A Functional Deep Dive on Two Simulations: Methodology, Results and Lessons Learned

Dr. Amy Henninger
Institute for Defense Analyses
Alexandria, VA
ahenning@ida.org

Roy Scrudder, Dennis Glover
Applied Research Laboratories
The University of Texas
Austin, TX
scrudder@arlut.utexas.edu

William C. Riggs
John Hopkins University Applied Physics Laboratory
Laurel, MD
riggswc1@jhuapl.edu

Dr. James Wall
Texas A&M Engineering Experiment Station
College Station, TX
jim-wall@tamu.edu

Karen Williams
PEO STRI
Orlando, FL
Karen.e.Williams.civ@mail.mil

ABSTRACT

The DoD has a huge inventory of models and simulation, which have many overlaps in terms of functional capabilities. In today's resource constrained environment, the DoD and the Services must make informed decisions about what models and simulations to continue to support. Thus the ability to perform functional assessments and analyses of currently fielded and planned simulations takes on great significance. In I/ITSEC 2013 Paper No. 13065 (Scrudder et al, 2013) defined an analytic framework to compare the functionality of two constructive entity-based simulations. This paper extends the work of Scrudder et al. by presenting an instantiation of that framework with data from the OneSAF simulation framework and the JCATs simulation.

Reviewing a total of 116 factors across 23 categories (e.g., entity movement, weapons effects, communications, non-kinetic effects, etc.) through a methodic approach, the researchers identified no significant differences in the functionality of 60 factors (52%). This paper and presentation will also identify the superior functional capabilities where they exist, as well as report lessons learned from the process.

This type of analysis is critical to comprehensive portfolio analysis, efficient migration to cloud-based computing paradigms, and compliance with various DoD CIO initiatives in data center consolidation and application rationalization. While this study focused specifically on OneSAF and JCATS, the framework is applicable to any simulations in the entity-based brigade and below portfolio, and the broader methodology is applicable to many classes of simulations.

ABOUT THE AUTHORS

Amy E. Henninger has developed expertise at the increasingly critical intersection of information technology, advanced analytics and the process of building strategic decisions at the enterprise-level. Currently a member of the Research Staff at the Institute for Defense Analyses (IDA), Dr. Henninger serves as the Test Director to the National Cyber Range. With a PhD in Computer Engineering and degrees in 5 fields including mathematics, engineering and management sciences, she has a broad base of analytical skills with focused expertise in advanced technology.

Roy Scrudder is the Program Manager for the M&S Information Management Group at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT). He has over 30 years experience in information systems analysis and development, concentrating the last 20 years in information management for M&S. Mr. Scrudder's professional experiences are in the areas of data management and data engineering with a specialization in metadata. He holds a B.S. in Applied Mathematics from the University of Tennessee.

William C. Riggs is a member of the Principal Professional Staff at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). He has 25 years professional experience in advanced distributed simulation and computer generated forces applications. His military background includes 20 years active and reserve service in the U.S. Army, attaining the rank of Major. He holds an M.S.F.S from Georgetown University, an M.S. in Technical Management from the Johns Hopkins University Whiting School of Engineering and a B.A in Political Science from Ohio State University.

James A. Wall is the Executive Director of the Texas Center for Applied Technology located at Texas A&M University. He has extensive experience in command and control systems, distributed simulation environments, and virtual reality applications. He holds a Ph.D. in Computer Science from Texas A&M University and an M.S. in System Technology from the Naval Postgraduate School. In 2009, Dr. Wall was designated as a Regents Fellow by The Texas A&M University System Board of Regents.

Karen E. Williams is a Chief Engineer for the Project Manager Integrated Training Environments (PM ITE) at the Program Executive Office Simulation, Training and Instrumentation (PEO STRI). She has over 30 years experience in the acquisition of M&S for the DoD. She holds a B.S in Physics from Jacksonville University and an M.S. in Engineering from the University of Central Florida.

Dennis J. Glover is a Research Scientist at ARL:UT in Austin, Texas. He has been actively involved with U.S. Army testing and training for over 25 years and has held positions in both academic and corporate environments. Areas of expertise focus primarily on instrumentation of tactical Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) communications, tactical engagement simulation systems, and data analysis. Mr. Glover holds a B.S. in Mathematics from Northern Arizona University and an M.S. in Statistics from the University of Arizona.

A Functional Deep Dive on Two Simulations: Methodology, Results and Lessons Learned

Dr. Amy Henninger
Institute for Defense Analyses
Alexandria, VA
ahenning@ida.org

Roy Scrudder, Dennis Glover
Applied Research Laboratories
The University of Texas
Austin, TX
scrudder@arlut.utexas.edu

William C. Riggs
John Hopkins University Applied Physics Laboratory
Laurel, MD
riggswc1@jhuapl.edu

Dr. James Wall
Texas A&M Engineering Experiment Station
College Station, TX
jim-wall@tamu.edu

Karen Williams
PEO STRI
Orlando, FL
Karen.e.Williams.civ@mail.mil

INTRODUCTION

The U.S DoD and Federal Agencies are faced with the a challenge common in many nations-- in today's resource constrained environment, we cannot afford to maintain redundant, overlapping capabilities. Like many types of software, this problem is evident in the huge inventory of models and simulations. These models and simulations have many overlaps in terms of functional capabilities. Decision on what simulations to continue to support and evolve must be based on sound decision based on functionality, as well as cost factors. I/ITSEC 2013 Paper No. 13065 (Scrudder et al, 2013) defined an analytic framework to compare the functionality of two constructive entity-based simulations. This paper extends the work of Scrudder et al. by presenting an instantiation of that framework with data from the OneSAF simulation framework and the JCATs simulation. While this study focused specifically on OneSAF and JCATS, the framework is applicable to any simulations in the entity-based brigade and below portfolio, and the broader methodology is applicable to many classes of simulations and can serve as a model for broader simulation portfolio assessments.

METHODOLOGY

Scoping the Effort

Scrudder et al (2013) examined a focused set of U.S. Army Brigade and Below constructive simulations and began with an examination of the full inventory of U.S. Army models and simulations used to represent tactical operations at Brigade and Below level, using a selection of entity-level simulations to evaluate their functional characteristics in depth. While the data and outcomes generated by these simulations may have operational and strategic consequences, the referent of these simulations is tactical. The studies described in this paper focused on the ability of simulations to represent tactical engagements. According to Field Manual (FM) 3-0 (Operations), [tactical] "engagements are typically conducted at Brigade level and below…executed in terms of minutes, hours, or days."

Thus, the definition of "Brigade and Below" simulations included all simulations capable of representing all the individual combatants and systems organic to a Brigade combat team at entity-level. (Scrudder, et. al., Jul 2012). Also purpose of this analysis, "entity-level" was defined as the ability to instantiate, control, and model individual soldiers and platforms. While numerous combat simulations represent individual combatants and weapons systems as aggregated groupings – occupying the same location, with the same field of view, and having the same cover and concealment posture, an entity-level simulation must be able to operate with entities dispersed in time in space, located in unique positions where appropriate (e.g., infantry and supplies occupy separate locations from their vehicles when dismounted or unloaded, but may occupy the same space as the vehicle when loaded).

With this scope, researchers used a variety of sources (e.g., DoD M&S Catalog, the Army Modeling and Simulation Resource Repository (MSRR), and stakeholder input) and identified an initial inventory of 198 distinct constructive models and simulations relevant to Brigade and Below operations. From this pool, 20 entity-level simulations shown in Table 1were identified that are capable of simulating one or more warfighting functions. Further characterization identified simulations that supported virtual, real-time 3D environments, stimulated C4ISR devices, or acted as effects servers in a distributed simulation environment or federation.

Table 1. Known Brigade and Below Entity Based Simulations

OneSAF	One Semi-Automated Forces
JCATS	Joint Conflict and Tactical Simulation
COSAGE	Combat Sample Generator
ALOTT	Army Low Overhead Training Toolkit
Athena	Athena
AWARS	Advanced Warfighting Simulation
BBS	Brigade/Battalion Battle Simulation (predecessor to WARSIM)
CBS	Corps Battle Simulation
CMS2	Comprehensive Munitions and Sensor Server
Combat XXI	Combined Arms Analysis Tool (successor to CASTFOREM)
EADSIM	Extended Air Defense Simulation
FireSim XXI	Fires Simulation XXI
IMASE	Intelligence Modeling and Simulation for Evaluation
IWARS	Infantry Warrior Simulation
JANUS	JANUS
JDLM	Joint Deployment Logistics Model
JNEM	Joint Nonkinetic Effects Model
JSAF	Joint Semi-Automated Forces
JTLS	Joint Theater Level Simulation
OTB	OneSAF Test Bed
STORM	Simulation Testing Operations Rehearsal Model
SWORD	SWORD (MASA Group)
TACSIM	Tactical Simulation
VBS2	Virtual Battlespace 2
WARSIM	Warfighter’s Simulation
WARSIM-WIM	WARSIM Intelligence Module

The second task, which is the focus of the remainder of this paper, includes a functional assessment and comparative analysis of selected simulations identified in Table 1. Given that the resources didn’t support evaluation of all of the simulations in Table 1, the study team selected two simulations (OneSAF and JCATS). These two were selected because of their prevalence of use in the US and the fact that information regarding them was easily accessible and reliable in the form of both documentation and subject matter expertise

Analytical Framework - Criteria and Scoring

The overall Functional Analysis Framework is discussed in Scrudder et al 2012 and will be summarized here. Given the framework (Scrudder et al, 2012) and the survey mechanism designed to support the framework , the study team focused on deriving objective comparisons of simulation functionality of OneSAF and JCATs. Unlike previous studies which were community-perception based measures of goodness, this study was focused on actual functionality as judged by algorithmic experts. These experts included experienced users, study team members, and experts identified by the program management offices responsible for the model. In the case on OneSAF, the program office is at PEO STRI; and in the case of JCATS, the program office is at Joint Staff J-7.

The majority of the framework was developed to provide functional comparison based on the Army Universal Task list (AUTL). This was found to be a reasonable and authoritative referent characterization of “what” a Brigade and Below simulation must simulate. Table 2 shows a small subset of the example of the AUTL. For describing the part of the framework, we focus on Stability Operations measures 7.3.1.2.4-02 and 7.3.1.2.4-03, which includes the establishment of a "safe area". In terms of simulation capability in the framework, this indicates a need for simulations to be able to follow rules of engagement (ROEs). To model brigade and below operations, the simulation allow these ROEs to be assigned to a unit or entity, but to realistically model operations, the simulation must be able to deviate from performance of the ROE behavior as conditions dictate.

Table 2. Stability Operations Task 7.3.1.2.4 Establish Protected Areas

No.	Scale	Measure
01	Yes/No	Unit surveyed and identified area.
02	Yes/No	Unit developed the rules of engagement and the memorandum of understanding for the safe area.
03	Yes/No	Unit disarmed and demobilized the safe area.
04	Yes/No	Unit was supported with information operations.
05	Yes/No	Unit established checkpoints and control measures.
06	Yes/No	Unit established a quick reaction force.
07	Yes/No	Unit planned for extraction or reinforcement.
08	Yes/No	Unit supported humanitarian efforts in safe area.

Table 3 illustrates how the Functional Analysis Framework scoring mechanism was applied in the area. In this example, the simulation function traces to the Stability Operations measures 7.3.1.2.4-02 and 7.3.1.2.4-03, which includes the establishment of a "safe area."

Table 3. Example Non-Kinetic Effects Simulation Functional Factor

11.D Adherence to ROE Q11D1 - Does the simulation account for rules of engagement? If so, how well do simulated units and entities follow the rules of engagement assigned to them? Select all that apply.	OneSAF	JCATS
R11D1 – ROE not explicitly modeled.		
R11D2 - Simulated units and entities always follow the ROE assigned by the scenario or user.	X	X
R11D3 - Simulated units or entities may deviate from assigned ROE based on automated (e.g. reactive) behaviors.		X
R11D4 - Simulated units or entities may deviate from assigned ROE based on combination of morale level and random variation.	X	
R11D5 - Other; please explain.		
Comments: OneSAF: Entities composed with dynamic side change component may spontaneously change sides and adopt enemy forces ROE.		

As this example illustrates, the subject matter experts provided comments which provide insight to the analyst, assisting in the interpretation of the discrete answer results. In this particular instance, two positive responses are recorded each for OneSAF and JCATS, indicating either complex constructive behaviors, or support for multiple methods of representing the simulated function.

For each of the assessment criteria in framework, an assessment was then made of which, if either, simulation provided more capability. In this specific example both simulation provide different capabilities beyond simply following ROEs unconditionally. Neither additional capability is clearly better, so for this factor, the simulations were rates as having "different capabilities, but advantage depends on user needs."

While implementation of AUTL tasks forms the core functional assessment criteria, there are criteria that go beyond "what" the simulation can simulate to "how" and "to what detail" it does that simulation. Table 4 provides an example of this—the modeling of articulation (moving parts) for entities. As can be seen from this table, OneSAF clearly provides more capability to support articulate models.

Table 4. Example: Entity Movement Control Simulation Functional Factor

1.A Articulation Q1A1 - Does your simulation support articulation of entities into moving parts? If so, what forms of articulation does your simulation support? Items in parentheses are examples as applicable to common simulated platform entities. Select all that apply.	OneSAF	JCATS
R1A1 - No moving parts.		X
R1A2 - Single articulated part (single body orientation).	X	X
R1A3 - Two articulated parts (main rotor-body).	X	
R1A4 - Three Articulated parts (gun-turret-chassis).	X	
R1A5 - Four to six articulated parts (torso, head, left arm, right arm, left leg, right leg).	X	
R1A6 – More than six articulated parts.	X	
R1A7 – Other; please explain. Comments: OneSAF: The simulation itself supports as many articulations as desired. Most entities have 1-3 moving parts but some have significantly more (chassis-main turret-secondary turret-main gun-pintle mounted gun, etc) JCATS: When viewed by federated 3D model has articulations—Chassis and turret orientation		X

In all, the Functional Analysis Framework covered over 23 categories encompassing 116 factors (see Table 5). Like Tables 3 and 4, each factor has a pick list for two to ten possible ratings, plus an "other" rating for which the analyst or subject matter expert could provide an explanation. A full list of the factors within each category is provided in Appendix A. A list of all the possible values far exceeds the available space for this paper. For those readers desiring to examine those factors, they can contact the first listed author.

Table 5. Categories and Factors with the Functional Analytic Framework

No.	Category	No. of Factors
1	Entity movement	9
2	Construct representation	3
3	Unit movement	12
4	Fire control	4
5	Fire distribution	6
6	Fire support coordination	5
7	Ballistics modeling	3
8	Missile flyout	3
9	Communication	7
10	Weapons effects	4
11	Non-kinetic effects	8
12	Terrain	5
13	Fuel resupply	3
14	Ammo resupply	2
15	Soldier sustainment	5
16	Equipment sustainment	4
17	Optical sensors	3
18	Imaging sensors	3
19	Radar	3
20	Acoustic sensors	3
21	Architecture	4
22	Scalability	4
23	Supportability	5

RESULTS

The data to collect and validate the data for this analysis began by soliciting inputs from the DoD organizations with primary responsibility for these simulations. For OneSAF, this was done by PEO STRI, and for JCATS, it was done by Joint Staff J7. Concurrent with those simulations, and independent analysis was conducted by a member of the analysis team, who use the most currently available simulation documentation to perform the functional analysis. The user manual-based analysis was provided to the primary responsible organizations, and in some cases resulted in a revision to the assessments they initially provided.

The evaluation of 116 factors (across 23 categories) resulted in the distribution shown in Figure 1. OneSAF provides more capability than OneSAF for nearly half of the factors evaluated, and JCATS provides more capability for less than 10% of the factors. The specific factors where each simulation provides more capability is list in Table 6. For slightly more than one third of the factors, no significant differences were noted between the two simulations. For 5% of the factors, the determination of which simulation provided the best capability would depend on the users needs. Table 6 adds detail to the precise categories/factors where one simulation was considered more capable. Table 7 lists those categories/factors where no significant difference was found between OneSAF and JCATS, either because none exists, or that no difference could be noted based on the available information. It is worthy to note that both simulations continue to evolve, so more current analysis might suggest very small differences in these numbers.

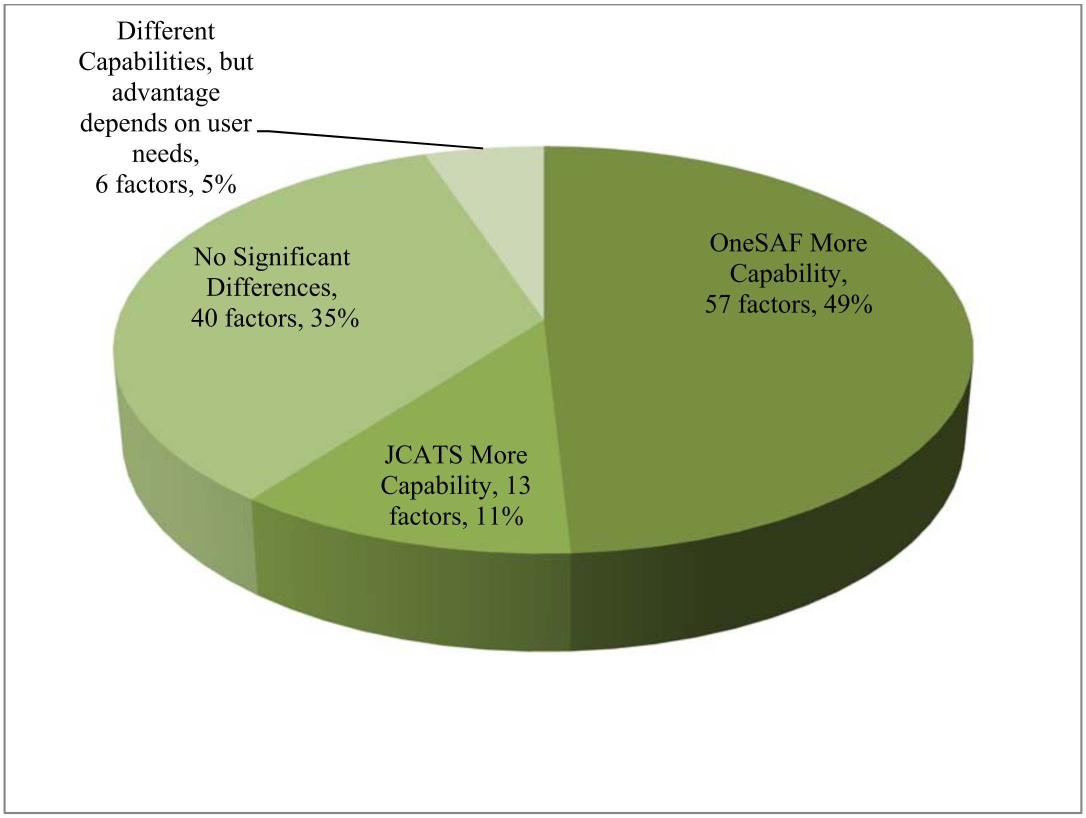

Figure 1. Results from Functional Analysis of Test Simulations (OneSAF and JCATS)

Table 6. Categories and Factors Where One Simulation is More Capable

Functions where OneSAF provides more capability	
1.A Articulation	10.A High Level Effects
1.B Motion	10.B Collateral Effects
1.C Rate of Movement	10.C Weapons Effects on Terrain
1.D Collision	10.D Impact of Atmospheric Conditions on Weapons Effects
1.E Dead Reckoning	11.A Morale Resolution
1.F Autonomy of Entity Movement	11.B Morale Effects
1.I Effects of Terrain on Entity Movement (Air)	11.C Learning Effects
1.J Atmospheric Effects on Entity Movement (Air)	11.G Non-Kinetic Effects of Terrain
3.A Movement Techniques	12.A Elevation Model Data Sources
3.B Unit Speed	12.B Feature Model Data Sources
3.C Movement Control	12.D Terrain Model Optimization
3.D Means to Specify Unit Direction	12.E Feature Data Representation
3.E Autonomy of Unit Movement	12.G Dynamic Terrain Representation
3.L Atmospheric Effects on Unit Movement (Air)	13.B Class III Status Reporting
4.A Commencement of Fire Controlled by	14.B Class V Status Reporting
4.C Effects of Terrain on Fire Control	15.B Representation of Class I Reporting
5.A Target Designation Inputs	16.A Representation of Class VII Delivery
5.C Primary Sector of Fire Designation	16.C Terrain Effects on Equipment Sustainment
5.E Terrain Effects on Fire Distribution	16.D Atmospheric Effects on Equipment Sustainment
5.F Atmospheric Effects on Fire Distribution	19.A Radar Sensor Representation
6.B Indirect Fire Mission Execution	19.C Atmospheric Effects on Radar Sensor Modeling
6.C Cooperative Targeting	20.A Acoustic Sensor Representation
7.B Terrain Effects on Ballistics Modeling	20.B Terrain Effects on Acoustic Sensor Modeling
9.A Tactical Message Modeling	20.C Atmospheric Effects on Acoustic Sensor Modeling
9.B Tactical Message Fusion	21.A Interoperability Architecture
9.C Tactical Message Transport Modeling	21.C Time Management
9.D Quality of Service Modeling	21.D Effects Adjudication
9.E Network Layers Modeled	
9.F Effects of Terrain on Communications Modeling	
9.H Contemporary Operating Environment Communications Modeling	

Functions where JCATS provides more capability
1.K Effects of Terrain on Entity Movement
2.B Aggregation
2.C Disaggregation
4.D Atmospheric Effects on Fire Control
6.A Indirect Fire Planning
7.C Atmospheric Effects on Ballistics Modeling
15.C Representation of Soldier Fatigue
15.D Terrain Effects on Soldier Performance
15.E Atmospheric Effects on Soldier Performance
18.A Imaging Sensor Representation
22.C Terrain Representation Effects on Entity Count
23.C Upgrade Time
23.F Initialization Difficulty

Table 7. Categories and Factors Where No Significant Difference Was Noted

No Significant Difference Exists	
1.D Collision	12.B Feature Model Data Sources
1.G Effects of Terrain on Entity Movement (Ground)	12.C Elevation Model
1.I Effects of Terrain on Entity Movement (Air)	12.E Feature Data Representation
2.A Echelon at Which Tactical Behaviors are Resolved	12.F Urban Terrain Representation
3.B Unit Speed	12.G Dynamic Terrain Representation
3.D Means to Specify Unit Direction	13.A Class III Representation
3.F Terrain Features that Effect Unit Movement (Ground)	13.B Class III Status Reporting
3.G Effects of Terrain on Unit Movement (Ground)	14.A Class V Representation
3.H Atmospheric Effects on Unit Movement (Ground)	14.B Class V Status Reporting
3.I Effects of Terrain on Takeoff and Landing	15.A Class I Representation
4.B Fire Termination Control	15.B Representation of Class I Reporting
5.A Target Designation Inputs	15.C Representation of Soldier Fatigue
5.B Target Deconfliction	16.A Representation of Class VII Delivery
5.D Secondary Sector of Fire Designation	16.B Representation of Class VII Repair
6.A Indirect Fire Planning	16.C Terrain Effects on Equipment Sustainment
6.B Indirect Fire Mission Execution	16.D Atmospheric Effects on Equipment Sustainment
6.C Cooperative Targeting	17.A Optics Representation
7.A Ballistic Munitions Flight Path Representation	17.B Terrain Effects on Optical Sensor Modeling
7.B Terrain Effects on Ballistics Modeling	17.C Atmospheric Effects on Optical Sensor Modeling
7.C Atmospheric Effects on Ballistics Modeling	18.A Imaging Sensor Representation
8.A Missile Munitions Flight Path Representation	18.B Terrain Effects on Imaging Sensor Modeling
8.B Terrain Effects on Missile Fly Out Modeling	18.C Atmospheric Effects on Imaging Sensor Modeling
9.A Tactical Message Modeling	20.B Terrain Effects on Acoustic Sensor Modeling
10.B Collateral Effects	21.B Time Representation
10.C Weapons Effects on Terrain	21.C Time Management
10.D Impact of Atmospheric Conditions on Weapons Effects	22.D Atmospheric Representation Effects on Entity Count
11.D Adherence to ROE	23.A Installation Time
11.E Side Definitions	23.B Installation Difficulty
11.F Adherence to Side	23.D Upgrade Difficulty
11.G Non-Kinetic Effects of Terrain	23.F Initialization Difficulty
11.H Non-Kinetic Effects of Atmosphere	

Available Information Did Not Indicate a Significant Difference
1.H Atmospheric Effects on Entity Movement (Ground)
1.J Atmospheric Effects on Entity Movement (Air)
3.C Movement Control
3.J Effects of Terrain on Flight Altitude
3.K Effects of Terrain (Aerial Obstructions)
3.L Atmospheric Effects on Unit Movement (Air)
4.A Commencement of Fire Controlled by
5.C Primary Sector of Fire Designation
5.E Terrain Effects on Fire Distribution
5.F Atmospheric Effects on Fire Distribution
6.D Terrain Effects on Fire Support Coordination
6.E Atmospheric Effects on Fire Support Coordination
8.C Atmospheric Effects on Missile Fly Out Modeling
9.A Tactical Message Modeling
19.B Terrain Effects on Radar Sensor Modeling
20.A Acoustic Sensor Representation
21.E Attribute Ownership
22.A Entity Count Limits
22.B Supportable Terrain Database Load
22.C Terrain Representation Effects on Entity Count

SUMMARY AND CONCLUSIONS

As the title of this paper suggests, the available methodologies for the comprehensive, accurate and objective characterization of Army constructive simulations are evolving and will continue to evolve as both the Current Operational Environment changes and as simulation technology improves. It is the authors' contention that the assessment methods described in this paper have broader applicability to a range of government and commercial simulation tools relevant to tactical simulation of current and future operations.

CIOs, on behalf of the DoD Components and Agencies they serve, are under great pressure to rationalize their application portfolios, consolidate their data centers, and migrate their portfolios to the cloud. Given that M&S across the Department is roughly as big of an investment as IT across the Department, it makes great sense that the efficiency initiatives applied to IT applications may also be applied M&S applications, particularly in a time of austere budgeting challenges and federal mandates. The results of this small pilot study suggest that there is significant saving to be accomplished through the reduction of unnecessary functional redundancy in simulations of the same genre. Multiply these results by the fact that, in the Army alone, there are at least 24 other simulations of that genre (see Table 1), and it isn't difficult to appreciate the potential in cost savings through a better managed approach to developing, converging and retiring simulations.

REFERENCES

Headquarters, Department of the Army, (HQDA) (2008) "Operations," Field Manual 3-0, February 27, 2008, pp. 4-3 to 4-8, 6-3.

Headquarters, Department of the Army, (HQDA) (2009) "Army Universal Task List," Field Manual 7-15, February 27, 2009.

Joint Staff (2009), "PDF version of Approved Universal Joint Task List (UJTL) Database," Washington, D.C., January 25, 2009.

Scrudder, R., Glover, D., Riggs, W., Morse, K., Henninger, A., and Wall, J. (2013). **"**Functional Analysis of Army Constructive Simulations: A First Step in Evolving Approaches". In Proceedings of Interservice / Industry Training, Simulation, and Education Conference (I/ITSEC) 2013. Orlando, FL.