APLET

Aide à la Planification d'Engagement Tactique Terrestre

M&S in Decision Support for Course of Action Analysis, APLET

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RESUME

APLET (Aide à la Planification d'Engagement Tactique terrestre) est un programme d'étude amont dont l'objectif est d'investiguer les différentes possibilités offertes par la simulation pour être intégrée dans un SIO, Système d'Information Opérationnel, de niveau brigade afin d'aider au choix et à la confrontation des modes d'action ami et ennemi. Ce projet vise également à explorer les difficultés techniques actuelles du couplage entre les SIO et la simulation et à fournir des recommandations concernant les interfaces et les modèles de données afin de combler le fossé existant entre le monde des SIO et celui de la simulation. Pour cela, des démonstrateurs technologiques illustreront et démontreront la faisabilité des différentes approches techniques étudiées et préconisées pour le futur.

Ce papier introduit tout d'abord les principales exigences opérationnelles pour la confrontation des modes d'action ami et ennemi issus du processus de décision opérationnelle MEDO (Méthode d'Élaboration d'une Décision Opérationnelle). Au regard des besoins utilisateurs, la seconde partie met l'accent sur les travaux qui sont à mener pour améliorer l'interopérabilité entre les futurs systèmes de simulation et les SIO. Les évolutions majeures du C2IEDM (Command and Control Information Exchange Data Model) afin d'être compatibles avec les données manipulées par les modèles de simulation et les mécanismes d'échange de type XML entre SIO et systèmes de simulation sont ici détaillées et commentées. Dans une troisième partie, ce papier aborde la définition et le développement de modèles physiques et comportementaux d'unités opérationnelles en s'appuyant sur les équations mathématiques de Réaction Diffusion, RDE (Reaction Diffusion Equations). L'optimisation et la valorisation de cet algorithme sont expliquées pour obtenir une représentation réaliste et fidèle du champ de bataille. La dernière partie de ce papier aborde la rareté de l'expertise opérationnelle reportant ainsi en fin de développement de projet la réalisation des modèles de type C2 (Comand & Control). Pour faire face à cette situation, l'architecture logicielle préconisée par APLET est introduite. Notamment, APLET recommande que le développement de modèles de type C2 s'appuie sur des machines à état fini décrit en UML.

Le programme APLET s'inscrit dans le cadre des différentes actions engagées par la DGA pour favoriser l'interopérabilité des SIO et des systèmes de simulation. L'objectif court terme est d'obtenir un premier niveau d'interopérabilité entre les SIO et les systèmes de simulation existants afin de répondre aux exigences opérationnelles immédiates. Dans cette optique, la convergence des modèles de données des

Paper presented at the RTO NMSG Symposium on "Modelling and Simulation to Address NATO's New and Existing Military Requirements", held in Koblenz, Germany, 7-8 October 2004, and published in RTO-MP-MSG-028.

SIO et des systèmes de simulation est considérée comme incontournable A moyen terme, l'objectif visé consiste à partager des composants communs entre les SIO et les systèmes de simulation afin d'accroître l'interopérabilité et donc d'étendre l'utilisation de la simulation sur le champ de bataille. A plus long terme, l'objectif porte sur la convergence des architectures permettant alors aux systèmes de simulation d'être embarqués dans les SIO et ainsi de couvrir l'étendue du besoin opérationnel.

Afin d'accroître l'interopérabilité entre les SIO et les systèmes de simulation, les auteurs recommandent, la création d'une activité technique sur le thème de la convergence des modèles de données des SIO et des systèmes de simulation et l'élaboration d'un dictionnaire commun. La mise en commun et le partage des résultats des études conduites en France, notamment le projet APLET, en Grande-Bretagne et aux Etats-Unis d'Amérique dans le cadre des travaux sur le BML, Battle Management Language, favoriseraient le démarrage de cette activité technique.

OVERVIEW

APLET (acronym for "Aide à la PLanification d'Engagement Tactique") is a French MoD R&T program which aims to investigate the capabilities offered by M&S for its integration into an existing Brigade level C4I system for Courses of Action Analysis (COAA) purposes. In addition, this program is dedicated to exploring the technical issues of C4I-M&S coupling and to providing recommendations for M&S interfaces, models and data models to overcome the gap between current M&S and legacy C4I. A series of demonstrators is developed to prove the feasibility and demonstrate the technical approaches studied and recommended for future use.

This paper first introduces the main COAA operational requirements derived from the French Military Decision-Making Process used at tactical level and called MEDO (Méthode d'Elaboration d'une Décision Opérationnelle). Regarding user needs, the second part highlights the works led to improve the interoperability between future simulation and C4I system. It presents the major amendments of the Command and Control Information Exchange Data Model (C2IEDM) to be consistent with simulation models requirements and C4I-M&S interchange mechanisms based on XML. In a third part, this paper addresses the definition and development of physical and behavior models for Armed forces units based on Reaction Diffusion Equations (RDE). It explains how such algorithms are optimized and customized to move closer to ground truth. The last part deals with the lack or rarity of military expertise that forced, until the latest time, the postponement of the development of Command and Control (C2) models. Overcoming such drawbacks, the technical software architecture designed for APLET is introduced. The paper then focuses on APLET's capabilities for C2 model creation considering such models as UML finite state machines.

This program is a part of different works on C4I-M&S interoperability led by the French MoD. A short-term objective is to obtain an operational interoperability between legacy C4I and simulation systems that meets the major Military requirements. Thus, alignment of C4I and simulation data models based on C2IEDM is seen as mandatory. A mid-term objective is to share common components between C4I and M&S in order to improve interoperability and then to extend Military use of simulation on the battlefield. The long-term objective is to reach the alignment of architectures, for embedding simulation into C4I thus covering the full spectrum of operational requirements. In that frame, cooperation is envisioned within SISO C4ISR-Simulation Product Development Group (PDG) and the DMSO Program on Extended Battle Management Language (XBML).

In order to improve the C4I-M&S interoperability, the authors recommend the creation of an NMSG Technical Activity based on the alignment of C4I and simulation data models and the definition of a common dictionary. The common sharing of results of the French studies, APLET for instance, UK and US works on BML, Battle Management Language, could facilitate to start such technical Activity.

1 INTRODUCTION

APLET is a French MoD R&T program which aims to analyze simulation concepts of use in order to facilitate and improve Course of Action Analysis performed at Brigade or Division Headquarters fitted with the C4I system named SICF. In addition, APLET addresses the technical issues of C4I – simulation coupling.

APLET's main objectives are:

- Automate the Military Decision-Making Process for Course of Action Analysis;
- Foresee capabilities and added value given by simulation in case of close integration with C4I systems and as an example with SICF;
- Explore and solve C4I-simulation inter-operability issues and propose recommendations to bridge the gap between those systems;
- Define the most suitable simulation granularity allowing Courses of Action Analysis (COAA) in a tight period and experiment new algorithms like RDE (Reaction Diffusion Equation);
- Propose mechanisms to automatically produce Operation Orders from a selected Course of Action.

The APLET's schedule is divided into three phases. The first one, called "preliminary study", was aimed to address the gathering of operational requirements and the analysis of different technologies for C4I and simulation coupling. This phase ended with a mock-up illustrating the military requirements collected during interviews.

The second phase goal is the development of a demonstrator for Brigade COAA that highlights the usability and the effectiveness of the technical recommendations proposed during the preliminary study phase. This demonstrator will be tested in real situation during a Brigade exercise in November 04.

The third and final phase objective is the implementation of a second version of the demonstrator, taking into account the lessons learned during experiments. Finally, the overall program will end in 2006 with the specifications for an operational system.

The present paper highlights the work performed on modeling during APLET's second phase. First, the French Military Decision-Making Process and the main operational requirements are introduced. Then, the paper focuses on APLET's data model, based on C2IEDM. The last part deals with simulation models and stresses work on behavior and C2 models for decision support purposes.

2 OPERATIONAL PROCESS & REQUIREMENTS FOR COURSE OF ACTION (COA) ANALYSIS

2.1 The French Army Military Decision-Making Process

The French Army Military Decision-Making Process is named MEDO, which stands for "Méthode d'Elaboration d'une Décision Opérationnelle" ([1]). MEDO aims at presenting to the Force Commander the main analysis and synthesis elements that will lead to an engagement decision and the drafting of an operation order for subordinates.

MEDO is implemented at the tactical level, from LCC-level to Squadron-level. It allows the HQ Staff to study and to research solutions for tactical problems in a rational way. The receipt of an OPOrder (OPeration Order) from the superior level or an evolution of the ongoing situation triggers the decision-making cycle.

MEDO consists of four main phases:

- The first phase is the analysis of the tactical situation that is divided in essential elements such as: own forces, opposite forces, terrain, population, etc. The data collected during the analysis is synthesized in order to choose “centers of gravity,” “decisive points” and finally the “major effect”;
- The second phase is dedicated to the elaboration of possible maneuvers (COA);
- The third phase is the decision phase: the comparison of friendly and opposite Courses of Action takes place and finally ends with the selection of a preferred Course of Action;
- The operation order is drafted during the fourth and final phase.

At Brigade-level, officers involved in the MEDO process are the General or his deputy, the chief of Staff, the HQ cell leaders (intelligence, planning, logistics, C4I) and the specialized arms liaison officers (Artillery, Engineer, Signals, etc).

Figure 1 depicts, for the different MEDO phases, the tasks that must be performed within a time-constrained period. The following sections detail MEDO activities at Brigade level.

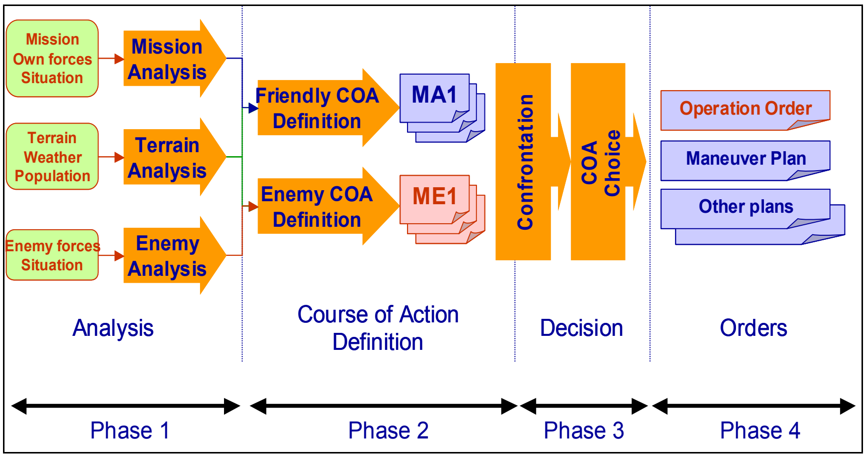

Figure 1: the MEDO process

2.1.1 Phase 1, Brigade: H to H + 4 hours

After reception of an OPOrder from Division, the G3/G5 cells of the Brigade HQ analyze the main paragraphs of this order (Forces situation, Mission, Operation objectives). Each HQ cell does so in order to prepare the first meeting with the Brigade commander. The purpose of this meeting is to align the common understanding of the order, to collect the initial assessment of the Brigade General as well as his first guidance.

After this meeting, a WINGO (Warning Order) is generally sent to the subordinate units to alert them on foreseeable operations. The WINGO purpose is to inform as soon as possible the subordinate units that an order is on preparation. Thus, they can already anticipate any preparatory actions needed, and proceed in the same manner with their own subordinates.

Then, HQ cells study in details: time and space frames, friendly and opposite forces. Each cell balances constraints, imperatives and tasks to be realized.

All these elements allow to determine enemy “gravity centers” as well as the “balance of forces”, and finally to choose a “major effect”. At the end of this reflection, several types of requests can be sent to Division level concerning:

- Reinforcement of the Brigade (units, material);
- Supports;
- Intelligence;
- Modification of the operations area limits;
- Timing modifications.

2.1.2 Phases 2&3, Brigade: H+4 to H+6 hours

This phase is dedicated to Course of Action elaboration, as well for the friendly side as for opposite forces. COA are independently elaborated by two distinct cells of headquarters:

- The G3/G5 cell elaborates tentative friendly COA;
- The intelligence cell (G2) elaborates possible opposite COA.

Each COA must be rather general and characterized by a particular style, according to the type of effort, space, time, etc.

After COA elaboration, the comparison takes place (phase 3): for each friendly / opposite COA couple. The balance of advantages, drawbacks and risks is determined. The choice of the preferred COA is made from those elements. The analysis is based on selection parameters determined by the Brigade commander, as he wishes, for example to privilege speed, surprise, or security of maneuver. These criteria are related to operations as well as to the commander's personality.

Finally, the COAs and the comparison results are presented to the General who selects one. Most of the time, he requires refinements and improvements before officially committing the right COA. Guidance is given to the OPOrder editorial staff too.

2.1.3 Phase 4, Brigade: H+6 to H+12 hours

This stage deals with the OPOrder drafting and broadcasting. To apply the previously approved COA, all HQ cells draft the OPOrder paragraphs related to them.

The G5 cell ensures coordination between the other involved cells during drafting, and thereby ensures the consistency of the OPOrder. At the end of this phase, the order is sent to the subordinates by G2.

2.2 Operational Requirements concerning simulation for CoA Analysis

The MEDO process, detailed in the previous section, is an intellectual process, not yet supported by any tool. During the first phase of the project, French Army officers' requirements for a simulation supporting MEDO were collected. This section summarizes their main requirements:

Process:
Within a national context, the simulation shall support the MEDO process. For operations in a multinational context, the simulation shall support the NATO process, named OPP (Operations Planning Process). OPP is quite similar to MEDO.

Scope of Operations:

The simulation will be used for "high intensity" operations, at Division or Brigade level.

Subordinate Units:
Simulated Subordinates Units shall be armor and infantry units for COA definition, and supporting units for COA refinement.

Main constraints:
SICF connection with the APLET simulation is a key requirement: interoperability is necessary to avoid delays due to manual data introduction in both systems.

The timing constraints are the following:

- On Brigade level, the simulation will be used every 8 to 12 hours, during no more than 2 hours at a time;
- On Division level, the simulation will be used every 24 to 48 hours, no more than 3 hours at a time.

Military symbols:
Units' and activities' cartographic representation shall be NATO APP-6A ([2]).

Main services:
The main services expected from the simulation system to support the MEDO process are:

- For the analysis phase:
  - Transfer of SICF data to simulation: mission, order of battle (OOB), tactical pictures;
  - OOB edition capabilities.
- For the COA definition phase:
  - Use of templates for unit deployment;
  - Missions definition;
  - Cartographic display and schedule display.
- For the confrontation phase:
  - Capability to simulate combats dynamically;
  - Cartographic display of a confrontation (optional mode, with lower priority than simulation in automatic mode);
  - COA modification during confrontation (step-by-step definition, wargaming).
- For the COAs comparison phase:
  - Use of qualitative and quantitative criteria;
  - Comparison of confrontations results;
  - Synthesis matrix (COA advantages, drawbacks, risks).
- For OPOrder drafting:
  - Use of sentence templates to generate a pattern of OPOrder for the selected COA (this pattern of OPOrder being coherent with the simulated scenario from time and geographic points of view);
  - Export towards SICF.

From an operational point of view, the APLET main requirements are the following:

- APLET is mainly focused on phase 2, 3 & 4 of MEDO (COA elaboration, confrontation and comparison);
- Interoperability with SICF is a key point;
- Simulations have to run in compressed time. Thus, special effort must be made on APLET MMI (Man Machine Interface) and simulation algorithms capabilities. In addition, the use of user-defined templates will help to reduce the time needed for COA configuration.

3 C4I – SIMULATION INTEROPERABILITY: C2IEDM IMPROVEMENTS

During the preliminary studies phase, a specific study was conducted to identify a C4I data model that could be re-used and improved to build the APLET's data model. This analysis led to the conclusion that the Command and Control Information Exchange Data Model or C2IEDM ([3]) was the most suitable to APLET requirements, for the following reasons:

- C2IEDM is a recent and very complete model (good coverage of the land forces requirements);
- Most of APLET data can be represented with the C2IEDM data model;
- C2IEDM is the current convergence point of the C4I international community works and is supported from an operational point of view;
- SICF is based on ATCCIS GH5, which is version 5 of C2IEDM.

This second part of the paper highlights the major improvements of the C2IEDM to be consistent with simulation models requirements and C4I-M&S interchange mechanisms based on XML.

3.1 C2IEDM description

C2IEDM is an object model, structured in two main parts. The first part of the model deals with "physical objects" and is the biggest part (about 70% of the data model). The second part deals with military actions, military capabilities and other notions like objectives for targeting.

Many of those data are operational as depicted in the Figure 2 below ("physical" objects are defined with attributes such as: type, identity, status, location…):

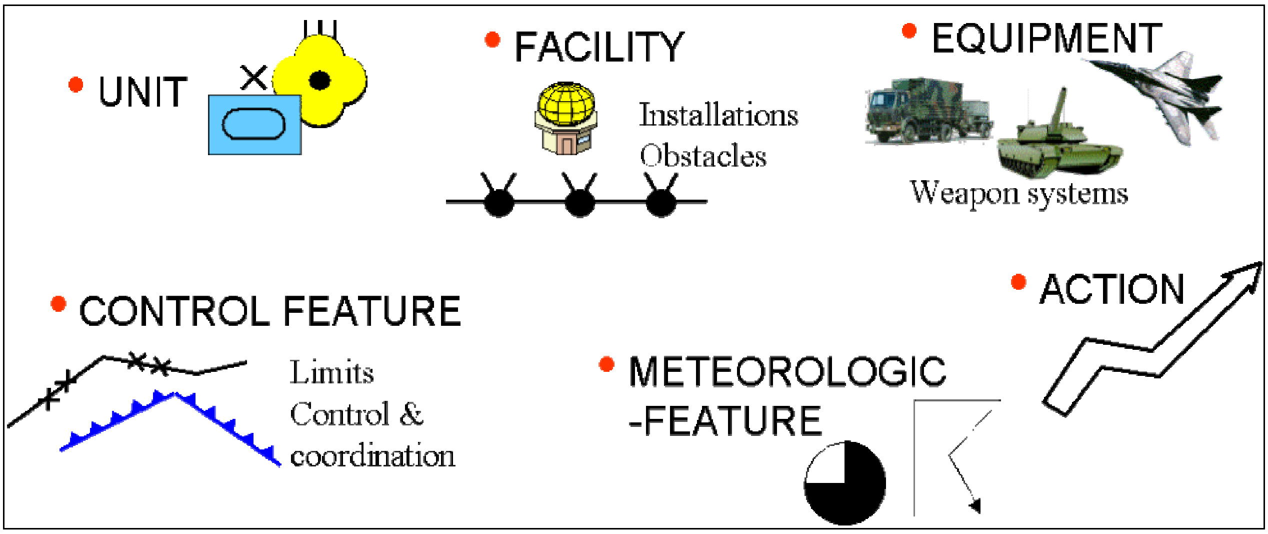

Figure 2: C2IEDM Objects

3.2 Specific requirements for APLET

The following Figure 3 shows an overall view of the APLET's system:

- SICF-APLET interchange mechanisms based on SICF XML format;

- APLET system consisting of:
  - Operator workstation : for exchanges with SICF, COA definition, COA comparison and OPOrder drafting;
  - APLET XML database, implementing APLET's data model;
  - APLET simulation, with "simulation initialization data" (COA) loaded from APLET XML database;
  - HLA connection used during simulation for cartographic display of simulated units.

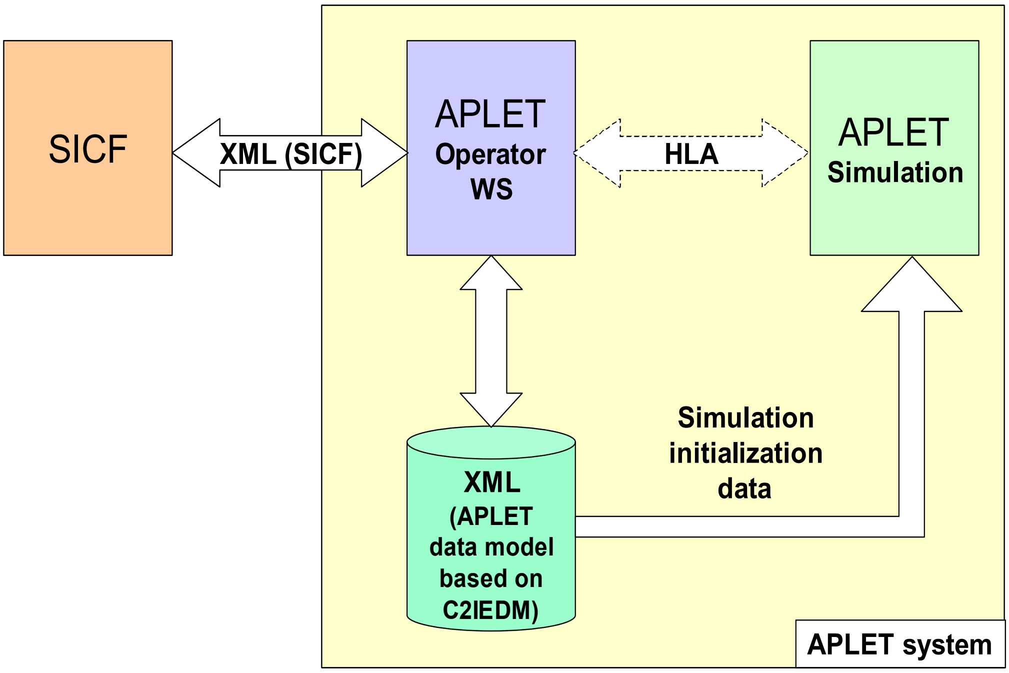

Figure 3 : APLET architecture

More generally, the following data are stored and managed within APLET:

- Operational data from SICF: order of battle (OOB), situations, operation order;
- Operational data for simulation models needs: terrain, decision-making and physical behaviors parameters…
- Operational data for COA selection: criteria, results, and indicators;
- Technical data for APLET software application.

The next paragraphs focus on specific requirements for the definition of APLET's data model. They deal with APLET – SICF interchange and with M&S.

3.2.1 APLET – SICF XML interchange

The analysis of APLET-SICF possible exchange mechanisms concluded that the best way was to use SICF XML messages among other SICF interchange options. The analysis was presented in [4] in detail.

The following Figure 4 illustrates APLET-SICF exchange requirements:

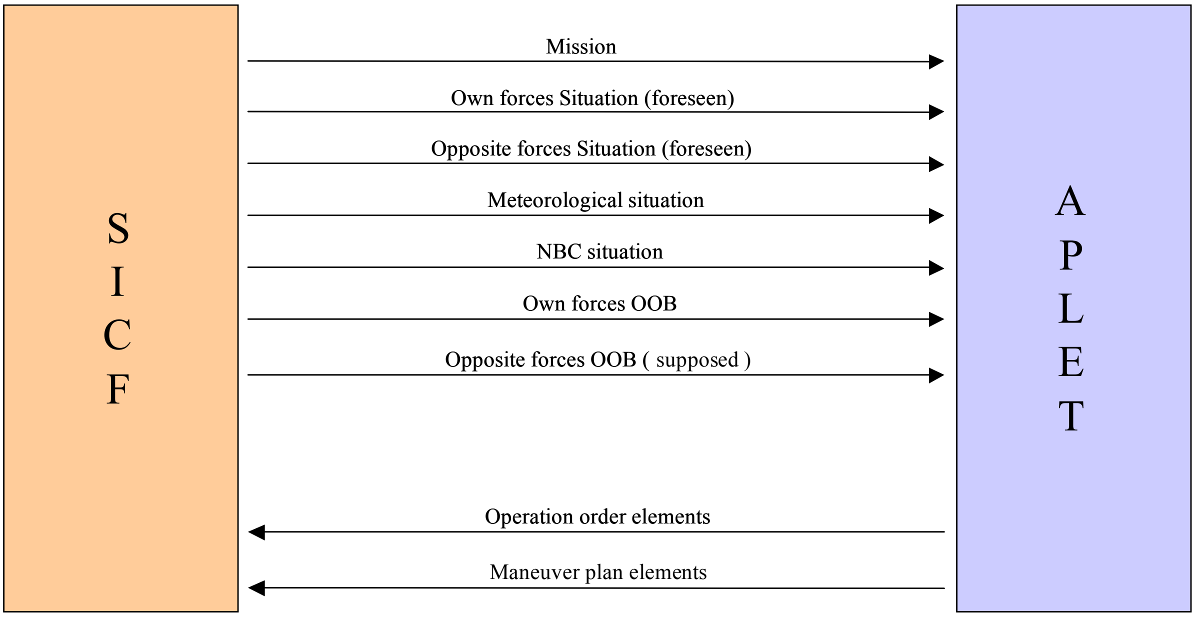

Figure 4: APLET-SICF Exchange Requirements

3.2.2 APLET M&S requirements for data model

Simulation needs many more parameters and attributes than C4I. Those specific requirements are introduced by several models for the simulation purposes, for example:

- C2 models requirements:
  - ➢ Line of departure, coordination lines;
  - ➢ Decision thresholds;
  - ➢ Boundaries;
  - ➢ Opposite units.
- Physical behavior:
  - ➢ Speed characteristics;
  - ➢ Probability of hit, probability of kill;
  - ➢ Detection probability;
  - ➢ Communication delays.

Moreover, a simulation needs to manage several values for some parameters. For example, a military unit has several "values" for its status:

- Status imported from the C4I system;
- Status modified by simulation operator to initialize the simulation;
- Set of values of the status along simulated time during simulation runs.

Being out of the scope of C4I systems, such objects, attributes and parameters are not within the frame of C2IEDM. They are managed internally by simulation and are not transmitted to the C4I system.

3.2.3 APLET's data model elaboration

APLET's data model was designed in several steps:

- "Coarse-grain" definition of APLET's data model,
- Identification of C2IEDM objects usable for APLET,
- Modification of C2IEDM objects to fit to APLET's data model,
- Finally, addition of specific objects and attributes required for M&S.

APLET's data model being designed as an extension of C2IEDM, this approach makes easy the mapping of APLET's data model with C2IEDM and gives APLET a "natural" interoperability with C4I systems based on C2IEDM, like SICF.

APLET's data model was documented in respect of rules used for C2IEDM definition (Annex E of C2IEDM – see [3]). The following Figure 5 shows examples of APLET's data model documentation:

Domain Name	object_type_category_code_gh6mod			
Definition	The specific value that represents the class of OBJECT_TYPE			
Definition Source	ATCCIS			
DOMAIN VALUES				
Value	**Definition**	**Source**	**Physical Value**	**Identifier**
FACILITY_TYPE	An OBJECT_TYPE that is intended to be built, installed or established to serve some particular purpose and is identified by the service it is intended to provide rather than by its content	Adapted FROM us Joint Pub 1-02	FA	1000001
FEATURE_TYPE	An OBJECT_TYPE that encompasses meteorological, geographic, and control features of military significance	ATCCIS	FE	1000002
MATERIEL_TYPE	An OBJECT_TYPE that represents equipment, apparatus or supplies of military interest without distinction to its application for administrative or combat purposes	Adapted FROM us Joint Pub 1-02	MA	1000003
MISSION_TYPE	A non_tangible OBJECT_TYPE that represents the possible missions of units	APLET	MI	1000008
ORGANISATION_TYPE	An OBJECT_TYPE that represents administrative or functional structures	Adapted FROM us Joint Pub 1-02	OR	1000004
POSTURE_TYPE	A non_tangible OBJECT_TYPE that represents the possible postures susceptible of influencing the capabilities of a unit	APLET	PO	1000007

Domain Name	vehicle-type-category-code_gh6mod			
Definition	The specific value that represents the class of VEHICLE-TYPE.			
Definition Source	ATCCIS			
DOMAIN VALUES				
Value	**Definition**	**Source**	**Physical value**	**Identifier**
Armoured	A vehicle that has some form of ballistic protection ~~(excluding tanks)~~.	MIP	ARMORD	1000027
Armoured infantry fighting/combat vehicle	An armoured vehicle used for transporting an infantry team and able to support it by the use of weapons.	Adapted from US JP1-02	AIFV	1000029
Armoured personnel carrier	A lightly armoured, highly mobile vehicle, amphibious and air-droppable, used primarily for transporting personnel and their individual equipment during tactical operations.	Joint Pub 1-02	APC	1000001
Armoured reconnaissance carrier	An armoured vehicle used to carry persons for reconnaissance activities.	ATCCIS	ARMRCC	1000002
Armoured reconnaissance vehicle	A lightly armoured, highly mobile vehicle, serving as the main reconnaissance in infantry and airborne operations.	Joint Pub 1-02	ARV	1000030
Armoured vehicle, light	[No definition given in APP-6A]	APP-6A OCT 98	ARVELT	1000004
Engineering, not otherwise specified	A vehicle used by engineers, without any other precision.	MIP	ENGNOS	1000032
Rocket launcher system	A vehicle designed to be equipped with a multiple rocket launcher.	Joint Pub 1-02 - modified	MLRS	1000062
Reconnaissance tank	A mobile armoured vehicle providing firepower and crew protection for reconnaissance activities.	Adapted from US JP1-02	RECTNK	1000068
Tank	An armoured vehicle whose principal weapon is a direct fire gun optimised for the destruction of armoured vehicles.	AintP-3 / Def. adapted from OED	TANK	1000009

USAGE		
Entity	**Attribute**	**Optionality**
VEHICLE-TYPE	vehicle-type-category-code_gh6mod	MA

Figure 5 : data model documentation examples

3.3 Examples of C2IEDM Improvements for APLET

The following Figure 6 shows some examples of C2IEDM improvements and extension for APLET. In APLET's data model, the following rules apply:

- Objects or attributes unchanged from C2IEDM are suffixed with _GH6 :
- OBJECT-ITEM_GH6
- Objects or attributes modified from C2IEDM are suffixed with _GH6Mod:
- OBJECT-TYPE_GH6Mod
- Objects or attributes specific to APLET are named with no reference to GH6 :

  LARGE-UNIT-TYPE

Examples above show:

- Attributes from GH6, attributes modified from GH6 and specific APLET's attributes
- APLET's objects (LARGE_UNIT, PAWN, …) are specialization of the GH6 object UNIT_GH6

All data modeling results will be made available in the Coalition Battle Management Language SISO Study Group (CBML-SG) created recently. The BML is presented in [5], [6] and [7].

4 APLET SIMULATION MODELS

This chapter focuses on APLET modeling for decision support in Course of Action Analysis (COAA).

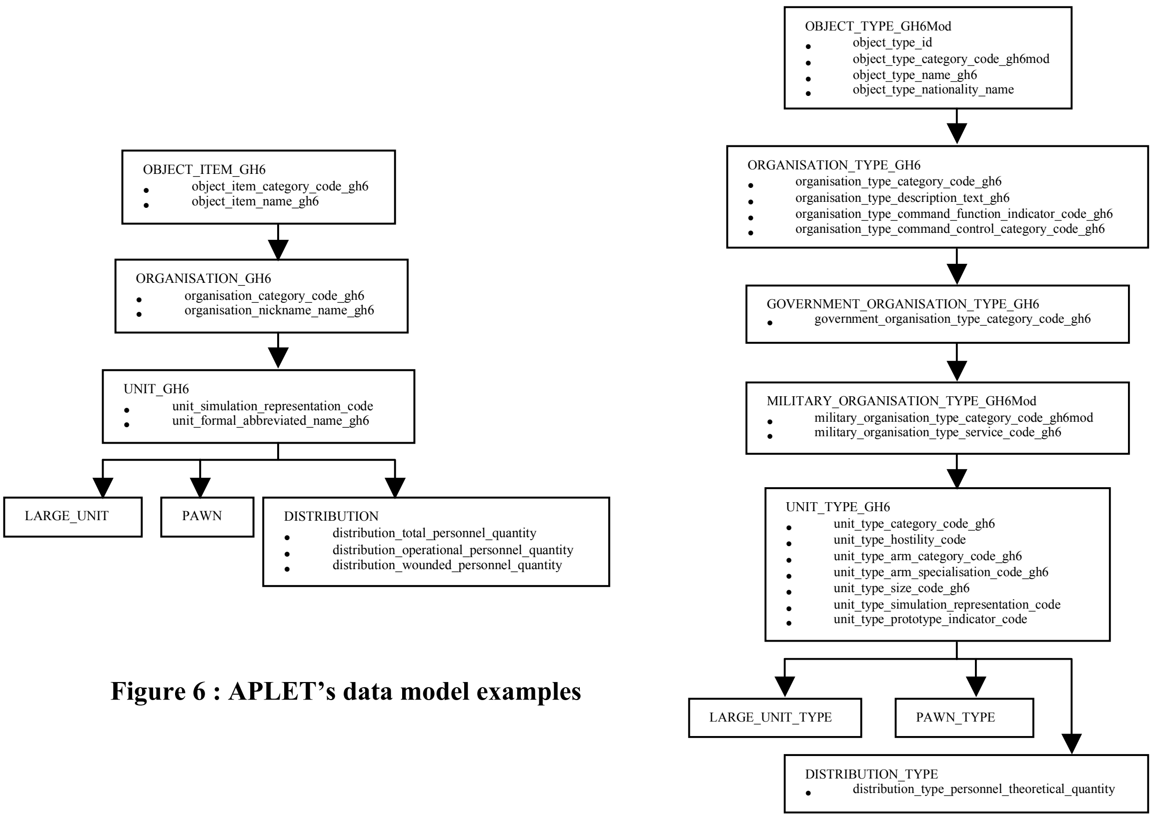

Figure 6 : APLET's data model examples

As depicted in Figure 7 hereunder, APLET simulation architecture is divided in four layers:

- COA definition, on operator workstation
- Synchronization (i.e. simulating the right mission at the right time)
- C2 models, for each unit and mission
- Physical models and behavior of simulated entities.

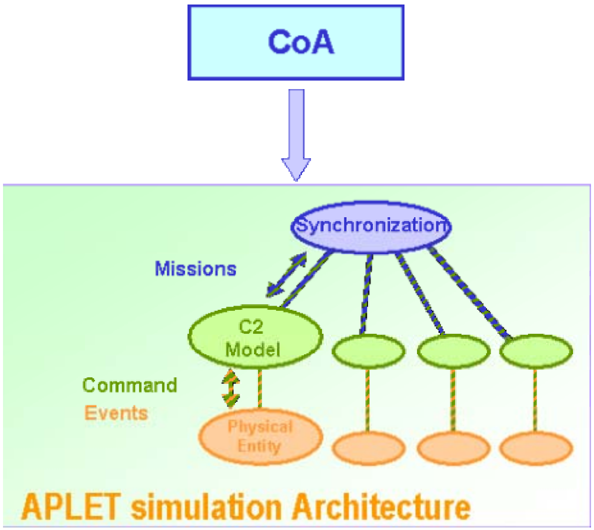

Figure 7: APLET simulation Architecture

4.1 Physical models

APLET physical modeling consists of several models to simulate:

- Movement
- Firing and attrition
- Observation
- Communication

Physical modeling is based on a specific representation of units. Units are modeled as "blobs", which surface on the terrain is representative of terrain occupancy by units and their subordinates. The level of the distribution is representative of its size (its number of vehicles).

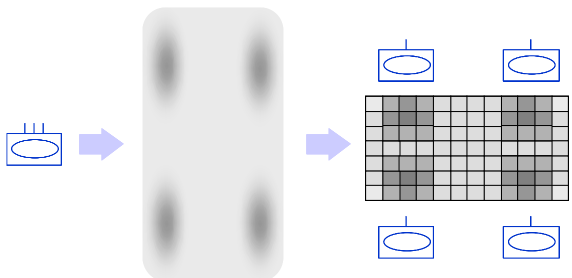

Figure 8: Units and physical representation

Force representation is then based on templates:

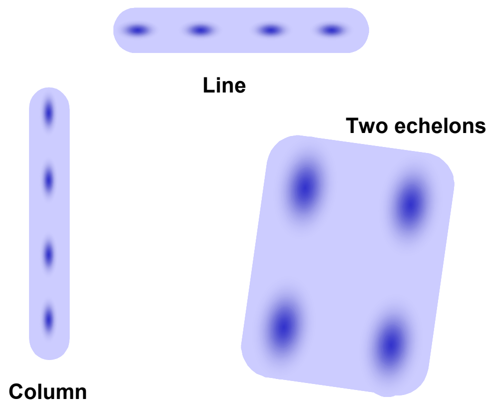

Figure 9: Units and physical representation

Those templates are flexible to the peculiarities of each mission:

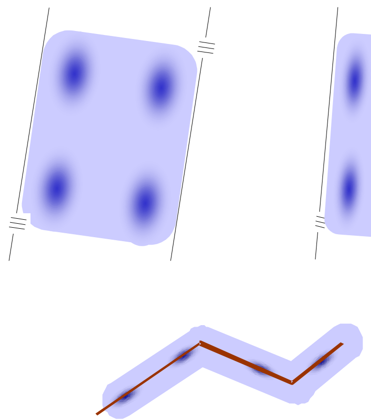

Figure 10: Units and physical representation

Movement with such representation is modeled like “fluid dynamics” with a system of differential equations called RDE, Reaction Diffusion Equation.

$$\begin{cases} \dfrac{\partial r}{\partial t} = \underbrace{\varepsilon_r \cdot \Delta r}_{\text{Dispersion}} - \underbrace{v_r \cdot \nabla r}_{\text{Movement}} + \underbrace{I_r(b,r)}_{\text{Attrition}} \\ \dfrac{\partial b}{\partial t} = \varepsilon_b \cdot \Delta b - v_b \cdot \nabla b + I_b(b,r) \end{cases}$$

Figure 11: Reaction Diffusion Equation

RDE are described with details in [8] and [9].

Movement and attrition modeling:

A simplified version of RDE is used (Figure 12) with no "dispersion" modeling. Indeed, dispersion is dedicated to unstructured movement modeling, like a crowd motion. For a military application, units have a structured movement and this part of equations can be neglected.

$$\begin{cases} \dfrac{\partial r}{\partial t} = -\underbrace{v_r \cdot \nabla r}_{\text{Movement}} + \underbrace{I_r(b,r)}_{\text{Attrition}} \\ \dfrac{\partial b}{\partial t} = -v_b \cdot \nabla b + I_b(b,r) \end{cases}$$

Figure 12: RDE for APLET

In those equations:

- b stands for the "distribution" of the Blue force;
- r stands for the "distribution" of the Red force;
- The left side of the equation is the variation of red (resp. blue) distribution along time;
- Modeling of movement is the product of the distribution gradient (∇r) and a field of vectors (v_r) combining unit objective, terrain slope and obstacles;
- Attrition is computed for each couple of blue and red distributions having intervisibility, considering number and types of armament, number and types of targets, distance and respective probability of hit / probability of kill. The result is a negative number, decreasing the level of the distribution.

Observation and communication modeling:

For other models:

- Observation is computed with a mesh-to-mesh intervisibility, the result depending on distance;
- Considering the time step, communications are considered as "ideal", with no modeling of delay.

Physical model validation:

The approach to validate APLET simulation is to use reference scenarios produced by a validated simulation using more detailed models than APLET.

For this purpose, JANUS was chosen for the following reasons:

- JANUS is a simulation at platform-level (compared to APLET simulation aggregating unit on battalion level);
- JANUS is well known by the French Army;
- JANUS has been tuned by CROSAT (Army Operational Simulation Research Center) and the set of parameters used in JANUS has been validated.

To the benefit of APLET's validation, CROSAT produced with JANUS a set of reference scenarios.

The same scenarios are simulated with APLET. Results from APLET and JANUS are used in a comparative way to adjust APLET parameters and get closer of JANUS reference. The process is detailed on Figure 13.

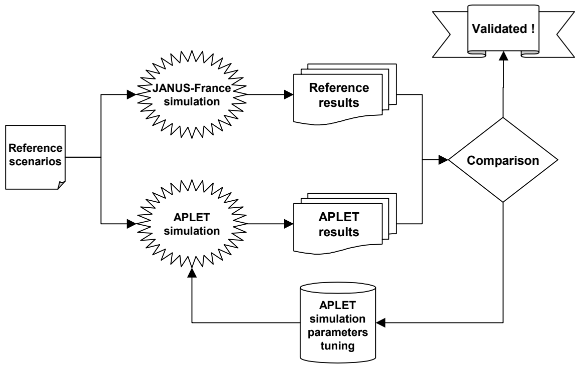

Figure 13 : Validation process for APLET simulation

This validation task is on-going to tune APLET parameters and validate models. One goal of APLET is to experiment new algorithms like RDE and get conclusions about realism of such algorithms.

4.2 C2 modeling

C2 modeling is required to "fill the gap" between COA description by operator and physical models.

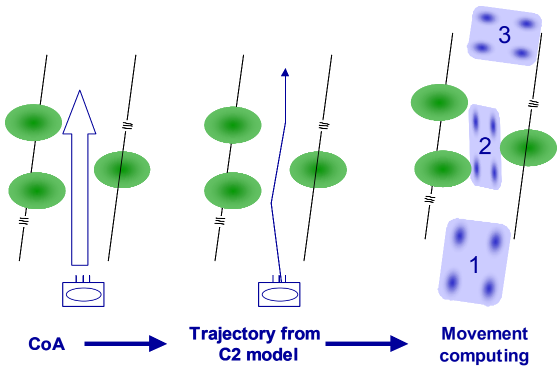

Figure 14: Units and physical representation

In order to build a Course of Action, different missions (attack, delay, block, etc) must be modeled for each unit. They will be represented by a set of actions at the physical-modeling level. Like APLET addresses the Brigade level, C2 models must represent combined arms units at the battalion level (Brigade subordinates). That level of modeling goes beyond the state of the art, mostly focused on C2 modeling for elementary units / section and platoon level.

The next parts of the paper focuses on the process defined from scratch for designing and implementing battalion C2 models. It covers the following items:

- Military expertise;
- Technical architecture for C2 modeling;
- Examples of models.

4.2.1 Military expertise availability

One key process in C2 modeling is the collection of military expertise on missions. This expertise is easily available for the low-level units (up to the company level). One lesson learned in APLET project is that no complete and detailed expertise is available for combined arms unit, such as a battalion level. Moreover, Army officers have not enough availability to provide such expertise. To face such difficulties, APLET approach was the following:

Recruitment of an Army officer to provide expertise specifically for APLET;

- Definition of a process to collect expertise in a structured way (see following figure);
- Validation of expertise by Army doctrine experts from CREDAT (Army Doctrine Research Center);
- Modeling of mission.

The Figure 15 details the structured document created for expertise collection:

Expertise collection : mission XXX

1. Units
2. Operational context: *free text description*
3. Limits of expertise: *free text description*
4. Operator input – MMI definition*: structured text description (table)*
5. Mission Informations: *structured text description (table)*
6. Situations*: structured text description (table)*
    - 6.1. Situation 1 : XXX
    - 6.2. Situation 2 : YYY
7. Low-level situations*: structured text description (table)*
    - 7.1. Low-level situation 1: xxx
    - 7.2. Low-level situation 1: yyy
8. Comments

Example of table for situation and low-level situations:

Short description	
Actions	
Input Conditions	
Output Conditions	

Figure 15: Structure of MS-Word document for APLET expertise collection

4.2.2 Technical architecture - Capabilities for model creation

The process mentioned before was a factor of risk in generating delays during APLET implementation. To avoid a global planning shift due to lack of availability and delays in expertise, APLET technical architecture was defined to allow integration of C2 models as late as possible.

The following choices were made:

- No C2 model will be hard-coded;
- Architecture needs to be open with the capacity to plug C2 models late in the implementation phase;
- Implementation of a “C2 model editor”;
- Automatic code generation based on RATIONAL Rose ([10]).

The Figure 16 shows the work sharing between Army officer and M&S engineer in the modeling process. A fruitful collaboration and common understanding is necessary in order to get valuable C2 models.

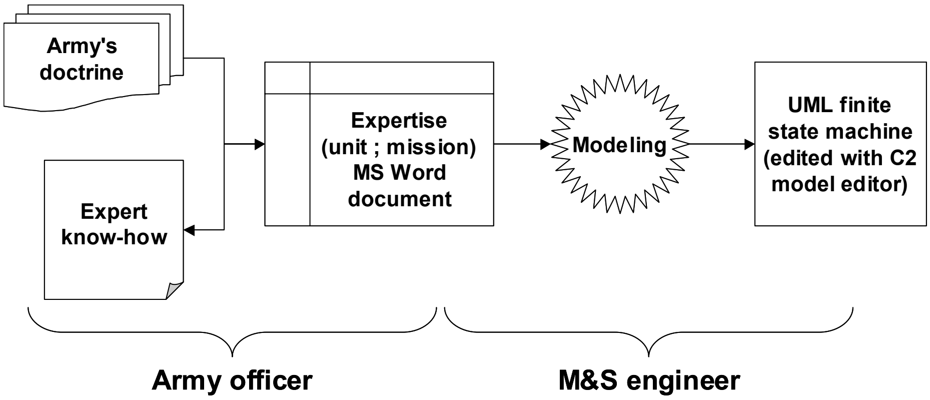

Figure 16: Process for C2 modeling

The Figure 17 shows the end of the modeling process: once a mission is modeled as a UML finite state machine, the C++ code generation capabilities of Rational ROSE is used to generate the model source code. This latter is then linked to the application software. To do so, a customization of Rational ROSE is mandatory to ensure controls and API compliancy.

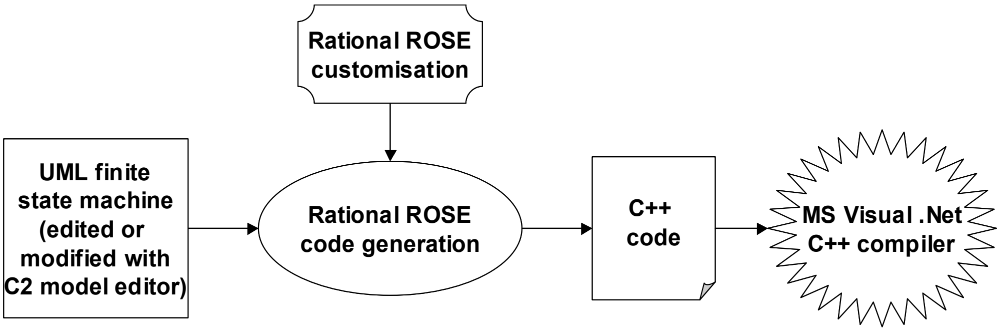

Figure 17: Process for C2 modeling

This global process is very flexible to improve and to add new C2 models. Updating a C2 model is made by editing the UML finite state machine in Rational ROSE. Once the model seems satisfactory to military experts and M&S engineers, the process of automatic C++ generation and compilation is launched to update APLET software.

4.2.3 Examples

This paragraph illustrates some results obtained in C2 modeling.

The Figure 18 shows the software architecture. Modularity is obtained by introducing several levels of modeling : from top to bottom :

- Physical models
- Low-level behaviors models (activating physical models)
- Generic missions models : generic modeling of missions in terms of sequence of low-level behaviours
- Units C2 models

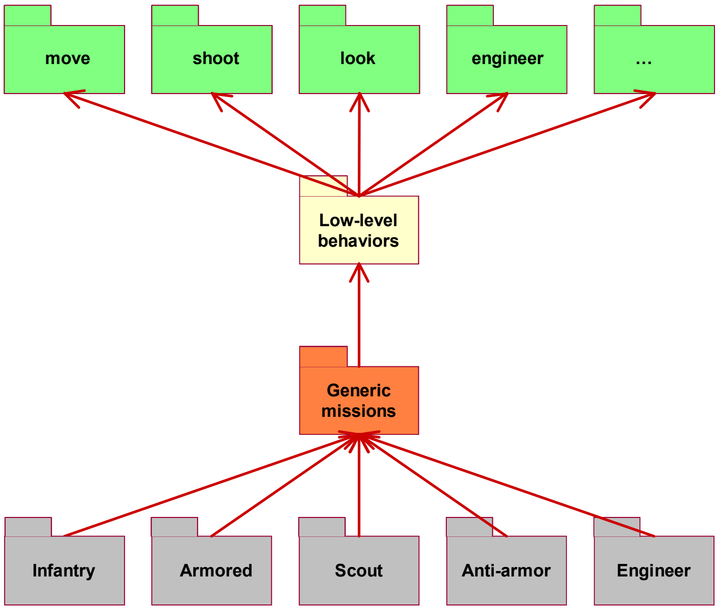

Figure 18 : Software architecture

The finite state machine hereunder shows examples of models obtained for low-level behaviors and one mission. Figure 19 illustrate low-level behaviors for moving and shooting.

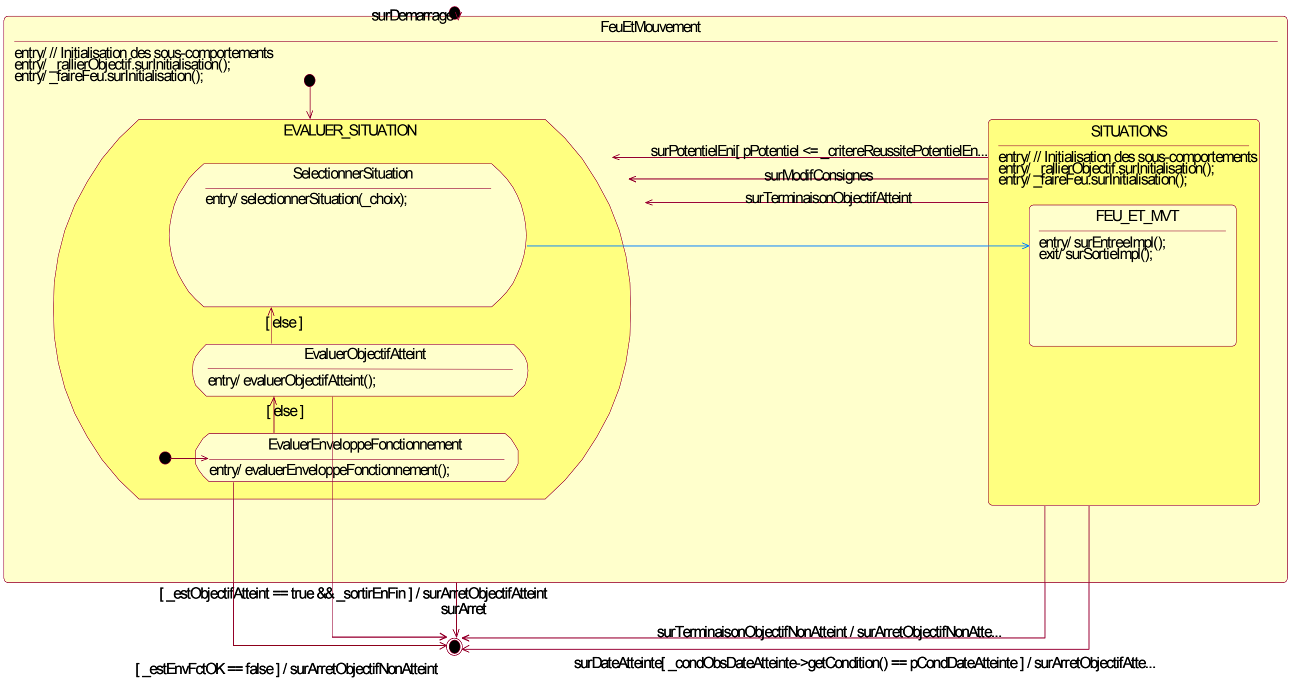

Figure 19 : "Low-level" mission : Shoot & move

Those low-level behaviors are then combined (with others) to model a mission. The UML diagram Figure 20 shows the finite-state machine for the "Attack" mission of a battalion.

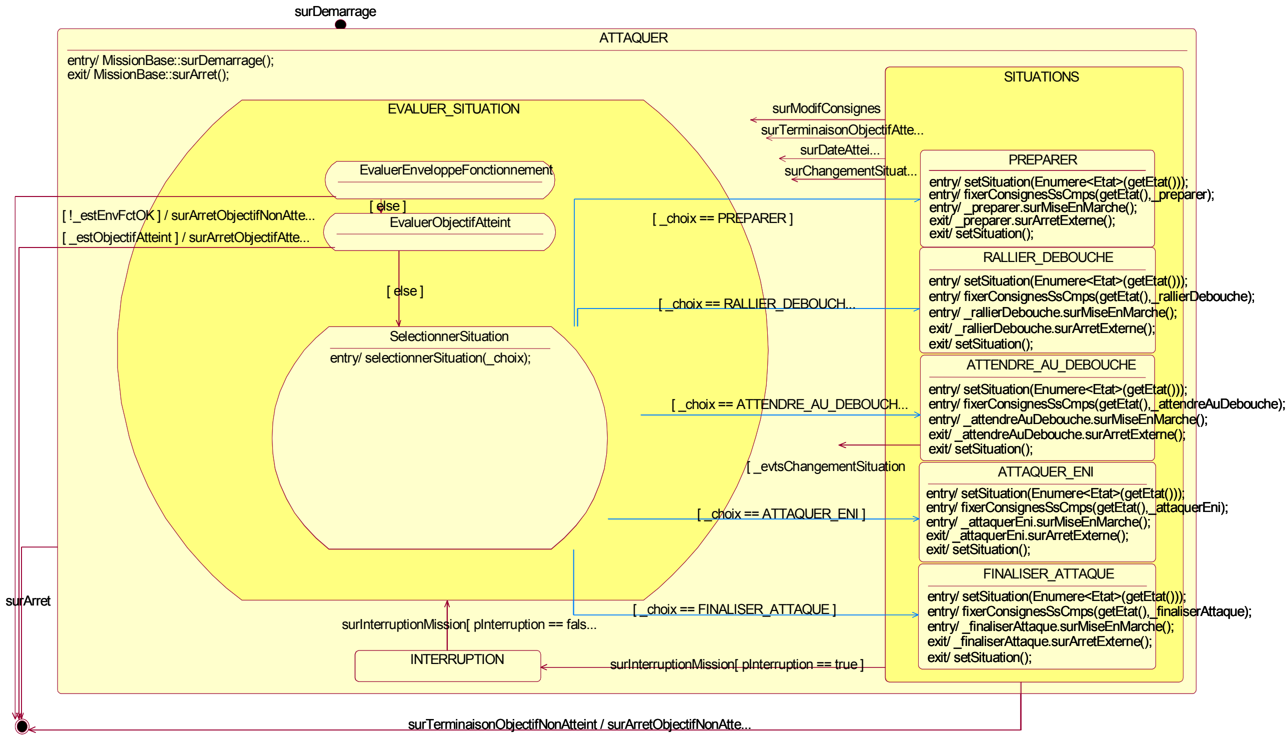

Figure 20 : "High-level" mission : Attack

Such tools allow a rapid modeling of missions and enlarge the set of missions in the APLET demonstrator. The delay for modeling one mission is now about one week, sometimes less.

5 CONCLUSIONS & RECOMMENDATIONS

This paper focused on two major topics. The first is data modeling in order to improve C4I-simulation interoperability. The APLET data model elaboration was explained and C2IEDM improvements were discussed with examples given. Those improvements were driven by simulation models requirements. In addition, suggestions for interchange mechanisms between C4I-M&S were made. They are based on XML.

For the future, the alignment of C4I and simulation data models, the definition of a common dictionary and XML tags are necessary objectives to improve C4I and M&S interoperability. That is why, the authors recommend to create an NMSG study group dealing with the latter topics. The French project APLET, the US and UK BML (Battlefield Management Language) studies could provide fruitful results and lessons learned to start this work.

The second topic addressed within this paper was the definition and development of simulation models for COAA and decision support. Explanations were given on how physical and behavior models for Armed forces units based on Reaction Diffusion Equation (RDE) could be optimized and customized to move closer ground truth.

C2 modeling was addressed too. The lack or the delay of military expertise that forced us to postpone at the latest time the development of Command and Control (C2) models was stressed. To overcome such drawback, the technical software architecture designed for APLET was depicted, focusing on APLET capabilities for C2 models creation considering such models as UML finite state machine.

6 ACKNOWLEDGMENTS

Special thanks to the French officers who have committed to support APLET in providing operational requirements advice and guideline:

- EMAT : Col Mellet
- CREDAT : Col Nuyttens
- EMF 3:
  - LCL Mercury
  - LCL Bonnaire
- CEPC: LCL Bottet
- CFAT: LCL Dillinger
- CROSAT:
  - CBA Serlooten
  - LT Parreira

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8 AUTHOR BIOGRAPHIES

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