Training Credibility in Cross Domain Events

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ABSTRACT

The US Air Force Distributed Mission Operations (DMO) Network employs cross domain solutions (CDSs) to isolate simulators within security-defined domains yet still permit inter-team training in a collective synthetic battlespace. The CDS conditions the collective battlespace by blocking, guising, or passing information contained in the network protocol data units (PDUs). Therefore, the various enclaves may experience different representations of the battlespace. One could expect that in an altered battlespace, behaviors and actions of virtual or constructive entities would be distorted because of altered or missing information, thereby affecting the credibility of training activities. Currently, there is no direct means to judge the training integrity of the conditioned battlespace. Current judgments are subjective, a priori opinions rendered by subject matter experts, usually from the perspective of the protected enclave.

There are several factors which hinder progress in aiding or supplementing judgments of training suitability of collective battlespaces which are altered or incomplete. This paper builds upon previous work by the authors and others regarding DMO cross domain solutions. It characterizes the problem more completely and presents a framework for describing the impact of altered and incomplete information to training integrity. The utility of the framework is that it provides more quantifiable measures for assessing potential training impacts of a conditioned battlespace. It could also be used to improve the development of CDS software as well as aid the security community in creating content for Security Classification Guides that is useful for simulator and simulation activities.

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INTRODUCTION

In 2011, the U.S. Air Force conducted 2,251 distributed training events among its operational fighter, bomber, and C2ISR bases. These readiness training events were a product of the Combat Air Forces (CAF) Distributed Mission Operations (DMO) program. The CAF DMO program provides standards, interoperability, and network services so that simulators at operational units can link together for daily training.

Among the services provided on the DMO Network are Cross Domain Solutions (CDSs). When CAF DMO simulators operate at different security postures, a CDS is used to filter simulator data that transits dissimilar security domains. The majority of CAF DMO distributed training events are cross domain activities. Therefore, the capability and limitations of a CDS have major impacts on the quality of distributed training.

Numerous papers have been published on the technical and security policy aspects of the DMO CDSs.[1] The purpose of this paper is to explain CDS implementation from the perspective of training credibility.

A Theatrical Analogy

High fidelity simulators are real-time, complex simulations that synthesize a fictional narrative of an artificial world. Actors in this digital theater are constructive and virtual entities that spontaneously generate dialogues that reflect their character's personalities and capabilities. A human immersed in this synthetic theater might acquire knowledge and skills that are directly transferable to similar episodes occurring in real life. If so, then the theatrical experience is a credible surrogate for reality.

In this theatrical analogy, security is a censor who imposes constraints on the dialogue. He or she might prohibit certain words or phrases. In doing so, the dialogue would be different which, in turn, might alter plot development. While the censor may be sensitive to the effects of these alterations on the credibility of the performance, the censor's primary concern is assessing the overall risk of the performance. Actors may forget their parts and ad-lib an illicit line or someone not intended to be part of the production may observe a potentially compromising scene. If a censor had a magical device that could alter speech as it is spoken, substituting proscribed words with authorized synonyms, he or she would be able to mitigate some risks, perhaps even expanding the audience to whom the play may be presented.

Problem Context

Censorship is a metaphor for a problem of significant interest for simulator-based warfighter training.

The primary requirement of CAF DMO training systems is that simulators must be concurrent with their respective weapons systems. In addition to weapons system performance and cockpit fidelity, concurrency means faithfully representing the full range of capabilities and vulnerabilities. Some of these capabilities and vulnerabilities—often the ones which define the operational utility of the weapons system and upon which its tactics are developed—are classified. Restricting high-side participants to actions that conform to the lowest common security posture is not acceptable.[2] High side-warfighters would have to create and learn "dumbed-down" tactical actions. True capabilities would be absent in the synthetic battlespace.

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[1] Danner and Djahandari (2008) report on the use of a control interface used to support a coalition connection on the DMO Network. Djahandari, Archer, & Danner (2009) discussed transitioning the CDS from the test environment to operational use. Danner (2009) discusses the accreditation challenges of obtaining approvals for persistent use of the CDS on the DMO Network. Bui and Taylor (2010) discussed the operations network management and training needed to establish and control a cross domain training event. Valle (2010) discussed CDS architectures. Chapman (2010) described how security policy is used to create rule sets for implemented in CDSs.

[2] "High-side" refers to the simulators being protected by a CDS. "Low-side" refers to the simulators to whom CDS-altered information is provided.

The alternative used in the CAF DMO program is to have a CDS censor high side information. High enclave warfighters are allowed to "fly" as if they were in combat but a CDS examines the data leaving the high-side enclave before it transits to the low-side enclave. The CDS uses a software-based rule set—a dynamic censor—to determine how data elements are modified or blocked.

Problem Description

Does withholding or altering information that would otherwise be used to populate a synthetic battlespace affect the training credibility of a distributed training event?

The answer is less clear than one might assume given the widespread use of flight simulators. The primary difficulty is not security policy but the artificial and fictional nature of simulation. Simulators aren't real aircraft although many of their sub-components, such as mission system software, are derived from the same source code. While exhibiting aspects of reality—using photorealistic terrain imagery for out the cockpit visual displays or intelligence-sourced data for electromagnetic parameters—the overall composition of virtual and constructive entities is artificial and constrained by the assumptions used in the design of the mission training battlespace.

If one could compare synthetic training events with similar episodes of real events, measuring credibility would be straightforward. Validated, baseline synthetic events could be used as benchmarks for judging the effects of CDS-altered versions. The synthetic battlespace, however, is much less congruent with reality than a simulator is with an aircraft. Not only is the synthetic battlespace composed of artificial actors, it is fictional. Training and even mission rehearsal scenarios are created from assumptions of conditions and intents—complex collections of "what ifs" and "might bes"—that reflect potential or anticipated military operations.

The artificial nature of simulators and especially the fictional nature of synthetic battlespaces used in combat readiness training make direct comparison of real and synthetic environments infeasible. Another complication in judging the training credibility of a CDS-supported distributed training event is that there is not a single, all inclusive synthetic battlespace but several versions at multiple locations.

Nevertheless, the problem of assessing a synthetic battlespace is not intractable. It can be approached indirectly thorough analytical comparison and deduction. But for that one needs a framework—a conceptual model—to structure the reflective comparison between simulation and reality.

Overview

The need for this framework, its composition and application, is the major thrust of this paper. This paper is divided into five discussion sections and culminates with concluding comments. Each section ends with a short "***Lessons Learned***" which were derived from our experience in creating nearly a dozen CDS rule sets over the last decade.

Section 1 discusses training transfer and approaches used to judge simulator-based training, primarily fidelity and task similarity.

Section 2 presents a conceptual model of a warfighter and a set of assumptions needed to assert validity of simulator training. It divides the problem space into ethological and ecological considerations, roughly equated to battlespace and simulator factors.

Section 3 describes the training structure in which the CDS operates: simulators and the frequency and types of distributed training are presented.

Section 4 reviews the characteristics of the DMO Network and its Cross Domain Solutions.

Section 5 discusses the types of CDS rules that have been developed for our CDSs descriptions and the effect of these rules on training credibility.

SECTION 1
FLIGHT SIMULATOR TRAINING

Although simulators have existed as long as aircraft, they have only recently emerged as an essential training capability for operational warfighters. In the two decades bracketing the turn of this century, the technology improved enough to justify fielding high-fidelity simulators at operational bases. (Bell and Waag, 1998, Chapman and Colegrove, 2012)

Training Transfer

Another noteworthy aspect of simulators is that there is no direct evidence to prove that skills learned in flight simulators are transferred to flying skills. It is impossible to construct experiments to provide conclusive evidence that such transfer occurs. In testing pharmaceuticals, test groups as well as the experimenters are "blind;" unaware of which medications are placebos and which are real. Such an approach is not possible in aviation training. You cannot hide from the pilot the difference between a simulator and an aircraft. For this reason, human behavior data gleaned from a simulator is not equivalent to similar data obtained from "real," live data. There is, however, ample data concerning within-simulator training.

The DMO program has sponsored numerous research efforts with the Air Force Research Laboratory (AFRL) which examine within-simulator training such as tradeoffs between simulator fidelity and task performance.[3] The data demonstrates that the more one trains in a simulator, the better one becomes at operating that simulator. We assume that if performance in a simulator improves so too should performance in a real aircraft. But we can never be certain. The tasks are not exactly the same; the conditions may appear similar but are qualitatively different. The absence of important physiological stresses, proprioception stimuli, and the infeasibility of duplicating the real consequences of poor performance are major limitations to assumptions of equivalency.

Training Equivalency in a Simulator

Within the flight training simulator communities, two complementary approaches are used to address virtual-to-live training transfer. Both presume that similarity insures validity, which in turn, results in transferring skills and knowledge gained in the simulator to competency in operating the real weapons system.[4]

First is reliance on physical modeling of the cockpit and detailed computational modeling of aircraft performance and the external environment. Hence, terms such as "high-fidelity," "immersive," "full-motion," etc., are used to describe flight simulators. This approach is used by the FAA in accrediting simulators. The fundamental reference for an FAA-qualified air transport simulator is flight test data from an instrumented aircraft. The performance of the simulator is measured against data from an instrumented aircraft flying in the same configuration and executing the same profile.

It is impractical to use the same approach for fighter and bomber simulators. The potential configurations are exponentially greater and change more frequently. An airliner has one basic configuration that changes only in a 1g, stable environment during takeoff, departure, arrival, and landing phases of flight. Fighter and bomber aircraft carry external stores (weapons, fuel, sensors, etc.) whose combinations are mission-dependent and which may be released from the aircraft in multi-g, dynamic environments.

The mission space of interest is also much different. Air transport simulator components, such as the systems that generate out-the-window visual displays, are oriented to details of the takeoff, approach and landing environment, especially at night and in adverse weather. This environment is unique, limited, and highly structured with very specific attributes of interest: navigation aids, airfield lighting, runway and taxi markings, etc. For operational combat units, representing the airfield environment is a tertiary interest. The primary training focus is the joint battlespace, a notoriously unstructured and much larger area with many attributes of interest, most of which are unique to a particular scenario.

Another approach to training transfer is decomposition of the operational activity. For the DMO community, two methodologies are used. The first is task decomposition. It used in structures such as Task Training Lists (TTLs) and Mission Essential Task Lists (METLs). They are concerned with either system operation (TTLs) or unit and organizational activities (METLs). The other form of decomposition is Mission Essential Competencies (MECs), which focuses on describing the experiences in which warfighters develop the competencies needed to operate a weapons system in a hostile operational environment. MECs have been used by ACC to document and prescribe live and simulator training requirements. (Colegrove & Alliger, 2002, Bennett and Crane, 2002)

Lesson Learned - Lacking comprehensive evidence of simulator training transfer, we cannot directly investigate the effect of a CDS on the credibility of distributed training in a synthetic battlespace.

[3] Our AFRL DMO research also examined aspects of live training such as scenario design and skill retention. We have also accomplished several studies which examine the appropriate mix of live and virtual training.

[4] See Chapman, 2004, for discussion on accreditation of CAF flight simulators.

SECTION 2
WARFIGHTER CONCEPTUAL MODEL

However, we can indirectly analyze the problem if we have a suitable framework that accommodates the operational context and the characteristics of the CDS rule set. A conceptual model of the warfighter and the weapons systems can provide this framework.

Figure 1 is a model of a cognitive agent, a purposeful, goal oriented, information processing system capable of generating adaptive behavior.[5]

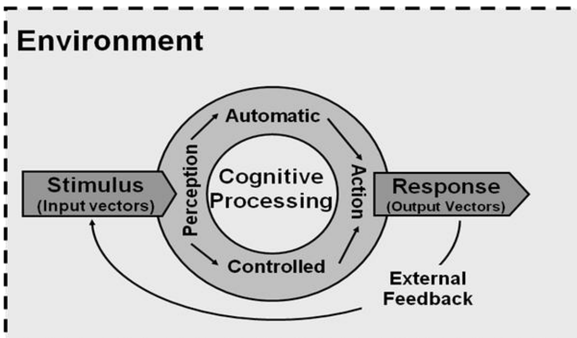


Figure 1. Cognitive Agent Model

Cognitive agents develop action schemas in competitive environments. The behaviors devised for competitive environments are produced by cognitive structures which produce adaptive responses to environmental stimuli. These stimulus-response experiences are generalized and retained in long-term memory as schemas. Schemas, through automatic and controlled cognitive processes, are used as patterns for future actions in both recognized and novel situations.[6]

Modeling the warfighter and the weapons system as a single cognitive agent provides a method to postulate assumptions about flight simulator training. Also, this approach is appropriate because in most modern aviation weapons systems, integration of the human and machine is so close that it's impractical to separate the two. It also logically separates the agent (warfighter/weapons system) from the environment (synthetic battlespace).

The real combat environment provides an incalculable level of detail about objects and activities in the battlespace. Warfighters observe and adaptively respond to these activities using tightly integrated human and system capabilities. A simulation system can neither provide all the detail nor support the entire range of human or weapons system perceptual and action possibilities. To be credible, the mission space of the simulation system (simulator and synthetic battlespace) must be designed with an *a priori* understanding of the training activity.

- Ethological credibility is the ability of the synthetic battlespace system to provide ambient activities of interest in the detail which the warfighter/weapons agent can perceive and adaptively respond.

- Ecological credibility is the ability of the simulator to provide the warfighter/weapons system agent the perceptual and action channels to observe and realistically respond to the ambient activity of interest.[7]

Necessary Assumptions for Synthetic Transfer of Training

The conceptual model and associated definitions of ethological and ecological credibility can be used to develop the assumptions needed to assert that simulator training provides credible training.

- Simulation systems can create synthetic experiences that are ethologically representative of real competitive environments.

5 "Cognitive Agent" is a term coined by the author and presented in other publications. (Chapman, 2010, 2006) This perspective of cognition as an information processing system began in the 1950's concurrently with the development of the computer. von Neumann, 1945; Newell & Simon, 1956; Newell, 1994; Anderson, et al, 2004; ACT-R, 2010) Computational modeling of cognition and human behavior is also an important research area in the military M&S community. (Gluck and Pew, 2005). Environmental factors affecting cognition and behavior in a military setting such "Naturalistic Decision Making" and "Tactical Decision Making Under Stress" are examples. (Cannon-Bowers, J. & Salas, E., 1998).

6 The adaptation component of the model rests on the research and theories of John Holland and Stuart Kauffman. (Holland, 1995; Kauffman, 1993) Schemas and patterns are consistent with Ulric Neisser (1976) and others. John Boyd's OODA loop is another source for the models recursive aspects. (Boyd, 1997)

7 Categorizing ethological and ecological concerns for synthetic training are based on the science of ethology as well as ecological validity in psychological experiments. Both the environmental and information processing perspectives of cognition are included in this conceptual model. This model contributes to discussion about the credibility of human-centered simulations because it separates the simulator from the synthetic environment. (Chapman, 2010) It is based on concepts used in human psychology for other purposes. (Eibl-Eibersfeldt, 1989; Tinbergen, 1951)

- If a simulation system is ecologically suitable, humans can develop action schemas in artificial experiences using the same cognitive mechanisms they use in real fitness situations.

- Transfer of action schemas from synthetic experiences to real situations will occur when the simulation system and the synthetic situation are ecologically and ethologically consistent.

The concepts of ethological and ecological credibility can also be used to describe the effect of individual rules which comprise a CDS rule set. This topic will be revisited in Section 5.

Lesson Learned - By altering perceptual channels or the content of the synthetic battlespace environment, a CDS can weaken or invalidate the assumptions needed to argue that simulator experiences positively influence performance in real situations.

SECTION 3
SIMULATORS AND THE DMO NETWORK

The Combat Air Forces (CAF) is an enterprise of several U.S Air Force major commands. Air Combat Command (ACC) is the lead command for the CAF. ACC responsibilities include fielding and sustaining fighter, bomber and C2 simulators for CAF operational squadrons. Table 1 lists the major simulators comprising the CAF DMO training constellation.[8]

Table 1. Major CAF Simulators and Training Systems

Air Superiority and Global Precision Attack	**Sites Active/ Planned**	**DMO Network**
A-10	4	Yes
B-1	2	Yes
B-2	1	2013
B-52	2	Yes
F-15C	3	Yes
F-15E	3	Yes
F-16C	3/6	Yes
F-22	3/5	Yes
(F-35)	0/?	Planned
Command and Control		
E-3C (Mission Crew)	3	Yes
CRC	5	Yes
JTAC/ASOS	0/24	Planned
Global Integrated ISR		
MQ-1/9	1	Planned
RC-135(Mission Crew)	3	Yes
EC 130H (Mission Crew)	3	Planned

[8] The table lists only DMO-capable training devices used at operational units. Part task trainers are not included.

Types and Magnitude of DMO Training

All of these devices provide a stand-alone, training capability and can independently create high-fidelity synthetic battlespaces for local team training. Most virtual training requirements are accomplished this way. But as many previous papers and articles have stated, some training is best conducted by linking simulators into a common synthetic training experience. (ACC, 2008; ACC, 2009). The DMO Network provides three types of events distributed training.

- The first is linking simulators of the same, or similar, weapons systems together. This category also includes training among dissimilar weapons systems when they are performing the same mission together, such as F-15Cs and F-22As. This training typically occurs in a single security enclave.

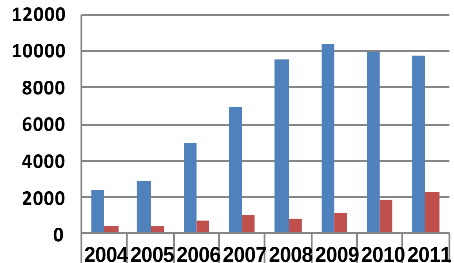
- The second is kill chain training. “Kill chain” is a term for a combat activity that is a linear segment of a larger, recursive cycle of Observation, Orientation, Decision and Action. Kill chains can be described for many different military activities. For the CAF DMO program, it means linking “shooters” to “sensors,” such as connecting F-22 simulators to the E-3C, A-10s to a ground controller (JTAC), or F-16C simulators to the E-8B. This type of distributed training usually transcends security enclaves.

- The third type is a large scale training exercise, such as Virtual Flag, which brings together many types of simulators to provide a complex training experience with multiple missions and kill chains. This type of distributed training should transcend several security enclaves, but is often conducted at the lowest common level.

Table 2 depicts the magnitude of distributed training among USAF fighter, bomber, and C2ISR units and also reflects its growth. The total time on the network has stabilized while the number of events has increased in spite of a decrease in total sites due to force reductions. A network hour is a single site on the network. Three sites conducting a 2 hour training event would be measured as 6 network hours and 1 event. (Training hours depends on the number of warfighters "flying" simulators. Most fighter units have 4 cockpits and C2 simulators can have more than a dozen crewmembers.)

This reflects the emerging preference for training in the first two categories--short duration, single mission kill chain events—and a relative decrease in the need for the large scale training events of the type described in the third category. Most distributed events among the "shooters" are supported by a CDS.

Table 2. DMO Network Activity



	2004	2005	2006	2007	2008	2009	2010	2011
Hours	2353	2868	4931	6896	9522	1040	9943	9765
Events	349	392	679	982	788	1091	1857	2251

Lesson Learned – The primary need for Cross Domain Solutions is in "Kill Chain" training. Simulators training within a specific mission area are more likely to be operating at common security posture. "Kill Chain" training, in contrast, typically requires distributed training among dissimilar weapons systems and security enclaves.

DMO NETWORK & CROSS DOMAIN SOLUTIONS

The DMO Network is available, on-demand, 24/7. The network is persistent in the sense that a connection is always available. However, sites aren't connected until immediately before an event.

Figure 2 illustrates two important attributes of the DMO Network. First, the non-intersecting rings denote that the network can conduct multiple simultaneous training events. Second, the different colored rings—red, green and yellow—can denote different security enclaves. For example, red might signify a SECRET enclave while yellow and green may indicate enclaves that have information that needs to be protected at a level other than SECRET.

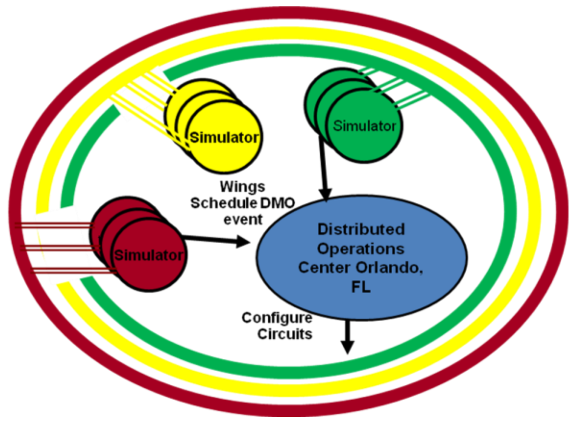


Figure 2. DMO Network

Cross Domain Solutions on the DMO Network

Figure 3 depicts how sites or enclaves connect the DMO Network. The DMO simulators previously listed in Table 1 use Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) standards. A DMO Network portal provides translation among differing protocol implementations.

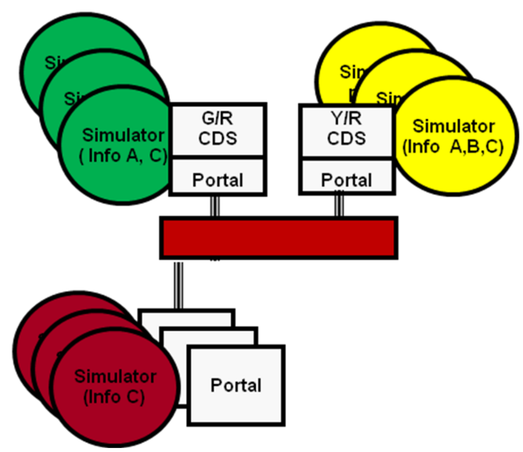


Figure 3. DMO Network Portals and CDS

To connect enclave sites operating at different colors, all the data leaving a protected enclave is examined by the CDS and reduced to a common or "low" color. (See Valle, 2010, for CDS architecture discussions.) The CDS uses a rule set to determine which data is blocked, changed, or passed unaltered.

In Figure 3, the three enclaves—red, green and yellow—have a common level of type C information.

The green enclave also has type A information which can only be shared with those sites also permitted to have information A. The green CDS will use a green-to-red (G/R) rule set to examine and manipulate, if needed, all the data leaving the green enclave to insure that type A information is protected. If there are several green sites, only one CDS will be used so that type A information can be shared within the green enclave.

The yellow enclave has type B information as well as type A. Therefore, the yellow-to-red (Y/R) rule set will contain rules to protect both types A and B information. The red enclave needs no CDS because everyone in all the enclaves are permitted have C information. One limitation of this CDS approach is that green and yellow enclaves cannot share type A information. One might think that the yellow enclave has the "big picture" because it includes type A, B, and C information. However, the yellow enclave won't receive type A information which is blocked by the green enclave CDS.

Lesson Learned – If a CDS is employed in a distributed training event, there is not a common, shared synthetic battlespace. Each enclave has a different but consistent battlespace but, in some instances, none may be comprehensive.

SECTION 5
CDS RULE SETS

The rule sets implemented in DMO Network CDSs are developed by a working group composed of individuals with expertise in simulation, simulators, security policy, and combat air operations. As depicted in Figure 4, rule sets begin with decomposition and analysis of the Security Classification Guides (SCGs) associated with an enclave.[9]

Rule Set Development

Statements of classified capabilities and vulnerabilities found in SCGs are usually insufficient for directly creating CDS rule sets. (SCGs are developed for acquisition and later modified for operational fielding—most of the information is irrelevant to simulation.) However, by carefully analyzing the content of an SCG, we can derive relevant indicators. An indicator is a simulator data artifact or synthetic battlespace behavior that could reveal a classified capability or vulnerability. Indicators are interactions among battlespace factors such as other friendly forces, adversaries, and the natural environment. For example, indicators of vulnerability might be mapped to threat behaviors or performance models.

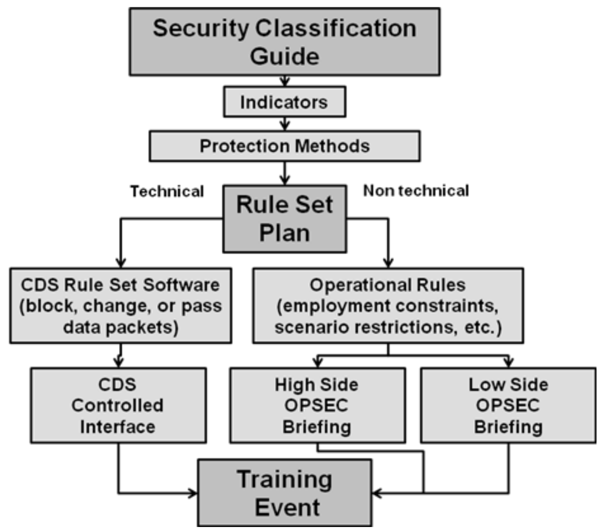


Figure 4. Rule Set Process

Each indicator is assigned at least one and usually several protection methods. A protection method can be either technical or non-technical. Technical methods are further developed into software used by the CDS to block or modify (guise) the data transmitted from the high-side simulator to the DMO network. For the previous example a technical protection for vulnerability might be to modify or block threat radar emissions data as it transits from the high side enclave to low side enclave.

Not all indicators can be protected with technical measures and other non-technical measures are not explicitly derived from the SCG, such as disposition of post-event data. Non-technical measures are the basis for the OPSEC briefings that are given to both the high- and low-side participants before a CDS-enabled training event. Non-technical protection also includes the pre- and post-event procedures for establishing and terminating a CDS-event.

The major factor in protecting classified capabilities and vulnerabilities is inference. Inferential evidence may be explicit or cumulative depending on the ease by which analysis of data elements can expose protected

9 Sec 1.4, EO 13526 defines eight categories of classified information. Besides capabilities and vulnerabilities, other types of classified information which may be found in warfighter simulators include operational plans, technical and non-technical intelligence.

information. For example, a series of positional elements provides explicit inference because flight path, velocity, and acceleration can be easily calculated.

Cumulative inference, in contrast, requires the collective examination of a large number of different data types. There are two opportunities for inference: participating or observing an event and post-event analysis. Both require consideration of multiple data types. For example, testing a hypothesis about weapon guidance mechanisms would require analysis of a large number of weapons fly-outs correlated with the position and sensor state of the launching aircraft.

Breaking the chain of presumed causality in numerous places makes cumulative inference much harder. For example, blocking the launch, fly-out, and emissions state of a radar-guided missile would make inference about the guidance characteristics of the weapon very difficult. Hence the previous statement that indicators are usually mapped to more than one protection methods.

Effects of Protection Methods

The CAF DMO program has fielded a dozen rule sets. The specific rules employed in the CDS systems for DMO are usually classified, so they cannot be detailed here. But they can be categorized in how they may affect the synthetic battlespace.

Direct effects come from protection methods that prohibit warfighter or weapons system actions or state changes. These protection methods exclude data from being received by low side training system components—simulators, threat simulations, etc. Obviously, blocking or prohibiting an action normally permitted to a warfighter or weapons system in a live environment alters the synthetic battlespace.

However, the effect on ecological and ethological credibility varies widely, from very significant to minor. If the data were essential to supporting an action or behavior that was important to the mission space design, then both forms of credibility would be jeopardized. However, not all simulator data are intended for the collective battlespace. And some data that is removed may not be observable to low side warfighters or weapons system sensors during the training event. This is often the case when data is altered to hinder post-event analysis.

Coupled refers to indirect effects resulting from rules that induce a disturbance in the content of the environment which impacts the cognitive agent's response. The environment appears normal (i.e. consistent with the mission space design) but nevertheless is distorted so that an appropriate response to the altered battlespace would be inappropriate in a real world context.

Schematic refers to indirect effects that result from warfighters attempting to understand complex causality in uncertain, dynamic situations. Developing expert-level mental schema requires extensive exposure, to similar but different experiences. Differences in conditions, progression, and outcomes are used to create complex mental maps that are retained for future use. Subtle changes in parameters and the way they are observed can alter the warfighter's mental calculus. The effect is particularly insidious because schema production continues well after the experience is over.

A schematic error occurs when real world inputs and responses are available in the synthetic battlespace but in incomplete or exaggerated form. In such cases, the conclusions drawn by the warfighter may differ from that which would have been conceived in a live setting. Hence, schematic effects are difficult to measure or observe. Nevertheless, because DMO is focused on training operational warfighters and inference is a significant risk vector, much of the rule set working groups discussion centered on complex causality.

These classes of effects are found in both technical and non-technical rules. Because a specific protection method may apply to more than one indicator, any rule may impact either the ethological or ecological validity of the simulation, perhaps both. However, broad characterization of typical CDS rules can be made that may help guide judgments of training effectiveness.

Non-Technical Protection Methods

Behavior Prohibition. These methods explicitly prohibit warfighters from performing specific actions, techniques, or procedures. Such rules have *Direct* effects on allowed activities and therefore an immediate impact to the ecological validity of the simulation.

Information Control. This type of rule is often a technical rule that restricts access to specific, protected information to the high side participants. This is a *Direct* effect that permits high side and low side crew to both train their tasks and so has a minimal effect on the ecological validity of the simulation. It may have an effect on the ethological validity of the low side depending on the degree to which that information would be observable in an equivalent scenario in the real world.

Certification. This CDS measure requires simulation vendors to assert that their modeling implementations follow conditions defined by the rules plan. Certifications have neither direct nor coupled effects; they assure the logic of the CDS rule set is functional.

Technical Protection Methods

Content Blocking. This method expressly blocks the passing of protocol information from the high side to the low side of the CDS. The effect can be *Direct, Coupled,* or *Schematic* in nature. In most DMO rule sets, they affect the synthetic environment and so may impact the ethological validity of the low side simulation systems, but usually do not affect the high side warfighters. Indirect effects may occur if low side players react differently to the distorted environment and often the choice of the implementation is made by rule developers to minimize this secondary effect.

Content Guising. This method substitutes one set of information for another in the protocol information as it passes from high to low. It's often a *Coupled* effect. The success of this method depends on the ability to make a logical substitution in the data that provides a reasonable environment to the low side training audience. When such a method is considered, the goal is usually to minimize the ecological impact by ensuring that the low side crews will react to the guised information as they would to the original content. Such an intuitive goal, however, is not certain to hold true. Secondary effects that influence the high side audience in their interactions with the low side players could impact ecological validity on both sides of the CDS. The effects are subtle, difficult to anticipate or measure, and may be impossible to correct in the simulation environment.

***Interaction Guising*.** This kind of rule seeks to represent a battlespace interaction as being of a different character than its simulated form on the high side. It is a *Direct* impact to the low side environment and will impact the ethological validity of the low side battlespace, Because of that impact, it probably will also cause the behavior of low side crews to differ from what they would exhibit in the corresponding real world scenario. In an inter-team training environment such as DMO, this will produce impacts on the high side crew interactions, thus impacting their ecological validity.

Lesson Learned – CDS rules can affect the synthetic battlespace in many ways most of which are subtly complex. The impact to training credibility cannot be measured objectively, but knowing the ecological and ethological dimensions of the mission space, rule sets can be designed to assure acceptability.

CONCLUDING COMMENTS

Because simulations can provide complex, synthetic experiences, they are accepted as useful tools for improving warfighter cognitive processes and psychomotor skills. When training a novice—a warfighter who is acquiring new knowledge, skills and experiences associated with operating his or her primary weapons system—the mode is predominantly prescriptive; novices are expected to respond in a prescribed manner to task-inducing stimuli. Flight simulators are very useful for novice training because the training setting can be precisely controlled to enable a novice to construct a basic cognitive schema for accomplishing newly-learned tasks. Simulators are also useful because they can be used to measure, mediate, and correct responses at the basic task level.

To move beyond novice and journeyman competency and achieve expert-quality performance, the training experience must be sufficiently deep and interactive so as to support the acquisition of the more abstract knowledge structures typical of experts. The shift in focus from task to the task environment for expert-level training requires a synthetic training environment of sufficient complexity to support one of the most fundamental of human capabilities—adaptation and survival in a dynamic and sometimes hostile environment. This kind of learning does not take place in a linear manner. It results from recursive and complex observations and interactions with the environment.

It is difficult to design a synthetic training environment that supports development of expert-level competency. Part of the difficulty is that a complex environment contains a bewildering collection of loosely coupled objects that create innumerable, subtle patterns of interaction. Which objects and patterns are important in developing expert-level mental schema is difficult to determine and may change over time.

The other difficulty is the lack of detailed data concerning military operations that can be used to construct or judge a similar synthetic mission space. Doctrine and history are largely anecdotal interpretations. Even if data were available, most warfighter simulator training experiences are constructed around imaginary scenarios that, hopefully, will never occur. Live training is even more constrained, especially with respect to employing lethal or expensive weapons. We believe that the quest for certainty and prediction in military simulation and training is not likely to succeed. We will continue to rely on expert opinion and investigative processes to create useful synthetic mission spaces for training systems.

CDS development relies on expertise provided by subject matter experts to determine how to shape the modifications to the simulation to protect the critical data. In doing so, they are making several implicit mappings between complex ontologies: the real world, the (usually undocumented) conceptual model of the mission space, the information space of the SCG, and the implementation space of the simulator. It is these complex, implicit mappings that make the process difficult and time-consuming, forcing the rules working groups to rely on informed intuition.

CAF DMO CDS rule sets prescribe the technical rules that are directly implemented in the controlled interface. Non-technical rules also regulate simulator implementation and limit simulated battlespace content and operator actions. Together, technical and non-technical rules protect critical information. But they also set additional boundaries on the utility of the simulation that weren't envisioned in the original design of the training system.

Does a CDS, by altering the synthetic battlespace, affect warfighter competency? Given the nature of adaptive learning and the limitations of a synthetic training experience, it is difficult to judge. A reasonable conclusion is that it depends on the specific alteration.

In the DMO program, we constructed technical and non-technical protection methods with the explicit intention of minimizing information deformation. The majority of these measures altered only low side observation of the battlespace. There are few direct effects imposed on the high side battlespace. Indirect effects are likely but given the restrictions on collecting data from CDS-enabled training events, degradation of training is a potential, but not substantiated, possibility.

Finally, one of the most important outcomes of our CDS rule set experience is the effect we have had on our designated approval authorities and data owners. Neither group—the first responsible for network connections, the second, authors of the security classification guides—have simulation expertise. Because of the success we had in inventing simulator-specific CDS rules set processes, we are now helping them shape security policy and reference documents by incorporating the concepts and terms presented in this paper. Therefore, while we may still bnot be able to directly ascertain training credibility in a CDS-altered battlespace, we have significantly improved the art and practice of distributed simulation training in a multi-level security setting.

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