

Interoperability: Tool to Assess for Multinational Live Training

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ABSTRACT

The international military community routinely conducts live training exercises to improve how nations work and fight together. These exercises allow countries to use their existing military equipment augmented with Tactical Engagement Simulation Systems (TESS) to simulate combat and combat-related activities. In general, each nation's TESS is customized for their military apparatus plus their training tactics and thus may not fully interoperate with another nation's TESS. Consequently, the overall effectiveness of the international training events may be hampered by imperfect interoperability of the equipment supporting the event. In 2018, a study team reported on the Interoperability Readiness Assessment Methodology (IRAM) that was developed to apply an established Levels of Conceptual Interoperability Model (LCIM) to the TESS interoperability problem in the live training systems domain.

Using artifacts from the NATO Modeling and Simulations Group (NMSG) Urban Combat Advanced Training Technologies (UCATT), the United States (U.S.) Army Program Executive Office Simulation, Training and Instrumentation (PEO STRI), Project Manager Soldier Training (PM ST) and The MITRE Corporation (MITRE) teamed to develop software to implement the IRAM. The Interoperability Readiness Assessment Toolset (IRAT) documents observed interoperability levels after a coalition exercise concludes. The scoring mechanism provides insight to exercise planners where TESS inoperability may limit the effectiveness of multinational training and decrease the ability to plan for real-world operations. Initial data collection using the IRAT with the international community has been favorable. The international community is currently steering the future direction of the IRAT to include adding analysis prior to an event using standards to gauge interoperability on individual interfaces.

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INTRODUCTION

The international military community routinely conducts live training exercises to improve how nations work and fight together. These exercises allow countries to use their existing military equipment augmented with Tactical Engagement Simulation Systems (TESS) to simulate combat and combat-related activities. In general, each nation's TESS is customized for their military apparatus plus their training tactics and thus may not fully interoperate with another nation's TESS. The United States (U.S.) Army formed the Multinational Live Training and Interoperability Study (MLTIS), a task force including U.S. partner nations, to identify these interoperability issues. MLTIS partnered with the NATO Modeling and Simulation Group (NMSG) Urban Combat Advanced Training Technologies (UCATT) team to identify common issues in interoperability.

Previous work introduced a methodology for assessing the interoperability of Live Training exercises (Benslay et al., 2019). This methodology was well received by the UCATT community who requested the study team automate the methodology so it could be more easily and consistently applied to multi-national live training exercises. This paper presents the status of that automation that now uses the name Interoperability Readiness Assessment Toolset (IRAT). The background leading to development, the evolution of the tool, level of acceptance by the community, and future directions for the IRAT are discussed.

Individuals/organizations who participate in planning and preparing for multi-national live training events and who experience the interoperability problems that arise between TESS equipment may consider adopting the Interoperability Readiness Assessment Methodology (IRAM) to improve consistency in assessing multinational training exercises. The IRAT enables and facilitates this adoption and could lead to the use of this methodology in other live training domains.

BACKGROUND

Interoperability Background

In this context, interoperability is the ability to exchange information and work together toward a common goal or delivery of a common service. Defining interoperability in this manner implies the outcome is not always binary and there exists the possibility of having different levels of interoperability, as some systems work together better than others. Interoperability is essential as organizations and systems that were developed independently are joined through improvements in networking and communication. Systems that can interoperate may be able to provide additional features and services that are not available in isolation. In Figure 1 Tolck and Muguira, (2003), introduced the Levels of Conceptual Interoperability Model (LCIM) to create a taxonomy of interoperability problems and guide solutions applicable to each level of interoperability. The LCIM is a seven-layer model that defines the different levels of interoperability that can be achieved in a wide array of situations, ranging from No Interoperability to full Conceptual Interoperability. This model for

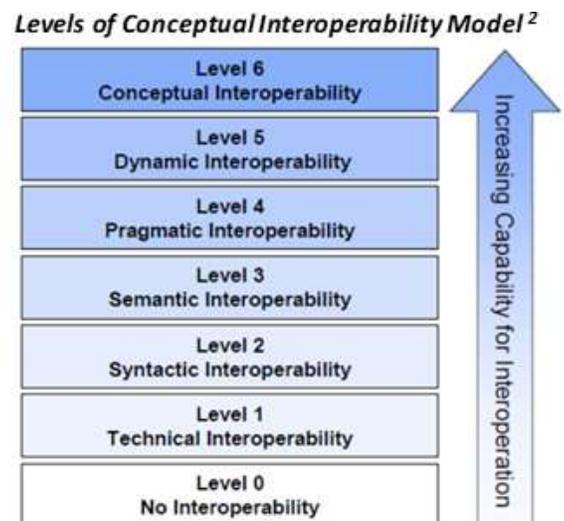


Figure 1. The Levels of Conceptual Interoperability Model (Tolck, A., and Muguira, J. A. 2003)

interoperability was applied to live training systems with the intent of measuring the level of interoperability between different systems after a training event (Benslay et al., 2019, Assessing and Measuring Interoperability Between Multi-National Live Training Systems). However, the LCIM can be used for more than just describing what was accomplished in an event. It prescribes the minimum levels of interoperability to ensure a live training event succeeds, supports an analytical view of the gaps enabling the systems in an exercise to function together, and identifies potential ways in which the gaps may be addressed.

Training systems are not the only area interested in assessing interoperability. With the increase in multinational engagements, the Command-and-Control community is investigating ways to evaluate the interoperability of their systems (Tolk et al., 2012). There is similar work being done on interoperability in the manufacturing realm (Tu et al., 2014). Likewise, interoperability is a concern in healthcare, especially with the movement toward electronic patient records (Gaynor et al., 2014). The unique component of the live training approach is the short-term duration of the interoperability. Live training events take hours, days, and occasionally weeks to accomplish. This means that the live training approach is focused on enabling systems to work together only for a short while and not as a way of making systems interoperate permanently, outside of the live training event.

Means of Measuring Interoperability

The systems that are interoperating consist of devices, training devices and computers, known as nodes. As more nodes are added to a system the possibilities for interoperability expand. The nodes may be similar, providing multiple origins for information, or the nodes may be dissimilar adding complexity requiring further evaluation. Live training simulation systems tend to have both many nodes and multiple types of nodes.

Some attempts to measure interoperability focus on routing or the number of connections between nodes to judge interoperability. In this circumstance, as the number of paths between the nodes increases, the level of interoperability rises. This approach does not consider the level of system comprehension or ability to understand the information being transferred and use it to perform a function. It assumes that connectivity implies interoperability. For a system with diverse types of nodes this is not an appropriate approach, because the nodes can be connected without being interoperable.

Another approach is to look at the interoperability between every interface and take the highest interoperability level as the overall level of the system. In this approach, one weak link lowers the interoperability of the entire combination even though it may be possible for the systems to operate as intended for the live training exercise without relying on the path with the low interoperability score. During live training events the event planners often use workarounds to improve interoperability despite component nodes that do not communicate well, for instance using middleware that can translate event data between systems who are unable to communicate on their own.

Considering these approaches, the IRAM uses the second approach. It calculates the interoperability levels across specific interfaces and combines the results to create an overall interoperability assessment. The next section describes the role that UCATT fulfilled by providing insight to select the key interfaces to assess.

Components of Live Training Exercises

Each live training exercise is unique, each having different training participants, technologies, and objectives. To reduce the risk of injury or fatalities during live training, normal weapons are fitted with TESS allowing a computer system to determine and monitor the effects of the weapons. In Figure 2, the UCATT defines a Functional Architecture (FA) to describe the setup of TESS supporting live training exercises. For further information on the UCATT FA, please visit the UCATT website <https://www.sisostds.org/StandardsActivities/DevelopmentGroups/UCATTPDG-UrbanCombatAdvancedTrainingTechnol.aspx> (Simulation Interoperability Standards Organization, n.d.).

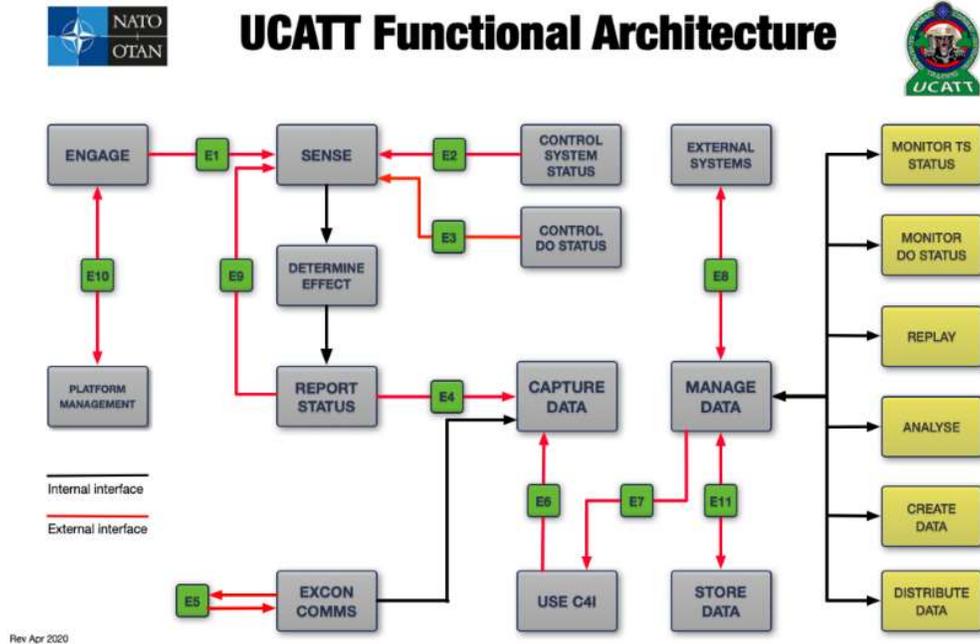


Figure 2. The UCATT-4 Functional Architecture (2018)

Typically, this setup includes laser-based communications during a firing event, and subsequent communications to an Exercise Controller (EXCON) transmitting the results of the engagement. Figure 3 shows an example of an EXCON.

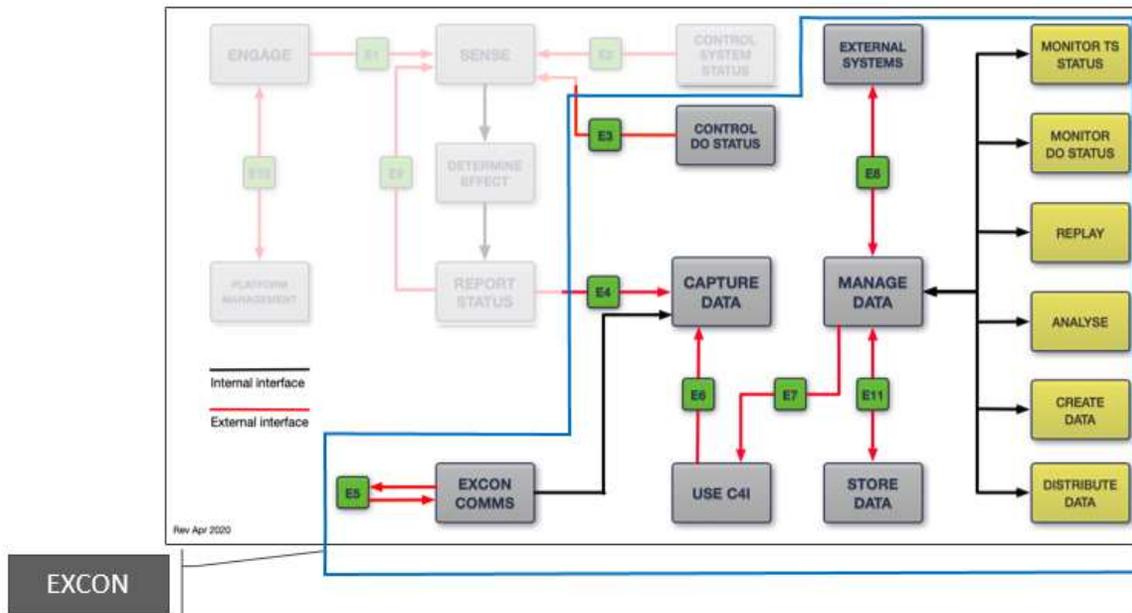


Figure 3. Description of an EXCON According to the UCATT Functional Architecture

TESS comprises many kinds of equipment, referred to as Dynamic Objects (DO), providing instrumentation for individuals, vehicles, structures, and aircraft. DOs represent all systems/elements that exist physically in the training environment and that can influence other entities (NATO Science and Technology Organization, 2016). Figure 4 shows an example of a DO.

In addition to the DO, the functional architecture includes the EXCON, defined as any system that can monitor, control, and collect data during a training exercise. Figure 4 shows the boundaries of the EXCON. The EXCON defines and (remotely) monitors and controls an exercise. Generally, this occurs from a central location, such as a training or simulation center near the training exercise area. Note, according to the UCATT definition, “Use C4I” exists within both the DO and EXCON boundaries, meaning the context of the exercise affects how the systems interoperate.

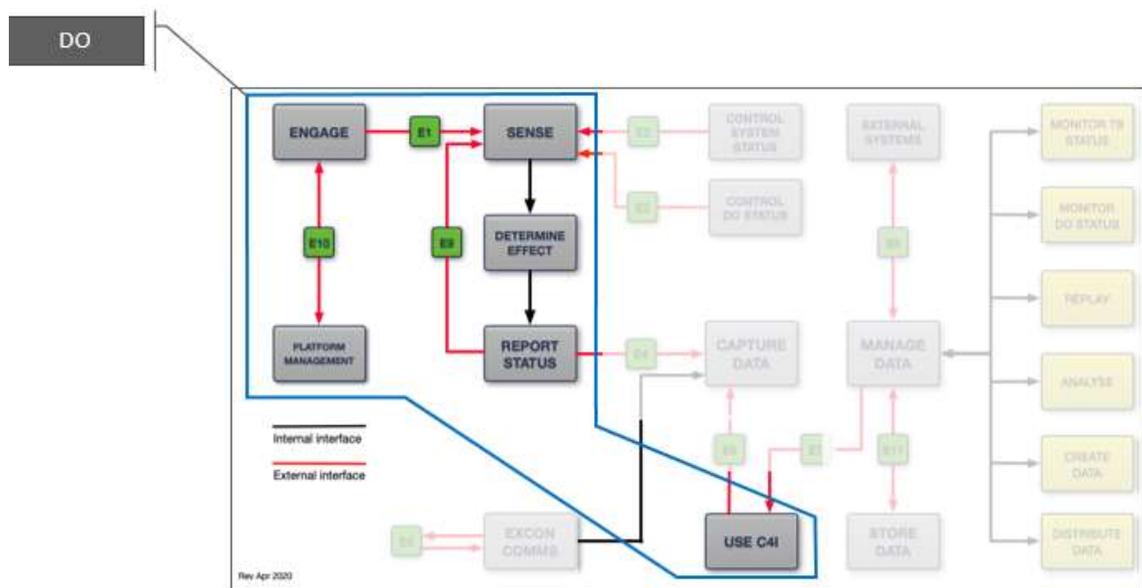


Figure 4. Description of an DO According to the UCATT Functional Architecture

Nations typically procure TESS which has been tailored to the specifics of their military equipment. Despite the differences in the composition of the exercises, the supporting TESS has some basic patterns. These patterns are useful in considering how to measure interoperability.

Urban Combat Advanced Training Technologies Use Cases and Interoperability Readiness Levels

The UCATT team has created a series of nine use cases that define all the possible relationships between systems in a live training event. Intended to be as general as possible, and independent of mission objectives, the UCATT Use Cases serve as a basis for the relationships that the IRAM evaluates in its assessments. In all Use Cases there exist some similarities; for instance, all have DOs, EXCONs, System Controllers, and Observer/Controllers entities in training events. The most important similarity between all use cases is that they have three unique relationships critical to interoperability:

1. DO-to-DO
2. DO-to-EXCON
3. EXCON-to-EXCON

These three relationships form the basis of connections in the IRAM’s assessment and are essential to the interoperability of a training event. It is important to note that these connections are bi-directional, meaning that the data flows in both directions and must be considered when determining interoperability. However, this only provides a framework for what will be measured for interoperability. To be able to offer a scale or measurement to assess these relationships, the LCIM and Interoperability Readiness Levels (IRLs) are needed.

Multinational Challenge in Live Training Events

The MLTIS partners involved in the study host several hundred exercises per year. Many, though not all, of these exercises involve participants from more than one nation raising potential issues regarding equipment interoperability. Admittedly, this tempo was greatly reduced during COVID, but the training did not end entirely.

After more than 40 years of laser-based training engagements, there are a wide variety of TESS in use. Generally, nations procure their equipment based on their national training needs without accounting for interoperability outside of their military. In the current environment, the global community is engaged in regular international training events. Due to the differences in procurement, laser and sensor standards, interfaces differ between the partners and can result in communication problems between the equipment, often requiring expensive workarounds that reduce the effectiveness of live training. Many times, this requires one country to use another country's TESS during a training event to ensure interoperability among the exercise participants. Consequently, the overall effectiveness of the international training events may be hampered by imperfect interoperability of the equipment supporting the event. In 2018, a study team reported on the IRAM that was developed to apply an established LCIM to the TESS interoperability problem in the live training systems domain, and is discussed below (PEO STRI, 2021).

Interoperability Readiness Assessment Methodology

The IRAM is able to use the IRL, defined in the LCIM, to effectively apply a measurement of interoperability between the interactions of different TESS and EXCON systems used during training exercises. By providing scores and descriptions of the level of interoperability of a connection, the IRAT supports more informed planning of future training events. The goal is to provide international allies a repository of knowledge of how TESS and EXCON systems have worked together in the past. This leads to more informed stakeholder perception surrounding post training assessments as well as more effective collaboration between allied nations. To better understand the underlying method of how the IRAM creates the interoperability scores between systems, a brief review of the UCATT Use Cases and how they are combined with the IRL is provided.

Each level in the LCIM includes a general description of interoperability, which was helpful in the IRAM in being more specific when doing assessments and providing a reference to event planners when performing assessments. With the LCIM and its IRL, MLTIS was able to provide a score to the relationships found in a training event that align with the nine UCATT Use Cases. The LCIM and IRL serve as the foundation for the IRAM's approach for assessing the interoperability of past training events called the Post-Event Assessment.

Originally, data collected from applying the methodology was tracked in a spreadsheet with discussion of establishing a database to manage the questions and results. Tracking the exercises and results became difficult to manage and susceptible to error, which created the need for a tool whose purpose is to track the information. Therefore, using artifacts from the NMSG UCATT, the U.S. Army Program Executive Office Simulation, Training and Instrumentation (PEO STRI), Project Manager Soldier Training (PM ST), and The MITRE Corporation (MITRE) teamed to implement the IRAM as a software application.

Post-Event Assessment

The Post-Event Assessment applies the LCIM and UCATT Use Case relationships to best describe the interoperability of interactions in an event. However, the connections in the IRAM and the IRAT provide planners the ability to create alternate connections that are not constrained to the UCATT Use Cases (see Figure 8 and Figure 9). This flexibility is necessary due to the wide range of systems and configurations that can exist in a live training event that might not reflect the UCATT Use Cases.

This need for human input is also required in how the Post-Event Assessment gathers data to determine the interoperability of a live training event. The IRAT accomplished this by presenting a series of branching questions to the exercise planner/analyst, who provide responses based on what occurred during the training event. Each question set is tailored to the connection and systems being analyzed. For instance, the questions for interoperability of a DO-to-DO relationship are not the same as those for a DO-to-EXCON or EXCON-to-EXCON connection. Figure 5 shows an example of the question tree from the tool. The underlying algorithm uses the answers to the branching questions trees to create a single number "IRL score," providing a clear comparison between events. For a complete description of how the IRL scores are calculated, refer to the IRAM (PEO STRI, 2021).

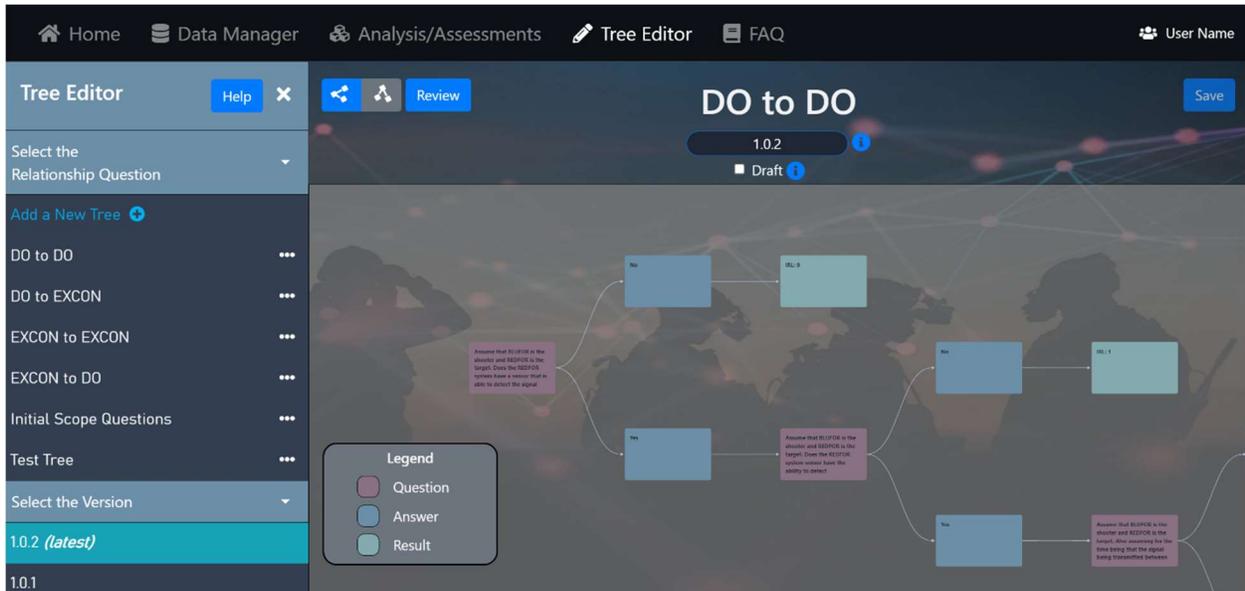


Figure 5. DO-to-DO Question Tree in the IRAT Tree Editor Tool

METHODS

This Methods section describes the process of creating the IRAT while ensuring that it implements the ideas and methodology of the IRAM. Additionally, the process for maintaining high usability and functionality will be discussed as well as how the international live training community reviewed the tool.

Tools Used to Create the Interoperability Readiness Assessment Toolset

The IRAT exists as a web application with a frontend user interface and a backend Application Programming Interface (API) and database repository. The partial frontend in Figure 6 was created using a variety of tools and languages including HTML 5, CSS 3, ES6, and jQuery, which allowed Document Object Model manipulation (DOM) utility. D3JS, Bootstrap, PopperJS libraries are used to make parts of the user interface (UI) easier to create and to test for usability and functionality. Finally, webpack, an open-source module bundler that handles JavaScript files, is utilized in creating a UI with high usability and functionality.

The IRAT backend, which uses a microservice architecture, is designed using NodeJS with an Express.js framework, allowing for a robust and flexible creation of the backend environment, due to NodeJS's scalability with microservices and use of JavaScript. MongoDB is used to store the data created by the IRAT (such as the "IRL quotients" from a live training event). MongoDB has an advantage over other options, such as MySQL, in being able to support unstructured and structured data, which means that the IRAT can handle different live training data formats. Extra data fields, missing information, and other differences in data can exist when dealing with live training information. MongoDB can handle all the intricacies that exist with live training data with its ability to support unstructured data.

Figure 6. Data Entry of TESS information in the IRAT

Interoperability Readiness Assessment Toolset Implementation of the Interoperability Readiness Assessment Methodology

An important consideration during the IRAT design and development is to avoid deviation from the IRAM. As the IRAT was first being developed, designers of the IRAM continuously validated the IRAT to make sure no inconsistencies existed between the two. This validation has not stopped as the IRAM and IRAT continue to change, with regular meetings held by the developers of both the IRAT and IRAM looking over the differences in each. Considering those differences, the team then decides how to change the IRAT to better reflect any changes in the IRAM. The team also considers where the IRAM needs to be expanded or clarified to reflect what is implemented in the IRAT. This routine checking makes sure that the IRAT stays a faithful implementation of interoperability assessment as documented in the IRAM.

Testing for Usability and Functionality in the Interoperability Readiness Assessment Toolset

During development of the IRAT, it is important to maintain high usability and functionality for users. To that end, a series of automated tests for both the backend and frontend of the IRAT are used. For the backend, Jest, a JavaScript testing framework used for functional unit testing, is utilized to make sure all backend functionalities work. For instance, a test ensures that user-entered data about a training event is successfully saved to the tool's database. For the frontend, in addition to Jest, Puppeteer, a node library that can imitate user inputs, is used to make sure that the UI looks and works as intended.

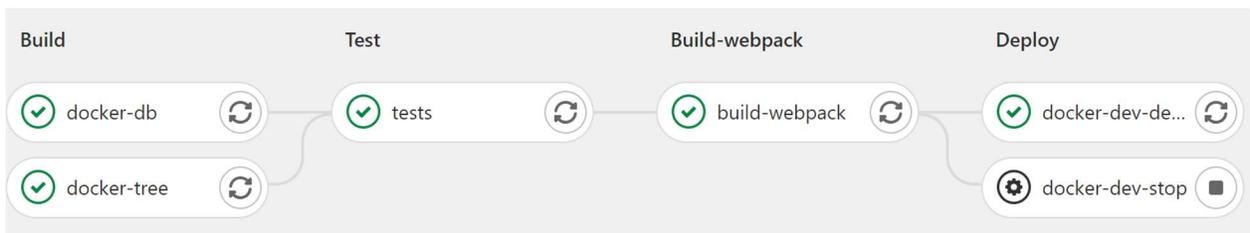


Figure 7. MLTIS Continuous Integration/Continuous Delivery Pipeline

As shown in Figure 7, the automated tests are integrated into the IRAT's CI/CD development pipeline, ensuring that any future changes to the tool continue to maintain the level of usability and functionality required. Additionally, as the IRAT continues to develop, new automated backend and frontend tests will be created and added to the pipeline as needed.

Interoperability Readiness Assessment Toolset Validation by Users

To make sure that the IRAT, and by extension the IRAM, can accurately analyze the interoperability of live training simulations, it undergoes continuous validation by different stakeholders. The IRAT is currently hosted on the Networked Experimentation, Research, and Virtualization Environment (NERVE) at MITRE, a distribution integration network that allows invited U.S. nationals to access the IRAT in a production environment. Thus, fresh perspectives on IRAT usability are obtained from those outside of the development team. For instance, the team gains insight as to how interacting with the tool feels, how intuitive it is, and how well it reflects the interoperability of training events based on the individual's own experiences.

Another method of validating the IRAT and IRAM measures of interoperability is through interactive data entry based on results from previous training events. Testing how well the Post-Event Assessment question sets and "IRL scores" reflect the actual interoperability of a live training event shows how the IRAM and IRAT could be improved to better reflect the complex interactions that happen in a live training simulation. For instance, one IRAT improvement is to add fields to take into consideration workarounds used for systems in an event to allow interoperability. Efforts to include more data from MLTIS international partners are currently underway.

Additionally, MLTIS international partners review the IRAT and IRAM in bi-monthly meetings, allowing the MLTIS team to demonstrate new features. These interactions provide opportunities for stakeholders to offer suggestions for improvement. For example, the MLTIS international community requested the questions be more specific about the TESS being discussed and include more details such as country, version, short/long name, the name of the exercise,

owner of the TESS, and configuration name (alias). As a result, the development team is updating the Post-Event Assessment questions to include parameters with TESS details.

RESULTS

Results of Entering Data into the Interoperability Readiness Assessment Toolset and Interoperability Readiness Assessment Methodology

To determine the effectiveness of IRAM and IRAT at testing interoperability, it is essential for the IRAT to use real event data. To that end, the MLTIS group is collecting data from past events from its UCATT partners, with future plans to receive data from Canada and Australia. Based on data from the 2018–2020 timeframe, the information collected is helpful in highlighting the strengths and weaknesses of the current methodology. In the initial design of the tool, the person entering the data for an exercise was expected to know and understand the particular UCATT use case configuration. However, a more flexible means of interactively depicting the use case is now available, simplifying the data entry tasks. Examples of the TESS and EXCON interconnections for two different use case options are shown in Figure 8 and Figure 9.

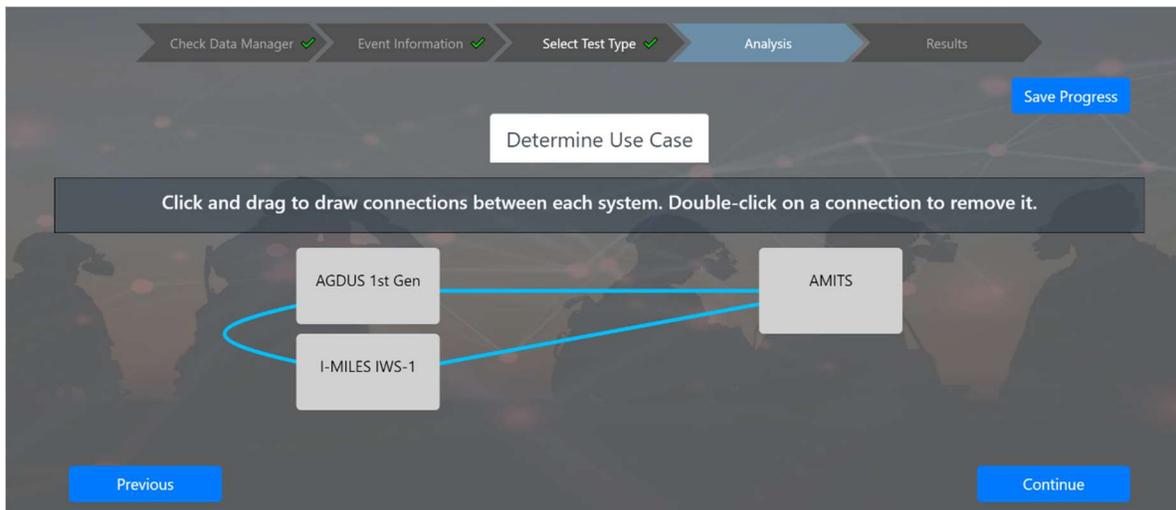


Figure 8. Replication of UCATT Use Case 2 Option 1 in the IRAT

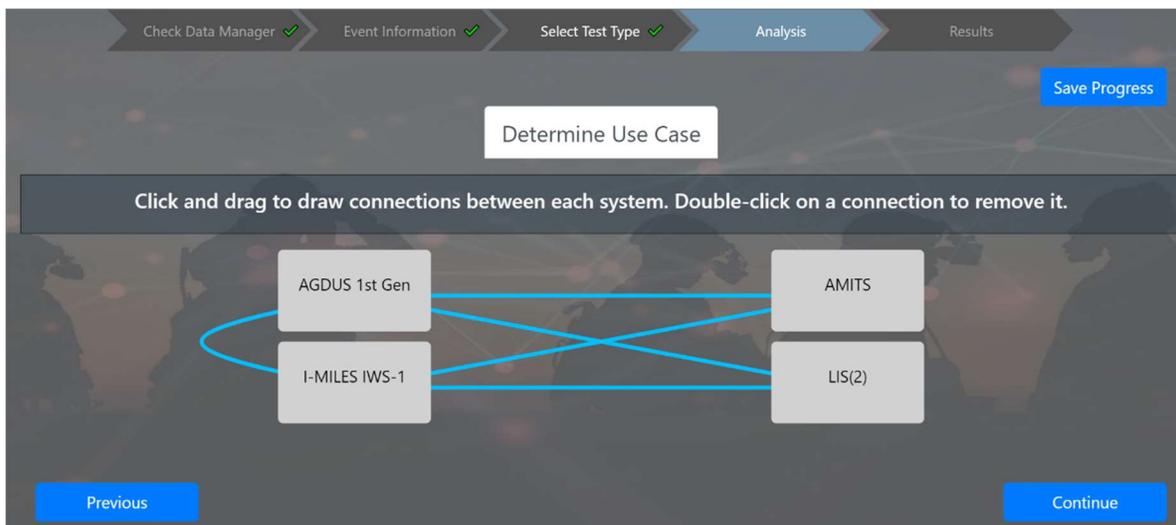


Figure 9. Replication of UCATT Use Case 2 Option 3 in the IRAT

Together with feedback from MLTIS partners, the data collected from the UCATT team uncovered flaws in the current Post-Event Assessment approach. One problem area that surfaced was that some of the questions were unnecessary for determining TESS interoperability. The observed result was a final “IRL score” that inaccurately represented TESS interoperability.

Another benefit from the data entry was the identification of a need for greater granularity in the interoperability measurement. For instance, two countries may have the same TESS, which would lead to the expectation that they are fully interoperable. However, there can still be variations between these two TESS that result in interoperability problems for a live training event requiring the use of middleware. These details are not considered in the IRAM but were discovered when implementing and testing with the UCATT data. From this, IRAT improvements were implemented to allow for a more precise assessment of the interface capabilities.

Reports of Live Training Events

Given the necessity to document and inform stakeholders about the findings from an event, the IRAT implements a reporting feature. When interacting with the reporting system a user extracts event information from the IRAT database into a PDF document. The report includes data in a tabular format containing the event name, event date(s), host country, list of participating countries, and the event “IRL score.” Additionally, a use case diagram illustrates the relationships between the TESS, providing a visualization of the connections. A table of contents enables efficient report navigation.

NEXT STEPS AND FUTURE DIRECTIONS

Building on the work of refining the question sets for each of the use cases, beginning later FY21 into FY22, the team will populate the database with information on actual TESS and EXCON products and establish a more comprehensive set of post-event IRL assessments based upon data from real-world events. The intention is to create an exercise database and reports as sources of information useful to the multinational training community. This will help provide the international community a better understanding of current levels of interoperability achieved across a variety of live training exercises and use cases involving many different TESS and EXCON configurations and countries. The expectation is that this data driving IRAT summary reports will be useful to plan exercises and inform leaders and decision makers where high levels of interoperability and gaps exist among countries and systems.

Discussions are in progress to assess reporting and information needs beyond the current IRAT reporting. The team expects to develop several levels of reports targeted for various audiences by mid to late FY21. For example, an exercise planner requires detailed information including responses to each question for each connection between DOs in a Live training event. Other audiences will likely not require that level of detail, and a general summary describing the participants, systems, and level of interoperability achieved might be more appropriate.

Pre-Event Analysis

A longer-term goal, going into FY22, for the IRAT is to provide a planning capability that “predicts” IRLs for specific sets of use cases, based on various configurations of equipment and countries. This capability, called a pre-event analysis, will rely on comparisons of specification compliance between TESS, and in the future, data from post-event assessments that involve the same TESS. Event planning should leverage previous engineering solutions for facilitating interoperability to influence future TESS enhancements.

Product Hosting

The IRAT is currently hosted on a network with security protocols restricting access to U.S. nationals. There is an ongoing effort to locate a hosting site that will allow direct access by all involved nations. This may involve teaming under a NATO site, such as the one run by the UCATT.

Reuse of the Tool Outside of the MILES Engagements

Currently, the IRAT and IRAM focus on TESS that is based on interactive laser engagements; however, the live training domain is incorporating types of non-laser-based simulators. Furthermore, the live training events may interoperate with other types of simulation, such as constructive simulations. The addition of synthetic training expands the possibilities for engagements and increases the complexity of interoperations. The IRAT’s flexible design enables it to add use cases and assessment questions that capture interoperability successes and best practices. As these options are further explored, the possibility of adding prediction or recommendation capabilities can be developed.

CONCLUSION

Originating from a single study focused on two exercises, MLTIS is currently expanding its IRAT technology to provide comprehensive assessment reports of multinational exercise interoperability (Butler et al., 2017). The IRAT ensures that assessments are measured and archived for use by future exercise planners. The development of additional features to support the analysis of planned exercises is underway. The IRAT implementation of the IRAM is beginning to demonstrate its effectiveness at measuring system/interface interoperability in multinational live training events. Other types of federated systems may benefit from adopting the IRAM and a modified version of the IRAT. Combining the framework of the IRAM based on established theory (LCIM) and the supporting technology of the IRAT allows for a standardized description and prescription of interoperability maturity or readiness levels on a large scale.

REFERENCES

- Benslay, J., Pritchett, R., Bogler, W. C., & Carrier, G. (2019). *Assessing and Measuring Interoperability Between Multi-National Live Training Systems*, Interservice/Industry Training, Simulation, and Education Conference (IITSEC) 2019, Orlando, FL.
- Butler, P., Crutchfield, R., Dugan, P., Evans, M., & Osborne, R. (2017). *Multinational Live Training Interoperability Report on United States and Allied Military Interoperability*, Internal MITRE Corporation report: unpublished.
- Gaynor, M., Yu, F. Andrus, C. H., Bradner, S., & Rawn, J. (2014). A general framework for interoperability with applications to healthcare. *Health Policy and Technology*, Volume 3, Issue 1, 2014, Pages 3-12, ISSN 2211-8837, <https://doi.org/10.1016/j.hlpt.2013.09.004>.
- NATO Science and Technology Organization (2016). *Urban Combat Advanced Training Technology Architecture, Final Report of Task Group 098*, NATO Science and Technology Organization.
- PEO STRI (2021). *MLTIS Interoperability Readiness Assessment Methodology (IRAM)*, Program Executive Office Simulation Training and Instrumentation (PEO STRI) Project Manager Soldier Training, Orlando, FL.
- Thinnes, A. (2017). *An Introduction to UCATT*, NATO, Science and Technology Organization.
- Tolk, A., Bair, L. J. & Diallo, S. Y. (2012). Supporting Network Enabled Capability by extending the Levels of Conceptual Interoperability Model to an interoperability maturity model. *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, 10(2) 145–160 2012 The Society for Modeling and Simulation International DOI: 10.1177/1548512911428457.
- Tolk, A. and J. A. Muguira, (2003). *The Levels of Conceptual Interoperability Model (LCIM)*, In Proceedings of the Fall Simulation Interoperability Workshop. Orlando, FL: SISO Inc.
- Tu, Z., Zacharewicz, G., & Chen, D. (2014). Building a high-level architecture federated interoperable framework from legacy information systems. *International Journal of Computer Integrated Manufacturing*, 27(4), 313-332. doi:10.1080/0951192X.2011.646306.
- Simulation Interoperability Standards Organization. (n.d.). *UCATT PDG/PSG – Urban Combat Advanced Training Technologies*. <https://www.sisostds.org/StandardsActivities/DevelopmentGroups/UCATTPDG-UrbanCombatAdvancedTrainingTechnol.aspx>.