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RESEARCH PLAN DEVELOPMENT FOR MODELING AND SIMULATION OF MILITARY OPERATIONS IN URBAN TERRAIN

Thomas M. Cioppa
John B. Willis
Niki Deliman Goerger
Lloyd P. Brown

U.S. Army Training and Doctrine Command Analysis Center
Monterey, CA 93943, U.S.A.

ABSTRACT

The transformation of the US Army to the Objective Force will rely heavily upon the use of modeling and simulation (M&S) for analysis, including assessment of our ability to fight in urban environments. Current model research for military operations in urban terrain (MOUT) is disjoint. Current models are judged to be insufficient as a foundation for simulation of urban operations. The Army Model and Simulation Office (AMSO) has formed a Focus Area Collaborative Team (FACT) to address these issues. The MOUT FACT directs all future urban operations modeling efforts to ensure that new simulations credibly depict MOUT. The MOUT FACT employs a top-down approach designed to (1) identify the best urban M&S projects that will address prioritized deficiencies and (2) identify potential collaboration opportunities. This paper details the methodology employed by the MOUT FACT to develop the urban M&S research plan and the results of its efforts to date.

1 INTRODUCTION TO FACTS

The Army Model and Simulation Office (AMSO) designed Focus Area Collaborative Teams (FACTs) as Army-wide focus groups used to research, identify, and coordinate simulation technology projects in specific Army Transformation high-payoff areas. FACTs emphasize the cross-domain collaborative teaming arrangements in developing an enterprise approach for their areas. This approach is modeled after the two Integrated Product Teams (IPTs) that currently exist: the Environmental Database IPT, and the Simulation to Command, Control, Communications, & Computers Interoperability Overarching. AMSO has currently formed FACTs for these areas: Military Operations in Urban Terrain (MOUT); Logistics; Command, Control, Communications, Computers, Intelligence, Surveillance & Reconnaissance; and Space.

A FACT is expected to be a body of expertise in a given area, and to develop the Army road map for investment in M&S technologies and enablers for its focus area. The FACT approach should identify M&S technology needs and ensure duplication is avoided. Furthermore, a FACT will support the Program Objective Memorandum process by providing the information needed for substantiating elements of a program and providing the evidence to the Program Element Group that the funding is not duplicative. The remainder of this paper explains the process and approach used.

2 MOUT FACT CONCEPT

The US Military's involvement in urban operations has escalated significantly over the past several years. Though modeling and simulation (M&S) has played a large role in the development and refinement of Army tactics, techniques and procedures, current model research MOUT is fragmented and inadequately resourced (FM 3-06, 2002). Core physical models are judged to be insufficient as a foundation for simulation of urban operations. To combat the deficiencies, AMSO formed a FACT. The MOUT FACT will direct all future urban operations modeling efforts, ensuring that new simulations credibly depict military operations in urban terrain. Coordinated, coherent Army research for urban M&S will reside in three main areas: Physical models, Terrain, and Behaviors. The overall purpose of the FACT is to ensure that a prioritized plan of research for urban M&S is formulated, documented and published.

There are several characteristics that define urban operations and make them far different than operations on less restrictive terrain. These differences include short ranges of intervisibility, the presence of man-made structures, multidimensional battlespace, difficult target identification in limited engagement areas, restrictive maneuver space, toxic industrial material, and the presence of non-combatants. Emerging models and simulations must accu-

rately portray these factors if they are to support the requirements of the three M&S domains: Advanced Concepts and Requirements; Research, Development and Acquisition; and Training, Exercises, and Military Operations (*SMART*, 2000).

Through numerous Subject Matter Expert groups, the MOUT FACT annually publishes a research plan that explicitly defines the research tasks to be accomplished in specific areas of simulation modeling for MOUT. The MOUT FACT employs a top-down approach designed to identify priorities, eliminate redundancy, and encourage collaboration. The MOUT FACT's business plan facilitates shared research from credible sources. Research tasks will result in demonstrable products with explicitly defined data requirements.

The MOUT FACT organizational structure contains the following elements:

- Program Coordination Team (based at Training and Doctrine Command Analysis Center - Monterey)
- Executive Committee (ExCom)
- Advisory Committee (AdCom)
- Distribution and Contact List

The Program Coordination Team serves as the point of contact for all MOUT FACT related activities and is responsible for overall management of the effort to include the monitoring of funded project deliverables. The ExCom conducts formal evaluation of proposals and holds voting privileges to define and prioritize the recommended research projects. The non-voting AdCom reviews proposals and provides subject matter expertise and feedback to the ExCom. The Distribution and Contact List receives MOUT FACT information traffic to stay abreast of the process and results. All four of the MOUT FACT organizational elements assist in defining the shortfalls and requirements for MOUT representation in M&S.

A joint Army/USMC Terms of Reference (TOR) document defines the authority, vision, purpose, responsibilities, products and leadership support for the MOUT FACT. The following senior decision makers approve the TOR: the Director of AMSO, the US Army Training and Doctrine Command Deputy Chief of Staff for Simulations and Analysis, the Deputy Undersecretary of the Army for Operations Research, the Department of the Army G3 Director of Analysis, and the Commanding General of the Marine Corps Combat Developments Command (MCCDC). The TOR identifies the MOUT FACT as a priority component of the Army Simulation and Modeling for Acquisition, Requirements and Training Execution Plan and assigns co-chairmanship of the effort to the TRADOC Analysis Center (TRAC) and MCCDC (*SMART*, 2000).

The MOUT FACT performs an assessment of deficiencies in urban M&S; establishes and prioritizes the needs and requirements of the M&S community with regard to urban representation; solicits, receives and evaluates urban M&S proposals; provides a recommended prioritized list of projects for funding; and provides oversight of the funded projects.

3 MOUT FACT METHODOLOGY OVERVIEW

The MOUT FACT process employs a top-down approach that (1) addresses prioritized deficiencies and (2) identifies potential collaboration opportunities. The goal is to promote shared, collaborative research from credible sources and subsequently eliminate duplicate efforts. Each research task will result in a demonstrable product with explicitly defined data requirements. The two major products provided by the MOUT FACT are a published, coherent research plan and a prioritized list of recommended projects to be funded based on that research plan.

There are four major stages the MOUT FACT uses to achieve its goals. These stages are shown in Figure 1 (the Roman numerals to the left of the flow chart indicate the stage).

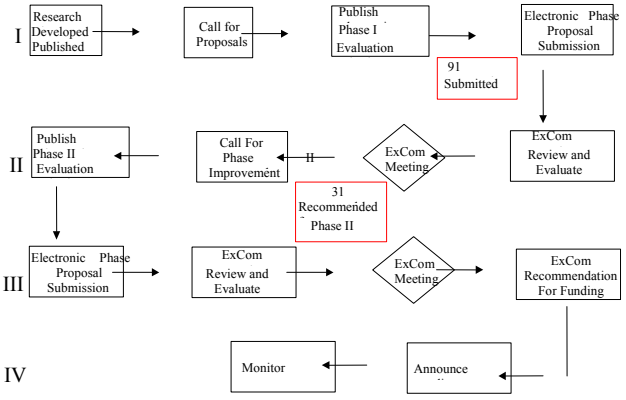

Figure 1: MOUT FACT Methodology Highlighting the Four Major Stages

The first stage includes identification and assessment of urban M&S areas requiring improvement. These areas include indirect and direct fires, search and target acquisition, tactical communications, acoustics, signal intelligence, radar, mobility, opposition forces and noncombatants, and human and organization behaviors. Within each of these areas, specific subtopics or needs are identified. To develop a slate of research projects designed to address deficiencies identified in the research plan, a two-phased proposal process is employed. In Phase I, the MOUT FACT identifies the requirements and then queries the community to submit proposals that address these requirements. A web-based management system is used to accept and evaluate proposals.

During the second stage, proposal evaluation is conducted. Each member of the ExCom is assigned a set of proposals to review through the web-based system (no member is assigned a proposal from their parent organiza-

tion). The proposals are also reviewed by the AdCom members who provide their professional judgment to the voting ExCom members. The evaluation criteria focus on the critical issues of Army/US Marine Corps/Department of Defense relevance, feasibility of approach, technology transfer, supportability of data requirements, risk, reasonableness of timeline, and return on investment. Statistical cluster analysis of the results is conducted and presented to the ExCom. From this information, the ExCom members meet in small groups to assimilate this collected data and prioritize their subset of proposals into one of three ordinal categories. This new information is melded into the first cluster analysis to generate a revised set of clusters. A detailed exploration and discussion of the analysis assists to achieve a consensus as to which proposals should be further considered. The ExCom voting process yields a final product: a list of projects to move on to the next phase. The ExCom provides the selected proposing agencies feedback to improve proposals, identifies possible collaboration between agencies, and provides directions for further literature review.

The third stage consists of a second set of submissions and review of proposals. The proposing agencies submit (again electronically) their revised proposals (based on feedback from the ExCom). The ExCom and AdCom then review the proposals and then conduct a second meeting to finalize the prioritized list of the remaining proposals. This list is cross-walked against the research areas and subtopics, thus ensuring there is a coherent linkage between what is being requested for funding and the actual requirements.

The fourth stage consists of presenting the prioritized list and research plan to the senior decision-makers responsible for the funding. Once funding is identified, the MOUT FACT monitors the progress of the projects to ensure milestones are satisfied and the deliverables match the original proposal.

The following sections will explain the MOUT FACT process in greater detail.

4 MOUT FACT METHODOLOGY – STAGE I

The first stage of the MOUT FACT process starts with the identification of agencies and individuals with urban M&S expertise who can serve as members of the MOUT FACT ExCom and AdCom. Next, subject matter experts are employed to identify and assess the critical urban M&S areas requiring improvement.

The Army Materiel Systems Analysis Activity published a series of white papers that assessed the Army's current models and their ability to represent operations in urban environments. The white papers evaluated the identified MOUT M&S focus areas. Each focus area was evaluated in three categories: basic knowledge, algorithms, and data. Each area was rated as Red (poor), Yellow (needs improvement) or Green (adequate). Table 1 provides an overview of the ability of current models to represent urban operations in the focus areas.

Table 1: MOUT FACT Focus Area Assessment

Focus Area	Basic Knowledge	Algorithms	Data
Indirect Fire	Green	Green	Yellow
Tactical Communications	Yellow	Yellow	Yellow
Mobility	Yellow	Yellow	Red
Direct Fire	Yellow	Yellow	Red
Wide Area Surveillance	Red	Red	Red
Search & Target Acquisition	Red	Red	Red

The following project areas have been identified as research tasks that must be completed to better our representation of indirect fire effects in an urban environment, 1) damage assessment to buildings and contents of buildings, 2) effects of object masking to blast and fragment damage of tactical targets, and 3) methodology for assessing collateral damage caused by engaging tactical targets in an urban environment.

Models are required to predict propagation loss of radio waves in an urban environment. Models are also needed to predict performance of the links in a network (e.g. bit-error rate) as well as the performance of the network itself (message completion rate and delay). Terrain representation is the biggest shortfall in the Army's current terrestrial propagation models. The Terrain Integrated Rough Earth Model uses a two-dimensional representation of terrain and multi-path effects (Sciandra, 1990). This works well for open terrain, but does not support the three-dimensional complexities of an urban environment. There is a high potential for reflections/multi-path from buildings that may not be adequately represented in a two-dimensional model. The same is true for satellite propagation modeling. Man-made features such as buildings, towers, and overhead wires will affect the attenuation, scattering, and multi-path fading/interference of satellite-to-ground links. Our current two-dimension models do not support urban phenomenology.

Cognitive or situational awareness modeling and human factor performance is lacking in many areas of the warfighting M&S environment. Maneuvering through urban terrain with the ability to recognize urban operational situations as they occur is limited and simple in design and application in current M&S. The ability to determine the effects of conventional weapon attack on an urban terrain is lacking and the ability to recognize obstacles and make complex decisions for alternative maneuvers around obstructions is all but absent. With these very critical concepts missing from the simulated warfighting environment, it is difficult to evaluate the effectiveness of new urban tactical doctrine or realistic consequences of battlefield decisions.

The current algorithms used in MOUT modeling for direct fire effects are normally the same algorithms used in open terrain modeling, but without the required changes necessary to accurately represent operations in urban areas. The tasks required to support clearing buildings and hallways or subterranean areas in MOUT should be similar to the clearing of caves and tunnels in the open environment, however these tasks have not been addressed in the open terrain modeling. Military M&S lacks many of the tools needed to simulate operating in and around buildings, as well as the data required to drive the tools. Proper entry and exit from a structure (i.e. opening and closing of doors), deformable surfaces, effects of non-lethal weapons, collateral damage, and extremely short-range engagements are just a few of the direct fire modeling challenges that have been identified. The data necessary to support the development of new tools is lacking due to a lack of experiments conducted in an urban setting. The development of urban test facilities is a requirement that has been identified but is slow to progress.

Wide Area Surveillance can be considered in three sub-focus areas: Radar, Acoustics, and Signal Intelligence.

For radar, there are two models that can be used for generating detection probabilities for air defense and counter battery acquisition in MOUT scenarios. Two military simulations, CASTFOREM and ATCOM, both have the Detect algorithm imbedded in them to allow detection of radar target pairings (*CASTFOREM*, 2001 and *ATCOM*, 1998). Neither model, however, accounts for multi-path conditions that would arise in an urban setting. There are currently no models that could be used in a MOUT environment for imaging or smart munitions.

The Acoustic Battlefield Aid model has been identified as one of the Army's primary tools for modeling acoustics due to its physics-based acoustics methodologies, availability of supporting data,, and ease of use (Wilson, 2000). Though it provides a highly flexible capability for item-level acoustic detection data for traditional open-terrain environments, there are a number of shortcomings when applied to MOUT. Urban effects on acoustic transmissions have not been properly researched and no approved propagation algorithms have been developed. Acoustic signatures, acoustic receivers, weather, background noise, terrain, and urban propagation are all shortcomings of our current models that must be addressed before application in urban terrain. There is a considerable amount of on-going work to improve acoustics models, but very little is being done to address the challenges of an urban setting.

The Link Budget Signal Intelligence model calculates the probability of detection versus range for single emitters and receivers. The model does not consider terrain, signal multi-path, structural attenuation, multiple emitters or multiple lines of sight, all of which are needed for urban terrain. The only condition that is considered for MOUT is background noise.

The Army's current standard algorithm for Search and Target Acquisition is the ACQUIRE model (*ACQUIRE*, 1995). Two obstacles exist in applying it to MOUT scenarios. ACQUIRE has not been calibrated/developed for engagements made within 200 meters. The reason for this lies in the anatomy of the eye. During urban conflict, 80% of all engagements are made within 100 meters. During most of these, the retinal image of the target is larger than the fovea of the eye. The ACQUIRE algorithm was developed for retinal image sizes that are smaller than the fovea, and generally, greater than 200 meters away. The second obstacle lies in data. There are many unique considerations for MOUT that have not been addressed or captured in the form of usable data.

The bottom line is that the ACQUIRE algorithm is likely adaptable for MOUT scenarios, but the challenges a MOUT environment represents must be addressed first. Search, cues, shadows rules of engagement, tactics, individual vs. crew performance, and multiple targets are all issues that have not been addressed to date.

To develop a slate of research projects designed to address deficiencies identified in the research plan, a two-phased proposal process is employed. In Phase I, the MOUT FACT identifies the requirements and then queries the community to submit proposals that addressed these requirements. The call for proposals is distributed throughout the M&S community through email, announcements in publications, and through the AMSO MOUT FACT Reflector (an electronic bulletin board and newsgroup). The MOUT FACT established a website <https://www.moutfact.army.mil> to support the proposal submission process and the site is also used by the ExCom/AdCom for proposal review and evaluation. Additionally, the website provides information and white papers about research focus areas, a calendar of MOUT FACT events of interest, a professional reading list, and links to MOUT related sites.

In the Fiscal Year 2003 (FY03) MOUT FACT process, there were 91 proposals received during the Phase I call for proposals indicating an enthusiastic response. Furthermore, the proposals covered the spectrum across the different areas and subtopics.

5 MOUT FACT METHODOLOGY – STAGE II

During the second stage, the ExCom methodically evaluated the Phase I proposals. AdCom members reviewed the proposals and provide feedback to the voting ExCom. Due to the overwhelming response during the FY02 process, each member of the ExCom was assigned 15 proposals to review (no member was assigned a proposal from their parent organization). Thus, each proposal was reviewed by

at least three ExCom members. The criteria used for the Phase I evaluations included:

- Scientific/technical merits of the project,
- Relevance to the MOUT Research Plan,
- Technology transfer,
- Targeted user/simulation,
- Sound technical approach,
- Feasible schedule of milestones and deliverables,
- Identified supportable data requirements, and
- Reasonable cost estimates

A statistical cluster analysis of the results was performed and presented to the ExCom at a coordinated meeting. For the FY03 process, this meeting was held in August 2002 in Monterey, CA. Using the initial cluster analysis, the ExCom separated into small groups to assimilate the data and prioritize a subset of proposals into one of three ordinal categories (high, medium, low). This new information was melded into the first cluster analysis to generate a revised cluster. The ExCom then met in a large group session and a detailed exploration and discussion of the cluster analysis was performed in order to achieve a consensus as to which proposals should be further considered. In the FY03 process, there were 31 proposals recommended to move on to the next phase.

6 MOUT FACT METHODOLOGY – STAGE III

The third stage took place following the ExCom/AdCom review of the selected Phase I proposals. Suggestions to improve proposals, identification of possible collaboration between agencies, and directions for further literature review were provided to the proposing agencies. These agencies then submitted (again electronically) their revised proposals (based on feedback from the ExCom). Representatives from several emerging simulation development teams also reviewed the proposals to provide further insight as to the likelihood of technology transfer and the value of projects to their particular simulation package. For the FY03 process, these representatives came from the following programs: OneSAF Objective System (*OneSAF*, 2001), Combat^{XXI} (*COMBAT^{XXI}*, 1998) and the Integrated Unit Simulation System (*IUSS*, 2001). The ExCom then reviewed this second set of proposals using a revised set of four key criteria. For the FY03 process, all ExCom members evaluated each of the selected 31 Phase I proposals. The criteria used by the ExCom for this second evaluation included relevance (linkage to Transformation, Objective Force, Homeland Security, etc.), technology transfer, return on investment, and risk. A second ExCom meeting was held to review the evaluation results and selected a final prioritized list of projects for recommendation to decision makers. Again, the ExCom employed statistical cluster analysis as a tool to aid in the prioritization. This list is cross-walked against the research areas and subtopics, thus ensuring there was a coherent linkage between what is being requested for funding and the actual requirements.

Figure 2 shows the results of the FY03 MOUT FACT process in terms of focus topic areas and number of proposals.

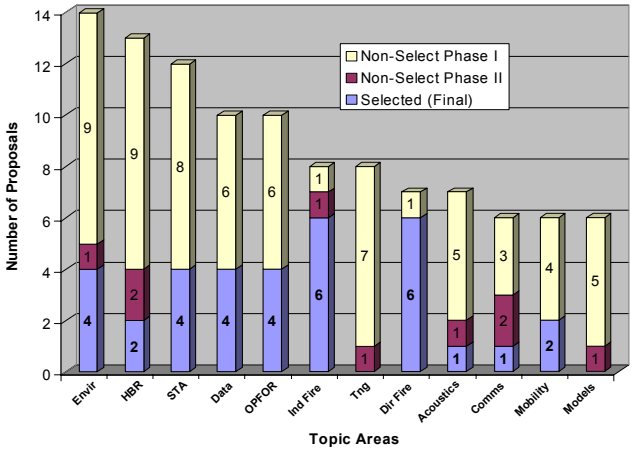

Figure 2: MOUT FACT Results for FY03 by Topic Areas

7 MOUT FACT METHODOLOGY – STAGE IV

During the fourth stage, the MOUT FACT ExCom presented the prioritized list and research plan to the senior decision-makers responsible for project funding. Once available funding is identified and a final list of projects are selected, the MOUT FACT monitors the progress of the projects to ensure milestones are satisfied and the deliverables match the original proposal. To date, at least six of the recommended proposals have been funded in excess of $2 million.

8 SUMMARY AND LESSONS LEARNED

To date, the MOUT FACT concept and methodology have proven successful. The MOUT FACT has met the overall intent to identify requirements for improving the modeling and simulation of urban operations. The requirements have been established and the substantial number of proposals is one indicator that the process has merit. There are some initial lessons learned that will assist the FACTs as the process continues to evolve. These include:

- The composition of the FACT ExCom and AdCom should be periodically reviewed.
- A web-based submission and evaluation process works well, especially with a large number of proposals.
- It is crucial to design and incorporate a database collection procedure into the web-based submission and review processes to facilitate analysis of results.

- Ensure rating scales (e.g., 1 to 5) are tied to specific and measurable objectives for the review process. Furthermore, ensure the assessment of the proposals is done systematically and objectively.
- The use of individual assessment, then small groups, followed by a large group discussion of proposals is effective in helping to achieve consensus and properly identify proposals of merit.
- The important criteria for assessing proposals included relevance, return on investment, technology transfer to existing simulations, and risk.
- The consideration of multi-year proposals is important is establishing a research program.
- A two-phased proposal call (to strengthen proposals and increase collaboration) shows merit.
- We received and consider it imperative to have the support of senior decision-makers.

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AUTHOR BIOGRAPHIES

THOMAS M. CIOPPA Ph.d., is a Lieutenant Colonel in the US Army and is currently the Director of the Training and Doctrine Command Analysis Center - Monterey. He earned his Ph.D. in Operations Research from the United States Naval Postgraduate School. His email address is <tom.cioppa@trac.nps.navy.mil>.

JOHN B. WILLIS is a Major in the US Army and is currently an operations research analyst with the Training and Doctrine Command Analysis Center - Monterey. He earned his Master of Science in Systems Engineering from the University of Virginia. His email address is <john.willis@trac.nps.navy.mil>.

NIKI DELIMAN GOERGER Ph.d., is a research engineer with the Mobility Systems Branch, Engineer Research and Development Center. Her expertise is in operations research and modeling & simulation. She earned her Ph.D. in Industrial Engineering from Texas A&M University. Dr. Goerger is currently serving as the ERDC liaison to the US Army TRADOC Analysis Center - Monterey where she works as part of the Military Operations in Urban Terrain Focus Area Collaboration Team program coordination team. Her email address is <niki.goerger@trac.nps.navy.mil>.

LLOYD P. BROWN is a Major in the US Marine Corps and is currently the Marine Corps Representative at the Training and Doctrine Command Analysis Center - Monterey. He earned his Master of Science in Operations Research from the United States Naval Postgraduate School. His email address is <lloyd.brown@trac.nps.navy.mil>.