# M&S as a Service: Paradigm for Future Simulation Environments

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**This paper presents work originally done by the many members of NATO MSG-131 and MSG-136. The authors act on behalf of MSG-136 as editors of this paper.**

## ABSTRACT

This paper presents results of NATO activities in the area of "M&S as a Service" (MSaaS). It illustrates potential benefits with regards to quality, efficiency, and interoperability that may be achieved by MSaaS and provides an insight how some of the existing challenges are currently being addressed.

As M&S products are highly valuable to NATO and military organizations it is essential that M&S products, data and processes are conveniently accessible to a large number of users as often as possible. This requires a new "M&S ecosystem" that 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. Due to many factors, service-based approaches are considered to be very promising for realizing future simulation environments. This idea is known as "Modeling & Simulation as a Service" (MSaaS).

NATO Modeling and Simulation Group 131 ("Modelling and Simulation as a Service: New concepts and Service Oriented Architectures") has investigated the idea of "M&S as a Service" as a 1-year Specialist Team. MSG-131 defined a consistent MSaaS terminology and placed MSaaS into the wider context of the NATO C3 Classification Taxonomy. Second, an exhaustive overview about service-based approaches used in the M&S domain in NATO and Partner Nations was produced. Third, a comprehensive overview of existing service-oriented (reference) architectures in the M&S domain was produced.

A more detailed investigation of MSaaS and first steps towards an incremental implementation of a "Federated M&S Eco-System" are objectives of MSG-136 ("Modelling and Simulation as a Service - Rapid deployment of interoperable and credible simulation environments") which started its 3-year term in November 2014. This paper presents results of MSG-131 and current work done by MSG-136.

## ABOUT THE AUTHORS

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## INTRODUCTION

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).

### Current Efforts

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.

### NATO Activities

This paper presents results of several NATO activities and German research studies. In 2014, 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 results of MSG-131 were used as input to a "NATO M&S as a Service Concept" that is currently being developed by NATOs Allied Command Transformation (ACT).

A more detailed investigation of MSaaS is carried out by a follow-on research task group MSG-136 ("Modelling and Simulation (M&S) as a Service (MSaaS) – Rapid deployment of interoperable and credible simulation environments") that started its 3-year term in November 2014. In addition to results generated by MSG-131 and MSG-136 this paper is based on experiences from several research studies of the German Armed Forces from 2008-2015 that evaluated service-based simulation environments and developed prototype implementations.

In a nutshell, MSG-131 evaluated and documented the current situation whereas MSG-136 addresses several of the identified gaps and aims to provide the technical and organizational foundations for a future permanent service-based M&S Ecosystem within NATO and partner nations.

### Outline

The paper is divided in two major parts: First, the status quo regarding M&S as a Service is described, e.g. definitions, categorization, existing implementations (case studies) and reference architectures. Second, the vision of future service-based is outlined "M&S eco-system" where M&S products can be accessed simultaneously and spontaneously by a large number of users for their individual purposes. Finally, we show which challenges are currently being addressed by NATO activities and which challenges and gaps still need to be solved to achieve the envisioned M&S eco-system.

## STATUS QUO OF M&S AS A SERVICE

### Definition

In literature several authoritative definitions for "Service" can be found that are applicable to the concept of "M&S as a Service", see e.g. (Oasis, 2006), (The Open Group, 2014), (Object Management Group, 2012). More definitions may be found in literature. As shown in (Siegfried and van den Berg, 2014) all definitions are quite similar and share the same thought.

With regards to Modelling and Simulation (M&S), MSG-131 and MSG-136 base their definition for M&S as a Service on the existing definitions for services and define M&S as a Service as follows:

> "M&S as a Service (MSaaS) is a means of delivering modelling and simulation (M&S) applications, capabilities and associated data on demand by providers to consumers."

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 technically integrated in 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.

### Perspectives On MSaaS

The above definition of MSaaS provides a high-level view of the concept. There are different perspectives arising from this general definition of MSaaS. MSG-131 identified 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.

Perspectives 1, 2 and 3 are illustrated in Figure 1.

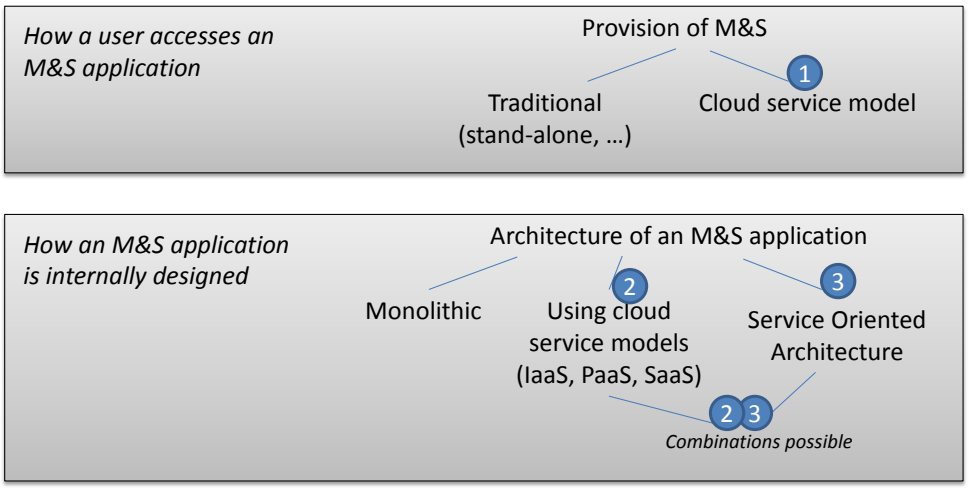


**Figure 1: MSaaS Perspectives.**

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. More details on the four perspectives are available in (Siegfried and van den Berg, 2014).

**Alignment Of MSaaS With The NATO C3 Classification Taxonomy**

A 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 in (NATO ACT, 2012).

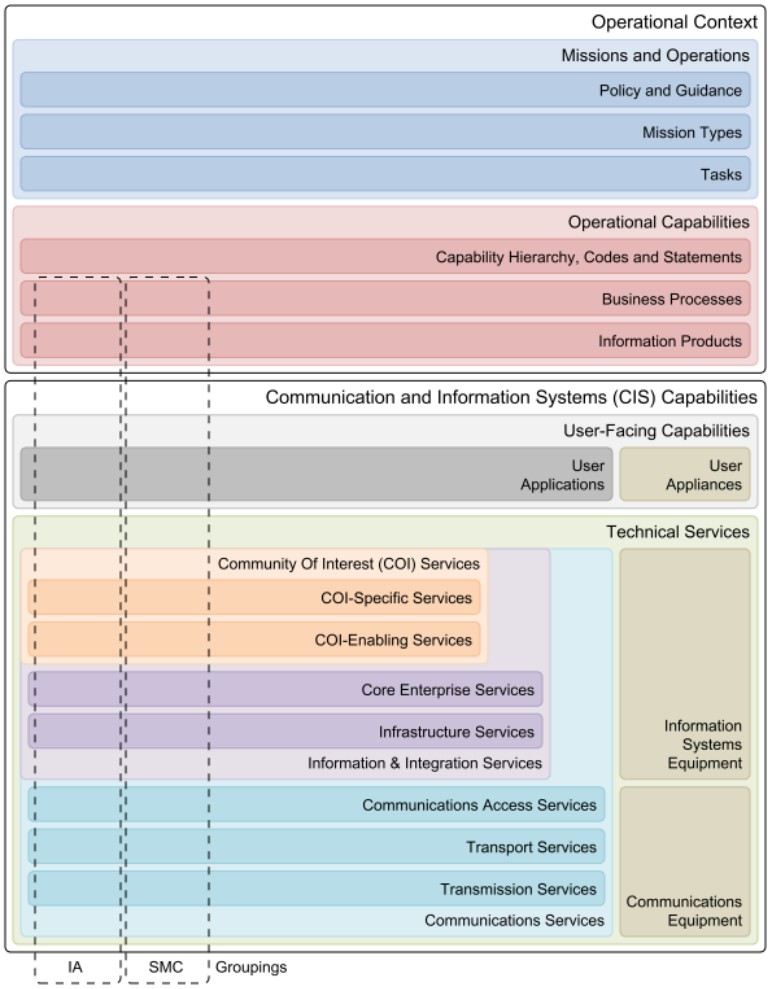


**Figure 2: Top-level View of NATO C3 Classification Taxonomy.**

The top-level view of the NATO C3 Classification Taxonomy is shown in Figure 2. 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 2: 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.

**National 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 (NATO STO, 2015). 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 key finding of MSG-131 is that although being a seemingly new approach, M&S as a Service (MSaaS) is already widely utilized by NATO and the Nations. However, the survey of national case studies also revealed a large diversity with regards to MSaaS in NATO and the Nations.

**Existing 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.

According to the NATO Architecture Framework (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)." (NC3B, 2007)

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. As already identified by MSG-086, comprehensive reference architectures for simulation environments are currently missing (NATO STO MSG-086, 2015). However, reference architectures for specific applications domains are existing, respectively are currently being developed.

Figure 3 gives an overview of existing reference architectures within the M&S domain as identified by MSG-131.


**Figure 3: Overview of existing Reference Architectures and Their Scope (NATO STO MSG-131, 2015).**

Figure 3 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 3, MSG-131 points out the urgent need to integrate M&S reference architectures with C2 reference architectures.

## ENVISIONED FUTURE M&S ECO-SYSTEM

### Motivation

To a great extent, future military training capabilities will be provided by simulation systems (either stand-alone or via distributed simulation environments). This is a consequence of limited or decreasing budgets, restrictions due to security and safety regulations, and shorter response times as well as increasingly faster changing mission profiles and operational needs.

### Vision

One of the main challenges of Nations, Organizations and Enterprises short- to mid-term is to provide M&S to a large user community in a flexible way. A detailed definition of high-level requirements (functional and non-functional) for next generation simulation environments is given by (Siegfried and Bertschik et al, 2013). This led MSG-136 to develop the following mission statement for their work:

> "To ensure that M&S products, data and processes are conveniently, simultaneously and spontaneously accessible to a large number of users for their individual purposes as often as possible."

Figure 4 illustrates the envisioned future Federated M&S Ecosystem. Key characteristics are:

- From a user's point of view there is exactly one single M&S Ecosystem that may be accessed through a user interface. The user interface may be integrated into a simulator (e.g., a flight simulator consuming a weapon effects service), into a C2 system (e.g., embedded route planning functionality that utilizes a route planning service) or may be provided by a thin client or dedicated application (e.g., a decision support system utilizing various services like terrain data service, intelligence information service etc.). The crucial aspect is that the user is not interacting directly with the (technical) M&S services, but through his usual tools (instruments in a simulator, C2 system) or specific applications (like the above mentioned decision support system) that orchestrate and integrate the available services.
- From a provider's point of view, it is important to understand that M&S services will be provided by different stakeholders (e.g., national clouds provided by MoD's, organizational clouds (e.g., by NATO), commercial cloud providers, etc.). The necessity to interconnect M&S services from different clouds led to the term Federated M&S Ecosystem. Standardizing service interface and service agreements will be the key to ensuring that different service implementations may be flexibly utilized (e.g., national weapon effects service in national exercises and NATO weapon effects service in multi-national settings).

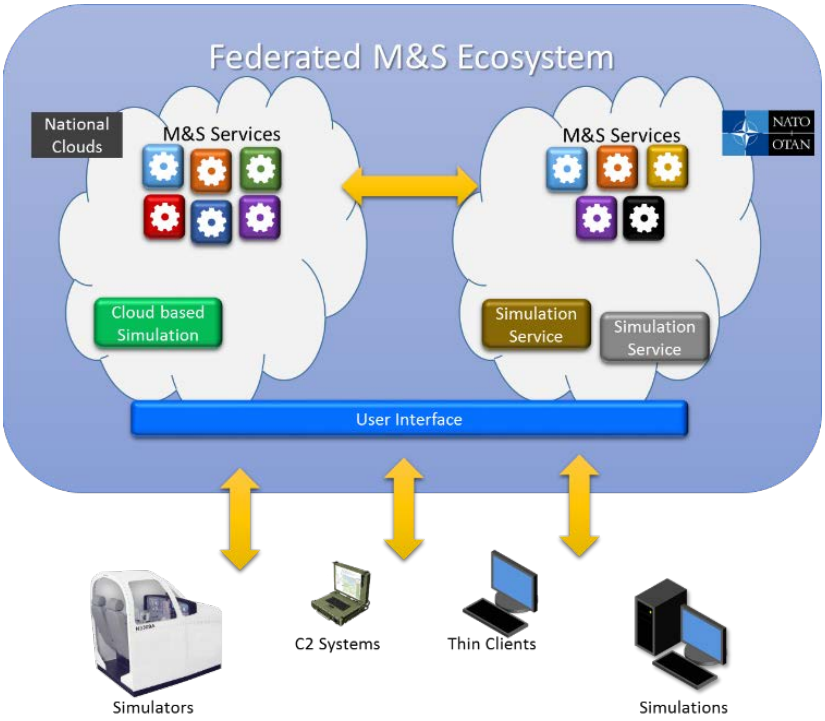


**Figure 4: Illustration of a Future Federated M&S Ecosystem (NATO STO MSG-136, 2015).**

**Concept Of Operations**

As a first step towards operationalizing the envisioned future M&S Ecosystem MSG-136 is currently developing a Concept of Operations. The main part of the Concept of Operations is a description of how this envisioned system will be used. It is important to have in mind that a Concept of Operations is a non-technical document that is written from a user's point of view. Thus, MSG-136 formed a sub-group that reflects the user community (i.e., no technicians but operational personnel).

The Concept of Operations is currently under development and will be presented once it is mature enough. To guide the development, five operational scenarios have been selected and are worked out in detail:

- Scenario 1: Training and Education

- Scenario 2: Support to Operations Planning
- Scenario 3: Capability Development
- Scenario 4: Mission Rehearsal
- Scenario 5: Procurement/Acquisition

These operational scenarios reflect the M&S application areas as defined by the NATO M&S Master Plan (NATO STO, 2012). Each operational scenario will be documented according to the following template:

- Name/Title
- Overview Diagram/Illustration
- Description (from NATO M&S Master Plan plus additional information plus references to NATO and national reference documents)
- Involved users and their roles and their interactions with the system
- Further stakeholders
- Workflows
- Example(s) (e.g., story board, reference to paper/presentation, …)
- Identification of existing systems/services/projects/… that are used within this scenario
- Identification of gaps in existing systems

**Identified Gaps/Shortfalls And Current Activities**

The establishment of a future service-based M&S Ecosystem requires overcoming organizational as well technical shortfalls. Organizational challenges include topics like service governance, security (both, IT security and military security/classification), IPR/export regulations and a business model (i.e., how to charge for services).

Already identified technical shortfalls include missing standards along the whole lifecycle. The critical observation is that realizing the full potential of cloud-based M&S requires automation of almost everything. Automation is a pre-requisite to achieve economies of scale and to achieve the flexibility and agility expected from service-based architectures. It is important to understand that automation is not restricted to simulation execution only, but that it is a cross-cutting requirement along the whole simulation lifecycle (i.e., deployment, initialization, execution, analysis).

Both areas, organizational and technical challenges, are currently being addressed by the 65+ members of MSG-136. Key deliverables of MSG-136 will be an official NATO guidance document covering the governance topics, a detailed Concept of Operations covering the operational aspects and multiple technical documents (including an MSaaS Reference Architecture, draft service interface specifications etc.) covering some of the identified technical challenges.

## CONCLUSIONS AND RECOMMENDATIONS

This paper presents the most recent results of NATO MSG-131 and MSG-136 in the area of MSaaS and related national results from research and development activities.

The first part of the paper presents the Status Quo with regards to M&S as a Service. For the first time, MSG-131 produced an exhaustive overview about service-based approaches used in the M&S domain in NATO and Partner Nations. For its outstanding and very original contribution to Defence Science and Technology for the benefit of the NATO technical community and the military community MSG-131 is awarded the 2015 NATO Science and Technology Organization Scientific Achievement Award. Based on the work done by MSG-131, the first part of the paper provides a definition of M&S as a Service (MSaaS) and puts MSaaS in context of the NATO C3 Classification Taxonomy. Four perspectives on MSaaS that were identified by MSG-131 and found most relevant are outlined. Finally, the first part gives a brief overview of case studies for MSaaS and existing reference architectures within this domain.

The second part of the paper defines the vision of a future service-based "Federated M&S eco-system" where M&S products can be accessed simultaneously and spontaneously by a large number of users for their individual purposes. After introducing the envisioned end state the second part gives an overview of current gaps and shortfalls. It is presented which challenges are currently being addressed by NATO activities and which challenges and gaps still need to be solved to achieve the envisioned M&S eco-system. MSG-136 addresses both technological as well as organizational gaps and challenges that need to be solved to establish a permanent service-based simulation environment. In its unique role MSG-136 acts as harmonizing body of national developments and at the same time as incubator for development of new standards and procedures (both organizational and technical).

A main conclusion is that M&S is a critical technology for NATO, the Nations, and Enterprises, independent whether it is provided "as a service" or not. However, service-based approaches to M&S offer many potential benefits.

## ACKNOWLEDGEMENTS

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