

Lessons Learned from leveraging Simulation as a Service in Viking18

**Nico de Reus, Tom van den Berg,
Henk Janssen, Wim Huiskamp**
TNO Defence Research
The Hague, The Netherlands
nico.dereus@tno.nl, tom.vandenberg@tno.nl,
henk.janssen@tno.nl, wim.huiskamp@tno.nl

Björn Löfstrand, Lennart Olsson
Pitch Technologies
Linköping, Sweden
bjorn.lofstrand@pitch.se, lennart.olsson@pitch.se

Cpt. Peter Lindskog
Swedish Armed Forces (SWAF)
Joint Training Centre
Enköping, Sweden
peter.j.lindskog@mil.se

ABSTRACT

Complexity is ever increasing in current military operations, due typically to the fact that missions are more often performed in a comprehensive environment with many different actors, including military and civil. In order to prepare for these missions, advanced training, in which the military and civil trainees are immersed in such complex environments, is required. (Distributed) simulation has been recognized by NATO as a solution to support training of these missions and the concept of “Mission Training through Distributed Simulation” (MTDS) is currently developed by several nations under the umbrella of the NATO Modelling and Simulation Group. The Netherlands MoD has also identified the need for MTDS capabilities and initiated an MTDS research programme in 2017.

Development of MTDS solutions is a technical and organisational challenge that can be addressed by defining a so-called Reference Architecture. The Reference Architecture and its specific generic elements descriptions (Architecture Building Blocks or ABBs) offer both a blueprint and a flexible approach for rapid implementation of exercise environments. The VIKING-18 CAX exercise was selected as a use-case to identify ABBs and evaluate service based implementations of these ABBs.

This paper presents the MTDS ABBs that have been derived from the VIKING-18 requirements as well as the lessons learned from their use. The specific ABB implementations provided for VIKING-18 consisted of simulation services for realistic computer generated maritime vessel traffic, including transmission of ‘Automatic Identification System (AIS)’ messages, and services for the simulation and control of land units. These simulation services leveraged the results of the NATO task group MSG-136 M&S as a Service (MSaaS). The work was performed in a collaborative effort by TNO Defence Research (NLD), Pitch Technologies (SWE), and the Swedish Armed Forces (SWAF) Joint Training Centre.

ABOUT THE AUTHORS

Nico de Reus is a senior scientist in the Modeling, Simulation and Gaming department at TNO, The Netherlands. He holds an M.Sc. degree in Mathematics from Delft University of Technology and has over 25 years of experience in simulation. His research area includes C2 to simulation Interoperability, simulation for decision Support and concept development & experimentation.

Tom van den Berg is a senior scientist in the Modeling, Simulation and Gaming department at TNO, The Netherlands. He holds an M.Sc. degree in Mathematics and Computing Science from Delft University of Technology and has over 25 years of experience in distributed operating systems, database systems, and simulation systems. His research area includes simulation systems engineering, distributed simulation architectures, systems of systems, and concept development & experimentation. He is a member of several SISO Product Development / Support Groups, participates in several NATO MSG activities, and is

co-chair of NATO MSG-136/MSG-164 (“Modelling and Simulation as a Service (MSaaS, Phase 1 and Phase 2) – Rapid deployment of interoperable and credible simulation environments”).

Henk Janssen is Project Manager in the Modeling, Simulation and Gaming department at TNO, The Netherlands. He holds an M.Sc. degree in Aerospace Engineering from Delft University of Technology, Delft, The Netherlands. Having for more than 25 years expertise and knowledge on (simulation) engineering, concept development and experimentation, and (distributed) simulation, Henk acts/has performed duties as a Subject Matter Expert and/or (Technical) Lead in various domains such as Maritime Theatre Missile Defense, Simulation Based Acquisition, Unmanned Aerial Vehicle development, (Simulation) System Architecture Development (for F-35, Road Driving Simulators, Airport Security Systems) and Mission Training through Distributed Simulation (MTDS). Recently Henk supported the NIAG Study Group SG-215 on “Future Combined / Joint Distributed Tactical Training through Simulation for joint and combined tasks and operations”.

Wim Huiskamp is Chief Scientist Modelling, Simulation and Gaming in the M&S department at TNO Defence, Security and Safety in the Netherlands. He received a M.Sc. degree in Electrical Engineering from Twente University of Technology, The Netherlands. His research areas include system architecture and, distributed real-time simulation and C2-Simulation interoperability problems. Wim acted as project lead for several national and international simulation (interoperability) projects and he leads TNO’s research program on Live, Virtual and Constructive Simulation, which is carried out on behalf of the Netherlands MoD. Wim is a member of the NATO Modelling and Simulation Group (NMSG) and acted as member and chairman in several NMSG Technical Working groups. He is a former Chairman of the NMSG, former Chairman of the NMSG M&S Standards Subgroup (MS3) and he is the liaison of the NMSG to the Simulation Interoperability Standards Organization SISO.

Björn Lofstrand is the Services and Training Manager at Pitch Technologies. He holds an M.Sc. in Computer Science from Linköping Institute of Technology (Sweden) and has been working with HLA federation development and tool support since 1996. He was the technical lead for the MSG-068 FOM and Federation Design (FAFD) work and co-lead of the technical subgroup of MSG-106.

Lennart Olsson works at the Services and Training section at Pitch Technologies. He holds an M.Sc. in Computer Science from Linköping Institute of Technology (Sweden) and has been working with HLA federation development and tool support since 1996. He has conducted many exercises as a Test and Integration Manager for HLA Federations. He has designed and developed a large number of HLA federates.

Cpt Peter Lindskog is a technical officer with the Swedish Armed Forces, stationed at the Command and Control Regiment in Enköping, Sweden. He has been in service for 36 years and has experiences in many of the army services in the Swedish Armed Forces. He is primarily concerned with the future development of Computer Aided eXercises (CAX) and how to rapidly deploy adapted and usable technical solution to improve the training effectiveness and particularly decision making skills in staff exercises (Command Post eXercises). He is currently a member of NATO MSG-136/MSG-164 (“Modelling and Simulation as a Service (MSaaS, Phase 1 and Phase 2) – Rapid deployment of interoperable and credible simulation environments”).

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henk.janssen@tno.nl, wim.huiskamp@tno.nl

Björn Löfstrand, Lennart Olsson
Pitch Technologies
Linköping, Sweden
bjorn.lofstrand@pitch.se, lennart.olsson@pitch.se

Cpt. Peter Lindskog
Swedish Armed Forces (SWAF)
Joint Training Centre
Enköping, Sweden
peter.j.lindskog@mil.se

INTRODUCTION

The characteristics of military missions are constantly changing. In recent decades, a change has occurred from a traditional environment with clearly defined missions, to a complex (multi-national) environment in which a comprehensive approach (with multiple actors) needs to be coordinated to pursue common objectives. This coordination requires flexibility and quick adaptation from the actors to the required operations based on understanding of and insight into this complex environment. Also, due to declining defence budgets and resources, a closer and more cost effective cooperation is required for coalition operations.

Training and exercises in a real world environment involving live systems currently are mainly used to prepare the warfighter for coalition operations. However, due to cost, complexity, resource availability and environmental restrictions, it is not always possible to train with live systems in a real world environment.

In the preparation of the warfighter for increasingly complex military operations, simulation technology can play an important role. In this context, NATO develops the concept of Mission Training through Distributed Simulation (MTDS), integrating national live, virtual or constructive (training) assets into a common (distributed) simulation environment. A typical design-sketch of an MTDS environment is shown in Figure 1, where simulation assets are connected through a common simulation run-time infrastructure (called "MTDS Backbone"). Non-compliant simulation assets are connected to this backbone via a gateway.

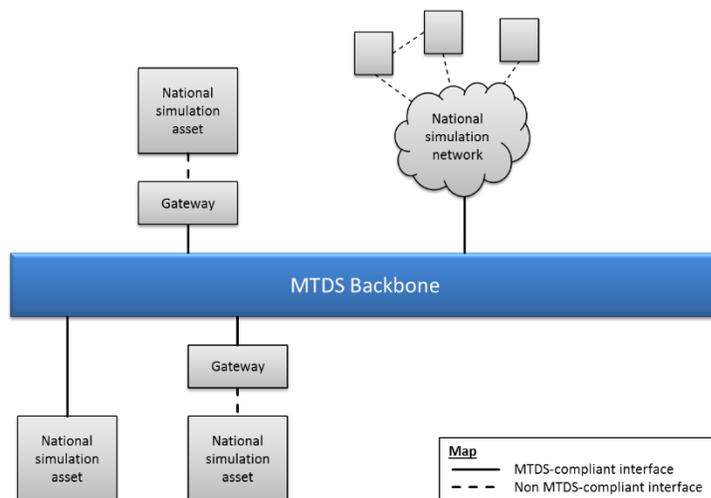


Figure 1: Design-sketch of MTDS environment.

The main obstacle to the more widespread use of MTDS is however the complexity of creating an MTDS exercise. The complexity is due both to technical aspects (e.g. number of different national simulation assets and interfaces) as well as organizational aspects (e.g. number of actors and disciplines). Depending on the scope and complexity of the exercise the preparation of an MTDS exercise can take from several months to even several years. In addition, simulation assets may have different classification levels where the

exchange of data is subjected to national security policies. Collective (international) mission training or mission

rehearsals therefore only take place sporadically, while missions are increasingly being conducted in international coalitions and with short preparation time.

To overcome this obstacle, the Netherlands MoD has initiated a national research program on MTDS that aims at (1) operationalising already available knowledge to effectively and efficiently create and perform MTDS exercises by (2) identifying and solving some of the current issues that still exist.

In order to realize an effective MTDS environment that can respond quickly to new training needs, common agreements on the process of planning, developing, executing and analysing the relevant MTDS training environment are required, as well as technical agreements on the development of the specific MTDS architecture. These agreements are currently developed per exercise separately, however general guidelines for assembling these agreements, specifically for assembling technical agreements, are still lacking. This is where a so-called *Reference Architecture* comes into play. The MTDS Reference Architecture is captured in a document in which all necessary agreements (process and technical) are collected and structured, and which provides the guidelines for implementing MTDS training and exercises (also called Collective Training and Exercises (CTE)).

The MTDS Reference Architecture is developed using top down and bottom up activities (see Figure 2). The top-down activities define the architecture and its components based on available literature and available knowledge and experience achieved by previously performed Collective Training and Exercises (CTEs). The bottom-up activities use actual implemented components in exercises as input to the development of the Reference Architecture. The descriptions of these components are called Solution Building Blocks (SBB).

The international VIKING-18 exercise is the first use case for defining and testing a set of supporting services (i.e. SBBs) from which Architecture Building Blocks can be derived during MTDS Reference Architecture development.

The MTDS Reference Architecture leverages the Modelling and Simulation as a Service (MSaaS) approach developed by NATO MSG-136 and MSG-164. The MTDS Reference Architecture incorporates many of the ABBs identified for MSaaS (NATO, 2017). Some of the MSaaS technology for providing simulation services (e.g. container technology, described later in this paper) has been assessed in VIKING-18.

The remainder of this paper presents the VIKING-18 use case, discusses the MTDS Reference Architecture and the ABBs that have been identified for VIKING-18. The paper then summarizes the lessons learned from the implementation of these ABBs as services in the actual exercise and concludes with a summary and recommendations for future application of services in MTDS exercises.

THE VIKING18 EXERCISE

VIKING-18 has been conducted during the period 16 to 26 April 2018 in Sweden and several additional countries. Civilians, military and police from invited nations and organizations, including the United Nations and other international organizations, regional organizations, government agencies and non-government organizations are participating.

VIKING-18 is a Computer-Assisted eExercise (CAX) including simulation, C2 systems and other supporting tools and services. The CAX concept includes two primary groups, Training Audience (TA) and Exercise Control (EXCON): The TA consists of 1500 individuals from military and other governmental and non-governmental (NGO) organizations. The EXCON (including Response Cells) consists of 500 people making the Trainer-Trainee ratio 1:3.

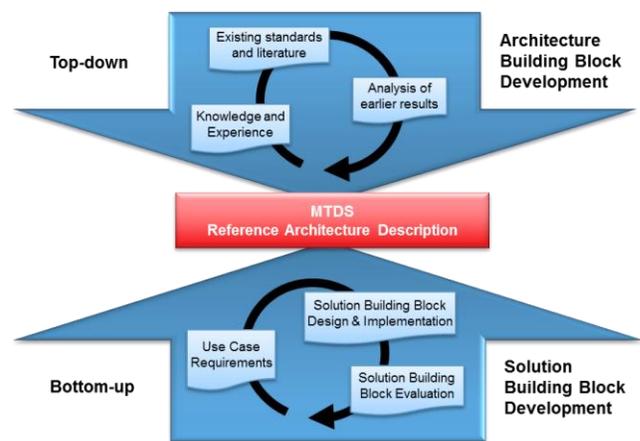


Figure 2: Reference Architecture development approach.

Since the first VIKING exercise in 1999 it has been progressively demonstrated that the VIKING concept is excellent for the development of military co-operation, as outlined in the Partnership for Peace program. VIKING exercises have also proved themselves as effective platforms for multinational education and training, and practicing co-operation between civilian, military and police personnel in a comprehensive approach. The exercise is also an excellent event to drive the technical concept further into the future and a base for development, test and evaluation of new assets in CAX environments for supporting the progress of MTDS.

VIKING-18 Technical Objectives

Besides the operational objectives there are also technical ones, such as:

- To reduce the EXCON workload by automation of some of their tasks.
- To reduce the size of the EXCON organization and thus support the motto “few train many” while increasing training efficiency. This supports the adage: “Use humans for human interaction and machines for laborious tasks”.
- To decrease the technical preparation time for the exercise.
- To reduce the integration efforts.

The VIKING-18 simulation environment

To execute the use-case in support of the development of the Reference Architecture the following subset, out of the whole VIKING-18 requirements set, was selected to comply with in the development of the Solution Building Blocks:

- Since a key aspect is to support the “train as you fight” methodology, the tools used by the TA shall only provide functionality and information as would be found in live systems.
- There is a need for the TA to perceive a realistic situational awareness in the maritime domain. Therefore, a maritime recognized picture shall be assembled from the available information in the simulation environment, to expose the TA to all civilian vessel traffic other than the specific ships included in the incidents. This will challenge the trained organization to manage information on a large scale.
- In order to support the “train as you fight” methodology, the recognized maritime picture shall be presented as AIS traffic (Automatic Identification System).
- The amount of maritime traffic in the scenario must be adaptable, depending on the staff’s training level.

The simulation environment architecture is based on the NATO standard High Level Architecture (HLA) (IEEE 1516-2010 (IEEE, 2010) and NATO STANAG 4603 (NATO, 2015)). The simulation backbone is compliant with NATO Education and Training Network (NETN) Federation Architecture and FOM Design (FAFD) guidelines (NETN FAFD/STANREC 4800).

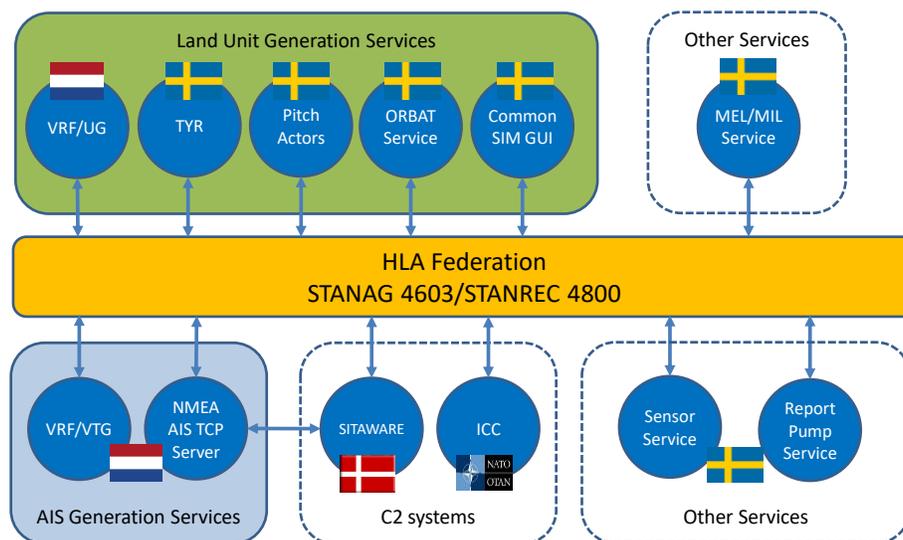


Figure 3: VIKING-18 Solution Architecture.

The VIKING-18 simulation environment of which the architecture is shown in Figure 3 includes many new services like:

- A VR-Forces based Vessel Traffic Generator (VRF/VTG) and a NMEA AIS TCP Server which together offer realistic civilian maritime traffic, including the transmission of AIS information which can be received and displayed by the C2 systems. (Kuijper, 2013)
- Two Command & Control (C2) systems as the main interface for situational awareness to the TA.
- Four different simulators for generating land, air and maritime units.
- An “ORBAT service” to publish an ORBAT in the federation using MSDDL.
- A “Common Simulation GUI”, a generic tool for controlling simulated units (Pitch, sd).
- A MEL/MIL Service provided by the EXCON management tool “Exonaut” (4C Strategies, sd).
- A Sensor and Report Pump Service for the automatic generation of intelligence reports (Ministry of Defence, sd).

The focus of this paper is on the Land Unit Generation Services and AIS Generation Services.

REFERENCE ARCHITECTURE FOR MTDS

This chapter explains what the (to be developed) MTDS Reference Architecture is and lists several (potential) Architecture Building blocks identified from the VIKING-18 exercise. First the concept of a reference architecture is explained.

Architecture Definitions

Architectures can be designed at various levels of abstraction and different types of architecture can be distinguished. There is little consensus in general on the various levels of abstraction or on naming conventions. In this section the concepts that are relevant for this paper are explained. The same approach as in the Technical Reference Architecture for M&S as a Service (MSaaS) (NATO, 2017) is followed, where several types of architecture are defined to declare an architectural framework. These types of architecture are in line with the architectural types in the NATO Architecture Framework (NAF) (NATO, 2016) and their naming and relationships are illustrated in Figure 4.

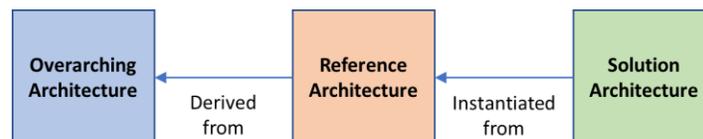


Figure 4: Architecture types.

An *overarching architecture* is a high level description of the desired capabilities of a system. It describes to a certain level of detail the functional requirements, i.e. what is needed in terms of capabilities. For the purpose of the MTDS Reference Architecture the NATO C3 Taxonomy (NATO-NCI, 2015) is considered as an overarching architecture. The NATO C3 Taxonomy is a model that represents the concepts and their relationships involved in all the life-cycle activities for NATO's Consultation, Command and Control (C3) capabilities. For the development of the MTDS Reference Architecture, the NATO C3 Taxonomy is used as a source for identifying and selecting Architecture Building Blocks for the reference architecture.

A *reference architecture* is generally an abstract, solution independent description of an architecture and provides a “template solution” for a concrete solution architecture. A reference architecture focuses on a specific subject area such as MTDS and how certain capabilities can be met. Two notions are important for the MTDS Reference Architecture, namely Architecture Building Block (ABB) and Architecture Pattern (AP) (NATO, 2017). ABBs are the elements that constitute the reference architecture. Each ABB has attributes that specify its purpose, function and interfaces, as well as applicable standards. APs are high-level guidelines for composing ABBs (Buschmann, 1996). An AP also has attributes that define the function of the composition.

The MTDS Reference Architecture is focused on MTDS and shall therefore include ABBs and APs with MTDS specific functions and interfaces, and shall use NATO standards for simulation interoperability. It shall also include guidelines for implementing ABBs and APs in so called Solution Building Blocks (SBBs).

A *solution architecture* is derived from the Reference Architecture and illustrates the implementation of the MTDS environment to support a specific MTDS exercise. In the NATO Architecture Framework (NAF) this type of architecture is called a Target Architecture. There can be several different (MTDS) solution architectures instantiated from the MTDS Reference Architecture, using the APs and ABBs described in that architecture. A solution architecture focuses on the with-what question. At this level choices are made w.r.t. for example simulation protocol and middleware solutions (DIS, HLA), gateway components, service implementations, simulation data exchange models (HLA FOMs), and simulation environment agreements. Reference data exchange models (such as the HLA RPR FOM) are provided through the MTDS Reference Architecture, and at this level agreements are made as to specifically which parts will be used from these reference data exchange models for the solution at hand. A solution architecture includes a listing of SBBs. The difference between ABB and SBB is illustrated in Figure 5.

Architecture Building Block (ABB)	Solution Building Block (SBB)
<ul style="list-style-type: none"> - Captures application and technology requirements - Lists applicable standards - Directs and guides the development/acquisition of SBBs <p>Examples:</p> <ul style="list-style-type: none"> - Message Oriented Middleware Services; standards include HLA IEEE 1516-2010 - Radio Services 	<ul style="list-style-type: none"> - Defines the component that is used to implement the functionality - Defines the implementation - Is vendor-aware <p>Examples:</p> <ul style="list-style-type: none"> - MaK HLA-RTI - ASTi Radio Simulator

Figure 5: Architecture Building Block vs Solution Building Block.

Architecture Building Blocks Identified From VIKING-18

This section elaborates two ABBs that have been identified from the VIKING-18 requirements (see also (Reus, et al., 2018)).

Automatic Identification System (AIS) Generation Services

The AIS Generation Services simulate maritime traffic and generate the associated AIS data in the area of interest. Several types of vessels can be simulated, with varying densities on defined shipping lanes and following different routes, as specified in the vessel traffic scenario.

Purpose:

The purpose of AIS Generation Services in the VIKING-18 exercise is to:

- Stimulate the TA with specific maritime traffic in the NFS.
- Increase trainee load by adding background “noise” with different levels of shipping intensity in the NFS.
- Present AIS data to the TA via an operational C2 system.

The AIS data is made available through several interfaces, one of which is the NMEA protocol (National Marine Electronics Association) (FreeNMEA.net, sd) via TCP/IP. The latter interface enables any TCP/IP enabled NMEA listener (also named “client”) to receive AIS data. An example of vessel traffic (VIKING-18 scenario) is provided in Figure 6, using OpenCPN (OpenCPN Chart Plotter Navigation, sd) for visualisation.

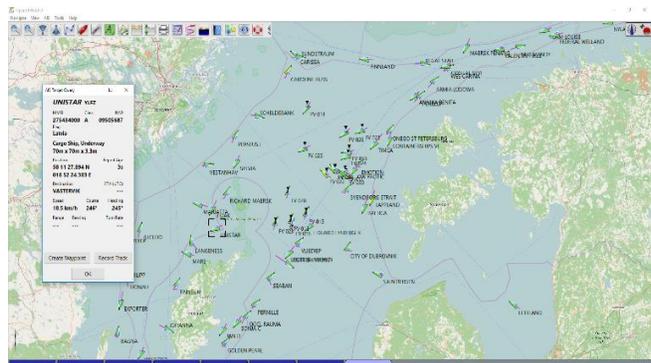


Figure 6: AIS data can be viewed with an NMEA listener, in this case OpenCPN.

In VIKING-18 the AIS Generation Services are provided by two components:

1. MaK VR Forces with the TNO Vessel Traffic Generator (VTG) plugin (Kuijper, 2013) for the simulation of vessels and generation of simulated AIS data, and
2. the TNO NMEA TCP Server for the generation of a “live” NMEA data stream from the simulated AIS data.

Functional requirements

The following functional requirements have been identified for the AIS Generation Services, based on the solution used in the VIKING-18 exercise and the Vessel Traffic Generator described in (Kuijper, 2013).

The AIS Generation Services shall:

1. provide the means to define a maritime traffic scenario.
2. the maritime traffic scenario definition shall specify:
 - a. Area of Interest
 - b. Location of harbours within area of interest
 - c. Other areas, such as fishing areas.
 - d. Shipping lanes and required densities (e.g. min, max, average) for vessel types (e.g. ferry, fishing boat).
 - e. Location data, shipping lanes and time tables for specific vessels.
 - f. Vessel data required for AIS messaging (e.g. ship MMSI, name, call sign, IMO number).
3. provide the means to simulate maritime traffic in real-time within the area of interest according to the maritime traffic scenario.
4. provide the means to generate standard NMEA AIS class A position reports, ship status and voyage related data messages for AIS-capable vessels.
5. provide the means to start the simulation at a given scenario time.

An example of parts of the maritime traffic scenario used in VIKING-18 is shown in Figure 7. This figure shows the shipping lanes and fishing areas, used by the AIS Generation Services for the generation of maritime traffic.

Applicable Standards

The AIS class A messages can be provided through several interfaces: HLA RTI and NMEA/AIS over TCP/IP or UDP/IP. The AIS Generation Services shall support the following standards:

1. HLA RPR-FOM 2.0 (SISO, 2015) for the exchange of ground truth ship platforms within the simulation environment.
2. HLA AIS FOM module for the exchange of AIS messages within the simulation environment.
3. NMEA 0183 for the exchange of AIS message with NMEA listeners via TCP/IP and/or UDP/IP (FreeNMEA.net, sd).

The HLA AIS FOM module currently models AIS class A Position Report messages and class A Ship Status and Voyage Related Data messages.

The AIS FOM module that is used in VIKING-18 is a candidate FOM module for addition to the NETN family of FOM modules (NATO-NETN, 2015) and will be reviewed and processed by NATO MSG-163 (Evolution of NATO Standards for Federated Simulation).

Solution Building Block

The AIS Generation Services are provided by two components: MäK VR-Forces with the TNO VTG plugin for the simulation of vessels and generation of simulated AIS data, and the TNO NMEA TCP Server for the generation of the corresponding non-ground truth NMEA data stream. Both components are containerized (using Docker container technology), and can be deployed and replicated on demand via a simple MSaaS Portal.

In the recent years the use of container technology has become very popular. In a nutshell, Docker (Build, Manage and Secure Your Apps Anywhere, 2019) is an open-source platform to build, ship, and run distributed container-based



Figure 7: Maritime scenario development in Google Earth: Shipping Lanes (white) and fishing areas (blue).

applications. Docker enables the creation of lightweight VMs – called container images – that can run on, in principle, any Linux or Windows host. A container image contains everything that an application needs in order to run, using a so-called Docker Engine. Because container images are lightweight and have a standard package format, it is easy to ship and run them on the fly (van den Berg, 2016). Docker container technology is used in VIKING 18 to containerize the HLA based simulation components for the AIS Generation Services and the Land Unit Generation Services.

Land Unit Generation Services

The Land Unit Generation Services provide the capability to simulate land-based units. The units can be controlled by EXCON using Low Level Battle Management Language (LLBML) tasks and report status/progress via LLBML reports. The tasks and reports are modelled by the NETN LLBML FOM module (NATO-NETN, 2015). The geographical terrain and the initial position of the units is defined by the scenario, provided via an MSDL file.

The purpose of Land Unit Generation Services in the VIKING-18 exercise is to:

- Manually control some land based units throughout the exercise.
- Trigger specific events at certain locations at certain times.

In VIKING-18 these services are provided by the following simulation systems: TYR, MäK VR Forces and Pitch Actors. The land units are controlled from the Pitch Common Simulation GUI, providing the user facing functionality to the backend Land Unit Generation Services (see Figure 8).

Functional requirements

The Land Unit Generation Services shall:

1. Provide the means to configure the possible behaviour of land units.
2. Enable the initialization of units via an initial scenario.
3. Start/restart the simulation execution once the units are initialized.
4. Provide the means to control units via a standard interface.

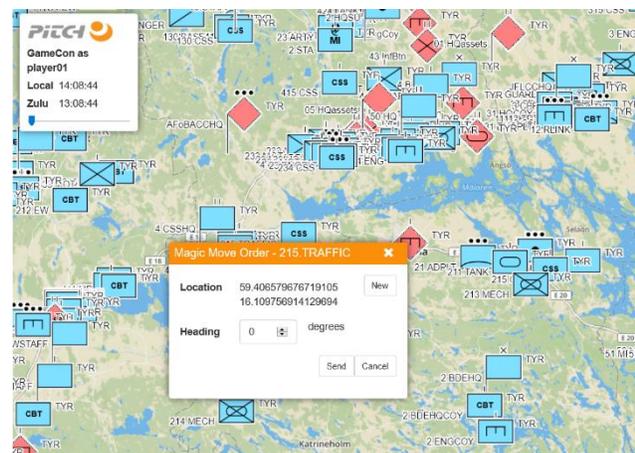


Figure 8: Controlled land units from the Pitch Common Simulation GUI.

Applicable Standards

The Land Unit Generation Services shall use several HLA FOM modules for the exchange of simulation data within the simulation environment:

1. HLA RPR-FOM 2.0 (SISO, 2015) for the exchange of ground truth unit data within the simulation environment.
2. NETN LLBML FOM module (NATO-NETN, 2015) for the exchange of unit tasks and reports within the simulation environment.
3. MSDL FOM module for the exchange of the initial scenario within the simulation environment.

Several extensions to the NETN LLBML FOM module were required for VIKING-18 (e.g. “magic move”) and have therefore been implemented in some of the Land Unit Generation Services. These extensions are a candidate for addition to the NETN standard and will be provided to NATO MSG-163 (Evolution of NATO Standards for Federated Simulation) for review. MSG-163 is currently addressing several (proposed) changes to the NETN family of FOM modules.

Solution Building Block

The Land Unit Generation Services are provided by several simulation systems (TYR, MäK VR Forces, Pitch Actors). VR-Forces was also containerized (see AIS Generation Services above) and deployed on-demand.

LESSONS LEARNED FROM VIKING-18

The VIKING-18 exercise was successfully completed on April 26 (ENDEX). The VIKING 18 simulation environment has been used throughout the exercise to support the Response Cells and stimulate the Training Audience. In general the VIKING-18 simulation environment has been the main supporting tool in the VIKING-18 exercise. Following below are the lessons learned in relation to the ABBs and SBBs for the AIS Generation Services and Land Unit Generation Services.

The AIS Generation Services implementation provided a realistic maritime picture to the TA through the C2 systems. Over 2000 vessels could be generated simultaneously in the area of interest. Nevertheless, several new features and improvements were identified, including:

- Ability to (temporarily) take control of specific vessels in order to manually create anomalous behaviour in the area of interest. The use of LLBML for command and control of individual vessels may be an option.
- The need for a database with information about vessels; simulation systems can use this database for configuration purposes, while the TA can use this database to retrieve further information about vessels in the area of interest.
- More randomness in the initial spread of vessels in the area of interest. Although vessels are initially spread across a shipping lane with some randomness (both in spacing between vessels and distance from the shipping lane), this turned out to be somewhat predictable when re-running the same scenario over and over. The ABB description should therefore include requirements for random behaviour and spread of vessels in the area of interest.
- Various small improvements in the maritime scenario. Such as positioning the start and end-point of some of the shipping lanes in harbours or at least outside the area of interest. Although this may not result in additional requirements for the ABB, the positioning of the begin and end point of shipping lanes is noticeable and therefore important to the TA.

The implementations of the Land Unit Generation Services support LLBML to some extent, and it is possible to command and control the land units in a uniform way via the Pitch Common Simulation GUI. It turned out that the provided information via the Common Simulation GUI was not sufficient for the EXCON staff to command and control the units from the GUI as the scenario was unfolding. For example, detailed logistical and resource information of each unit was missing in the GUI, neither was this information provided by the simulation systems using LLBML. It is clear that functional requirements to cover this type of information should be included in the ABB descriptions.

The use of MSDL to initialize the Land Unit Generation Services and the ability to dynamically adapt the ORBAT during simulation execution from a single user facing application was very successful. This reduced the time to make ORBAT updates and ensured correlation between the different systems. It would be worthwhile to investigate if MSDL can also be used to initialise the maritime scenario for the AIS Generation Services.

The provisioning of service implementations using Docker container technology proved fairly flexible. In addition, the use of container technology also enabled a relatively easy transfer of different component versions between the TNO MSaaS Docker Registry and the VIKING-18 simulation environment. However, the introduction of new technology and the as-a-service approach increased the complexity of monitoring and control of the individual simulation systems. As services can now be scaled up and down on demand (and can run anywhere), the availability of adequate and coherent service management and control functionality to oversee the execution of these simulation services becomes evident. These service management and control services should also provide sufficient insight in the internal state of individual simulation services. For example to understand why certain simulation services respond too slow or do not respond at all. Something that is lacking with current simulation systems anyway and hence requires the development of additional APIs to query internal state data.

Many of the VIKING-18 simulation services (i.e. for AIS Generation, Land Unit Generation, Tracking, and Reporting) are “state-full” services, i.e. services that maintain time-dependent simulation state data. In VIKING-18 these services interact via the HLA-RTI to exchange distributed simulation state data and to create and maintain a common and coherent view on the entire simulation. A few of these simulation services provide a service interface to “external” user-facing applications such as the AIS Generation Services and Reporting Services. State-full services are inherently difficult to scale and only the AIS generation service implementation could be scaled up/down depending on demand. For VIKING-18 this solution was both sufficient and successful. However, other exercises may need more scalability for certain services and hence require state-less service implementations.

SUMMARY AND RECOMMENDATIONS

An MTDS Reference Architecture that can serve as a template for MTDS exercise solutions is currently under development for the Netherlands armed forces in close cooperation with its coalition partners. The MTDS Reference Architecture is being developed by using a two track approach. First, a paper study is performed to identify building blocks from existing sources, such as national activities, the NATO C3 Taxonomy and the NATO MSG-136 MSaaS Technical Reference Architecture. Second, collective training exercises, NATO MSG activities and other opportunities are leveraged to identify potential services and explore/test solutions. One of these is the VIKING-18 exercise as described in this paper.

The VIKING-18 exercise yielded several potential building blocks for the MTDS Reference Architecture, such as AIS Generation Services and Land Unit Generation Services. Solutions for these building blocks must (together) produce a realistic land and maritime picture for the TA to enable them to act in their normal environment, using their normal procedures and supported by their live systems. In addition the need for adequate Service Management and Control Services to oversee the execution of simulation services became clear in VIKING-18. More attention should be paid to these so called enabling services.

While defining the AIS Generation Services and Land Unit Generation Services building blocks and developing solutions for them, several improvements have been identified for the applied standards. These improvements will be submitted as change requests to NATO MSG-163 (Evolution of NATO Standards for Federated Simulation). In several new FOM modules have been developed. The AIS FOM module and the MSDL FOM module are candidates for addition to the NETN family of FOM modules. Furthermore, the developed solutions such as the AIS Generation Service, are modular, interchangeable and independent of a specific exercise. They are developed as services in the spirit of the NATO MSG-136/MSG-164 MSaaS concept.

Although not the focus of this paper, several other potential ABBs have been identified based on the solution building blocks used in VIKING-18. Some of these ABBs have already been defined in the MSaaS Technical Reference Architecture (NATO, 2017), however requirements need to be refined for these ABBs based on VIKING-18 (work in progress) and future MTDS exercises (e.g. VIKING-21).

The conclusions and recommendations are in summary:

For the ABBs:

- AIS Generation Services:
 - Investigate the use of LLBML to command individual vessels.
 - Investigate the use of MSDL to initialise the maritime scenario.
 - Propose to add the AIS FOM module to the NETN family of FOM modules.
- Land Unit Generation Services:
 - Develop additional requirements for logistical and resource information, and look into potential standards for exchanging this type of information.
 - Propose to add the identified FOM improvements in an update to the NETN LLBML FOM module.
 - Propose to add the MSDL FOM module to the NETN family of FOM modules.
- New Services / other ABBs:
 - Develop requirements for Traffic Database Services to provide information about e.g. vessels, ports, shipping lanes.
 - Develop requirements for Service Management and Control Services to oversee the execution of simulation services.
 - Define new Services / ABBs based on the VIKING-18 results.
- Develop architecture guidelines for a balanced use of state-full and state-less services.

For the SBBs:

- Provisioning of service implementations using Docker container technology provides flexibility.
- Various improvements in the maritime scenario have been identified.

The MTDS Reference Architecture and the building block implementations will alleviate some of the main obstacles in providing cost-effective simulation based training opportunities. The MTDS Reference Architecture design and the service's implementations will evolve in the coming years and further results will be published.

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