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M&S as A Service (Msaas): Proof of Concept Development and Integration Of A Sensor-As-Service for A Virtual Flight Training Eurofighter Simulation

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ABSTRACT

The NATO Modelling and Simulation Group MSG-136 "Modelling and Simulation as a Service (MSaaS)" as well as the follow-on MSG-164 "M&S as a Service (MSaaS) Phase 2" targets to develop a service architecture providing rapid deployment of interoperable and credible simulation environments.

This paper presents the results of a proof of concept implementation of an optical and infrared sensor which is realized as a Sensor-as-a-Service. This Sensor-as-a-Service can be provided to other simulators or real operational systems as a lightweight service which can easily be deployed and hosted e.g. on a NATO cloud. As a use case the sensor-as-a-service was integrated into a flight training Eurofighter simulator of Airbus.

Through this proof of concept implementation it was investigated, how a sensor-as-a-service can be designed and hosted on a cloud system and be interconnected with a virtual flight training Eurofighter simulation.

A key issue in infrared image generation is to provide a virtual 3D terrain including multispectral information such as terrain surface types. In this proof of concept demonstration the OGC standard Common Data Base (CDB) was selected. Moving objects are received either through DIS/HLA distributed simulation networks or optionally passed through a service request to the sensor as a service. The sensor parameters like the spectrum, orientation or zoom level can be steered by the virtual Eurofighter cockpit through the service interface.

1.0 INTRODUCTION

Modelling and Simulation (M&S) is a key enabler for the delivery of capabilities to NATO and Nations in the domains of training, analysis and decision-making. M&S solutions have to be integrated seamlessly in future computer information systems capabilities to ensure increased efficiency, affordability, interoperability and reusability. NATO and the nations regularly use distributed simulation environments for various purposes (e.g., training, mission rehearsal, or decision support in acquisition processes). Achieving interoperability between participating systems and ensuring credibility of results still require substantial effort with regards to time, personnel, and budget. There is a lack of simulation standards, agreements, and reference architectures that focus on higher levels of interoperability and simulation credibility, compared to the current standards like DIS (Distributive Interactive Simulation) or HLA (High Level Architecture), which mainly focus on technical, syntactic and – to a limited degree – on semantic interoperability.

The follow-on activities in MSG-164 will mature MSaaS from a lab environment to an operationally relevant environment and conduct necessary research and development efforts. Through close cooperation with the operational user community and participation in exercises, this activity contributes to realizing the MSaaS vision that "M&S products, data and processes are conveniently accessible and available on-demand to all users in order to enhance operational effectiveness" with the following objectives:

- advance and promote operational readiness of M&S as a Service;
- align national efforts and share national experience in establishing capabilities of M&S as a Service;
- investigate critical research and development topics to further enhance benefits from M&S as a Service.

This activity will establish a cloud-native demonstrator to support the M&S as a Service approach by including an exemplary flight simulator device (representing a real operational user interface) that connects to several national services, like computer generated forces service, sensor service as well as two weapon services. The conceptual vision is to offer a simulation environment that is easy to setup no matter in which network it's used and the central provision of main functionalities which can be of interest for other systems or client.

2.0 DEMONSTRATOR CONCEPT AND ARCHITECTURE

2.1 Allied Framework for MSaaS

Figure 1 gives a high level overview of the Allied Framework for MSaaS as described in the MSG-136 Operational Concept Document (OCD) – see [3]:

The basic idea is to "servicize" the M&S components to Modelling-/Simulation Services (e.g. a computer generated forces service) or Data Services (e.g. a Synthetic Environment Service providing terrain data). In addition, there might be for management purposes Repository- and Registry Services as well as MSaaS Portal Services, to Discover, Compose and Execute Services within a MSaaS portal.

Those services may be hosted either in National clouds, a NATO cloud or in Mission & Coalition clouds. In addition, those clouds need to be accessible through legacy systems like Thin Clients, Simulations / Simulators and operational C2 (command and control) systems in order to provide those systems the necessary services.

Finally, the setup of the MSaaS environment is supported by the MSaaS Technical Reference Architecture and the MSaaS Process and Governance Policies.

The objective is to realise the MSaaS vision that M&S products, data and processes are conveniently accessible and available on demand to all users in order to enhance operational effectiveness.

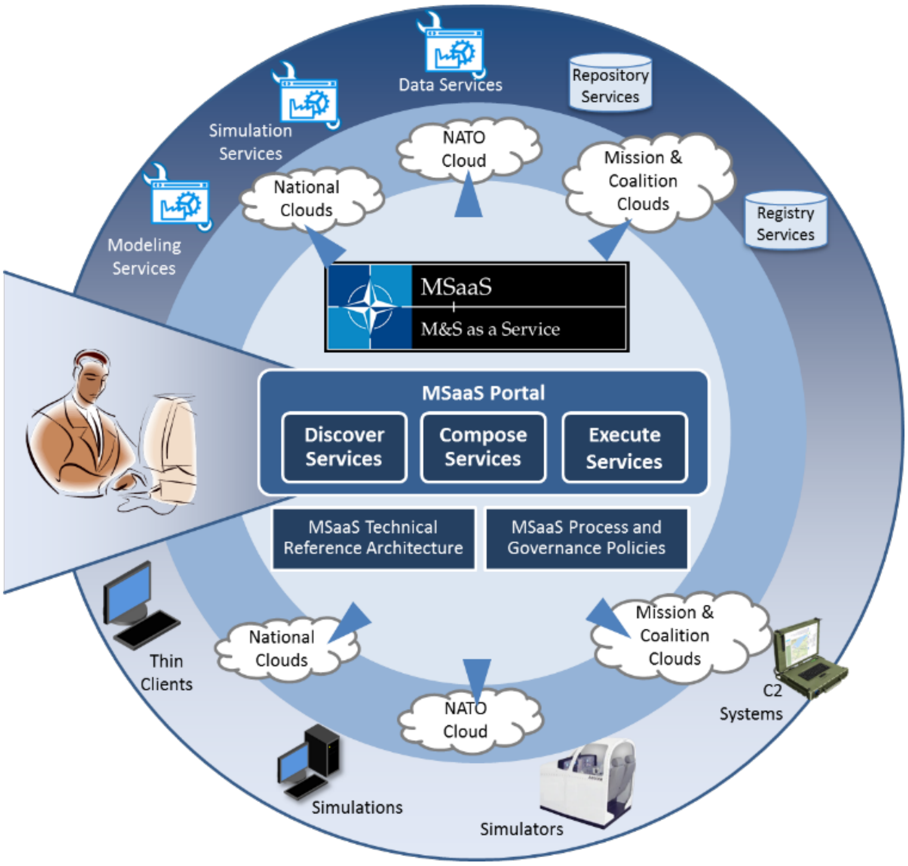

Figure 1: The Allied Framework for MSaaS

2.2 Demonstrator Concept

Based on the Allied Framework for MSaaS and the MSaaS Technical Reference [11], the German MSG-164 members designed a proof of concept demonstrator to evaluate the feasibility of parts of the MSaaS approach.

The proof of concept demonstrator should not be limited to one specific M&S application area, say, for training or for simulation-based analyses, but must show the general technical capabilities of a MSaaS system implementation. Each chosen system within the demonstrator in Figure 2 should represent a specific component of the architecture:

- Most units of all forces managed and distributed within the MSaaS service cloud are computer generated forces (GCF) simulated by a **CGF simulation service**. For this purpose, the German agent-based 3D simulation model PAXSEM from AIRBUS was selected. PAXSEM as a CGF service may run without user-interaction, as it can be controlled remotely through a web **simulation control application COP**.
- The **weapon effect service** (WES) is able to monitor a DIS/HLA federation in order to centrally compute weapon effects on simulation entities in order to help to solve fair-fight problems. As an extension, the **exterior weapon service** (EWS) is capable to be used to provide weapon models outside of a simulation. The service is capable to be used for ballistic weapons (e.g., artillery) as well as for unguided rockets and guided missiles.
- The **virtual sensor service** is capable of providing an optical (and infrared) view of an electro-optical sensor of simulated entity in HLA/DIS federation. The sensor orientation may be controlled through

a network protocol (currently through a proprietary network protocol of a GE camera vendor - future extendable through a REST API).

- A flight training simulation including a **virtual cockpit** is representing a Eurofighter system that is publishing its own entity into the service cloud.

Figure 2: Concept overview of the Proof-of-Concept Demonstrator

3.0 DEMONSTRATOR COMPONENTS AND IMPLEMENTATION

In order to connect the demonstrator components, two buses are foreseen: Simulation bus and Service bus. The simulation bus puts up a standard DIS communication protocol, using a standard object model (Real-time Platform-level Reference (RPR v2) - based) to exchange data between the services. For cases, when the services need an extended or custom communication channel, the service bus is introduced providing a REST interface.

3.1 PAXSEM CGF Service

The CGF service is realized through the agent-based simulation framework PAXSEM for technical & tactical simulation of operational scenarios. PAXSEM has been developed by AIRBUS on behalf of the German Armed Forces since 2008 and has already provided a proof of concept when applied in several simulation based analyses involving the method Data Farming as well as a scenario generator in distributed environments such as the German system demonstrator VIntEL (see [6][7]).

PAXSEM engages so called agents, who interact in virtual scenarios. These agents independently execute activities, perceive their environment (sensors), intervene therein (effectors) and react upon the changes in the respective ambience (dynamics). This way, multiple differential decision alternatives are created describing a wide sample space. The mutual interference of individual agents allows courses of simulation that are often impossible to predict and uniquely confined by the agents' abilities. PAXSEM is applied in two following mode of simulation.

PAXSEM as a scenario driver within a networked simulation environment: Here, PAXSEM feeds in data in real-time into a distributed simulation environment and is a peer federate to other virtual and real systems connected. Besides training such testbeds enable to do conceptual examinations whose real-world execution would be difficult (consumption of scarce resources) or even impossible (safety regulations, systems to be developed).

Among its multiple standards PAXSEM comes with standardized interfaces which allow its flexible integration in heterogeneous testbeds or other experimental activities. Through the interfaces PAXSEM can generate a wider operational picture when CGF provide a simple stimulus or dynamic interaction to other simulators or real systems connected. Therefore PAXSEM has a built-in C2-Sim Gateway module which is able to feed C2 systems through standards, such as C-BML, STANAG 5527 conform NFFI and a range of other standardized formats. PAXSEM can feed tailored scenarios into compatible simulators (e.g., through DIS or HLA [4]) e.g., for training or analyses.

3.2 Weapon Services

3.2.1 Weapon Effect Service

The WES is the central component in a distributed environment that computes the weapon effect on simulation entities on the basis of a munition detonation (see Figure 3). Thus, the service evaluates the geographic position of the munition detonation and calculates the resulting direct and indirect (coverage by other entities considered) damage state of the requesting simulation (target) entity. In the follow up, the calculation result is published back to the distributed environment on basis of a weapon effect.

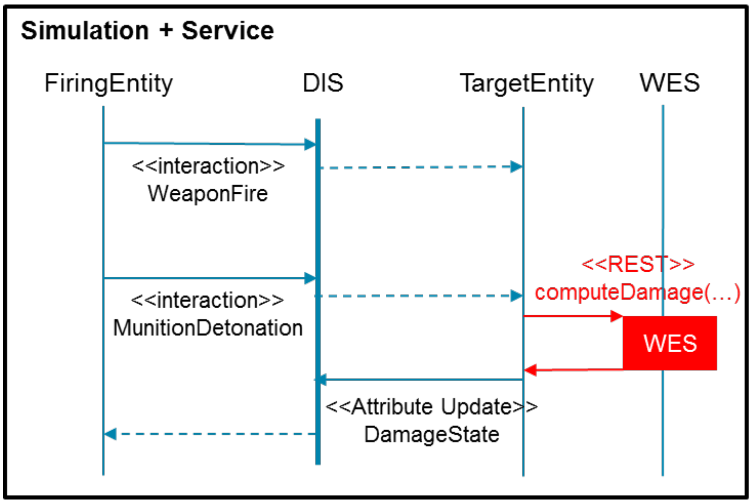

Figure 3: Communication model in context of a weapon effect

3.2.2 Exterior Weapon Service

The EWS simulates, in addition to the WES, the whole process of weapon fire, missile creation throughout the munition detonation (see Figure 4). Depending on the missile model, the missile flight is calculated and published back continuously (including attribute updates, e.g., spatial position) to the distribution environment. As soon as the flight model calculates the munition detonation, the corresponding interaction is sent back to the distributed environment.

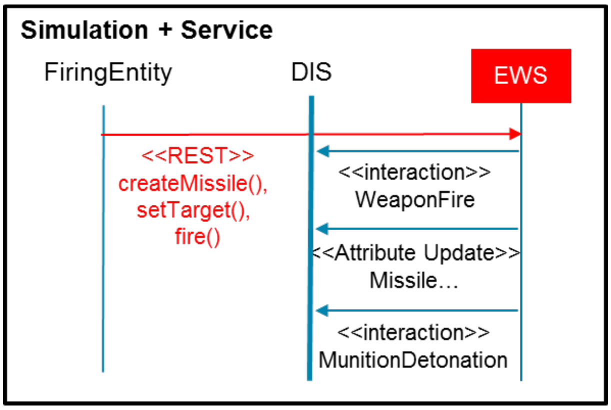

Figure 4: Communication model in context of aiming and firing

3.3 Virtual Sensor Service

The Virtual Sensor Service is a component in a distributed environment that enables to attach a virtual sensor to an entity of interest and to stream that specific camera view to the requestor (see Figure 5). At first, the sensor service connects to the simulation bus to reflect on the available entities. After a client registered for a camera component, an update requests allows to change the sensor relative placement, sensor orientation as well as to detach it from the entity of interest again (fixed position sensor). On another request, the sensor returns the endpoint of the video stream considering the selected camera spectrum, an optical, infrared or thermal view. The video stream itself is based on STANAG 4609 which includes metadata regarding the sensor configuration, too.

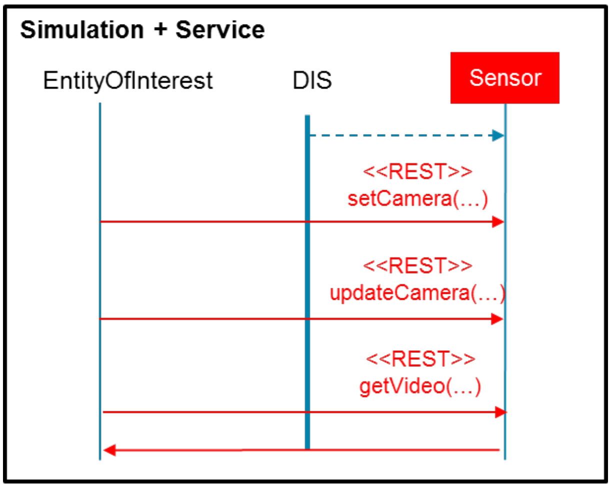

Figure 5: Communication model in context of virtual sensor

3.4 Virtual Cockpit of Eurofighter

The flight training device (FTD) Eurofighter simulation features a cockpit similar to the conventional cockpit in Figure 6. It incorporates three full colour multi-function head-down displays (MHDDs), a wide angle head-up display (HUD) as well as other command and control elements to interact with the Eurofighter. As a separate input device a throttle and centre stick (HOTAS) is attached to the FTD system.

A LITENING targeting pod (LDP) is an advanced precision targeting pod system currently operational with a wide variety of aircraft worldwide, including the Eurofighter. LITENING significantly increases the combat effectiveness of the aircraft during day, night and under-the-weather conditions in the attack of ground and air targets with a variety of standoff weapons (i.e., laser-guided bombs, conventional bombs and GPS-guided weapons). The targeting pod contains a high-resolution, forward-looking infrared (FLIR) sensor that displays an infrared image of the target to the aircrew.

As a replacement for the missing physical targeting device, the virtual sensor service is used to inject an infrared camera view into the MHDD. The same service interface is used to forward the optical camera view to the HUD representing the (environment) view in front of the cockpit. The camera views are synchronized in regards to position and orientation over the simulation bus which is crucial to a sound user experience.

Figure 6: Illustration of a conventional Eurofighter cockpit

3.5 COP Service

The COP service is a lightweight JavaScript based client side web application. It Uses OpenLayers to display all types of maps using any OGC WMS (Web Map Service – see [8]). The COP may be used as a static scenario editor / visualizer. In addition, the user interface supports the visualization of KML [9] and MSDL [10] files for dynamic military scenarios including APP6 symbology.

For this concept demonstrator, the COP service in Figure 7 receives the ground truth unit positions and tactical symbols through KML which is provided by a REST service hosted by the PAXSEM CGF service.

The COP service is able to remotely control the PAXSEM CGF simulation run. So, the operator is able to start, pause and stop a given scenario. The simulation control hereby is performed through a REST interface of PAXSEM.

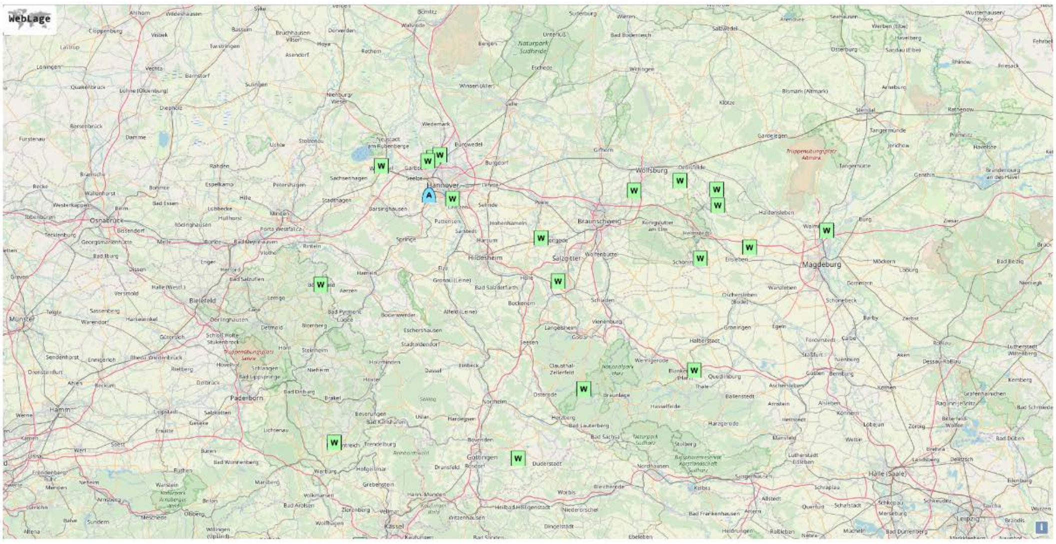

Figure 7: Web application displaying COP

4.0 SENSOR SERVICE IMPLEMENTATION DETAILS

The workflow diagram of the sensor service in Figure 8 shows the inner details that consist of an offline process as well as a runtime process:

The result of the offline process is a generated terrain for the 3D simulation model PAXSEM and an infrared database that includes (surface) temperatures and atmospheric information specific for the former result. In the later runtime process these two results are crucial for applying and using the sensor service.

The individual steps of workflow are described in the next two chapters more in detail.

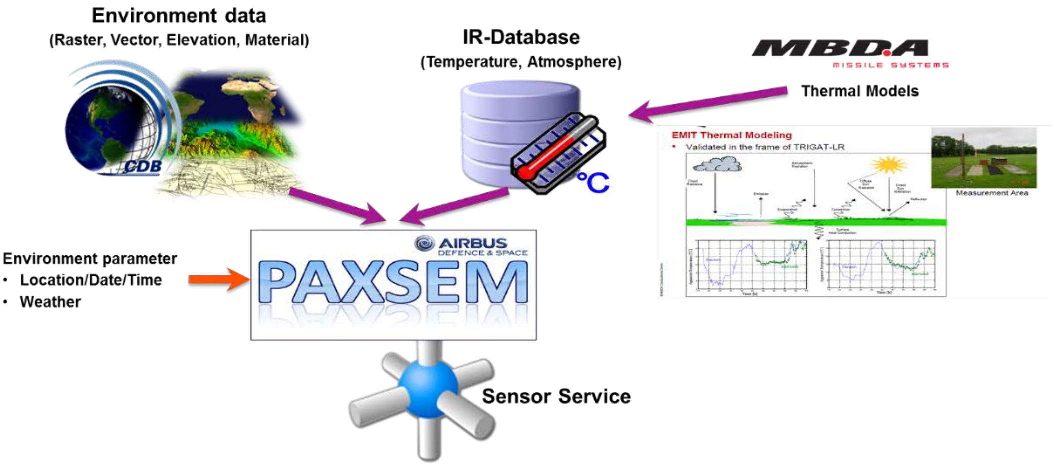

Figure 8: Workflow process of (infrared) sensor service

4.1 Preparation of the sensor service in offline context

In the preparation phase the environment data is examined with regards to the central CDB model which defines a structure for a single, "versionable", virtual representation of the earth. For the service implementation the main focus is on the CDB layers: imagery, altimetry and material.

On the one hand, the layer data is used to generate an optimised terrain for PAXSEM, due to performance reasons and to thermal considerations. In the latter case, the terrain elements are classified by their material definition (texture-based, pixel-based) so that the infrared model is able to generate sound thermal images, such as emitted radiation from an object and radiation transfer in atmosphere.

On the other hand, the layer data is used as an input for the thermal models which feed the IR-Database with pre-calculated results. This cache mechanism is essential, as it acts as a lookup table for the infrared model.

4.2 Application of the sensor service in runtime context

At first, the sensor service usually loads a scenario (gaming area) on which the scene is playing. This means, the underlying pre-generated terrain is loaded. Moreover, the scenario describes the environment parameters like weather condition, exact date and time and the corresponding location that are valuable information to simulate the infrared view. As a next step, the sensor itself is calibrated with the help of a configuration file which specifies the sensor parameters like field of view, wave length or image filters that are chained together etc.. Last, the thermal information of the infrared database is imported and merged into the runtime context considering the specific scenario situation. That includes the temperatures for the surface, atmospheric radiation paths and relevant scene object material information.

If these preconditions are successfully passed, the sensor service waits for incoming requests to serve the sensor view, either as optical (Figure 9) or as infrared image (Figure 10).

Figure 9: Target view (optical)

Figure 10: Target view (infrared, white hot)

5.0 DEMONSTRATOR SCENARIO

5.1 Scenario Overview

The purpose of this scenario is to demonstrate the feasibility of the MSaaS architecture based on the demonstrator concept as introduced in chapter 2.2. The goal is to use the CGF to provide the simulated environment for all other services. Then, the virtual cockpit is used as a lightweight FTD that interacts with the CGF. Secondly, the controls (of the virtual cockpit) connect to the weapon services as well as the head-up displays reach out to the virtual sensor service to enable a user to interact with the virtual cockpit.

As a quick introduction, the scenario map in Figure 11 shows the initial operational areas and scenario elements which are desribed more in detail in chapter 5.2.

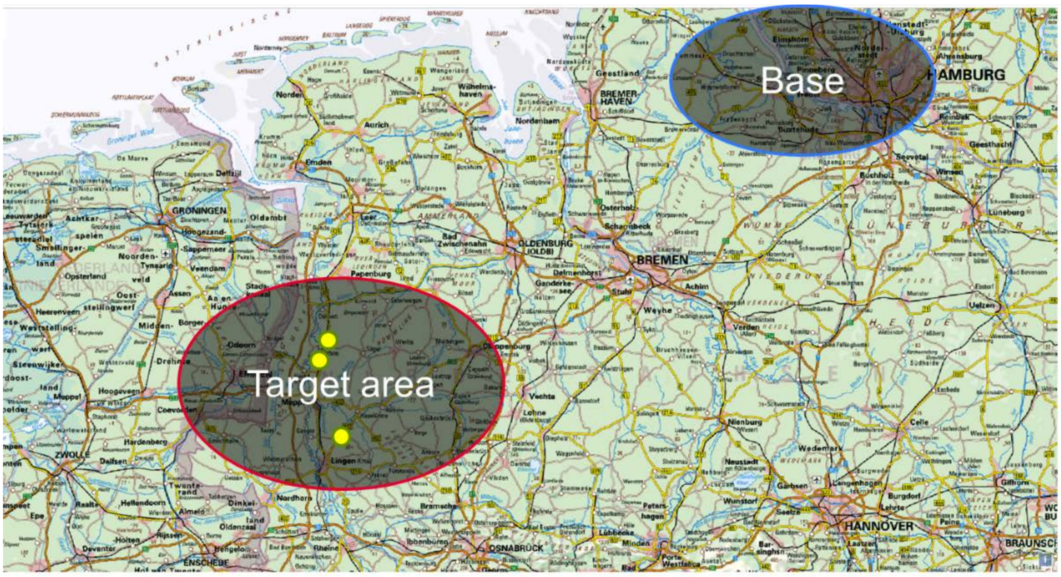

Figure 11: Scenario map and elements

5.2 Scenario Course of Events

Finally, the following technical service workflow is demonstrated:

- All services which are required to initialise with terrain data, execute a request to the central, shared data cloud to setup the virtual environment. The COP service requests this through its OGC WMS interface to a 2D map service.
- The scenario operator starts the CGF service through the COP service, loading a reconnaissance scenario. The CGF service starts simulating a scenario with air- and ground-based simulation entities (e.g., blue air tracks and neutral/red pickups and trucks).
- The CGF service tasks a simulated air track to conduct a reconnaissance mission. The updated picture is displayed in the COP service in parallel.
- The air track arrives at the target area and detects some suspicious vehicles. One of the vehicles is attacking the air track on its mission. The weapon effect and damage state for the air track are calculated by the central WES, if any.
- Based on the current situation, the air track is leaving the target area and returning to home base.
- As a result, the virtual cockpit operator starts from home base to the target area in order to engage the enemy forces. During the movement, the HUD is displaying the optical image that is requested from virtual sensor service as well as the MHDD is displaying the infrared information.
- The virtual cockpit operator targets to the enemy forces and shoots missile which is calculated by the central EWS. Depending on the engagement results, the service sends a munition detonation or not.
- After successful engagement, air track returns to home base and ends mission.

6.0 SUMMARY & OUTLOOK

MSaaS and cloud-based or cloud-native M&S will impact all future simulation environments and acquisition programs. This activity demonstrates that MSaaS and cloud-based simulation is not only an idea existing on slides, but actually works (today!) in operationally relevant environments.

The underlying technology that is used for the MSaaS environment (here: Docker) will be further extended and stabilized, concerning the demonstrator setup, until end of 2019. It's envisaged to verify the advantages of containerisation solutions such as rapid setup and deployment of simulation experiments as well as reusing container services to foster scaling effects.

A central component in the demonstrator environment, the flight training device, currently requires to setup a HLA runtime infrastructure. This means that a HLA/DIS gateway is necessary to forward the data messages within the simulation bus. In the future, the FTD will support the DIS communication protocol which simplifies the setup even more, as no HLA RTI is required anymore.

Finally, to validate the outcome of the proof of concept implementation, it's important to participate in international experiments like VIKING in order to connect to other services and also to offer own services to other possible clients.

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