Towards A Common Reference Architecture for Mission Training Through Distributed Simulation

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ABSTRACT

NATO and nations have a common need for combined and joint collective training to ensure mission readiness. There are however significant challenges: current and future operations are multinational in nature, missions and systems are becoming more complex and need detailed preparation and rapid adaptation to changing circumstances. At the same time, opportunities for live training and mission preparation in multinational context are reduced due to fewer available resources and limited time span between political decision making and deployment.

Simulation has become an essential tool to meet the training demands of our military forces and nations are moving toward adopting national Mission Training through Distributed Simulation (MTDS) capabilities. Over time several NATO Modelling & Simulation Group (NMSG) initiatives provided valuable inputs into the development of a NATO MTDS vision and concept of operations (MSG-106 NETN, MSG-128 MTDS). So far these have not led to a persistent NATO wide capability to deliver meaningful synthetic collective training, due to the lack of a common technical framework and complexity of preparing a multinational MTDS event.

Building on previous results, ongoing NMSG activities (MSG-165 MTDS-II, MSG-169 LVC-T) aim to address this need by amongst others developing a common MTDS Technical Reference Architecture (TRA) for Joint and Combined Operations. The TRA defines MTDS guidelines in the form of building blocks, interoperability standards and patterns for realizing and performing collective synthetic training and exercises supported by distributed simulation, independent of application domain (land, air, maritime).

MTDS will be crucial to NATO and national readiness. This paper provides background, objectives and principles of the MTDS TRA, an interim status update of the work, and planned way ahead. The work is performed in a collaborative effort by several NATO nations, partner nations and organizations under the auspices of the NMSG.

ABOUT THE AUTHORS

Tom van den Berg is a senior scientist in the Modelling, Simulation and Gaming department at TNO, The Netherlands. He holds a 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").

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Patrice Le Leydour is a senior system architect at Thales Avionics – Training and Simulation. He has 20 years of experience in distributed simulation architectures for use within live, virtual and constructive (LVC) assets. He is a member of several SISO Product Development / Support Groups, and has been involved in several NATO MSG activities, including the former MSG-128 on Mission Training via Distributed Simulation (MTDS) and the ongoing MSG-165 MTDS-II.

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INTRODUCTION

NATO and nations have a common need for combined and joint collective training to ensure mission readiness. There are however significant challenges: current and future operations are multinational in nature and require coordination between multiple actors to pursue common objectives; new systems and platforms are becoming more complex and require more preparation time to use. At the same time, opportunities for live training and mission preparation in a multi-national context are reduced due to fewer available resources and limited time span between political decision making and deployment. Cost, complexity, environmental restrictions and improved hostile (electronic) monitoring capabilities often make it impossible to train with live systems in a real world environment.

Simulation has become an essential tool to meet the training demands of our military forces and nations are moving toward adopting national Mission Training through Distributed Simulation (MTDS) capabilities. Over time several NATO Modelling & Simulation Group (NMSG, (NMSG, 2019)) initiatives have provided valuable inputs towards the development of a NATO MTDS vision and concept of operations, such as MSG-106 NATO Education and Training Network (NETN), and MSG-128 MTDS. So far these have not led to a persistent NATO wide capability to deliver meaningful synthetic collective training due to the lack of a common technical framework and the complexity of preparing an MTDS event. The complexity is due both to technical aspects (e.g. number of different, often legacy national simulation assets and interfaces) as well as organizational aspects (e.g. number of actors and disciplines). In addition, simulation assets may have different classification levels where the exchange of data is subjected to national security policies. Depending on the scope and complexity of the exercise, the preparation of an MTDS event can take several months up to sometimes a year when one counts in the planning meetings. Collective (international) synthetic training or mission rehearsals therefore only take place sporadically, while actual missions are increasingly being conducted in international coalitions and with short preparation time.

NATO MTDS must deliver maximum value and efficiency and focus on areas not captured in existing training arrangements. It therefore does not seek to replicate training delivered through existing national activities, but rather provide an additional coalition synthetic training capability. Conceptually, training requirements and delivery can be broken into three increasingly complex and challenging levels, as shown in Figure 1 for the Air Domain:

- Level 1: Individual Competence, covering individual training and currency of personnel, allowing personnel to safely operate in role.
- Level 2: Tactical Team training, training sub-unit ‘building blocks’, preparing individuals and crews in operational tactics and procedures.
- Level 3: Operational Collective training, providing training for complex operations, requiring multiple capabilities and units to achieve an operational task.

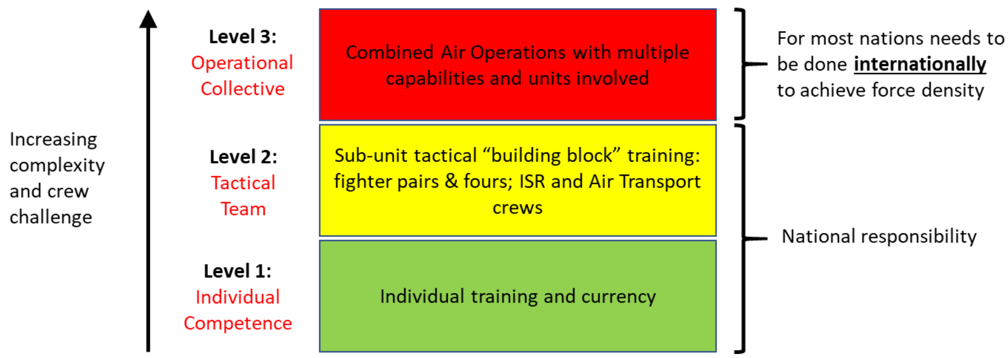

Figure 1: Levels of (Air) Training

Level 1 and 2 training will routinely remain a national responsibility. However, level 3 operational collective training by its nature becomes (also) a multinational NATO MTDS requirement in order to achieve the necessary force density required for realistic training. This level is naturally the focus and priority of a NATO MTDS capability, since individual nations cannot easily replicate it. Nonetheless, as a secondary priority where residual NATO MTDS capacity allows, an MTDS capability could be used to improve the realism and complexity of level 2 training.

The NATO MTDS capability is intended to integrate national or NATO simulation assets into a distributed synthetic collective training environment where the assets are connected through a common simulation infrastructure. Simulation assets are generally connected to this infrastructure via a gateway or portal. Building on previous results, ongoing NMSG activities (MSG-165 MTDS-II, MSG-169 LVC-T; see (Technical Activities of the STO, 2019)) aim to contribute towards developing an MTDS *Technical Reference Architecture* (TRA) for Joint and Combined Operations. The TRA outlines MTDS requirements in the form of building blocks, interoperability standards and patterns for realizing and performing synthetic collective training and exercises supported by distributed simulation, independent of application domain (land, air, maritime).

The consistency of the synthetic training environment as well as the simulation scenarios are also a key to the interoperability of simulation assets involved in collective synthetic training and exercises. The production of databases with synthetic environmental data may be a significant part of the overall M&S cost, meaning that the TRA should provide for reuse in these areas.

MTDS will be crucial to NATO and national readiness. The work is being performed as a collaborative effort by several NATO nations, partner nations and organizations under the auspices of the NMSG. This paper provides background, objectives and principles of the MTDS TRA, an interim status update of the work, and concludes with a summary and plans for the way ahead.

ARCHITECTURE CONCEPTS

In order to realize a synthetic collective training environment for MTDS that can respond quickly to new training needs, common processes and technical agreements for the development and engineering of the training environment are required. Since technical agreements are typically developed per exercise, a commonly agreed simulation infrastructure with associated engineering processes and technical agreements is still missing. This is where the MTDS TRA comes into play.

The MTDS TRA focusses on the technical agreements for the development of a synthetic collective training environment. It provides an abstract, solution independent description of the architecture of such a training environment, using the notions *Architecture Building Block* (ABB) and *Architecture Pattern* (AP) to describe the technical elements in the training environment and the way these elements may be composed. Each ABB has attributes that specify the purpose, function and required (technical) interfaces, as well as applicable standards. An AP also has attributes that define the function of the composition. The MTDS TRA is focused on synthetic collective training and exercises and will therefore include building blocks and patterns with MTDS specific functions and interfaces. Since

TRA is developed in a NATO context, it will also leverage NATO standards for simulation interoperability such as AMSP-04[1].

The simulation environment architecture for a specific training or exercise event (such as the Spartan Warrior exercise series or the Viking exercise series) is called a *Solution Architecture*. Since the MTDS TRA provides a “template solution” for synthetic collective training environments, many of the requirements for the elements used in the solution architecture should in principle be derived from the TRA. Still, some refinement may be needed to meet the requirements of the specific event. This could include the selection of simulation protocol and specific middleware solutions (DIS, HLA), gateway components, cross domain solutions, and data recording tools. Reference data exchange models such as the NATO Education and Training Network (NETN) family of FOM modules (ref. AMSP-04) are provided through the TRA, but the solution architecture still needs an agreement on which specific parts from these reference data exchange models will be used in the specific event. The elements used in describing the solution architecture are called *Solution Building Blocks* (SBBs).

The notions ABB and SBB are illustrated in Figure 2 from (van den Berg, Huiskamp, & et al, 2018). An ABB captures e.g. requirements and standards, whereas an SBB provides the description of the solution used.

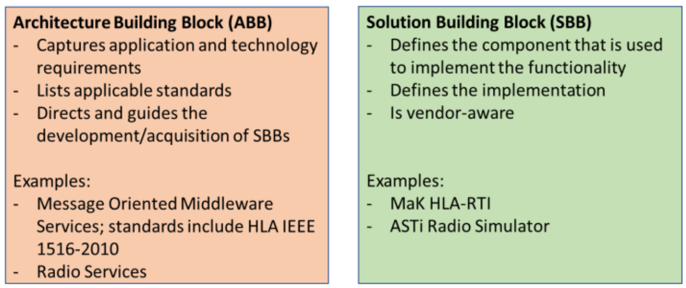

Figure 2: Architecture Building Block vs Solution Building Block.

An initial use case for identifying building blocks and patterns is described in (van den Berg, Huiskamp, & et al, 2018). The paper also introduces several of the notions for describing the TRA, and elaborates on two building blocks identified (and used) in the Viking 18 exercise held in 2018.

ARCHITECTURE PRINCIPLES

Principles are general rules and guidelines, intended to be enduring and seldom amended, that inform and support the way in which an organization (i.e. NATO and the nations) sets about fulfilling its mission (TOGAF Version 9.1, 2011). Principles may be just one element in a structured set of ideas that collectively define and guide the organization, from values through to actions and results. Depending on the organization, principles may be established within different domains and at different levels. Two key domains inform the development and utilization of an architecture, the focus of this paper being the architecture principles:

- *Enterprise principles* provide a basis for decision-making throughout an enterprise, and inform how the organization sets about fulfilling its mission. Such principles are commonly used as a means of harmonizing decision-making across an organization. In particular, they are a key element in a successful architecture governance strategy. In our context, NATO is viewed as the ‘Enterprise’.
- *Architecture principles* are a set of principles that relate to architecture work. They reflect a level of consensus across the enterprise and embody the spirit and thinking of existing enterprise principles. Architecture principles govern the architecture process, affecting the development, maintenance, and use of the enterprise architecture, in this case the MTDS Technical Reference Architecture.

It is common to have sets of principles form a hierarchy, in that Architecture principles will be informed by, elaborated on and constrained by enterprise principles. Architecture principles define the underlying general rules and guidelines for the use and deployment of resources and assets. They reflect a level of consensus among the various elements of

[1] Allied Modelling & Simulation (M&S) Publication, AMSP

the enterprise, and form the basis for making future decisions. Each architecture principle should be clearly related to the operational objectives and key architecture drivers. The main architecture principles defined for MTDS are discussed below:

1. Support synthetic collective training and mission rehearsal for NATO operations

The primary intended application for the MTDS effort is synthetic collective training in a NATO context. A common technical and procedural solution shall be developed for single-service as well as joint operations. Mission rehearsal is considered to be closely related to mission training as far as the technical requirements are concerned. Solutions shall be independent of service, nation, organization or vendor/service provider as much as feasible. Specific needs for either of these stakeholders shall be designed and provided as add-ons to a common technical and procedural framework. Cost sharing between NATO and nations must be addressed at the NATO level.

2. Enable (Blended) Live, Virtual and Constructive assets

MTDS shall (in the future) support (blended) Live, Virtual and Constructive simulated players. Collective training for joint and combined operations requires complex training scenarios with many simulated entities. The training audience will typically train in Live, Virtual and blended LVC settings. MTDS shall enable connection to Live elements (including C2 units). Solutions shall support blended integration of LVC. The challenges related to interoperating with Live elements will need to be further investigated before common solutions can be established.

3. Provide flexibility and ability to evolve

MTDS shall provide a flexible and extendable solution. Many nations already use simulation systems for training. However, these existing systems are often technically very different. MTDS shall support integration of (legacy) systems with different generations of technology. However, an MTDS capability should not be restricted by the lowest common denominator. Technology evolves rapidly and MTDS should be designed and developed to evolve in a flexible, yet controlled way. The MTDS TRA shall be modular, extendable and allow the (future) addition of more specific capabilities. The MTDS TRA shall define a framework that is technically advanced and not restrictive (e.g. extendable with new simulated assets) and does not unnecessarily impede training (e.g. bandwidth, robustness). Portals or gateways shall be defined to allow integration of legacy systems in MTDS and allow the flexibility required for MTDS. The interfaces offered through portals shall be limited in type and scope.

4. Use open standards

NATO promotes the use of open standards as it fosters cost-effective interoperability. Open standards can be freely used by all parties. There are no restrictions imposed on the use by private parties (e.g. vendors). Open standards are developed and maintained in a transparent and open environment which prevents undue influence. Agreements shall be made about the open standards to be used. Open standards are used for, but not limited to: simulation data exchange, environment data, scenarios, and exercise evaluation.

5. Comply with NATO policies and standards

MTDS shall be compliant with NATO policies and agreements for M&S interoperability and standards. Deviations from this principle require justification, including assessment of suitable NATO standards and comparison with alternative solutions. The NMSG has the mandate w.r.t. M&S interoperability standards development and recommendations in NATO. The following baseline policies and agreements shall apply to MTDS:

- AMSP-01: (NATO M&S Standards Profile (AMSP-01, Edition D, Version 1), 2018);
- AMSP-03: (Guidance for M&S Standards in NATO and Multinational Computer Assisted Exercises with Distributed Simulation (AMSP-03, Edition A, Version 1)), 2018);
- AMSP-04: (NATO Education and Training Network Federation Architecture and Federation Object Model Design (AMSP-04, Edition A, Version 1), 2018);
- AMSP-05: (Handbook (Best Practise) for Computer Assisted Exercises (CAX) (AMSP-05, Edition A, Version 1), 2018);
- STANAG[2] 4603: (M&S Architecture Standards for Technical Interoperability: HLA (STANAG 4603), 2015)
- Certification: tools shall be provided to expedite test & integration of new participants, including the NATO Interoperability Verification and Certification Tool (IVCT) developed by MSG-163. (IVCT, 2019).

[2] NATO STANdardization Agreement, STANAG

6. Support use at or up to NATO Secret level
MTDS shall support synthetic training and mission rehearsal for NATO operations. Classified aspects of systems, doctrine and mission execution need to be protected. Agreements shall be made about implementation and accreditation of systems, networks, sites and persons with access to the above. Open standards are to be used for implementation when possible. Protection shall include offline and runtime data exchange.

7. Support multiple security domains or enclaves in one exercise
MTDS shall support synthetic training and mission rehearsal for NATO operations in which partner nations and non-NATO nations or organizations can participate when needed. Agreements shall be made about implementation and accreditation of information exchange between systems, networks, sites and persons belonging to the different enclaves, possibly through the use of a Cross Domain Solution (CDS). Accreditation of a CDS between each nation and NATO will be undertaken by each nation.

8. Provide a representative training environment
MTDS shall provide a representative collective training environment that supports fair-play (or fair-fight) for all players in an exercise. Differences in simulation system performances should not lead to unrealistic (dis)advantages for certain players. MTDS shall allow for a sufficiently accurate representation of common systems such as Tactical Data Links to enable realistic training. Common datasets (e.g. terrain, weather, threats, sensor performance, weapon performance and weapon effects) should be available and implemented. In addition, agreements should be made about distribution, accreditation and implementation of datasets and behavior/algorithms.

The MTDS principles provide the requirements and standards for multiple stakeholder perspectives. The MTDS TRA provides a generic and reusable description that complies with the above architecture principles.

MTDS FRAMEWORK APPLICATIONS AND SERVICES

Overview

The MTDS TRA uses the notions of ABB and AP to define a framework of Applications and Services that enable (national) simulation assets to be integrated into a (distributed) synthetic collective training environment. An overview of the MTDS Framework is provided Figure 3 and described further below.

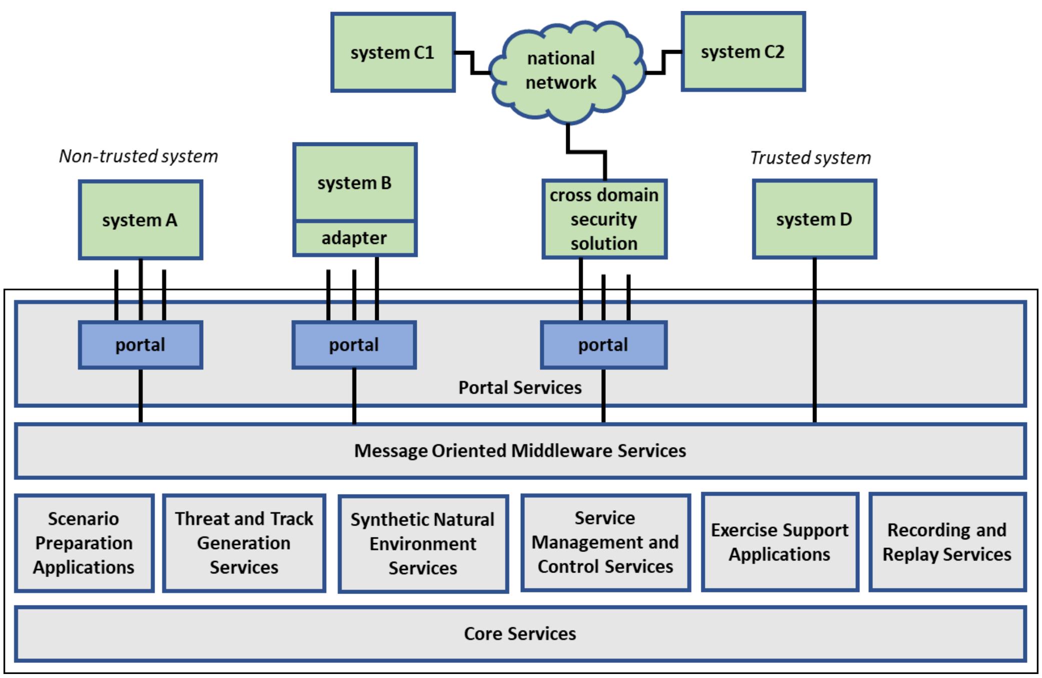

Figure 3: MTDS Framework Applications and Services

The name of each Framework building block (ABB) in Figure 3 starts with capital letters to delineate its role w.r.t. solution building blocks (SBBs) written in non-capital letters, e.g. "Portal Services" vs "portal" solutions. *Applications* in Figure 3 are *user facing* capabilities that interact with the *back-end* capabilities called *Services*. The figure shows for example that – at the solution level – there will be one or several applications for scenario preparation; these software components interact with back-end service implementations such as the threat generation services to provide simulation scenario data to these services. The details of the relationships between ABBs are not shown in the figure above and are not further elaborated in this paper. The Framework inherits many of the ideas and concepts provided by NATO MSG-136/164 Modelling and Simulation as a Service (MSaaS) (Hannay & van den Berg, 2017).

The ABBs shown in Figure 3 are not complete (work in developing the TRA is ongoing). A subset of the Framework Applications and Services is discussed in more detail below, namely: Portal Services, Message Oriented Middleware Services, Threat and Track Generation Services, and Synthetic Natural Environment (SNE) Services. The other Applications and Services shown in Figure 3 will be elaborated in follow-on publications.

Portal Services

In many synthetic collective training environments for MTDS there will be a mix of simulation assets, each supporting different (versions of) simulation standards, tactical datalinks, and/or HLA FOM modules, e.g. DIS version 7, IEEE 1516.2000 (HLA), IEEE 1516.2010 (HLA Evolved), RPR-FOM, NETN-FOM modules, or different Tactical Data Link simulation standards. The MTDS TRA defines Portal Services in order to perform the most commonly found transformations required to connect systems using non-HLA (e.g. DIS) or legacy HLA (e.g. HLA 1.3) to the common protocol used within the MTDS Framework (i.e. IEEE 1516™-2010 for run-time exchange of simulation data). Figure **3** illustrates different ways for connecting systems to the Framework Applications and Services. If a system is marked as "trusted", it may connect directly to the Framework Applications and Services rather than via the Portal Services.

The Portal Services, similar to the spokes in the hub-and-spoke model adopted by the commercial aviation, are an essential part of the Framework. Their purpose is to:

- Adapt national communication protocols to the MTDS Message Oriented Middleware Services requirements (i.e. HLA RTI);
- Translate national data models to the MTDS reference data exchange model;
- Provide a standard range of translations and adaptations for legacy communication protocols and data models.

National simulation assets may use different standards and techniques but would have to be compatible with the Portal Services in terms of standards for communication protocols and data models. Configuration of a specific portal solution is the responsibility of the asset's owner. It may be necessary for the asset's owner to use additional adapters and translators in order to fulfill the requirements of the Portal Services.

Portal Services can provide additional protection against 'misbehaving' systems and can also provide some security features that may normally be found in a CDS. Traffic through a portal can be monitored/metered, adapted and filtered, at the cost of some latency depending on the specific portal and network implementation. Note that trusted applications such as management and control tools can be allowed access to the Framework Applications and Services directly. Obviously, the design and implementation of Portal Services needs work as part of ongoing task groups. An open source and non-proprietary portal solution is promoted.

Message Oriented Middleware Services

The Message Oriented Middleware Services enable the interoperability of Framework Applications and Services, as well as external systems. The Message Oriented Middleware Services comply with NATO STANAG 4603 and NATO Standard AMSP-04. NATO STANAG 4603 mandates the use of the IEEE 1516™-2010 (HLA Evolved) standard on High-Level Architecture for distributed simulation environments. AMSP-04 defines a suite of HLA-FOM (NETN) modules (see Figure 4), along with architecture and design guidelines. The NETN FOM modules are designed to maximize re-use and interoperability between simulation systems. Other FOM modules supported by the Message Oriented Middleware Services concern Tactical Data Links (i.e. Link 16).

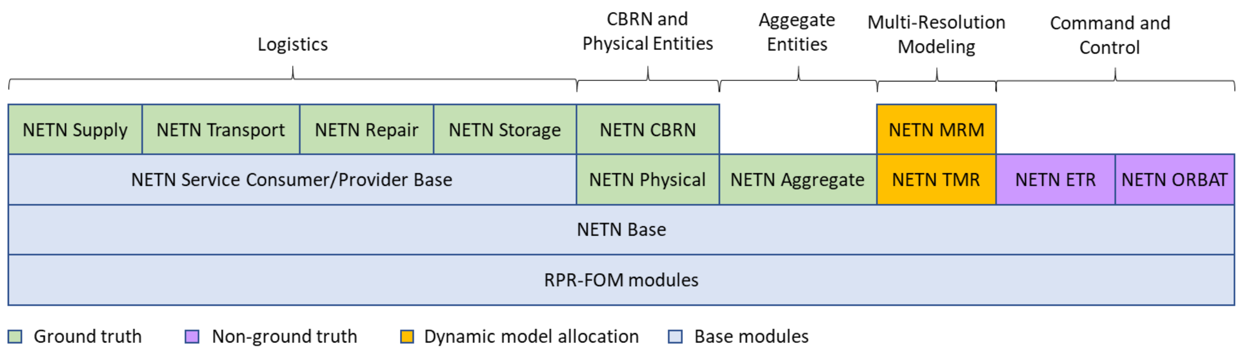

Figure 4: NETN FOM modules in AMSP-04 (including foreseen updates)

AMSP-04 is currently under revision by MSG-163 (Evolution of NATO Standards for Federated Simulation, see also (NETN FAFD, 2019)). The next edition will include several improvements to existing modules, and some new modules. Updates include an Entity Tasking and Reporting (ETR) module for the low level control of simulation entities, and a new Order of Battle (ORBAT) module for the exchange of order of battle information at simulation execution time. The use of HLA Evolved in MTDS is a fundamental design decision which affects many parts of the Framework.

Threat and Track Generation Services

These services generate both ground truth and non-ground truth data to stimulate connected simulation assets with (simulated) air, land or maritime platform information or aggregate level information, such as enemy aircraft, missiles, decoys, land units and maritime vessel traffic. The traditional solution is to generate this information with a Computer Generated Forces (CGF) application. The TRA does not state how this information should be generated, but provides the requirements and standards for the services interfaces. For instance, the ground truth platform or aggregate level information should be provided in accordance with AMSP-04 (HLA RPR-FOM, NETN Physical FOM, or NETN Aggregate FOM). At the solution level these services can be provided by a single CGF, or by several specialized applications or service implementations. For example, in (van den Berg, Huiskamp, & et al, 2018) two services are defined: Automatic Identification System (AIS) Generation Services, and Land Unit Generation Services. Both are specializations of the Threat and Track Generation Services and comply with AMSP-04. In addition, the AIS Generation Services provide NMEA compliant maritime information to e.g. C2 systems.

The Threat and Track Generation Services require simulation scenarios for the configuration of e.g. the initial positions of entities. Simulation scenarios are provided by the Scenario Preparation Services (not addressed in this paper). Associated requirements include support for e.g. Military Scenario Definition Language (MSDL) and the ORBAT FOM module discussed earlier.

Synthetic Natural Environment Services

Consistency between different databases with synthetic environmental data is key to the interoperability of simulation systems involved in MTDS. In addition, as production of these databases is a significant part of the overall exercise development cost, reuse of database creation efforts shall be encouraged. It has been identified in the training community that simulation system providers use the same source data tools and formats from the GIS community, and the same high-level process in the generation of their environmental data products. However, the detailed data generation processes and the detailed semantics differ slightly from one producer/integrator to another. These differences complicate data reuse and jeopardize the final interoperability of the target applications.

To tackle these issues, harmonization of environmental data representations and processes among the database providers must be sought. This shall be done while preserving the internal consistency of the source data (to keep intrinsic correlation factor) and without introducing specific target application constraints (limiting reuse). To these ends, the MTDS TRA promotes the use of the RIEDP Data Model Foundations (Reuse and Interoperation of Environmental Data and Processes (RIEDP) Data Model Foundations (SISO-GUIDE-007-2018), 2018) which formalizes all the components needed for environmental data sharing between producers and consumers in M&S applications:

- The RIEDP Reference Process Model (RPM), a high-level database generation process;
- The Reference Abstract Data Model (RADM), for expressing any data produced through that process;
- Geospatial Conventions, and a list of RIEDP-Required formats;
- An attribution model (detailed in the RIEDP Detailed Features Description – SISO-STD-XXX);
- An organization for metadata, and an organization of data on the media;
- Profiles for Conformance.

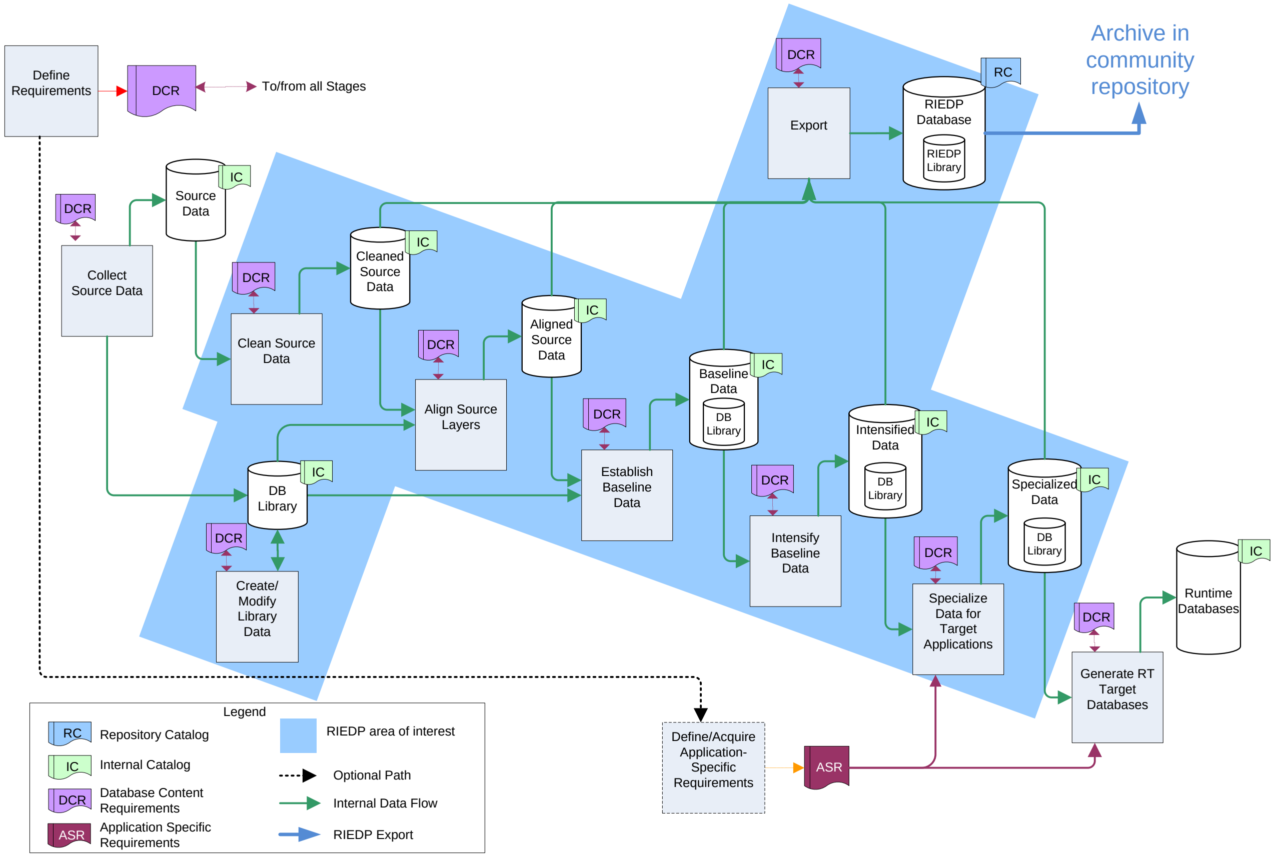

Figure 5: RIEDP Reference Process Model

Database creation efforts should be shared between providers in accordance with the RIEDP components above, and at various levels of achievement in their creation processes, as shown in Figure 5: from early development efforts (Source, Cleaned or Aligned stages) to advanced states of the database (Baseline, Intensified or Specialized stages). Databases may be stored in a common NATO MTDS repository or in producers' own repositories. The MTDS TRA defines several (to be elaborated) SNE Services in relation to RIEDP compliant databases, grouped as follows:

- Catalog Services, using the RIEDP metadata (including RIEDP Profiles);
- Consultation Services, using Open Geospatial Consortium (OGC) compliant Web services (e.g. WMS, WFS);
- Sharing Services, using OGC compliant Web services (e.g. WMTS, WFTS).

Core Services

In addition to the previously discussed Framework Applications and Services, an MTDS capability depends on a number of Core Services. These services are called Core Services because they are not specific to simulation, but apply to a wide range of environments, e.g. C2. The Core Services are defined in the NATO C3 Taxonomy (C3 Taxonomy Baseline 2.0, 14 March 2016) and are briefly discussed in an MTDS context below.

- *Database Services*: Database Services are used to provide access to shared, structured data and for information persistence as part of the MTDS environment. Data may include, but is not limited to: terrain data, scenario data, component configuration data, exercise logs/recordings. Dependent on the data standards used the data mentioned above may be shared by using Data Transfer Services.
- *Distributed Time Services*: Due to the speed of air units, simulations in the air domain are especially dependent on good time synchronization. When judging whether a missile hit or missed, a fraction of a second can mean a difference of up to hundreds of meters. Additionally, Tactical Data Link messages need accurate timestamps in order to be processed properly, especially when the MTDS capability includes live TDL systems. It is therefore necessary to keep clocks synchronized across all simulation systems using e.g. a Network Time Protocol (NTP) service, so that timestamps and associated spatial data may be compared in the same frame of reference.
- *Data Transfer Services*: File transfer between simulation participants is important in all phases – from setting up the MTDS environment to post-execution analysis. Files include technical documents, configuration files for simulation systems, scenario files, and possibly simulation assets such as 3D models. A central File Transfer Protocol (FTP) server should be used, providing the additional benefit of collecting all files in a single location. For a synthetic collective training environment operating across several security domains, it may be necessary to set up a separate FTP server for each security domain. Data transfer services also include sharing of video streams, e.g. for video teleconferencing (VTC).
- *Communication Services*: Real-time communication between participant sites is necessary to coordinate a distributed exercise. Text chat may be sufficient as a bare minimum, but voice communications greatly simplify coordination across participant sites. Previous groups such as MSG-128 have used Voice over IP (VoIP) telephony to great effect. Conference software with video and screen sharing may also be useful for briefings and after action reviews.
- *Domain Name Services*: Most of the aforementioned services use a client-server architecture. The synthetic collective training environment should use a Domain Name Service (DNS) in order to simplify the act of connecting to the different services.

Other Applications and Services

Several other Applications and Services are important to the MTDS Framework, such as Security Services (w.r.t. a CDS), Service Management and Control Services, Recording and Replay Services, Scenario Preparation Applications, and Exercise Support Applications. These will be elaborated in follow-on publications.

SUMMARY AND CONCLUSIONS

NATO and nations must develop and leverage simulation capabilities to meet the operational needs. MTDS should provide an effective and persistent training solution at an affordable cost. The MTDS TRA is an abstraction that complies with the MTDS Architecture Principles and allows a more generic and reusable MTDS design. The MTDS TRA addresses multiple stakeholder perspectives:

- For *nations* implementing MTDS within their organizations, the TRA should be used to state standard capabilities, building blocks, architectural guidelines, and other attributes in order to assess conformance.
- For *product vendors*, the TRA should provide a set of standards and enough specificity to enable vendors to evaluate compliance of their products with those standards.
- For *integrators*, the TRA should be a reference source to define specific constraints and directions for MTDS solution implementations.
- For *standards bodies*, the TRA should provide a reference against which standards can be developed or extended, guidelines provided, and more detailed levels of specificity defined.

The MTDS TRA leverages the Modelling and Simulation as a Service (MSaaS) approach developed by NATO MSG-136 and MSG-164, and incorporates many of the ABBs identified for MSaaS (NATO, 2017). MSaaS technology for implementing the MTDS Framework (i.e. container technology) has been used and assessed in Viking 18. In this exercise it was demonstrated that several MTDS Framework Applications and Services can be provided on-demand from a cloud environment.

MTDS will enable a persistent synthetic training and mission rehearsal capability for NATO in which partner nations and non-NATO nations or organizations can participate when needed. In order to implement, operate and maintain the synthetic collective training environment, NATO and the individual nations will incur both initial investment costs and recurrent costs for staffing and use of the nation's assets. These costs need to be justified by the additional operational value, but also more pragmatically offer savings over current training solutions.

NMSG task groups will continue to work towards a common Framework for MTDS, which is developed, validated and implemented in an iterative approach. The overall roadmap for the Framework and its specific standards will be refined and updated as work progresses. The Operational community will at the same time develop and refine the CONOPS for planning and execution of collective synthetic training through MTDS.

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