Validating M&S Standards Interoperation in CWIX 2022

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ABSTRACT

NATO operational commands have a major initiative underway to define Federated Mission Networking (FMN): federated architecture, standards and practices that will enable information interoperability for coalition operations. NMSG Technical Activity 201 M&S in FMN is assisting in this initiative by providing input to FMN specifications for M&S standards and practices to enhance information technology capabilities for coalition warfighters to prepare for and execute coalition missions. An essential part of this process is validating those standards and practices supporting NATO interoperability in the annual Coalition Warrior Interoperability eXploration eXperimentation eXamination eXercise (CWIX).

This paper provides an overview of the FMN Spiral 5 Procedural Instructions (PI) for Mission Rehearsal and associated Service Instructions (SI) for Modelling and Simulation, both drafted by an NMSG Technical Activity, that form the specification to be validated in CWIX. This will be followed by a description of the process for detailed testing of a distributed system-of-systems with C2 systems and multiple simulation systems, some supported by cloud computing. The results of testing will be described, including execution of a truncated brigade-level mission rehearsal to validate the ability of the SI specification to effectively support execution of Mission Rehearsal.

1.0 INTRODUCTION

NATO operational commands have a major initiative underway to specify Federated Mission Networking (FMN), which will define how NATO and coalition partners' information systems will interoperate in the future. This paper describes our effort in MSG-201 *Modelling and Simulation in FMN* to support the specification of M&S aspects of FMN by participating in CWIX 2022.

1.1 What is FMN and why is it important

The aim of FMN is to provide standards and practices for secure, scalable, flexible and agile federated Mission Networks (MN) through which accredited applications can safely and reliably exchange data and information [1]. Following long experience with NATO's International Security Assistance Force (ISAF) operations and similar coalition activities, it was concluded that a new networking approach was needed to enable Day Zero, mission-ready networking capabilities for future deployments and to support evolving command and control

requirements. The FMN initiative is led by NATO's Allied Command Transformation (ACT) co-operating with NATO's Allied Command Operations (ACO). Clearly, FMN needs M&S; equally clearly, M&S will gain most effective use only if it is deployed as part of FMN. Supporting details can be found in [2].

1.2 What is CWIX and how does it support FMN development

The effectiveness of FMN depends on the national affiliates collaborating to reach and test implementable specifications based on existing NATO and commercial standards. To that end, ACT carries out the annual *Coalition Warrior Interoperability Exploration, Experimentation, Examination and Exercise (CWIX)*, involving all stages of each ongoing Spiral tested either in person or via secure network or semi-secure Internet VPN. CWIX provides a structured testing methodology coupled with a testing environment that enables evaluation of system interoperability and visibility of results. It is therefore an excellent environment for evaluation and demonstration of the appropriateness of standards and practices for FMN. The primary CWIX site is the NATO Joint Forces Training Centre (JFTC) in Bydgoszcz, Poland. Access to the facility requires a NATO SECRET clearance; testing is supported at that level as well as NATO UNCLASSIFIED.

2.0 FMN SPIRAL 5

Development of FMN specifications is proceeding as an overlapped sequence of "spirals," as shown in figure 1. Each spiral specification stage has four milestones: Draft, Candidate, Proposed and Final. Spirals 1 through 4 have reached the Final specification milestone. MSG-201 currently is participating in Spiral 5 as a "syndicate" to support the specification of M&S for Mission Rehearsal. MSG-201activity will expand in 2024 with a proposal to include additional M&S support in Spiral 6 (for example M&S for Collective Training or M&S for planning).

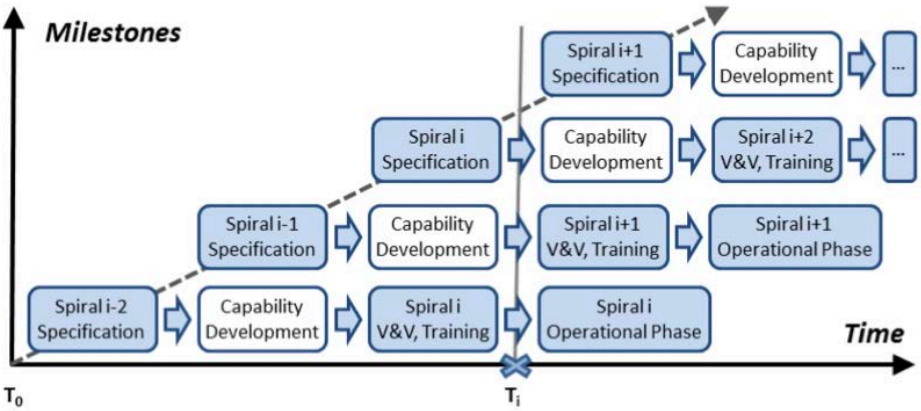

Figure 1: The FMN Spiral Development Process [3]

Mission Rehearsal (MR) is an early operational requirement of the FMN. MR is conducted at all levels of a military organization to ensure Coalition forces understand their role in a planned operation [4]. MR involves the practice of a defined mission in a specific operational context. It can begin 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. An MR covers the actions planned in an operations order (OPORD). It is intended to achieve risk mitigation, not to hone or evaluate skills of participants.

The operational requirements for FMN capabilities are specified in documents called Procedural Instructions (PI), describing what information is needed when, and by whom, in order to achieve a particular FMN function. The current PI for MR [5] defines the needs of mission rehearsal prior to deployment that is supported in the land Operational Communications and Information Systems (OPCIS) environment (tactical and joint MR were deferred to Spiral 6). It describes the processes required, including the functions of each role, related non-

functional requirements, information products, and specific information exchange requirements to be met by FMN. It doesn't describe how the MR functionality should be implemented. The technical specifications supporting the actual implementation are part of the so-called Service Instructions (SI), described below.

The PI includes architectural elements based on the NATO Architecture Framework v4 using ArchiMate Viewpoints and related diagrams. Each diagram is accompanied with a narrative that explains each activity, role, and information exchanges. This information is captured in the FMN Spiral 5 database available on Tidepedia [6].

2.1 FMN Service Instructions specification for M&S

FMN *Service Instructions* (SI) provide specification of standards and practices for achieving information interoperability based on the operational requirements provided by the PIs. The operationally required information interoperability drives the technical requirements for the use of standards between C2IS and M&S (C2SIM) while the non-functional operational requirements drive the technical requirements for the distributed and interactive use of simulators (HLA).

The SI for M&S provides M&S standards and requirements for the interoperation of C2 and simulation capabilities across NATO and national network sites to support the requirements specified in the PI for MR. The M&S standards provided are:

- Command and control-simulation interoperation (C2SIM)
- High-level architecture for M&S (HLA)
- NATO Education and Training Network Federated Object Model (NETN-FOM)
- Cloud-based deployment of M&S Resources as described in M&S as a Service (MSaaS)

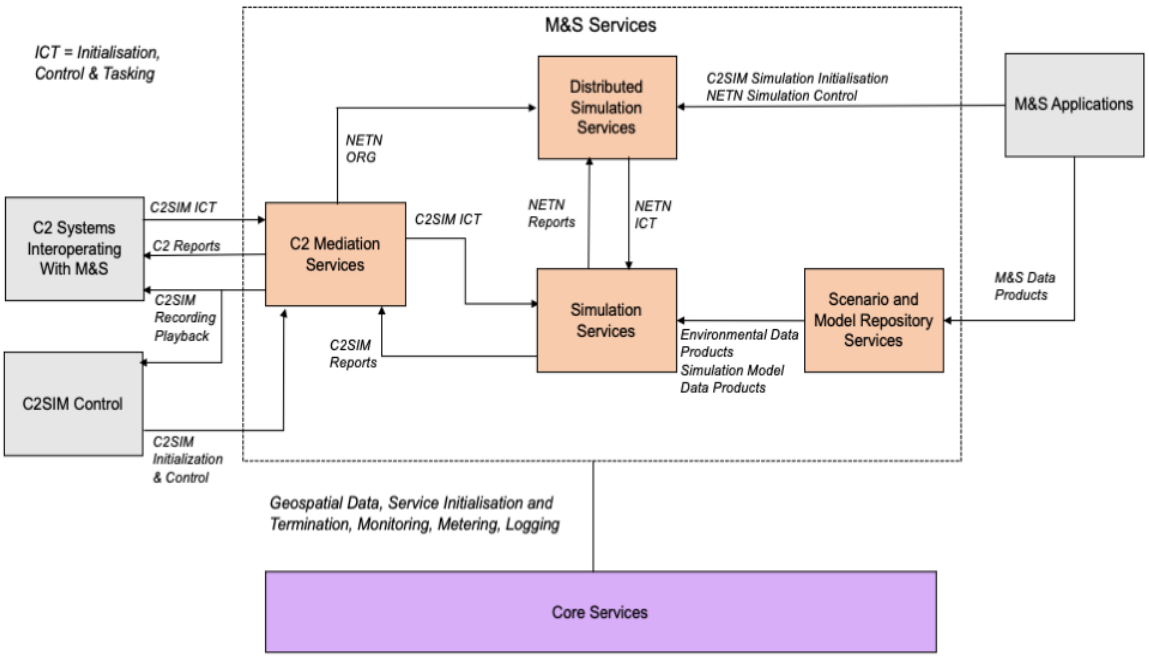

Figure 2: Spiral 5 SI Top-Level Information Architecture for M&S Support of MR in FMN

2.2 Future testing with FMN CIAV

As Spiral 5 continues, its *SI for M&S* will be tested in conjunction with the FMN Coalition Interoperability Assurance and Validation (CIAV) Working Group's evaluation of the readiness of recommended standards and practices for FMN implementation. MSG-201 has taken a "crawl, walk, run" approach to CWIX (as did MSG-145): in 2021 we did limited, completely distributed testing of two simulations running C2SIM and HLA; in 2022, with a draft *Spiral 5 SI for M&S* available, we expanded the scope of testing, based out of the main CWIX site at JFTC. In 2023 we expect to complete a robust suite of tests, patterned after that of 2022 and including a more significant MR exercise to satisfy CIAV.

3.0 MSG-201 CWIX 2022 TESTING

In CWIX 2022 we started the process of testing the specified capability with the standards and practices described in the Spiral 5 SI for M&S. Several "Capability Configurations" were brought together at CWIX with the primary objective the verification of the FMN M&S Service Instructions for Mission Rehearsal. The secondary objective was to provide an initial and basic capability to support a truncated "Mini" Mission Rehearsal (Mini-MR) using M&S.

3.1 Supporting scenario

To provide a framework for testing, we generated a scenario where a NATO multinational brigade assists a fictitious nation called "Bogaland" which is experiencing insurgency sponsored by a neighbouring nation. The brigade consists of ground battalions from three nations, augmented by a rotary wing air element. The scenario involves suppressing insurgent operations. The OPORD provided a realistic context for testing simulation transactions and allowed a Mission Rehearsal focused on deploying the ground battalions in a road march to their new operations areas, and in the process experience a feinting ambush, a typical activity of the insurgents. This "Mini-MR" allowed us to experience, in abbreviated form, a testing environment where all systems were required to work together to support an MR. The scenario was adapted from one originally developed for *MSG-145 Command and Control-Simulation Interoperation Standards Support* [7], which conducted similarly distributed CWIX testing in 2019.

For the Mini-MR, a US Army Lieutenant Colonel (personnel code Functional Area 57, Simulation Operations) was present as an operations subject matter expert (SME) to provide realistic input to the test scenario.

3.2 Supporting facilities

We tested the interoperation under the standards and practices laid out in the Spiral 5 SI for M&S: C2SIM, HLA, NETN-FOM, and cloud-based deployment for M&S services and applications. This was achieved using:

- Simulation systems: SWORD from MASA Group (France) on an individual computing platform and in MSCoE cloud, VR-Forces from VT-MAK (USA) on an individual computing platform and in NLD MoD cloud, and KORA from IABG-GmbH (Germany). Each of these is able to operate under the SI for M&S standards.
- Cloud-based deployment of instances of SWORD, VR-Forces, and a number of other M&S applications and services (see Figure 2), provided by the Netherlands (NLD) Ministry of Defence (MoD) in Maasland, Netherlands, and by the NATO M&S Centre of Excellence (MSCoE) in Rome, Italy. The NLD provided services include an NVG service to feed simulation data as NVG overlays to C2 Systems, such as the NLD C2 System; and an ORBAT service to initialize simulation systems.
- C2SIM Orders generated by the Sketch-Thru-Plan system from Hyssos Tech [8] (USA) and editor systems C2LG GUI from Fraunhofer-FKIE (Germany) and George Mason University (GMU) (USA)

- C2SIM Reports were displayed on the SitaWare Command and Control Information System from Systematic (Denmark). These reports were also used to update the situation picture in C2LG-GUI from Fraunhofer-FKIE (Germany).
- C2SIM Server was provided by GMU (USA); HLA Runtime Infrastructure by Pitch (Sweden)

The main testing site was the JFTC in Bydgoszcz, Poland. The various Capability Configurations were linked by a virtual private network (VPN) as shown in Figure 3. Distributed testing sites included Dutch MoD in Maasland, Netherlands; MSCoE in Rome, Italy, USA Naval Postgraduate School (NPS) in Monterey California, USA, and MASA Group in Paris, France.

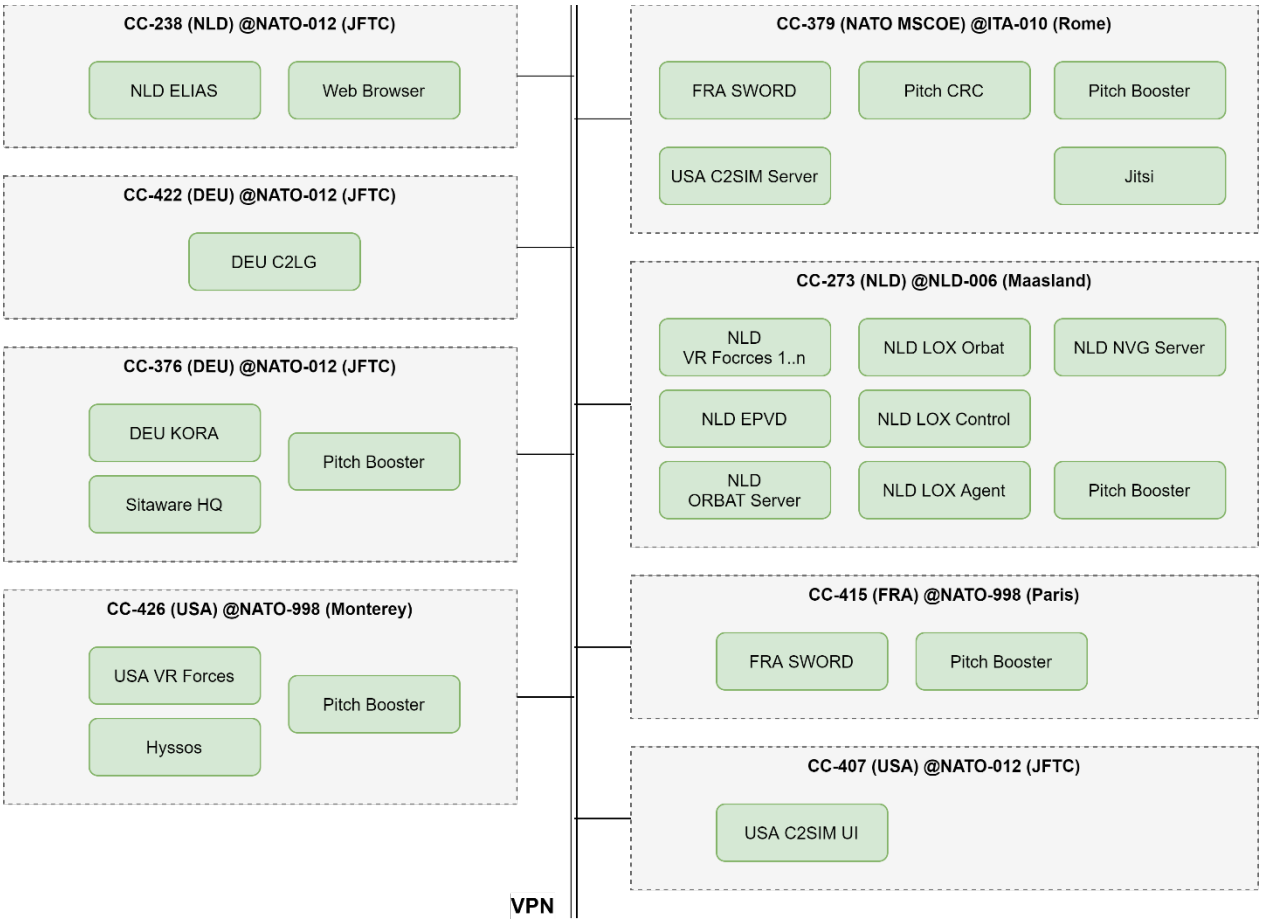

Figure 3: Network Sites and Capability Configurations for CWIX 2022
Testing FMN Service Instructions for M&S

3.3 Detailed transaction testing

CWIX has a well-developed methodology for structuring testing and reporting the results [9]. In addition, a Simulation Environment Agreements document [11] was developed by the team to detail the specific interactions between the applications and services participating in this CWIX event. Using the CWIX test methodology and the simulation environment agreements, we built a series of CWIX Test Templates and derived Test Cases of them that tested C2SIM, HLA/NETN-FOM, and Service Management and Control transactions involving the simulation systems.

The fact that the two simulations were supported by cloud-based deployment had responses indistinguishable from the instances on individual computing platforms relieved us of any need to test cloud-supported simulation separately. The transaction types tested were:

- C2SIM Server connection from simulation
- C2SIM control and initialization to simulation
- C2SIM Order to simulation via server
- C2SIM Report simulation to server
- C2SIM Move Order to simulation via server, with resulting reports
- C2SIM Attack Order to simulation via server, with resulting reports
- HLA RTI connection from simulation
- HLA information sharing among simulations, via RTI
- HLA information sharing reflected in C2SIM Reports
- Cloud-based deployment of a subset of M&S applications and services via Service Management and Control capabilities

3.4 Mini-MR testing

For the Mini-MR, we were testing whether the standards and practices, working together, effectively supported Mission Rehearsal. In this context it is important to recognize that, unlike simulation-supported Collective Training, MR simply carries out an OPORD under control of unit commander and staff, to familiarize them with the planned operation and allow recognition of aspects that could be problematic. This means that, although the simulators worked in a distributed way, they were not interactive since combat interactions were not simulated because the commander/staff decides who wins, not the simulators. Having tested that the individual transactions would work, the Mini-MR role players submitted C2SIM representations of the scenario OPORD and observed the simulated results. To ensure that our Mini-MR execution was faithful to actual military operations, our commander/exercise director role player was an active-duty US Army Lieutenant Colonel. The other role players were MSG-201 CWIX team members, who in this process both learned more about how MR is conducted and validated the performance of their simulations.

4.0 TESTING EXPERIENCE

Testing was carried out over a four-day period (13-16 June), with 17 June available for fallback, following setup at JFTC.

4.1 Impediments to testing

From the details presented in section 3 above, it is evident that a great deal of coordination and setup were needed prior to testing. During the month prior to CWIX-2022 we had performed pre-testing to the extent possible using a different VPN provided by GMU. Our purpose was to confirm that the simulations were able to execute the scenario orders, working with the C2SIM Server and HLA RTI. Because of delays in getting the IP connectivity fully functioning we were not able to complete all pre-testing with orders. As it turned out, we had to make revisions to the orders during CWIX execution to have an interoperable system.

The CWIX infrastructure provisioning and operational rules resulted in the VPN we used not being available until the week before testing (in some cases, this turned out to be the day of testing). Network issues were particularly time-consuming:

- Differences between the GMU VPN and the one provided by JFTC precluded realistic checkout of the HLA RTI configuration to be used; that was critical component to the overall operation.

- We found it impractical to conduct distributed testing without effective intra-group communications; for the pre-testing we were able to use commercial Internet conferencing, but Internet access was precluded during CWIX execution for security reasons. Therefore, we set up a Jitisi open-source conferencing system. This worked well for audio and screen-sharing but during CWIX execution we discovered it was not practical for multiple channels on JFTC VPN. So we could not coordinate multiple tests simultaneously, which hampered our testing effort.
- We ended up spending the first two days of our testing getting network, conferencing, and RTI details correctly configured.
- After the whole network was functional, it was still necessary to adapt our testing configurations daily because the JFTC VPN assigned different IP addresses every day to client systems outside of JFTC. Network outages also made the MSCoE server system unavailable on multiple occasions; during these outages C2SIM and HLA testing was not possible.

Even with the fallback day, this foreshortened the actual testing period and led to a very full agenda. We were able to complete all planned testing by working after scheduled hours and using the fallback day.

4.2 Testing results

Our testing was organized under the Modelling and Simulation Focus Area (FA), where MSG-201 was responsible for three of the FA's eight objectives. MSG-201 overall statistics for simulations by CWIX category were:

- SUCCESS: 128
- LIMITED SUCCESS: 31
- INTEROPERABILITY ISSUE: 3

The LIMITED SUCCESS test cases were those where the transaction was completed but some detail was problematic such that revisions to the simulation software or the testing configuration is needed. INTEROPERABILITY ISSUE indicates a "show-stopper" problem where the information sharing did not happen correctly; these were cases where the simulation could not exchange information coded per the C2SIM schema or the HLA NETN-FOM. (If we had time to complete pre-testing, these issues should have been resolved before CWIX execution; they will need to be resolved as part of preparation for CWIX 2023).

Testing of the Mini-MR resulted in LIMITED SUCCESS. This was because some of the transactions needed (in particular, C2SIM Orders) had been evaluated as LIMITED SUCCESS in transaction testing, so that not all complete OPORD sequence in the scenario could be conducted. Given longer time this might have been worked around, however time lost due to issues described in section 4.1 resulted in minimal time available to conduct the Mini-MR.

4.3 Lessons learned for CWIX 2023

In our after-action review, we logged the following improved practices as recommended for MSG-201 participation in CWIX 2023:

- *Achieve a stable testing network and computing environment, including multichannel conferencing and fully functional JFTC VPN, at least one month before CWIX execution.* Happily, the JFTC BATLAB has indicated it will join MSG-201 and will make its infrastructure available on a 24x7 basis from the beginning of CWIX 2022 preparations.

- *Locate all essential services at JFTC during CWIX execution and conduct as many of the testing operations as possible in-person at JFTC.* This will greatly reduce time lost due to network problems. However, it will remain necessary to include distributed testing sites and testing operators because some of the MSG-201 testing team participants do not have budget to relocate at JFTC for two weeks annually to support CWIX execution.

- *Schedule all critical testing personnel to be available during setup as well as testing time.* We had expected pre-testing to require one week in May; participants scheduled around this with the result that expertise was not always available when the process continued into June. The plan for 2023 to establish a continuing setup on JFTC BATLAB systems will enable earlier setup that is not dependent on last-minute network configuration.

- *Adopt a more rigorous simulation engineering approach.* We went into CWIX 2022 having experience with a similar number of distributed simulations from 2019 MSG-145 testing, but without complete understanding of the complexity involved in combining C2SIM, HLA, and NETN-FOM. For future CWIX events, we expect to apply the SISO standard Distributed Simulation Engineering and Execution Process [11] in order to manage the complexity involved. (This is likely to result in incorporation of DSEEP in the FMN Spiral 6 SI for M&S to be drafted MSG-201.). Capturing agreements in a simulation environment agreements documents is essential.

- *Assemble a "dashboard" that displays critical status information from all components being deployed, including their modelling responsibilities.* We had access to this information in CWIX 2022 but it required accessing multiple tools and digging through multiple layers of information. This Service Management and Control "dashboard" will greatly simply dealing with the complexity of controlling components in a federated environment. We expect to refine the dashboard in use and offer it as an example of an effective way to manage the simulation tools recommended in the *Spiral 6 SI for M&S*.

- *Be sure that all the people involved in the testing have enough knowledge of the tools under their responsibilities*. For instance, personnel involved as Cloud service provider should have quite a deep knowledge about the tools shared in Cloud, so as to avoid wasting precious time while installing, updating and using the tools during the exercise. If necessary, specific training activities before CWIX should be organized.

- *Track the changes writing procedures to put in place the following days whenever needed.* Sometimes there were issues related to the overlapping of activities made by different actors when the information related were not properly shared. For instance, MASA SWORD needed to load scenarios and configuration files which changed during the exercise. These changes were not tracked and the related configuration were not permanently saved (too much effort related to the minor changes). Consequently, time was wasted to repeat identical activity. It is the essential to always track the changes writing procedures to put in place the following days whenever needed. Continuing the CWIX 2022 practice of a daily meeting, a sort of daily "After Action Review", to share information and track all changes, is highly recommended.

- *Test simulations with the available GMU C2SIM sandbox server before deploying in CWIX context.* Align server with Service Management and Control "dashboard" during 2023 development process.

5.0 CONCLUSIONS

As the second step in "crawl, walk, run," we believe the MSG-201 testing in CWIX 2022 was a significant success. We assembled a representative collection of interoperating systems for simulation-based Mission

Rehearsal and tested them in a distributed environment representative of the likely OPCIS envisioned in the FMN Spiral 5 Procedural Instructions for Mission Rehearsal and Service Instructions for Modelling and Simulation. This included transaction testing for interoperation among three simulations, two of them including cloud computing support, as well as a truncated "Mini-MR" to evaluate the effectiveness of combined standards and practices in supporting Mission Rehearsal. Despite serious impediments in the testing environment, test results were about three-quarters SUCCESS and one-quarter LIMITED SUCCESS, with only two INTEROPERABILITY ISSUES. We learned a great deal about interoperating simulations using C2SIM and HLA with NETN-FOM, supported in a cloud computing environment; and we arrived at firm recommendations to improve future testing that will be needed to satisfy the FMN CIAV Working Group. Along the way we recruited interest from a new partner for MSG-201, the JFTC BATLAB, that will improve our testing and overcome many of the impediments we experience in CWIX 2022.

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