Modelling and Simulation in NATO Federated Mission Networking

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ABSTRACT

NATO has ongoing a major initiative called Federated Mission Networking (FMN), aiming to establish a common technical and training basis among NATO member and partner nations such that their forces will have interoperability of critical information systems whenever needed for coalition operations. FMN is not a network; it is a set of standards and practices for interoperation. The authors are leading the efforts of the MSG-193 Specialist Team that has been working to support inclusion of appropriate modelling and simulation (M&S) standards and practices in FMN. This paper summarizes how FMN specifications are being developed, including the role of MSG-193 as "M&S Syndicate" contributing to the process. The paper then highlights the culture gap between science and technology of NMSG and the military operations enabled by the FMN, and how that gap is being bridged effectively. Spirals (phases) 5 and 6 of FMN development will be the primary focus for modelling and simulation, including mission rehearsal, training, and decision support. The paper concludes with a summary of the M&S technologies in the current recommendations for those spirals.

1.0 INTRODUCTION

NATO has ongoing a major initiative called Federated Mission Networking (FMN), aiming to establish a common technical and training basis of standards and procedures among NATO member and partner nations such that their forces will have interoperability of critical information systems whenever needed for coalition operations. FMN is not a network; it is a set of standards and practices for interoperation [1]. The authors are leading the efforts of the MSG-193 Specialist Team that has been working to support inclusion of appropriate NATO Modelling and Simulation Group (NMSG) sponsored standards and practices in FMN. This paper summarizes how FMN specifications are being developed, challenges of specification development by cooperative effort between NMSG and NATO operational commands, work achieved thus far by that cooperation, and in conclusion a list of M&S technologies in the current recommendations for FMN. For extended details see [2].

1.1 Why FMN

Due to the issues faced by forces from NATO and coalition partners in early deployments to Afghanistan, the Afghan Mission Network (AMN) was conceived and successfully developed, which required overcoming interoperability challenges implementation. AMN was designated as the primary Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Network for the coalition. In the aftermath of a number of NATO's operations, and predominantly because of their deployment to Afghanistan, a key lesson identified was the need to have its command and control processes

and supporting technology interoperable before the start of a mission, in what is termed "Day Zero Interoperability." In order to achieve this, it was decided by NATO's Military Committee (MC) in 2012 that NATO had to develop Federated Mission Network (FMN) as a common capability among NATO nations [3]. The FMN concept was endorsed in 2016 by the NATO Warsaw Summit, where it was stated by NATO leaders that "Interoperability of our armed forces is fundamental to our success and an important added value of our Alliance" [4].

The mission of FMN is *Enhanced Operational Readiness & Effectiveness Today and in the Future* and its vision is *Day Zero Interoperable Forces*. Day Zero capability refers to the minimum capability required to support the needs of the Commander during the pre-deployment and initial deployment phases of an operation and to support rapid, smooth, and efficient transition from pre-deployment to initial operations (see Figure 1). As articulated by NATO Allied Command Transformation (ACT), the FMN vision has two components: 1) *Operate Together: Exploit our Strategic Advantage* and 2) *Adapt Together: Effectively Transform Capabilities to Maintain our Edge* [5].

Figure 1: FMN Ready Force Requirements [6]

1.2 Why M&S in FMN?

M&S has emerged as a powerful technology for mission preparation, operational analysis, and training; as such it is a necessary part of the FMN. M&S is a fundamental adjunct to many NATO capabilities because it provides a safe, often cost-effective means of reducing risk, providing training, and evaluating and developing capabilities, equipment and processes. As in traditional operations, there are a number of benefits in bringing M&S to FMN. One particular strength is the ability for simulations to provide an accurate representation of the forces, environment and operational context to support Mission Rehearsal (MR), linked to operational command and control information systems (C2IS). Another is use of a similar representation to support course of action (COA) analysis. In line with the FMN development philosophy, M&S capabilities need to be addressed as part of the accredited portfolio of FMN capabilities. This section gives a short summary of what M&S is, how it is used, and, by extension, how it may be used in FMN. Supporting details can be found in [7].

1.3 NMSG Contributions to the FMN Specification

NATO Science and Technology Activity 145 (MSG-145) was third in a sequence of such activities that supported development of the Command and Control – Simulation Interoperation (C2SIM) [8]. During development of C2SIM it came to the attention of NMSG that, while approval of a C2SIM STANAG would be useful to support NATO use of C2SIM, the focus of interoperation in the future will lie with FMN.

Furthermore, several other standards and practices advocated by the NMSG are highly appropriate for FMN use. Therefore NMSG sought approval of a new Specialist Team, now identified as MSG-193, to contribute M&S expertise toward formal development of the FMN specification.

FMN development proceeds in stages called *Spirals*. Of the four Spiral stages Draft, Candidate, Proposed and Final definitions, Spirals 1 through 4 have reached the Final stage. Spirals 5 is Proposed and still ongoing work, while Spirals 6, 7 and 8 are just beginning. NMSG had intended to join the M&S Syndicate for Spiral 6 but learned that there is an operational requirement for MR in Spiral 5, therefore focused MSG-193 on M&S standards and practices most pertinent to Spiral 5. FMN Management has welcomed the contributions of MSG-193.

2.0 DEVELOPMENT OF FMN SPECIFICATIONS

As set forth in [9], the aim of FMN is to provide secure, scalable, flexible and agile federated Mission Networks (MN) through which accredited applications operating in NATO and national can safely and reliably exchange data and information. This must be achieved among over 30 NATO and partner nations (the "FMN Affiliates") with widely differing levels of information technology sophistication and resources. FMN seeks to achieve that objective using three main components:

- Governance – to provide overall management of FMN requirements, development and instantiation;
- FMN Framework – to cover all aspects of policy, design, architecture, testing, accreditation, support tools, processes, etc. needed for creating MNs; and
- MN Instances – these provide Day Zero FMN-compliant capability to support operations, training events, exercises and/or interoperability verification activities.

2.1 FMN Management Structure

As defined in [10] FMN has overall management and support, plus a collection of *working groups* that meet separately and then come together in the FMN track of ACT's "TIDE Sprint" assembly twice yearly [11]:

- Overall management group
- Supporting secretariat staffed by ACT
- Operational coordination working group (OCWG) linking to NATO commands
- Multinational CIS security management authority working group (MCSMAWG)
- Capability planning working group (CPWG) and syndicates
- Change and implementation coordination (CICWG) working group
- Coalition interoperability assurance and validation (CIAV) working group

MSG-193 efforts supporting definition of M&S requirements for FMN interact with all of these, particularly with:

- OCWG to specify operational requirements
- CPWG to specify standards-based technology solutions
- MCSMAWG to ensure the resulting capabilities incorporate appropriate security
- And ultimately, with the CIAV working group

2.2 FMN Spirals and Roadmaps

The concept of FMN development laid out in [5] follows in a general way the spiral development approach that has become very popular in the commercial sector, where a short sequence of phases is continually repeated, with active user involvement, coming closer in each cycle to the overall goals of the development (see Figure 2). The approach may be described as repeated plan-a-little/build-a-little/test-with-users/rethink-results.

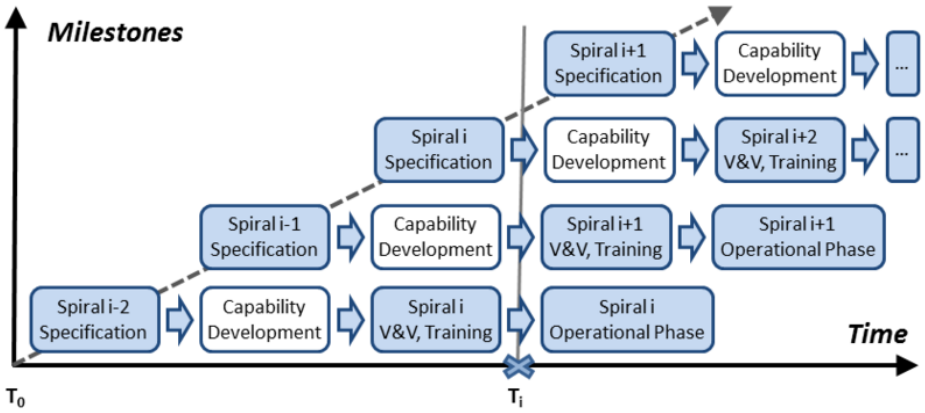

Figure 2:- The FMN Spiral Development Process [9]

Although commercial development spirals can be as short as one month in duration, the Spirals in FMN are much longer; each one has planned specification phase of about two years with a total spiral duration of six years. The phases of each Spiral are described in [1] as Operational and Security Requirements, Proposed Specifications, Final Specifications, Emerging Operational Use, and afterward Preferred Operational Use. The process is standards-based; products of each spiral are characterized as Requirements, Interoperability Architecture, Standards Profile, and Instructions. A revised Roadmap is created annually to document what has been achieved in ongoing Spirals and what is expected to be achieved, gaining more detail as Spirals produce greater understanding of the interoperating capabilities.

A particularly important source of consistency among the growing details arising from the Spirals is the NATO C3 Taxonomy shown in Figure 3, which can be viewed as an “Enterprise Architecture” framework that represents the concepts and their relationships involved in all the life-cycle activities for NATO's Consultation, Command and Control (C3) capabilities.

3.0 CHALLENGES FOR MSG-193

To fulfil its charter, MSG-193 must provide insight and detailed information about M&S standards and practices that will enable FMN to meet operational requirement in a superior way. This requires understanding and integrating with the many other aspects of FMN across the range of activities and services in the C3 Taxonomy.

3.1 S&T Perspective vs Operational Perspective

Some difficulty arises due to the sizable gap in cultures between NMSG’s Science and Technology (S&T) orientation and the operational orientation of the existing FMN management and development community. The S&T culture emphasizes learning and technological sophistication, whereas the operational focus of ACT, and even more of its partner Allied Command Operations (ACO), focuses on getting things done, expeditiously and reliably. It is important that the solutions that are proposed have a technical readiness level

sufficient for operational use. The two perspectives share common goals but tend to approach them in different ways. When providing recommendations on FMN, MSG-193 must temper its enthusiasm for "doing things better" with a concern for the practicalities of military coalition operations.

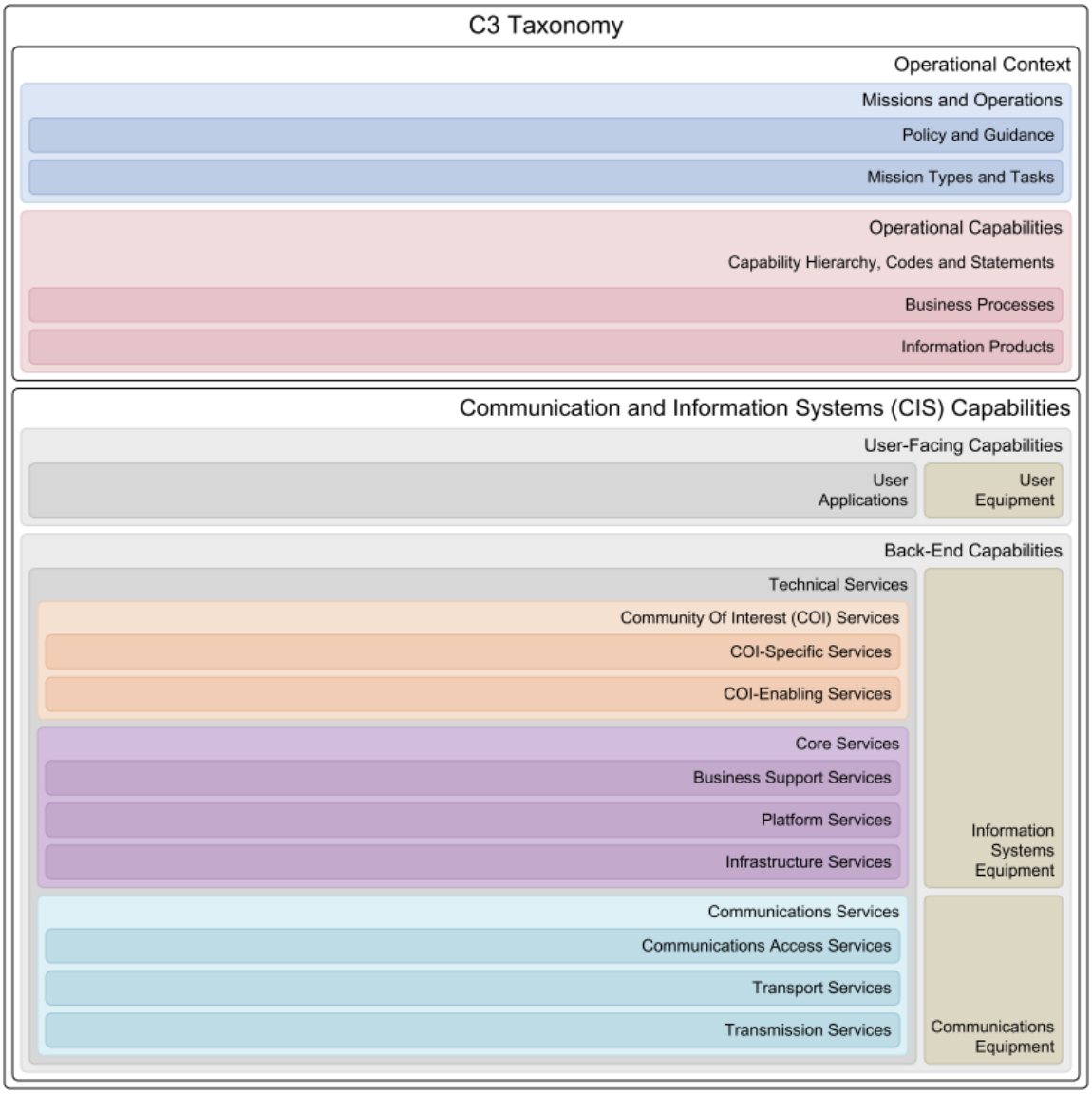

Figure 3: C3 Taxonomy for FMN [12]

3.2 MSG-193 as FMN M&S Syndicate

The OCWG welcomed NMSG Spiral 5 M&S inputs and designated MSG-193 as their "M&S Syndicate". The role of a syndicate is described in [13]: "*syndicates are informal working bodies - often already existing as collaborative undertakings for a specific subject, product or community of interest - focused at providing expert advice and tangible input for one or more FMN working groups*." While this concept is not unheard-of in government, when combined with the spiral concept it provides an interesting extension to the more typically bureaucratic structure of FMN management, allowing for participation of technical laboratory staff, industry experts, and academics. This is consistent with the FMN goal "*adapting existing capabilities for quick start*."

3.3 Interactions with FMN Working Groups

Each of the various working groups described in section 2.1 above has its own subculture. MSG-193 began its efforts with the OCWG, starting from a skeletal operational requirement for MR and ending with Spiral 5 Procedural Instructions (PI) document for M&S that describes where NMSG technologies fit and how they can enable more effective coalition operations in the Operational Communications and Information Systems (OPCIS) environment, supported by advanced networks and information systems. (Spiral 6 is expected to consider a much broader range of M&S capabilities.) FMN management indicated its confidence in the work of MSG-193 by including M&S in the 2021 FMN Roadmap. When the PI draft was materially complete, MSG-193 moved on to work with the CPWG on technical standards and procedures, and also with the MCSMAWG to ensure the resulting systems will be appropriately secure. Both the OCWG and CPWG have provided experienced, knowledgeable contacts who helped the MSG-193 team structure its work to fit well in the FMN context.

3.4 Drafting Procedural Instructions

The FMN Procedural Instructions for Modelling and Simulation, drafted in cooperation with the OCWG, is organized as follows:

1. Introduction
   - Purpose and Intended Audience
   - Aim
   - Scope
   - Structure of the Document
   - Resolved Issues
2. Context of FMN M&S
   - Capability Need
   - Information Sharing Construct (MR etc.)
   - Current M&S Capability Gaps
   - Use Cases/Scenarios
3. Processes
   - MR Processes in Operational CIS Environment
   - MR Processes in Tactical CIS Environment
4. Technology
5. Requirements
   - Functional Requirements
   - Non-functional Requirements
   - Information Exchange Requirements
6. List of Abbreviations

It can be seen from the document organization that the focus of the PI is very much operational, with little emphasis on technology; the Technology section is very generic, in keeping with the operational focus of the PI. The MSG-193 team decided to focus the Spiral 5 M&S PI on MR in the Operational CIS (OPCIS) Environment, which is supported by networking much like the commercial Internet and potentially includes multi-domain security. While this leaves a broad range of M&S applications for Spiral 6 (and potentially beyond), it led to a comfortable scope for an initial set of recommendations. It also enabled a good working relationship with the OCWG, who were concerned that the “level of ambition” of the M&S Syndicate might be impractical. Sections of the PI requiring particular attention from an M&S standpoint were Process and Requirements, particularly the Information Exchange Requirements, which we derived from Mission Threads descriptions.

3.5 Drafting Service Instructions

With the PI defining FMN M&S needs to meet Operational Requirements (for Spiral 5, MR in the OPCIS Environment), the role of the SI is to define information technology services and their interfaces that can meet the needs shown in the PI. The services and interactions must have existing specifications, generally in the form of open standards. The technical thrust of an SI is evident from its organization:

1. Introduction
   - Aim
   - Scope
2. Changes
3. References
4. Context
5. Interoperability Architecture
   - Interactions
   - Architecture Items
   - Procedures
7. Standards
8. Service Functions
9. Dependencies
10. Requirements
11. Roles and Responsibilities
12. Configuration Options

Sections of the SI requiring most attention from an M&S perspective are Standards, Service Functions, and Requirements, with details also needed for References, Definitions, Dependencies, and Configuration Options. MSG-193 concluded that the M&S SI should take the form of two documents, describing: *External* interfaces to other FMN applications (Figure 4) and *Internal* interfaces among M&S subsystems (Figure 5).

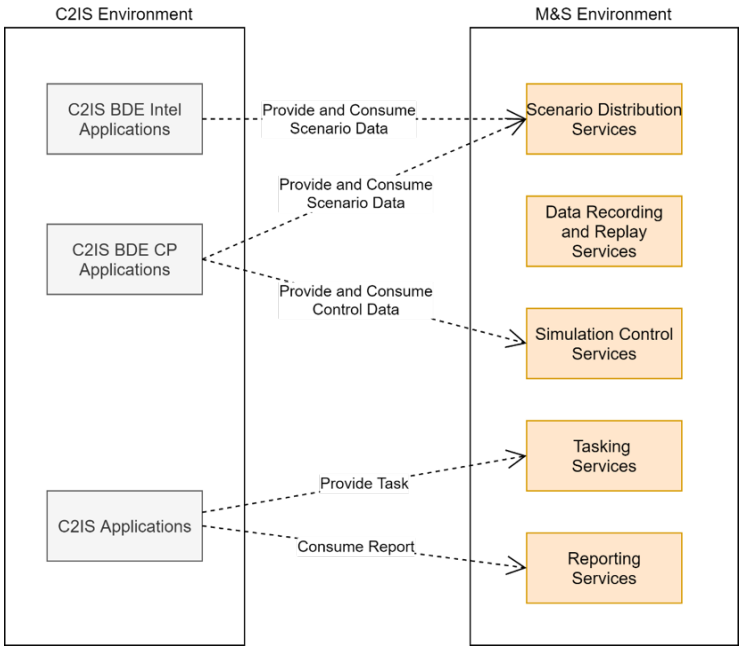

Figure 4: External Interfaces to M&S Systems [14]

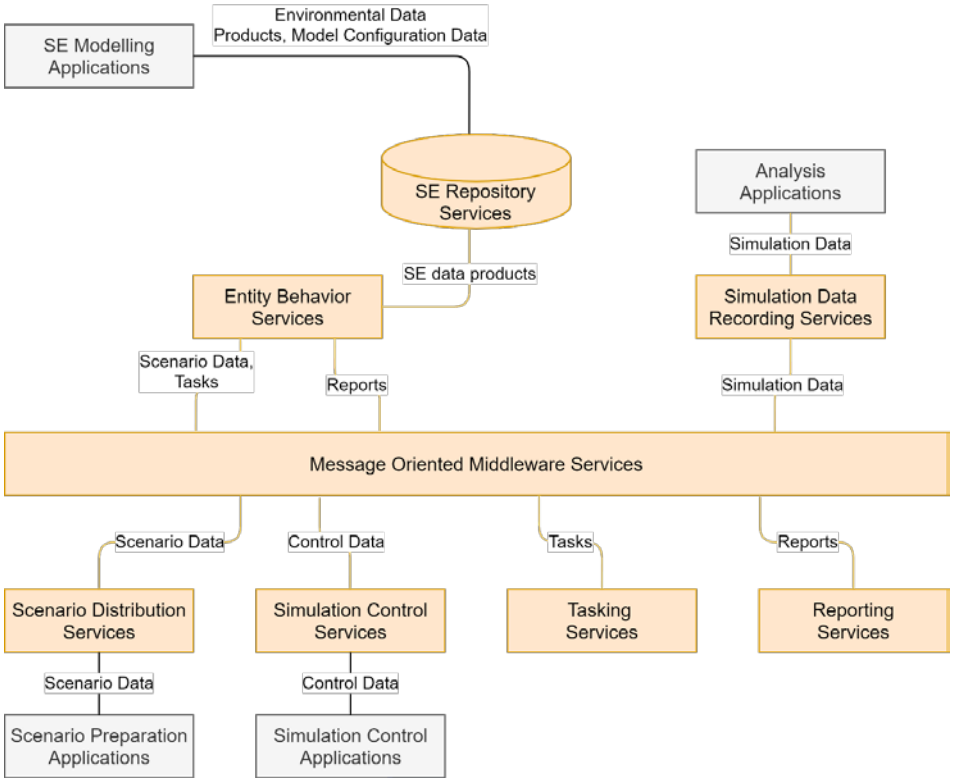

Figure 5: Internal Interfaces among M&S Subsystems [15]

3.6 Role of FMN in Computer Assisted Exercises

Computer Assisted Exercises (CAX) employing M&S provide a well-accepted capability for achieving collective training of today's national and coalition military in preparation for operations and therefore an important role for FMN. NATO defines how a CAX simulation-based synthetic environment can support an exercise in automating the processes, preventing duplication of work, enhancing the exercise environment and ensuring that the exercise process flows towards the objectives [16]. In a CAX, a Command Post Exercise (CPX) is executed with the support of computers simulating the operational environment and providing event resolution, in either distributed or not-distributed form or a combination of both. As the future framework for allied operational information technology, FMN will define much of the system interoperability for CAX [17]. Since M&S is already heavily applied in CAX, FMN can look to CAX for M&S capabilities that will become part of FMN; but organizations conducting CAX must also look to FMN for standards, practices, and interfaces they must implement in order to represent NATO operations effectively.

CAX support tools can categorized into four classes as follows. Each of these is essential to CAX but also has broader applicability to training, COA analysis and MR, in the networked operational environment of FMN.

Planning and management tools: CAX support tools for exercise planning and product development must support collaborative development of scenario modules with respect to georeferenced data and information and documentation to support achievement of the exercise aim and objectives. They must present to the training audience the data and information in the expected formats and levels of granularity that they would expect to see if the situation were real.

Constructive simulation systems and ancillary tools: Constructive simulation systems play the role of

friendly and opposing force including actions, effects of events and conditions not controlled by human trainees and exercise controllers. They compute the possible outcomes of commands given to the simulated units and entities and must be interoperable with C2 systems to receive orders and to send back reports.

Interfaces to C2 systems and functional area services: Constructive simulation systems and all the other related software must be transparent to the trainees, providing a realistic training environment and enabling trainees to command their subordinates by using C2 systems normally available to them. The new C2SIM standard described below offers way to do this that will provide plug-compatibility to FMN C2IS.

Experimentation and analysis tools: Support is required for collection of observations and subsequent post-exercise analysis and production of reports on achievement of exercise aims, objectives and requirements. These tools also can assist in reconstructing events and derive lessons for users in real-world operations.

4.0 M&S RECOMMENDATIONS FOR FMN SPIRAL 5

As part of the PI and SI documents, the M&S Syndicate provides general descriptions of M&S capabilities needed in FMN, supplemented by significantly more detail on those standards and practices required for MR in the OPCIS Environment [18]. More M&S standards and practices are expected in Spiral 6.

4.1 FMN M&S Spiral 5 Focus: Mission Rehearsal

MR is an early operational requirement of the FMN. MR is conducted at all levels of a military organization to familiarize coalition forces prior to a planned operation [19]. MR involves the practice of a defined mission in a specific operational context, after the superior commander and subordinate rehearsing commander(s) have developed their plans and focuses leaders on key execution tasks and the synchronization of combat power to achieve the mission's objectives. It is intended to achieve risk mitigation, not to hone or evaluate skills of participants. MR is expected to follow processes for mission planning, including analysis of various possible COA. To be effective, the environment and conditions simulated must be as close as possible to those pertaining to the actual mission being rehearsed. An MR capability can be based on a collective training capability that effectively incorporates latest available intelligence and information about the mission environment (terrain, weather. etc). Logging for after-action playback may be useful to examine actions taken in the simulation-based rehearsal environment.

4.2 C2-Simulation Interoperation (C2SIM)

The SISO C2SIM standard [20] has been developed to provide a means of exchanging information from C2 systems and modelling and simulation (M&S) systems, particularly constructive and virtual simulations. C2SIM can also be used to exchange information between different C2 systems and between C2 systems and autonomous systems. In Figure 6, C2SIM is represented by the arrows joining the different types of system.

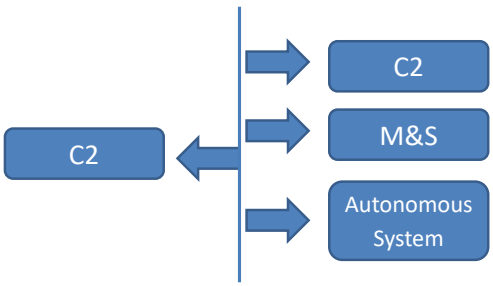

Figure 6: C2SIM Overview [20]

C2SIM was developed by SISO and has been proposed as the basis for NATO STANAG 4856. It uses a common data model which permits unambiguous data to be exchanged between systems to convey initialization information (e.g. force structures and dispositions), plans, orders, tasks, requests and reports. C2SIM is highly pertinent to FMN in that it is intended to support plug-and-play compatibility between C2IS and military simulations. Uses for this capability are coalition operational training, COA analysis, and MR. C2SIM development was supported by MSG-048, MSG-085, MSG-145 [22];

C2SIM is intended for an environment like the FMN where each national component uses its own, familiar C2 system and is represented in the simulated coalition by a simulation that accurately depicts its national staffing, equipment, and doctrine. Its workability was validated in CWIX 2019, the testing environment of choice for FMN development. In CWIX 2021, C2SIM was tested successfully in combination with the HLA standard (see next section).

4.3 High Level Architecture (HLA) for M&S

HLA [21] is an IEEE simulation interoperability standard developed by SISO that has been adopted as NATO STANAG 4603. HLA is well suited to the Federated environment of FMN, where different national simulations combine to represent the coalition force. It uses an object model approach to define the information that may be exchanged between simulations. HLA is supported by its own management services for things such as object management and time management provided by a service known as Run-time Infrastructure (RTI). The objects, interactions and associated ancillary information are defined in a Federation Object Model (FOM).

4.4 NATO Education and Training Network (NETN) FOM

An HLA federation must have an agreed model for data to be exchanged and rules that govern the exchange, which is captured in its FOM. For FMN to employ the HLA standard, it will need a standardized FOM. NMSG has developed a standard FOM known as NATO Education and Training Network (NETN) FOM (STANREC 4800) [23] that represents shared data in distributed simulation environments, where M&S services (federates) are connected and federated using the HLA. Development of the NETN FOM has been supported by MSG-106, MSG-134, and MSG-163.

As shown in Figure 7, the modules address many aspects, including Initialization (Order of Battle (ORBAT), environment datasets and other initial scenario settings leveraging the Military Scenario Definition Language (MSDL), predecessor of C2SIM (with backward compatibility), Multi-Resolution Modelling (MRM) to manage aggregation and disaggregation of simulated units and physical entities, transfer of modelling responsibilities between federates that simulate the entity at different levels of resolution, logistics, CBRN, Simulation Control (start, stop, pause) etc. The NETN FOM provides a rich basis for employing distributed simulation on a federated basis in FMN.

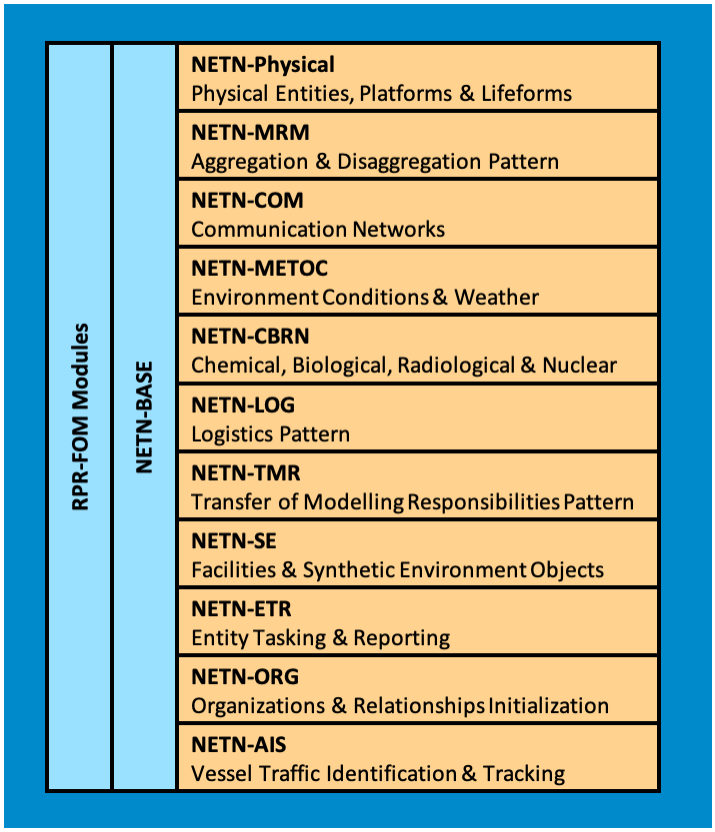

Figure 7: NETN FOM Modules

4.5 Modelling and Simulation as a Service (MSaaS)

MSaaS is a *technical approach* as well as a *business approach* to provide M&S services and resources from different suppliers on-demand to a large set of users [24]. The aim is to support M&S capabilities by resource pooling, and to improve operational effectiveness by having more readily and timely available services and resources. Development of MSaaS has been supported by MSG-136 and MSG-164.

Specific goals of MSaaS are [7]:

- To provide a framework that enables credible and effective M&S services by providing a common, consistent, seamless and fit-for-purpose M&S capability that is reusable and scalable in a distributed environment.
- To make M&S services available on-demand to a large number of users through scheduling and computing management. Users can dynamically provision computing resources, such as server time and network storage, as needed, without requiring human interaction. Quick deployment of the customer solution is possible since the desired services are already installed, configured and on-line.
- To make M&S services available in an efficient and cost-effective way, where convenient short set-up time and low maintenance costs for the community of users will be available; and to increase efficiency by automating efforts.
- To provide the required level of agility to enable convenient and rapid integration of capabilities, MSaaS offers the ability to evolve systems by rapid provisioning of resources, configuration management, deployment and migration of legacy systems. It also is tied to business dynamics of M&S that allow for the discovery and use of new services beyond the users' current configuration.

In cases where FMN requires powerful M&S that needs to be available in a shared/networked "cloud" form, MSaaS provides effective procedures for implementation.

5.0 CONCLUSIONS

The FMN initiative is working to provide a powerful new environment for coalition information interoperability that will be a force magnifier for NATO. It is generally recognized that M&S is a necessary part of that federated, networked environment. NMSG has taken up the challenge of helping the operational elements of NATO to specify appropriate standards and procedures for that purpose.

MSG-193 is off to a promising start as "M&S Syndicate" for FMN, having forged working ties with operational and technical elements (OCWG and CPWG) and with FMN Management. Well-documented draft Procedural Instructions and Service Instructions for M&S in FMN Spiral 5 have been developed. It is clear that NMSG has a highly-leveraged opportunity to continue supporting the specification of FMN through Spiral 6, in a successor activity to MSG-193.

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