Assessing and Measuring Interoperability Between Multi-National Live Training Systems

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ABSTRACT

The U.S. military increasingly uses virtual environment training simulators which are demonstrating to be an effective complement, but not a replacement for Soldiers training in "live" physical environments using real vehicles and weapons. To ensure Soldiers' safety when training with real weapons, the Army has used an advanced version of "laser tag", which is currently referred to as the Instrumentable Multiple Integrated Laser Engagement System (I-MILES). Several U.S. coalition partners have adopted MILES-like systems from various companies to conduct live training of their own forces. Unfortunately, these MILES-like systems are not always interoperable which limits our ability to train with allies. When allied countries cannot effectively train together, it becomes a significant limiting factor for planning real-world joint operations. To help address these interoperability issues, PM TRADE tasked MITRE to conduct the Multi-national Live Training Interoperability Study (MLTIS). As part of this effort, we are partnering with the NATO Modeling and Simulations Group (NMSG) Urban Combat Advanced Training Technologies (UCATT) team to develop a common picture of training systems interoperability. A significant early outcome of this partnership is a methodology for consistently and objectively assessing the level of interoperability achieved at an exercise event using multiple MILES-like systems. This approach, referred to as the Interoperability Readiness Assessment Methodology (IRAM), leverages the previously established Levels of Conceptual Interoperability Model (LCIM) and applies that model to the live training systems domain. This paper will provide an overview of the IRAM and demonstrate how it provides a defined and objective approach to identify interoperability issues in live training systems. The U.S. with our MLTIS coalition partners is currently developing the IRAM as an essential foundational element in promoting live training between multi-national allied forces.

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BACKGROUND AND INTRODUCTION

The U.S. experienced great success in creating alliances and participating in a multi-national force during conflicts. The Multi-National Force – Iraq (MNF-I) is a recent example, a coalition of more than 30 countries committed to fighting the Republic of Iraq & jihadist groups between 2004 and 2011 [1]. Operations like these underscore the need for multi-national live training, which would prepare all partners for the intricacies of fighting as part of a multi-national force. This need is explicitly mentioned in the United States' 2018 National Defense Strategy, which identifies interoperability as an element "for achieving a capable alliance and partnership network" [2].

Unfortunately, this multi-national live training need was not realized until many training systems had already been procured. As a result, training systems are often inoperable during multi-national training. The U.S. and its allies have coordinated in the past decade to develop standards and technical solutions to address these interoperability gaps. During development efforts, the United States Army realized that one crucial piece was missing – an objective methodology for assessing interoperability. Such a process would provide a "common picture" of the level of interoperability between two systems, like a laser transmitter and a laser receiver/detector. Assessment of these relationships had been attempted before in many interoperability meetings with multi-national partners but failed to provide a description that all groups could agree on due to differing views on the scope of the relationship and definitions for the individual entities. In order to support training requirements within Joint Publication 3-16 on Multinational Operations [3], which states that members must develop consistent and shared training doctrine, the U.S. Army established a new working group, the Multi-National Live Training Interoperability Study (MLTIS), to investigate and address this capability gap.

The MLTIS group's new Interoperability Readiness Assessment Methodology (IRAM) builds upon previous academic work to provide a common frame of reference for assessing interoperability. Its purpose is to classify the relationship between systems in a way that the U.S. and its partners can agree on. This methodology will enable us to understand the problem better and determine a robust strategy for developing a solution.

Current State of Live Training Simulation Systems

Live training provides Soldiers with a realistic representation of situations they will experience in the operational environment. The United States Army maintains a robust training doctrine and schedule, enabling Soldiers to train for leadership, collective, and individual tasks in the live environment. The Army's Combat Training Centers (CTCs) and home station training centers provide units with the facilities, technologies, and support staff for training at more than 30 locations across the country and in partner countries around the globe.

Due to cost and operational constraints, and safety concerns, some parts of a combat situation (such as live fire) are simulated during training exercises. For more than 30 years, the Multiple Integrated Laser Engagement System

(MILES) product line has been used to simulate live fire engagements during training. MILES is the military's advanced form of laser tag for dismounted Soldiers and mounted personnel/platforms and is composed of Tactical Engagement Simulation Systems (TESS). MILES products exchange data via laser-based communications during a firing event. This data exchange sends the shooter's data to its target, which determines the effect of the shot and reports the event to an Exercise Controller (EXCON) system. The MILES Communications Code (MCC), a communications standard developed by the Cubic Corporation for U.S. TESS-to-TESS communications, governs interactions by specifying a common "language".

Generally, these MILES systems consist of a set of laser detectors, a laser transmitter (for entities capable of live fire) and a control unit. This equipment is attached to a Soldier, vehicle, or structure, and simulates firing or hit events. Laser-based training systems are not exclusive to the U.S.; many countries have procured similar systems from a myriad of developers.

The U.S. has continually updated its TESS systems over the last three decades, adding and improving capabilities. However, there are still capability gaps that the U.S. continues to experience during multi-national training exercises.

Unfortunately, many of these laser-based TESS did not have requirements for interoperability with partner nation systems during development. The result is that training system interoperability remains a problem during multi-national live training exercises. The communications standards and physical interfaces vary from one country to another, and interactions between different countries' systems often result in unexpected or unintended outcomes (such as, missed "kill" events or misinterpreted messages). Many systems' communications standards are proprietary to their developer, so interoperability is limited to a subset of these developers' systems. Due to interoperability problems, partners either accept a reduction in realism or are forced to implement workarounds, such as using exercise staff as "umpires" during force-on-force engagements. These compromises often introduce additional strain on funds and manpower while limiting the utility of the training.

Existing Practical Approaches to Multi-National Live Training

Interoperability problems have existed as long as multi-national training with TESS/MILES gear. The U.S. Army has developed a couple workarounds to address this problem (with varying levels of success).

The Army's Joint Multi-National Readiness Center (JMRC) in Hohenfels, Germany, often hosts European partners for multi-national training [4]. Many of these partners utilize the **O**ptische **S**chnittstelle für **A**GDUS und **G**efÜbZ H (OSAG) interface on their TESS systems. For those allied partners who do not use an MCC-based system, the 7th Army Training Command (which oversees training events at JMRC) often issues old MILES equipment to partners instead. To make sure the equipment is utilized properly, 7th ATC developed a multitude of application-specific brackets and interface boxes. It's a time-consuming and expensive workaround and provides interoperability at the cost of realism.

7th ATC also uses their Deployable Instrumentation System – Europe (DISE) to provide a mobile multi-national training solution. This instrumentation system, procured in 2016, includes TESS systems capable of communicating via both the MCC and OSAG communications standards. The standard is based on the partners participating in the exercise. This creates the ability for partners to bring their OSAG-based TESS systems to a DISE exercise and interact with the U.S.'s MCC-based TESS systems. However, there are limitations – DISE systems have implemented OSAG communications differently from European implementations. This sometimes leads to "fair fight" issues, because U.S.-based TESS lasers can effectively engage foreign targets at distances that exceed the real weapon's range.

LAYING THE FOUNDATION FOR AN INTEROPERABLE SOLUTION – A COMMON STANDARD AND ASSESSMENT METHODOLOGY

Role of UCATT in Defining the Functional Architecture, Use Cases, and Writing Common Standards

Since 2003, the NATO Modeling & Simulations Group (NMSG)-sponsored Urban Combat Advanced Training Technology (UCATT) task group [5] has worked to "identify interoperability requirements and a suitable architecture and a standard set of interfaces that would enable interoperability" [6]. In order to accomplish these goals, the group has developed many products over the last 16 years. The following three sub-sections identify the principal products, all of which were used to provide a frame of reference for the IRAM.

UCATT Functional Architecture

UCATT began by developing the "UCATT Functional Architecture" (FA), a visual representation providing "insight into the functions of the training system, how they are grouped together into components and what types of interactions take place between those components" [6]. This architecture defines how different systems communicate during a live training exercise by categorizing interactions based on the type of functionality they provide, such as simulated engagement or sensing. UCATT has improved the FA as new capabilities or relationships were introduced to live training systems. Figure 1 is the latest version of the FA; it was released in April 2019.

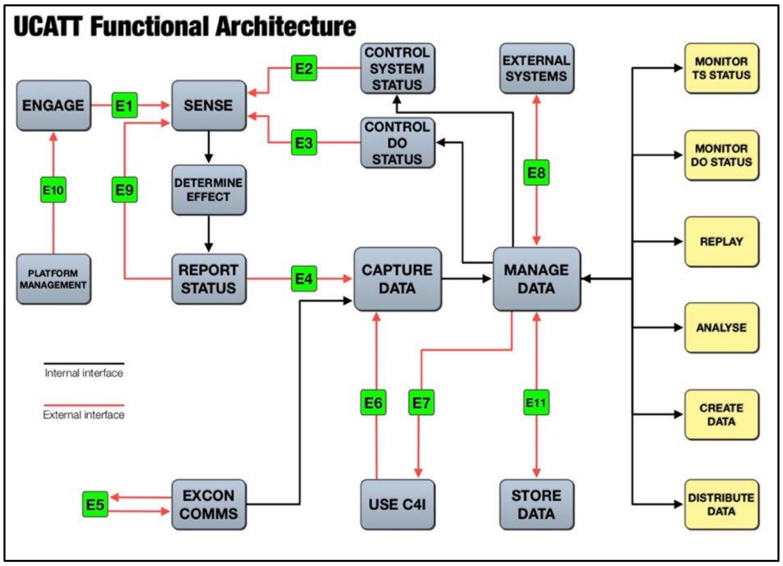


Figure 1. UCATT Functional Architecture

The FA is decomposed into a set of functional interfaces ("E-interfaces"), which are further deconstructed into a set of physical interfaces ("I-interfaces"). An example is the E4 interface, which represents communication of status from a Dynamic Object (such as a TESS system) and the Exercise Controller (EXCON). This data transfer passes through multiple physical interfaces (TESS to radio, radio to tower, tower to EXCON). Communications standards developed under UCATT focus on the physical interfaces.

UCATT Use Cases

The UCATT group developed Use Cases and supporting documentation to depict these scenarios "to both visualize and understand the complexities in each case that had to be considered in order to determine training requirements" [6]. Use Cases focus on the relationships between systems within the context of a specific training event. For example, one Use Case involves a foreign nation using a host nation's training facility and the host's equipment, while another involves the foreign nation using foreign equipment at the host nation's training facility.

UCATT Standards

One of the most important goals of the UCATT group is to develop international standards for communication between systems during live training events. Standardized interfaces enable current and future training system interoperability - by specifying these standards in procurement and acquisition processes, they ensure that their systems will be able to speak a common language with foreign systems.

The UCATT group's process for standardization often begins by analyzing existing standards to determine if they can be used as a starting point for the standardization process. The group uses their Functional Architecture, Use Cases, and national requirement sets to modify the original standard so that it satisfies everyone's needs. The standard is reviewed by the NATO Modeling & Simulations Group and the Simulation Interoperability Standards Organization (SISO) for completeness prior to being publicly released.

As of 2019, one standard - the UCATT Laser Engagement Interface Standard (ULEIS) - has been approved by the SISO, with official recognition by NATO as a NATO Standardization Recommendation (STANREC) [7]. This standard provides a consistent method of communication within the UCATT Functional Architecture's Enage/Sense interface.

Role of PEO STRI/PM TRADE Initiating MLTIS to Assist UCATT

MLTIS was established by the former Program Executive Officer for Simulation, Training and Instrumentation to investigate interoperability issues at the Joint Multinational Readiness Center (JRMC) and Canadian training exercises. In 2017, MLTIS' original objective was to examine interoperability challenges between the U.S. and Canada; however, the MLTIS scope expanded to include all U.S. partner nations. The PEO STRI PM TRADE – MITRE team developed a multinational training interoperability roadmap including applications, metrics, and measures applicable to assessing the effectiveness of interoperability in a multinational training environment.

MLTIS is a collaborative partner to the UCATT group. Where UCATT's focus is planning for a unified TESS architecture and interface standards, MLTIS provides capabilities to observe, conduct analysis, and document the actual interoperability between TESS components. MLTIS is developing multiple data-driven products that when integrated, provide a 'Common Picture' of multinational live training interoperability. MLTIS' products enable informed decisions about the level of interoperability between systems available to a training event, enabling more effective planning, preparation, and execution. These products will form the basis of actionable recommendations that will, in turn, inform stakeholder decisions towards impactful mission outcomes. The first of these products is the Interoperability Readiness Assessment Methodology (IRAM).

To help develop the Common Picture of multinational live training, the MLTIS team is developing a methodology to accurately describe the level of training system interoperability at both test and training events. The IRAM utilizes the concept of Interoperability Readiness Levels (IRLs), as defined in The Levels of Conceptual Interoperability Model (LCIM) by Dr. Andreas Tolk and James A. Muguira [8], coupled with established live training system Use Cases authored by the UCATT working group.

INTEROPERABILITY READINESS ASSESSMENT METHODOLOGY (IRAM)

Basic Concepts: Combine UCATT Use Cases with LCIM IRLs

The fundamental concept behind the IRAM is to apply the IRLs as an objective interoperability measure for TESS components used in live training events that are aligned with the UCATT Use Cases. In other words, the IRAM provides the ability to objectively apply IRL measure values to interface pathways identified in the UCATT Use Cases. When completed, the IRAM will contain a combined set of descriptions, definitions, processes, assessment questions, and scoring algorithms that will provide live training exercise stakeholders the ability to efficiently and consistently describe the demonstrated interoperability readiness of systems involved in a live training exercise or test event. The result will be to contribute objective knowledge about what TESS are interoperable so that international allies are able to conduct live training more efficiently, effectively, and more often. To understand this idea, it's helpful to examine the Use Cases and IRLs more closely.

UCATT Use Cases

As briefly described earlier, an early UCATT group effort established a series of Use Cases that describe a variety of multi-national training scenarios. These Use Case scenarios characterize the general interoperability relationships in an exercise event and are abstracted from any particular training/mission objectives. For example, the specific objectives of an exercise might involve a tank platoon maneuvering through a rural area to find and engage an opposing surface-to-air missile site that is being guarded by an opposing tank platoon. The UCATT Use Cases, however, simply indicate that there are opposing tank forces using dissimilar TESS. Accordingly, the Use Cases represent the breadth of the generalized relationships possible in multi-national exercises and they serve as a mature reference given the UCATT group has been using them for over a decade.

There are currently nine UCATT Use Cases [9]. Figure 2 presents an example of one of these Use Cases (taken from a UCATT presentation). The blue and red colors denote a nation or group using their chosen brand/model of live simulation equipment. In this Use Case, a blue team/country is hosting an exercise event wherein a red team/country has brought their own simulation equipment and the two systems must interoperate at the host location.

NATO OTAN NORTH ATLANTIC TREATY ORGANIZATION SCIENCE AND TECHNOLOGY ORGANIZATION

Use case 2: Use other nations training facility and staff

Option 1: they only bring training equipment for their operational systems

MSG-140 UCATT LSS

Figure 2. UCATT Use Case 2, Option 1

In this Use Case, DO stands for "Dynamic Object" and is defined [10] as a live, virtual or constructive element in the training environment that: 1) has a physical presence in the training or test environment and, 2) either has a valid status, or, can influence the status of other DOs (execute engagements), or possesses both of these characteristics. In this paper, DO's represent live entities such as physical Soldiers and/or vehicles.

EXCON stands for "Exercise Controller" and is defined [10] as an element in the training environment with the capability to define, (remotely) monitor, and control an exercise. An EXCON will generally comprise a collection of interoperating systems such as:

- radio-based networks to gather DO telemetry and status data in an exercise area
- software to track DO locations and display on a map
- hardware to control certain fire and smoke effects
- software to calculate and display exercise event metrics
- software to help prepare after-action review analysis
- data interfaces to external intelligence and major command information systems.

SYSCON stands for "System Controller" and O/C stands for "Observer/Controller". Although we do not have the space to discuss them in this paper, we will include both in the final IRAM.

The yellow arrows in the figure represent the interfaces between dissimilar systems that we want to evaluate. The black arrows represent interfaces between system components that have already been designed/demonstrated to be interoperable.

To better understand the interfaces involved we cross-reference this Use Case with the UCATT Functional Architecture (FA) presented earlier. Within their formal group reports [6] [10], the UCATT team has defined the boundaries between the DO and EXCON functional areas. In Figure 1, the DO to DO interaction occurs on the E1 interface and is implemented as a laser emitter (sender) and a laser sensor (receiver). The DO to EXCON interaction occurs along the E4 interface and is implemented as a radio network interface. (In the FA diagram, this means that the "Report Status" functionality belongs to the DO, and the "Capture Data" functionality belongs to the EXCON.) Note that the DO to EXCON interface in Figure 1 is unidirectional. The reverse EXCON to DO interface is also a radio network interface but it has a separate designation as E3, because the types of data that are sent in the EXCON to DO direction are different than the data sent across the E4 interface.

It is important to note that the yellow interaction arrows in the Use Case are bi-directional, indicating that information flows both ways. It is possible that two systems or components are interoperable in one direction, and not interoperable in the other direction. For example, consider a TESS A that is compliant with the MCC, but TESS B is compliant with another standard built on MCC that has been considerably extended. TESS B could interpret all TESS A data, but not necessarily the other way around. This is an important consideration when assessing the interoperability and determining IRL values as we will examine in subsequent sections. The key point is that bi-directional interfaces must be evaluated in both directions separately, and thus each bi-directional yellow arrow will have two IRL values.

Applying the LCIM to the UCATT Use Cases

Whereas the nine UCATT Use Cases and the FA form the foundational basis of *what* is to be measured, the LCIM and the IRLs provide the *objective scale* of the measure.

As mentioned earlier in this paper, the Levels of Conceptual Interoperability Model (LCIM) was first introduced by Dr. Andreas Tolk and James A. Muguira in their 2003 paper “The Levels of Conceptual Interoperability Model” [8]. Dr’s. Andreas Tolk, Weiping Wang, and Wenguang Wang significantly expanded the LCIM in their 2009 paper “The Levels of Conceptual Interoperability Model: Applying Systems Engineering Principles to M&S” [11]. The latter paper is the one on which the IRAM work is based.

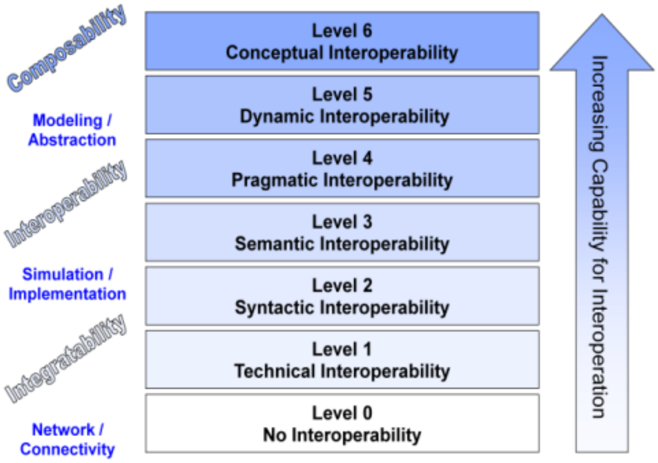


Figure 3. The Levels of Conceptual Interoperability Model

The foundational concept of the LCIM is a sufficiently defined yet flexible, seven-layer conceptual model that can be adapted for use within a potentially wide variety of domains. Figure 3 presents a diagram that identifies the seven levels of the LCIM. It shows increasing levels of defined interoperability ranging from none to highly defined and composable. The IRLs are defined below.

The LCIM can be used to describe the interoperability achieved at an event (descriptive) and specify the expected or desired level of interoperability at a future event (prescriptive). The paper by Tolk et al. demonstrates how to interpret the model from both perspectives.

For the IRAM, MLTIS is focused on the descriptive role at this time but plans to extend it to include a prescriptive role. Table 1 (Tolk et al [11]) presents the high-level definitions for the IRLs in a descriptive role.

Levels	Description of Interoperability at this level
L6(Conceptual)	Interoperating systems at this level are completely aware of each others information, processes, contexts, and modeling assumptions.
L5(Dynamic)	Interoperating systems are able to re-orient information production and consumption based on understood changes to meaning, due to changing context as time increases.
L4(Pragmatic)	Interoperating systems will be aware of the context (system states and processes) and meaning of information being exchanged.
L3(Semantic)	Interoperating systems are exchanging a set of terms that they can semantically parse.
L2(Syntactic)	Have an agreed protocol to exchange the right forms of data in the right order, but the meaning of data elements is not established.
L1(Technical)	Have technical connection(s) and can exchange data between systems
L0(No)	NA

Table 1. Descriptive Role of the LCIM

Three Essential Elements of IRAM

As a product, the IRAM has three essential elements, listed here, and described in the following sections:

1. Contextual IRL definition extensions for the UCATT Use Cases
2. A method for determining which UCATT Use Case best describes an exercise event
3. A method for evaluating IRLs against Use Cases in an exercise event

Defining IRLs in Context

During our initial analysis for using the LCIM to measure live training systems interoperability, we thought the definitions were too generalized for our purposes and chose to extend the definitions with contextual examples that fit the UCATT Use Cases. This set of definition extensions addresses each relationship type (i.e., the yellow arrows shown the Use Case example in Figure 2). Within the nine UCATT Use Cases, there are only four unique interoperability relationships depicted:

1. DO(1) to DO(2)
2. DO to EXCON
3. EXCON to DO
4. EXCON(1) to EXCON(2)

Table 2 contains the extended IRL definition set for the DO to DO interoperability relationships, and Table 3 contains the extended IRL definition set for the DO to EXCON interoperability relationships. The actual IRAM document contains the definition tables for the EXCON to DO and the EXCON to EXCON relationships [12].

Having the extended definitions will now enable a more distinct delineation between IRLs and make it possible for key stakeholders to understand and agree what the interoperability levels mean within a live training systems context.

Method for Determining Which UCATT Use Case Best Describes an Event

For IRAM information to be useful, there must be a mechanism that ensures exercise stakeholders are comparing “apples to apples” when evaluating descriptive IRL values. Understanding the Use Case under which a descriptive IRL value was determined is essential for ensuring the right comparisons are being made. The full IRAM document contains an easy to understand logic/question tree that will determine the correct Use Case that applies to a given exercise event. The IRAM does not prescribe at this time who must answer the questions, but it is not necessary to have any pre-existing knowledge of the UCATT Use Cases in order to use the logic/question tree. For example, a person with overall knowledge of the exercise purpose and setup, such as an exercise planner or even an observer/controller, should be able to answer the questions.

Method for Evaluating IRLs Against Use Cases in an Event

The most significant element of the IRAM is the mechanism for deriving the IRL scores for an exercise event. The MLTIS team is implementing a logic/question tree that evaluates each of the IRL extended definitions as they apply to the governing Use Case of an exercise event. A draft of this logic/question tree will be completed this calendar year. The goal is to create the logic/question tree with straight-forward, performance-based, observation questions that will enable a knowledgeable exercise coordinator to answer the questions without any prior knowledge of IRLs or UCATT Use Cases. It may be necessary to have one or more subject matter experts answer the questions in the logic/question tree. The branching logic of the logic/question tree will determine the IRL score based on the extended IRL definitions. We intend to create the logic/question tree such that all lower level conditions must be met in order to achieve a higher-level ranking. For example, all level 1 and 2 criteria would need to be met in order to achieve a level 3 score.

How Will IRAM Be Used?

There are many potential uses for the IRAM. From a descriptive perspective, TESS developers, program managers, exercise planners, and CTC managers will use the IRAM information to determine what live training simulation equipment is interoperable with other live training simulation equipment. Training system program managers could use the objective scoring to highlight interoperability deficiencies to provide justification for requirements modification and procurement expenditures. Exercise planners could use IRL assessment results from previous events to validate multi-national exercise plans and provide risk-mitigation justification when considering mixing dissimilar TESS components.

From a prescriptive perspective, the IRAM is useful to exercise planners to inform and specify, to potential exercise participants, an objective interoperability scale for intended/possible TESS components. In other words, CTC exercise planners can simply say to prospective exercise participants, “If you want to bring your own TESS to our exercise, your DO components must have been previously evaluated at an IRL 4 with our host system XYZ.” Exercise planners can verify said evaluations through the IRAM database and reports (see ‘Vision’ section below).

IRL	Base LCIM Definition	Extended MLTIS Definition
L6 (Conceptual)	Interoperating systems at this level are completely aware of each other's information, processes, contexts, and modeling assumptions	The DO in question will have sufficiently descriptive documentation that will enable another group to understand the DO, how it functions, what interfaces it uses, what data is exchanged, and what specifications it complies with.
L5 (Dynamic)	Interoperating systems are able to re-orient information production and consumption based on understood changes to meaning, due to changing context as time increases	The DO in question will be able to accept a change of state, based on either informational or physical stimuli to the state change. The DO will be able to adapt and perform within the established rules for the new state. In order to achieve IRL 5, the DO must have at a minimum two distinctly defined states and be able to transition between them based on established stimuli.
L4 (Pragmatic)	Interoperating systems will be aware of the context (systems states and processes) and meaning of information being exchanged	The recipient DO will be able to successfully process the information received in the signal from the engaging DO. For TESS, this will mostly mean making a determination if the engaging DO's simulated weaponry had any effect on the recipient DO and to what extent.
L3 (Semantic)	Interoperating systems are exchanging a set of terms that they can semantically parse	Both DO1 and DO2 can use/interpret the same message data specification. This specification will define semantically what is meant by the data contained in the signals. For TESS, examples include PMT-90, OSAG 2.0, HEX-L-2C, and ULAIS 1.0.
L2 (Syntactic)	Have an agreed protocol to exchange the right forms of data in the right order, but the meaning of data elements is not established	Both DO1 and DO2 can use/interpret the same transmission protocol. This transmission protocol will establish at a minimum the frame structure of the data being exchanged without necessarily defining what data may be contained in the frames. The transmission protocol may be contained within the information definition specification.
L1 (Technical)	Have technical connection(s) and can exchange data between systems	Assuming that DO1 is able to emit a signal of some type and is able to convey information in that signal, all three conditions must be met to attain this IRL: a) The Sense functionality of DO2 can physically receive and interpret a signal that is being sent to it from the Engage functionality of DO1. For example, most TESS utilize a laser signal to engage from one DO to another. To achieve IRL 1, DO2 must be able to detect a laser signal in the same physical wavelengths as being emitted by DO1. If DO2 is not able to detect the signal from DO1, then IRL 1 is not achieved. b) The Sense functionality of DO2 must be able to detect a differentiation in the signal from DO1. This ability implies that information can be conveyed in the signal differentiation. For current TESS that use lasers, this means being able to detect the changes in pulses or the light frequencies being emitted by DO1. If DO2 is not able to interpret the differentiation in the signal from DO1, then IRL 1 is not achieved. c) DO1 signal strength and DO2 sensory sensitivity must both be within defined and mutually agreed tolerances. For example, if DO1 is using a class 1 laser, then DO2 sensors must be rated for the power level of a class 1 laser. If DO1 and DO2 are not operating within defined and mutually agreed tolerances, then IRL 1 is not achieved.

Table 2. DO to DO IRL Definitions

IRL	Base LCIM Definition	Extended MLTIS Definition
L6 (Conceptual)	Interoperating systems at this level are completely aware of each other's information, processes, contexts, and modeling assumptions	The EXCON will have sufficiently descriptive documentation that will enable another group to understand the EXCON, how it functions, what interfaces it uses, what data is exchanged, and what specifications it complies with. More specifically, the documentation will be clear how the DO information is used.
L5 (Dynamic)	Interoperating systems are able to re-orient information production and consumption based on understood changes to meaning, due to changing context as time increases	The EXCON, either as a whole or a sub-component therein, will be able to conduct a change of state based on informational stimuli from the DO. In order to achieve IRL 5, the EXCON must have at a minimum two distinctly defined states and be able to transition between them based on established stimuli. Note that different portions of the EXCON can be in different states simultaneously.
L4 (Pragmatic)	Interoperating systems will be aware of the context (systems states and processes) and meaning of information being exchanged	The recipient EXCON will be able to successfully process the information received in the signal from the engaging DO. For TESS, this will mostly mean that one or more components within the EXCON use data from the DO in a meaningful way.
L3 (Semantic)	Interoperating systems are exchanging a set of terms that they can semantically parse	Both the DO *Report Status* and the EXCON *Manage Data* can use/interpret the same message data specification. This specification will define semantically what is meant by the data contained in the signals. For TESS, examples include PRF-PT-00552, PRF-PT-290065, PRF-PT-706014, Combat Training Center-Instrumentation System (CTC-IS) standard, etc.
L2 (Syntactic)	Have an agreed protocol to exchange the right forms of data in the right order, but the meaning of data elements is not established	Both DO Report Status and EXCON Capture Data can use/interpret the same transmission protocol. This transmission protocol will establish at a minimum the frame structure of the data being exchanged without necessarily defining what data may be contained in the frames. The transmission protocol may be contained within the information definition specification.
L1 (Technical)	Have technical connection(s) and can exchange data between systems	Each of the following parts must be met in order to achieve an IRL 1 for this interface: a) The DO has a TESS component that has the ability to communicate via radio specifically for the purposes of sending data (not to be confused with the DO being able to communicate via voice over radio to other DO's). b) The EXCON has a TESS component that has the ability to communicate via radio specifically for the purposes of receiving data from DO's (the EXCON's radio system may do other functions as well as long as it has the ability to receive data signals from DO's). c) Both the DO radio and the EXCON radio must be able to operate on compatible frequencies.

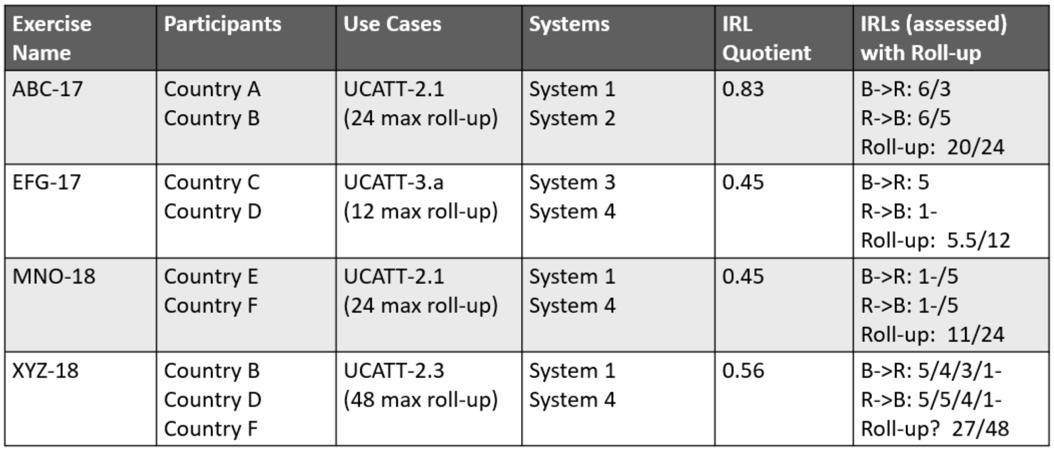
Table 3. DO to EXCON IRL Definitions

Vision for IRAM

Currently, the IRAM comprises a set of extended IRL definitions plus the "in-development" logic/question trees. The MLTIS team is planning to expand the IRAM into a capability having the following components:

1. Technical Specification: This document will form the technical foundation for the IRAM by including all of the extended IRL definitions and will include the foundational logic/question tree for determining IRL values.

2. Web-based Analysis Tool: A cloud-based, intuitive application that will provide guided interviews and will determine the appropriate Use Case and IRL scores based on the logic/question tree defined in the technical specification.
3. Database: A history of all evaluations undertaken.
4. Dynamically Generated Reports: Tailorable reports created on demand that show various comparisons of exercise events with the TESS that were used, which UCATT Use Cases apply, and the IRL scores assessed for those scenarios. Table 4 is one possible example IRAM report product with hypothetical IRL evaluation data [12]. The MLTIS team determined that some additional nomenclature would be necessary to manage the complexities of reporting on multiple interface pathways within a single Use Case. From Table 4, a “Roll-Up” is simply the sum of all individual IRL determinations within the Use Case. The “Max Roll-Up” is the maximum possible IRL score in the Use Case. The “IRL Quotient” is the result of dividing the “Roll-Up” by the “Max Roll-Up”. The “B->R” and “R->B” elements stand for “Blue to Red” and “Red to Blue” and indicate the directionality of the interfaces identified in the Use Cases. The values after the “B->R” and “R->B” represent the assessed IRLs of the interfaces in a specific order as established in the IRAM document [12]. For example, “B->R: 6/3” means there are two interfaces in the Use Case going from Blue to Red, and one was evaluated at IRL 6 and the other at IRL 3. Different Use Cases have differing number of highlighted interfaces, thus the variability in the “B->R” and “R->B” report data. The IRAM does expand on the LCIM by allowing for partial level scores through assigning “+/-” designators. In this example, the reader can see that exercises “ABC-17” and “MNO-18” both had the same Use Case, but “ABC-17” had a higher overall IRL Quotient, and thus the reader can determine that exercise “ABC-17” had a higher degree of interoperability with the specified TESS. The “Roll-Up” gives an indication of how the individual interfaces compare within the stated Use Case. This example report product is only meant to give the high-level perspective however, and other (linked) products would give a more detailed perspective.



Exercise Name	Participants	Use Cases	Systems	IRL Quotient	IRLs (assessed) with Roll-up
ABC-17	Country A Country B	UCATT-2.1 (24 max roll-up)	System 1 System 2	0.83	B->R: 6/3 R->B: 6/5 Roll-up: 20/24
EFG-17	Country C Country D	UCATT-3.a (12 max roll-up)	System 3 System 4	0.45	B->R: 5 R->B: 1- Roll-up: 5.5/12
MNO-18	Country E Country F	UCATT-2.1 (24 max roll-up)	System 1 System 4	0.45	B->R: 1-/5 R->B: 1-/5 Roll-up: 11/24
XYZ-18	Country B Country D Country F	UCATT-2.3 (48 max roll-up)	System 1 System 4	0.56	B->R: 5/4/3/1- R->B: 5/5/4/1- Roll-up? 27/48

Table 4. Hypothetical IRAM Report Product

SUMMARY

Achieving the Army’s mission: "To deploy, fight, and win our Nation’s wars by providing ready, prompt, and sustained, land dominance by Army forces across the full spectrum of conflict as part of the Joint Force," [13] requires conducting live training with allied nations continuously. The Interoperability Readiness Assessment Methodology (IRAM) has been developed to provide a normalized, objective methodology for characterizing interactions between Tactical Engagement Simulation System (TESS) and Exercise Control (EXCON) systems during a multinational training event and is based on the UCATT defined Use Cases. Interoperability Readiness Levels (IRL) are assigned to respective TESS system interfaces based on information provided by exercise planners, observer/controllers, and exercise participants. This methodology supports both descriptive (defining interactions for analysis), and prescriptive (helping exercise planners determine problem areas before an exercise) purposes and can be used to provide a normalized scale for assessments involving the interoperability of training systems.

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