



**Simulation Interoperability
Standards Organization**

"Simulation Interoperability & Reuse through Standards"

SISO-GUIDE-011-2024

User's Guide for Simulation Interoperability Readiness Levels (SIRL) Standard: Assessing Interoperability Risks to the Integration of Distributed Simulations

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Simulation Interoperability Readiness Levels
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Revision History

Version	Section	Date (MM/DD/YYYY)	Description
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Draft	All	02/4/2022	Update based on comment round 1
Draft	Metadata	12/12/2022	Switch from reference product to guidance product
Draft	All	12/19/2023	Update based on comments against the standard during balloting
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Final	Various	7/20/2024	Respond to balloting comments

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1 INTRODUCTION

Integrating simulations for training, mission rehearsal, test and evaluation, and analytical purposes is necessary but risky. No single simulation provides the comprehensive, sufficiently-accurate, synthetic environment required. The integration risk lies in the different assumptions and constraints made when the individual simulations were designed and developed. For example, some simulations include water features as an obstacle. Others assume perfect command and control. Lack of awareness of these differences and a means to reconcile these assumptions / constraints impacts the efficacy of the resulting integrated simulation.

Rapidly and accurately determining whether a set of simulations can be integrated to produce a working, federated simulation producing valid results remains one of the key challenges for distributed simulation. A joint effort between the Simulation Interoperability Standards Organization (SISO) Federation Engineering Agreements Template (FEAT) Product Support Group (PSG), Distributed Simulation Engineering and Execution Process (DSEEP) PSG, and Verification, Validation and Accreditation (VV&A) Product Development Group (PDG) resulted in a draft of Simulation Interoperability Readiness Levels (SIRL). [SISO-REF-076-2020, SISO-REF-076.1-2020] This User's Guide is an update to SISO-REF-076-2020 to accompany the standardized SIRL [SISO-STD-024-2024].

1.1 Purpose

The purpose of the SIRL standard is to create a framework for senior decision makers, simulation developers, and simulation integrators to make rapid, quantitative, evidence-based assessments of the feasibility and risk of attempting to integrate simulations prior to committing effort and funds to doing so. This document is the User's Guide for the SIRL Standard.

1.2 Scope

The initially stated scope of this effort only encompassed training applications. The use cases employed all came from the training domain. However, the SIRL developers brought their collective experience in all simulation domains to bear, and we believe this approach is broadly applicable to other domains as well.

1.3 Objectives

Given any two simulations, how do we rapidly and accurately determine the likelihood that they will interoperate? And if they won't, what are the risks and costs of trying to make them interoperate?

The objective of SIRL is to provide an objectively measurable methodology based upon engineering artifacts. Metrics for assessing individual simulations will contribute to easing the integration of a distributed simulation and can make the integration more mechanical and less prone to error-based discovery.

1.4 Intended Audience

This document is intended for simulation developers, simulation integrators, and senior decision makers.

2 REFERENCES

2.1 SISO Documents

The following SISO documents were used in generating the policies and procedures defined herein. When the following documents are superseded by an approved revision and that causes a conflict with this document, the revision of the below-referenced documents shall supersede this document. These documents are available via the SISO web site at <https://www.sisostandards.org/>.

Document Number	Title
SISO-STD-012-2013	Federation Engineering Agreements Template
SISO-ADM-005-2011	"The Style and Format of SISO Documents"

Document Number	Title
SISO-ADM-005-2011	"The Style and Format of SISO Documents"
SISO-REF-017-2006	SISO Simulation Conceptual Modeling (SCM) Study Group (SG), "Simulation Conceptual Modeling (SCM) SG Final Report," https://sisostandards.connectedcommunity.org/viewdocument/siso-ref-017-2006-simulation-concep?CommunityKey=14211bb0-09e7-4c67-871c-e1eabffa138f&tab=librarydocuments
SISO-STD-014	SISO-STD-014.1-2018, "Standard for Gateway Description Language," 12 September 2018, Version 1.0
SISO-STD-024-2024	SISO SIRL PDG, "Simulation Interoperability Readiness Levels (SIRL)," January 2024
SISO-REF-076-2020	SISO FEAT PSG, "Simulation Interoperability Readiness Levels Product," September 2020
SISO-REF-076.1-2020	SISO FEAT PSG, "SIRL Heatmap Example," September 2020

2.2 Other Documents

Document Number	Title
Blais and Lacy	Curtis Blais and Lee W. Lacy, "Semantic Web: Implications for Modeling and Simulation System Interoperability." Paper presented at the Fall 2004 Simulation Interoperability Workshop, Simulation Interoperability Standards Organization, Orlando, FL.
DEMS	Digital Engineering, Modeling, and Simulation, "DoD M&S Glossary," https://www.de-bok.org/glossary
FEAT Editor	https://sourceforge.net/projects/feateditor/
Fujimoto	Richard M. Fujimoto, <u>Parallel and Distributed Simulation Systems</u> , section 2.2, Wiley Interscience, 2000
IEEE 610.3™-1989	"IEEE Standard Glossary of Modeling and Simulation Terminology," https://standards.ieee.org/standard/610_3-1989.html
IEEE Std. 1730™-2022	Distributed Simulation Engineering and Execution Process
IEEE Std. 1516™-2010	IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) — Framework and Rules. IEEE Std. 1516-2010. New York: IEEE. Aug 18, 2010.
IEEE Std. 1278.1™-2012	IEEE Standard for Distributed Interactive Simulation – Application Protocols. IEEE Std. 1278.1-2012. New York: IEEE. December 19, 2012.
IEEE Std. 1730.2™-2022	IEEE Recommended Practice for Verification, Validation, and Accreditation of a Federation—An Overlay to the Distributed Simulation Engineering and Execution Process. IEEE Std. 1730.2-2022. New York: IEEE. Feb 10, 2023.
JP 3-60	"DoD Dictionary of Military and Associated Terms," Jan 2020
Kuhl, et al	Dr. Frederick Kuhl, Dr. Richard Weatherly, and Dr. Judith Dahmann, "Creating Computer Simulation Systems: An Introduction to the High Level Architecture," Sections 5.3.2 and 5.3.3, 2000
McGraw-Hill	The McGraw-Hill Companies, Inc., <u>McGraw-Hill Dictionary of Scientific & Technical Terms</u> , 6E, 2003

Document Number	Title
Merriam-Webster	Merriam-Webster Dictionary On-line Version , https://www.merriam-webster.com/
Morse and Drake	Katherine L. Morse and David L. Drake, "Multi-Viewpoint Conceptual Modeling," Proceedings of the 2020 NATO CA2X2 Forum, virtual, 22 September 2020
Sari and Akkaya	Arif Sari and Murat Akkaya, "Fault Tolerance Mechanisms in Distributed Systems," Oct 13, 2015
USD AT&L	Undersecretary of Defense, Acquisition, Technology, and Logistics "DoD Guide for Achieving Reliability, Availability, and Maintainability," Aug 3, 2005
Weyns, et al	Danny Weyns, H. Van Dyke Parunak, & Fabien Michel (Editors), "Environments for Multi-Agent Systems," First International Workshop, E4MAS 2004
Wikipedia:Coordinate System	"Coordinate system," https://en.wikipedia.org/wiki/Coordinate_system
Wikipedia:Decision-Making	"Decision-making," https://en.wikipedia.org/wiki/Decision-making
Wikipedia:Motion	"Motion," https://en.wikipedia.org/wiki/Motion

3 DEFINITIONS

Term	Definition
Interoperability	<p>The ability of systems, units, or forces to provide data, information, materiel, and services to, and accept the same from, other systems, units, or forces and to use the data, information, materiel, and services exchanged to enable them to operate effectively together. [DoD CIO]</p> <p>The capability of a system to automatically, without human intervention, provide services to and accept services from other systems, and to use the services so exchanged to enable the systems to work together to achieve a desired outcome. [Blais and Lacy]</p>

4 ACRONYMS AND ABBREVIATIONS

Acronym/Abbr	Definition
DEMS	Digital, Engineering, Modeling, and Simulation
DIS	Distributed Interactive Simulation
DSEEP	Distributed Simulation Engineering and Execution Process
FEAT	Federation Engineering Agreements Template
HLA	High Level Architecture
HWIL	Hardware in the Loop
IEEE	Institute for Electrical and Electronics Engineers
M&S	Modeling and Simulation

OE	Operating Environment
OS	Operating System
PDG	Product Development Group
PSG	Product Support Group
SAC	Standards Activity Committee
SCM	Simulation Conceptual Modeling
SIRL	Simulation Interoperability Readiness Levels
SG	Study Group
SISO	Simulation Interoperability Standards Organization
TAD	Technical Area Director
TRL	Technology Readiness Level
UC	Utility Curve
USD AT&L	Undersecretary of Defense, Acquisition, Technology, and Logistics
VV&A	Verification, Validation and Accreditation

5 SIRL Goal

The goal of the SIRL standard is to create a framework for senior decision makers, simulation developers, and simulation integrators to make rapid, quantitative, evidence-based assessments of the feasibility and risk of attempting to integrate simulations prior to committing effort and funds to doing so. The use of SIRL or high scores for an individual simulation are not a guarantee of interoperability for any particular intended use. Rather they are an assurance that a preponderance of evidence exists to make an informed interoperability decision.

In practice, interoperability needs to be assessed between a set of simulations. For the purpose of simplicity, this document focuses on performing this assessment for only two simulations, i.e., given any two simulations, how do we rapidly and accurately determine the likelihood that they will interoperate? And if they won't, what are the costs and risks of trying to make them interoperate? The answers to these questions must be based on measurable engineering evidence.

5.1 Levels of Interoperability Readiness

Five levels of interoperability readiness were identified based on the complexity / effort of comparing two simulations at that level, e.g., whether the comparison can be performed mechanically via a tool¹ or requires human intervention. The levels, illustrated in Table 5-1, are Conceptual, Modeling, Simulation Control, Data, and Technical/Syntactic. It's worth noting that the bottom three levels are substantially solved by robust simulation interoperability solutions such as the High Level Architecture (HLA) [IEEE 1516™-2010] and the Distributed Interactive Simulation (DIS) protocol. [IEEE 1278.1™-2012]

The levels were identified by assessing each agreement in the FEAT, determining whether it was applicable to a single simulation, and sorting them by complexity of evaluation. This necessarily eliminated many management and logistics agreements, e.g., schedules and facilities. Table 5-1 identifies the levels and provides a definition for each level.

¹ This assessment is based on currently available tools or the ease of producing a suitable tool. Improving documentation at higher SIRL should enable development of support tools for those levels.

Table 5-1: SIRL Hierarchy

Simulation Interoperability Readiness Level	Definition
Conceptual	Conceptual model: "The description of what the model or simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the user's requirements." [DEMS] The conceptual model identifies entities, behaviors, and their interactions; who does what to whom.
Modeling	Model: "A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process." [DEMS] These are choices about how to model real world phenomena.
Simulation Control	These are design decisions about controlling the execution of the simulation.
Data	These are the formats and models of data to be used for initialization, run time data exchange, and logging.
Technical / Syntactic	These are decisions about the simulation architecture including hardware, software, and protocols.

As Figure 5-1 illustrates, the levels are organized according to complexity of the assessment effort for evidence at that level. The higher the level, the more human intervention and effort are required.

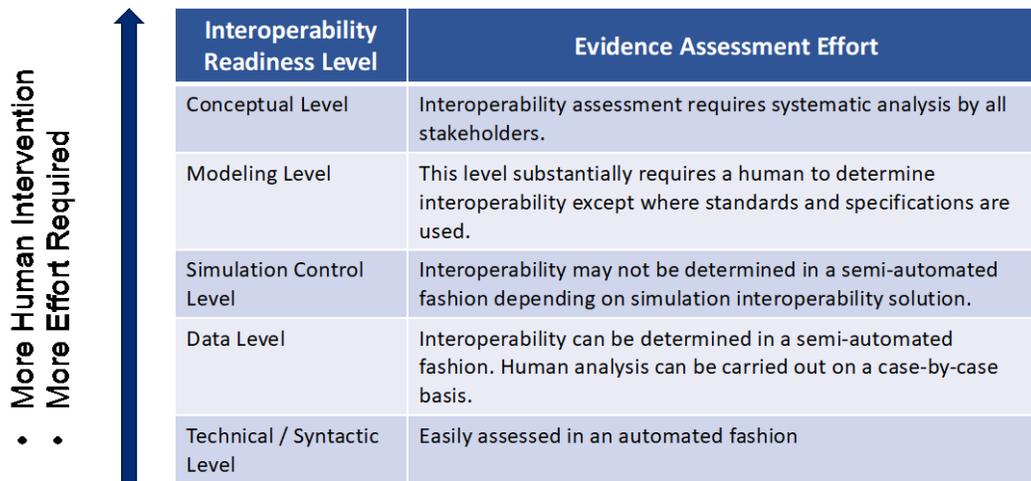


Figure 5-1. Increasing Complexity at Higher Levels

5.2 SIRL Standard Structure

All of the tables, utility curves, heatmaps, radar charts, and a nominal example of applying SIRL are included in the standardized SIRL Excel spreadsheet. [SISO-STD-024-2024]

The SIRL standard meets SISO-ADM-005-2011 by providing individual tabs for the following mandatory sections:

- Title page
- Revision history
- Table of contents
- Section 1

- Introduction
- Purpose
- Scope
- Objectives
- Intended audience
- Acknowledgments
- Section 2 – References
- Section 3 – Definitions
- Section 4 – Acronyms and abbreviations

Section 5 is represented in the following tabs:

- SIRL
- Data Entry - Example
- Value Limits (hidden tab)
- Dashboard
- System Comparison
- Conceptual Model Utility Curves (UC)
- Modeling UCs
- Simulation Control UCs
- Data UCs
- Technical – Syntactic UCs

6 Simulation Interoperability Readiness Levels

6.1 Conceptual Level

Because the conceptual level has a single item of engineering evidence, the conceptual model, additional detail on engineering evidence is not provided in this document. An example format can be found in [Morse and Drake]. The SISO Simulation Conceptual Modeling (SCM) Study Group (SG) previously reviewed the state of art for conceptual modeling and concluded that further work is required in this area [SISO-REF-017-2006].

Interoperability assessment at this level requires systematic analysis by all stakeholders.

6.2 Modeling Level

This level substantially requires humans to determine interoperability except where standards and specifications are used.

Table 6-1 lists all the items at the modeling level and provides descriptions of each item of engineering evidence.

Table 6-1: Modeling Engineering Evidence

Engineering Evidence	Description
Terrain geometry interaction	Description of issues associated with interacting with terrain geometry and implemented solutions to those issues.

Engineering Evidence	Description
Environmental effects assumed or modeled	Description of how the physical environment enhances or alters the performance characteristics of humans and systems.
Simulated time representation	The mathematical, data, and algorithmic representation chosen to represent simulation time. "simulation time: The shared time being simulated within a simulation exercise; it may advance faster, slower, or at the same pace as real time." [IEEE 1278.1™-2012]
Kinetic effects adjudication	Effects adjudication agreements ensure a "fair fight" by specifying what component has the authority to determine the outcome or effect of an interaction between member applications; e.g., the kinetic effects could be adjudicated by the "shooter" (the one initiating the effect), "target" (the one the effect is perpetrated on), or "server" (some 3rd party member application). Kinetic effects are those resulting from traditional munitions.
Aggregation and disaggregation algorithms	Aggregation: The process of grouping entities while preserving the salient effects of entity behavior and interaction while grouped. An aggregate is a group of entities or a group of other aggregates considered as a single unit. The substitution of the word "unit" is used to avoid phrases like "aggregate aggregate." [IEEE 1278.1™-2012, DEMS]. Disaggregation: The process of replacing a single aggregate with two or more aggregates or entities at a higher level of detail. [DEMS]
Communications (representation)	The simulation of communications through means other than human-to-human within aural range.
Non-kinetic effects adjudication	Non-kinetic effects adjudication involves the same types of mechanisms for ensuring fair fight as in the kinetic domain, but for the non-kinetic domains; e.g., cyber and electronic warfare.
Intervisibility	The ability of one simulated entity to "see" another. Intervisibility is impacted by terrain, weather, obscurants, and entity volume representations.
Movement (physics)	The change in the position of an object over time. Motion is mathematically described in terms of displacement, distance, velocity, acceleration, speed, and time. [Wikipedia:Motion]
Decision-making behavior	The cognitive process resulting in the selection of a belief or a course of action among several possible alternative options. Decision-making is the process of identifying and choosing alternatives based on the values, preferences, and beliefs of the decision-maker. [Wikipedia:Decision Making]
Human performance modeling	Metrics for measuring human accomplishment of a task in accordance with agreed-upon standards of accuracy, completeness, and efficiency.
Platform / equipment performance (not movement, e.g., reliability)	<p>Platform Reliability is composed of the following:</p> <ul style="list-style-type: none"> • Reliability is the probability of an item to perform a required function under stated conditions for a specified period of time. Reliability is further divided into mission reliability and logistics reliability. • Availability is a measure of the degree to which an item is in an operable state and can be committed at the start of a mission when the mission is called for at an unknown (random) point in time. Availability as measured by the user is a function of how

Engineering Evidence	Description
	<p>often failures occur and corrective maintenance is required, how often preventative maintenance is performed, how quickly indicated failures can be isolated and repaired, how quickly preventive maintenance tasks can be performed, and how long logistics support delays contribute to down time.</p> <ul style="list-style-type: none"> Maintainability is the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair [USD AT&L]
Entity resolution	The degree of detail used to represent aspects of the real world or a specified standard or referent by a model or simulation. [DEMS]
Position estimation	The method to determine the most probable location of an entity determined from incomplete data or data of questionable accuracy. (Derived from [McGraw-Hill])
Human behavior representation (pattern of life)	A representation of the action of a single human or the collective action of a team of humans. Human behavior representation models the aspects of the complicated facets of human behavior including ability to reason, ability to change the environment, reaction to comfort or discomfort, susceptibility to injury and illness, emotional response, communication with others, ability to sense the environment and physical capabilities and limitations. [DEMS]

6.3 Simulation Control Level

Interoperability may not be determined at this level in a semi-automated fashion depending on simulation interoperability solution.

Table 6-2 lists all the items at the simulation control level and provides descriptions of each item of engineering evidence.

Table 6-2: Simulation Control Engineering Evidence

Engineering Evidence	Description
Update rates	A frequency rate that counts the number of times the attributes of an entity are updated over a period of time in a simulation, typically measured in Hertz. The rate is stated in terms of simulation time. In a real-time simulation that runs in lock-step to wall-clock time, the update rate for the entity will occur synchronously with wall-clock time advancement. In a scaled real-time simulation, the update rate will be appropriately scaled. [Fujimoto]
Execution states	A list of commonly used names describing the state of a model within a simulation. These states are from the viewpoint of the simulation's infrastructure, and the model enters the state by making a request to the infrastructure to transition to the requested state. [Kuhl, et al]
Synchronization points	Abstract points in simulation time that represent coordination milestones that are used to allow a phased execution of a simulation, where all models know what synchronization points they have previously achieved and what the next synchronization point they are progressing to. Typically, modern simulation infrastructures have

Engineering Evidence	Description
	mechanisms to allow the models in a simulation to determine when a synchronization point has been achieved, and to communicate that event to all other models in the simulation, permitting the simulation to advance through a coordinated series of phases. [Kuhl, et al]
Interest management	A filtering mechanism associated with a model based on a set of filter expressions, called "interest expressions," that can be used to select only the subset of communicated information which is relevant to the model, typically based on location, entity type, or range of an attribute, such as frequency. Modern simulation infrastructures can use these interest expressions to limit communications before being sent, allowing for more efficient communication within the federation. [Weyns, et al]
Control transfer	The ability and mechanisms to transfer responsibility for representing an entity from one simulation to another.
Time advancement	The process in simulations in which simulation time is moved / stepped by a fixed or independently determined amount to a new point in time, and the states or status of some or all resources are updated as of that new point in time. Typically, these time steps are of constant size, but they need not be. (Based on time step simulation definition in [DEMS])
Simulation control mechanisms	Software that encapsulates a simulation to control its execution, parameters, and/or interfaces for the purposes of simplifying one or more simulation executions. A common example of a simulation control mechanism is "Hardware in the Loop" (HWIL), where a hardware component is initialized and configured for embedding within a simulation execution. Another example of a simulation control mechanism is a simulation test harness, which can set model and simulation-wide parameters and subsequently execute the simulation in varying states, such as Monte Carlo test execution. Another example is a federation manager, which can perform initialization duties such as distributing containers that encapsulate model images to available computers, allowing for distribution of execution across an array of computing devices.
Fault tolerance mechanisms (failure modes)	This attribute refers to the ability to withstand a fault (or failure) without having an operational failure. It may be achieved by active or inactive redundancy. [USD AT&L] The "fault tolerance mechanism helps in detecting of faults and if possible recovers from it." [Sari]

6.4 Data Level

Interoperability at this level can be determined in a semi-automated fashion. Human analysis can be carried out on a case-by-case basis.

Table 6-3 lists all the items at the data level and provides descriptions of each item of engineering evidence.

Table 6-3: Data Engineering Evidence

Engineering Evidence	Description
Initial laydown of entities and entity starting states	An entity describes facilities, individuals, virtual (nontangible) things, equipment, or organizations. [JP 3-60] The initial laydown is the

Engineering Evidence	Description
	starting location at the beginning of the scenario. The state is the internal status of a system, component or simulation as defined by the state variable. [DEMS] The state variable is a variable that defines one of the characteristics of a system, component, or simulation. The values of all such variables define the state of the system, component, or simulation. [IEEE 610.3™-1989, DEMS]
Terrain playbox	The geographic limits of a simulation scenario.
Terrain format	Specification or standard for representation of terrain.
Environment format/representation	A model, simulation, or database designed to produce an accurate and consistent data set for one or more parameters that characterize the state of the physical environment. [DEMS] Environment is the circumstances, objects, or conditions by which one is surrounded. [Merriam-Webster]
Authoritative data sources	Sources of validated data about entities and behaviors, e.g., platforms, platform performance, terrain, and behaviors.
Data storage formats	Formats for storing simulation input and output data, e.g., scenarios, terrain, simulation logs, performance parameters, force laydown, and environment.
Data exchange models	A data object model that provides a representation of the persistent and transient objects shared during a distributed simulation execution. These data object models include attributes and behaviors to the extent that the distributed simulation's models have a consistent world-view of the entities. [SISO-STD-014]
Coordinate systems	A system that uses one or more numbers, or coordinates, to uniquely determine the position of the points or other geometric elements on a manifold such as Euclidean space. [Wikipedia:Coordinate System] Simulations may use different coordinate systems (Lat - Long vs Military Reference Grid) and reference systems, e.g., datums such as WGS-84.

6.5 Technical / Syntactic Level

This level may be easily assessed in an automated fashion.

Table 6-4 lists all the items at the technical / syntactic level and provides descriptions of each item of engineering evidence.

Table 6-4: Technical / Syntactic Engineering Evidence

Engineering Evidence	Description
Middleware / protocol	Software and protocols that connect or integrate other software modules or components, typically providing a set of communications or interaction functions that may be invoked by the linked modules.
Secondary communication channels	Non-data exchange model data, e.g., video or chat; live entity, C4I protocols, and HWIL communication protocols.
Hardware	Electronic computational devices to which software must be deployed. This category includes identification of performance / capacity requirements and specialized devices/systems.

Engineering Evidence	Description
Operating Environment (OE) / Operating System (OS)	Operating environment or system(s) on which the simulation runs including type, version, and patch level.
Simulation support tools	Non-simulation tools required to support the simulation system and its execution, e.g., plan-view displays, loggers, and after-action review tools.

7 Metrics / Utility Curves

SIRL adopts a utility curve approach to defining metrics because the value of steps in the completeness of engineering evidence specification may be non-linear. All the utility curves defined are cumulative, i.e., achievement of the higher utility values requires achieving the lower values. Figure 7-1 provides an excerpt from the utility curves defined in SIRL.

Level	Evidence	Utility Curve Specification
Conceptual		
<i>Conceptual model: "The description of what the model or simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the user's requirements." - DEMS Glossary. This is entities, behaviors, and their interactions; who does what to whom.</i>	Conceptual model	0 = no evidence .1 = identification of approach .3 = identification of entities and behaviors .4 = identification of triggers .8 = documentation of patterns of interplay in a consistent (symbology and nomenclature) format 1 = documentation of patterns of interplay in an executable format
Modeling		
<i>Model: "A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process." - DEMS Glossary. These are choices about how to model real world phenomena.</i>	Terrain geometry interaction	0 = no evidence .5 = Identification of terrain geometry interaction issues 1 = Identification of terrain geometry interaction issue solutions
	Environmental effects assumed or modeled	0 = no evidence .2 = environment effects identified .4 = assumptions documented .7 = representation defined 1 = algorithms / mechanisms documented
	Simulated time representation	0 = no evidence .5 = time advancement increment specified .75 = artifacts specify control mechanisms for time (start, stop, pause, resume, rewind/reset) 1 = specification of time representation and standard used

Figure 7-1. Sample Utility Curve Excerpt

Figure 7-2 provides a graphical representation of the utility curve for the conceptual model, illustrating both the non-linearity and cumulative natures of the curve.

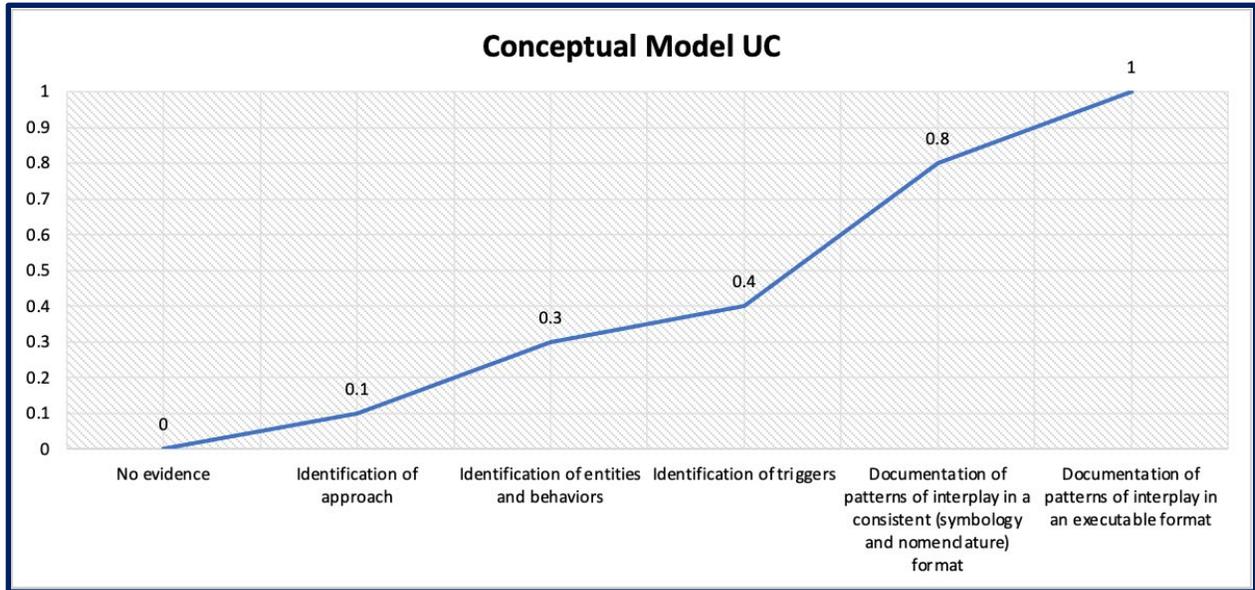


Figure 7-2. Conceptual Model Utility Curve

To aid simulation developers in accurately assessing the engineering evidence of their simulations, examples are also provided of the type of evidence that would suffice to achieve each utility value. These examples are informative not normative, i.e., there is not an expectation that the evidence a simulation developer provides will look exactly like the examples; they only provide the appropriate level of detail that should be found in the documentation of engineering evidence.

Figure 7-3 provides an excerpt from the Simulation Control level.

Simulation Control		
<i>These are design decisions about controlling the execution of the simulation.</i>	Update rates	0 = no evidence .8 = periodicity of updates specified 1 = conditional triggers for updates specified
	Execution states	0 = no evidence .2 = execution states identified (e.g., initialization, start, stop, save, restore) .8 = triggers for execution states defined 1 = mechanisms and formats (e.g., for saving state, designed)
	Synchronization points	0 = no evidence .4 = synchronization points triggers defined 1 = mechanisms defined
	Interest management	0 = no evidence .2 = mechanism / approach identified .7 = application to entities defined 1 = triggers / algorithm defined

Figure 7-3. Simulation Control Evidence Examples

8 Applying SIRL

8.1 Measure Completeness of Engineering Evidence

This activity is performed by the simulation developer. Although the process could be “one and done,” it should be updated by the simulation developer as more engineering evidence is recorded. Such updates would improve the simulation’s scoring in subsequent assessments. If a simulation does not provide the capability identified at a level in the utility curve, this doesn’t mean that the simulation cannot achieve that level. The full score can be achieved by clearly documenting that the capability isn’t provided. For example, for Modeling:Communications, a simulation that doesn’t model failure modes and environmental effects should include in its documentation that these phenomena are not modeled. This represents the potential for SIRL to encourage better documentation.

The score for an individual item of engineering evidence means that the simulation developer can provide documentation containing the piece(s) of information specifically requested. To aid simulation developers in accurately scoring each item, examples of evidence are provided for each score in the SIRL spreadsheet. Figure 8-1 illustrates an excerpt of the scores for a single, hypothetical simulation against the utility curves.

Conceptual Model	1.00
Conceptual Model	1.00
Modeling	1.00
Terrain Geometry Interaction	0.10
Environmental Effects	0.00
Time Representation	0.05
Kinetic Effects	0.05
Aggregation / Disaggregation	0.00
Communications	0.20
Non-kinetic effects	0.00
Intervisibility	0.05
Movement	0.15

Figure 8-1. Example Scores for a Hypothetical Simulation

To be clear, this is NOT comparing actual engineering solutions. That happens at the end of the process after the potential cost and risk are assessed to be low enough to warrant attempting integration.

8.2 Verifying Scoring of Engineering Evidence

For SIRL to be effective, it's critical that the scores for items of engineering evidence be verifiably accurate. Otherwise, the assessment of potential interoperability (section 8.4) will be skewed, probably toward a more optimistic assessment. The result would be unidentified uncertainty, which leads to risk. Therefore, verification of the scores by an independent third party is appropriate. The VV&A team is the logical party to perform this review if the project / program has one. To support this verification task, the simulation developer provides their scoring and the supporting engineering evidence documentation to the VV&A team. This task is in scope for activity 3.1, Support selecting distributed simulation member applications, of the DSEEP VV&A Overlay [IEEE 1730.2™-2022].

8.3 Weight the Engineering Evidence

This step in the process is the first one performed by the project / program simulation integrator. A weight is assigned to each item of engineering evidence based on its relevance to the intended use of the simulation. Scores for items that aren't relevant to the intended use are set to 0. The weights within each level must sum to 1. If the weights don't sum to 1, the sum will be highlighted in bold, red font.

The same weights must be applied uniformly to all systems under consideration because this results in a fair comparison of the systems. This is implemented in the Notional Example tab of the SIRT standard with a single column of weights that are applied to both System A and System B. For each simulation under consideration, the weighted score is calculated for each item of engineering evidence, and the weighted scores are summed for each level.

The values in the Individual Item Score columns (columns G and J) are limited to those in the drop-down menu. Clicking inside the cell will provide the button to select from a drop-down menu. There is a hidden value limits sheet which cannot be modified by the user.

Figure 8-2 illustrates this process for the isolated personnel use case developed by Schleh and Whittington. Color-coding for weighted scores is defined by the integrator to indicate program-specific tolerance of risk at each level. For this example:

- 0 <= Red <= 0.5
- 0.5 < Yellow <= 0.75
- 0.75 < Green <= 1.0

	Weight		Individual Item Score	Weighted
Conceptual Model	1.00			0.80
Conceptual Model	1.00		0.80	0.80
Modeling	1.00			0.73
Terrain Geometry Interaction	0.10		0.55	0.06
Environmental Effects	0.00		0.20	0.00
Time Representation	0.05		1.00	0.05
Kinetic Effects	0.05		0.70	0.04
Aggregation / Disaggregation	0.00		1.00	0.00
Communications	0.20		0.75	0.15
Non-kinetic effects	0.00		0.75	0.00
Intervisibility	0.05		0.00	0.00
Movement	0.15		1.00	0.15

Figure 8-2. Weighted Scores for the Isolated Personnel Use Case

The user can change the red, yellow, green “stoplight” color bounds in the Weighted column (columns H and K) for each system being compared, by setting the upper bounds in the Stoplight Color Coding Key located in rows 37 through 41 as illustrated in Figure 8-3.

Stoplight color coding key	
Color	Bounds
Green	1
Yellow	0.75
Red	0.5

Figure 8-3. Stoplight Color Coding Key

8.4 Assess *Potential* Interoperability

This step in the process determines whether a rapid, accurate assessment of *potential* interoperability is possible. A complete assessment requires the actual evidence. As Figure 8-4 illustrates, assessment is feasible when the engineering evidence is strong. Weak evidence, i.e., a low value for any level, represents uncertainty, and therefore, risk.

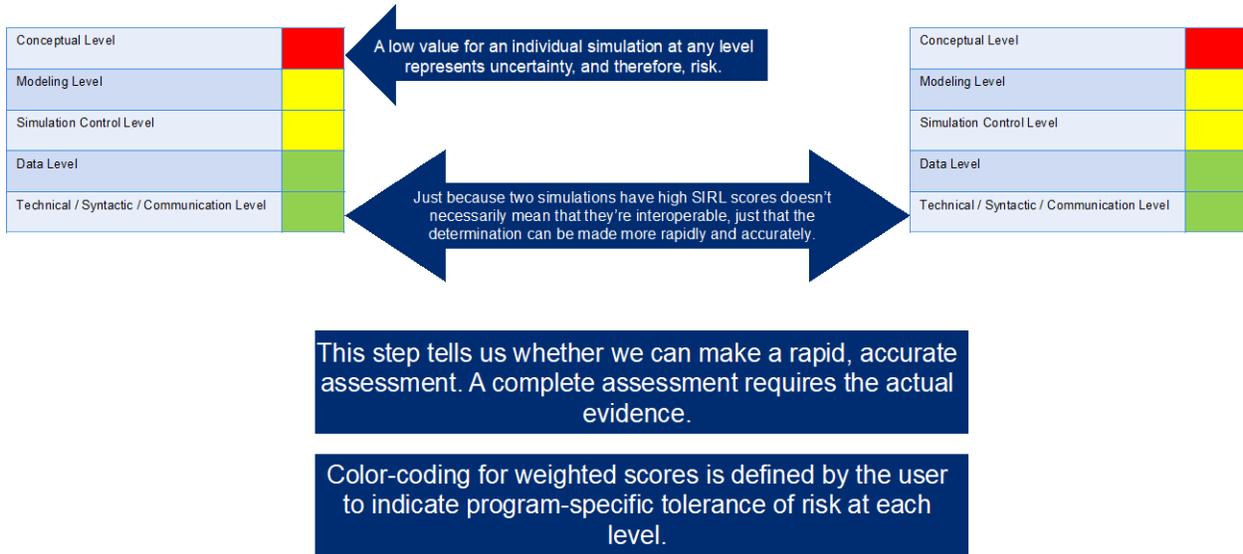


Figure 8-4. Top Level Feasibility Assessment

How good is the evidence for a single simulation? If the evidence is weak across all levels for a single simulation, it's always a risk as illustrated in Figure 8-5.

Conceptual Level	Red
Modeling Level	Red
Simulation Control Level	Red
Data Level	Red
Technical / Syntactic / Communication Level	Red

Figure 8-5. Lack of Engineering Evidence = Risk

How *risky* is trying to integrate two simulations given their SIRL assessments? The simulation with weak evidence illustrated in Figure 8-5 automatically introduces a lot of risk. But suppose you have two simulations with a mixture of weak and strong SIRL, i.e., some good evidence and some insufficient. If both are strong on the same items of evidence and insufficient on the same items, your risk might be lower because you only have to worry about the subset that's insufficient.

Consider the two simulations in Figure 8-6. We should be able to assess the two illustrated simulations rapidly at the data and technical / syntactic / communication levels. The simulation control level is more work, but not necessarily intractable.

But what if the subsets are mismatched, i.e., you have insufficient evidence for one where you have good evidence for the other? You have to work through every single item of evidence, filling in missing detail and assessing risk. That takes a lot of time. The conceptual and modeling levels are problematic for the two simulations in Figure 8-6.

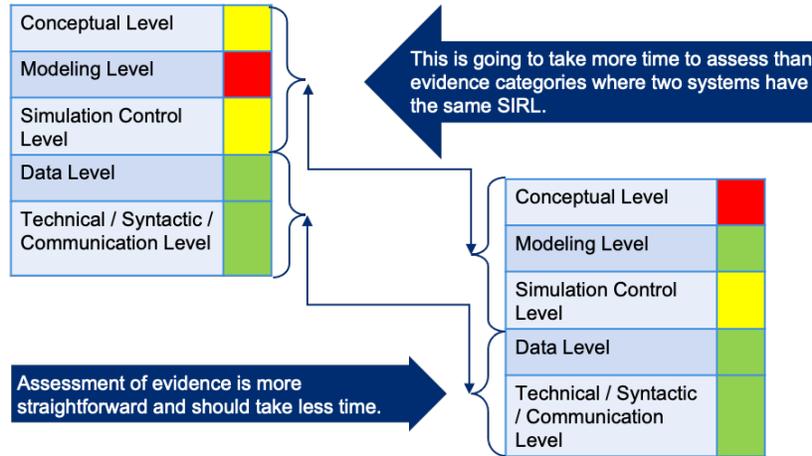


Figure 8-6. Relative Challenges of Assessing Evidence

How *costly* is it to integrate two simulations? This requires assessing against the actual evidence and making detailed plans to address every item where there's good evidence, but mismatches in specific solutions.

Radar charts are an alternative visual representation of alignment, which can give the integrator a more precise grasp of the sufficiency of evidence and a visual understanding of alignment as illustrated in Figure 8-7 and Figure 8-8.

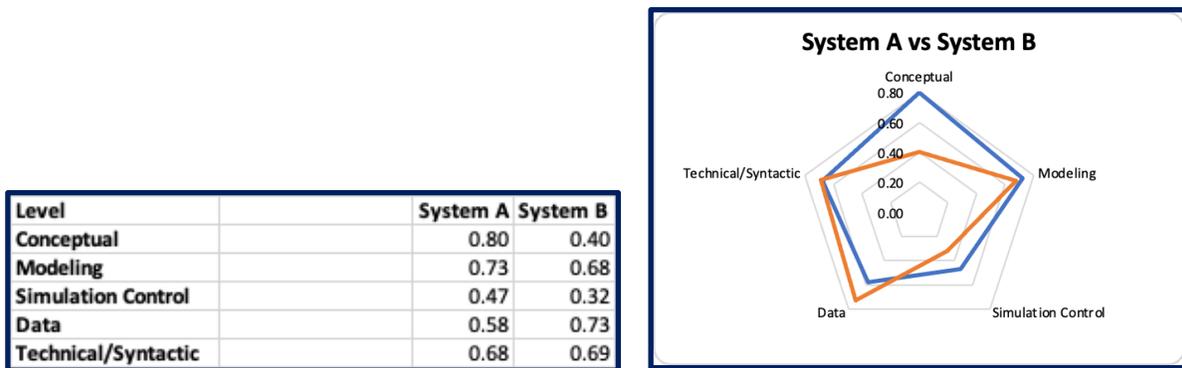


Figure 8-7. Radar Chart Top Level Example

Modeling		0.73	0.68
	Terrain representation and correlation	0.06	0.06
	Environmental effects assumed or modeled	0.00	0.00
	Simulated time representation	0.05	0.00
	Kinetic effects adjudication	0.04	0.05
	Aggregation and disaggregation algorithms	0.00	0.00
	Communications (representation)	0.15	0.15
	Non-kinetic effects adjudication	0.00	0.00
	Inter-visibility	0.00	0.03
	Movement (physics)	0.15	0.15
	Decision-making behavior	0.08	0.08
	Human performance	0.06	0.02
	Platform / equipment performance (not	0.00	0.00
	Entity resolution	0.05	0.05
	Position Estimation	0.10	0.10
	Human behavior representation (pattern of	0.00	0.00

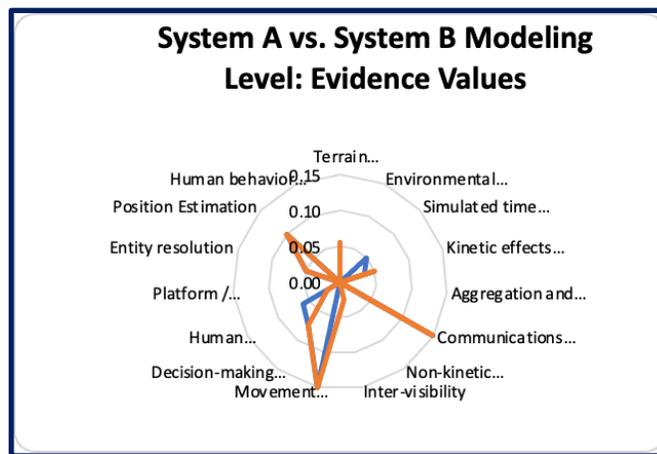


Figure 8-8. Radar Chart Modeling Level Example

8.5 Determine Actual Cost and Risk of Integration

SIRL assessments and evidence comparison do not offer cost estimates directly, but they can offer quantification of risks, which individual programs can translate into costs based on their own cost models. Assessing actual interoperability of two simulations requires analysis of engineering evidence. The more accurate and precise that evidence is, the more accurate and precise the assessment will be. Standardizing the formatting of evidence, e.g., applying principles from the FEAT standard, enables more automated analysis via tools. The FEAT Editor is illustrated in Figure 8-9. It records engineering evidence, but does not currently perform comparisons.

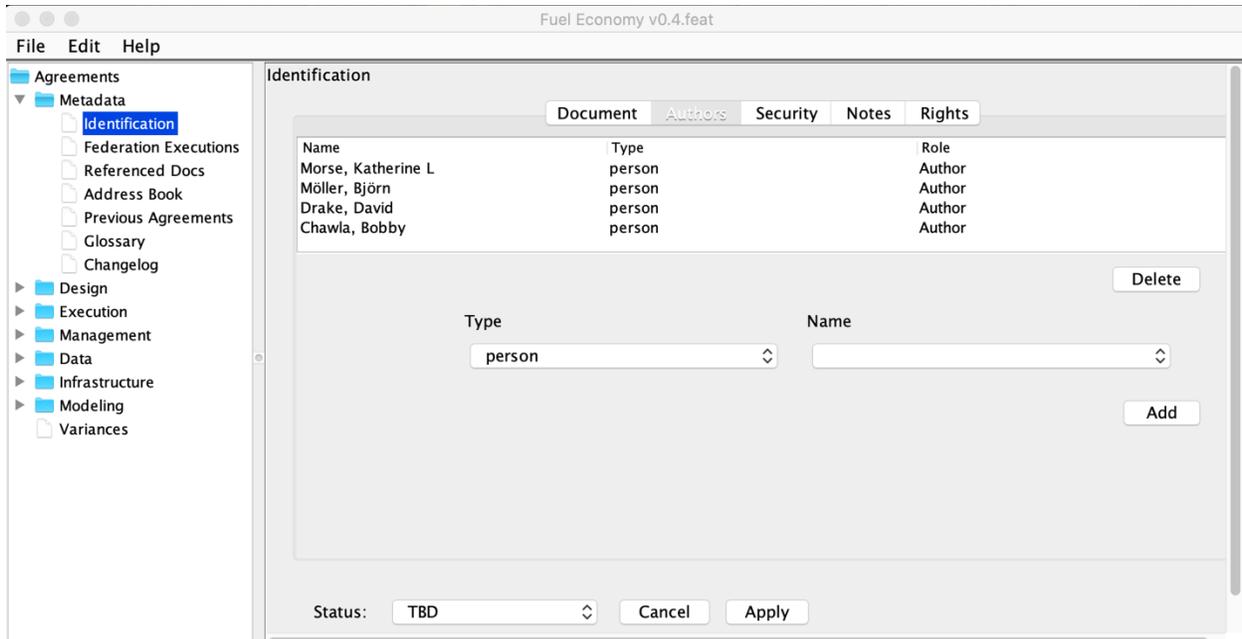


Figure 8-9. FEAT Editor Views

Even if the evidence is complete for both simulations, you still need to assess the cost of integration if the two simulations have a different solution for an item of evidence.

9 SIRL vs TRL

SIRL may suffer by comparison to Technology Readiness Levels (TRL) because you can assess the readiness of a single technology in isolation (TRL), but interoperability is about a group of simulations, potentially with different interoperability readiness levels. The SIRL methodology offers a way of collecting the data necessary to assess the feasibility of that group of simulations working together. This could be cast as a single roll up number, but it wouldn't be quite analogous to a TRL in that it wouldn't tell you what your next steps are. It would just tell you how hard / risky it's going to be to move forward. Levels in TRL are cumulative, i.e., reaching a higher level requires achieving the lower levels. Levels in SIRL are independent, i.e., higher scores at higher levels are possible despite lower scores at lower levels.