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NATO Initiative in Multi-national Mission Training through Distributed Simulation

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EXECUTIVE SUMMARY

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NATO Initiative in Multi-national Mission Training through Distributed Simulation

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Problem area

NATO and nations face challenges regarding live training and exercises. Current and future operations are multi-national in nature, the missions and the systems are becoming more complex and need detailed preparation. Furthermore rapid adaptation to changing circumstances is needed. At the same time opportunities for live training and mission preparation are reduced due to less available resources, more peacetime restrictions and limited time span between political decision making and deployment. Mission Training through Distributed Simulation (MTDS) presents a solution to these challenges and is therefore crucial to NATO and nations' mission readiness. Despite a number of initiatives in the past to set up a NATO MTDS capability, currently NATO does not have a standing operational MTDS capability.

Description of work

In October 2013 the NATO task group MSG-128 was set up with the objective to establish essential elements for a permanent NATO MTDS capability for air operations and validate these elements through initial operational exercises and evaluation. The approach of MSG-128 was two-fold:

1. Define a concept of operations and reference architecture for a permanent MTDS infrastructure for air operations, including architectural requirements for integration of live components (connected flying platforms) in the MTDS architecture.
2. Build the MTDS environment incrementally by executing a yearly MTDS exercise.

Results and conclusions

During the MSG-128 exercises permanent connections to a secure NATO network have been established at multiple training location. The networking capabilities of the simulation tools have been improved and federation agreements have been documented. A thorough test approach and test plan covering both technical and operational aspects have been developed.
The MSG-128 concluded its work with a 4th exercise in March 2017. This exercise proved that realistic combined mission training for fighter pilots and controllers can be achieved in the initial NATO MTDS capability.

Applicability

The MTDS reference architecture provides an initial baseline for multi-national training exercises, even if gaps remain to facilitate the MTDS exercise employment. The maturity of multi-national MTDS exercises will be a long process. The following axes of efforts are recommended to reach this maturity:

1. Progress on the operational maturity of small/medium exercises.
2. Continue to validate these solutions on operational exercise environment 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 exercise.

GENERAL NOTE
This report is based on a presentation held at I/ITSEC, Orlando, 29 November 2017.

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Summary

NATO and nations face challenges regarding live training and exercises. Current and future operations are multi-national in nature, the missions and the systems are becoming more complex and need detailed preparation. Furthermore rapid adaptation to changing circumstances is needed. At the same time opportunities for live training and mission preparation are reduced due to less available resources, more peacetime restrictions and limited time span between political decision making and deployment. Mission Training through Distributed Simulation (MTDS) presents a solution to these challenges and is therefore crucial to NATO and nations' mission readiness. Despite a number of initiatives in the past to set up a NATO MTDS capability, currently NATO does not have a standing operational MTDS capability.

In October 2013 the NATO task group MSG-128 was set up with the objective to establish essential elements for a permanent NATO MTDS capability for air operations and validate these elements through initial operational exercises and evaluation. The approach of MSG-128 is two-fold:

1. Define a concept of operations and reference architecture for a permanent MTDS infrastructure for air operations, including architectural requirements for integration of live components (connected flying platforms) in the MTDS architecture.
2. Build the MTDS environment incrementally by executing a yearly MTDS exercise.

The MSG-128 concludes its work with a 4th exercise in March 2017. This exercise proves that realistic combined mission training for fighter pilots and controllers can be achieved in the initial NATO MTDS capability.

This paper describes the concept of operations and initial MTDS environment that provide NATO and nations already with a current capability to conduct realistic multi-national training for air operations. The paper concludes with a path for future growth towards an effective persistent LVC environment for air operations training which is defined by the reference architecture and the requirements for integrating live flying assets.

Contents

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1 Introduction

The focus of this paper is to describe the concept of operations and an initial Mission Training through Distributed Simulation (MTDS) environment that provide the North Atlantic Treaty Organization (NATO) and its nations with a capability to conduct realistic multi-national training for air operations. The paper reflects the work performed by the MSG-128 task group that was tasked to establish essential elements for a permanent NATO MTDS capability. The MSG-128 activity is conducted under the umbrella of the NATO Modelling and Simulation Group – one of 8 panels and groups forming the NATO Science and Technology Organization (STO).

In the past NATO has had a number of initiatives in this field starting with the study SAS-013 on MTDS (2000) [1]. 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 the training demonstration exercise First WAVE, “First Warfighter Alliance in a Virtual Environment” (SAS-034/MSG-001, 2004) [2]. 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 the NATO Industry Advisory Group (NIAG) Study Group 162 on distributed simulation for air combined and joint mission training [3]. These studies have provided valuable inputs in the development of a NATO MTDS vision and concept of operations (CONOPS), however none have provided a persistent MTDS capability to support the warfighter in achieving increased Mission Readiness. 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 Operational Readiness for the Forces of contributing nations to conduct future Coalition Operations.

This paper starts exploring the operational need for air combined and joint tactical training. Then it will outline how the task group is organized and explain its approach, followed by a description of the derived concept of operation. The next chapter introduces the reference architecture developed for MTDS followed by a description of the architecture that was implemented by the task group for the final exercise. Then the initial exercises and the lessons learned from the exercises are summarized. An outlook is presented how live players can be integrated in the future in this MTDS environment. The paper ends with a number of conclusions and recommendations for a growth path towards an effective persistent LVC environment for air operations training.

2 Operational need

The North Atlantic Treaty Organization (NATO) and nations face challenges regarding training and exercises. NATO has a stated requirement for a full range of operationally ready capabilities to deter and defend against any threat to the safety and security of its populations. This includes an explicit statement of the need to carry out the necessary training, exercises, contingency planning and information exchange for assuring defense against conventional and emerging security challenges. NATO operations are multi-national in nature, and the missions and the weapon systems are becoming more complex and need detailed preparation and rapid adaptation to changing circumstances. At the same time cost savings are important in light of optimal utilization of defense budgets. We also see that opportunities for (live) training and mission preparation are hampered due to available live equipment and limited time span between political decision making and deployment.

It should be noted that simulation has become an essential tool to meet the training demands of the military forces. Improvements in technical capabilities and reduced costs have enabled more effective use of simulation tools across nations and organizations. Nations have enhanced their ability to generate representative complexity in operational setting, to avoid real-world constraints and to lower costs, risks and unintended consequences compared to live training. From a NATO perspective, the MTDS element is therefore crucial to NATO's and nation's readiness. At a time when many member nations are moving toward greater use of advanced simulation for mission training and adopting national MTDS capabilities, NATO does not currently have a collective MTDS capability to leverage these national developments.

The vision for Mission Training through Distributed Simulation (MTDS) was discussed in the NIAG Study Group 162 amongst a number of NATO nations' Air Force Representatives and was generally described as follows: "***A shared training environment that includes a blending of live, virtual and constructive simulations within a common synthetic environment that will allow warfighters to train individually or collectively at all levels of war"*** [3]. While many Air Forces are working to implement this vision nationally, they also see significant benefits of extending the capability to include Joint and Combined training, particularly within the NATO context. The US have acknowledged the value of such a system and are applying it in practice utilizing a persistent Distributed Mission Operations Network and Distributed Mission Operations Centre to conduct national mission training as well as hosting multi-national "Coalition Virtual Flags".

It is not anticipated that NATO will be responsible for generating all tactical level live, virtual or constructive training system elements to support NATO MTDS. The majority of the training assets are expected to be provided by NATO member or partner nations who have available live, virtual or constructive simulation capabilities within national distributed simulation networks that can be connected to a multi-national network for broader Distributed Mission Training. NATO MTDS should permit warfighters to enhance Operational Readiness by conducting complex mission training within an environment as operationally realistic as possible including interdependent consequences of human-in-the-loop performance with supported and supporting capabilities, all within a lower risk, lower cost and lower consequence environment.

3 Task group

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 the task group MSG-128 "Incremental Implementation of NATO MTDS Operations" to establish essential elements for a persistent NATO MTDS environment and to validate these elements through initial operational test and evaluation. In October 2013 the MSG-128 started with seven NATO countries (Canada, France, Germany, Netherlands, Norway, Turkey and USA), the NIAG, and the NATO E-3A Component. The approach of MSG-128 is two-fold:

1) Define a reference architecture and CONOPS for a permanent MTDS architecture (focus on the longer term)
2) Start building the MTDS environment incrementally by organizing a yearly MTDS exercise (focus on short term).

To achieve these two objectives the MSG-128 task group has created three working teams: OPS (Operational), TEK (Technical) and IMPL (Implementation). The OPS team mainly consists of active military operators and focuses on the operational aspects of MTDS exercises. The TEK team mainly consists of experts and specialists in the field of distributed simulation and simulation architectures. The focus of the TEK team is long-term and its main task is recommend a reference architecture for MTDS. The IMPL team mainly consists of national simulation experts and technical staff from the participating simulator sites. The focus of the IMPL team is on implementing the architecture for the initial exercises and preparing the participating simulators and tools.

Aside of these three teams there is a fourth team incorporated in the MSG-128 task group. This is the Air Combat Training Architecture Requirements (ACTAR) team. The ACTAR team originates from a NATO Air Force Armaments Group (NAFAG) study (2011-2014) which focused on the architectural requirements derived from operational needs of the live air combat platforms to be integrated within MTDS architectures. The scope of work for the ACTAR team is:

- Identify data formats/protocols standards for the live part of MTDS exercises
- Develop architectural requirements for integration of live components (connected flying platforms) in the MTDS architecture
- Propose a live instrumentation experiment for MSG-128 follow-on (connection of live elements to a ground network).

4 MTDS concept of operations

The MTDS CONOPS describes MTDS system characteristics from an operational perspective in order to run the future MTDS IOC. The MTDS IOC provides for training of individual, team and inter-team combat skills for operators of different weapon platforms and Command and Control forces from geographically separate locations, i.e. distributed, within NATO. The objectives for MTDS are as follows:

- Employ own assets in a realistic (maximum extent to enable follow-on objectives) simulation environment
- Train standing NATO procedures and tactics (Joint / Combined)
- Development and validation of new NATO procedures and tactics in given future scenarios of interest
- Train effective interactions and communication in a Joint / Combined environment
- Train correct processing, evaluation and effective sharing of gathered information
- Satisfy all training requirements from periodic generic training up to time critical mission rehearsal
- Cover the whole spectrum from small scale missions (minimum 1 versus 1 with GCI (Ground Control Intercept)/AWACS) to full-up large force (Dissimilar) Air Combat Training (ACT) and even include Combined Air Operations (COMAO)-type exercises including support and ground entities
- Employ own forces without peacetime restrictions under wartime Rules of Engagement (ROEs)

The CONOPS describes the complete mission cycle for MTDS exercises, including mission planning, mission execution and mission debriefing. Additionally, the CONOPS describes the initial coordination phase prior to the mission cycle in which pre-requisites are defined that have to be met in order to participate within an MTDS exercise as well as the division of roles and responsibilities that need to be coordinated. It is essential during the initial coordination phase to define the training objectives in order to achieve mission success.

It must be noted that the complete mission cycle – as described within the MTDS CONOPS – mimics the mission cycle of a live exercise. When required the MTDS CONOPS portrays specific simulation considerations that need to be addressed as well, such as the availability of terrain data sets and Computer Generated Forces (CGF) and overall network connectivity among participating sites.

5 Architecture for initial mtds capability

5.1 MTDS Reference Architecture

An MTDS exercise involves interconnecting heterogeneous simulation based training devices and in some cases real equipment in a common network. NATO has mandated the use of High Level Architecture (HLA), IEEE 1516.2010™ (HLA Evolved) [4][5][6], as the preferred architecture for distributed simulation. HLA has mechanisms that facilitate scalability in large federations and flexibility to adapt and to evolve the simulation data exchange model (SDEM) according to the needs. However, acknowledging that a lot of existing simulators already have a Distributed Interactive Simulation (DIS) interface, or uses legacy HLA implementations, a concept of gateways and bridges has been developed to support other distributed simulation standards and versions. This concept, developed for the NATO Education and Training Network Federation (NETN) [7], has also been adapted for the MTDS reference architecture, see Figure 1. The bridging of federations furthermore allows for more detailed control of the data a site exchanges with the other sites through the common HLA backbone, and simplifies the management of the backbone federation.

The MTDS reference architecture uses a subset of the Real-time Platform Reference Federation Object Model (RPR-FOM) 2.0 [8] as basis SDEM together with the SISO Standard for Link 16 Simulations [9]. The Combined Federated Battle Laboratories Network (CFBLNet) was selected as common network infrastructure.

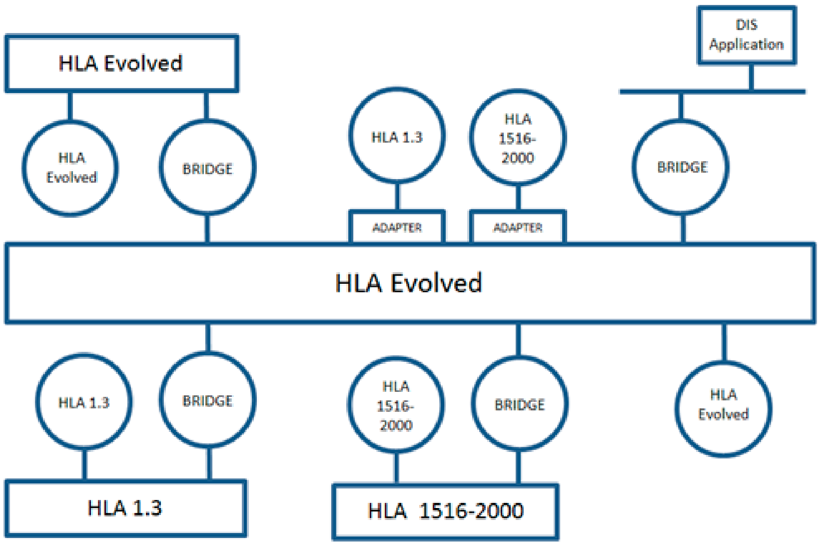

Figure 1. MTDS Reference Architecture [7].

5.2 Federation Agreements Document

Implementing an MTDS capability distributed across nations is a challenging task. The participating training devices have been developed according to the needs in the Nations. Having a set of common requirements and agreements to ensure a certain level of interoperation is therefore crucial. MSG-128 has developed a Federation Agreement Document (FAD) to minimize integration time and create a reference for future MTDS members. The FAD developed in MSG-128 reflects an initial MTDS capability with focus on air-to-air operations and with a limited air-to-ground capability.

The main topics are the following:

- Federation architecture and member applications overview
- Data exchange models including tactical data link (TDL)
- Interest matrix with publish/subscribe responsibilities for each federate
- Enumerations for entities and emitters
- Time representation and dead reckoning of entities
- Simulated radio communications
- Federation states including start-up and shutdown procedures
- Run-Time Infrastructure (RTI) agreements including RTI services and RTI configuration
- Modelling responsibility
- Common damage models
- Synthetic Natural Environment (SNE) agreements.

5.3 Exercise Architecture

NATO Standardization Agreement (STANAG) 4603 [10] mandates the use of HLA as the interoperability backbone for the NATO MTDS capability. As most assets already implemented a DIS interface, the first two MTDS exercises used DIS, transitioning to an HLA backbone for the third exercise. Due to missing HLA capability of the existing radio simulation tools at all sites, DIS is however still used for radio voice communication simulation, see Figure 2. Correlated replay of parallel DIS and HLA data streams for debriefing is possible with existing debriefing tools. It is however desirable to transfer voice communication to HLA in the future in order to simplify the MTDS architecture and to simplify After Action Review as voice currently is logged by a separate tool.

Link 16 is a fundamental capability for air operations training. Link 16 simulation requires both correct implementation of J-Messages and tactical data link functionality for track management and Command and Control (C2). Even though the SISO Link 16 Base Object Model (BOM) was the obvious choice for Link 16 simulation a lot of gateways are needed in order to make all systems interoperate. In addition to the SISO Link 16 BOM numerous other protocols are being used by the participating simulators: Standard Interface for Multiple Platform Link Evaluation (SIMPLE) [11], Link 16 over DIS (SISO J), Joint Range Extension Application Protocol (JREAP) [12] and J-Messages over the RPR FOM RawBinaryRadioSignal Interaction. Thus, Link 16 simulation requires special attention in the future development of NATO MTDS in order to reduce the integration effort prior to MTDS exercises.

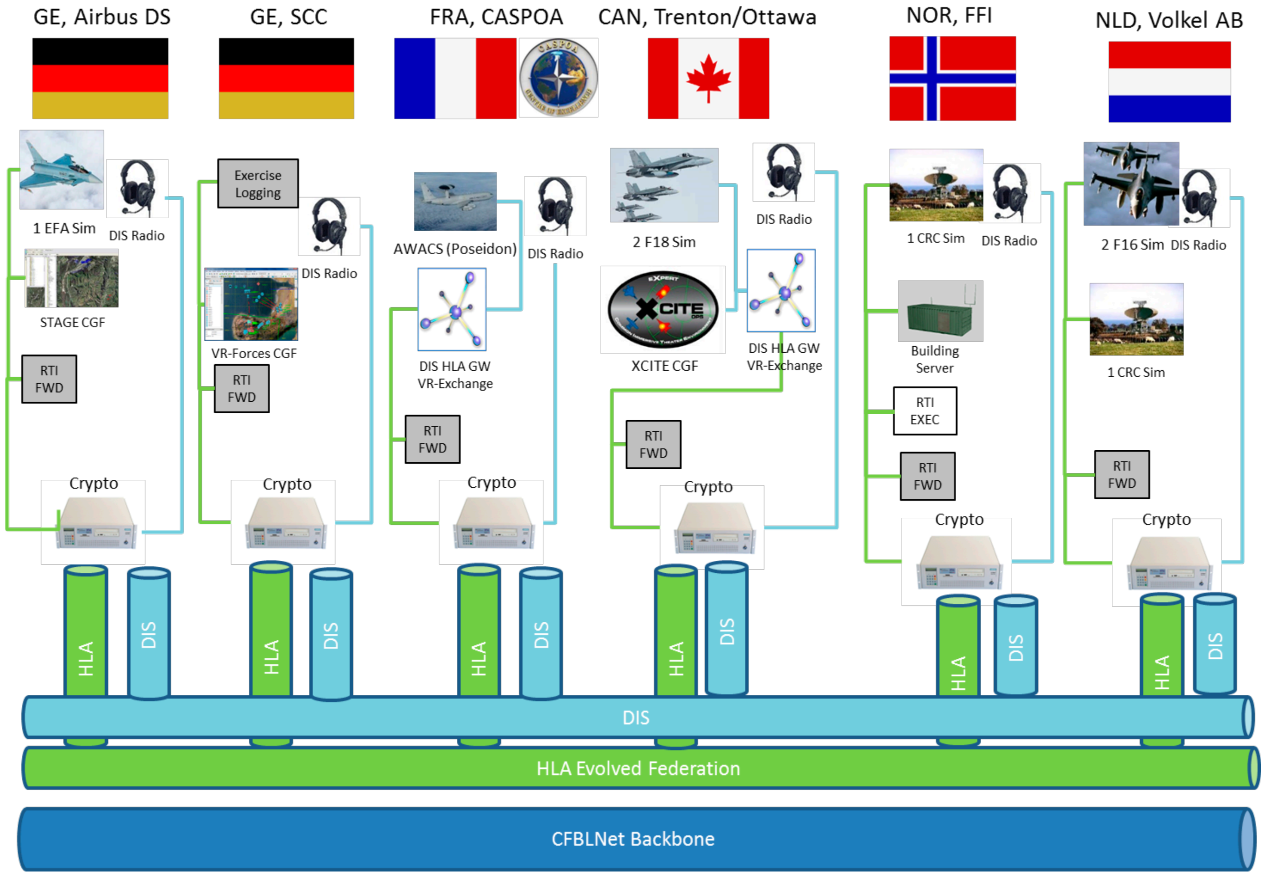

Figure 2. Exercise 4 Technical Architecture.

6 MTDS exercises

The fourth NATO MTDS exercise was conducted during week 12 2017, with a two-week test period prior to the exercise. This chapter briefly introduces the scenarios used in the exercise followed by a description how the setup was tested and the lessons learned. Figure 3 shows the six sites participating in exercise 4:

- The German Air Force Simulation Control Centre, Cologne
- Airbus, Manching
- Royal Canadian Air Force – Canadian Forces Aerospace Warfare Center (CFAWC), Trenton
- Volkel Air Base
- CASPOA, Air Operations Center of Excellence, Lyon
- Norwegian Defence Research Establishment (FFI), Kjeller

Figure 3. The sites participating in MSG -128 exercise 4.

6.1 Scenarios

Four exercises were conducted during the lifetime of MSG-128. The exercises built on each other with increasing complexity with respect to the scenario and operation. The exercises started out with very simple 1 versus 1 air to air mission controlled by AWACS (Airborne Warning And Control Station) to a Combined Air Operation (COMAO) including air to ground targets, Electronic Warfare (EW) elements and Tactical Data Link controlled by AWACS and two Control and Reporting Centres (CRCs). Mission duration was roughly one hour, and 2-3 missions where executed in a regular exercise day.

One major challenge when interconnecting simulator systems from so many countries was the availability of a terrain database for the staging area. For the two initial exercises already existing databases were used. From exercise 3 and onwards the scenarios also included air to ground elements. This required that the database generation process was included in the exercise preparation in order to have a shared terrain database including destructible buildings for ground targets. A source data set using common terrain standards was shared among the participants, together with a description of which common terrain features should be built. This allowed the different flight simulators to employ their custom tools and database generation processes.

Except for the very first air to air engagements during the first exercise, all red air, ground threats and white traffic was constructive, generated by various scenario generation tools. It was fairly early on decided in MSG-128, that the objective was to train NATO operators to fight together in a coalition force and not against each other.

6.2 Test Plan

The main objective of the exercises in MSG-128 was to validate and evaluate the operational and technical concepts required to implement a MTDS capability in NATO. This was done through four exercises with increasing complexity, starting from fairly simple to complex missions.

The biggest challenge of the exercises was not only to integrate multiple virtual and constructive simulation systems into a federation, but also to provide a collaboration environment for the technicians, IT-administrators and, last but not least, for the operators. All this had to happen with in the limited time span of two weeks. The technical equipment needed included Voice over IP (VoIP) phones, gateways, data recording and replay tools, 2D/3D viewers and analysis tools, not forgetting to mention the crypto equipment required to run on a NATO SECRET level.

In order to use the two weeks available for implementation and testing efficiently, a test plan and test schedule was developed. The test plan comprised all technical and operational aspects, tailored to the requirements, which needed to be fulfilled to ensure the operators would be able to reach their mission objectives. The test schedule put it all into a logically structured timeline.

The test plan for MSG-128 exercise 4, the final and most complex exercise, contained the following main components:

- Test Schedule
- Locations and Participant Contributions
- Scenario and Database Identifiers
- Classification
- Roles and Responsibilities
- Operational Test Conditions
- HLA Configuration and DIS Settings (voice communication)
- Detailed Equipment and Location
- Test Cases
    - Network Connectivity
    - Simulation Environment Technical Setup (HLA, DIS, JCHAT)
    - Basic Entity Verification
    - Coordinate System Accuracy
    - Weapon Fire / Munition / Detonation Interactions
    - Simulation Environment (Operational)
    - Voice / Data and Link Messages
- MTDS environment architecture

The test plan turned out to be a detailed and somewhat lengthy document. Sometimes it was not so easy to separate the content of the FAD from the test plan and borders became fluent. Therefore it was decided to create a test matrix for better usability and clarity. The test matrix contained the following main test items:

- Connectivity
- Federation
- Tactical Data Link
- Operational Communication
- Terrain Database
- Interaction Simulator to Simulator
- Interaction CRC / AWACS to Simulator
- Interaction CRC to AWACS
- Interaction CGF to Simulator
- Weapon deployment

The test items were broken down into many smaller test cases to create small and fairly constrained test cases. When working through the test according to the very strict test schedule, color coded test results, when necessary with detailed commentary, were filled into the test matrix. This approach provided a good overview about the progress made at all times and proved very useful.

6.3 Results and Lessons Learned

The following results have been achieved during the initial exercises:

- Establishments of permanent connections to the CFBLNet at multiple training locations.
- Improvement of the capabilities of the networking RTI to better support a distributed federation set-up.
- Verification and improvement of COTS DIS to HLA gateways.
- Integration of multiple COTS DIS Radio tools for simulated radio communication.
- Verification of the capabilities of multi standard TDL tools to support a common TDL network despite using different standards.
- Generation of a FAD where the main agreements for an initial MTDS capability have been agreed.
- Establishment of a test approach and test plan that comprise both technical and operational aspects.

The following lessons learned reflect the overall picture, condensed from the experiences made during the individual exercises:

- "National admin" must be completed in due time before an exercise, i.e. accreditation complete, crypto gear available and configured, licenses/dongles & hardware available, required personnel in place.
- "International admin" must be completed, i.e. CFBLNet (Common Federated Battle Lab Network) accreditation and initiative.
- All simulation systems and tools used must be ready for use in a federation and thoroughly tested prior to joining the NATO MTDS federation. They have to be sufficient to fulfil the training objectives of the exercise.
- To allow for sufficient time for testing is important even though this requires a lot of resources. With a fairly low repetition rate of the exercises, there will be new systems, new people, and expertise will be lost between exercises. All this will slow down the integration process.
- The test phase must be well organized and coordinated to make efficient use of the critical resources time and man power. A logical test schedule has to be made and adhered to.

- All participants must be ready at the beginning of the test phase.
- A dedicated and stable Network Infrastructure with minimum bandwidth of 10 Mb/s is a prerequisite. Commercial off the shelf RTI implementations should have a certain level of robustness against short connectivity losses that may occur in Wide Area Networks (WANs).
- Fair fight has to be strived for. This needs to be taken into consideration when designing the training scenarios with regard to terrain databases, 3D-models and objects, fidelity of sensor, weapon and EW simulation.
- A collaboration environment to create a virtual briefing / debriefing room is a must for the operators as well as for the technical staff. During the execution of the exercise sufficient means of communication need to be available for the technical staff and the white cell / exercise control.
- Especially for larger COMAO-like exercises, a standing, permanent Distributed Mission Operation Center (DMOC) should be beneficial as a NATO facility. Nations, who have the demand of MTDS, have to have a permanent point of contact, which has the required expertise in preparing and executing MTDS exercises.

7 Integration of live players

The previous sections explain and outline the MTDS architecture and the initial operational capability of an MTDS environment for air operations mission training. The initial capability is fully built up with simulators and simulation tools. The NIAG SG-162 has already recommended pursuing greater integration and interaction with live components [3]. So, a next step is to also integrate live players into the MTDS environment and to set up a real Live Virtual Constructive (LVC) exercise. Therefore as part of the MSG-128 objectives a study, assigned to the Air Combat Training Architectural Requirements (ACTAR) [13] team, aims to produce requirements for the integration of “Live (in the air)” into the MTDS environment.

This ACTAR team has already in 2002, as part of NIAG SG-71 [14], surveyed air combat training systems for live systems in service and commonly used in the limited parts of LIVEX training. The report covers air combat training systems’ capabilities and limitations, identified a number of interoperability shortfalls and provided recommendations to improve their utility. Since air combat training systems were used for individual squadron and combined/joint exercises with multi-national participants flying a variety of aircraft, interoperability and security was paramount.

LVC systems combine live, virtual and constructive simulations and applications into a single distributed system. An important observation that needs to be made at this stage is the drastic transformation that takes place in the world of military training. Increasing complexity in weapon systems, rising concern for training costs and advancing simulation technologies push for the formation of synthetic battlespace that enable LVC simulations. This vision is well integrated with the globally emerging concept of MTDS.

LVC synthetic range architecture must ensure the interoperability of the distributed simulations, tactical data links and radio communications in the training scenario environment [15]. The NATO Modelling and Simulation Standards Profile (NMSSP) [16] defines interoperability between simulations as: “The capability for simulations to physically interconnect, to provide (and receive) services to (and from) other simulations, to use these exchanged services in order to effectively work together”. This definition refers mainly to “technical interoperability” that means the possibility to physically interconnect and communicate. A lot of additional work has to be done after interconnection is ensured, to reach higher levels of interoperability (semantic or substantive interoperability)”.

In May 2011, the ACTAR team was tasked by the NATO Air Force Armaments Group (NAFAG) Air Capability Group 2 (ACG2) to identify the scope of operational and technical requirements to operate and inter-operate live air platforms as part of future MTDS architectures. In [13] the ACTAR team provides conclusions and recommendations suggesting the way ahead for the provision of Future Air Combat Training Systems which are interoperable with LVC systems. The team first reviewed the generic air combat training concepts within NATO nations as well as the emerging applications on MTDS architectures and LVC. Two main challenges were identified from the perspective of integrating Air Combat Training Systems into MTDS systems. The first one is system interoperability (aircraft, UAV, ACMI, ground station, other LVC actors) and the second one is the security of data to be shared between international actors.

LVC systems have difficulties in communicating with each other due to every participant using different simulation architectures. Current LVC architectures are not interoperable. Every architecture has its own area of interest like HLA which is mostly used for integrating virtual and constructive assets, while TENA is mostly used to integrate live assets into training exercises [17]. Architectures are successful in fulfilling the domain requirements but they were not designed with a focus on assuring architectural interoperability. Combining these architectures to create large-scale

LVC systems faces unique interoperability challenges. Bridges must be installed and configured, and special gateways and data exchange models must be developed [18].

In the scope of operational needs for live air combat training in the context of MTDS, the ACTAR team makes the following opinions based on the literature survey, review of existing studies and limited survey results:

- There is a desire to have LVC capable of air combat training systems,
- Although the Nations aim to decrease expenses with LVC, pilots have some concerns to lose their proficiency with replacing live training with simulators,
- LVC systems improve exercises, save time and money.

Long term objectives for the ACTAR team are:

- Development of requirements for synthetic battlespace training concepts potentially ask for embedded training components regarding to LVC training,
- To enhance real-time interoperability of live integrated training systems,
- Development of requirements for LVC mission planning and post mission analysis,
- To enhance secure data exchange in multiple layers,
- Develop a concept which defines the open datalink architecture supporting LVC,
- Conceptual architecture for weapon simulation and embedded training.

The NIAG SG-215 has an objective for “providing recommendations on the balance between the advantages of virtual vs real world training given the competition for airspace”. This objective merges ACTAR team’s current and long term objectives.

8 Recommendations and way forward

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. The MTDS reference architecture provides an initial baseline for multi-national training exercises, even if many gaps remain to facilitate the MTDS exercise employment, such as:

- Standard process for exercise management and collaborative working tools between exercise manager at central level, national training site level and at training units, for the preparation, execution and post exercise phase. Currently some limited services exist on CFBLNet (VoIP, JCHAT, Video Tele Conferencing (VTC)).
- Standardized scenario description for distribution from central level to training units. Some initiatives exist such as MSDL (Military Scenario Definition Language) and C-BML (Coalition Battle Management Language). These are mainly applicable for land tactical simulation, but not yet appropriate for air mission scenario distribution over the number of sites and training units, including; 4D trajectories, data link network organization and alignment of operational C2 data with the simulation environment. Currently the instructors enter the scenario data manually into each simulator or simulation.
- Consistent terrain (and other environmental data) representation over the multiple formats used by the Live (instrumented systems), Virtual and Constructive training units. This gap is not specific to the air mission exercise, but has a lot of air domain specific requirements, such as the size of the terrain, models for Air Ground Surveillance (AGS), targeting, etc. Currently the terrain data are regenerated for each simulator and simulation. Common terrain entities (bridge, building) are added in the scenario and in the terrain databases in order to provide coherent terrain representation in the multiple sites.
- Data Link representation. There are several different ways to manage Link 16 J-series messages in the simulation: encapsulation in DIS or HLA, separate IP data flow (JREAP, SIMPLE). No simulation standard exists for other data links such as Full Motion Video and specific sensor data links (high number). Discussions remain on the value of the encapsulation approach instead the use of C2 standards over IP. Currently, SISO-J is applied only for Link 16, after integration of multiple gateways.
- LVC concepts and technical solutions need to mature and be standardized. Currently, we do not yet mix MTDS and Live exercises.
- Network and security are progressing, but remains a constraint for the exercises. Better MTDS infrastructures are required in order to provide higher bandwidth and equivalent Quality of Service (QoS) on the multiple national networks interconnected to CFBLNet. Several VPN (Virtual Private Network) could be required in order to avoid side effect of voice dataflow overload on DIS/HLA packets. All connected sites must be compliant with the higher security level even if only one simulator requires this security level, independently of the scenario classification.

The maturity of multi-national MTDS exercises will be a long process. The following axes of efforts are recommended to reach this maturity:

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 environment 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 exercise.

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