NATO MSaaS – A Comprehensive Approach for Military Operational Requirements Development

Lt.Col. Marco Biagini, Lt.Col. Michele La Grotta, Capt. Fabio Corona, Lt. Sonia Forconi

NATO Modelling & Simulation Centre of Excellence
Rome, Italy
mscoe.cd01@smd.difesa.it, mscoe.sp01@smd.difesa.it, mscoe.cd04@smd.difesa.it, mscoe.cde02@smd.difesa.it

Marco Picollo, Christian Faillace

Finmeccanica, Land & Naval Defence Electronics Div.
Genova, Italy
marco.picollo@finmeccanica.com, christian.faillace@finmeccanica.com,

ABSTRACT

What is the best approach to define a Modelling and Simulation as a Service (MSaaS) operational capability in a military domain such as the NATO and Allied Community of Interest? This paper is intended to illustrate how the existing state-of-the-art technology can be incorporated into MSaaS concept to support M&S applications in the military domain.

NATO MSaaS is a means of delivering value to customer nations via Internet cloud technology by enabling access to M&S applications, capabilities, and data without nations incurring the costs associated with ownership. The MSaaS concept is under development by NATO Modelling & Simulation Group (NMSG), with contributions from NMSG 131 and its successor NMSG 136. In accordance with NATO Concept Development & Experimentation for Modelling and Simulation, the authors propose the application of the NATO Comprehensive Approach (CA) to define the Allied Framework for MSaaS operational concept, considering all DOTMLPFI domains (Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities, Interoperability).

The M&S CoE has been applying the NATO CD&E process and NATO Comprehensive Approach to develop a sub-concept to analyze and support the evolution of a real use-case, "MSaaS supporting the NATO Urbanization Project". In conclusion, the research has emphasized how Modelling and Simulation as a Service can be adopted to support operational capability development, related reference architectures (RA), and business models for NATO.

ABOUT THE AUTHORS

Lt.Col. Marco Biagini is the Concept Development and Experimentation (CD&E) Branch Chief at NATO Modelling & Simulation Centre of Excellence. He has a Ph.D. in Mathematics, Engineering, and Simulation. He has master degrees in strategic studies, peace keeping and security studies and, new media and communication. He has more than 15 years of experience in the M&S field. He was Battalion Commander at the Italian Army Unit for Digitization Experimentation (USD) and Section Chief in Computer Assisted Exercise (CAX) and M&S Branches at the Italian Army Simulation and Validation Centre. He is visiting professor at Libera Accademia di Belle Arti (LABA) University, member of the Board of Directors of the Italian Movement for Modelling & Simulation (MIMOS) and member of Emergency Management division of Simulation Australia and member of NMSG 145, NMSG 136 and other NATO working groups. He is leading the M&S CoE's MSaaS working group.

Lt. Col. Michele LA GROTTA is the Support Branch Chief at the NATO Modelling & Simulation Centre of Excellence. He has more than 25 years of experience in the Communication and Information Systems (CIS) field. He was CIS Squadron Commander at the NATO Airborne Early Warning & Control Force E-3A Component and Chief J6 at ITA-JFHQ. As Chief J6 at ITA-JFHQ, he contributed in designing, developing and setting up all CIS mobile assets and services for the high readiness element (Operational Liaison Reconnaissance Team) as well as for short/medium deployment headquarters.

Capt. Fabio Corona is the Operational Research Section Chief of the Concept Development and Experimentation (CD&E) Branch at NATO Modelling & Simulation Centre of Excellence in Rome. He earned a Ph.D. degree in Electrical Engineering from Politecnico di Torino and a M.Sc. degree in Electronics Engineering from Roma Tre University. After joining the Italian Army, his employment ranged from the internet working field under the Italian Army Signal Headquarter to the maintenance and procurement of optoelectronic and communication systems under the Italian Army Logistics Headquarters. During his Ph.D. studies, the main research focus was in efficiency and power quality of photovoltaic systems under mismatching conditions.

Lt. Sonia Forconi earned a PhD in Telecommunication Engineering at "Tor Vergata" University of Rome, Italy (2016), with the thesis "Functional analysis of the Data Streaming service in 4G Long Term Evolution technology and study simulation of relations between Quality of Service and Quality of Experience". She is a researcher at the University of Rome "Guglielmo Marconi" and currently, she is a Lieutenant selected reserved IT Army (OF-1) working in Communication and Network Simulation (Information Technology (IT) Defence network modelling and simulation, Cyber modelling and simulation, Integration Test Bed). She was an IT Consultant engineer for Telecom Italia S.p.A. (2010) and for Avanade Italy S.r.l (2011).

Marco Picollo has a Master's Degree in Physics and almost 15 years of experience in M&S working in the Italian Defence Industry. His expertise covers M&S standards and M&S application fields such as CD&E, distributed simulations, training and integration with real systems and command & control in air, naval and land domains. He has been participating in Italian M&S industry and academic organizations and in international organizations, such as the Simulation Interoperability Standards Organization (SISO) and Network Centric Operations Industry Consortium (NCOIC), and in various NATO working groups and activities: NATO Industrial Advisory Group (NIAGs), NMSGs, Technology for Information, Decision and Execution Superiority (TIDE) and Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, eXercise (CWIX). Currently, he is the Head of the Control Rooms Unit in the Engineering function of Finmeccanica Land and Naval Defence Electronics Division.

Christian Faillace has a Master's Degree in Computer Science and 8 years of experience in M&S working in the Italian Defence Industry. His expertise covers Software Architecture Patterns mostly in Web, Service Oriented Architectures and Cloud Development environments. Currently he is a member of the Control Rooms Unit in the Engineering function of Finmeccanica Land and Naval Defence Electronics Division and works in M&S applications, including distributed simulations, training and integration with real systems and command & control in air, naval and land domains. He has been participating in Italian M&S industry and in various NATO working groups and activities: TIDE and CWIX.

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NATO Modelling & Simulation Centre of Excellence
Rome, Italy
mscoe.cd01@smd.difesa.it, mscoe.sp01@smd.difesa.it, mscoe.ds05@smd.difesa.it, mscoe.cd04@smd.difesa.it, mscoe.sp03@smd.difesa.it, mscoe.cde02@smd.difesa.it

Marco Picollo, Christian Faillace

Finmeccanica, Land & Naval Defence Electronics Div.
Genova, Italy
marco.picollo@finmeccanica.com, christian.faillace@finmeccanica.com,

INTRODUCTION

To a great extent, and according to the NATO M&S masterplan "NMSMP" (NATO Allied Council, 2012), future military capabilities (i.e. doctrine, training, operations, etc.) will be developed and supported by Modelling and Simulation (M&S). Two main barriers are cost and accessibility. M&S technology is highly valuable to NATO and military organizations. To underline the importance of M&S in NATO, the North Atlantic Council (NAC) set up the NATO Modelling and Simulation Group (NMSG) to supervise the implementation of the NMSMP and to propose updates, promoting co-operation among Alliance bodies, NATO member nations and partner nations to maximize the effective utilization of M&S (NATO STO, 2016). According to this vision, it is essential that M&S tools are conveniently accessible to a large number of users as often as possible. To achieve a so widespread accessibility a new M&S framework is required, where M&S tools can be accessed simultaneously and spontaneously by a large number of users for their individual purposes. This "as a Service" paradigm has to support stand-alone use as well as integration of multiple simulated and real systems into a unified simulation environment whenever the need arises.

The NATO Modelling and Simulation Group MSG-136 "Modelling and Simulation (M&S) as a Service (MSaaS)" has defined MSaaS as "the combination of service-based approaches with ideas taken from cloud computing" (NATO STO MSG 136, 2016, June 10) . MSaaS seems to be a promising approach for realizing next generation simulation environments. This group was tasked to investigate, propose and evaluate standards, agreements, architectures, implementations, and cost-benefit analysis for incremental implementation of a permanently available, flexible, on-demand cloud-based services framework to provide M&S tools on-demand accessible to a large number of users.

Furthermore, the NATO M&S Centre of Excellence (CoE) in collaboration with Leonardo Finmeccanica are contributing to the NMSG 136 working group in the design of an experimentation environment to support MSaaS experiments known as the Open Simlab initiative.

NATO CD&E APPROACH TO MSAAS OPERATIONAL CONCEPT DEVELOPMENT

Concept Development and Experimentation (CD&E) for NATO is an enabler for transformation through the structured development of creative and innovative ideas into viable solutions for capability development. Paraphrasing the NATO CD&E Policy (North Atlantic Military Committee, 2009), Concept Development is a process aimed at finding solution-oriented transformational ideas that address capability shortfalls or gaps. The development of the MSaaS concept is of this kind, in which NATO would like to take advantage of new technology to obtain new capabilities.

NATO Capability Development Comprehensive Approach applied to MSaaS

In the NATO framework, a capability is a "the ability to execute a specified course of action or achieve a certain effect" and when it is necessary to introduce a new capability several aspects should be taken into account, adopting the so called "comprehensive approach". Different components could need changes or completely new developments. The components that are considered are: Doctrine, Organisation, Training, Materiel, Leadership, Personnel, Facilities,

and Interoperability (DOTMLPFI). In details, the meaning of each component, as from NATO CD&E Handbook is adapted in the following, the Allied Framework for M&S as a Service as defined by the Operational Concept Document (OCD) Draft (NATO STO MSG 136, 2016 June 10) under development by the MSaaS OPS Sub groups analysed using the DOTMLPFI approach.

- **Doctrine** *(The way we use MSaaS to support capabilities development)***:** MSaaS is considered a modernization of existing M&S capability and technology. Although major doctrine changes are not expected, minor revisions or adaptations may be required.
- **Organization and Policy** *(How to organize NATO and Allied M&S structures)***:** The need for an Allied Framework for M&S as a Service results from national policies like the United Kingdom's Defense Information & Communications Technology Strategy (Ministry of Defence, Chief Technology Officer, 2013), United States Department of Defense (DoD) Cloud Computing Policy (Department of Defense Chief Information Officer, 2012, July), the Italian Ministry of Defense (MoD) NEC001 (Stato Maggiore Della Difesa, VI Reparto Sistemi C4I e Trasformazione, 2007*).* and NATO policies (NATO Communications and Information Agency, 2014). Establishing the Allied Framework for M&S as a Service requires installation of an MSaaS Governance Authority (as defined by Allied M&S Publication AMSP-02 / Standardization Recommendation (STANREC) 4794) and accompanying policies (e.g., mandating the sharing of M&S resources). These policies also call for the establishment of national and/or NATO "Simulation Centres" that have oversight of national/NATO MSaaS activities. Adopting the Allied Framework for M&S as a Service will influence procurement as M&S services may be acquired on a pay-per-use or share-principle and ownership is not necessarily transferred. This has impacts on the relationship of provider (e.g. industry) and buying authorities.
- **Training** *(How we prepare NATO and Allied MSaaS specialists)***:** Training is required to prepare users (e.g. Exercise Control (EXCON)/Simulation Control (SIMCON) staff) to fully utilize the Allied Framework for M&S as a Service (e.g. to discover simulation services, to orchestrate and deploy services, etc.). MSaaS should enable and transform training in NATO, improving quality and quantity (NATO Allied Command Transformation (ACT), 2015, July 15). MSaaS will require new skills (e.g. regarding cloud computing, virtualization, service-oriented architectures, and emerging M&S-related technology etc.) and appropriate education and training.
- **Leadership** *(Chain of Command and Control and relationships in NATO and Allied according to MSaaS)***:** To realize the full potential of MSaaS, an enterprise approach is required which requires senior leaders to approve the MSaaS concept and to support the transformation activities.
- **Materiels** *(All the hardware, software, equipment and systems related to MSaaS necessary to NATO and Allies to manage, to support and to develop M&S Services)***:** The MSaaS concept requires establishment of a cloud infrastructure and appropriate network connections/infrastructure. Full adoption of MSaaS requires gradual transformation of existing M&S applications, data, etc. to comply with the MSaaS concept.
- **Personnel** *(Availability of qualified people according to MSaaS needs)***:** It is expected that the amount of resources required for preparing and conducting exercises and experimentation are reduced (less personnel to run EXCON/SIMCON, less administration efforts due to automation, etc.). It will likely be required to educate/re-skill personnel.
- **Facilities** *(Data Centres, Training facilities and Battle Labs available to provide and to consume MSaaS services)***:** Cloud infrastructure and appropriate data centres are required.
- **Interoperability** *(How to provide interoperable and accessible MSaaS services in NATO and Allied Overarching MSaaS Architectures)***:** The MSaaS concept promotes an open systems approach and requires the adoption of open standards (for data formats, protocols, etc.). If required, existing proprietary solutions need to be replaced by open standards. To enable the MSaaS concept, sharing of M&S resources needs to be mandated.

MSaaS Conceptual Architecture Development

The MSaaS architecture development follows a standard methodology called NATO Architectural Framework (NAF) based on the TOGAF(TM) Architecture Development Method (ADM) (The Open Group, 2016) with input from other

sources such as the MODAF (The UK Ministry of Defence Architecture Framework) learning portal and systems engineering standards, such as ISO15288 (ISO, 2015).

The NATO Architecture Framework (NAF) is an Enterprise Architecture (EA) framework by NATO. The Enterprise Architecture provide decision support, in the context of the enterprise strategy, for the use of resources (processes and procedures) in the enterprise. The architecture is responsible for defining how resources (M&S services) will be used to support enterprise strategy (MSaaS implementation plan) and benefit the NATO goals and objectives as defined by the MSaaS Operational Concept according to the NATO M&S Masterplan.

MSAAS ACTIVITIES

NATO Modelling and Simulation Group

The NATO Modelling and Simulation Group (NMSG) is conducting activities related to the MSaaS concept development and experimentation. The preliminary study was performed by the MSG-131 specialist group with the follow-on activity MSG-136. This section will introduce briefly these activities.

NMSG 131 Technical Report

According to the results of the NATO MSG-131 (Siegfried R. at all, 2014), a main conclusion of the specialist team is that service-based approaches to M&S offer many potential benefits, taking advantage of recent technical developments in the area of cloud computing technology and Service Oriented Architectures (SOA). Moreover, an alignment of "M&S as a Service" with the Connected Forces Initiative (CFI) is required, as the primary objective of the CFI (i.e., sharing and pooling of resources) is resembled in MSaaS. Similarly, it is required to align M&S and MSaaS with the NATO Consultation, Command and Control (C3) Classification Taxonomy as this is the primary tool used by NATO to chart the NATO C3 landscape.

The general approach taken by this specialist team was to perform a survey of the experiences from members regarding the use of cloud computing and service-oriented approaches within the M&S domain. The goal was to agree upon a shared understanding of what "M&S as a Service" is within NATO and to provide a comprehensive documentation of MSaaS case studies with an overview of existing service-oriented architectures in the M&S domain. Based on these existing experiences and architectures, conclusions and recommendations derived on the way forward.
The following definition of MSaaS derived from the "service" definitions provided by ITIL glossary (ITIL, 2011) and ISO/IEC 20000 (ISO, 2011): *"M&S as a Service (MSaaS) is a means of delivering value to customers to enable or support modelling and simulation (M&S) user applications and capabilities as well as to provide associated data on demand without the ownership of specific costs and risks."*

Several perspectives of the MSaaS concept arising from this definition, as follows:
1. MSaaS as a cloud service model;
2. MSaaS using cloud service models;
3. MSaaS as a Service Oriented Architecture;
4. MSaaS as a business model.

The hands-on experiences with the identified case studies (15) provided guidance and candidates for architectures, data models and interfaces that could become future SISO standards. In accordance with its Technical Activity Description, MSG-131 recommended to investigate MSaaS in more detail.

NMSG 136 Activities

The "MSaaS: Rapid deployment of interoperable and credible simulation environments" (NMSG-136) is the Science & Technology Organization (STO) research task group which received the heritage of MSG-131. Its objectives are to investigate, propose and evaluate standards, agreements, architectures, implementations, and cost-benefit analysis of the MSaaS approach. Specifically, with regards to evaluation of the use of M&S domain services to improve simulation interoperability and credibility, and to the analysis of the organizational M&S services perspective to establish a sustainable and efficient management of M&S services in NATO.

The MSG-136 is composed by several sub-groups as illustrated in Figure 1.

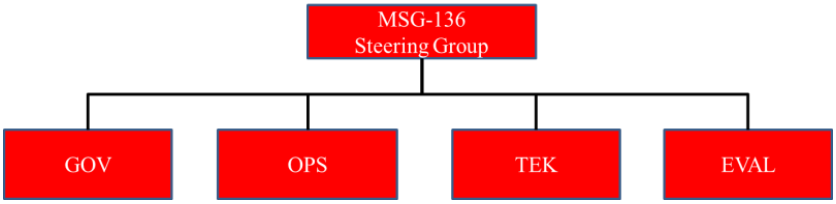

Figure 1 MSG-136 organization

In particular, the goals and expected deliverables of each sub-group are here detailed:

- Governance (GOV) Sub-group: defines policies for joining the MSaaS Ecosystem and defines how to maintain MSaaS Ecosystem. Its main deliverable is the AMSP-02, which contains these policies and standards;
- Operations (OPS) Sub-group: develops operational concepts and describes the desired characteristics and requirements of the MSaaS Eco-System from a users' perspective, including its major structures and capabilities to create an MSaaS Reference Architecture (RA). Its main deliverable is the Operational Concept Document (OCD);
- Technical Perspective (TEK) Sub-group: conducts technical investigations and experiments using specific MSaaS Target Architecture aspects to help generate MSaaS Reference Architecture, detailing the technical requirements for M&S Services using the MSaaS Target Architecture. Among its deliverables can be found the Technical Reference Architecture, the Service Description Template, the NATO Architecture Framework (NAF) descriptions and the Reference Engineering Process;
- Evaluation (EVAL) Sub-group: explores opportunities to participate in experimentation venues to test some implementations of the MSaaS RA, e.g., test beds with a Target Architecture derived from the RA.

In this context, the M&S CoE and its industrial partners are participating in the development of the MSG-136 deliverables and they are building a first experimental cloud infrastructure to conduct experimentation on the MSaaS concept. Moreover, the M&S CoE was leading the EVAL sub-group, which participated in the 2016 edition of the Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, eXercise (CWIX), as part of the M&S Focus Area, under the coordination of the same M&S CoE.

CWIX

The NATO CWIX programme provides a unique venue that allows systems and network engineers to come together to solve existing interoperability issues and explore and share potential solutions in anticipation of future operations and budget constraints, an opportunity for NATO commands/agencies and member and partner nations to prove, disprove, and improve NATO, National and Coalition Communication and Information Systems Interoperability. During this event, initial MSaaS experimentation was performed. In particular, via the unclassified network of the Joint Training Force Centre (JTFC), a Scenario Generator and Animator (SGA) acted both as consumer of services generating scenarios and as provider of services through a Computer Generated Forces (CGF) service. In addition, other capabilities where provided under a service paradigm, like the United States Air Tasking Order Generator (ATOG), which generated flight tracks from Air Task Orders (ATOs).

MSAAS TECHNOLOGY – STATE OF THE ART

Cloud technology and Containers solution

Cloud computing, often referred to as simply "the cloud", is the delivery of on-demand computing resources over the Internet on a pay-for-use basis or in a private environment (IBM, 2016). The main enabling technology for cloud computing is virtualization. Virtualization software separates a physical computing device into one or more "virtual" devices, each of which can be easily used and managed (Virtual Machines) to perform computing tasks. This technology minimizes user involvement, provides automation to speed up the process, reduces labor costs, and reduces the possibility of human errors. Cloud computing provides all of its resources as services, and makes use of the well-

established standards and best practices gained in the domain of SOA to allow global and easy access to cloud services in a standardized way.

Today another kind of virtualization is available, specifically operating-system or kernel-virtualization called Containers Virtualization. With operating-system-level virtualization essentially creating a scalable system of multiple independent computing devices, idle computing resources can be allocated and used more efficiently as shown in Figure 2.

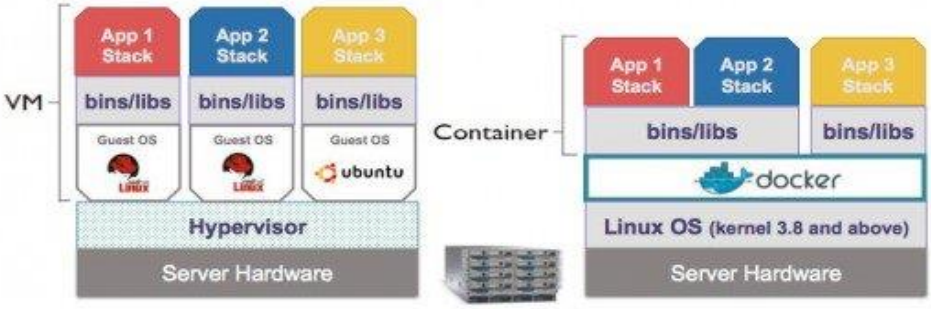

Figure 2 Virtual Machine Virtual Systems Container technology

This technology adds a new layer to cloud-computing; so the layers accessible within a stack are now IaaS (Infrastructure as a Service), PaaS (Platform as a Service), SaaS (Software as a Service) and CaaS (Container as a Service).

IaaS refers to online services that abstract the user from the details of infrastructure like physical computing resources, location, data partitioning, scaling, security, backup etc. A hypervisor, such as KVM and Xen (Bhanu P Tholeti, 2011) VMware ESX/ESXi (VMWARE, 2015), or Hyper-V (Zerger P., Posey B., Henley C., 2012) runs the virtual machines as guests. PaaS vendors offer a development environment to application developers. The provider typically develops toolkit and standards for development and channels for distribution and payment. In the PaaS models, cloud providers deliver a computing platform, typically including operating system, programming-language execution environment, database, and web server. Application developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers. Conversely, in the SaaS model, users gain access to application software and databases. Cloud providers manage the infrastructure and platforms that run the applications. SaaS is sometimes referred to as "on-demand software" and is usually priced on a pay-per-use basis or using a subscription fee. In the SaaS model, cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients. Cloud users do not manage the cloud infrastructure and platform where the application runs.

CaaS is a type of IaaS, such as a Docker (an open platform to build, ship and run distributed applications), specifically geared toward efficiently running a single application. A container is a form of operating system virtualization that is more efficient than typical hardware virtualization. It provides the necessary computing resources to run an application as if it is the only application running in the operating system -- in other words, with a guarantee of no conflicts with other application containers running on the same machine (Daconta M., 2013).

Cloud Security

Common security challenges for cloud services are listed as the top security threats to cloud computing by the Cloud Security Alliance (CSA). In addition to the twelve most treacherous threats (CSA 2016), considering an international military MSaaS environment and its architectures, another major challenge is the so called multi-level security (MLS). Benefits of an MSaaS can be fully achieved when true MLS is realized. That means all users with different clearances can access a cloud and an automated security mechanism can guarantee secure flow control and sanitization of what is distributed (Caiyrcy E. 2013).

MSAAS ENTERPRISE ARCHITECTURE

The Open SimLab initiative by the NATO M&S CoE consists of an innovative business model developed to attract industry, academia and organizations (NATO, military/governative/non-governative agencies) based upon the use of M&S in order to experiment on new concepts and ideas involving the integration of different systems and technologies.

The Open Cloud Ecosystem ApplicatioN (OCEAN)

The OCEAN project is being developed by the Leonardo Company under a technical agreement with the NATO M&S CoE. To develop the project further other partners are joining the NATO M&S CoE under the Open Simlab initiative. The aim of OCEAN is to provide to MSaaS Community of Interest (CoI) and other partners an experimentation environment based on cloud technology. In this embryonic framework, it is possible to consume the available MSaaS services, and/or deploy new M&S services, for testing and experimentation purposes to verify and exploit the MSaaS operational concept development.

A set of fundamental Modelling and Simulation services are categorized under the C3 Taxonomy as COI-Specific and COI-Enabling services (NATO ACT, 2012, June 15) (see Figure 3):

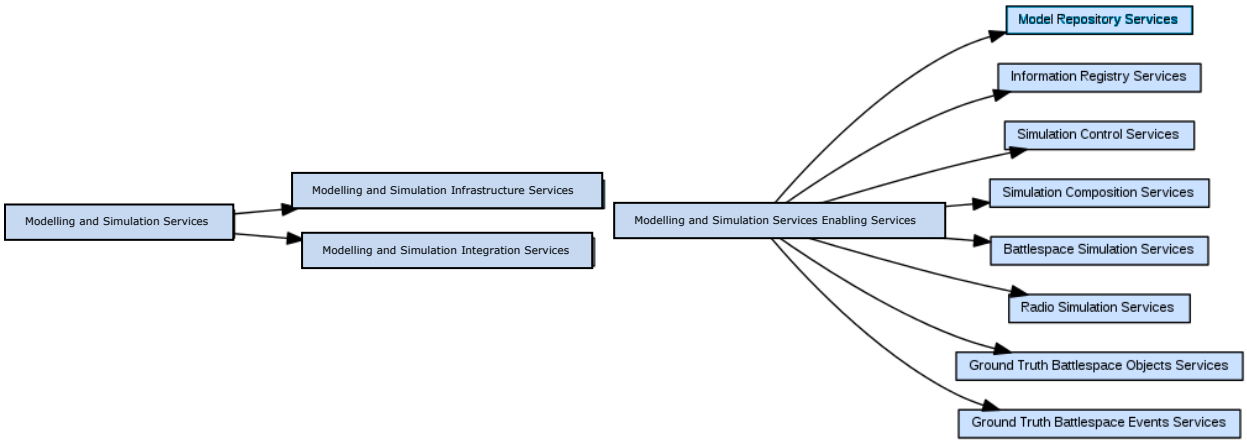

Figure 3 C3 Taxonomy – M&S COI Services

The following basic services are available in the cloud infrastructure provided by the OCEAN prototype:

- Infrastructure/Integration Services: allows users to interconnect each other, from Voice over Internet Protocol (VoIP) to VTC to specific M&S applications, such as High Level Architecture (HLA) Run Time Infrastructure;
- Synchronization Services: allowing systems being time-synchronized especially useful for real-time applications, mainly based on Network Time Protocol;
- Information Exchange Gateways Services: useful whenever a connection between systems using different interfaces is necessary; they can translate the exchanged information inside the simulation network or between simulation and real systems;
- Information Registry and Model Repository Services: allows users to get information about the available services and assets and to have access to a repository of models;
- Simulation Composition and Control Services: assembles the necessary components together to control the overall execution of the experiment;
- Terrain Databases and geospatial Services: shares terrain data information and guarantees coherence and proper correlation among all of the participants;
- Synthetic Scenario (Battlespace) Services: a widely used set of services to generate and animate a shared virtual reproduction of a real-world situation, in terms of static and moving entities and their interactions;
- Communication Services: used whenever a simulation of real-world radio or network communications among entities and systems is necessary.

MSAAS FRAMEWORK

The OCEAN project offers an embryonic framework made of a combination of hardware, software and services ("platform as a service", "software as a service", "data as a service") to automate the deployment of M&S tools and applications in a cloud environment. The framework offers a unique point of access through a web portal. The web portal provides a secure environment with access to the portal resources (services) granted by a user identity management system. The availability of services is managed by an M&S services management system, who facilitate the delivery, versioning, testing, consumption, termination and disposal of services.

The main phases of the services management are identified as follows:

- Services Provisioning: preparation of the available services
- Services Deployment: making the services available to users through the cloud system
- Network Provisioning: automating network reconfiguration
- Services On-demand: users services consumption

The above phases can be performed through the following sessions:

1. Sessions isolation: Test, experimentation, integration and training sessions are virtual separated environments (sessions) inside a cloud. The session isolation allows a multi-tenant services consumption by users, partitioning service applications with one or more customized virtual instances that are independent from each other in the cloud.
2. Integration session: Instantiates a session inside a cloud connecting it to real systems.

OCEAN framework software architecture takes advantage of Hypervisor and Container–Based virtualization technology (see Figure 4) allowing the orchestration between applications using a Cloud Application Program Interface (API) and Docker API together.

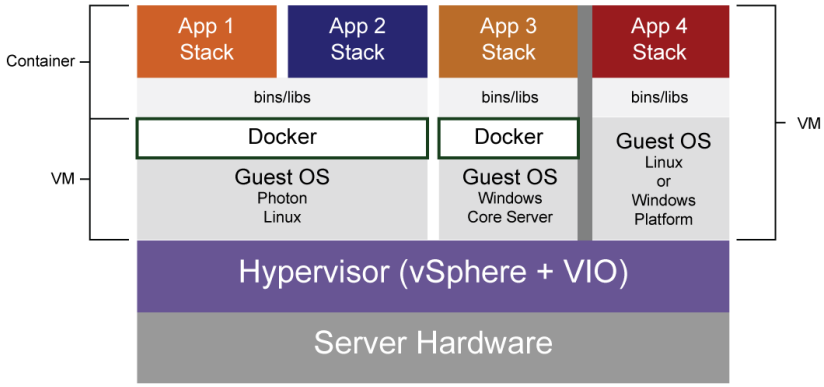

Figure 4 Hypervisor and Container–Based Virtualization Services

Assets Repository

User select assets from a marketplace-like repository of simulation and real systems, as shown in Figure 5. For example, users could create a simulation environment and translate simulation data from/to Command & Control/ Command data with a Command and Control Simulation Stimulation Gateway (translator) service.

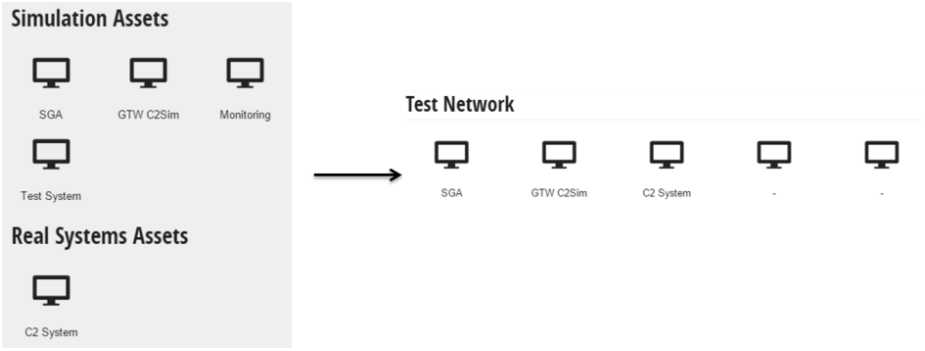

Figure 5 Asset repository

Scenario Service

A Representational State Transfer (REST)-based technology service prototype manages a synthetic environment CGF application (Scenario) through a web interface. All applications and services could be managed by similar interfaces, as shown in Figure 6.

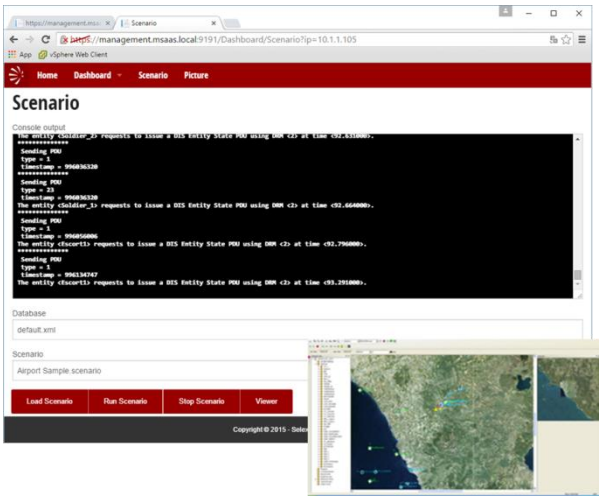

Figure 6 Web interface for scenario generation service

Web Viewer

A web viewer is used to monitor and control the simulation environment from any location and with any device like a smartphone or a tablet. The interface resides in a web browser and it is operating system agnostic. (Figure 7)

Figure 7 Web viewer

Security

At the beginning, the OCEAN project will be deployed on a cloud infrastructure based on Openstack VMware Solution. From the security perspective, it should be specifically noted that OpenStack has not undergone a Common Criteria certification, however VMware have achieved Common Criteria Certification. As a possible security baseline

solution, the system will be installed by separating the client network from the one used by the virtual systems involved preventing the possibility to access the real data.

USE CASES

According to the experiments and the experience in which the M&S CoE is involved, it could be possible to reuse other projects run by the M&S CoE to provide already developed and well-proved use cases for MSaaS experimentation activities. In particular, an identified use case for study is the Urbanization Project "Archaria" model.

Urbanization Project (UP)

The NATO ACT Urbanization Project (UP) (NATO ACT, 2015) is an example of ACT CD&E activity to conduct an Urbanization Conceptual Study and Experiment to examine the impact on NATO military operations of potential crises in urban areas and consequences of Urbanization in 2035. The M&S CoE was tasked in this framework to develop a model for a future city, representing an urban environment, which could be the terrain for different kinds of instability scenarios, like megacity turmoil, large scale disaster and disruptive impacts of migration, as defined within the Framework for Future Allied Operation (FFAO). Several layers of the megacity were designed and filled with relevant data, considering different aspects of the urban environment like roads, transportations, communications, utilities, etc. All of these layers, about 250 modelled and filled with data, can be reused to generate scenarios settings services to provide a set of large urbanized area simulation, as shown in Figure 8.

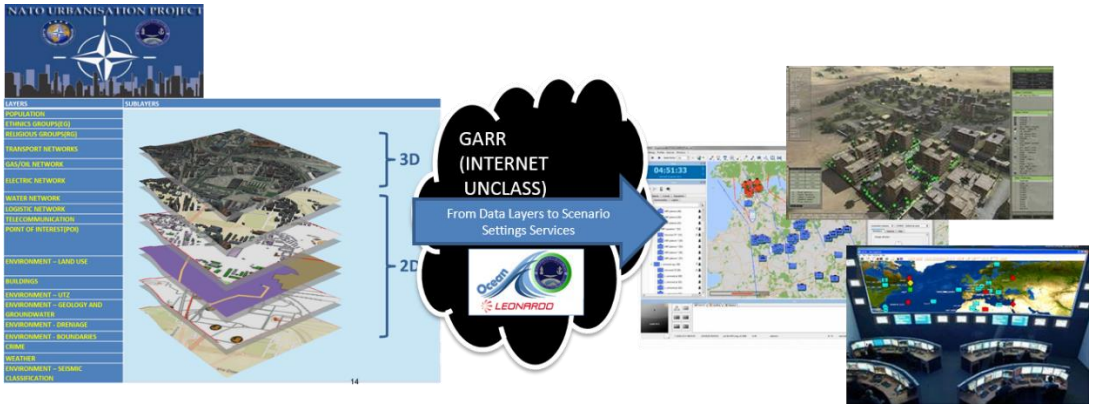

Figure 8 Evolution of NATO UP "Archaria" under an MSaas paradigm

CONCLUSIONS

The M&S CoE with Leonardo and other upcoming industrial and academic partners, which are joining the project under the OPEN SIMLAB initiative, have started to design and develop an initial MSaaS Prototype called OCEAN. According to the administrative and technical timing needs of the NMSG 136 MSaaS Implementation Roadmap, shown in Figure 9, the initial deployment at the M&S CoE of the OCEAN solution prototype providing embryonic MsSaaS services will be implemented no later than the end of 2016 with the goal of leveraging existing experiments, such as UP "Archaria", to demonstrate the value of MSaaS.

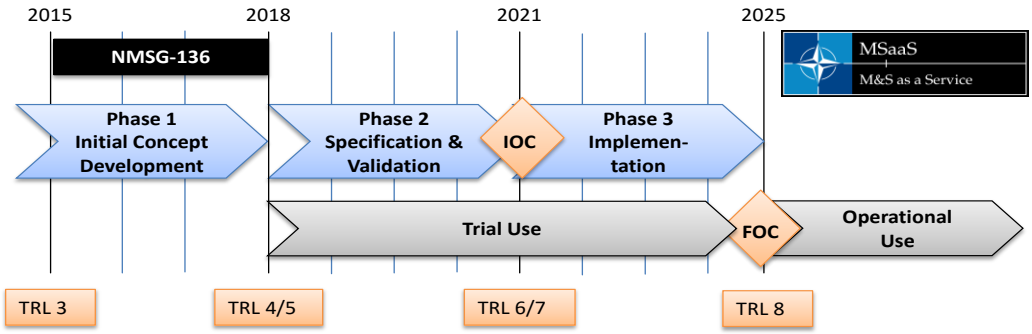

Figure 9. MSaaS Implementation plan

Regarding the concept development and experimentation phase and related Verification and Validation (V&V) activities, a viable way to proceed could be to identify the right experimentation and exercise events to perform V&V activities at least once a year. The CWIX event could be one of the best experimentation venues where it is possible to experiment and verify MSaaS services before their validation and implementation. Regarding the validation and accreditation of MSaaS services, a large exercise event like Trident Juncture, Steadfast Cobalt or Viking could be the right venue for MSaaS services validation and accreditation before their implementation (IOC).

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