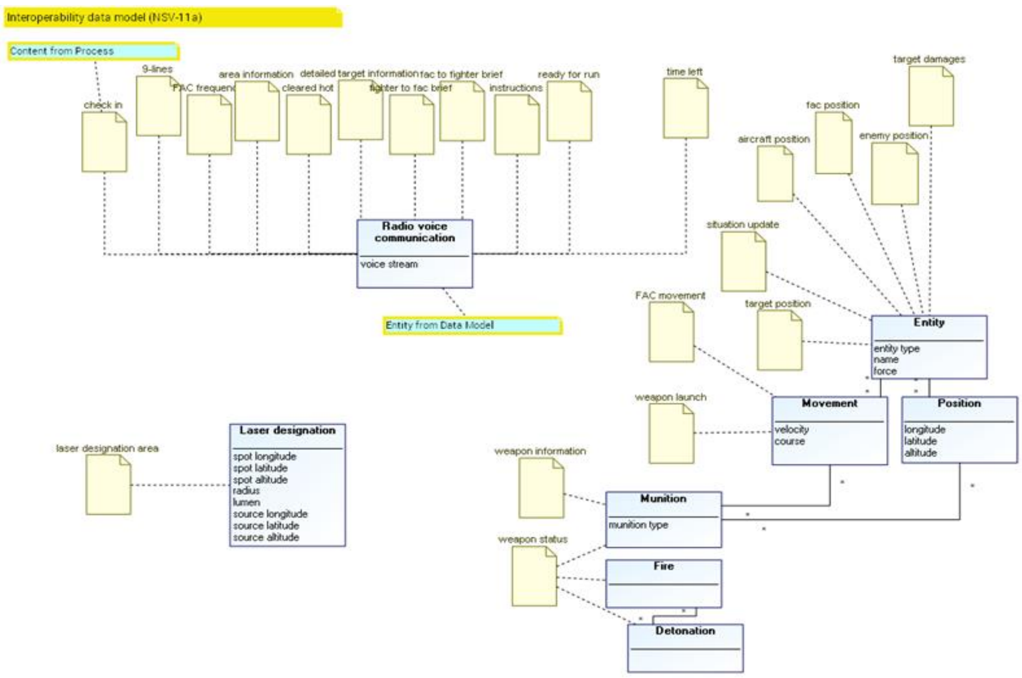


Figure 4.12: Logical Data Model (NSV-11a)

Two matrix are finally developed:

- Connection between the information to exchange and the related data model to develop
- Connection between Data Model and interface

The last step is to select the suitable protocol or standard for each interface. Hence, the logical data model as an outcome of the process is assessed against the data model provided by the standard.

As an example, the figure below highlights the results for two expected information exchange dealing with « check in » et « FAC location ».

Data model entity	Content	Interface	Protocole	Standard	PDU
Entity	fac position	simulation data channel	IP/UDP/DIS	IEEE1278.1a-1998	Entity State
Radio voice communication	check in	simulation radio channel	IP/UDP/DIS	IEEE1278.1a-1998	Transmitter Signal

Figure 4.13: Standard to exchange FAC location and Check in (NSV-11b)

4.4 Conclusion

The overall process describing how to master interoperability when developing a simulation based environment

guide is depicted below. It reuses but also refines and details the GSD approach in order to clarify what is a conceptual scenario and how to build the executable scenario. It identifies the required NAF Views to develop at every steps.

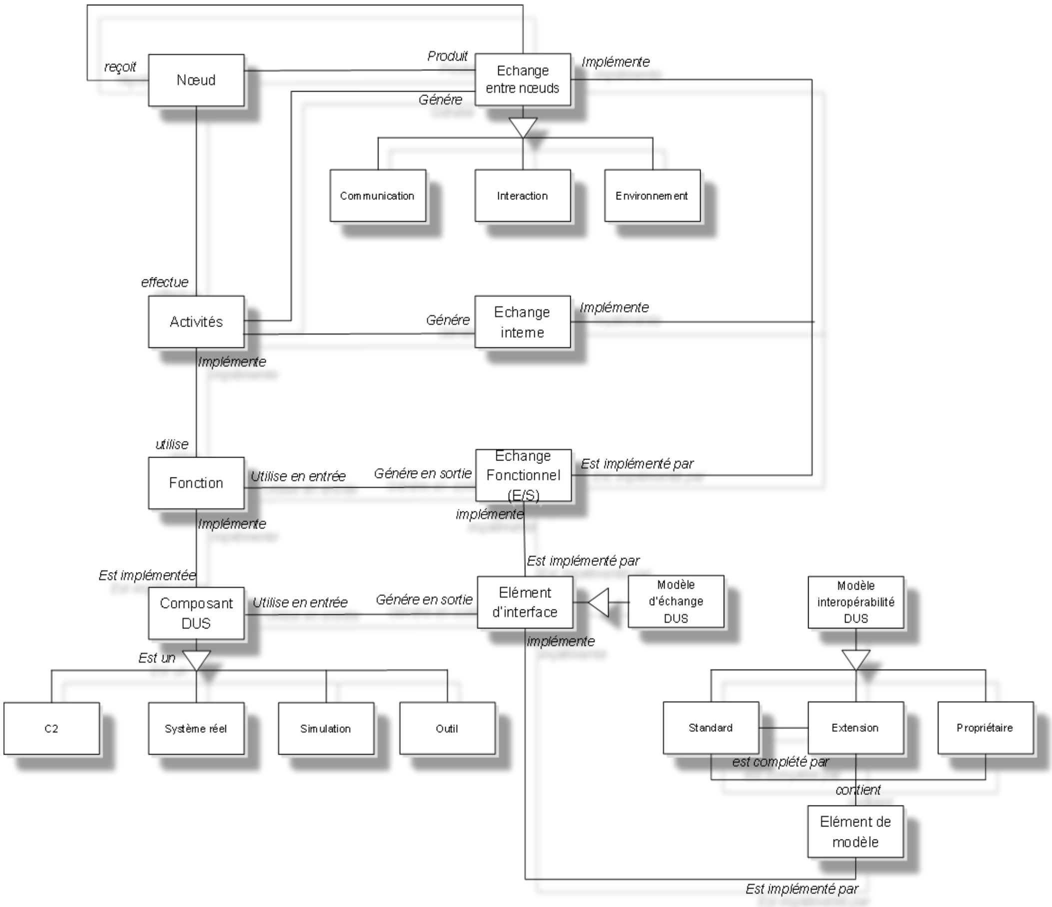


Figure 4.14: Modeling process to master simulation based environment interoperability

5 MODELING TO SIMULATION AUTOMATION

The EASE for SE (Extended Architecting and Simulation Environment for Systems Engineering) research project is part of the digital transformation for the definition, evaluation and development of large systems. Considering SE practices for programs of record, management and evaluation of Systems and Systems of Systems architectures require more and more interconnections between modeling and l simulation capabilities. Thus, the main objectives of the EASE for SE project is to bridge Architecture and Simulation activities in the context of Model Driven Systems Engineering (MBSE) and Computer-Generated Forces.

The ongoing research leads to explore technical solutions in order to ease the design of the simulation, automate the initialization of the simulation and ensure the smooth running of the simulation. However, it is critical not to change the NAF approach in introducing new concepts or in modifying its use. The guideline is clearly to leverage the NAF Views to better express the requirements in using a common ontology.

Based on the guide to master interoperability when developing a simulation based environment, the key activity is to translate the nodes, activities into simulated entities and related behaviors. The works achieved so far provides a gateway fully dedicated to work with DirectCGF. It generates an executable scenario, in a proprietary format, ready to initialize simulation and to execute the conceptual scenario according to the targeted operational initial conditions (e.g. terrain, weather, …).

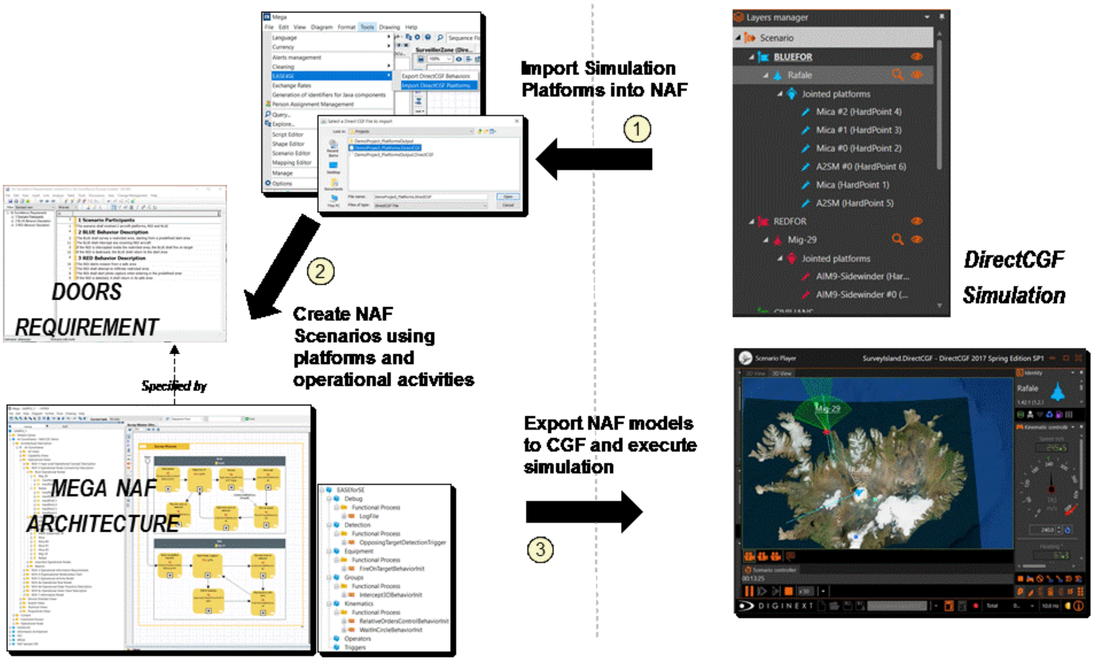


Figure 5.1: Experimentation performed to assess the transition from Modelling to Simulation

The current experimentation performed in connecting DirectCGF and NAF MEGA as well as the lessons learned are nowadays very promising. The next step will be to generate a C2SIM executable scenario to extend the approach to different simulation frameworks like VR-Forces and SWORD.

6 ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Meaning
ATO	Air Task Order
CAS	Close Air Support
C-BML	Coalition Battle Management Language
CONOPS	Concept of Operations
DGA	Direction Générale de l’Armement (French Mod)
DSEEP	Distributed Simulation Engineering and Execution Process
EDS	Enterprise Data Service
FAC	Forward Air Controller
GSD	Guideline on Scenario Development for simulation environments
JTAC	Joint Tactical Air Control
M&S	Modelling and Simulation
MSDL	Military Scenario Definition Language
NAF	NATO Architecture Framework
NCV	NAF Capability Views
NATO	North Atlantic Treaty Organization
NOV	NAF Operational Views
NSV	NAF System Views
SISO	Simulation Interoperability Standards Organization
SME	Subject Matter Expert