M&S as a Service Composability Lessons from NATO

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ABSTRACT

Over the last decade, the North Atlantic Treaty Organization (NATO) Science and Technology Organization (STO) has conducted a series of Research Task Group (RTG) activities focused on realizing the concept of "Modelling and Simulation (M&S) as a Service (MSaaS)." Of the many Science & Technology (S&T) topics investigated to enhance MSaaS benefits, simulation services composition has emerged as especially critical. Composition in a MSaaS context concerns determining the simulation services to deploy and execute in order to fulfill the simulation requirements for a particular use case. Moving towards a service-oriented, cloud-enabled M&S architecture necessitates simulation engineers to have a different perspective than in traditional simulation environments. Based on the national inputs from MSaaS RTG participants, as well as results from related S&T efforts, a reference information model has been developed for composition that accounts for the important considerations, topics, properties, and data elements that a "MSaaS project" should have in an implementation.

This paper will describe the work related to composition in the NATO MSaaS context. It will describe why composition in a MSaaS context is different from the traditional simulation composition, present the reference information model, and explain which elements of the information model are reusable across "MSaaS environments," and which are specific to each implementation. This paper will also discuss how conceptual information from the domain of interest may be leveraged in the "MSaaS Simulation Engineering Process" to ensure the resulting service composition is meaningful and valid. Finally, we will substantiate why composition is one of the major capabilities for organizations to address when moving towards a MSaaS paradigm.

ABOUT THE AUTHORS

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INTRODUCTION

North Atlantic Treaty Organization (NATO) Modeling and Simulation Group (MSG) – 195, Modeling and Simulation as a Service (MSaaS) Phase 3, is the third of three working groups chartered by the NATO Science and Technology Organization to fully investigate the potential applicability of the MSaaS concept with NATO modeling and simulation. The group's focus has been to mature the MSaaS concept and related standards, mature enabling Science and Technology (S&T) concepts, build an initial MSaaS framework, and educate stakeholders.

MSaaS is a new concept of providing and consuming M&S Services. The concept includes service orientation and the provision of M&S applications via the as-a-service model of cloud computing. It has both an organizational dimension as well as a technical dimension. The concept has the potential to greatly reduce the barriers of cost and accessibility, and to result in greater utility of M&S throughout NATO and the nations.

The concept is described in four documents, together called the Allied Framework for MSaaS: MSaaS Operational Concept Description, MSaaS Concept of Employment, MSaaS Business Model, and MSaaS Technical Reference Architecture. The latest publically available framework documents are from the preceding Research Task Group MSG-164:

- Final Report (Modeling and Simulation as a Service (STO-TR-MSG-164-VOL-I), 2024);
- MSaaS Technical Reference Architecture (Modelling and Simulation as a Service (MSaaS), Technical Reference Architecture (STO-TR-MSG-164-VOL-II), 2024);
- MSaaS Business Model (Business Model for the Allied Framework for M&S as a Service (STO-TR-MSG-164-VOL-III), 2024).

The key capabilities supported by the Allied Framework for MSaaS are described in the MSaaS Operational Concept Description. These are:

- Discover Services: A mechanism for users to search and discover M&S services and assets (e.g., Data, Services, Models, Federations, and Scenarios).
- Compose Services: The ability to compose discovered services to perform a given simulation use case.
- Execute Services: The ability to deploy the composed services automatically on a cloud-based, local computing, or hybrid infrastructure.

NATO MSG-195 conducted a series of MSaaS tests at the NATO Coalition Warrior Interoperability Exercise (CWIX) 2024 to illustrate the concept of MSaaS Composability. Consider a notional NATO training exercise in which the NATO Response Force is training leaders to coordinate tactical actions with NATO partners in a large-scale combat operation. The NATO Allied Command Transformation is the customer who has resourced the provider, The NATO Joint Forces Training Center (JFTC), to offer simulation services to these users. To support the JFTC, The Netherlands built a MSaaS portal in which multiple nations supplied capabilities that could be offered to users as-a-service.

MSG-195's Composability Tiger Team's emphasis is bringing the latest advances in M&S composability into the MSaaS framework. MSaaS Composability offers the opportunity to compose existing simulation services into a larger composition to meet customer needs that cannot otherwise be met by the existing individual services. The collective training test thread in our CWIX experimentation called for a control cell, staffed by simulation operators, to control simulated units that are not part of the training audience. Two Constructive simulations, one for high-resolution entities and another for low-resolution entities, execute the simulated operation. The MSaaS portal offers each of these simulations as different Joint Domain Simulation Services. These services are compliant with Allied Modelling and Simulation Publication (AMSP)-04 NATO Education and Training Network (NETN) (NATO MSCO, 2021) and are integrated via the High-Level Architecture (HLA) Run-Time Infrastructure (RTI) (IEEE, 2010). The exercise director only has one simulation operator to operate this entire system. To support this scenario, an integrator working for the MSaaS provider composes the two simulators, an HLA RTI, an order of battle service, and a web-based entity tasking service into a single composition that executes as the Unit Control Service, providing the capability to control the entire simulation from one operator station (see Figure 1). This is a composition that provides an integrated capability by composing existing services.

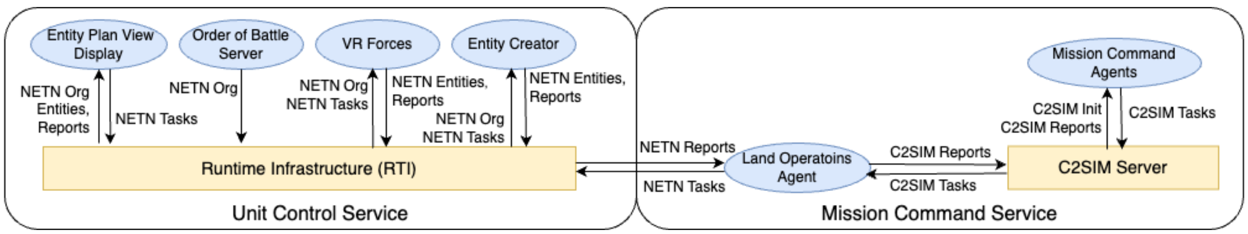

Figure 1: Unit Control Service and AI Unit Control Service composed of MSaaS building blocks.

Consider the following example of how these services could work together as a whole. A NATO Response Force user would like to add an additional threat unit to the battlefield, but the exercise director does not have another simulation operator to control these forces. Instead, the USA supplies the Mission Command Service as another composition to the JFTC, which is also offered via the Netherlands MSaaS portal. This service uses Artificial Intelligence (AI) instead of a human operator to control simulated forces. The composition consists of Mission Command Agents, a Command and Control – Simulation Interoperation (C2SIM) server for the exchange of scenario initialization data, orders, and reports in accordance with the NATO C2SIM standard (SISO, 2020), and a Land Operations Extension (LOX) (SISO, 2020) Agent for the mediation of data between the Unit Control Service and the C2SIM Server.

The Composability Tiger Team investigated methods and tools to more broadly enable creation of valid and useful services, such as those in Figure 1. This paper will step through the MSaaS Engineering Process used to build these services, referencing how the building blocks and information model of the MSaaS Technical Reference Architecture support composability.

MSAAS COMPOSABILITY LEXICON

The following definitions of composability are commonly referenced in simulation literature (Petty and Weisel, 2003):

Composability is the capability to select and assemble simulation components in various combinations into valid simulation systems to satisfy specific user requirements. They distinguish composability from *interoperability* by noting that composability takes place prior to runtime, and interoperability takes place at runtime. Interoperability is a necessary, but insufficient condition for composability. This is because the interoperability connection must also be semantically valid. They further define two types of composability.

Engineering composability requires that the composable components be constructed so that their implementation details, such as parameter passing mechanisms, external data accesses, and timing assumptions are compatible for all of the different configurations that might be composed. This is also called *syntactic composability.*

Modeling composability is a question of whether the models that make up the composed simulation system can be meaningfully composed, i.e., if their combined computation is semantically valid. This is also called semantic composability. Follow-on research has further defined *static semantic composability* and *dynamic semantic composability* that arise from their static composition of entities or the behaviors arising from their dynamic interplay respectively (Mahmood, 2013).

The composition of MSaaS services requires an as-a-service perspective to composition, so it is more than just composing models. To support this view, MGS-195 uses the following two types of composability:

MSaaS Composability is the capability to select and assemble Simulation Services in various combinations into a valid Composed Simulation Service.

M*SaaS Conceptual Composability* is the ability to meaningfully compose Simulation Services into a valid Composed Simulation Service. It is analogous to semantic composability. MSG-195 takes the view that MSaaS Conceptual Composability is a human process. However, the information model, as presented by the MSaaS portal, can provide significant aid to the human decision maker.

MSaaS Engineering Composability is the ability to select and configure the services of a Composed Simulation Service so that it may be automatically deployed and executed in the MSaaS implementation. It is analogous to syntactic composability. Implementation of the MSaaS Information Model via the MSaaS portal allows for automated support for MSaaS Engineering Composability.

MSAAS BUILDING BLOCKS OVERVIEW

The MSaaS Technical Reference Architecture uses the notion "Architecture Build Block" (ABB) to describe the key MSaaS capabilities in terms of building blocks. A building block provides requirements and standards but does not prescribe how the building block should be realized and what technology should be used. This is up to the Solution Building Block (SBB).

The MSaaS Technical Reference Architecture defines, amongst others, the following building blocks:

- M&S Portal Applications: building blocks that users interact with, hence known as "User-Facing." M&S Portal Applications provide functionality to support the key MSaaS capabilities, such as the ability to browse, compose, and deploy M&S User Applications and Simulation Services, and the ability to supply M&S Resources and the associated M&S Resource Metadata. Types of M&S Portal Applications are:
    - Integration Portal Application: enables the user to create a composition of M&S User Applications and Simulation Services, together with information on how such a composition may be deployed. To determine the candidate M&S User Applications and Simulation Services to be integrated in a composition, the Integration Portal Application provides access to M&S Registry Services and M&S Repository Services to search and identify candidates, and to retrieve the associated metadata of these candidates.
    - Simulation Execution Portal Application: enables the user to browse, select, configure, start, monitor, and terminate previously prepared compositions of simulation applications and services. The Simulation Execution Portal Application is the front-end to several back-end M&S Enabling Services that provide the necessary supporting capabilities, such as Repository Services and Composition Services.
    - The Supplier Portal Application: enables the supplier to provide new, or update existing, M&S User Applications and Simulation Services as M&S Resources and M&S Resource Metadata associated with the M&S Resources. The Supplier Portal Application is supported by various back-end capabilities, such as M&S Repository Services, to manage M&S Resources, and M&S Registry Services to manage M&S Resource Metadata.
- M&S Enabling Services: these building blocks are the back-end enablers for M&S Portal Applications. These include:
    - M&S Repository Services: provide the ability to store, retrieve, and manage M&S Resources and associations with, as well as references to, M&S Resource Metadata managed by M&S Registry Services. The M&S Repository Services support any simulation resource that may be required for a simulation execution, independent of type and purpose (i.e. service implementations, applications, data files).

  - M&S Registry Services: provide the ability to store, manage, search, and retrieve data about (i.e., metadata) M&S Resources stored by the M&S Repository Services, such as description of services interface and contract, information about Quality of Service (QoS) policies, and security and versioning information. Different types of M&S Registry Services may be distinguished, depending on the kind of M&S Resource Metadata.
  - M&S Composition Services: provide the ability to create and verify a composition of M&S User Applications and Simulation Services. The M&S Composition Services make use of M&S Resource Metadata provided by M&S Registry Services and the M&S Composition Services interact with the M&S Information Model Services to determine appropriate simulation compositions.
  - M&S Schema Repository Services: provide the ability to store, query, and retrieve authoritative M&S metadata that can be referenced by other services. For instance, Standard Entity Type definitions and HLA reference Federation Object Models.
  - The M&S Information Model Repository Services: provide the ability to store, retrieve, and manage the information that is brought together for a composition of applications and services in accordance with an information model.
- M&S User Applications and Simulation Services: instances of these building blocks are stored, managed, and provided as M&S Resources by the M&S Repository Services, and are integrated into verified compositions by the M&S Composition Services. These building blocks provide the means for the synthetic representation of simulated objects and events in the simulation environment. M&S User Applications and Simulation Services can be divided in many sub-types of building blocks, depending on the domain of interest, as shown in Figure 2, such as Air Domain Simulation Services and Land Domain Simulation Services. The requirements and standards associated with these building blocks provide direction for creating an instance (a solution) of such ABB, and for creating an integration between instances of such ABBs, i.e., a composition.

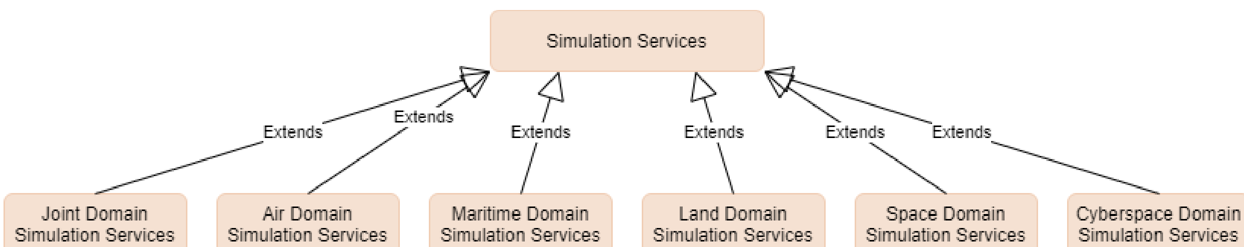

Figure 2. Architectural building blocks for simulation services across the warfighting domains.

COMPOSABILITY INFORMATION MODEL OVERVIEW

The NATO MSaaS group has worked many years across several versions of the group researching, describing the best of the breed, and trying to find opportunities for standardization within the composability domain. The complexity of composability has been documented in many published artifacts and standards, so the NATO group is focused on those elements of composability that are specific to MSaaS, but in order to be complete, we still want to include and account for the elements of composability that are required, but not very specific to MSaaS.

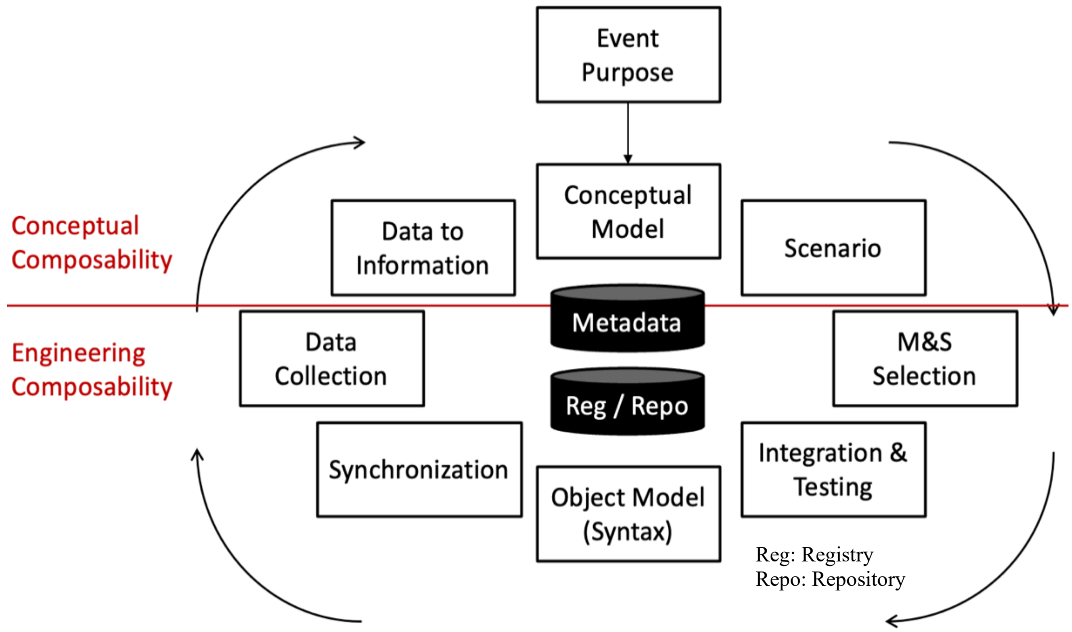

Figure 3. Overview of the MSaaS Composability Information model divided across conceptual composability and engineering composability information elements.

The NATO MSaaS group divided the Composability concept into two areas, Conceptual Composability and Engineering Composability, as shown in Figure 3. Conceptual Composability is supported by information elements to link a simulation event with the simulated system's conceptual model within the simulation scenario. It allows translation of the data produced by the simulation event into the relevant information for the simulation user. Engineering Composability refers to the information required to implement the simulated systems in the scenario and the technical data required to implement the MSaaS environment. This information includes the technical agreements/ runtime interoperability agreements, such as time management, update rates, and dead reckoning.

Conceptual composability can be further refined in several levels (Moradi, F., 2008), (Moradi et. al., 2009), (Mahmood et. al., 2009), (Mahmood, I., 2013) with increasing complexity in verification:

- Syntactic level: concerned with the structure of the simulation services, i.e., can the output of the producing simulation service be read as the input of the consuming simulation service, and do message names, modes of action, and number of message parameters match between simulation services. This level of composability is supported by engineering composability information, such as the object model or data collection specifications.
- Static-Semantic level: concerned with the meaningful interaction of the composed simulation services, i.e., do the concepts, the type of information, and their properties match between services. This level may use domain concepts from the conceptual information model to determine if concepts are the same.
- Dynamic-semantic level: concerned with the dynamic consistency of the composed simulation service, i.e., does the behavior of composed simulation services match over time. This level may use state-machines, Unified Modeling Language (UML) models, and other languages to describe the dynamics of the simulation services over time. For example, the conceptual composability information model could contain Systems Modeling Language (SysML) representations of service interplay in activity diagrams, sequence diagrams, or state diagrams.

Structure Description

The information model is divided into seven categories of fields: Core, Syntactic, Semantic, Synchronization, Scenario / Functional, Deployment, and Business. Each of these groups has data elements about the service that will be important for composing a simulation environment based on the event's purpose, functional capabilities (modeling, semantics, and synchronization of representations), technical capabilities (syntax and deployment details), and business considerations (licensing, pricing, etc.).

Within each section, it is expected that each MSaaS environment will include a slightly different list of fields depending on their domain, use case, security environment, and integration with other MSaaS environments. This information model includes a list of possible additional fields in each section to be used as inspiration or ideas for the MSaaS implementor. The data storage mechanism (e.g. object database, relational database, etc.) is left to the MSaaS engineers to determine when developing the MSaaS environment and related toolsets.

Data Types

The data type used for each of the fields within the information model are implementation specific. Although we initially attempted to assign data types to each of the fields, we realized that the types could be different across MSaaS environments depending on how the field is used, and whether the fields will be used by a human simulation integrator or used by one or more software programs that assists in the composition, deployment, configuration, execution, and monitoring of the MSaaS environment.

Information Model

The information model description herein includes the fields that should be considered when implementing an MSaaS environment but is not meant to be a database design. These categories and fields are an example of the type of fields that should be considered for MSaaS environments.

Category	**Field Examples**	**Description**
Core	Unique Identifier (ID), Name, Description, Owner, Point of Contact (POC), Version, M&S Resource Type, Uniform Resource Locator (URL), National Affiliation, Origination Date, Last Updated Date, etc.	The Core fields are those that refer to the M&S resource at the foundational level including the unique identifier, name, description, POC, etc. that provide a high-level glimpse of what the M&S resource is, what it does, and where to access the resource.
Syntactic	Middleware Protocol, Object Model, Publish/Subscribe, Other Communications, Encoding, Custom Structures, Application Programming Interface (API), etc.	Syntactic fields describe the syntax of the M&S resource, including protocol(s) and structure(s), what the resource publishes and subscribes to, and any other details required to understand the data that the M&S resource uses.
Semantic	Fidelity, Resolution, Location Representation, Environment Representation, Aggregation, Navigation, Sensing, Dynamics over time, etc.	Semantic fields describe the meaning, and the dynamics of the data used by the M&S resource including the fidelity (accuracy), resolution (level of detail), and information about how the M&S resource represents important simulation subjects, such as environment, location, etc.
Synchronization	Time Management, Dead Reckoning, Update Rates, Data Distribution Management, Interest Management, Start, Pause, Stop, Save, Restore, Entity/Unit Control Transfers, Performance Thresholds, etc.	Synchronization fields describe the methods for M&S resources to communicate within simulation environments to operate smoothly with other services, including middleware specific elements, such as time management, as well as data specific elements, such as dead reckoning.

Functional / Scenario	Functional Configuration, Engineering Configuration, Scenario Configuration, Deployment Configuration, Terrain, Pedigree, etc.	Many large simulation services can be configured in many different ways depending on the use case and scenario. Functional and Scenario elements describe how to configure simulation resources based on the functions required, scenario used, deployment chosen, etc.
Deployment	Information Security, Data Collection, Network Configuration, Hardware Allocation, Releasability, Security Classification, etc.	Deployment elements are those fields that describe deployment details for M&S resources, including networking, security, and hardware details.
Business	Usage Terms, License Management, Costs, Contact Information, etc.	The Business fields describe the financial and usage terms associated with the M&S resource and will be specific to the M&S resource licensing agreements within the MSaaS environment.

Table 1. Elements of the MSaaS Information Model.

The categories and fields in the table above provide a high-level structure and information decomposition for MSaaS environments to use depending on their respective situations. Architectural decisions within the MSaaS environment can dictate which information model elements are important. If the MSaaS environment is strict on its design criteria, then the information model can be simpler vice if the MSaaS environment is flexible in the technical options, then more attributes must be captured and used to determine interoperability between the M&S resources for any given instance / deployment of the MSaaS.

COMPOSABILITY VIA THE MSAAS ENGINEERING PROCESS

The MSaaS Provider manages service composability primarily through the role "Integrator," who manages compositions of multiple Simulation Services for the execution of scenarios. The MSaaS Engineering Process covers the engineering necessary for the Integrator to compose Simulation Services within the provider's Integration Portal Application. The MSaaS Engineering Process mirrors the Distributed Simulation Engineering and Execution Process (DSEEP) (IEEE, 2011). Considering the Simulation Services developed for CWIX 2024, we will illustrate how the Integrator uses the MSaaS Building Blocks and Information Model through the steps of the engineering process.

Step 1: Define Simulation Service Objectives

This step of the engineering process populates the Event Purpose element of the conceptual information model. The Integrator relies on the NATO Allied Command Transformation (ACT) Tidepedia Wiki. It is an implementation of an Information Model Repository Service. This service is part of the "Think-Tank for Information Decision and Execution Superiority" (TIDE) initiative, which builds on Technologies for Information, Decision, and Execution superiority. It allowed collaboration across the CWIX M&S Focus Area to build objectives and interoperability test cases related to the simulation, command and control, and MSaaS requirements for supporting mission rehearsal and collective training. These objectives drove the integrated development of services within the M&S Focus Area. In particular, the Netherlands Unit Control Service and USA Mission Command Service needed to enhance interoperability for NATO mission rehearsal and collective training.

Step 2: Develop Conceptual Model

This step of the engineering process populates the conceptual model and scenario elements of the conceptual information model. Operational experts within the M&S Focus Area developed an operational scenario complete with NATO and opposing force units, operational missions, and timings on a geo-specific terrain area. Various simulation services helped in the development of this scenario. In particular, Hyssos Tech, a US-based M&S service provider, provided the Sketch-Thru-Plan family of products (Hyssos Tech, 2018) to transform the conceptual scenario specification into an engineering level specification that could be used for development. The semantic elements of this information are described via the C2SIM standard (SISO, 2020) and its land operation ontology. The syntactic elements of the scenario were described in a series of Extensible Markup Language (XML) files for initialization of the scenario and for orders generated during execution of the training event. The Netherlands Order of Battle Service hosted this initialization file for all participants and provided a translation to the Military Scenario Definition Language (MSDL) (SISO, 2015) so that federates that had not implemented the C2SIM standard could still participate.

This engineering information plus synchronization information provided in federation agreements, combined with the deployment information elements provided by JFTC for the exercise, drove the full set of requirements for the participating simulation services. The interoperability requirements were further specified as CWIX test cases in the Tidepedia Wiki for the exercise. This wiki service gave each simulation service developer one-stop access to the complete CWIX engineering information model that allowed for more complete understanding of each service's role in the exercise and provided detailed engineering requirements. An example of a conceptual model supporting the Mission Command Service is shown in Figure 4 and Table 2.

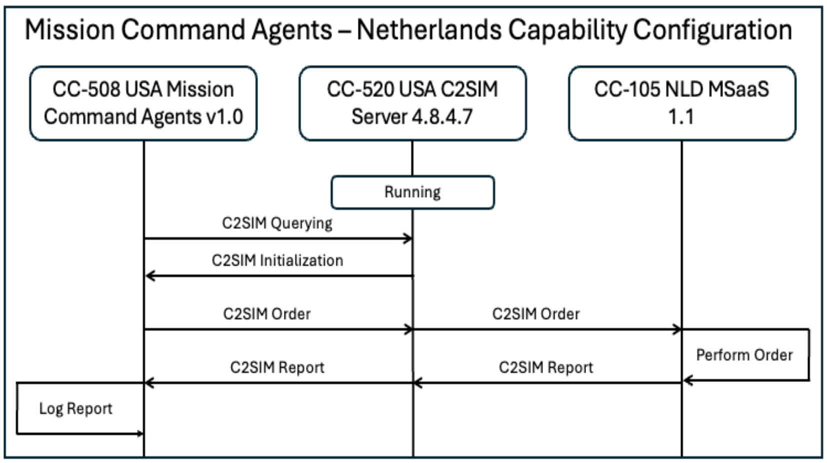

Figure 4. Notional Sequence diagram for Mission Command Agents (MCA) exchanging command and control messages with the Netherlands Capability Configuration (CC)-105: an example of dynamic semantic information about composed services.

Step	Expected Result
MCA sends Unit Control Service a C2SIM move order for previously initialized object.	Object moves as designated on the simulation status display and produces a position report for the object.
MCA sends Unit Control Service a C2SIM attack order for previously initialized object.	Object attacks as specified in the simulation status display and creates a corresponding report for the object.
Object attacks as specified in the simulation status display and creates a corresponding report for the object.	Object defends as indicated on the simulation status screen and creates a corresponding report for the object.
MCA sends Unit Control Service a C2SIM scout order for previously initialized object.	Object executes the scout order as shown on the simulation status screen and creates a corresponding report for the object.

Table 2. Steps of test case for Mission Command Agents exchanging command and control messages with the Netherlands Capability Configuration, which includes the simulation model.

Step 3: Design Simulation Services

In developing their respective unit control services, development teams from the Netherlands and USA used core, static, and semantic information to discover and select M&S services that could be used within their capability configurations. For example, sharing the details of the C2SIM standard ontology served as a M&S Schema Repository

Service, and sharing the scenario initialization and orders files expressed via that standard served as a M&S Resource Repository.

For the Netherlands, the Entity Creator service was the simulation driver running the NETN-Federation Object Model (FOM) via the HLA RTI. It received NETN organization data from the Order of Battle (ORBAT) server to instantiate the entities for simulation over the NETN network. Finally, the Entity Plan View Display (EPVD) provided a web-based interface to the simulation environment so that simulation operators could issue orders to simulated entities via the Entity Tasking and Reporting (ETR) elements of the NETN-FOM.

For the USA, C2SIM was selected as the standards protocol for understanding the state of the simulation environment and issuing orders to units. The Netherlands Land Operations Extension Agent translated the NETN-FOM information into C2SIM reports for the C2SIM server. This allowed Mission Command Agents to build situation awareness and, in response, issue orders to the C2SIM server. The LOX Agent translated these orders to NETN-ETR simulation tasks for execution by the Entity Creator.

Step 4: Develop Simulation Services

The service requirements in the Tidepedia Wiki, combined with design information from Step 3 of the engineering process, allowed developers in the Netherlands and USA to develop and internally test their compositions according to the specifications of the MSaaS information model. For example, the scenario information was provided via an XML initialization file downloaded from the CWIX Wiki. The wiki also hosted additional information about the HLA implementation, NETN-FOM, and C2SIM Server to enable composition.

The Netherlands developed a MSaaS service description of the Unit Control Service that captured the service-level agreements needed to offer it to users via their MSaaS portal application. As a service supplier, the USA provided a MSaaS service description to the Netherlands so they could provide the Mission Command Service to users via their MSaaS portal application.

Step 5: Plan, Integrate, and Test Simulation Services

During the early phases of CWIX testing, the individual services of our larger compositions tested their ability to exchange data with other services via the NATO NETN HLA and C2SIM standards. This is the equivalent of component level testing in a larger Systems Engineering architecture. This testing gave confidence that these components would not only work together as part of a NATO simulation architecture, but also be interchangeable with other services performing the same functions.

Step 6: Execute Simulation Service

During the later part of CWIX testing, the Unit Control Service and Mission Command Service were deployed via the MSaaS portal and worked together with other services to control simulated units during a mission rehearsal and collective training test. Both services successfully reduced the overall load on the simulation operators controlling the exercise.

Step 7: Analyze Data and Evaluate Results

The test results and data collected during CWIX were all published to the Tidepedia Wiki along with an enumeration of interoperability issues discovered during testing. From an interoperability perspective, the Mission Command Service needed to redeploy to a local server within the CWIX network because the virtual private network connection to its cloud hosting environment was intermittent and unreliable. This also complicated integration with the MSaaS portal. Otherwise, both services worked well from an interoperability and standards perspective. However, exercise observers noted the complexity in setting up these services, initializing them with data, and getting them to be reactive with respect to the evolving scenario, which identified areas for improvement in the future.

CONCLUSION

NATO MSG-195 has demonstrated delivery of training capabilities via MSaaS through the composability research and experimentation described in this paper. In particular, existing M&S services from different nations were composed into two compositions that were used to control simulated units in the exercise. They were composed via the MSaaS engineering process, using information for the MSaaS Composability Information Model and supported by different services in the MSaaS implementation. Furthermore, these processes and their supporting standards were validated at CWIX 2024. Over the course of its remaining time, MSG-195 will incorporate these findings into study group reports and NATO standards. In particular, the Building Blocks, information model, and engineering process will underpin the MSaaS Technical Reference Architecture for future incorporation into NATO M&S standards and policies. Follow-on study groups will continue to evolve additional supporting capabilities and standards enabling MSaaS as NATO works towards an M&S Ecosystem for Multi-Domain Operations (MDO).

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