The Spanish MoD M&S Infrastructure: a new perspective for for the development and reusability of simulations assets

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ABSTRACT:

Spanish Ministry of Defence (SP MoD) has developed in recent months the Technology and Innovation Strategy for Defense (ETID). The ETID concentrates on an important part of the R&D activities in Defense: the activities of Technological Research (T&R) and Innovation. Its work is, therefore, to advance in the coordination and management of activities leading to acquisition and application of advanced knowledge and technologies, not yet sufficiently developed, establishing the bases for them to be applied in the near future armament and equipment systems required by the Spanish Armed Forces (SAF). ETID describes the technological analysis in three levels of detail (Functional Action Areas, Functional Action Lines and Technological Goals), which have been studied in order to make a coherent and systematic approach to the development of new technologies based on the operational requirements. .

In the M&S functional action line of the ETID, there are specific technological goals to improve M&S interoperability, enhanced modelization, and to develop new M&S technologies for a cost effective development of the future simulation systems.

Under this perspective "La Marañosa" Technological Institute (ITM) and NADS have partnered to develop an infrastructure to support the full life cycle of models, from conceptual specification and design to execution, test, versioning and storage in a repository. Based on SimWare Simulation framework and others third party COTS, and implementing M&S standards like IEEE HLA and an emerging standard like OMG DDS, this environment is created to support ITM's efforts to create high fidelity models for different simulation applications, such as training, analysis or operational research.

1. Introduction

Spanish Ministry of Defense acquire, develop, use and maintain dozens of vehicle and military simulation systems, each one of them have their own different requirements, applications, usages, technologies and capabilities. Under a holistic point of view some questions comes to the authors of this paper: is there a way to improve reusability, cost-effectiveness, and versatility of M&S systems? Is it possible to better manage models and their simulation implementation life cycle? Those are complex questions to answer and several factors are involved. Apart from organizational, roles and policies issues there is still room to evolve and enhance present technologies and methodologies to provide solutions those questions.

Under the authors perspective there is a big gap between the conceptualization of models and their representations into software in simulation systems and some of the roots of the previously stated problems are linked with this gap. System developers use different approaches to develop simulation systems and traditional software engineering process and methodologies seems to be as effective as expected to create simulations. There are few widely accepted tools, standards and frameworks used in the process of designing and building simulation software and their components.

An inherent problem in this gap that authors have experienced is the situation where subject matter experts (SMEs) or engineers being able to represent real world concepts and behaviors for vehicle and military into models are in most cases the developers that create simulation systems and their software implementations. In those situations, software is developed by non-computer specialists. If expected results is just working systems this approach is valid, but results like reusability or cost-effectiveness are not always reached.

This paper will present the results of the author's organizations efforts in order to create a generic M&S infrastructure, framework and process to develop simulation systems, which provides tools for engineers to create models, and tools for software developers to create simulation systems from those models.

2. Spanish MoD M&S Infrastructure: background and user needs

In 2010, the Spanish MoD R&D "La Marañosa" Technical Institute (ITM) started a research activity derived from the Technology and Innovation Strategy for Defense (ETID) ([6]) to attempt to fulfill one of the M&S specific technological goals defined in ETID. ETID is the guide for R&D efforts in Spanish MoD and pilots the efforts of different R&D related bodies through specific technological goals.

The three M&S objectives are: a) improved interoperability, b) enhanced modelization and simulation for battlefield representation, and c) new M&S technologies for a cost effective, flexible, versatile and effective development of the future simulation systems.

ITM launched a competition and awarded NADS with a contract to develop a comprehensive infrastructure to support the full life cycle of models, from conceptual specification and design to software development and execution, test, versioning and storage in a repository.

Based on NADS SimWare Simulation framework ([1],[2]) and others third party COTS as Mathworks Simulink, and implementing M&S standards like IEEE HLA and an emerging standard like OMG DDS ([3],[4],[5]), a new simulation development environment (MoD M&S Infrastructure) was created to support ITM's efforts to create models for different simulation applications, such as training, analysis or operational research.

The main requirements for MoD M&S Infrastructure were:

1. To provide tools for SMEs or System Engineers Experts (SEEs) to create models with physical behaviors using conceptual modeling, mathematics and physics expressions and their relationships for vehicle and military systems. Those tools should provide languages familiar to SMEs/SEEs.
2. Capability for system/subsystem model specifications and decomposition.
3. A comprehensive methodology for model developing and life cycle management. From unit developing to full system integration.
4. Full automated source code generation. From model description to running software, transferring, without user intervention, model creation/modifications avoiding man-made errors in the loop.
5. Target software platform independency. Being able to run in different simulation frameworks (as the own MoD M&S Infrastructure runtime framework or other COTS like VT Mäk Vr-Forces) and operating systems.
6. Capability to use parallel and distributed computing.
7. Compliant with open distributed architectures.
8. Publish/Subscribe paradigm for inter and intra system data interchange.
9. Support for generic simulation services, like terrain information, meteorological /atmospheric data o generic calculations like line of sight or detonations and damage.
10. A simulation runtime framework for simulation execution, hard real time or near real time capabilities, simulation functions and control, instructor operator system and other traditional simulator functionalities.

11. A central repository for model and simulation assets control and versioning with web searching and browsing functionalities

3. Spanish MoD M&S Infrastructure: architecture

MoD M&S infrastructure is structured in two major components, a development and runtime framework.

The main users of the first element are SME and SEE who define models, their decomposition and data connection. Once done, the development framework facilitates the creation in SimWare SimDeveloper ([7]), based on Mathworks Simulink, of the corresponding blocks for model behavior description. Also the framework provides blocks and functions for the simulation specific control and the features needed to test and integrate the models. After V&V has been done the models can be transformed into C++ software for specific platforms. This process is ruled by the developed methodology and corresponds to high level requisites from 1 to 5.

When the models and their corresponding software are ready, comes the time for the second element of the infrastructure, the runtime, used by simulation software engineers. The runtime provides tools and resources to build and run the software generated: a) host and kernel, b) middleware to deploy and connect the software running in parallel (multithreading) and distributed (in different platforms), c) instructor operator station and d) third party system connectivity (high level requisites from 5 to 9).

4. M&S development framework

M&S development framework is focused on providing a full cycle support for developing simulation modules, being compatible with the paradigm of MDA (Model Driven Architecture). It is an environment that allows the development of platform independent modules (PIM concept of UML 2.0).

The simulation modules development methodology starts with specification of the list of simulation modules and other simulation entities that will compose the simulator. The next step is to define the common data model of the simulator. This data model relies on the concept of publication and subscription of objects and interactions. Meta data model is based on OMT templates of HLA specification.

To define the simulator data model, a specific tool, called Modeler, is used. This tool allows the developer to define the simulation entities, types of objects, defined by their attributes, and interactions, defined by their parameters. Other attributes of the simulator, are also defined using this tool, as execution frequency, data transmission method, or the nodes of the simulator.

Once the data model of the simulator is done, the tool

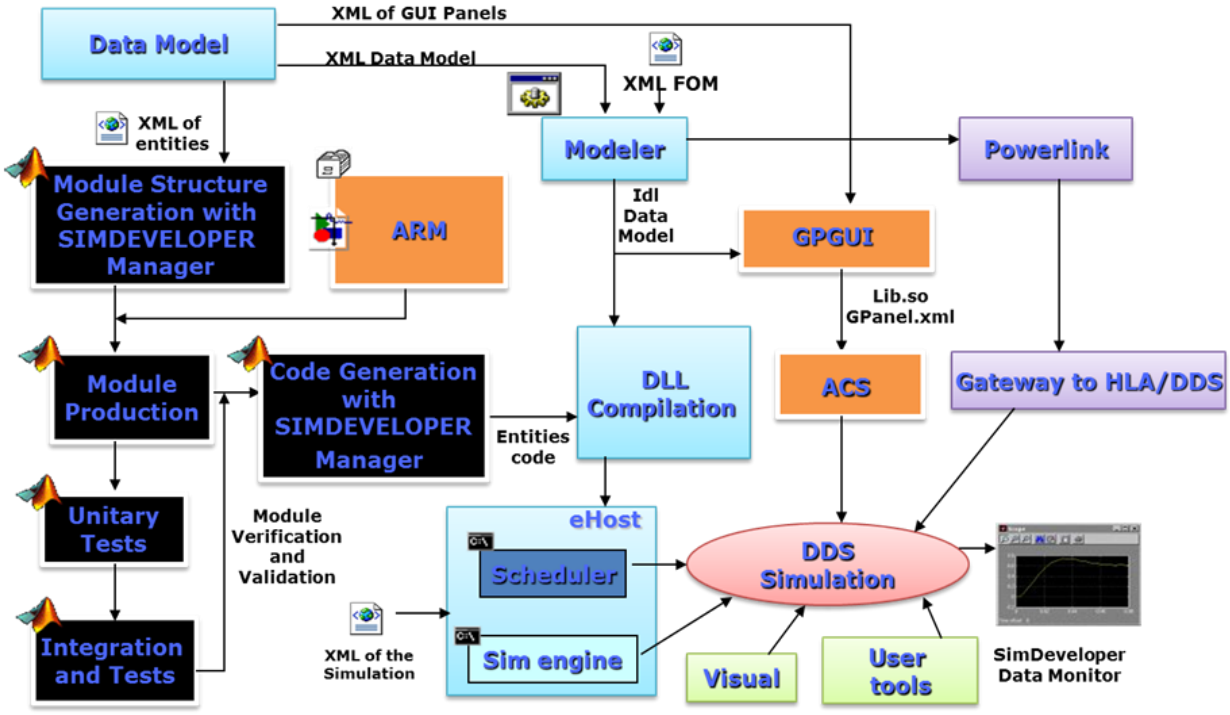

Figure: M&S Metodology Conceptual Schema

auto generates an XML file for each simulation entity. These simulation entities can be simulation modules, applications for controlling and monitoring the simulator or any other element that publishes or subscribes data in the system. These XML files contain all the information needed for communicating the entity within the simulator.

Modules development process is carried out using Simulink enhanced with SimDeveloper Blockset. SimDeveloper Manager is one of the Simulink blocks included in this blockset. It is used to load the XML data file for each module, and builds the structure of the module with the inputs, outputs, providing also the state machine of the simulator.

The simulation modules are subdivided into functional units called "Functional Models". These models are responsible of specific functions and are developed as parametric blocks, in order to allow their easy adaptation into different modules. There is a SimDeveloper repository management tool of Modules and Functional Model, called ARM, where these elements, once they have been developed and validated, are stored. When a new simulation module is going to be developed, the M&S Engineer may search into SimDeveloper Functional Models repository, the models with the desired functionality to be integrated within the module. The repository allows the re-using of model, speeding up the modeling process and also it enhances the system reliability since the models are matured ones, having been used and tested in former simulators.

After integrating all the functional models necessary to complete the functionality of the simulation module, it is submitted to a unit testing module within Simulink. Verification activities are performed in this environment.

The next step is the generation of C++ model source code for being built and integrated into the simulator execution environment. This process is fully automated by the Simdeveloper Manager block. This block takes use of the Realtime WorkShop Embedded Code Generation feature of Matlab/Simulink and over the code generates by this tool, it generates a source code wrapper. The result is a model library, that is fully compliant and directly integrated into the simulator execution environment.

The generated code is completely open and independent of Simdeveloper and Matlab/Simulink, so it can be deployed and maintained independently of the development environment.

Following the same concepts explained for simulation modules, this M&S methodology includes an easy way to generate Graphical User Interfaces for controlling modules execution. The GUIs are developed using the GPGUI tool. If simulation engineer is going to deploy the simulation models as independent simulation components (specialized HLA federates or DDS simulation services) these UI panels can be managed in runtime using the tool ACS, included in the runtime infrastructure, otherwise if the simulations models are going to be integrated into a simulator, these panels could be integrated in its IOS.

5. M&S runtime infrastructure

With this runtime infrastructure, simulation software engineer can deploy simulation models as:

- An HLA federate.
- A DDS simulation service.
- A simulation model integrated in Vr-forces runtime environment.

In first two cases, ITM M&S infrastructure is using Simware framework, composed for a simulation middleware compliant with HLA and DDS and a real time simulation infrastructure fully distributed. The main advantage of using a middleware interface instead of a pure DDS or HLA interface is that, in this way, the same model can be deployed on a HLA federation or a DDS domain only changing a parameter.

The runtime infrastructure, called eHost, is based on an advanced real time Simulation Manager which controls a high resolution clock and the state machine of the global simulation system.

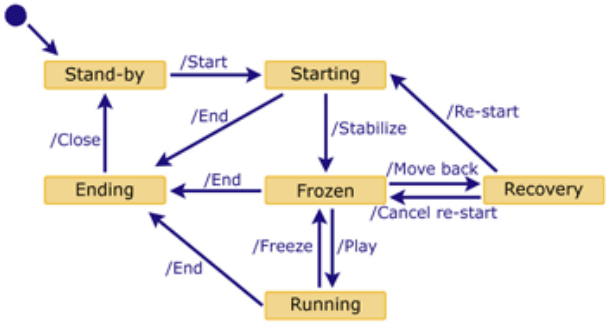

Figure: eHost components and SimWare state machine

This software coordinates multiple simulation engines, running in a fully distributed computing environment where each simulation module node can be hosted in different CPU/Core.

Such simulation engines control the execution of simulation modules (which can be implemented as services or libraries) running in each node. An advantage of such architecture is itself the distribution along the network, providing great flexibility and scalability to the system. This scalability can be used to develop clusters of simulation models covering mathematical models of any-complexity.

Besides the simulations engines, there are other applications that follow the clock and the state machine of the runtime infrastructure. Some of these applications are the ACS, for executing the model control GUIs or the gateways developed with the tool PowerLink.

In HLA federation executions, it is possible to configure one or more simulation services to be run as a federate, providing an unique publish-subscribe interface (Simulation Object Model, SOM) to the federation. This federate can be controlled by the eHost Manager, or can be run as any other independent federate, managed by the HLA Federation Manager (if available).

In order to integrate legacy components into new simulators or to interoperate with other simulation or real systems, the environment includes the tool Powerlink.

PowerLink is based on an extended version of Modeler. This tool allows creating and modifying flexible gateways between HLA and DDS data models. These gateways can even incorporate conversion functions between HLA and DDS data. Modeler provides functions to generate automatically all the artifacts needed (datamodels, libraries) to deploy a gateway.

PowerLink is not only useful for DDS-HLA interoperability but also to provide gateways solutions between RTIs from different vendors, avoiding the problem of lack of wire interoperability between HLA vendors.

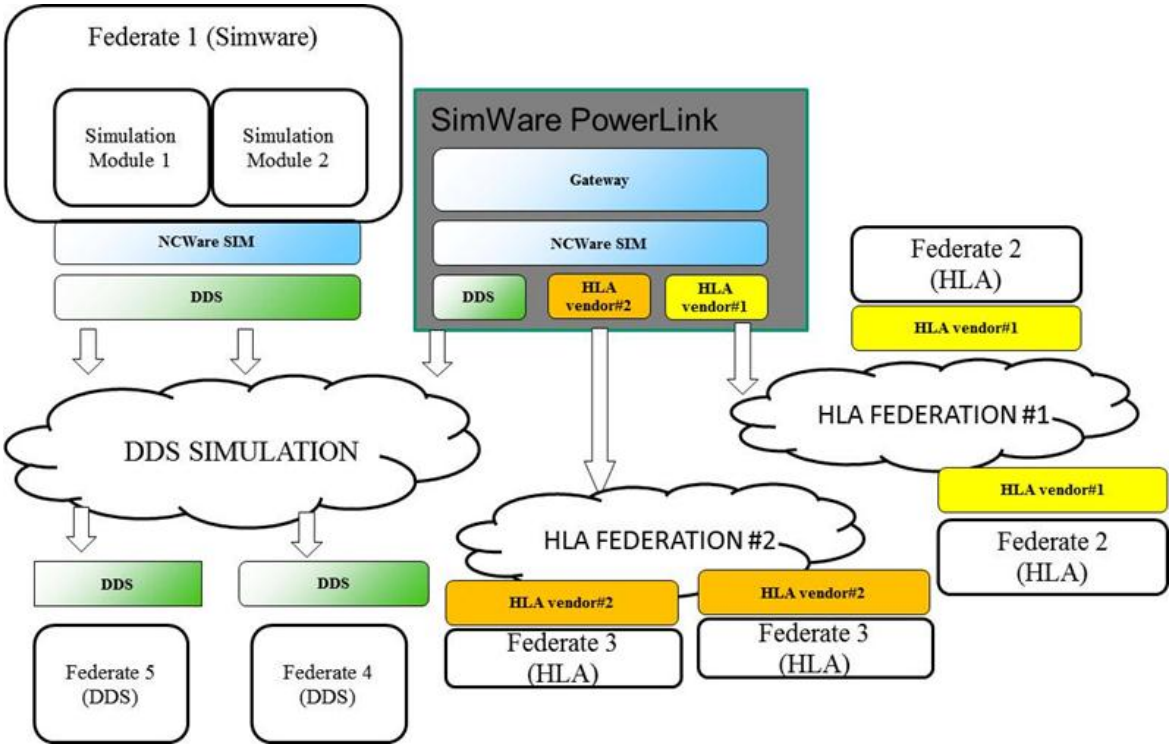

Figure 1 Gateways solutions using M&S runtime infrastructure

6. Using MoD M&S Infrastructure.

During 2011, in a first stage of the project, M&S infrastructure has been tested conducting a proof of the concept experimentation based in a simulation test bed for missile decoy strategies for engineer analysis and operational research applications. Based in the concept of system/subsystem specification, different models for IR and RF missiles (active and semi active), chaff and

flares, EW equipment, atmosphere IR and RF propagation and different targets(air and naval) have been built.

The objective is to create simulations to be used in aircraft/ship defense strategies scenarios, in operational research conducted by Spanish navy. The models have been designed with three mayor constraints: generic design and reusability, clear system/subsystem specification and platform independence.

The missile simulation model has been divided in several components: aerodynamic, atmospheric, detection, movement, guidance, mass and propulsion. The components were designed to be generic enough to be reused but they fitted the missile simulation. Models have some assumptions and simplifications because the unclassified rated. Some of the components are generic and parameterized but other used data extracted from publications representing unclassified data.

The simulation is being made at two different levels:

- Model (system) interoperability: using HLA and RPR-FOM, where interoperability between missiles, targets, and EW systems can be used by existing standard data models and can be interconnected with third party simulations.
- Subsystem interoperability: using DDS, where real time performance is critical and rates beyond 100 HZ are needed and critical for simulation.

Some conclusions apart from the experiment have been extracted:

- **Models can be evolved and reused** with no overall impact in the development process. The introduction of new parameters and constraints can be made an almost real time process.
- **High reusability,** the models built can be used to develop future improvements as static and dynamic behavior using engineering language. Models contain all the details needed to execute it, and transformations can be made to run it in different platforms. Generic simulation services are available to be integrated in the models.
- **Deployment** of the models in an execution environment is a **short operation**.

7. Next steps

Experience acquired with the first experiments has defined a future roadmap to support two types of application:

- **Operational research**. In order to use MoD M&S Infrastructure for Operational Research some additional capabilities are need.

- The ability to generate test batteries for Montecarlo analysis. The ability to identify certain independent variables and generate thousands of combinations of those variables and simulate scenarios with those combinations.
- Identification of success and failure outcomes and success metrics.
- Automatic data logging for statistical analysis.

- **A cloud of Simulation services**. Simulation models could be deployed as services since MoD servers. The use of open interfaces (HLA and DDS) facilitates the functional integration of this simulation services into a simulator or an operational system. This approach would have many important advantages for the Spanish MoD:

- Configuration management is made in a single point.
- Management of classified models is made in MoD sites.
- A simulator manufacturer should integrate models provided by the MoD repository, reducing technical risks, costs and development time. A dynamical integration could be possible for new simulators developed with an open architecture. In this way reusability to component level could be achieved. An unique simulation model for each instance of an entity in the network (for example a IR missile) will avoid problems provoked when two different simulators are simulating the same entity with a different level of fidelity.
- Simulation functions could be provided into a Net-Centric environment.

8. Conclusions

Simulation technology is maturing at an amazing pace. High fidelity and hyper-realistic simulations are available and fulfill most end users expectations. Under a comprehensive MoD perspective this is not enough, and other criteria's must be used for simulation systems acquisition and sustainability. As this paper have tried to show, there are gaps like reuse, improved

modeling, and better integral methodologies where new solutions can be applied.

Even there is no silver bullet and no model/simulation will fit every application, this effort can be considered a humble start to avoid re-invent the wheel situations where similar models are created from scratch in different MoD programs. With the present budget and economic situation this is something that MoD cannot afford. New approaches for M&S development have to be explored.

References

[1] Patricio Jiménez, Jose M. López-Rodriguez, Rodolfo Martín. How to Develop True Distributed Real Time Simulations? Mixing IEEE HLA and OMG DDS standards. 11S-SIW-072.

[2] Lopez-Rodriguez, Jose-Maria. *Use of the OMG DDS standard in Simulation. A new Way for developing Real Time Distributed Simulations*. OMG's Workshop on Real-time, Embedded and Enterprise-Scale Time-Critical Systems. March 2011.

[3] Lopez-Rodriguez, Jose-Maria; Corsaro, Angelo. *The Fabric for building Open System of Systems*. Interoperable Open Architecture 2011. October 2011.

[4] OMG. *Data Distribution Service for Real-time Systems Specification (DDS) v1.2*, January 2007. http://www.omg.org/spec/DDS/1.2/

[5] *DDS Interoperability Protocol (DDS-RTPS) v2.1. January 2009.* http://www.omg.org/spec/DDS-RTPS/2.1/

[6] Spanish MoD. *ETID 2010. Estrategia de Tecnología e Innovación para la Defensa* (In Spanish).http://www.mde.es/en/areasTematicas/investigacionDesarrollo/planNacional/index.html?locale=en

[7] Fernando Cartechini, *SIMDEVELOPER: An M&S development tool to boost interoperability and reusability*. 06E-SIW-20

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