Simulation Based Leadership Decision Support Simulator for Countering Weapons of Mass Destruction

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ABSTRACT

A review of Decision Support Systems literature finds that such systems have historically been associated with managerial or industry long-term decision-making (Alter, 1980). Decision Support Systems also refers to an academic field of research that involves designing and studying systems in their context of use (Schuff et al. 2011). This paper discusses the extension of the field to the support of decision-making for Combatting Weapons of Mass Destruction (CWMD). It describes the development of a scenario-based Decision Support Simulator (DSS) prototype using an iterative design approach that leverages a working group of subject matter experts to identify simulator and scenario requirements. The goal for the DSS is to enable decision makers to develop courses of action in response to crisis events by simulating response cells, logistics information, doctrine, tactics, and procedures in a real-world context. At critical decision points during DSS scenarios, direct feedback and metacognitive prompting are presented as appropriate and key performance metrics are recorded for comprehensive after action review. Existing operational tools are leveraged to facilitate realistic scenario interactions. The goal is to unify disparate technologies and resources through a web interface that is extensible to multiple areas of expertise when dealing with crisis events. This paper details the approach to establishing the requirements of the design of a portable DSS prototype, including the CWMD scenario, instructional and system architecture, and assessment methodologies.

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DEMAND SIGNAL

The threat of Weapons of Mass Destruction (WMD) coupled with terrorism continues to undermine global security. Decision makers at all levels require ongoing training support to react effectively to chaotic events that require coordinated response from various components within the United States Government. In crisis events, decision makers are required to assess information and make critical decisions under tremendous psychological stress and physical demand (Klann, 2003; Leonard, 2004). Training support for these conditions requires sustained rehearsal, practice, and learning in a variety of mission contexts, from the tactical to the strategic level. While improving crisis event decision-making is best achieved by "living the crisis conditions and the possible consequences of the taken decision" (Cesta, Cortellessa, & DeBenedictis, 2013), this type of training is very expensive and logistically challenging. To minimize the risk of failures in live-action circumstances, scenario-based simulation technologies are ideal for training decision makers in complex scenarios involving crisis events.

A review of Decision Support Systems literature finds that systems that support decision-making have historically been associated with managerial or industry-centric long-term decision-making (Alter, 1980). Further, these systems typically do not leverage scenario-based simulation technologies to support complex and time sensitive decision-making. Decision Support Systems is also an academic field of research that involves designing and studying systems in their context of use (Schuff, 2011). USMC MajGen Mullen's Vision Statement for the Ideal Training Environment at Marine Air Ground Task Force Training Command/Marine Corps Air Ground Combat Center (MAGTF/MCAGCC; Mullen, 2017), states "Enhanced modeling and simulation…includes a full complement of simulators for every element of the MAGTF" (p. 1). In this statement he also refers to a "thread" that "should run throughout every training evolution and tools that we need to acquire or better develop…" (p. 1). He goes on to highlight a specific thread, "Plan for it (Chemical, Biological, Radiological, and Nuclear [CBRN]) and learn to fight and win within it…CBRN remains a significant threat..." (p. 2). This paper describes an effort to meet this need and the strategic goals for the Defense Threat Reduction Agency (DTRA) through the development of a Decision Support Simulator (DSS) for upper-echelon decision makers that extends the traditional focus of a Decision Support System to the training of decision-making for Combatting Weapons of Mass Destruction (CWMD), (Defense Threat Reduction Agency, 2017).

CONCEPT

The DSS prototype was conceived with the objective of achieving Technology Readiness Level (TRL) 3, the proof of concept validation as demonstrated through technical feasibility using implementations exercised with representative data; and TRL 4, component/subsystem validation in laboratory environment–standalone prototyping implementation and test.

The intent for the DSS prototype is to enable decision makers to develop basic Courses of Action (COAs) in response to a crisis event. In this specific case, that event is built around a CWMD scenario. The DSS uses simulated personnel, and provides logistics information, doctrine, tactics, and procedures across collaborating units. During the WMD scenario, at decision points, direct metacognitive prompts can help users "think about their thinking" and Measures of

Effectiveness (MOE) provide traceability to decision points and comprehensive after action review. Existing operational tools are leveraged to facilitate realistic scenario interactions.

Ambiguity, urgency, and high-level risk are associated with crisis management, and it is necessary to have effective leadership in place. To focus on the tactical decision maker within a CWMD scenario, the initial prototype scenario is designed around the training of a United States Marine Corps (USMC) Operations Officer (OPSO) within a Battalion Combat Operations Center (COC). The OPSO is responsible for execution of the Commanding Officer's intent, and is able to take action to enact decisions. Simulated personnel within the DSS COC communicate, model, and function according to training objectives relevant to the USMC and include:

- Commanding Officer (CO)
- Personnel (S-1)
- Intelligence (S-2)
- Operations Officer (OPSO)
- Operations Chief (OPS Chief)
- Air Officer (AIRO)
- Logistics (S-4)
- Civil Affairs (S-5)
- Communications (S-6)

The DSS also provides scripted communications between these roles and the CO and delivers resources and intelligence reports similar to those used in live exercises for the training.

The goal is to unify disparate technologies and resources through a web interface that is extensible to multiple areas of expertise when dealing with WMD threats. Data and information collected during testing of the prototype DSS at USMC battalion-level field exercises will guide the next steps and processes needed for future iterations and scenarios, and highlight a transition path and enhance downstream training objectives.

DESIGN

Following a spiral development process, researchers executed an iterative approach for the design of the DSS. In collaboration with an operational working group composed of subject matter experts, scope and requirements were refined to identify the desired end-state of the DSS prototype, including system and instructional architectures. Together with a Blue Ribbon Panel consisting of representatives of the Marine Corps Tactics and Operations Group (MCTOG), USMC Battle Simulation Center Simulation and Training, and University of Central Florida researchers and software engineers, a prototype system and instructional architecture were designed to support a scenario focused on a chemical release from a state actor.

System Architecture

To support the complexity of roles and interactions within the COC, while still being portable, flexible, and controllable for assessment, a scriptable architecture using events was identified to drive a web interface. A web-based system enables training and rehearsal wherever a user is located, without the need to install any additional software beyond what they already have. The information and input requirements for the interface were captured through observation of COC training exercises at 29 Palms and includes: 1) interactive chat windows to request/receive information and give commands among members of the COC and other parties; 2) an interactive map of the battlefield; 3) reference materials; and 4) aggregated status information posted in the COC. Furthermore, the system supports presentation of dialogs to users tied to decision points within scenario scripts. These pop-up dialogs may be used to present meta-cognitive prompts and capture rationale for decisions for after-action review.

The ability to create new branching scenarios that are instantiated upon the actions of an end-user was a key requirement under this effort, as it would be prohibitive to task programmers with adding new events or scenarios as requirements change. As a result, the DSS system architecture uses JAVA Object Script Notation (JSON) to describe scenario content in a script file capable of driving interface elements. Each JSON event is capable of modifying the interface to update map content, simulate chat, modify other display elements, and update internal state information (e.g. user scores). Events are triggered based on scenario time, internal state information set from previous events, actions a user takes, and combinations thereof. Although complex in nature, this architecture provides scenario developers with the ability to enable nested branching and multiple decision paths for users to take.

Instructional Architecture

In order to develop a crisis event scenario that is as accurate and as realistic as possible, a previously conducted live disaster response exercise was used as an example, or template, to establish baseline decision points. The design phase included collaboration and extensive discussion with instructors on the Blue Ribbon Panel to ensure the scenario captures information required for training an instantiation in simulation. Design requirements also included a scenario format that was easy for instructors to understand and compare against potential training objectives. An initial scenario was scripted using baseline decision points and then expanded to a larger scenario.

We used the Observe, Orient, Decide, Action (OODA) Loop as a framework for identification of places for input from who, what, where, why and when (5Ws) outputs. The 5Ws (who, what, where, why and when) are incorporated throughout the scenario. The 5Ws that exist pre-decision may or may not be valid post-decision, and may result in a new set of 5Ws as the scenario progresses. This type of situational shift and the degree of difference between the two situations points to the impact of the decision. Any of the Ws can move in the desired direction while the others move in an undesired direction. The ideal result is that all 5Ws move to the desired state, but due to the dynamic and fluid unknowns there may not be a guarantee that they will remain there.

In a live exercise, the many branches described by the 5Ws will occur organically. However, as part of the DSS prototype scripting process, it was decided to limit the possible branches that resulted from a decision to a binary (Yes, No) result that, in turn, reduced back-end scripting workload for early iterations and proof-of-concept development. An example of this binary decision-tree and results is shown in the table below. Note: arrows indicate direction of communication.

Table 1. Binary Decision Example

	Event	Role	Description	Note
1	Communication	S6→ WO→ OPSO	"Company X reports that they were hit with something that came out the sky, some indirect fire, and now they're really confused, they're missing four or five Marines, and they're having trouble breathing."	A condition that requires a decision is presented.
2	Communication	OPSO	Recommend appropriate MOPP level	Simulated personnel recommends action.
3	Decision 2 (Y/N)	OPSO	Set MOPP level	Decision root.
4	Derived Action: (Y)	OPSO → WO	"Set MOPP level # for Company X and supporting units."	Positive – action is taken.
5	Result: Optimal	OPSO	Casualties are minimized.	Positive result.
6	Derived Action: (N)	OPSO	MOPP level is not established.	Negative – action is not taken.
7	Result: Undesirable	OPSO	Higher number of casualties are sustained.	Negative result.
8	Feedback	DSS	As appropriate	DSS delivers appropriate feedback.

To verify the capability of the scenario to achieve its purpose for laboratory testing, discussion of the content of the scenario was held during a face-to-face workshop with the Blue Ribbon Panel. From the Panel's input, adjustments were made to better align to the needs of the end-users and requirements of the CWMD training scenario. For example, for the purpose of simulating communications, since the COC falls under the authority of the Commanding Officer (CO), the role of CO was included to allow the OPSO to act and interact as accurately as they would in a live exercise.

During the next six months, researchers continued collaboration with members of the Blue Ribbon Panel to refine the DSS scope and solidify the requirements. For the instructional architecture, the primary need was to determine which decisions the scenario was to enable, how those decisions would be made in the WMD exercise, and which realistic corrective actions could be presented.

An opening portion to the scenario script that could be used as the basis of the system design, including a preceding narrative referred to as "Road to War" was needed for the scenario to provide mission awareness and describe the Commander's intent. The DSS Road to War was designed prior to lab testing and developed further for implementation at battalion-level field exercises. Due to classification restrictions, design could not include aspects of any available condition other than a chemical event. Thus, after the opening portion of the scenario designed for evaluation of the DSS, the scenario continues as a crisis chemical event for training the OPSO.

User performance feedback within the DSS prototype scenario is context-relevant and modeled based on instructor-trainee interactions in a live training exercise. This feedback is developed from the objective measures captured at decision events and is provided to the user at key points throughout the scenario.

Instructional Evolution

At the heart of the DSS is a scenario that drives user interactions in response to events that require complex and time-sensitive tactical decision-making. The scenario forms the basis of the user experience and is one of the main determinants of user performance outcomes. It contains the key stimuli required to facilitate complex interactions while maintaining plausibility and realism. It also accurately incorporates personnel, logistics, and doctrine information to integrate the proper tactical elements involved in CWMD response efforts.

The scenario development effort is a systematic, iterative process focused on designing interactions that engage the user in meaningful and instructive decision-making activities. The scenario development process consists of the following seven key steps:

1. Development of a scenario outline
2. Identification/engagement of subject matter experts to guide scenario development
3. Definition of scenario elements to provide realism
4. Identification/development of decision nodes (tasks/decisions/interactions)
5. Analysis of alternatives at each decision node
6. Identification/development of scenario assessment metrics
7. Development of scenario outcomes

The opening portion to the scenario script that served as the basis of the system design, including a preceding narrative referred to as a "Road to War", was developed with the input from the Blue Ribbon Panel from 29 Palms Battle Simulation Center. After the opening narrative, the scenario continued as a crisis chemical event that required a coordinated response from battalion and supporting units. To achieve a realistic scenario, a high level of SME input is required for authoring the narrative and understanding the process flow in which an eventual user will have to work through. The DSS takes into consideration all aspects of the scenario and information that is required to make decisions in a CWMD situation.

The DSS scenario is designed to simulate an actual crisis in order to appropriately tailor the user experience to support the actual decisions and CoAs that would be employed in real-world crises. CoA development is based on the pre-decision and post-decision conditional states of the 5Ws and is focused on decision parameters for conducting a CWMD mission. Sample CoAs are listed below:

- Conduct the mission in a clean area if the mission can be accomplished while staying out of contamination.
- Conduct the mission in a contaminated area using a higher Mission Oriented Protective Posture (MOPP) level, but this may take more time.
- Conduct the mission in a contaminated area using a higher MOPP level, but use more Marines or equipment to compensate for time and energy.
- Delay the mission until the contamination has weathered.
- Conduct the mission in the same amount of time with same amount of Marines, but take a greater risk by using a MOPP level that does not provide maximum protection.

MOEs were developed based on the type of feedback trainees receive during a live exercise. This feedback is triggered dependent on MOE outcomes and an appropriate script is delivered to the trainee. MOEs identified for the DSS included time-to-decide and right/wrong decision. Scripted feedback with metacognitive prompts were also developed to be given as augmentation to performance feedback.

EVALUATION

To measure DSS effectiveness in supporting decision makers, laboratory and representative evaluations of the system and instructional architecture were conducted at the events on the approximated dates shown in the table below.

Table 2. Evaluation Schedule

Date	Event
Nov 2017	USMC Blue Ribbon Panel validation of Chemical Release Attack
Jan 2018	Prototype simulation Alpha Testing at UCF
Mar 2018	Prototype simulation Beta testing with Blue Ribbon Panel
Apr 2018	Assessments of prototype with TALONEX CPX-1 course instructors at 29 Palms

System Evaluation

To implement an evaluation of the DSS to determine the capability of the DSS to enable training of tasks aligned to learning objectives, as well as identify areas for continued development and refinement, a Systematic Team Assessment of Readiness Training (START) process will be used. Importantly, as criteria for achievement of TRL 8, a Verification and Validation must be completed; this is what the START is designed to support.

START assesses training device capabilities to support performance of tasks associated to Training and Readiness (T&R) events and training objectives. START establishes a data-driven evaluation methodology that assesses a training device's ability to enable and support the training of tasks (physical and/or cognitive, individual and collective actions) performed by warfighters in their operational mission or job. As part of this assessment, the START process identifies areas for improvement to support training objectives, enhance trainee proficiency and optimize return on investment. START efforts also provide effective, efficient identification of specific environmental and operational stimuli required for successful transfer to live training events reflective of the contemporary operational environment (COE).

START employs algorithms that combine two sets of task and attribute ratings (criticality and capability) to illustrate the level of training support a training device provides for tasks associated to T&R events or, when appropriate, other training objectives. The START process is performed in multiple steps. It begins with determination of the tasks to be used as representative tasks for the START baseline. After community SMEs validate the tasks, each of the training device attributes are evaluated to determine how critical it is for that attribute to provide the level of fidelity found in live, operational training for the performance of the tasks.

After this is determined for each of the identified tasks, evaluation of the training device's *capability* to deliver the necessary attribute's fidelity is assessed. Table 3 contains the START criticality rating scales and definitions.

Table 3. Criticality Ratings and Definitions

Rating	Attribute Criticality	Attribute Criticality to Task Performance
5	Absolutely Critical	Task cannot be executed without this attribute.
4	Critical	Attribute is critical, contributing to important cues to task execution.
3	Important	Attribute is important and contributes to task execution, but work-around is acceptable.
2	Nice but not important	Attribute is nice to have but peripheral and not essential to task execution.
1	Irrelevant	Attribute is irrelevant or not applicable and contributes nothing to task execution.

Source: (Dunne, Harris, Arrieta, Tanner, Vonsik, Lalor & Muir, 2017)

Table 4 contains the START capability rating scales and definitions.

Table 4. Capability Ratings and Definitions

Rating	Attribute Capability	Device Capability to Enable Task Performance
5	Fully Capable	Device is fully capable of providing attribute to support task performance with little or no capability gaps and no departure from realism. No compensation needed to support task execution.
4	Effectively Capable	Device effectively provides attribute to support task execution with minor/annoying capability gaps and some departure from realism. Minimal compensation needed to support task execution.
3	Borderline Capable	Device is borderline capable of providing attribute to support task execution with moderate capability gaps and significant departure from realism. Considerable compensation needed to support task execution.
2	Marginally Incapable	Device is marginally incapable of providing attribute to support task execution with significant capability gaps and very little realism. This severely diminishes the device's capability of supporting task execution.
1	Completely Incapable	Device is completely incapable of providing attribute to support task execution.

Source: (Dunne, Harris, Arrieta, Tanner, Vonsik, Lalor & Muir, 2017)

Once criticality and capability data are collected for all T&R events and associated tasks, the data analysts use the START algorithm to generate Training Task Support (TTS) and Code Training Support (CTS) scores for each task.

The START methodology allows the analysis team to:

- Specify training device attributes (sensory input provided by the training device to the user to provide operational context and influence task performance) that are required to effectively support performance of tasks.
- Determine which training device attributes provide sufficient simulation fidelity for the training environment.
- Determine which training device attributes require improvement.

Task Training Support
The TTS score is derived from the assessments made by the SMEs of the capability of a device to support performance of a particular task. The TTS levels are divided into three categories and described in Table 5.

Table 5. TTS Levels and Descriptions

Level	Description
Level 3	Training device is capable of supporting operator performance of the task sufficient enough to allow T&R qualification of the operator upon satisfactory performance of the task.
Level 2	Training device provides Attributes at a fidelity sufficient for beneficial training but not for T&R qualification.
Level 1	Training device is incapable of supporting training for the task.

Source: (Dunne, Harris, Arrieta, Tanner, Vonsik, Lalor & Muir, 2017)

Code Training Support

START analysts work with SMEs to map the tasks to T&R events and determine whether those tasks are relevant or critical to support event execution. The CTS score is derived from the assessment made by the SMEs of the level of training support a device provides for execution of specific tasks and is expressed on a scale of one to five.

The START algorithm calculates the CTS scores by cross-referencing TTS scores to the task-to-code mapping and produces two types of CTS scores: CTS_1 and CTS_2. The CTS_1 score indicates training capability with respect to tasks critical to successful completion of that T&R event and therefore critical for the training device to enable. Tasks deemed critical are weighted heavier by the START algorithm than those simply deemed relevant. The CTS_2 calculation specifies the training capability with respect to both non-critical and critical training tasks associated to a T&R event. The levels of CTS are described in the table below.

Table 6. CTS Levels and Descriptions

Level	Description
5.00	Full Training Capability: T&R code can be thoroughly and accurately trained in the simulator with no compensation required for the individual to execute and accomplish the T&R code.
4.00	High Training Capability: T&R code can be effectively trained in the simulator with minor compensation required for the individual to execute and accomplish the T&R code.
3.00	Moderate Training Capability: T&R code can be trained in the simulator, but with considerable distractions requiring significant compensation for the individual to execute and accomplish the T&R code.
2.00	Low Training Capability: T&R code can be addressed in the simulator, but with severe distractions requiring extraordinary compensation to have a useful affect towards executing and accomplishing the T&R code.
1.00	No Training Capability: T&R code cannot be trained in the simulator, and no amount of compensation allows the individual to effectively execute and accomplish the T&R code in the simulator.

Source: (Dunne, Harris, Arrieta, Tanner, Vonsik, Lalor & Muir, 2017)

Simulator Attribute Analyses

During DSS evaluations SMEs will provide DSS attributes ratings that are then used to determine TTS levels as described in Table 5. During analysis these levels are averaged across all tasks and rated using the attribute criticality and capability ratings and descriptions to provide clarity as to which DSS attributes are most critical and which DSS attributes the system is most/least capable of providing. This analyses will assist the developers in their next evolution to determine which attributes, if improved, will provide better return on investment.

Instructional Evaluation

To evaluate the accomplishment of mission objectives and achievement of desired results quantitative data in the form of MOEs will be collected by embedded software to provide qualitative feedback and quantitative data.

Due to schedule and personnel limitations, evaluation of the instructional effectiveness will not be conducted to sufficient levels of validity and reliability. However, evaluation of the affordances of the DSS will be after completion of battalion-level field exercises by collecting feedback from instructors and other SMEs who took part. Likert scale questionnaires will be used to collect reactions to the training the DSS enabled as well as the instructors' motivation to use the DSS. Example questions are contained in the table below.

Table 7. Evaluation Questionnaire Examples

Reaction	Motivation to Use
After training, I feel more confident of success in WMD decision-making.	As a trainee, I want to use the DSS more to increase or sustain my WMD event decision-making.
I found the training to be realistic.	I recommend the DSS be used for WMD event decision-making training purposes.
The exercise I trained with gave me new ways to think about how I make decisions.	I think the DSS could be used for other CBRN decision-making training.
The training I was able to present gave a thorough understanding of WMD event decision-making.	I want to find more ways to use the DSS to help me be a better instructor.
After training, I have more confidence in the CO's WMD event decision-making.	I feel the more trainees use the DSS the more prepared for CBRN event decision-making they will be.
After training with the DSS, trainees have improved and/or sustained their WMD event decision-making skills.	As an instructor, I want to use the DSS to help other Marines in the COC learn their roles.

Quantitative data in the form of performance metrics will be collected to provide objective feedback and enable deeper analysis for downstream applications. This data includes: decision/no decision made, time-to-decide, correct/incorrect decision.

WAY FORWARD

After analysis of evaluation data, results will be available for further refinement of the DSS prototype. Building on the groundwork laid by the successful collaboration with and cooperation of the Blue Ribbon Panel members, future discussions will aid in the advancement of the DSS to a higher TRL.

Capabilities that will be put in place for the next evolution of the DSS include the capability for instructors to tailor the chat screens/input/outcomes and enable part-task/limited user training of Training and Readiness events and associated tasks. The degree of fidelity the DSS will be required to achieve is a requirement to be determined and will likely be dependent upon learning strategy and objectives.

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