MSG-168 Lecture Series on
Modelling and Simulation as a Service (MSaaS)

3. Simulation Resources Reuse and Tools Demo

4. MSaaS Use Cases and Experimentation

10. MSaaS Engineering Process

15a. M&S Ecosystem Implementation Guidance

17. Current NATO MSaaS Program of Work

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ABSTRACT

NATO and nations use simulation environments for various purposes, such as training, capability development, mission rehearsal and decision support in acquisition processes. Consequently, Modelling and Simulation (M&S) has become a critical capability for the alliance and its nations. M&S products are highly valuable resources and it is essential that M&S products, data and processes are conveniently accessible to a large number of users as often as possible. However, achieving interoperability between simulation systems and ensuring credibility of results currently requires large efforts with regards to time, personnel and budget.

Recent developments in cloud computing technology and service-oriented architectures offer opportunities to better utilize M&S capabilities in order to satisfy NATO critical needs. M&S as a Service (MSaaS) is a new concept that includes service orientation and the provision of M&S applications via the as-a-service model of cloud computing to enable more composable simulation environments that can be deployed and executed on-demand.

This paper covers the following topics:

- *Simulation Resources Reuse and Tools Demo*
- *MSaaS Use Cases and Experimentation*
- *MSaaS Engineering Process*
- *M&S Ecosystem Implementation Guidance*
- *Current NATO MSaaS Program of Work*

1.0 SIMULATION RESOURCES REUSE AND TOOLS DEMO

1.1 MSaaS from the User Perspective

M&S as a Service (MSaaS) enables users to discover new opportunities for training and working together

and enables users to enhance their operational effectiveness, saving costs and efforts in the process. By pooling individual user's requirements and bundling individual requests in larger procurement efforts, the position of buying authorities against industrial providers is strengthened.

MSaaS aims to provide the user with discoverable M&S services that are readily available on-demand and deliver a choice of applications in a flexible and adaptive manner. It offers advantages over the existing stove-piped M&S paradigm in which the users are highly dependent on a limited amount of industry partners and subject matter experts.

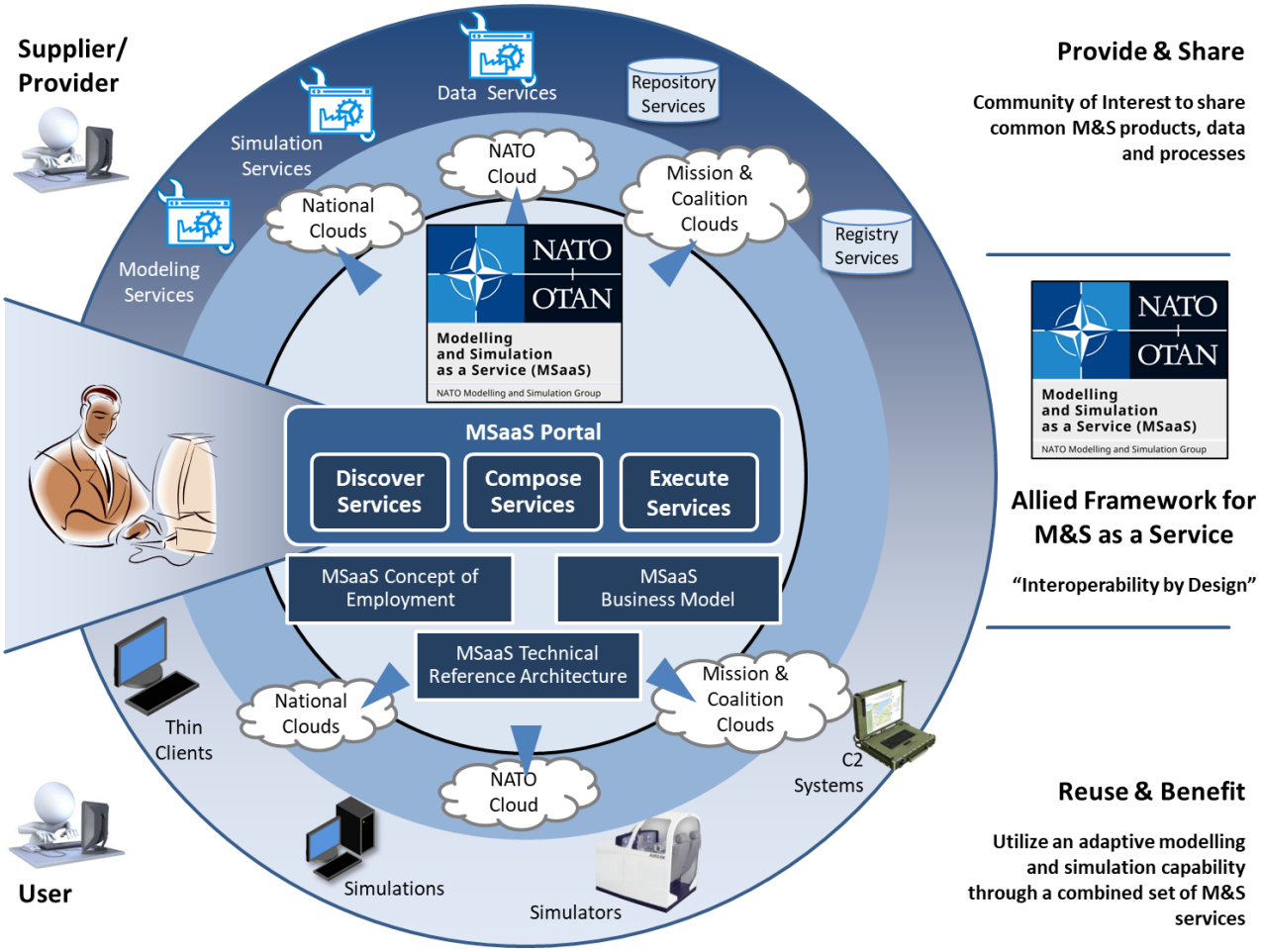

Figure 1: Overview of the MSaaS concept.

The MSaaS concept is illustrated in Figure 1. MSaaS is an enterprise-level approach for discovery, composition, execution and management of M&S services. MSaaS provides the linking element between M&S services that are provided by a community of stakeholders to be shared and the users that are actually utilizing these capabilities for their individual and organizational needs.

The *Allied Framework for MSaaS* defines user-facing capabilities (front-end) and underlying technical infrastructure (back-end). The front-end is called the MSaaS Portal. The front-end provides access to a large variety of M&S capabilities from which the users are able to select the services that best suit their requirements, and track the experiences and lessons learned of other users. The users are able to discover, compose and execute M&S services through the front-end, which is the central access point that guides them

through the process:

Discover: The Allied Framework for MSaaS provides a mechanism for users to search and discover M&S services and assets (e.g., Data, Services, Models, Federations, and Scenarios). A registry is used to catalogue available content from NATO, National, Industry and Academic organizations. This registry provides useful information on available services and assets in a manner that the user is able to assess their suitability to meet a particular requirement (i.e., user rating, requirements, simulation specific information, and verification and validation information). The registry also points to a repository (or owner) where that simulation service or asset is stored and can be obtained, including business model information (i.e., license fees, pay per use costs).

Compose: The Framework provides the ability to compose discovered services to perform a given simulation use case. Initially it is envisaged that simulation services will be composed through existing simulation architectures and protocols (e.g., using DIS, HLA, DDS) and can be readily executed on-demand (i.e., with no set up time). In the longer term, distributed simulation technology will evolve, enabling further automation of discovery, composition and execution than is possible today.

Execute: The Framework provides the ability to deploy the composed services automatically on a cloud-based or local computing infrastructure. The automated deployment and execution allows to exploit the benefits of cloud computing (e.g., scalability, resilience). Once deployed and executed the M&S services can be accessed on-demand by a range of users (Live, Virtual, Constructive) directly through a simulator (e.g., a flight simulator consuming a weapon effects service), through a C2 system (e.g., embedded route planning functionality that utilizes a route planning service) or may be provided by a thin client or by a dedicated application (e.g., a decision support system utilizing various services like terrain data service, intelligence information service etc.). The execution services support a range of business models and are able to provide data relevant to those models (i.e., capture usage data for a pay-per-use business model).

The Allied Framework for MSaaS is the linking element between service providers and users by providing a coherent and integrated capability with a Technical Reference Architecture, recommendations and specifications for discovery, composition and execution of services, and necessary processes and governance policies.

1.2 Example: Aditerna SRP

Various MSaaS Portal implementations have been made available by participating nations to the NMSG MSaaS working groups. Examples include Aditerna SRP, UK AIMS and ITA Ocean. This section briefly describes the Aditerna SRP MSaaS Portal.

Aditerna SRP is a modular training and data management platform for effectively managing today's complex simulation environments. It provides key capabilities like Modelling and Simulation (M&S) Resource Management, Training and Exercise Management, and M&S as a Service (MSaaS). Aditerna SRP is a browser-based modular platform for training and data management.

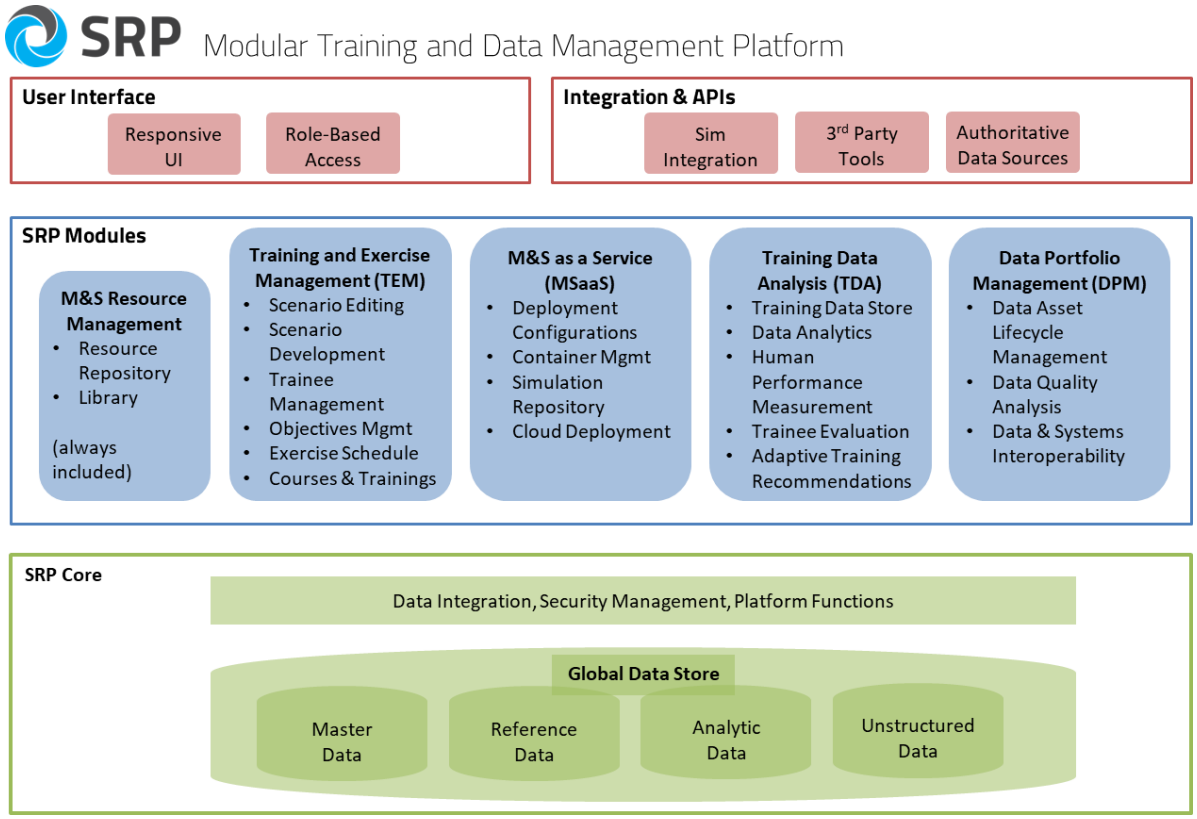

Figure 2: Aditerna SRP Capability Overview.

Figure 1 shows an overview of Aditerna SRP. While the SRP Core provides the underlying data storage and cross-cutting functionalities like data integration, security management and workflow processing, the actual SRP training and management capabilities are provided as individual modules. Modules can be deployed individually, depending on user needs. Currently, five modules are available:

- M&S Resource Management (part of each SRP instance)
- Training and Exercise Management (TEM)
- M&S as a Service (MSaaS)
- Training Data Analysis (TDA)
- Data Portfolio Management (DPM)

The M&S Resource Management capabilities enable management of simulation resources like models, scenarios, exercises and many more. Description of each resource may be customized to fit individual customer and organization needs. Pre-defined resource types include Models, Simulators, Scenarios and M&S Services. Additional resource types may be defined as needed.

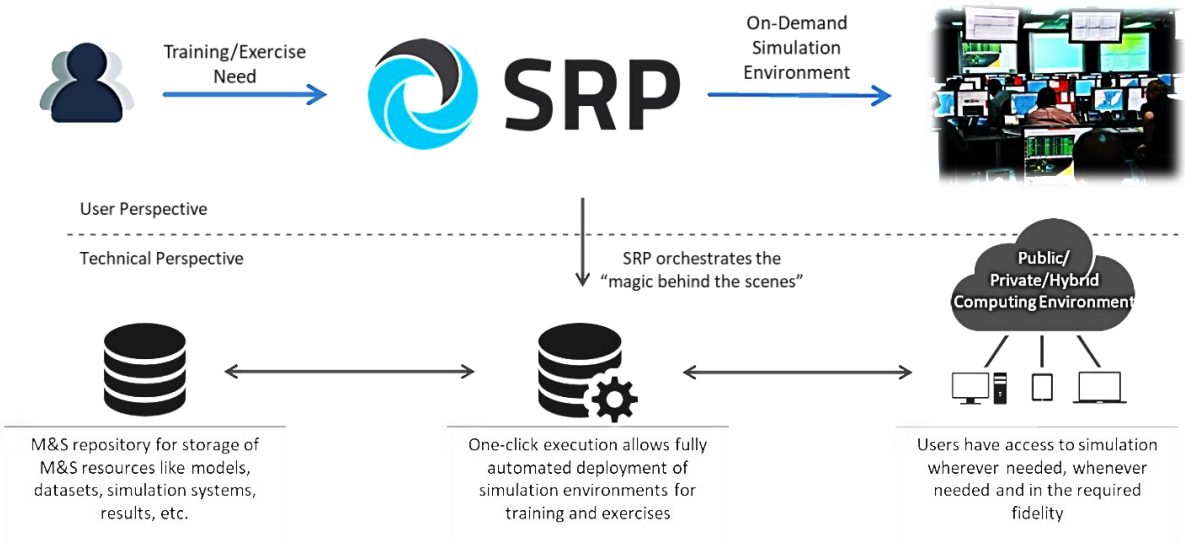

Figure 3: MSaaS Capabilities in Aditerna SRP.

Aditerna SRP allows on-demand, one-click execution of simulation environments (M&S as a Service), thus giving warfighters and users access to simulation whenever and wherever needed. As illustrated in Figure 3, Aditerna SRP provides a repository for storing M&S resources, including virtual machines and containers of simulation systems, middleware technologies, data recording and analysis tools etc. Specifically, Aditerna SRP supports the following features:

- Discovery of simulation resources. SRP features a simulation repository which provides a comprehensive overview of all accessible simulation resources. This includes resources within the own organization (local) as well as resources available via linked repositories (remote).
- Identification of Training/Exercise needs. Once a user has identified a training/exercise need, Aditerna SRP provides him an overview of readily available simulation environments in local, but also in linked and only remotely accessible systems.
- One-Click Execution. Deploying and executing a simulation environment is as easy as pushing a single button.
- Open Standards. Aditerna SRP supports open standards for all in- and outbound interfaces. The internal data model for describing M&S resources is aligned to the MSC-DMS standard. The external interface for federating SRP with other systems implements the prototype "Resource Discovery Specification" (RDS) currently being developed by MSG-164.
- On-demand Simulation Environment. The simulation environment that satisfies the users training/exercise needs is available on-demand. Without extensive support from subject matter experts, any user can execute simulation environments whenever and wherever necessary, using cloud-technology to easily operate simulations and services.

1.3 Screenshots

The following screenshots are meant to give an impression how an MSaaS Portal may look like.

SRP Dashboard

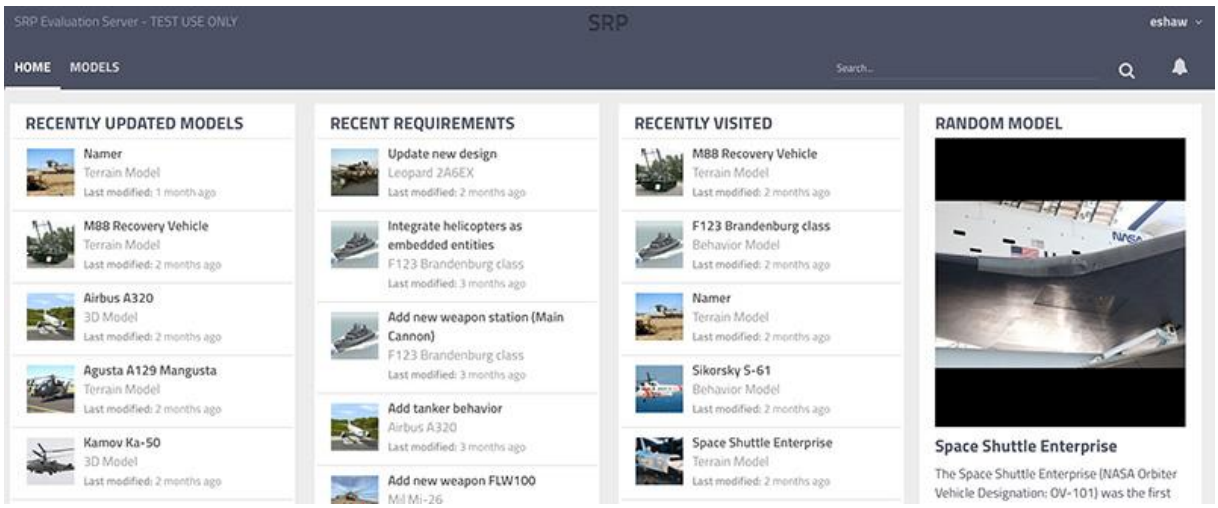

Figure 4: Dashboard.

The dashboard is shown every time a user logs in into SRP. The intent is to provide the user an overview about most recent changes and activities within his organization/area.

Currently, four panels are pre-defined (but more/other panels can be added):

- Recently updated: This panel shows models/scenarios/exercises/etc. that have recently been updated.
- Recent requirements: SRP provides a function for users to attach requirements to resources (like models, scenarios, etc.). This panel shows the most recent created and updated requirements.
- Recently visited: This panel shows the last few resources (exercises, scenarios, etc) a user has visited. The intent is to provide a short-cut for users to continue their work on specific resources that they worked on in the past.
- This might be interesting: As the content in the SRP resource library grows and more and more models, scenarios, exercises, etc. are being documented, this panel shows resources that might be of interest for the current user.

The above four panels are the default configuration, SRP allows addition of more user/organization-specific panels.

Model Library

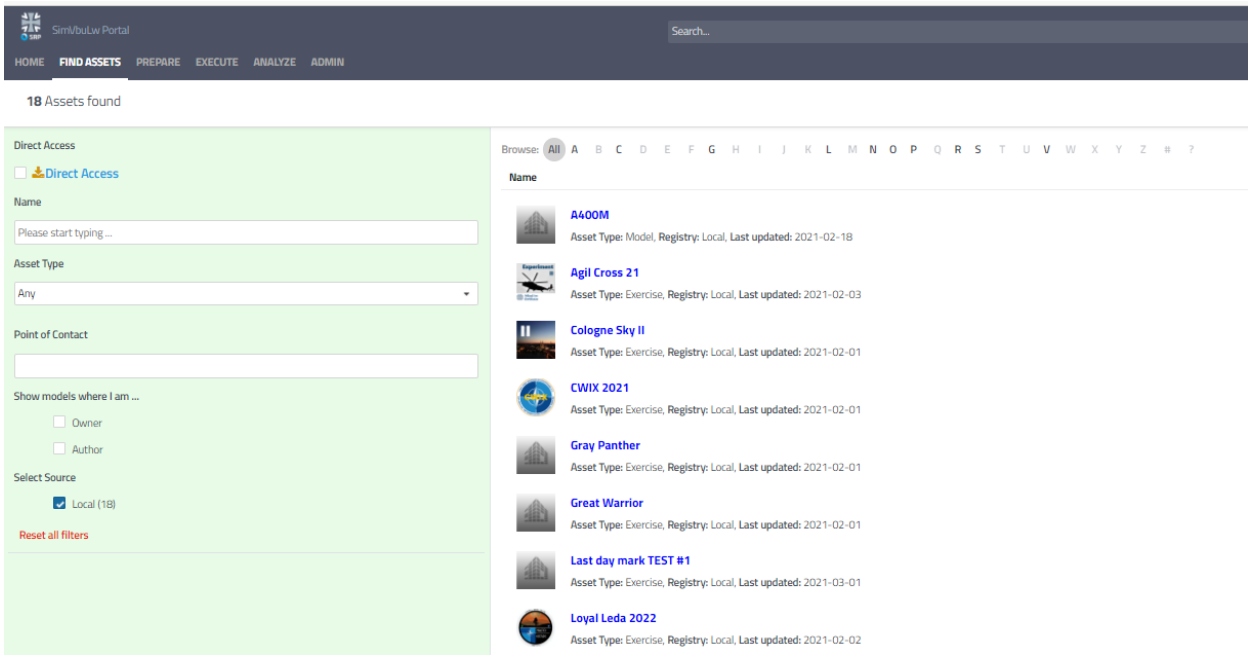

Figure 5: Model Library in the MSaaS Portal.

One of the key components of Aditerna SRP is to provide a repository for M&S services and related M&S resources. By default, five resource types are pre-defined:

- Models
- Simulators
- Scenarios
- Exercises
- M&S Services.

The top menu enables quick access to each of these resource types. Additional resource types may be defined as needed. By selecting one of the M&S resource types from the top menu (Models, Simulators, Scenarios, Exercises, M&S Services) users are shown the individual repository content, i.e. the models, scenarios etc. that are stored in the system. Figure 5 shows a screenshot of the model catalogue.

The repository offers users multiple options for filtering content (e.g., based on classification, project etc.) to ease navigation and asset discovery.

- Intuitive search and filter functionality to find what you are looking for
- Narrow down search results by individual filters
- Configure your search and filter results individually

Detail view of models

Once a user has selected a resource (model, scenario, etc.) from the repository, SRP provides a detail view of the individual resource – see examples below.

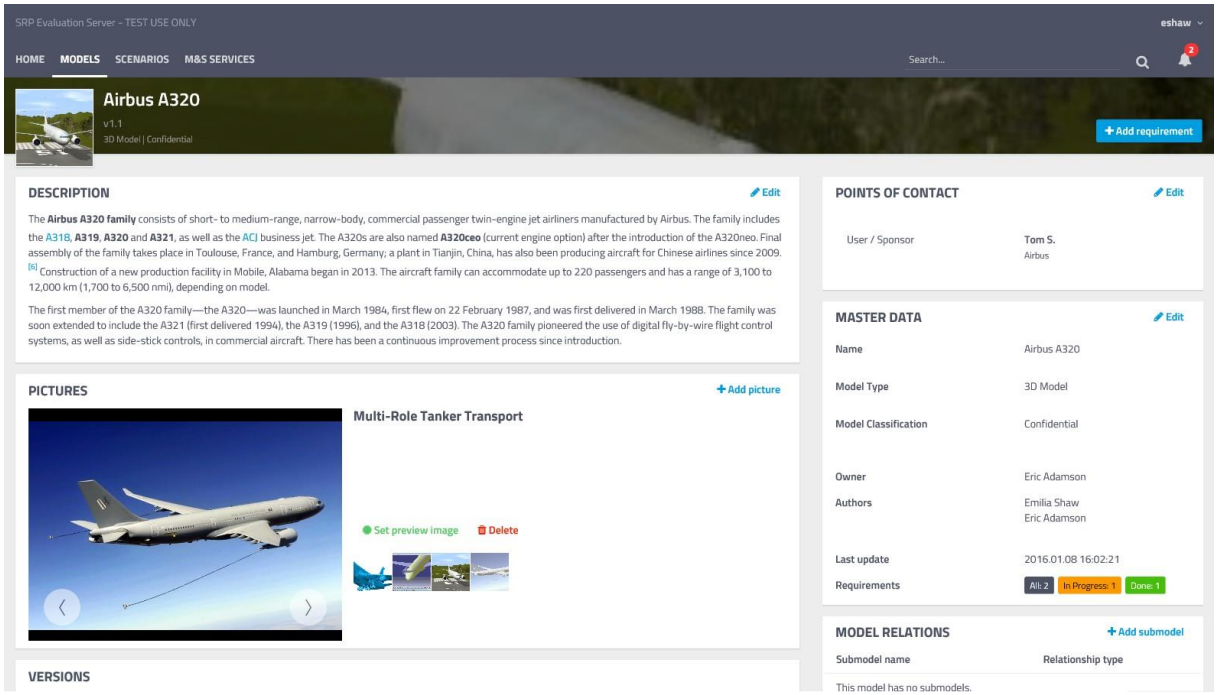

Figure 6: Detail view of 3d model Airbus A320.

The detail view provides similar (basic) information about all resources, independent of resource type:

- Name, Description
- Points of Contact
- Pictures, Screenshots, etc.
- Version Information (see Figure below)
- Attachments
- Documents => SRP allows admin users to define document templates and associate those templates with individual resource types
    - Example: To ensure consistent scenario documentation, three document templates are pre-defined for each scenario: Initial State, Course of Events, Termination Conditions. Once a new scenario is created, these three documents are instantiated and the user is asked to provide the information.

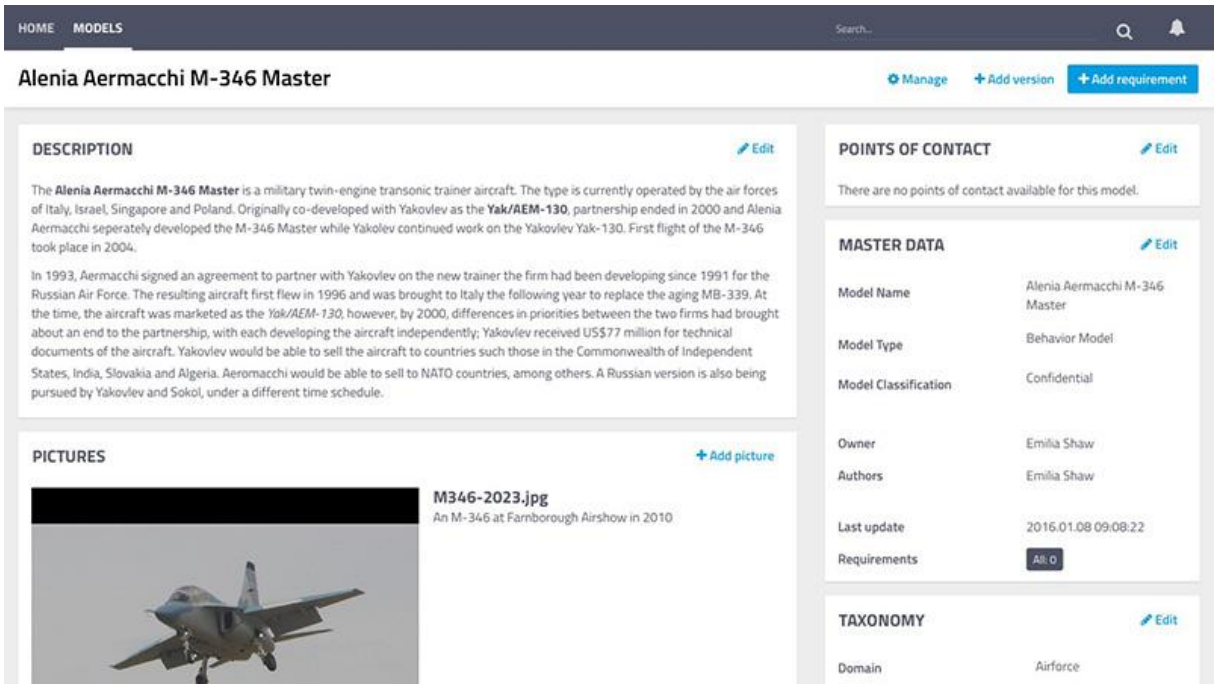

Figure 7: Detail view of model AA M-346 Master.

- Detailed information about all M&S resources
- Easily find all important information about your M&S assets
- Support for various asset types like models, scenarios, etc.
- Possibility to drill down for further information on each M&S asset

2.0 MSAAS USE CASES AND EXPERIMENTATION

MSG-136 performed several experiments to test enabling technology for MSaaS. Two strands of experimentation were performed: (1) experimentation to explore and test enabling technology for architecture building blocks from the reference architecture, and (2) experimentation to test solutions for certain types of Simulation Services. Test cases were defined, tests performed, and test results recorded in an experimentation report [MSG136-EVAL]. A brief overview of the experimentation and test cases follows below.

2.1 Explore and Test Enabling Technology

Most test cases in this strand of experimentation evolve around container technology as the enabling technology for a number of Architecture Building Blocks. This technology enables M&S Enabling Services and M&S Specific Services to run on a local host as well as in a cloud environment.

The experiment environment that was used for the test cases is illustrated in the following figure. The experiment environment is a collection of private clouds and a common cloud. The common cloud is Amazon Web Service (AWS), sponsored by NATO CSO.

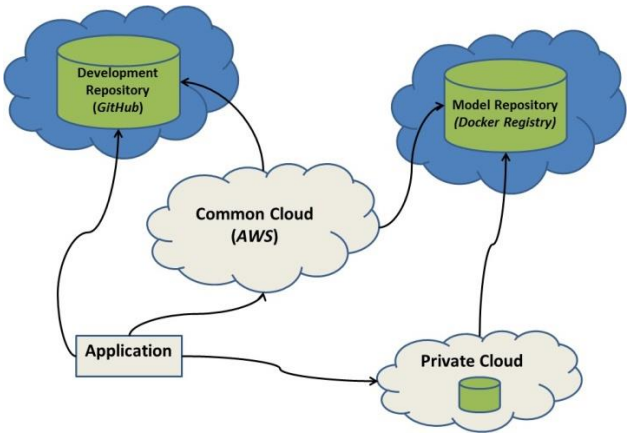

Figure 8: Illustration of experiment environment.

Common components are:

- A private Docker Registry and a web-based front-end for the exchange of Docker container images (provided by NLD);
- A private GitHub repository for the description of container images in the Docker Registry, and for the exchange of software, configuration files and other developmental data (provided by USA).

The Docker Registry contains several container images for containerized HLA federates, from which various compositions can be created for the different test cases. Many of these images have been created following the design patterns in [Berg2016]0.

Test cases include:

- Container networking: explore different container networking models for connecting containerized HLA federate applications.
- Containerization of HLA federates: evaluate approaches in containerizing HLA federate applications (see also [Berg2016]).
- Metadata Repositories and Discovery: Demonstrate interoperation of repositories across nations.
- Simulation Composition: explore automated composition and execution of services.
- Container Orchestration Environments: evaluate two popular container orchestration environments for M&S (see also [Berg2017]).

2.2 Test Solutions for Simulation Services

Tests cases in this strand of experimentation concern the interoperation of applications with certain types of Simulation Services. Test cases include:

- Computer Generated Forces (CGF) – Synthetic Environment Service: connect a CGF simulator to a Synthetic Environment Service to request environment data in various formats.
- C2 Application – Route Planning Service: connect a C2 Application to a Route Planning Service to request route planning information.

3.0 MSAAS ENGINEERING PROCESS

The MSaaS Operational Concept Document (OCD) [MSG136-OCD] describes the intended use, key capabilities and desired effects of the Allied Framework for M&S as a Service from a user's perspective.

The Allied Framework for M&S as a Service enables:

1. The community of users to discover new opportunities to train and to work together.

2. Users to enhance their operational effectiveness, saving costs and effort in the process. By pooling individual user's requirements and bundling individual requests in larger procurement efforts, the position of buying authorities against industrial providers is strengthened.

3. M&S services that are readily available on-demand and deliver a choice of applications in a flexible and adaptive manner. It offers advantages over the existing stove-piped M&S paradigm in which the users are highly dependent on a limited amount of industry partners and subject matter experts.

If the above capabilities are to be realized, NATO simulation engineers must have a well-developed and documented process for bringing them into being. The OCD identifies this requirement in the Figure below.

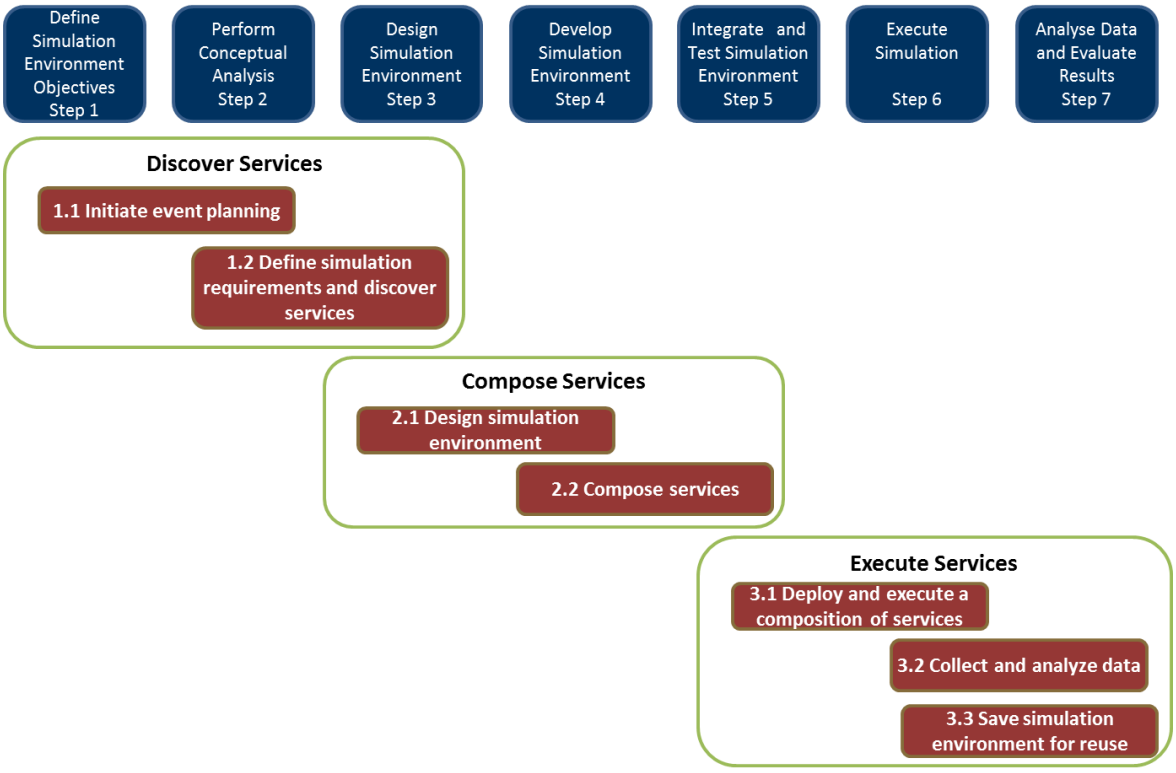

Figure 9: This figure, taken from the MSaaS Operational Concept Document (OCD), shows the alignment of engineering activities with the DSEEP.

The MSaaS Engineering Process (MSaaS-EP) defines that process [MSG136-EP]. However, it is important for engineers to understand the larger set of engineering environments and processes in which it is executed.

The MSaaS-EP is executed within an existing MSaaS Implementation, the specific realization of M&S as a Service by a certain organization as defined in the Operational Concept Document. An MSaaS

Implementation includes both technical and organizational aspects [MSG136-GOV]. The Allied Framework for Modelling and Simulation as a Service (MSaaS) Governance Policies [MSG136-GOV] establish policies that guide the development of an MSaaS implementation. This implementation will include implementations of M&S Enabling Services which provide capabilities to create a simulation in which M&S Services and M&S User Applications are brought together to fulfil the purpose of that simulation.

The MSaaS-EP is executed to build Composed Simulation Services compliant with the MSaaS Reference Architecture (RA). The MSaaS-RA [MSG136-RA] defines a set of architectural building blocks and architectural patterns to support the MSaaS-EP.

The services used during the MSaaS-EP to construct a composed simulation service are catalogued using the M&S Registry Services. Volume 2 to of the MSaaS technical documentation, Discovery Service and Metadata [MSG136-DIS], defines the data standards that allow service discovery in an MSaaS implementation.

The MSaaS-EP mirrors the IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP). The documentation of the MSaaS-EP assumes engineering knowledge of the DSEEP [DSEEP], and it will only address the MSaaS-specific engineering considerations during DSEEP execution.

If the MSaaS-EP is executed in a multi-architecture environment, it will also mirror the DSEEP Multi-Architecture Overlay (DMAO). The documentation of the MSaaS-EP also assumes knowledge of the DMAO [DMAO]. As multi-architecture compositions are discussed, it will only address MSaaS-specific engineering considerations in the context of the DMAO.

In short, the MSaaS engineering process covers the engineering necessary to develop composed simulation services within an MSaaS implementation, but it does not cover the engineering necessary to develop and maintain an MSaaS implementation within an organization.

4.0 M&S ECOSYSTEM IMPLEMENTATION GUIDANCE

MSG-164 is currently developing an “MSaaS Implementation Guidance Document” (MSaaS IGD). The MSaaS IGD will capture current best practices and recommendations for implementing an MSaaS infrastructure as well as individual M&S services.

The proposed structure is as follows:

- Introduction/Overview
- Implementation Guidance
  - Service Discovery
    - Registry: SDT, DSDS
    - Repository: Harbor
  - Service Composition
    - Service Implementation: stateless, remote UI, …
    - Open standards: NTP, WFS, WMS, KML, …
  - Service Execution
- Service Definitions (Description, Interface Specification, Conformance Criteria)

- Weapon Effect Service
- Missile Service
- Common Operational Picture (COP) Service
- 2d Map Service

MSG-164 plans to publish an initial draft of the MSaaS IGD in summer/fall 2021, with regular updates over the following years.

5.0 CURRENT NATO MSAAS PROGRAM OF WORK

Service-based approaches rely on a high degree of standardization and automation in order to achieve their goals. Therefore, the development and implementation of a recommended set of supporting standards is a key output of the reference architecture. MSG-136 research has identified the importance for the following capabilities:

- M&S Composition Services: create and execute a simulation composition. A composition can be created from individual simulation services or from smaller compositions.
- M&S Repository Services: store, retrieve and manage simulation service components and associated metadata that implement and provide simulation services, in particular metadata for automated composition.
- M&S Security Services: implement and enforce security policies for M&S services.

MSG-136 proposed an incremental development and implementation strategy for the Allied Framework for M&S as a Service. The incremental approach facilitates a smooth transition in the adoption of an Allied Framework for M&S as a Service and describes a route that will incrementally build an Allied Framework for M&S as a Service.

5.1 Implementation Strategy

The proposed strategy also provides a method to control the rate of expansion of the new framework permitting the iterative development and training of processes and procedures. Finally, it permits those nations that have been early adopters of an Allied Framework for M&S as a Service and have national capabilities to accrue additional benefits from their investments and highlight the benefits as well as providing lessons learned and advice to those nations considering similar investments.

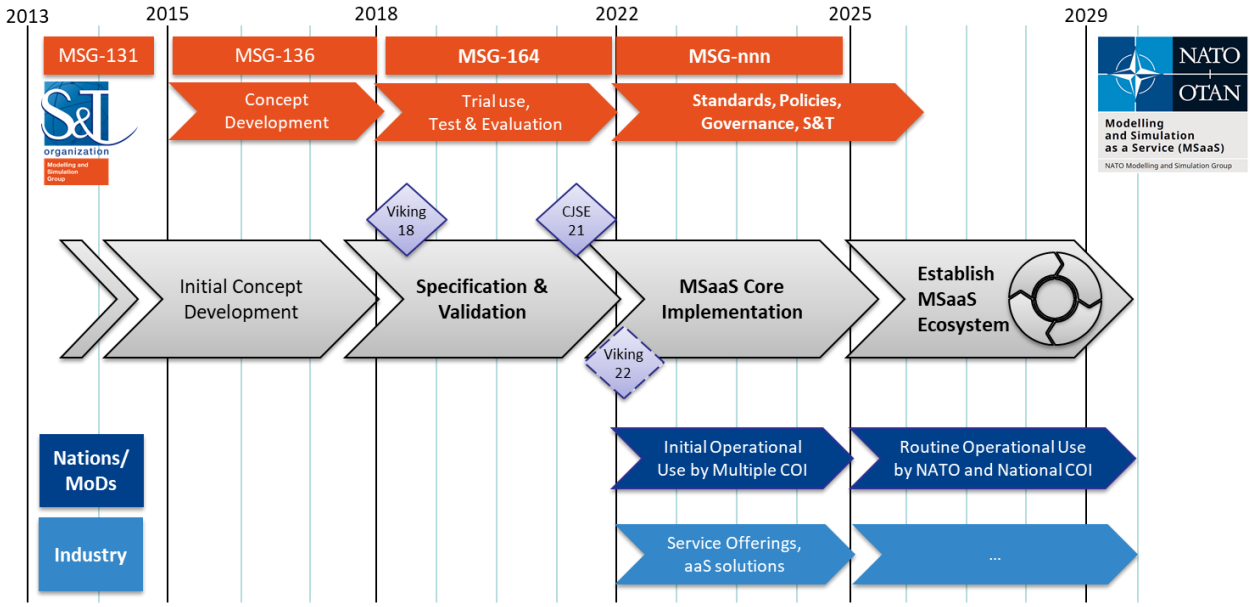

Figure 7: MSaaS implementation strategy.

As illustrated in Figure 7, the implementation strategy is broken down into multiple phases:

1. Initial Concept Development
   The Initial Concept Development (2015 until end of 2017) was executed by NMSG-136 and focused on concept development and initial experimentation. For this period an MSaaS Portal and individual M&S services were provided by individual members of MSG-136 for trial use.

2. Specification & Validation
   From 2018-2021 MSG-164 will mature MSaaS in an operationally relevant environment and conduct necessary research and development efforts to evolve and extend the initial concepts as developed by MSG-136. This phase includes development of suitable STANAGs or STANRECs, and moving from prototype implementation to operationally usable and mature systems.

3. MSaaS Core Implementation
   By 2025 Initial Operational Capability (FOC) is achieved which includes adaptation of many existing simulation related services to the MSaaS Reference Architecture. This is achieved primarily by adding services to the Allied Framework for M&S as a Service.

5.2 Current Efforts

The current efforts to define and evolve the Allied Framework for MSaaS are executed by MSG-164 (see previous section). MSG-164 kicked off in February 2018 and will finish in 2021. Building upon the Allied Framework for M&S as a Service developed by MSG-136 this activity addresses three main objectives:

1. To advance and to promote the operational readiness of M&S as a Service.

2. To align national efforts and to share national experiences in establishing MSaaS capabilities.

3. To investigate critical research and development topics to further enhance MSaaS benefits.

MSG-164 will specify and test an MSaaS infrastructure that is suitable for use in an operationally relevant

environment and will support continued MSaaS experimentation and evaluation efforts. This activity will also deliver a Technical Report and recommendations with regards to the organizational perspective of introducing MSaaS in NATO and in the Nations.

To address the objectives, MSG-164 covers the following topics:

1. Demonstrate MSaaS application in an operationally relevant environment through operational experimentation as part of exercises and integration into simulation applications (like simulation-based capability development). Annual participation in CWIX to develop MSaaS to maturity through a phased approach.

2. Maintain and enlarge the MSaaS Community of Interest.

3. Establish interim governance structure and collect experiences w.r.t. MSaaS governance.

4. Collect and share experiences in establishing MSaaS capabilities and providing M&S services.

5. Conduct research on M&S-specific service discovery and service composition.

6. Conduct research and development activities on M&S-specific federated cloud environments, federated identity management and cyber secure communications.

7. Conduct research on enabling services like scenario specification services, etc.

Additionally, MSG-164 will

1. Act as governance body for the Allied Framework for M&S as a Service, maintaining and updating (if needed) the therein included documents, i.e. AMSP-02 (MSaaS Governance Policies), the MSaaS Operational Concept Description, and the MSaaS Technical Reference Architecture) with associated technical documents.

2. Collaborate with international standards bodies (like SISO, IEEE, etc.).

3. Inform and engage stakeholders in NATO, Academia, and Industry about MSaaS.

5.2 Next Steps

From the progress made so far, it is evident that initial concept development and basic specification efforts have been largely completed. The next step is to develop and establish an “MSaaS Core Implementation”. Achieving this requires a concerted approach:

1) The NMSG will continue to investigate critical S&T topics and further develop the Allied Framework for MSaaS, including necessary standards, policies, guidance documents etc.

2) NATO and Nations will build up initial MSaaS implementations for a variety of Communities of Interest. This includes establishing required infrastructure (like cloud computing environments) as well as defining and prototyping M&S services, and validating S&T results.

3) Industry partners will be key to providing service implementations and actually implementing the MSaaS paradigm into products and solutions.

6.0 REFERENCES

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