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REPRESENTATION OF URBAN OPERATIONS IN MILITARY MODELS AND SIMULATIONS

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ABSTRACT

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 for military operations in urban terrain (MOUT) is fragmented and inadequately resourced. Core physical models are judged to be insufficient as a foundation for simulation of urban operations. To combat our deficiencies, the Army Modeling and Simulation Office (AMSO) has formed a Focus Area Collaborative (FAC) Team. The Urban Operations FAC Team will direct all future urban operations modeling efforts, ensuring 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 FAC Team is to ensure a coherent plan of research for urban M&S is formulated, documented and published.

1 INTRODUCTION

The first step toward addressing and, ultimately, solving the shortfalls in the representation of urban operations in our simulations was to conduct a thorough analysis of current model capabilities. The Army Material Systems Analysis Activity (AMSAA) evaluated the Army's legacy simulations in the areas of direct fire, indirect fire, mobility, search and target acquisition, tactical communications and wide area surveillance. Each study area was broken down and evaluated in their levels of knowledge, algorithms and data. The outcome of the performance assessment was, to no surprise, that our current simulations lacked in all performance areas for representation of urban operations. Sixteen out of eighteen assessment areas rated in the Needs Improvement or Poor categories. Had the assessment been expanded to other focus areas, the results, most likely, would have been even less favorable.

To combat our deficiencies, the Army Modeling and Simulation Office (AMSO) has assigned a single program coordinator to take charge and develop a plan. The Training and Doctrine Command's (TRADOC) Analysis Center (TRAC) in Monterey, California (TRAC-Monterey) is formulating, documenting and publishing a coherent research plan to help guide the modeling and simulation community better represent urban operations. Based on the AMSAA assessment of our current simulations, the urban operations Focus Area Collaborative (FAC) Team, through numerous subject matter expert (SME) groups, is publishing a research plan that explicitly defines the research tasks that need to be accomplished in specific areas of simulation modeling for MOUT. It is a top-down, vice solicited, approach that is designed to identify two or more agencies doing similar work. Rather than competing for the same funding, the urban operations FAC Team's business plan facilitates shared research from credible sources. Each research task will result in a demonstrable product with explicitly defined data requirements.

Research will be conducted in one of three main areas: Physical modeling, Terrain/Synthetic Natural Environments (SNE) and Behaviors. The SMEs will form competent research project teams with experience in urban operations or modeling in urban environments. The criteria for participation on such a project team requires knowledge as a coder or algorithm developer, knowledge acquisition at the workbench and completion of selected readings, chosen to educate all participants in current urban issues. Groups are organized to create, rework or evaluate proposals, provide verification and validation (V&V) guidelines and evaluate deliverables.

With a concentrated effort in the improvement of the representation of urban and complex environments in the Army's legacy and objective simulations, we can overcome many of our deficiencies. Following a published research plan that is revised and reevaluated annually will allow top programmers to work together in the most efficient and economical manner. Though it may take a number of years, having a research plan that is formulated, documented and published throughout the M&S community, we can produce a series of products that will ultimately benefit our leaders and decision makers.

2 SCOPE

The spectrum of urban operations can be broken down into four operational types: offensive, defensive, stability and support. Within each type there lies a wide range of operational concepts. For example, stability operations may include noncombatant evacuation, peacekeeping, humanitarian and civic assistance, security assistance, counter-drug support, insurgent support, combat of terrorism or show of force. Figure 1 provides a list of the full spectrum of operations.

The enemy's actions during each type of operation determine the operation's conditions. Surgical operations most closely resemble policing actions. They are the least destructive and involve small-scale seizures, arrests and special purpose raids. Precision operations normally involve combat action under restrictive rules of engagement (ROE). Combat actions can be very violent but last for short periods of time. The number of noncombatants or political considerations for the area of interest governs the degree of intensity. Operation Restore Hope in Somalia is a recent example of a precision urban operation. The High-Intensity Urban Operation is the most combat intensive. Combat occurs against an enemy in prepared positions or conducting planned attacks. Defeat of the enemy will be done by whatever force is deemed necessary to accomplish the mission.

Though the United States military has participated in most, if not all, of the above mentioned operations, our models and simulations do not accurately depict urban operations. Our core physical models are judged to be inadequate as a foundation for the simulation of MOUT.

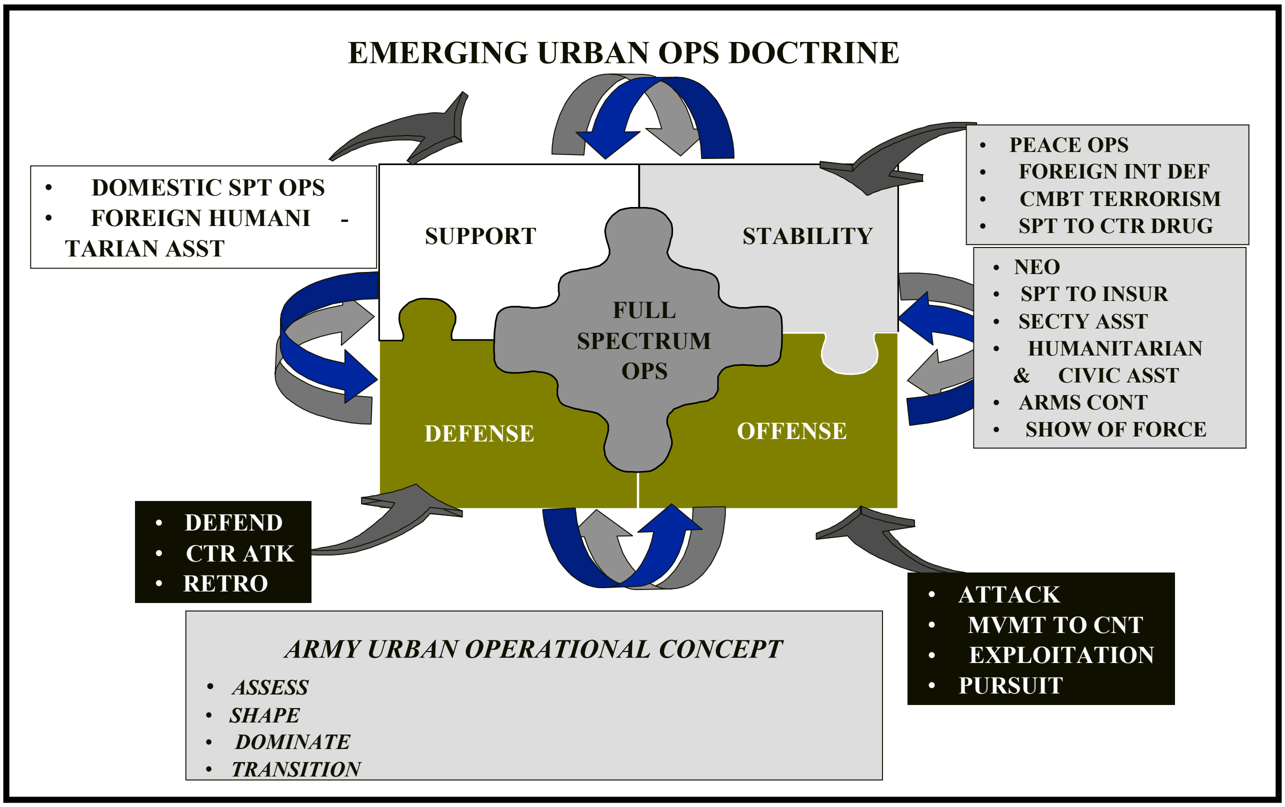

Figure 1: Spectrum of Operations/Operational Concept (FM 3-06.11 Coordinating Draft)

3 THE FACT PROCESS

The Focus Area Collaborative Teams are comprised of subject matter experts from a variety of fields. Each field falls under one of three major modeling categories: Physical Models, Terrain/Synthetic Natural Environments (SNE) and Behaviors. The focus area of each team is to sustain coordinated, coherent research to support modeling and simulation of urban military operations with emphasis on concepts, requirements, research and development. Each SME group will guide model research, in their respective areas, to ensure new simulations credibly depict military operations in urban and complex terrain. The supporting thrust for this effort is to develop new models and integrate them into legacy simulations with MOUT capabilities.

Subject matter experts were selected based on three criteria: 1) knowledge at the workbench, 2) ability to code or develop algorithms, and 3) self-development through professional readings.

Workbench knowledge refers to past or current experiences operating in an urban environment. This would also include use of simulations for training and analysis of urban operations.

The ability to code models or develop algorithms puts first–hand knowledge of urban operations in the hands of the programmers. The knowledge to differentiate between urban and other-than-urban operations must be exercised in all possible cases. For example, the ACQUIRE Algorithm is a common search and target acquisition algorithm used in many Army force-on-force models. It is an excellent model for target acquisition and engagements made beyond 200 meters. In an urban environment, however, 80% of all engagements are made inside of 100 meters. It is imperative that the programmers know this type of information.

Self-development can be accomplished through professional readings. The FAC Team has provided a list of 10 non-fiction books that capture military operations in an urban environment. The following books make up the required reading list:

Craig, W. 1973. *Enemy at the Gates: The Battle for Stalingrad*. New York: Ballantine.

Bowden, M. 1999. *Blackhawk Down*. New York: Penguin.

Ryan, C. 1974. *A Bridge Too Far*. New York: Simon & Schuster.

Christmas, R. 1977, Feb. A Company Commander Remembers the Battle of Hue. *Marine Corps Gazette, LXXVII, vol 2.*

Whiting, C. 1976. *Bloody Aachen*. New York: Stein and Day.

Center for Army Lessons Learned 1999. *Newsletter 99-16*. Urban Combat Operations.

Huelfer, E. 2000, Jan-Apr. *The Battle for Coco Solo, Panama, 1989*. Infantry Magazine, vol 90, n1.

Lieven, A. The World Turned Upside Down: Military Lesson of the Chechen War. Armed Forces Journal International, Aug 1998.

Unkown. 1999. Aachen: Military Operations in Urban Terrain 26th Infantry Regimental Combat Team, 8-20 Oct 1944. *26th Infantry Regimental Association, 2nd edition*.

Nolan, K 1983. *Battle for Hue*. Presidio Press.

Each SME is required to read at least five from the above list, along with other journals and articles made available through a variety of sources. Having the Army's simulations follow published doctrine is especially important. Simulations must emulate current doctrine to test tactics, techniques and procedures (TTPs). The Combined Arms MOUT Task Force (CAMTF) has rewritten nearly all the Army's urban operations doctrine. This includes FM 90-10-1, Infantryman's Guide to Combat in Built-up Areas, which has been renamed FM 3-06.11, Infantry Guide to Urban Operations. FM 3-06.11 is considered to be the Army's primary manual for conduct of operations in an urban area.

4 ASSESSMENT OF CURRENT MODELS

AMSAA has recently published a series of white papers that assess the Army's current models and their ability to represent operations in an urban area. The white papers evaluate the areas of Search and Target Acquisition, Mobility, Direct Fire, Indirect Fire, Wide Area Surveillance and Tactical Communications in the Army's force-on-force simulations. Each focus area was evaluated in three categories, basic knowledge, algorithms and data, and given a rating of Red (poor), Yellow (needs improvement) or Green (adequate). Figure 2 gives an overview of the ability of our current models to represent urban operations in each of the focus areas.

The papers provided a base for identifying the research tasks that need to be undertaken to improve Army MOUT modeling. From the papers came a prioritized list of shortfalls in urban representation. The shortfalls were transformed into project proposals and staffed by the SME groups.

4.1 Indirect Fire

Though the area of Indirect Fire is the most complete of the selected study areas, it still requires a great deal of improvement. The effects of indirect fire in an urban area can be difficult to measure. There is no standard for representing the effects on buildings, building contents, roads, bridges and subterranean infrastructure in our force-on-force simulations. Current effects are estimated by enhancing a few factors in algorithms used for open terrain. A new methodology and new modeling tools are required to develop a proper set of lethal area estimates for built-up areas.

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.

Some work is already being done to support the projects areas listed above. The Modular Effectiveness/Vulnerability Assessment (MEVA) MOUT model has been developed to address the damage of buildings and building interiors, including probability of kill (P_k) of personnel, for a limited set of building types and personnel job types. Some changes are already in progress to develop the MEVA MOUT model beyond its current capabilities.

The Support Warfare Analysis Mean Area of Effects Model is another that has been identified for use in representing urban indirect fire effects. It is used to generate new lethal area estimates for tactical targets located in the various levels of urbanization. It could also be used to develop templates for collateral damage estimates.

4.2 Tactical Communications

Tactical communications in built-up areas is a research focus area that has not been exploited to the necessary levels for military use, but has been studied to great depth by the commercial telecommunications industry. Models are required to predict propagation loss of radio waves in an urban environment for the following:

1. Interior to interior (including between floors) – same building
2. Interior to interior – different buildings
3. Interior to exterior
4. Exterior to exterior

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 and Target Acquisition	Red	Red	Red

Figure 2: Model Assessment Findings

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 (TIREM) uses a two-dimensional representation of terrain and multi-path effects. 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.

At least three propagation models have been developed for commercial use through government funding, however, the government does not own the rights to them. There are other efforts to which the government will be the benefactor. The MOUT Advanced Concept Technology Demonstration (ACTD) has undertaken an effort, led by CECOM, to address the effects of urban features on radio propagation. The FCC has also been funded to develop a database of propagation loss for the city of Denver. The work began in the summer of 2001 and will study bandwidth up to 2 GHz. This effort will be beneficial in validation other urban propagation models.

4.3 Mobility

Mobility is a very large topic when addressing the movement of entities through an urban environment in the Army's models and simulations. Wheeled vehicles, tracked vehicles, individuals, aircraft and water craft each have different mobility requirements based on their mission, surface conditions and obstacles.

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 NATO Reference Mobility Model (NRMM) has been identified as the Army Modeling and Simulation Office standard for ground vehicle movement. It provides an excellent platform for adding/improving algorithms to represent sub-scale vehicles and dismounts. Model movement (speed /NO-GO) for wheeled and tracked vehicles, dismounted infantry, aircraft, and watercraft for multiple conditions (pavement / gravel / slopes / wet / snow / ice) and obstacles (buildings, intersections, cars, traffic congestion, rubble, walls, bridge limits, overhead limitations) must be integrated for the representation of MOUT.

4.4 Direct Fire

There are many shortfalls in the focus area of Direct Fire. 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. Over the past year, AMSAA has reviewed and updated ground combat performance estimates data in the AMSAA Performance Estimates Database Systems (APEDS). Studies have shown a significant deficiency in short range data (< 100 meters) for nearly every direct fire weapon system, which is the range that most direct fire systems would be used in urban areas. It should be brought out that the list of weapons studied is not all-inclusive, nor should some of them be used at extremely close ranges or within a room.

There are two ongoing projects relating to enhancing direct fire MOUT representation. AMSAA is developing the AMSAA Infantry MOUT Simulation (AIMS). AIMS is a constructive simulation designed with the intended purpose of urban operations analysis. The other project is a data mining effort in conjunction with the TRADOC System Manager for Soldier Systems (TSM-Soldier) in an effort to fill in the some of the gaps where the Army's simulations lack the proper data.

4.5 Wide Area Surveillance

Wide Area Surveillance, arguably the most deficient of the focus areas, can be considered in three sub-focus areas: Radar, Acoustics and Signal Intelligence (SIGINT).

4.5.1 Radar

Tactical radar has many different applications for air defense, counter battery fire, imaging, Smart munitions and target acquisition, just to name a few. Though it has developed rapidly since its inception in the first half of the twentieth century, modeling its capabilities has not.

There are two models that can be used for generating detection probabilities for air defense and counter battery acquisition in MOUT scenarios. CASTFOREM and ATCOM both have the Detect algorithm imbedded in them to allow detection of radar target pairings. 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.

4.5.2 Acoustics

The Acoustic Battlefield Aid (ABFA) 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. 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.

4.5.3 SIGINT

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 necessary for use urban terrain. The only condition that is considered for MOUT is background noise.

4.6 Search and Target Acquisition

The Army's current standard algorithm for Search and Target Acquisition (STA) is the ACQUIRE model. 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, 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. Here are some of the questions that need to be answered in the form of research-validated data:

1. What is the contrast (visual or thermal) of vehicles and dismounted troops against urban backgrounds?
2. How long and to what degree are MOUT targets typically exposed?
3. What are the search sectors of responsibility for dismounted troops and vehicle crewmembers in an urban area?
4. What is the N50 scale parameter? (N50 is the parameter indicating the difficulty of a particular task. It is the most important parameter that will effect STA predictions)

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 v. crew performance, and multiple targets are all issues that have not been addressed to date.

5 SUMMARY

The recent and projected increase in the US Military's operations in urban terrain has caused the modeling and simulation community to evaluate the way we represent urban environments in our force-on-force simulations. Though the tasks are many and cover a wide rang of topic areas, initial efforts will be to solve the physics-based modeling issues. Concurrently, efforts are getting underway addressing terrain/synthetic natural environments and behaviors.

The only way to attack such a large problem is through concerted execution of a research plan where a single organization takes the lead. Current resources no longer allow disjointed efforts solicited from the bottom up. Research needs must be directed from the top down through a coherent program that guides research projects.

The Urban Operations FAC Team was formed by groups of subject matter experts who lead the field in their areas of study. They are responsible for ensuring a coherent plan of research for Army MOUT M&S is formulated, documented and published. They will also ensure a demonstrable product results from each project and has a high return on investment. The ultimate goal is to have competent researchers perform credible, applicable, demonstrable research for a reasonable price.

Initial projects will result from the assessment of the Army's force-on-force models done by AMSAA. Each research task will be developed into a proposal, prioritized, and then published in a Research Plan. The Research Plan will be re-evaluated/rewritten annually to ensure a successful end state is met. The end state should be an objective simulation that accurately represents the spectrum of operations in urban terrain that can assist our leaders in making timely, accurate decisions.

AUTHOR BIOGRAPHY

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