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Mission Training through Distributed Simulation for Joint and Combined Air Operations

CUSTOMER: Ministry of Defence

NLR – Royal Netherlands Aerospace Centre

Mission Training through Distributed Simulation for Joint and Combined Air Operations

Problem area

Factors such as reduction of range space, airspace limitations, weapon systems availability, lack of target simulation capabilities, hostile and capability monitoring are driving the transition of NATO towards distributed synthetic enabled training. To help achieve this transition, NATO Science and Technology Organisation (STO) task group MSG-165 was established and tasked to execute a first Incremental Implementation of Mission Training through Distributed Simulation (MTDS) for Joint and Combined Air Operations.

Description of work

The MSG-165 task group goal is to establish essential elements for a persistent NATO MTDS environment and to validate these elements through initial operational test and evaluation. To reach this goal the task group has installed several sub groups which worked on identifying a set of coalition collective training objectives for MTDS, formulating a technical Reference Architecture, and investigating cross domain security concepts and solutions. In the Netherlands this task group has been supported through the L1701 Research Program MTDS. In 2020, the final year of the task group, a validation exercise was organized in conjunction with the Spartan Warrior exercise 20-9.

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Results and conclusions

Whilst several challenges remain, the work undertaken so far has offered solutions for other existing NATO synthetic training issues. Amongst others these include:

- Analysis of future collective Air training requirements, leading to re-confirmation of the benefit of multinational MTDS activities.
- Establishment of a set of common collective Air training objectives, helping to define Alliance training requirements and to align appropriate training media accordingly.
- Formulation of Reference Architecture providing a technical foundation for Joint MTDS capability employment.
- The development of an MSG 165 vision of how MTDS could be employed to support NATO Joint & Combined Air operations training. The methodology employed in developing this vision shows wider utility, and the potential for use in helping other components define their own future training visions.

Applicability

With the progression made by the MSG-165 task group NATO should be able to make the next step forward to a NATO Joint MTDS capability by:

- Development of a NATO synthetic exercise requirement, commencing with an annual NATO sponsored MTDS exercise. This would help to both increase awareness of a MTDS capability possibilities and benefits across NATO and aid development of MTDS as a core capability in NATO Joint and Combined training.
- Formal definition of the Alliance objective for multinational synthetic training. We believe this provides significant benefits and offers an initial element of the necessary top-down direction and guidance to help drive progression of MTDS capabilities.

GENERAL NOTE

This report is based on a presentation held at the virtual I/ITSEC, December 2020.

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Summary

Factors such as the reduction of range space, airspace limitations, weapon systems availability, lack of target simulation capabilities and hostile capability monitoring are driving the transition of NATO towards distributed synthetic enabled training. To help achieve this transition, NATO Science and Technology Organisation (STO) task group MSG-165 was established and tasked to execute a first development step in the Incremental Implementation of Mission Training through Distributed Simulation (MTDS) for Joint and Combined Air Operations.

The development of MTDS capabilities is not limited to the work of MSG-165; indeed, it is one of NATO's Smart Defence Initiatives, sponsored by the United States, and therefore has good visibility on various levels. In the Netherlands NLR and TNO has undertaken a large 4-year research program L1701 MTDS. Whilst several challenges still remain, the work undertaken so far by the group has offered the following solutions for NATO synthetic training:

- Establishment of common set of Collective Air training objectives, helping to define Alliance training requirements, helping to align appropriate training media.
- Formulation of Reference Architecture, providing a foundation for a Joint MTDS capability implementation and deployment.
- Set-up of a first incremental MTDS capability by running a validation exercise, called SPARTAN WARRIOR 20-9 (SW 20-9). SW 20-9, as a modification of the previous SPARTAN WARRIOR scenario, is a multilateral engagement opportunity coordinated by the USAFE-AFAFRICA Warfare Center (UAWC) to provide Coalition partners persistent connectivity over the Combined Federated Battle Laboratories (CFBL) Network at NATO Secret classification level for daily, coalition focused, unit-led training.
- The development of a vision on how MTDS could be employed to support NATO Joint and Combined Air operations training. The methodology employed in developing this vision shows wider utility, and the potential for use in helping other components define their own future training visions.

This paper will highlight the advancements made by MSG 165 towards a common NATO Joint MTDS environment and sketch the following steps to mature this upcoming important training capability.

Contents

Abbreviations

ACRONYM	DESCRIPTION
AADP	Area Air Defence Plan
ABB	Architecture Building Block
ACC	Air Component Command
ACO	Air Control Order
ADAFCO	Air Defense Artillery Fire Control Officer
ALR	Acceptable level of risk
AOR	Area of Responsibility
AP	Architecture Pattern
ASOC	Air Support Operations Centre
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BDA	Battle Damage Assessment
CAOC	Combined Air Operation Command
CAS	Close Air Support
CCTO	Coalition Collective Training Objective
CDS	Cross Domain Security
CFBL	Combined Federated Battle Laboratories
COMAO	Composite Air Operations
CONEMP	Concept of Employment
CRC	Control and Reporting Centre
CT	Collective Training
C2	Command & Control
DIS	Distributed Interactive Simulation
DT	Deliberate Targeting
EAG	European Air Group
HLA	High Level Architecture
ISR	Intelligence Surveillance Reconnaissance
JSTARS	Joint Surveillance Target Attack Radar System
JTAC	Joint Terminal Attack Controller
LVC	Live Virtual Constructive
MSaaS	Modelling & Simulation as a Service
MSG	Modelling and Simulation Group
MTDS	Mission Training through Distributed Simulation
M&S	Modelling & Simulation
NATO	North Atlantic Treaty Organisation

ACRONYM	DESCRIPTION
NIAG	NATO Industrial Advisory Group
NLR	Royal Netherlands Aerospace Centre
NMSG	NATO Modelling and Simulation Group
OCA	Offensive Counter Air
RA	Reference Architecture
RAF	Royal Air Force
SAA	Security Accreditation Authority
SCAR	Strike Coordination and Reconnaissance
SEAD	Suppression of Enemy air Defence
SPE	Synthetic Physical Environment
SPINS	Special Instruction
STO	Science and Technology Organisation
SW	Spartan Warrior
TENA	Test and Training Enabling Architecture
UAWC	USAFE AFAFRICA Warfare Center
USAFE	United States Air Force Europe

1 Introduction

NATO and nations have a common need for combined and joint collective training to ensure mission readiness. A range of factors (reduction of range space, airspace limitations, weapon systems availability, lack of target simulation capabilities, hostile capability monitoring) are driving NATO to transition towards distributed synthetic enabled training. To help achieve this transition, NATO Science and Technology Organisation (STO) task group MSG-165 is established, tasked to execute Incremental Implementation of Mission Training through Distributed Simulation (MTDS) for Joint and Combined Air Operations. In the Netherlands a large 4-year research program MTDS has been set-up which supported the work of this task group.

This paper will highlight the achievements towards a common NATO Joint MTDS environment. It starts by explaining the background of the NATO MTDS capability and the preceding efforts in realizing this capability. Then it presents the training objectives and describes the steps to mature this upcoming important training capability. This is followed by the definition of the MTDS principles that provide the requirements and standards for multiple stakeholder perspectives. This leads to the MTDS Reference Architecture which provides a generic and reusable description that complies with the above architecture principles. In the next part security issues are considered that should be taken into account when deploying MTDS Cross Domain Security solutions for coalition collective training. The paper ends with an overlook of the Spartan Warrior 20-9 exercise that is used as a validation exercise of the NATO MTDS capability.

2 Background MTDS research in NATO

Synthetic capability has become an essential tool to meet the operational training needs of NATO military forces. New systems and platforms are becoming more complex and require more preparation time to use. Improvements in technical capabilities and reduced cost, coupled with increasing environmental restrictions and improved hostile (electronic) monitoring capabilities of live activity, have made the use of synthetic training more attractive. Collective Training (CT) enabled by Mission Training through Distributed Simulation (MTDS) has therefore becoming increasingly important to NATO's and member nations' readiness. Many member nations are moving toward a greater use of advanced simulation for mission training and adopting national MTDS capabilities, yet NATO does not currently have a collective MTDS capability to leverage these developments for Coalition CT.

In the past NATO has undertaken a number of initiatives in this field, starting in 2000 with the SAS-013 study on MTDS (NATO RTO SAS-013, 2004). This study identified aircrew mission training practices and limitations among participating nations and determined whether advanced distributed simulation could enhance the training of NATO pilots and aircrews. It proposed a way ahead that would foster development of a distributed simulation capability for NATO aircrew training and mission rehearsal. This was taken forward in 2004 in the training demonstration exercise First WAVE, "First Warfighter Alliance in a Virtual Environment" (NATO RTO SAS-034, (2007). First WAVE encountered no insurmountable technical obstacles and confirmed that MTDS could provide a significant new capability to address NATO mission training needs. The MTDS task group recommended that NATO and the Nations should endorse the potential of MTDS and work together to take MTDS forward to an operational capability. The First WAVE initiative was followed up by the NATO SMART (2007), NATO Live, Virtual, Constructive (LVC) (2010) projects, and in 2011-2012 the NATO Industry Advisory Group (NIAG) Study Group 162 on distributed simulation for air combined and joint mission training (NIAG SG 162, 2012). These studies have offered increasing clarity in the development of a NATO MTDS concept of operations (CONOPS). However none have yet provided a persistent MTDS capability with the aim of supporting the warfighter in achieving Mission Readiness for future operations. In light of decreasing exercise budgets, decreasing availability of assets for live exercises and increasing difficulty in realistically simulating the complex threat environment NATO is missing a cost-effective means to enhance collective Operational Readiness for the future Coalition Operations.

The NATO Modelling and Simulation Group's (NMSG) mission is to 'develop and exploit Modelling & Simulation (M&S) for the benefit of the Alliance and its partners'. The considerations above were the motivation for the NMSG to initiate in 2013 the Task Group MSG-128 'Incremental Implementation of NATO Mission Training through Distributed Operations' (NATO STO MSG-128, 2018). The MSG-128 study has validated the technical feasibility to connect heterogeneous operational training simulators in order to provide real training value for multi-national air mission exercises. It has drafted MTDS reference architecture providing an initial baseline for multi-national training exercises, even if many gaps remain to facilitate the MTDS exercise employment. The maturity of multi-national MTDS exercises will be a long process. The MSG-128 group recommended the following axes of efforts to reach this maturity (Lemmers and Faye, et al., 2017):

1. Progress on the operational maturity of small/medium exercises providing technical solutions to the above identified gaps.
2. Continue to validate these solutions on operational exercise environments and consolidate these solutions in a MTDS best practice document.
3. Extend the MTDS exercises in scalability to large and joint exercises, including Air domain interoperability between Air Force, Navy and Army and including Joint Intelligence, Surveillance and Reconnaissance (JISR). This action will be a booster for LVC developments and MTDS use in multi-national coalition exercises.

The MSG-128 was succeeded in 2018 by the follow-on Task Group MSG-165 ‘Incremental Implementation of Mission Training through Distributed Simulation for Joint and Combined Air Operations’ that runs till beginning 2021. Its goal is to establish essential elements for a persistent NATO MTDS environment and to validate these elements through initial operational test and evaluation. The development of MTDS capabilities is not limited to the work of MSG-165; indeed, it is one of NATO’s Smart Defence Initiatives, sponsored by the United States, and therefore has good visibility on various levels, but sadly still fails to achieve the necessary progress. Whilst several challenges remain, the work undertaken thus far by the group has offered solutions to other existing NATO synthetic training issues. These are captured in documents and include:

- Establishment of common Air training objectives, helping to define Alliance training requirements, helping to align appropriate training media.
- Formulation of Reference Architecture principles, providing a foundation for Joint MTDS capability employment.
- Set-up of an Air MTDS capability validation exercise, called SPARTAN WARRIOR 20-9 (SW 20-9). SW 20-9 is a multilateral engagement opportunity coordinated by the USAFE AFAFRICA Warfare Center (UAWC) to provide Coalition partners persistent connectivity over the Combined Federated Battle Laboratories (CFBL) Network at NATO Secret classification level for daily, coalition focused, unit-led training.
- The development of an MSG-165 vision of how MTDS could be employed to support NATO Air operational training. The methodology employed in developing this vision shows wider utility, and the potential for use in helping other components define their own future training visions.

3 Common air training objectives

To deliver maximum value and efficiency, the NATO MTDS must focus in areas not captured in existing training arrangements. It therefore does not seek to replicate training delivered through existing national or NATO activities, instead providing an additional coalition synthetic training capability. NATO has the ability to deliver synthetic Collective Training (CT) of operational air component command capabilities. However, it does not yet have an ability to synthetically train the tactical capabilities below air component command (ACC). This gap, in the synthetic delivery of 'wheels up to wheels down' air activity, is the primary focus for NATO MTDS delivered training. Nonetheless, to enable end-to-end synthetic training, any future system should be able to connect to existing NATO synthetic training capabilities, in particular supporting (NATO STO MSG-165, 2019):

- Synthetic dissemination and execution of Air Component Command (ACC) training derived Air Tasking Orders (ATO), Airspace Control Orders (ACO) and Special Instruction (SPINS).
- ACC execution phase training, linking synthetically trained missions to ACC tactical staffs to support their dynamic training.

Air training requirements can be broken into three increasingly complex and challenging levels as shown in Diagram 1 and described below:

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

Of these three levels, level 1 and 2 training will remain a national responsibility. However, level 3 Tactical CT is the key multinational NATO MTDS requirement; this stems from difficulty for many nations in achieving the density and range of capabilities required for realistic training at this level. Despite this, where residual NATO MTDS capacity allows, as a secondary priority MTDS use would be for Level 2 training, as a means to improve the realism and complexity of this training.

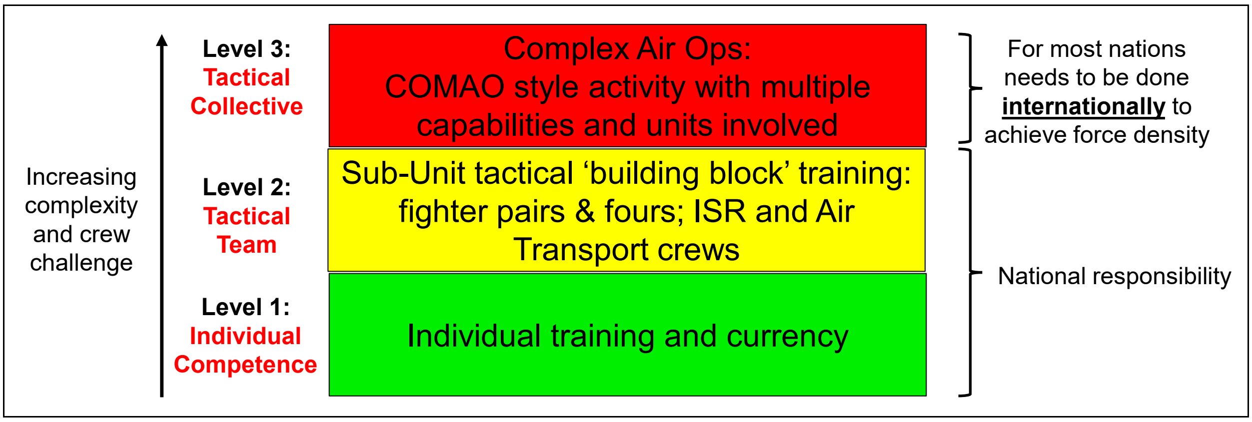

Figure 1: Levels of Air Training

To ensure that any future MTDS capability can meet the necessary operational training and rehearsal requirements, the types of operational training which will be delivered by MTDS must be defined. NATO Coalition CT Objectives (CCTOs) have therefore been developed through consultation with MSG-165 Operations Sub-Group representatives

(NATO STO MSG-165, 2019). This work provides 50 CCTOs. These CCTOs have been grouped together to provide broad mission sets which a MTDS solution must be able to support, as well as aid future training design. The following mission sets were identified: Attack, Offensive Counter Air, Defensive Counter Air, Air C2, Air Mobility, Air Intelligence Surveillance & Reconnaissance, Combat Support, Air-Land Integration, and Air-Maritime Integration.

In the Individual and building block training captured in Level 1 and 2 activity, the focus is on ensuring that crews are able to undertake the necessary actions in cockpit to effectively fight their platform. However, in Level 3 training, whilst correct aircrew actions remain important, the conceptual focus subtly shifts. Level 3 training must provide training opportunity to ensure correct, timely C2 interactions occur between controllers and crews within often large and complex formations, as shown graphically in Figure 2.

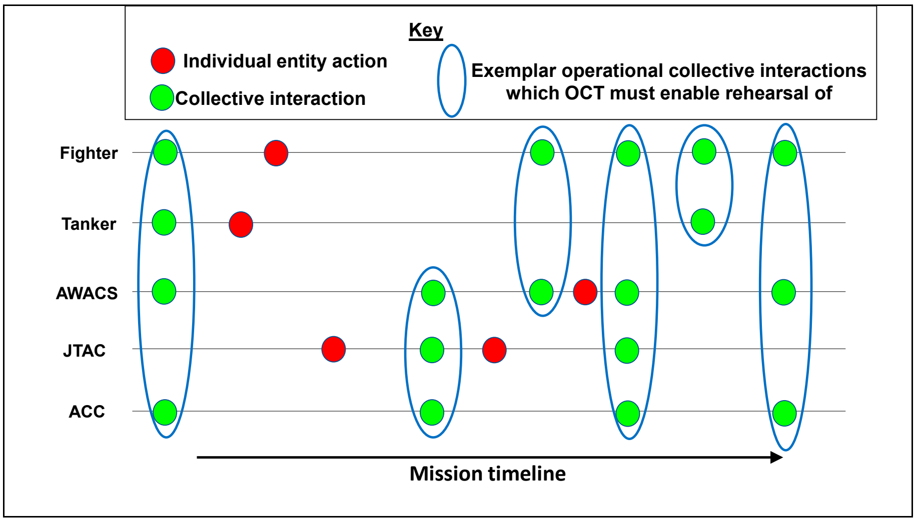

Figure 2: Operational interactions to be replicated in the CT environment

The subtle change in focus for level 3 training allows a greater focus on synthetic training delivery than for level 1 and 2 training. Therefore, whilst live large-force exercises will remain important means of achieving training realism, confidence building and strategic messaging, a much greater proportion of NATO air training can be routinely delivered in the synthetic environment. This assumption has been discussed and tested within the MSG-165 Ops Sub-Group and the key headline is that for level 3 multinational training, for mission sets, more than 50% of training could be delivered synthetically.

4 Reference architecture

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. Consistency of the synthetic training environment is also the 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 reuse should be fostered. Simulation asset providers generally use the same high-level process for the generation of their environmental data products, but the detailed data generation processes differ slightly from one producer or integrator to another. These differences complicate data reuse and jeopardize the final interoperability of the target applications.

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 Reference Architecture (RA) comes into play (van den Berg, Huiskamp, et al., 2019). The RA 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 MTDS RA is focused on synthetic collective training and exercises and will therefore include building blocks and patterns with MTDS specific functions and interfaces. Since RA is developed in a NATO context, it will also leverage NATO standards for simulation interoperability.

The simulation environment architecture for a specific training or exercise event (such as the Spartan Warrior exercise series) is called a Solution Architecture. Since the MTDS RA 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 RA. 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, data recording tools, and the protocols and formats for representing the Synthetic Physical Environment (SPE). Reference data exchange models are provided through the RA, 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.

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 the enterprise, and form the basis for making future decisions. In MSG-165 10 main architecture principles for MTDS have been defined. These 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.
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. Solutions shall support blended integration of LVC.

3. Provide flexibility and ability to evolve
   Many nations already use simulation systems for training. However, these existing systems are often technically very different. The MTDS RA 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.
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).
5. Comply with NATO policies and standards
   MTDS shall be compliant with NATO policies and agreements with respect to M&S interoperability and standards. Deviations from this principle require justification, including assessment of suitable NATO standards and comparison with alternative solutions.
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.
7. Support multiple security domains or enclaves in one exercise
   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 CDS solutions. Accreditation of a CDS solution 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.
9. Address multiple stakeholder perspectives
   MTDS uses a RA to provide a generic and reusable description of the design of a specific MTDS solution. The RA is described in terms of architecture building blocks with requirements and applicable standards for solutions to these building blocks. To implement MTDS, different stakeholders will be involved. These building blocks should provide guidance for different stakeholder perspectives.
10. Provide cost effective training solutions for NATO and Nations
    Collective training by networking simulators shall not impose unacceptable constraints to users, and to the Centers and their staffs, that are not worth the time spent and are not outweighed by the operational benefits.

The MTDS principles provide the requirements and standards for multiple stakeholder perspectives. The MTDS RA provides a generic and reusable description that complies with the above architecture principles. It uses the notions of Architecture Building Block (ABB) and Architecture Pattern (AP) to define a Framework of Applications and Services that enable national training systems to be integrated into a distributed synthetic collective training environment. An overview of the main ABBs in this framework is provided in Figure 3.

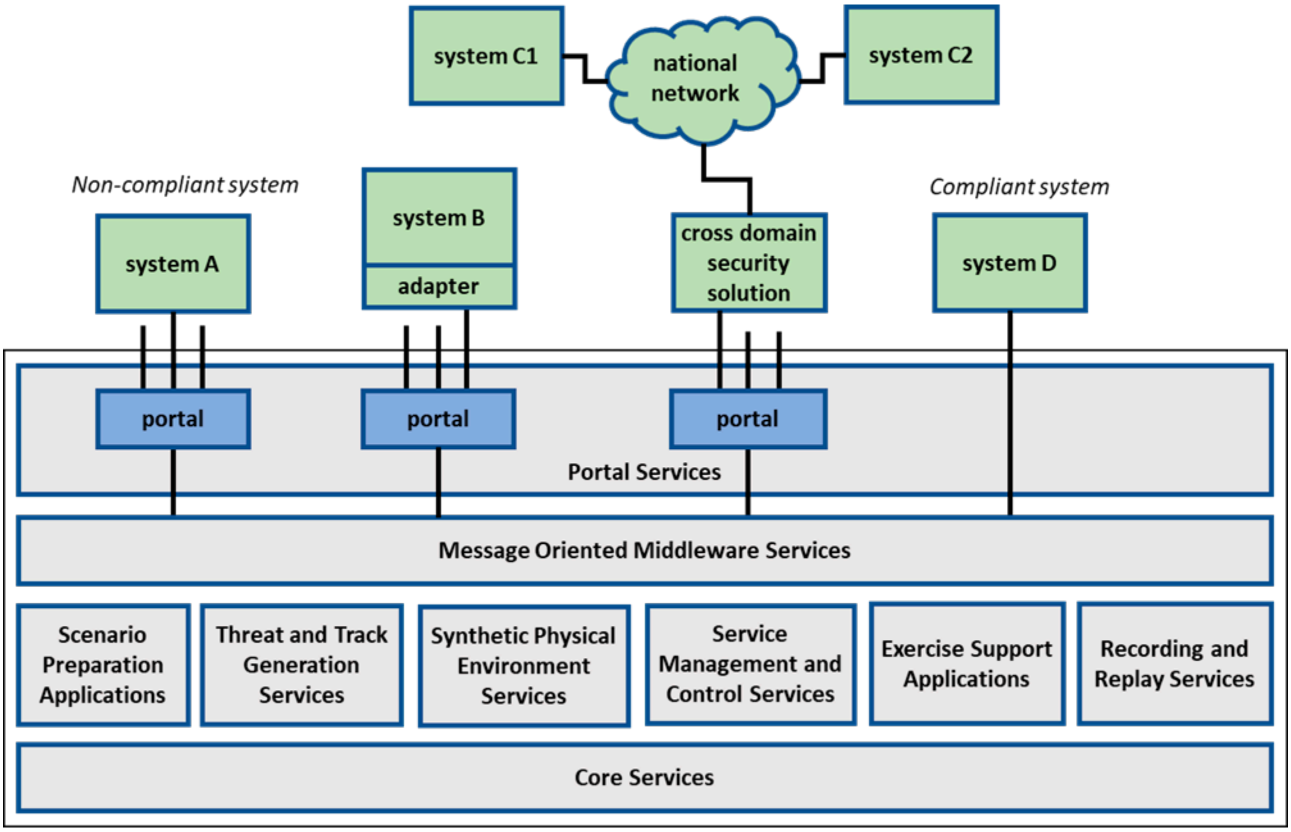

Figure 3: MTDS Framework applications and services

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. A subset of the Framework Applications and Services (Portal Services, Message Oriented Middleware Services, Threat and Track Generation Services, and Synthetic Physical Environment (SPE) Services) is discussed in more detail in (van den Berg, Huiskamp, et al., 2019).

5 Cross domain security

NATO nations have the need to integrate and operate their nationally or sovereign classified simulation assets within NATO MTDS exercises to realize their common air collective training objectives. Meanwhile, NATO nations want to protect these most sensitive or classified assets, their underlying data and information, against exposure to (cyber) security threats that could result from joining such NATO MTDS exercises. Implementing secure connectivity and interoperability between simulation assets of different national sensitivity, trust or security classification level is essential for the successful implementation of NATO MTDS capabilities and exercises.

M&S cross-domain security (CDS) services aim to address this requirement by enabling NATO nations to securely interoperate simulation assets that reside in their national security domains, over the common shared NATO MTDS simulation backbone. A security domain in this context is defined as a simulation asset operating under a consistent security policy and under the ownership of one organization, nation and/or Security Accreditation Authority (SAA). A security policy defines key elements such as the security classification, releasability, community of interest and any other special handling caveats for the data and information of the actual military systems and doctrines contained and processed within the simulation asset.

An M&S CDS is defined here as a system comprising security-enforcing services tailored to mitigate the specific security risks of transferring simulation data between simulation assets operating in different security domains. Such an M&S CDS can be seen as a form of a gateway environment. Unlike commonly applied M&S (network) gateways, an M&S CDS provides a wide range of security controls to provide comprehensive simulation data filtering and defence-in-depth with a higher level of assurance. M&S CDS services are a dedicated part of the whole spectrum of security measures needed to protect the whole NATO MTDS infrastructure and its constituent simulation assets against all forms of security threats. Among other things, this includes: physical and network boundary protection devices of simulation asset and facilities, physical security of the simulation asset or facility connectivity to networks, cryptographic communication protection between simulation assets and monitoring, personnel security clearances and awareness training. These common security measures should be in place for secure execution of MTDS exercises, as well.

In theory many generic application topologies can be envisioned in which M&S CDS solutions are deployed to ensure the controlled and secure simulation data exchange between multiple security domains. However, in practice the implementation of such topologies has to comply with the cross-domain security requirements and constraints imposed by the specific use-case(s) and threat environment for which they are deployed. This means that cross-domain security of distributed simulation environments involves more than just focusing on M&S CDS appliances (e.g. data-diodes, guards or information exchanges gateways) in isolation. The appropriate level of security of the entire distributed simulation environment (and vice-versa) can only be assured if the simulation assets and network segments within each connected security domain satisfy certain trusted security policies, practices and requirements, and whose associated security risks are fully understood and acceptable. Therefore, within the NATO MTDS user context and threat environment, the following security considerations should be taken into account when deploying M&S CDS solutions for coalition collective training:

1. Foremost, each NATO nation requires maintaining the full control over its nationally owned simulation data and information, and how this is shared prior to, during and after a MTDS training exercise. This implies that each nation will always connect their classified simulation assets to the NATO MTDS simulation backbone through nationally owned CDS appliances, which are governed by their national SAA and security policies.

2. All NATO nations that will participate in a NATO MTDS exercise use the private military network NATO Coalition Federated Battle Laboratories (CFBL) network as the common network infrastructure to connect their classified simulation assets and other related training applications up to the NATO Secret level. This implies that participating NATO nations have a common agreement to trust each other on security level enforcement applied by each nation on these assets or applications, and under which they can connect, share data and information over this network. Cascading connections from this NATO CFBL network to lower trusted security domains is therefore, at present, highly undesirable, if not unacceptable, to any NATO nation.
3. NATO MTDS will deploy simulation interoperability middleware services (e.g. HLA, DIS and TENA) that comply with NATO STANAG and Standards to interoperate the national simulation assets within a unified distributed simulation environment for collective mission training and exercises. Currently, these middleware standards exchange simulation data through a common shared data space and simulation information exchange data model which do not provide any security measures. This implies that any nation that has access to the NATO CFBLNet and allowed to join a specific MTDS exercise with the right cryptographic keys, can also directly access all simulation data that is exchanged between the participating simulation assets. Hence, this collective simulation data set is a "shared secret" of all participating nations (i.e. security domains) within the MTDS exercise.
4. Too much complexity in the M&S CDS deployment topology will complicate the security assurance and operation of the classified simulation assets within each national security domains, and possibly increase the attack surface, risk of convert data flow channels and of cascading connections to lower trusted environments. This implies that overly complex deployment topologies may introduce additional costs and lead-time to NATO nations throughout the MTDS exercise preparation, execution and debrief phases. Therefore CDS deployment topologies should be designed to be as simple as possible while still meeting national security and training requirements.

Figure 4 depicts the reference topology for deploying M&S CDS in the context of a NATO MTDS exercise that has been defined in compliance with the previously mentioned security considerations (Roza, et al. 2020).

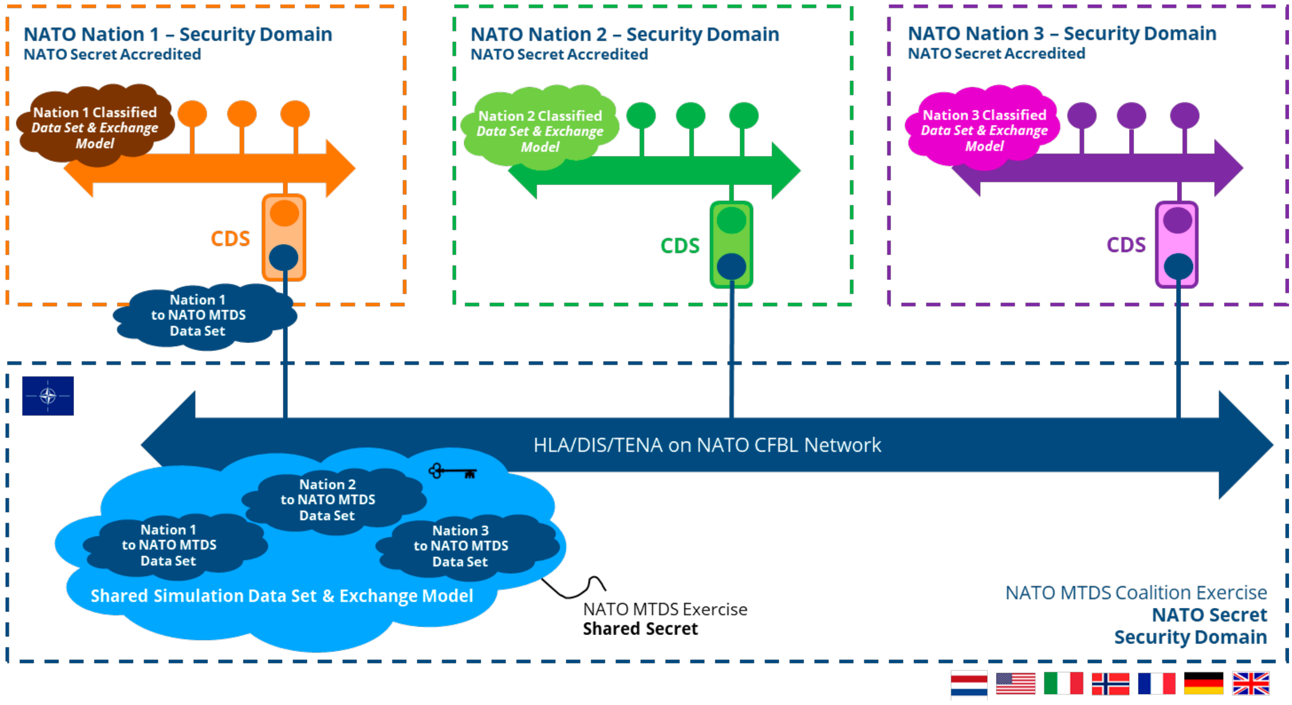

Figure 4: Reference topology for NATO MTDS CDS deployment

The reference topology reflects the typical situation where simulation assets participating in the NATO coalition level distributed simulation environment are owned by different nations, and thus belong to security domains that are governed by different SAAs. To ensure that each nation has the full control of its nationally owned classified simulation data and how this is shared with other nations, each nation shall typically use its own CDS appliance(s). In here each nation's CDS first transforms and maps its own sovereign classified simulation data set into a releasable data set, and then publish it into the collective shared simulation data set according the agreed simulation information exchange model for the collective simulation. This shared data is collectively protected with common agreed security measures such as data encryption to assure confidential information exchange over third party network infrastructure and security measures imposed on each nation's participating simulation facility in order to gain access to join in the NATO MTDS coalition level exercise. Vice-versa the national owned CDS appliance(s) protects the individual or federated set of national classified simulation assets against the cyberattacks from the NATO CFBL Network including unauthorized simulation data based intrusions that result from subscription to data within the shared data space.

6 MTDS validation exercise

Selected from the UAWC's exercise options, SPARTAN WARRIOR events are multinational, air-focused training exercises via distributed simulation. This exercise will be hosted on NATO's CFBLNet and use each nation's simulation or simulator to connect through both DIS and HLA over the four-day period. UAWC simulations/environment generators will provide the overall synthetic environment, secure voice, chat capabilities, and red forces to populate the domain.

In order to create the required area of operations to support the large-scale exercise, the UAWC employed other simulation centre experts including the Air Battle Training Center (RAF Waddington, UK), NATO AWACS ASCOT controllers (Geilenkirchen NATO Air Station), and the Leonardo Company (Italy). Additionally, planned participation includes the French Air Force, Italian Air Force, NATO AWACS, Royal Air Force (UK), Royal Canadian Air Force (RCAF), Royal Netherlands Air Force, Spanish Air Force), United States Air Force, and the US Army. As such, it will also enable Joint and NATO interoperability training by employing US Army Air Defense Artillery Fire Control Officer (ADAFCO) embedded with Allied Control and Reporting Centres (CRCs) and NATO AWACS. To continue interoperability opportunities, the exercise will also support the Intelligence Surveillance Reconnaissance (ISR) "Iron Triad" via the NATO AWACS E-3, a constructive E-8 JSTARS, and the RAF RC-135 Rivet Joint simulator. This ISR fusion capability emulates critical real-world ISR integration for decision-making skills across multiple platforms and agencies. This training will also execute USAFE Air Support Operations Centre (ASOC) connections between Allied CRCs and Joint Tactical Air Controllers (JTACs). Lastly, in support of this effort, there will be multiple counter-air and attack aircraft, both constructive and manned simulators, to support coordinated strikes through deliberate targeting (DT), strike coordination and reconnaissance (SCAR), and close air support (CAS).

As the opportunity presented itself to enable the validation exercise, currently established infrastructure and systems were utilized. The resulting systems and networks in use presented mixed opportunities to explore prescribed RA and CDS configurations. As a result, the data supporting the exercise is recorded for further reference architecture testing and comparison which allowed exercise planners to focus on achieving the Coalition Collective Training Objectives (CCTOs) outlined in the MTDS CONEMP (NATO STO MSG-165, 2019). By focusing on achieving as many CCTOs as possible by creating level 3 training opportunities throughout the exercise area of responsibility (AOR), exercise planners were able to incorporate 37 of the 50 CCTOs as planned objectives (NATO STO MSG-165, 2019).

Referencing figure 2, the interactions between differing missions and aircraft types help to establish the complexity of level 3 training. To begin the process of establishing the required force interactions, the planners looked to establish a battlespace capable of supporting the complexity needed with the available participants. With four (4) command and control (C2) elements in use, structured lanes were assigned to each C2 element. With these lanes comes the requirement to control both the offensive/defensive actions of the fighter aircraft as well as the support requirements to ensure air refueling kept the required CAPs on station. This initial collective action connects fighters and their tankers with the C2 agency controlling them in order to meet the prescribed Area Air Defence Plan (AADP) established by the Combined Air Operations Command (CAOC) in planning documents. This seemingly simple interaction now takes place between four (4) different elements, conceivably in four (4) different locations. For Spartan Warrior 20-9, the interaction between the Italian Air Force Eurofighter in a lane controlled by the NATO AWACS as the C2 agency with its refueling tanker controlled by the UAWC as a constructive entity now ties 3 disparate units together to meet a relatively benign collective training objective, AAR.02 – air to air refueling while co-located. Similarly, a collective grouping can accomplish a much more complex initiative with Composite Air Operations (COMAOs) designed to meet Offensive Counter Air (OCA) objectives OCA.01 (Escort), OCA.02 (Combat Air Sweep), and SEAD.01 (Suppression of

Enemy Air Defence). To establish this collective objective, planners utilize the C2 agency to organize aircraft that are part of the COMAO package to their rally point during their window of opportunity and then provide the air cover (escort) assuming the acceptable level of risk (ALR), stipulated by planning documentation from the CAOC, is met. This objective brings decision making to the C2 agency with their ability to discern the ALR from previous strikes (were air defences sufficiently suppressed?), the status of the COMAO package, the status of the escort OCA group to establish air control, followed by the battle damage assessment (BDA) messages after the strike has taken place. These collective actions now account for multiple groups in multiple locations dealing with fused intelligence (status of enemy air defences) and effective message traffic both pre- and post-strike.

For planners of MTDS events, the complexity of the scenario should not overshadow the complexity of the task at hand. In this instance, the planning documents define restrictions based on ALR and known timing events are established to create these strike windows. This creates the opportunity, or lack thereof, based on the inputs provided to the decision maker – in this case, the C2 agency receiving the training. For the exercise planner, the desired CCTOs become the focal points to drive specific scenarios. By creating these decision points to gather associated information across multiple platforms, all of whom are coordinating for known events, the collective training point is achieved. With larger events, the opportunities to achieve these functions may become lost in the sea of details and opportunities to elicit larger force reactions. However, it is by controlling the process and flow of information by keeping the tasks simple that the CCTOs can be routinely achieved without overwhelming either the training audience or the white force elements creating the supporting environment.

Lastly, in order to vary the assignments in the AOR, specific mission sets were rotated throughout the AOR. This rotation enabled the different C2 agencies to change their focus for each of the four exercise days. While some agencies were tasked with supporting CAS, others became tasked with coordinating COMAO packages, SCAR assets, or dynamic targeting events. Further, the nature of the battle was changed over the four exercise days. By not keeping the timeline linear (Exercise Day 1 = Day 100, Exercise Day 2 = Day 101, etc.), the planners can further construct the exercise events with smaller daily inputs. In this instance, exercise days moved forward in 10-day increments. As such, resupplies can be accomplished for both sides, but more importantly, the tone of the war can be adjusted. For SW 20-9, the 10-day increments provided opportunities to create a red force push day, a blue force push day, a cease-fire (and subsequence collapse back into war) day, and a stalemate day. These all create tones and changes in the overall interpretation of events that have to be accounted for, from possible defectors to fratricide concerns. Together, these variations provide an array of events and mission sets for all players to interpret and establish their courses of action leading to increased training opportunities amongst the collective.

7 Conclusions and recommendations towards NATO joint MTDS

The development of MTDS capabilities within NATO is not limited to the work of MSG-165. The MSG-180 task group puts effort in setting up an MTDS capability (named LVC-T) in the maritime domain (NATO STO MSG-169. 2019). Further the work of these two groups is linked to the MSG-164 Modelling & Simulation as a Service (MSaaS) (NATO STO MSG-164. 2018). MTDS is also one of NATO's Smart Defence Initiatives, sponsored by the United States, and therefore has good visibility on various levels, but still fails to achieve the necessary progress in realizing a persistent MTDS capability. To aid this, it is the intention to combine efforts in Smart Defence as well by integration of the Maritime Domain into an MTDS capability. Whilst several challenges remain, the work undertaken thus far has offered solutions to other existing NATO synthetic training issues. These include:

- Analysis of future Air training requirements, leading to re-confirmation of the benefit of multinational MTDS activities.
- Establishment of common Air training objectives, helping to define Alliance training requirements, helping to align appropriate training media.
- Formulation of Reference Architecture principles, providing a foundation for Joint MTDS capability employment.
- The development of an MSG 165 vision of how MTDS could be employed to support NATO Air operational training. The methodology employed in developing this vision shows wider utility, and the potential for use in helping other components define their own future training visions.

To support the progression towards NATO Joint MTDS, the following recommendations are given:

- Development of a NATO synthetic exercise requirement, commencing with an annual NATO sponsored MTDS exercise. This would help to both increase awareness of MTDS capability and benefits across NATO and aid development of the necessary priority for MTDS enabled training.
- That the Alliance expectation for future multinational synthetic training be formally defined. We believe this provides significant benefits and offers an initial element of the necessary top-down direction and guidance to help drive progression of MTDS capabilities.

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