M&S as a Service: Expectations and challenges

Robert Siegfried
aditerna GmbH
Otto-Hahn-Str. 13 B
85521 Riemerling, Germany
robert.siegfried@aditerna.de

Tom van den Berg, Anthony Cramp, Wim Huiskamp
TNO
Oude Waalsdorperweg 63
NL-2597 AK The Hague
The Netherlands
{tom.vandenberg, anthony.cramp, wim.huiskamp}@tno.nl

ABSTRACT: *Modeling & Simulation as a Service (MSaaS) is a concept that potentially offers all kinds of possibilities to support M&S users and providers. For many reasons service-based approaches are considered to be very promising architectures for realizing next generation simulation environments. The combination of service-based approaches with ideas taken from cloud computing is known as "Modeling & Simulation as a Service".*

Over the past year, NATO Modeling and Simulation Group MSG-131 ("Modelling and Simulation as a Service: New concepts and Service Oriented Architectures") has investigated the concept of MSaaS and collected national perspectives and experiences regarding MSaaS. The resulting "Multi-National Concept for M&S as a Service" provides an overview about the nations' activities in this area and is input to "NATO M&S as a Service Concept" that is currently being developed by NATOs Allied Command Transformation (ACT).

This paper presents the most recent results of NATO MSG-131 Specialist Team in the area of MSaaS and related national results from research and development activities. It illustrates potential benefits that may be achieved by MSaaS and challenges that remain to be solved. National experiences with service-based distributed simulation environments are reported.

1 Introduction

1.1 Motivation

M&S is a key enabler for the delivery of capabilities to NATO and Nations in the domains of training, analysis and decision making. However, for various reasons M&S has not been exploited fully to best take advantage of these capabilities. Recent technical developments in the area of cloud computing technology and Service Oriented Architectures (SOA) may offer opportunities to better utilize M&S capabilities to satisfy NATO critical needs. This approach is known as M&S as a Service (MSaaS).

NATO and Nations are already implementing cloud-based initiatives to support non-M&S requirements. NATO is developing the Future Mission Network and supporting the Connected Forces Initiative (CFI) using SOA and cloud-based solutions. Nations are also working independently on cloud-based initiatives.

Some potential benefits of cloud and SOA approaches are:

- Reduced operation and maintenance costs
- Improved interoperability
- Enhanced sharing of resources
- Improved deployment and accessibility

M&S solutions should be integrated seamlessly into future computer information systems capabilities to ensure increased efficiency, affordability, interoperability, and reusability.

1.2 Objectives

The objectives of the NATO MSG-131 Specialist Team (ST) are summarized as follows:

- to define the problem to be solved under the Nations and ACT demands, and to agree on a common understanding of the terminology, also important for future implementations of MSaaS in NATO.
- to develop a primer on M&S shortfalls regarding training and exercises and other M&S applications areas as identified in the NATO M&S Master Plan (NMSMP) [14].

- to develop a primer of the NATO technical concept for MSaaS. This document will have to be sufficient to support the other objectives, and will be further elaborated later if needed.
- to provide additional consolidated knowledge, if required, informed by standards and technical documentation on MSaaS, which serves as a basis and permits development of a specific concept and architecture to be used by NATO nations and bodies.
- to develop a draft Reference Services Oriented Architecture which will allow conducting improved training and exercises and other applications areas as identified during the first phase of the project.

The results from this ST will provide the baseline for a follow-on Research Task Group (RTG) under the NATO Modelling and Simulation Group (NMSG).

1.3 General approach

The general approach taken by MSG-131 ST is to collect experience from members regarding the use of cloud and service-oriented approaches within the M&S domain. This survey is used to develop a shared understanding of what "M&S as a Service" is in the NATO context. In addition the survey provides a comprehensive documentation of MSaaS case studies and provides an overview of existing service-oriented (reference) architectures in the M&S domain. Based on these existing experiences and architectures, conclusions and recommendations are derived on the way forward.

2 M&S as a Service

2.1 Definition

In literature several authoritative definitions for "Service" can be found that are applicable to the concept of "M&S as a Service".

OASIS (Organization for the Advancement of Structured Information Standards) is a non-profit consortium that has developed an abstract framework (see [1]) for understanding significant entities and relationships between them within a service-oriented environment, and for the development of consistent standards or specifications supporting that environment. Within this framework a service is defined as:

"A service is a mechanism to enable access to one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description."

The Open Group developed a reference architecture for a service oriented architecture (see [2]). In [3] a service is defined as:

"A service is a logical representation of a repeatable activity that has a specified outcome. It is self-contained and is a 'black box' to its consumers."

The *Object Management Group* (OMG) is an international standards organization and has developed a specification for a service-oriented architecture modeling language (SoaML). In this specification (see [4]) a service is defined as:

"A service is value delivered to another through a well-defined interface and available to a community (which may be the general public). A service results in work provided to one by another."

The above three organizations have written a joint white paper to help the Service Oriented Architecture community to navigate the technical products produced by these organizations (see [5]).

And finally, two more definitions are provided by ITIL and ISO/IEC 20000, as described next.

The *Information Technology Infrastructure Library* (ITIL) is a set of practices for IT service management and defines service as follows:

"A service is a means of delivering value to customers by facilitating outcomes customers want to achieve without the ownership of specific costs and risks." [6]

A good explanation and analysis of this definition is given in [7].

ISO/IEC 20000 is an ISO standard for IT service management that was originally developed to reflect best practice guidance contained within the ITIL framework. This standard has adopted the ITIL definition, and defines service as:

"A service is a means of delivering value for the customer by facilitating results the customer wants to achieve." [8]

More definitions may be found in literature. As can be seen, the ITIL, ISO/IEC and OMG definitions are quite similar. Actually, many of the definitions share the same thought.

With regards to Modelling and Simulation (M&S), MSG-131 bases its definition for M&S as a Service on the ITIL definition for services and defines M&S as a Service as follows:

"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."

What exactly "value" is, is defined by the customer. The value of a service is determined by what it enables the customer to do. A service in the MSaaS context is for example a professional service, such as a verification and validation (V&V) service, where an organization or human provides a service to a customer. Another example is an IT or technical service, such as a weapon effects service, where the service is integrated within a larger simulation environment.

As such, MSaaS is an architectural and organizational approach that promotes abstraction, loose coupling, reusability, composability and discovery of M&S services. The objective of M&S as a Service is to effectively and efficiently support operational requirements (like e.g. executing an exercise) and to improve development, operation and maintenance of M&S applications.

2.2 Perspectives

The definition of MSaaS provides a high-level view of the concept. There are different perspectives arising from this general definition of MSaaS. MSG-131 takes the following perspectives on MSaaS:

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.

Perspective 1 (MSaaS as a cloud service model) is concerned with the question how an M&S application is provided to a user (or equally, how a user may access an M&S application). Perspectives 2 and 3 are concerned with the architecture of an M&S application. Perspective 4 is primarily concerned with the provision of M&S applications as an organizational or professional service.

The four perspectives are orthogonal to each other, meaning they do not exclude each other. For example, an M&S application can both be provided as a cloud service model, as well as designed as a service oriented architecture.

Perspectives 1, 2 and 3 are illustrated in Figure 1. All perspectives are described in detail in the following sections.

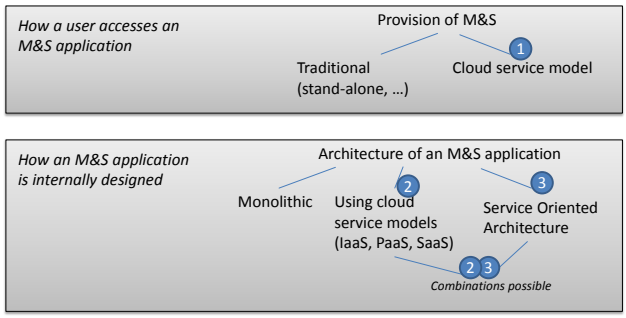

Figure 1: MSaaS perspectives.

2.2.1 MSaaS as a cloud service model

The first perspective is to 'servicize' M&S. That is, to bring to M&S all the characteristics attributed to Cloud Computing and the Infrastructure as a Services (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) models.

Cloud computing is defined by [9] as:

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

and is composed of five essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.

As such cloud computing is not a service, but an IT mechanism or approach for providing a service to a customer, also called "service model". Cloud computing supports the three service models mentioned previously: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [10].

Each service model varies the capability that is provided to a consumer and the aspects that are removed from the consumer's need to manage and to control. The SaaS model allows the consumer to use the provider's applications running on a cloud infrastructure without the consumer needing to manage or to control the underlying cloud infrastructure. The IaaS model allows the consumer to provision processing, storage, networks and other fundamental computing resources allowing the consumer to deploy and to run arbitrary software. In the middle, the PaaS model allows the consumer to deploy onto the cloud infrastructure consumer-created or acquired applications developed using programming languages, libraries, services, and tools supported by the provider.

Therefore, from this perspective, the goal of MSaaS is to provide M&S applications as a cloud computing service model so that they are available on-demand, over the network, with the ability to charge per-use rather than the need to purchase the entire M&S product. This approach aims to reduce cost of ownership for the consumer (pay per use, no maintenance of local installations).

This perspective on MSaaS is illustrated in Figure 2.

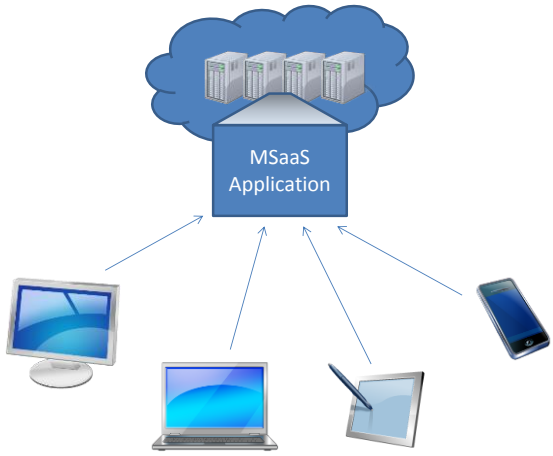

Figure 2: MSaaS as a cloud service model.

2.2.2 MSaaS using cloud service models

This perspective is slightly different from the first. The aim here is to make effective use of existing cloud computing service models to improve M&S applications. It focusses on how cloud computing technology, in particular the IaaS, PaaS, and SaaS models, can best be used in support of M&S. For example, how can IaaS be used on-demand in support of running distributed simulations so as to reduce the need for the simulation owner to also own and maintain the simulation computing resources? This perspective raises a number of questions, especially in the military domain, such as what are the security implications?, what happens if the cloud resources are not available due to outages at the cloud or in the network connecting to the cloud?

2.2.3 MSaaS as a Service Oriented Architecture

This perspective looks to use Service Oriented Architectures (SOA) as the infrastructure for connecting and combining M&S services (see Figure 3). In [4] SOA is described by the OMG as an architectural paradigm for defining how people, organizations, and systems provide and use services to achieve results.

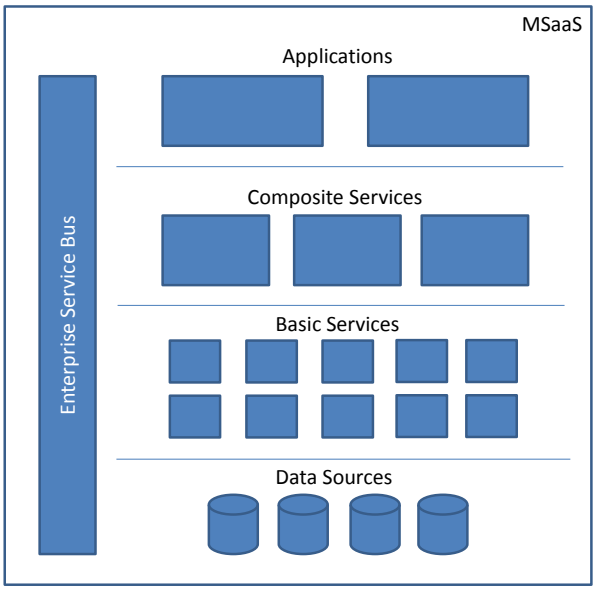

Figure 3: MSaaS as a Service Oriented Architecture.

Meaningfully combining services requires a SOA that captures details on the service infrastructure, restrictions on the data model, types of allowed services, processes for developing services, and the governance of maintaining the services. Following a system-of-systems approach services may be combined to form new (possibly, more complex) services. An example is a computer-generated forces (CGF) service that consumes a line-of-sight service. M&S services may themselves also use non-M&S specific IT services or service models, such as SaaS.

Each service requires an interface definition that defines how the service may technically be accessed by a consumer, and requires a service level agreement (SLA) that provides a consumer with non-technical service aspects such as fidelity, cost, timescale, uptime guarantees, etc. of the service.

Service orientation is a design paradigm to develop services according to certain design principles or patterns, within the context of a Service Oriented Architecture. Design principles include service abstraction, loose coupling, reusability, composability and discovery. Service orientation has a myriad of definitions and "purities", but for MSaaS, three central aspects of service orientation are:

1) communication following standards so that service contracts can be declared and processed over a range of actors (components),
2) loose coupling in the sense that components are usable in a wider context, and
3) interoperability in the sense that components may function together to generate a larger, different piece of total functionality.

Service discovery is in the essence of SOA, but at present, service discovery is in effect possible only at design time; except for very mature systems. MSaaS should enable service discovery in the sense that components are ready for a predefined set of service types and may call upon these services at need.

This perspective potentially requires the definition of multiple, different SOAs. Integrating M&S services relevant to the M&S business domain will require a SOA different from a SOA used to integrate military domain specific simulation services in order to create a distributed simulation to support a training or analysis activity.

2.2.4 MSaaS as a business model

This perspective focuses on organizational services and underlying business models, such as the Distributed Networked Battle Labs (DNBL) [11], [12], that provide a framework for registering, identifying and contracting providers of M&S services (e.g., networks, infrastructure, software, data, V&V, certification) in order for a client to fulfil an M&S need (Human-to-Human or Organization-to-Organization).

2.3 Service categorization

There are many ways to categorize services and often services fit in multiple categories at the same time. One possible service categorization uses the type of consumer and provider of the service. Given the types "Human", "Machine" and "Organization" possible service categories are Machine-to-Machine, Human-to-Machine, Human-to-Human and Organisation-to-Organisation services.

Other service categorizations are service application area and service domain. An application service concerns the use of a service for a kind of application, for example a weapon effects service for engagement simulations. A domain service concerns the use of a service in a certain domain or problem space, across a group of applications, for example a simulation data recording service.

Other categorizations may take into account other aspects of a service, such as time. Examples are a Real Time service or a Non-Real Time service.

MSG-131 is primarily focussed on the category of services that include a Machine, i.e. Machine-to-Machine and Human-to-Machine services. These services may be combined with other services to a form a new service, or may be integrated into a simulation environment. MSaaS examples in this context are a weapon effects service within a simulation environment (Machine-to-Machine), planning support services, and scenario development services (both Human-to-Machine).

The professional type services in the form of Human-to-Human and Organisation-to-Organisation services are not in the focus of MSG-131. But it is possible for these services to be supported by Machine services, either as enabling or intermediate services. For example, a V&V service is initiated by a human/organization and the service is performed by a human/organization, but the process is facilitated by technical systems like a Request for V&V Service and V&V Progress Tracking Service.

2.4 Alignment with NATO C3 Classification Taxonomy

Another categorization scheme that may be used for service categorization is the NATO C3 Classification Taxonomy. The taxonomy is a layered categorization scheme of capabilities in support of Consultation, Command and Control (C3). More information on the C3 Classification Taxonomy can be found at [13].

The top-level view of the NATO C3 Classification Taxonomy is shown in Figure 4.

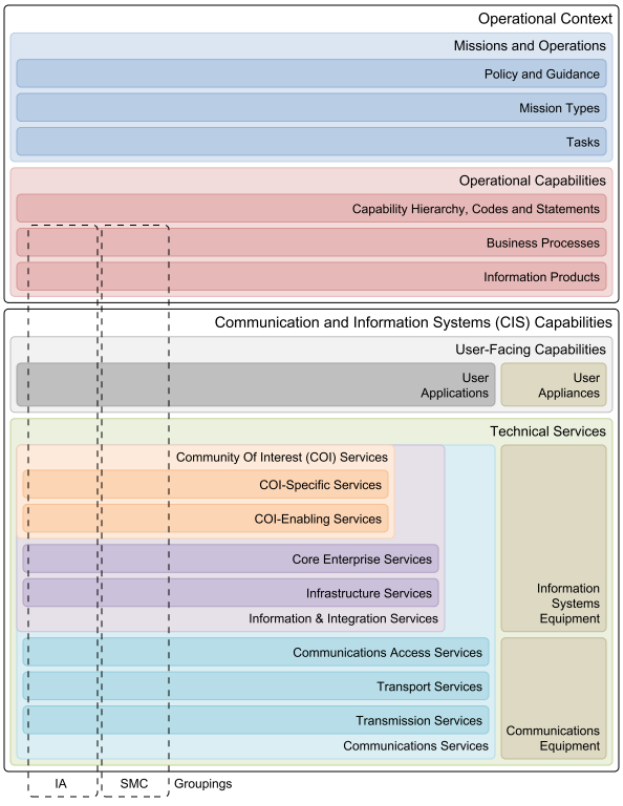

Figure 4: Top-level view of NATO C3 Classification Taxonomy.

The taxonomy consists of the following main layers:

- Operational Context, which consists of Missions and Operations that are supported by Operational Capabilities.

  Missions and Operations capture NATO's Political and Military Level of Ambition as derived from the Strategic Concept and Political Guidance. These ambitions are expressed as a series of possible mission types and related tasks, as well as references to relevant concepts, guidance, policies, and publications.

  Operational Capabilities capture everything required by NATO to successfully complete Mission Types and achieve stated Levels of Ambition. Operational Capabilities are linked to established Business Processes. To support the implementation of C3 capabilities, Information Products are captured separately and linked to these Mission Types and Key Tasks.

- Communication and Information Systems (CIS) Capabilities, which consists of User Facing Capabilities, and that are supported by Technical services. The User Facing Capabilities consist of domain-oriented user applications. The Technical Services on their turn are decomposed in a number of sub-layers: Community Of Interest (COI) Services, Core Enterprise Services, and Communications Services.

  User-Facing Capabilities express the requirements for the interactions between end users and all CIS Capabilities, in order to process Information Products in support of Business Processes. User-Facing Capabilities incorporate the User Appliances, as well as the User Applications that run on those appliances. User Applications – also known as application software, software applications, applications or "apps" – provide the computer software components designed to help an end user perform singular or multiple related tasks.

  Technical Services express the requirements for a set of related software and hardware functionalities that can be reused for different purposes, together with the policies that should control their usage. These requirements are derived from the operational needs expressed by the collection of User-Facing Capabilities. Inherently, the Technical Services must support all NATO Mission Types.

There are also two cross-cutting layers in Figure 4: Information Assurance (IA) and Service Management and Control (SMC).

The taxonomy is expanded in more detail in additional diagrams, providing more information on each layer. For example, the next level of expansion lists various user facing applications and COI services. This expansion is not included in this paper, and the reader is referred to the references given.

For each of the listed capabilities in the C3 taxonomy M&S may play a role. The layers that are most relevant for M&S are from the Business Processes down to the Infrastructure Services. In fact, the same categorization that is used for the C3 capabilities can be applied to M&S. M&S User Facing Applications are for example training systems or decision support systems. M&S COI Services are for example specific simulation services such as weapon effects, execution management, data and voice recording, or CAX support services. And a basic M&S Infrastructure Service is for example the simulation run-time infrastructure (such as the HLA RTI) and gateways.

2.5 Advantages and disadvantages

The use of MSaaS can have several advantages and disadvantages. Several advantages and disadvantages are listed below, based on literature search and discussions within MSG-131.

2.5.1 General advantages and disadvantages

A number of general advantages and disadvantages of "as a Service"-approaches and cloud computing can be found in literature or the public internet. No distinction is made here as to what MSaaS perspective this is most relevant to.

General advantages include:

- on-demand self-service;
- broad network access;
- resource pooling;
- rapid elasticity;
- measured service;
- automatic upgrades; composability.

General disadvantages include:

- security, privacy, accountability, intellectual property rights, risk and trust become more complex;
- effective composition of services is still an open area of research;
- dependency on a unique service; vulnerability to undesirable network effects (e.g. latency or response time jitter);

- adaptation of existing M&S assets required to make them service-enabled;
- lack of local control.

The verification and validation of the results provided by a specific service may also be more challenging when there is limited control or visibility of the internal 'mechanics' of the service provider.

2.5.2 Military user specific advantages

From the military user point of view there are a number of (perceived) advantages of MSaaS. The advantages are grouped by most relevant perspective.

MSaaS as a cloud service:
- no major hardware necessary (e.g. on front-line) where you do not want it (it could be in a back-office);
- SMEs at a distance;
- less end-user maintenance of complex, military M&S assets (typically in large distributed training: version differences requiring upgrades, technical problems, etc.);
- accessible from around the world (allowing e.g. training wherever you are);
- flexibility: adaptable depending on the training audience or selected scenario and required assets, solutions can be made to fit due to elasticity at the provider or by selecting another provider;
- try before you buy
    - during acquisition: if only the use cost is calculated, and no interface adaption is necessary, several MSaaS versions of some service can be tried before a final subscription is chosen
    - also, if after acquisition it turns out that the service is not used, it does not cost much.
- scalability: adaptable depending on size of the training audience, solutions can be made to fit due to elasticity at the provider.

MSaaS as a SOA:
- level playing field if all users access the same services (e.g. communication effects or weapon effects modules);
- work in a heterogeneous environment typical for distributed simulation.

MSaaS as a business model:
- outsourcing of parts of the M&S;
- specialisation by small start-ups becomes possible.

2.5.3 Military user specific drawbacks

There are also several (perceived) drawbacks, again grouped by most relevant perspective.

MSaaS as a SOA:
- Adaptation of existing software is needed (e.g. replace internal weapon effects calculation of a simulation system with an interface to a service providing the same functionality). This may prove difficult or impossible in the case of COTS products. Note that it may be possible for some legacy/COTS products to act as an MSaaS by encapsulating it in a wrapper.
- In current distributed M&S applications, often significant tailoring of gateways etc. is required before use.
- Validation of specific services may be more difficult when they are more remote and internal operation is shielded of to a large degree.

MSaaS as a cloud service:
- Poor performance of network infrastructure available to military users, especially those deployed, may make access to and use of M&S services difficult or impossible.
- If a composed MSaaS service is validated for some use, updates to individual services may require re-validation. Mitigating this requires well defined service management and governance to allow service users to continue using validated services while newer updates go through the validation process.
- There is less face-to-face contact if M&S assets are no longer needed locally since an exercise can be executed distributed. If there is an advantage of face-to-face meetings, they have to be held anyway.

3 Case studies

MSG-131 surveyed several national case studies of existing activities that use MSaaS ideas or borrow ideas from service oriented architectures in general.

In total, 15 case studies were identified and described by MSG-131. A fixed template was used for collecting information, such as description of the case study, the supported business process (for example, acquisition, test and evaluation, training, lifecycle cost analysis), role of end-user, security-related information, and type of services provided. If possible, expected and observed benefits from taking a service-oriented approach were documented.

A number of potential M&S services were identified from these national case studies. Some examples are provided

in the following table. Further categorization (application area and domain) and structuring of these services will need to be done in MSG-136, the follow-on activity of MSG-131.

Service	Category
Weapons Effects Service	Machine-to-Machine
Communication Effects Service	Machine-to-Machine
Exterior Ballistics Service	Machine-to-Machine
Synthetic Environment Service	Machine-to-Machine
Synthetic Dynamic Service	Machine-to-Machine
Initialization Service	Machine-to-Machine
Computer Generated Forces Service	Machine-to-Machine Machine-to-Human
Weather Service	Machine/Human/Organization-to-Machine/Human
Live Data	Machine-to-Machine/Human
Terrain Generation Service	Machine/Organization-to-Machine
Verification and Validation Service	Organization-to-Human/Organization

4 Reference architectures for MSaaS

With regards to reference architectures for MSaaS, MSG-131 discussed terminology and identified existing (reference) architectures for M&S as a Service and reference architectures that utilize MSaaS ideas.

4.1 Terminology

In general, reference architectures can be considered to be a special kind of reference models. Reference models are usually characterized by the two main attributes *universality* and *recommendation character* [15]:

- Universality refers to the idea that a reference model should be applicable not only in one special case but to a certain class of problems.
- Recommendation character refers to the idea that a reference model should serve as a blueprint or even as a default solution for certain problems.

Reference architectures may be characterized in the same way, i.e., using the attributes *universality* and *recommendation character*. This is also reflected in the NATO Architecture Framework (NAF) that defines reference architectures as the linking element between overarching architectures and target architectures. According to the NAF,

"Reference architectures reflect strategic decisions regarding system technologies, stakeholder issues, and product lines. They render user requirements, processes, and concepts in a high-level solution from which individual projects can be identified and initially programmed. Their primary focus is on services, processes and component functionality, and they provide the basis for the development of Target Architectures (TA)." [16]

Building target architectures for specific simulation systems or simulation environments on foundations from established reference architectures will increase not only the efficiency of work in time and budget, but also the quality of the results, and will lead to improved interoperability. A Reference Architecture (RA) states for example that HLA Evolved IEEE1516-2010 [17] is used. The Target Architecture (TA) states which version, which data model and which version of that model, and which vendor will provide the RTI and in which version etc. The RA is the general blueprint while the TA makes it very specific.

As elaborated by MSG-086, comprehensive reference architectures for simulation environments are currently missing ([18], Ch. A.2.6). However, as described in the following section reference architecture for specific applications domains are existing, respectively are currently being developed. Application domains are for example entity level simulation, and Command and Control (C2).

4.2 Existing (reference) architectures

Figure 5 gives an overview of existing reference architectures within the M&S domain as identified by MSG-131.

Figure 5: Overview of existing reference architectures and their scope [19].

Figure 5 also tries to give an indication of the scope or level that is addressed by each reference architecture. Each reference architecture is described in more detail by MSG-131.

Additionally to the reference architectures shown in Figure 4, MSG-131 points out the need to integrate M&S reference architectures with C2 reference architectures.

5 Conclusions and recommendations

This paper presents the most recent results of NATO MSG-131 in the area of MSaaS and related national results from research and development activities.

Based on the work done by MSG-131, this paper provides a definition of M&S as a Service (MSaaS) and puts MSaaS in context with cloud computing approaches. Four perspectives on MSaaS that were identified by MSG-131 and found most relevant are discussed, including their advantages and drawbacks. Finally, this paper gives a brief overview of case studies for MSaaS and existing reference architectures within this domain.

A main conclusion of MSG-131 is that M&S is a critical technology for NATO and the Nations, independent whether it is provided "as a service" or not. However, service-based approaches to M&S offer many potential benefits. Therefore, 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 closely resembled in MSaaS. Similarly, it is required to align M&S and MSaaS with the NATO C3 Classification Taxonomy [13] as this is the primary tool used by NATO to chart the NATO Consultation, Command and Control (C3) landscape.

MSG-131 identified various open issues with regards to MSaaS, spanning a broad range from technical to organizational questions. Some examples are:

- How are reference architectures on different levels related to each other?
- How to specify technical (domain) services, especially with regards to non-functional requirements?
- How to establish permanent/persistent services (in NATO)?
- What are the requirements on governance and how should service management be organized?

In accordance with its Technical Activity Description, MSG-131 recommends to investigate MSaaS in more detail. This investigation should be carried out by a follow-on research task group. A Technical Activity Proposal for such a group was developed by MSG-131 and endorsed in June 2014. The task group MSG-136 ("Modelling and Simulation (M&S) as a Service (MSaaS) – Rapid deployment of interoperable and credible simulation environments") will start its 3-year term in November 2014.

The NMSG has a formal Technical Cooperation Agreement with SISO on the development of M&S interoperability standards. Examples of this close cooperation are the development of the Coalition Battle Management Language (C-BML) and the Generic Methodology for Verification and Validation (GM-VV). MSG-136 will continue to engage with the SISO community to investigate areas where standardisation efforts are needed related to MSaaS. The hands-on experiences with case studies will provide guidance and candidates for architectures, data models and interfaces that could become future SISO standards.

6 Acknowledgements

The authors would like to thank all members of MSG-131 for their excellent work and for many fruitful discussions.

Furthermore, the authors encourage any interested party to join MSG-136 for a more in-depth discussion of this topic and multinational experimentation with technical approaches.

7 References

[1] OASIS, Reference Model for Service Oriented Architecture 1.0, OASIS Standard, 12 October 2006. https://www.oasis-open.org.

[2] The Open Group, SOA Reference Architecture, document number C119, November 2011. http://www.opengroup.org.

[3] The Open Group, Service-Oriented Architecture Ontology, Version 2.0, document number C144, April 2014. http://www.opengroup.org.

[4] Object Management Group, Service oriented architecture Modeling Language (SoaML) Specification, Version 1.0.1, May 2012. http:// http://www.omg.org/spec/SoaML/1.0.1/.

[5] Navigating the SOA Open Standards Landscape Around Architecture, Joint White Paper from OASIS, OMG, and The Open Group, July 2009. https://www2.opengroup.org/ogsys/catalog/w096.

[6] ITIL Glossary: http://www.itil-officialsite.com, ITIL_2011_English_glossary_v1.0.pdf, ITIL glossary and abbreviations, AXELOS Limited 2011.

[7] Jack Probst: "Anatomy of a service – A Practical Guide To Defining IT Services", Pink Elephant, 2009.

[8] ISO/IEC 20000: http://www.iso.org, ISO/IEC 20000-1:2011.
[9] Peter Mell, Timothy Grance, "The NIST Definition of Cloud Computing", National Institute of Science and Technology, U.S. Department of Commerce, Special Publication 800-145.
[10] http://en.wikipedia.org/wiki/Cloud_computing.
[11] Michael Oberndorfer, Jan van Geest, "Modelling & Simulation Events Enabled by the Distributed Networked Battle Labs Framework", RTO-MP-MSG-087: Enhance or Replace: Finding the Right Live vs Synthetic Balance. Paper 6. October 2011.
[12] Michael Oberndorfner, "The Distributed Networked Battle Labs Framework (DNBL) as the Operating and Business Model for Experimentation, Test and Evaluation", STO-MP-MSG-094: Transforming Defence Through Modelling and Simulation – Opportunities and Challenges. Paper 16. October 2012.
[13] NATO Allied Command Transformation (ACT) C4ISR Technology & Human Factors (THF) Branch: "C3 Classification Taxonomy", Baseline 1.0, 15 June 2012.
[14] NATO: NATO Modelling and Simulation Master Plan, Version 2.0, 14 September 2012, Document AC/323/NMSG(2012)-015.
[15] Oliver Thomas. Understanding the Term Reference Model in Information Systems Research: History, Literature Analysis and Explanation. In Christoph Bussler and Armin Haller, editors, Business Process Management Workshops, volume 3812 of Lecture Notes in Computer Science, pages 484–496, Berlin, Heidelberg, 2006. Springer-Verlag.
[16] NATO Consultation, Command and Control Board (NC3B): NATO Architecture Framework. Version 3, AC/322-D(2007)0048-AS1. 2007.
[17] IEEE Standard for Modeling and Simulation (M&S), High Level Architecture, Framework and Rules, IEEE Standard 1516, 2010.
[18] NATO STO: Final Report of NATO MSG-086 "Simulation Interoperability". STO Technical Report STO-TR-MSG-086-Part-I.
[19] NATO STO: Final Report of NATO MSG-131 "Modelling and Simulation as a Service: New concepts and Service Oriented Architectures". STO Technical Report STO-TR-MSG-131. To be published! (May be requested through your national representative in NMSG).

8 Author biographies

ROBERT SIEGFRIED is a Senior Consultant for IT/M&S Projects and Managing Director of aditerna GmbH, a company providing specialized services and consulting in this area. Prior to this, he was research associate at the University of the Federal Armed Forces in Munich, Germany (Universität der Bundeswehr München). His primary research areas are agent-based modeling and simulation, and parallel and distributed simulation. Within several projects from the German Federal Office of Defense Technology and Procurement, he has worked on topics like documentation guidelines, model management, distributed simulation test beds and process models.

TOM VAN DEN BERG is a scientist in the Modeling, Simulation and Gaming department at TNO Defence, Security and Safety, The Netherlands. He holds an M.Sc. degree in Mathematics and Computing Science from Delft Technical University. His research area includes simulation systems engineering, distributed simulation architectures and concept development & experimentation.

ANTHONY CRAMP is a Defence Science and Technology Organisation (DSTO, Australia) International Fellow working within the Modeling, Simulation and Gaming department of TNO Defence, Security and Safety, The Netherlands until February 2015 on topics including M&S as a Service and HLA performance. His research interests include distributed systems and simulations, software architectures, and programming languages. From March 2015 he can be contacted via his DSTO email address: anthony.cramp@dsto.defence.gov.au.

WIM HUISKAMP is Chief Scientist Modelling, Simulation and Gaming in the M&S department at TNO Defence, Security and Safety in the Netherlands. Wim leads TNO's research program on Simulation, which is carried out on behalf of the Dutch MOD. Wim is a member of the NATO Modelling and Simulation Group (NMSG) and currently acts as its Chairman. He has also chaired several NMSG Technical Working groups, including the NMSG M&S Standards Subgroup (MS3) and he is the liaison of the NMSG to the Simulation Interoperability Standards Organization (SISO).