Characterizing Models, Simulations, and Games

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ABSTRACT

Including the engaging features of commercial role-playing games in military training systems is of great interest in the simulation community. However, how to assess the trade-offs between player enthusiasm and needed scenario realities are not well understood. In fact, this is just one case of an overall need to effectively characterize models, simulation, and games (MS&Gs) and the degree to which they can support each other and meet mission requirements. Thus, accurately and comprehensively characterizing MS&Gs is the goal of this effort.

It begins by proposing consistent definitions of models, simulations, and games that are simple yet insightful. Provided with each definition are amplifying descriptions, a list of typical types, and MS&Gs uses. Next, the relationship among MS&Gs and between MS&Gs and their application domains are described, first in general terms and then through the derivation and description of approximately forty individual characteristics. These characteristics are grouped into six categories, their inter-relationships described, and an order of importance postulated.

A proof-of-concept was conducted by applying these results to a pair of training events: a Multi-Group In-port Training (MGIT) exercise and a Fleet Synthetic Training–Joint (FST-J) exercise. The definitions, MS&G characteristics, relationships, and importance were examined in the context of these complex, real-time, distributed, training events. With the lessons learned in mind, the next effort focused on developing metrics for a key subset of MS&G characteristics. These metrics reflect how specific features could be measured and begin to associate scales, ranges, and potential values based on MS&G applications.

Finally, it is planned that this initial effort will be expanded to examine MS&Gs in other application domains (analysis, acquisition, and operational support) and to focus on M&S support to gaming, especially to war games.

ABOUT THE AUTHORS

Ivar Oswalt defines simulation requirements, assesses their value, proposes design and development concepts, and evaluates their application. He leads the Studies and Analyses Division at VisiTech, Ltd., and supports the Office of Naval Research and the Navy's M&S Office by developing M&S application assessments and enhancement strategies. He also supported the Defense Modeling and Simulation Office in its M&S composability efforts. He authored the Navy's Simulation Baseline Assessment which describes simulation requirements, use, and funding and co-authored a study for Fleet Forces Command that examined the current use and future potential of simulation to support to the Navy Continuous Training Environment. Dr. Oswalt has developed and applied complex techniques to measure the contribution and key characteristics of new technologies and process improvements.

Stephen Kasputis as Chief Scientist of VisiTech, Ltd., has led the VisiTech team that delivered the core simulation, system initialization control, a state-of-the-art after action review system with unique capabilities, and system integration to the prototype Marine training system, the Deployable Virtual Training Environment. Dr. Kasputis was also the concept originator and principal investigator for a Small Business Innovative Research Project on advanced verification and validation techniques. That effort developed a method of characterizing not only regions where simulation results would become invalid, but also the nature of the simulation in the boundary to those regions. He is currently the principal investigator for the development of semantic descriptors that will provide a means to characterize the assumptions and abstractions inherent in models and simulations.

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INTRODUCTION

Including the engaging features of commercial role-playing games in military training systems is of great interest in the simulation community. However, how to assess the trade-offs between player enthusiasm and needed scenario realities are not well understood. In fact, this is just one case of an overall need to effectively characterize models, simulation, and games (MS&Gs) and the degree to which they can support each other and meet mission requirements. Thus, the goals of this effort are to develop accurate and mutually consistent definitions of MS&Gs, to describe a structured set of MS&G uses and characteristics, and to propose characteristic measurement approaches with initial values provided through the observation of two recent Navy training exercises.

It is hoped that such information will allow program managers and other users to make more informed and effective decisions when choosing MS&Gs to support the mission objectives. For instance, as a result of this effort, a potential MS&G user has a structured and prioritized list of characteristics that can be used to assess the ability of a model to support a simulation and a simulation to support a game, or the ability of any one or combination to meet training, acquisition, assessment, or similar goals.

The overall analytic structure adopted in this effort is a three-dimensional array of MS&G uses, types, and features. In that way, specific MS&Gs can be associated with user needs and provided capabilities. The goals of MS&G application are enumerated. Next, MS&G types are listed, with specific instances of each annotated. Finally, the features that can be used to describe MS&Gs are summarized (see Figure 1). This three-dimensional structure allows particular MS&Gs (the blue boxes shown) to be placed where appropriated. Many perspective MS&Gs, from the fields of international relations, game development, military modeling, and MS&G application were considered in this effort (Brewer, 1979; Dunnigan, 1992, Hughes 1989; Perla, 1990; Thomas 2005; Yardley, 2003; Ward 1985).

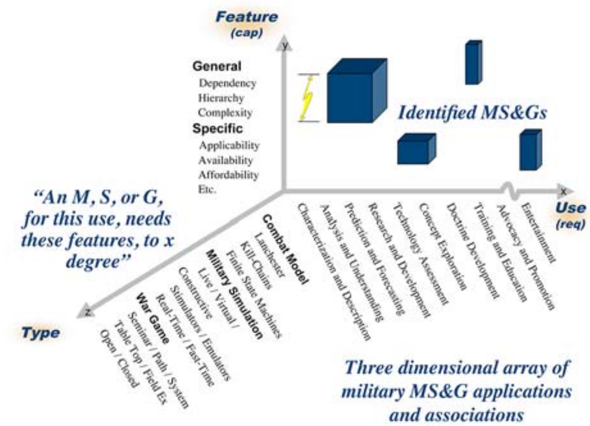

Figure 1. MS&G Study Analytic Approach

In simplest terms, a model is a representation that has the relevant features of the original, a simulation is a dynamic model, and a game is a simulation or activity with people interacting in accordance with rules, where the results are not operational. Combat, military, or war MS&Gs are those that represent, or focus on, military operations. These definitions may seem overly concise, but they avoid some standard pitfalls. They are intuitive and inclusive. They don't restrict MS&Gs to those of only processes, methods, or implementations, they allow for representations of mental as well as physical activities, they include games that are conducted both as simulations (like chess) and those conducted solely for entertainment (like hop scotch), and the list goes on.

MODELS

These simple definitions have been augmented with elaborating information. Starting with a model, or a representation that has the relevant features of the original, it is important to note that representations include those of entities (devices, persons), activities (systems, processes), and situations (events, scenarios). In addition, the use of the term 'relevance' means a model's construction is purposive, its value is conditional. Finally, it is our assertion that data alone is not a model. Informing our definition of a model are instances where models are described as schematic or abstracted descriptions of a system, theory, or phenomenon that accounts for known or inferred properties; models as an archetypical example of a thing or process; and model as a miniature, simplified structure, or preliminary work that serves as a plan from which a final product is to be made.

There are a variety of model types. They include conceptual or mental models which are psychological models of real, hypothetical, or imaginary situations; verbal or narrative models which are representations in native languages and constructs; rules, sets, and logical models which are well structured atomic, sequential, and combinatoric symbols and principals; mathematical or quantitative models that use sequential and dynamic equations to describe behavior; syntactical or semantic models which focus on construction or meaning; physical, functional, and organizational models; and analog and discrete model representations.

A military model is a representation of military operations that has the relevant features of the original. Representations include those of entities (platforms, warfighters), activities (engagement, sensor-shooter kill chains), and situations (combat events, scenarios). Traditionally military models have used Lanchester equations, Lanchester derivatives, or multi-variant approaches to represent theater-level combat and support activities. More recently, sensor-to-shooter kill chains, probability tables, finite state machines, and intelligent agents are employed to reflect platform and system-level interactions.

SIMULATIONS

A simulation is a dynamic model that includes mechanisms for representing sequential events (usually relative to time, but also state transitions or causal chains). Simulations are often predictive systems implemented in software that use probabilities or other forecasting techniques to estimate future events. However, they can also display visual information without predictive indices (like in mission preview systems). Simulations are often software that uses state information that has not been obtained from direct measurement or instrumentation (as opposed to operational combat sensors, that is those used in actual deployed environments), represent interactions between complex objects and events; and include synthetic representations of events or processes (i.e., re-enactment).

Types of simulations include analytic simulations which are representations of operations that aid in understanding processes, procedures, hardware effectiveness, and manning; operational decision aids that provide relevant and timely inputs to decision makers; hardware-in-the-loop facilities and systems that include actual hardware or software to emulate activity or performance; training simulators that are three dimensional physical devices representing relevant system features and movement; interactive virtual environments that are immersive representations of multiple senses that allow interaction and feedback; among others. The military uses each of these types of simulations, with an emphasis on understanding, planning, executing, and predicting combat.

GAMES

A game is a simulation or activity with people interacting in accordance with rules, where the results are not operational. They often use emotional features, engaging scenarios, and team loyalty to interest and persuade players to continue and have recreational, fitness, or competitive aspects. Definitions of games which are consistent, but emphasize different features of these environments include: a sport in which players contend with each other according to a set of rules for entertainment or amusement; an active interest or pursuit, especially one involving competitive engagement or adherence to rules; and a mathematical theory that describes participants and stipulates rules governing all aspects of their interaction.

It is important to point out that this definition of game includes both games that are simulations, like chess is of warfare, and games that are played purely for the sake of enjoyment. In either case, rules control activity, conducted by people, in environments that are not genuine, but result from the construction of the game. Types of games include sports, a physical activity conducted for recreation, competition, or self-actualization; board and miniature games where competition played on a pre-marked surface, with pieces moved according to rules; first person games, in which an immersive environment is rendered in real-time from the point of view of the player; role-playing games (RPGs) in which character development is the main driving game-play mechanic; strategy, adventure, or fantasy game that emphasize thinking and problem solving or experiencing a story through a character in a historical or future-oriented context; distributed interactive virtual environments in which earth-sized synthetic worlds support highly interactive and distributed play; and massively multiplayer games

(MMPs) which allow many people to interact in a shared, persistent, three dimensional environment.

A war game is a simulation or activity of military operations with people interacting in accordance with rules where the results are not operational. People provide information processing, decision making, or communications either acting as them selves or playing roles. They use rules, events, and data to guide action in an actual or fictitious scenario. Included in this definition are simulations of historical conflicts with miniature figures fighting battles over 3D terrain, their movement and combat being regulated by rules that create historically accurate battles and the full-scale rehearsal of military maneuvers as practice for warfare (although in current military parlance, such events are normally called 'field exercises'). "War game" is most often used by professionals with "wargame" being used by hobbyists (Although some professionals use the single word, following the German one-word form "Kriegspiel" (kreig = war, spiel = game)).

There are many types of war games. They include tabletop games with a small number of players and a limited tactical scenario and command post exercises that involves the commander, his staff, and the communications within (internal) and between (external) headquarters that normally focus on procedures. Path games are used to explore alternatives by identifying decisions that enable or prevent outcomes; in systems games information and actions are limited by rules that control flow and volume; in seminar war games information flows between participants in an unrestricted manner and players simultaneously, carry out decision making roles, simulate threat actions, convert actions into results, assess outcomes, and discuss decisions. Distributed or remote games are conducted across a network of connected nodes where players are separated from the models and activities being used to support the simulated activities and hybrid games combine two or more of the previously listed modalities.

MS&G USES

MS&Gs are used for many purposes. One of the first is to characterize, describe, or visualize an item, process, or activity. In this case the objective is to create an abstraction of an empirical phenomenon. This abstraction can then be used as an experimental environment to better understand the item or process and to conduct analysis in support of decision making. This analysis can support research in technology assessment, process improvement, human factors design, and many others. In addition to observing the behavior of the abstraction, simulations and games are often used to predict or forecast the next state of a dynamic system. That is, they represent both changes over time and stochastic or probabilistic values, which interact in complex and sometimes unforeseen ways, to provide insights into the future.

MS&Gs are also used, especially in the military, to assist in strategy, doctrine, and concept development, assessment, and testing. Differing concepts of operation, executed by friendly, hostile, and neutral forces can be examined over time in a controlled environment of kinetic, non-kinetic, human, and autonomous systems, to name just a few. In addition, MS&Gs have a long and successful history of supporting training. Basic training and instruction are supported using simulators that teach system familiarization and operations. Simulations that project operational outcomes and those used to stimulate on-board systems assist with exercises and training events. In university settings, role-playing simulations and commercial war games are used to teach subject fundamentals.

In support of operations, simulations have been integrated into tactical decision aids and weather prediction systems, deliberate and crisis action planning tools, and intelligence, logistics, personnel, and similar decision support systems. In each, simulations allow platform capabilities, environmental conditions, and plans to be projected ahead to assist decision makers in making prudent tactical, operational, and strategic decisions. The purchasing or manufacturing of an item or system can also be supported by MS&Gs. Simulation can be used in pre-systems acquisition, systems acquisition, and logistics support to help reduce cost, cycle time, resource requirements, and risks and to increase the quality of systems being acquired.

MS&Gs have also been used to promote positions as well as for entertainment. Promotional MS&Gs emphasize or seek to educate observers, users, and participants, on particular points of view. The movie *WarGames* and the conclusion reached by the War Operation Plan Response Simulation about the war fighting utility of the superpower's nuclear arsenals, that "The only winning move is not to play" the game, comes to mind. [i]

There is a significant and growing use of MS&Gs for amusement and entertainment, which runs the range from stand-alone micro-computer based simulations to entertainment system's programs and on-line games. "The entertainment industry and the Department of Defense (DOD)—although differing widely in their motivations, objectives, and cultures—share a growing interest in computer-based modeling and simulation. In entertainment, these technologies helped revive the U.S. animation industry and now drive multi-billion-dollar markets in video games, film, virtual reality, attractions, and theme parks. For the military, modeling supports training troops, evaluating military doctrine and tactics, and assessing the effectiveness of new weapons systems."[ii]

RELATING MS&Gs

In associating MS&Gs, we have defined two classes of relationships using general and specific features (the y axis in Figure 1). General relationships address relative standing in broad areas which are not universal; e.g., they may only apply when a game uses a simulation. Specific relationships address more detailed issues that associate modeling with simulation with gaming or related to fulfilling requirements of a particular application.

GENERAL RELATIONSHIPS

Because of their nature and applications, there are general relationships between models, simulations, and games with respect to their dependency, order in a hierarchy, and complexity. The first general relationship is that of dependency. Since a simulation is defined as a dynamic model, one cannot have simulations without models. Simulations can be, and typically are, composed of several models, so they must address issues of integration and interfaces between models. Simulations are thus more complex than models, but still entirely dependent on them.

The dependency relationship between games and simulations is a multi-faceted one.[iii] Many games are themselves simulations. Chess can be considered a simulation of warfare. Also, simulations can be used to any extent within a game. At one end of the spectrum, games can exist without simulations. One does not need a simulation for a game of tag, for example. The broad middle of the spectrum is comprised of the various levels of support that simulations can provide to games. An example is a simulation of a C^3 system providing message routing, delay, and bandwidth limitations in a seminar game that is studying logistic support decision making. At the other end of the spectrum, a simulation can be the game. In games like Doom for the home computer or arcade games of shooting bad guys with electronic guns, the simulation provides everything for the game except the players.

The above dependencies lead to the other general relationship between models, simulations, and games seen in Figure 2.

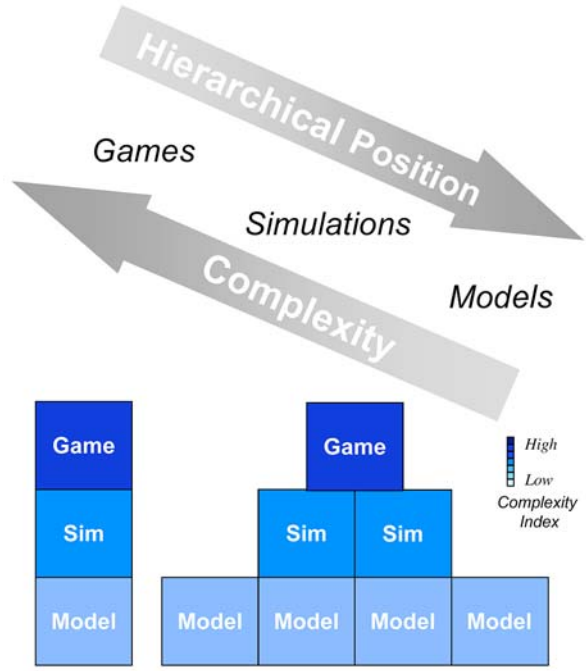

Figure 2. General MS&G Relationships

That relationship is the hierarchy among them. In general, models support simulations and simulations support games. This hierarchy follows the general level of complexity associated with models, simulations, and games as well as the level of information provided by each. Thus the hierarchy of support is a rather natural one based on the nature of models, simulations, and games. In general models provide data that address rather simple direct questions. The repeated production of data with respect to time or space from a simulation results in information that can be used to answer more complex inquiries. The assessment of information by the game player results in additional information and knowledge that can address even more intricate investigations.

The hierarchical relationship between models, simulations, and games does not mean that information flow is strictly one-way. Results from a war game could, for example, be used to modify some of the parameters of a model. The use of the information flow down the hierarchy, however, in general takes place over a longer timescale.

Implicit in both the hierarchical and dependencies relationships comes another general relationship; that of complexity. Simulations are more complex than models and are often composed of several models. For example, a simulation of a bouncing ball needs to have models of both the ball's motion in air under the influence of gravity, and the ball's interaction with the surface off of which it bounces. A game supported by a simulation is inherently more complex than that simulation. A game can also be supported by more than one simulation. A war game, for example, may be supported by an entity level combat system simulation to determine the results of conflicts as well as a communications simulation to determine message latencies and routing errors. For simulations and games that use simulations, their complexity can be thought of as inheriting the complexity of the model or simulation it uses and adding to it.

SPECIFIC RELATIONSHIPS

Because of the hierarchical nature of the relationship between models, simulations, and games one can begin to ask the question of how well a given model supports a given simulation or how well a given simulation supports a given game. This support must be specifically focused. To execute a successful game, the objectives of the game must first be clearly defined. Next, the functions required to successfully meet the objective must be identified. This provides a list of functional requirements that the resources employed in the game must meet. The design process then begins by identifying specific resources that can meet subsets of the requirements. This process also identifies the interactions and interfaces between the resources so that the collection of them can meet the full functional requirements set. A simulation supporting a game is one of its resources. Thus, when a role for a simulation in support of a game is identified, it comes with an allocation of functional requirements. Similarly, the models that support the simulation get allocated a portion of these requirements.

The requirements of a model, simulation, or game can be stated in terms of specific characteristics. Use of characteristics in the context of stating requirements provide two distinct advantages. First it provides a framework that is consistent between models, simulations, and games. That is, there is no need to try to interpret a requirement for a game into the language of the requirements of a simulation, as both are presented using the same terms. Secondly, identification of MS&Gs characteristics allows for the requirements at all levels to be stated quantitatively. This can be accomplished by stating the requirements in terms of measures of the metrics associated with each characteristic. This also offers the potential for an objective assessment of goodness of fit of existent systems into new requirement sets.

MS&G CHARACTERISTICS

To support the identification of the requirements sets for MS&Gs, we identified forty one characteristics associated with them. These characteristics can be grouped into eight classes. The first three classes of applicability, availability, and affordability are the first ones that must be addressed by a manager attempting to build or procure a MS&G. The other classes address more detailed issues associated with the employment of the MS&Gs. Although a thorough discussion of each of these characteristics is not possible here, some examples of how requirements can be specified using them will be provided. The forty one characteristics we have identified grouped into the eight classes are provided in the tables below. The intent is to develop quantitative metrics of these characteristics, based on application requirements.

Applicable, available, and affordable are the first set of MS&G characteristics that are critical for a decision maker to assess. They reflect a system's ability to provide a synthetic environment that meets mission goals, whether it can be obtained, and its cost. These characteristics are summarized in Table 1.

Table 1. Applicable, Available, Affordable

Is the MS&G…	*____ is the Degree the MS&G's…..*
Applicable	**Applicability** – Provide a synthetic environment or output measures that support the mission
	Impact – Effect processes and outcomes, relative to the mission's goal
	Longevity – Provide useful outputs and insights for a long time
Available	**Availability** – Exist, and if so, are attainable – along with supporting data, systems, etc.
	Fidelity – Represent (include) important features: in terms of both types and numbers
	Resolution – Include relevant features at a particular level
Affordable	**Affordability** – Can achieve mission goals within the budget specified
	Cost Effectiveness – Provide benefits that are worth the costs required for their development and use
	Manageability – Can be used, and results obtained, without undue oversight expenditure

The next set of characteristics describes MS&G features that are important in the system's application. Whether the MS&G provides sound analytic results, is entertaining, or user friendly. These characteristics and their components are listed in Table 2.

Table 2. Analytic, Engaging, Usable

Is the MS&G…	*____ is the Degree the MS&G's…..*
Analytic	**Traceable** – Outputs can be associated with inputs, and understood
	Powerful – Provide key insights to users / decision makers
	Innovative – Include significant new capabilities or provide functionality in a unique way
Engaging	**Emotiveness** – Involve players emotionally by stimulating feelings of competition, loyalty, fear, or similar
	Interactivity – Provide appropriate and timely responses (continuous, reactive, etc.) to user input
	Verisimilitude – Promote suspension of disbelief and immerse users in the synthetic environment. Appears to be real
Usable	**User Friendliness** – Can be employed without extensive training
	Accessibility – Use data and algorithms that can be inspected and are maintained in a manageable form
	Inter-visibility – Allow observation of interactions between levels of abstraction

Another feature that is often important to assess when reviewing MS&Gs are their credibility. That is, how accurate are they and how accepted is their use and the results they generate. Table 3 lists the components of credibility.

Table 3. Credible

Is the MS&G…	*____ is the Degree the MS&G's…..*
Credible	**Credibility** – Produce results that are logical
	Accredited – Have been formally recognized as being appropriate for an application
	Validity – Correctly represent the critical variables, for a given application
	Accuracy – Faithfully represent the relevant features of the original
	Repeatability – Will yield the same results when input conditions are the same
	Verified – Act according to their design

Finally, the technical features of an MS&G can be very critical. That is, whether the system is modular, interoperable, portable, and similar concerns. Table 4 lists the technical characteristics applicable to an MS&G.

Table 4. Technical

Is the MS&G…	*____ is the Degree the MS&G's…..*
Technical	**Maintainability** – Allow the identification, understanding, and correction of errors
	Modifiability – Construction can be changed and updated (e.g., source code)
	Re-configurability – Input values and parameters can vary (e.g., data files)
	Adaptability – Can be used in a different application area or in a different way
	Expandability – Can include features not originally envisioned / encoded
	Time Flexibility – Can adapt to the timing parameters of a new application
	Supportability – Need resources (manpower or funds) to conduct / run it
	Modularity – Components are internally consistent and loosely coupled
	Composability – Can be quickly reconfigured and federated with others; often via automated tools
	Scalability – Can accommodate a large increase in users, workload, or transactions without strain
	Interoperability – Can be modified in a timely manner to pass data, syntactic, or semantic information
	Standardization – Conform to standards including hardware, software, database, and interface
	Efficiency – Execute quickly given their architecture and size / lines of code
	Portability – Can be conducted at alternate sites or using varied hardware or software configurations
	Reliability – Will run without errors, is stable and dependable
	Architectural Flexibility – Support distributed, synchronous / asynchronous, multi-level application
	Fundamental Features – Includes speed, lines of code, design, architecture (empirical characteristics)

Again, the intent is to develop quantitative metrics of these characteristics, based on application requirements.

MS&G CHARACTERISTICS – AN EXAMPLE

As an example of considering the characteristics in the definition and allocation of requirements, consider the following example. A game is to be devised that investigates the effectiveness of various tactics in employing a new sensor that is capable of detecting improvised explosive devices (IED) at a range of 500 yards. For the game to be applicable to the question at hand, it needs to include some form of actors to employ the tactics, a representation of the physical aspects and entities in the game space, and a way to adjudicate interactions between aspects or players in the game space; for example, using an algorithm to determine the effects of an IED explosion. Either intelligent software agents that can be trained in the tactics or live role players could be applicable for the requirement to provide actors to employ the tactics being investigated. Suppose now that part of the investigation is also to see which tactics provide the most consistent results across a spectrum of experience levels for the decision maker employing the tactics. If one form of intelligent agent is simply employing a single rule set in an unvarying manner, it may now not be appropriate for the requirement of the game. If another software agent can roughly simulate experience level by changing decision times it may be applicable to some extent with its level of applicability definable on a scale. A cross section of live players is likely to rank higher on that scale of applicability. If no live players are available, however, the less applicable intelligent agent simulation may need to be the solution of choice and either the game design or analysis of the results modified to mitigate the shortcomings.

Consider now the game requirement for representation of the new sensor in the game space. Suppose also that actual soldiers are used for the employment of the tactics and there is the additional goal of evaluating the tactic effectiveness under varying levels of stress for the decision maker. Representation of the sensor could be accomplished by a referee with access to the ground truth of the game space handing notes to the soldiers when he determines that the sensor has made a detection. It could also be accomplished with a simulation of a sensor that provides a visual and audible warning to the soldier. To accurately assess the effectiveness under various stress levels, the soldiers need to be immersed in the scenario and experience the "suspension of disbelief." This means that the representation of the sensor should provide some degree of verisimilitude. The first option of the use of a referee would have a low level of verisimilitude, where the simulation would have a higher level and thus be desirable based on that characteristic. There may be other evaluations of characteristics that make the simulation unacceptable, however. If it had no time flexibility for example, and required several minutes to evaluate if detections were made, it may be unsuitable for use in a game with live players.

From the above examples, it can be seen that pertinence of any characteristic is very much context or requirements dependent. If there were no need to evaluate the tactics in the above example for varying stress levels, verisimilitude might be of little or no importance, for instance. Identifying the relative importance and level of acceptability for each of the characteristics must, therefore, be done on a case by case basis.

A proof-of-concept was conducted by applying these frameworks to a pair of training events: a Multi-Group In-port Training (MGIT) exercise and a Fleet Synthetic Training – Joint (FST-J) exercise. The definitions, MS&G characteristics, relationships, and importance were examined in the context of these complex, real-time, distributed, training events.

EXERCISE INSIGHTS

We observed the Fleet Synthetic Training – Joint (FST-J) exercise (FST-J 06-01), which was the first time that major combat operations (MCO) certification was awarded to a deploying battle group based on a synthetic event. This result was generated by a situation in which the scheduling of an at-sea Joint Forces Exercise (JTFEX) was impossible and the training provided by a simulated event was reasonable. Thus, as Figure 3 displays, between the bounds of unacceptable (-) and all encompassing (+), given the scheduling constraints, the value reflected by the interval between 'Without JTFEX' and 'With JTFEX' was great enough to warrant the exercise and allow for the possibility that an MCO certification could be based on the successful completion of it.

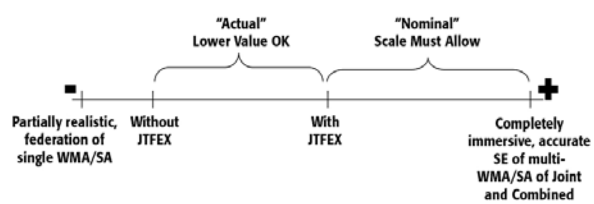

Figure 3. Sample Exercise Scale

Yet, MS&G characteristic values, minimums, maximums are relative to the requirement established by the user. It is important to point out that decision maker's thresholds and values will vary with regard to characteristic and risk and that MS&G effectiveness is dependent upon the infrastructure provided.

Another insight from the exercises observed was the understanding that risk is an equal factor with the other MS&G characteristics. Although it varies by decision maker, application, and context, it is critical to consider when assessing the value of MS&G characteristics (see Figure 4).

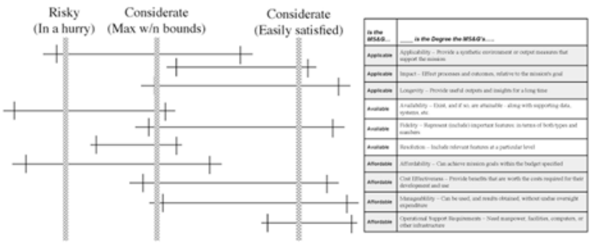

Figure 4. Risk Relative to MS&G Characteristics

Finally, observing these exercises made it clear that any method for measuring MS&G characteristic values needs to include how a decision maker's risk can change over time. For instance, if characteristic values decrease as a synthetic event takes place, when is a break-point reached and the commander decides to switch from using one type of MS&G to another, or to a live exercise?

MS&G APPLICATION METRICS

Current effort has been focused on developing the application metrics for the characteristics of MS&G support. That is, values that can be assigned to each of the characteristics listed that reflect the needs of the application and the capabilities of the MS&G system. These values will be scenario or event dependent, yet it is intended that they reflect direction, dependency, and dimension of interaction and have associated numeric indices. These indices reflect the degree to which a MS&G has a characteristic or a user has a need. The steps in their development are summarized in Table 5.

Table 5. Metrics Development Approach

First are the **classes / categories**	E.g., Technical
Associated with each group are a set of **characteristics / terms** describing features	Maintainability, Design
Associate these with more specific **properties**	MTBF, Type
Decompose these into **metrics**, which are standards of measurement, like variables	1-10hrs Compiled, Interpreted
Metric values are relative to a **scale** (a specified, graduated reference used to measure) and may be nominal, ordinal, interval, or ratio in type	1-2-3-4-5-6-7-8-9-10 C, I
Can **range** from 0 or no representation to X, where X represents a complete implementation in the MS&G of the area	(For interval and ratio data)
Metrics are **assigned values**, based on the features of the MS&G (the act of measurement) or MS&G requirement	E.g., 9, Compiled

The approach to measurement envisioned is to start with the characteristics classes. For example, the class of Technical features. Within each class are a set of characteristics which describe particular features. For this example, they could be maintainability and design (under Fundamental Features). Associated with these characteristics are properties, like mean time between failure (MTBF) and execution type. Matched to these properties are metrics, which are standards of measurement similar to variables. In the case of MTBF and execution type, they could be 1-10 hours and complied or interpreted.

Metric values to be assigned are relative to a scale (a specified, graduated reference used to measure) and may be nominal, ordinal, interval, or ratio in type. For our example, the scale could be (1,2,3,4,5,6,7,8,9,10) for MTBF, the pair (complied, interpreted) for execution type and the scale types could be ratio and nominal respectively. For interval and ratio types, the values are intended to range from 0, reflecting no representation, to x, where x represents a complete implementation in the MS&G of the characteristic. Finally, metrics are assigned values based on the degree it exhibits the features (the act of measurement) or the level needed by a user to meet a requirement. In the case of maintainability and design, the metric values could be '9' and 'compiled.' This MS&G application metric development approach is congruent with standard multi-attribute utility theory and specific approaches like "Practical Software Measurement."[iv]

CONCLUSIONS AND NEXT STEPS

This effort, although not complete, strives to show the value of developing accurate and mutually consistent definitions of MS&Gs, describing a structured set of MS&G uses and characteristics, providing some initial insights based on recent exercises, proposing characteristic measurement approaches, and describing needed next steps. These next steps will be to examine MS&G uses in other events (e.g., analysis, acquisition, operational support), to validate definitions and expand the characteristic list and value scales, and to focus on gaming and MS&G capabilities relative to specific requirements.

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ENDNOTES

[i] *WarGames*, MGM/UA, 1983, Copyright MCMLXXXIII UA, CBS/FOX Video, Michigan.

[ii] Committee on Modeling and Simulation, (1997). *Modeling and Simulation: Linking Entertainment and Defense,* Washington, DC: National Academy Press.

[iii] The term simulation will be used here for ease to refer to both models and simulations. Since games typically have some extent in time, any model used as part of or in support of a game would probably require more than one execution. Multiple executions of a model can be interpreted as a simulation.

[iv] McGarry, J., et al. (2002). *Practical Software Measurement: Objective Information for Decision Makers*, Addison-Wesley.