



# UNITED STATES AIR FORCE RESEARCH LABORATORY

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## CROWD CONTROL MODELING AND SIMULATION RESEARCH PLAN

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<b>13. SUPPLEMENTARY NOTES</b> 					
<b>14. ABSTRACT</b> The purpose of this document is to lay out a plan for research on Crowd Control Modeling and Simulation. Models and simulations that predict or describe crowd behavior do not exist at the present time in a form that could be used to describe the dynamics of crowds and how the use of NLWs will impact their behavior. In order to provide proper training and a dependable range of options to warfighters, effective M&S techniques, which incorporate recent and reliable data on human behavior and computer generated forces (CGF), must be developed. The JNLWD will be able to develop a set of usable tools in a shorter time period, and at a lower cost, if a coordinated plan is maintained and executed that leverages research currently being supported by the JNLWD and other agencies.					
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## Executive Summary

Lt. Gen. Steele, USMC, Chairman of the NLW IPT, has stated: "The recent past indicates the increasing need for non-lethal capabilities for our warfighters. It is imperative to provide troops, both today and in the future, with a full range of options, both lethal and complementary non-lethal, in order to broaden the set of responses available to the political and military strategies and tactical commanders."<sup>1</sup> Throughout the past decade, U.S. military forces have been involved in military operations other than war (MOOTW) and military operations in urban terrain (MOUT). These scenarios make the case for non-lethal options even stronger as in these situations combatants can, and do, easily blend in with the civilian population. Today, non-lethal weapons are being designed and employed that can help separate the non-combatant civilians from those who are motivated to be slightly more confrontational.

Due to the increasing trend of U.S. military humanitarian missions, the ability to control a crowd has become a critical need. "Crowd Control" is one of the six functional areas established by the Joint Concept for NLW within the categories of counter-personnel and counter-material.<sup>2</sup> The proper use of Non-lethal counter-personnel capabilities will enable the application of measured military force with reduced risk of fatalities or serious injury among non-combatants, friendly, or enemy forces.

The desired outcome is a means of influencing the behavior and activities of a potentially hostile crowd, as well as the capability to bring a mob engaged in a riot under control.<sup>3</sup> According to the JNLWP Master Plan, modeling and simulation (M&S) will provide a capability to train commanders and troops, develop doctrine and tactics, formulate and assess operational plans, conduct mission rehearsal, define operational requirements, and provide operational input to the acquisition process.<sup>4</sup> As research efforts continue and more data is gathered, useful M&S tools for crowd control will become available.

In order to provide proper training and a dependable range of options to warfighters, effective M&S techniques, which incorporate recent and reliable data on human behavior and computer generated forces (CGF), must be developed. One of the challenges facing crowd control M&S is the ability to simulate crowd behavior as part of the overall equation. This review of CC M&S programs has not yet identified an existing model that can be used to train in crowd control tactics, used for trade-off studies, or mission planning exercises. There are, however, several efforts underway which show promise to deliver tools that will be useful in building models and simulations. To become useful tools, additional investment in studying how human (or crowd) behavior is affected by the employment of NLW's, as well as appropriate techniques for implementing the correlating algorithms will be required.

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<sup>1</sup> "1998" - A Year of Progress" (January 1999). 1998 Joint Non-Lethal Weapon Program (JNLWP) Annual Report, p. iii.

<sup>2</sup> JMAA Report

<sup>3</sup> "1997 - A Year of Review," 1997 Joint Non-Lethal Weapons Program (JNLWP) Annual Report, p. 5.

<sup>4</sup> Joint Non-Lethal Weapons Program - Master Plan June 2000, p. 20-21.

## Crowd Control M&S Research Plan

Many strides have been made towards creating a valid, working model for non-lethal weapons. According to the 1999 JNLWP newsletter, "M&S activities for the JNLWP have been focused on the development of analytical tools capable of modeling NLW technologies and engagements in a variety of scenarios including urban terrain. The challenge, though, has been to integrate NLWs and their effects into a joint model accredited for use as an analytical tool."<sup>5</sup> Furthermore, a more recent report by the Human Effects Advisory Panel states, "...sufficient information does not exist to develop models with validated crowd behaviors and motivations. Additionally, artificial scenarios do not have any real meaning to operators."<sup>6</sup>

If Crowd Control Models are to reach maturity for use in training, systems trade-off studies, or strategic planning, a number of concerns must be resolved. Current models lack the ability to model, simulate, or predict human behavior, crowd psychology, or crowd dynamics. Another challenge that current models also face is the implementation of human performance data into computer-generated forces (CGF). Two limiting factors are that the developers of the constructive simulations are not typically trained human performance researchers or modelers, as well as the difficulty of adding and maintaining CGF code to reflect the most recent and relative data from human systems integration research.<sup>7</sup> To overcome these challenges, data is being generated from the current literature on Human Behavior Models (HBMs) and Performance Moderator Functions (PMFs).<sup>8</sup> This literature involves one's reaction to sound integrated with a connectionist model of emotional processing creating a synthetic force model. This synthetic force model can then be used to investigate improved realism in generating complex human-like behavior that is sensitive to emotional assessments related to fear, anger, joy, etc.<sup>9</sup>

Literature reviews, in conjunction with a considerable amount of discussion with subject matter experts, have been conducted on the state and maturity of CC M&S, revealing that many critical questions remain unanswered. Appendix A contains a list of the references used in refining this roadmap and setting this course. Issues and concerns of prime importance involve the ability to quantify and define human behavior dynamics, the determination of key variables to be studied and quantified for both the control and opposing forces, as well as appropriate modeling techniques for implementing the model. The crowd control M&S research program is laid out in five distinct areas of clear value and interest essential for understanding and reducing the risks in developing and validating a useful suite of models and modeling tools.

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<sup>5</sup> "Joint Non-Lethal Weapons Program: A Year in Review," 1999 Joint Non-Lethal Weapons Program (JNLWP) Annual Report, p. 25.

<sup>6</sup> "REPORT OF FINDINGS: Crowd behavior, crowd control, and the use of non-lethal weapons" (January 2001). Human Effects Advisory Panel, p. 34.

<sup>7</sup> Archer, R, Archer, S. and Warwick, W. Synergy between human systems integration and training to improve CGF realism. 11<sup>th</sup> CGF and BR Conference, May 7-9, 2002.

<sup>8</sup> Cornwell, JB. Silverman, BG., et al. A demonstration of the PMF-extraction approach: modeling the effects of sound on crowd behavior. 11<sup>th</sup> CGF and BR Conference, May 7-9, 2002.

<sup>9</sup> Jones, RM., Henninger, AE. and Chewn, E. Interfacing emotional behavior moderators with intelligent synthetic forces. 11<sup>th</sup> CGF and BR Conference, May 7-9, 2002.

## **Overview**

- I. Program Integration**
- II. Development of a Foundation Model**
- III. Human Behavior and Cognitive Processes**
  - a. Human Behavior #1 – Field Studies (Storm Chaser)**
  - b. Human Behavior #2 – Identify/Quantify Critical Variables**
- IV. Modeling & Simulation of Crowds & Mobs**
- V. Product Development**

## **Budget**

Along with integrating efforts for this important, militarily relevant program, the managers estimated costs and benefits. The final program likely will last for a six year period at a cost of \$5 million.

## Deliverables

	FY04	FY05	FY06	FY07	FY08	FY09
<b>I</b>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Update Roadmap</li> </ul>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Updated Roadmap</li> </ul>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Updated Roadmap</li> </ul>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Updated Roadmap</li> </ul>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Updated Roadmap</li> </ul>	<ul style="list-style-type: none"> <li>• Oversee program</li> <li>• Coordinate research amongst agencies</li> <li>• Updated Roadmap</li> </ul>
<b>II IIIa IIIb</b>	<ul style="list-style-type: none"> <li>• Draft Foundation Model</li> <li>• Stormchaser Reports</li> <li>• Development Workshop</li> <li>• User Workshop</li> </ul>	<ul style="list-style-type: none"> <li>• Stormchaser Reports</li> <li>• Working Papers</li> <li>• Develop. Workshop</li> </ul>	<ul style="list-style-type: none"> <li>• Stormchaser Reports</li> <li>• Working Papers</li> <li>• Develop. Workshop</li> <li>• User Workshop</li> </ul>	<ul style="list-style-type: none"> <li>• Stormchaser Reports</li> <li>• Working Papers</li> <li>• Develop. Workshop</li> </ul>	<ul style="list-style-type: none"> <li>• High % Solution Foundation Model</li> <li>• Stormchaser Reports</li> <li>• Working Papers</li> <li>• Develop. Workshop</li> <li>• User Workshop</li> </ul>	<ul style="list-style-type: none"> <li>• Working Papers</li> </ul>
<b>IV</b>	<ul style="list-style-type: none"> <li>• Working Papers</li> </ul>	<ul style="list-style-type: none"> <li>• Determine top 5 modeling techniques</li> </ul>	<ul style="list-style-type: none"> <li>• Working Papers</li> </ul>	<ul style="list-style-type: none"> <li>• Working Papers</li> </ul>	<ul style="list-style-type: none"> <li>• Select top techniques based on scenario</li> </ul>	<ul style="list-style-type: none"> <li>• Working Papers</li> </ul>
<b>V</b>		<ul style="list-style-type: none"> <li>• M&amp;S Tools for Training</li> </ul>	<ul style="list-style-type: none"> <li>• Data driven Crowd Behavior Module</li> </ul>	<ul style="list-style-type: none"> <li>• M&amp;S Tools for Training</li> <li>• Updated Crowd Behavior Module</li> <li>• M&amp;S Tool for Planners &amp; Cdr's.</li> <li>• M&amp;S Tool for Acquisition Analysis</li> </ul>	<ul style="list-style-type: none"> <li>• Updated M&amp;S Tool for Planners &amp; Cdr's.</li> </ul>	<ul style="list-style-type: none"> <li>• Updated Data driven Crowd Behavior Module</li> <li>• Updated M&amp;S Tool for Acq. Analysis</li> <li>• Integrated suite of Software tools for Crowd Behavior Modeling</li> </ul>

## **I. Program Integration**

**Purpose:** *To ensure coordination between the human behavior research and model implementation, to maximize leveraging opportunities, and to ensure timely execution of CC M&S roadmap.* There are various organizations funding human behavior and crowd control modeling efforts. An overall plan for development of the required models and a central repository of information is critical for ensuring that efforts are complimentary and leveraging opportunities are fully utilized.

**Description:** Development of a suite of Crowd Control M&S tools is a multi-disciplinary effort. Therefore, it is critical that an overarching management plan be set up and maintained throughout the program to ensure communication between the disciplines and research efforts. Such a management plan will ensure that the "big picture" is maintained and will identify how the funded research will contribute to the common goals. A program manager will be required to facilitate the necessary interaction between agencies, revise and update the overarching plan, and oversee the work being sponsored by the JNLWD. A database of known entities working in the area of human behavior as it relates to crowd dynamics, or riots, as well as modeling techniques for implementing this type of information, will be maintained and regularly updated. Contact with other funding organizations will be made to reduce duplication of effort and encourage data sharing between organizations.

## **II. Development and Maturation of a Foundation Model**

**Purpose:** *To develop a standard assumption base for crowd control models, providing a universal language for human behavior / target effectiveness data collection for non-lethal weapons.* It is essential to have a standard set of variables and scenarios to be used in the testing and comparison of crowd behavior models. It is unrealistic to expect that comparisons of models that have different implementation techniques, coding schemes, as well as platform inconsistencies, can be made without a standard baseline of variables and expected outcomes. Therefore it is necessary to develop and mature standard sets of scientifically developed inputs and known outcomes that can be used to provide a platform for comparison of different models and modeling techniques.

**Description:** The foundational model will be a controlled, living document. This model will be comprised of the variables required for developing crowd behavior models, will describe the relationship between the variables, as well as the variable data types (qualified vs. quantified). Users who are currently involved in the use, or planning the use, of NLWs in the field will be asked to participate in workshops to update the requirements and scenarios. Workshops comprised of modelers and human behavior researchers who are actively engaged in this field will be held to update the variable list,

the data collection techniques being used, and the expected outcome. At this time, a revision of the CC M&S projected research plan will be accomplished to reflect research needs based on variables being added, or existing variables being removed. Modeling techniques will also be evaluated to determine which techniques are best suited for the data being collected, as well as ensuring that new techniques are considered for use.

### **III. Human Behavior and Cognitive Processes**

The body of literature for crowd behavior modeling was surprisingly small. There is a growing interest in this area, as well as a growing pull from the military community for useful predictive M&S tools, especially crowd control. As noted by the HEAP in their report, behavior modification depends on understanding the motivation of an individual or group.<sup>10</sup> However, the lack of data regarding the response of an individual or crowd to a NLW makes prediction of behavior nearly impossible.

#### ***Human Behavior #1 – Field Studies (Storm Chaser)***

**Purpose:** *To develop and maintain a team of experts which can quickly assemble and collect crowd / control force behavioral data in a field setting.* This research task will assist in the validation and verification of variables that are included in the foundation model, as well as identify variables that have not been captured. This research will also assist in quantifying the variables being used. This data is critical for validating the information on variables and cues being collected in the laboratory or in limited field tests.

**Description:** Standard psychophysical scientific methods will be used to analyze the behavior of the individuals (both control and opposing forces) involved in the situation. Where possible, structured interviews will be held. This effort will require a team of individuals, comprised of 2 – 3 behavioral scientists (psychologists, sociologists), and data collection technician(s) to assemble and coordinate the various data sets being collected. Initial Storm Chaser data collected on 18 January 2003 and 12-13 April 2003 in Washington, D.C. indicate that data analysis will be a substantial portion of this effort.

#### ***Human Behavior #2 – Identify/Quantify Critical Variables***

**Purpose:** *To develop an understanding of the influence of NLWs on human behavior as well as identifying and quantifying the critical variables required defining the behavior.* There are numerous and varying theories on human behavior. While some theories may have stronger support at certain times, it is unrealistic to expect that a particular theory will ever be agreed upon as the underlying theme for the effect of NLWs on human behavior. However, it is reasonable to expect that critical factors, or

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<sup>10</sup> REPORT OF FINDINGS: Crowd behavior, crowd control, and the use of non-lethal weapons” (January 2001). Human Effects Advisory Panel, p. 4.

variables, which affect human behavior, can be identified, and agreed upon, and used as a baseline for understanding the effects of NLWs in crowd control situations.

**Description:** Based on the results of the yearly foundational model workshop, a list of the variables thought to be the most critical to defining human behavior in a crowd will be developed. For each variable identified, the ability to properly represent the data type (qualified or quantified) must be determined, as well as the fidelity of the information available. Techniques for collecting and reporting qualified data will be standardized. The critical variable list will then be prioritized to determine what research is required, the risk associated with gathering the required data for that variable, as well as the anticipated payoff in terms of validating or verifying the foundation model. Research efforts will then be started, augmented, or continued, to fill the data gaps that have been identified.

#### **IV. Modeling & Simulation of Crowds & Mobs**

**Purpose:** *To optimize the development of functional crowd control models and increase probability of stable, long-term platform.* This effort will assist in risk reduction of developing a suite of usable, critical crowd control modeling tools. A determination of the viability of any proposed model or modeling technique will be made before further investment into the model is made.

**Description:** In order to provide proper training and a dependable range of options to warfighters, effective M&S techniques, which incorporate recent and reliable data on human behavior and computer generated forces (CGF), must be developed. One of the challenges facing crowd control M&S is the ability to simulate crowd behavior as part of the overall equation.

It is clear that the need for a validated suite of CC M&S tools exists. The challenge is determining the appropriate technique for implementing the algorithms once they are developed. Currently, efforts using agent-based models and weather forecasting techniques (and wavelet transforms) appear to be promising techniques. However, crowd models are required for training environments, trade-off studies for weapon and payload selections, as well as strategic planning tools. It is anticipated, and highly likely, that there will be a suite of models that are developed and appropriate for use only in one of these areas. It is also likely that techniques that work well in one situation will not be the best method of implementation in another. Therefore it is critical that an understanding of modeling techniques and user need (product) are well understood and defined. Overall, the model must be able to be adapted to accept the input parameters stipulated by the foundation model. For this effort, models will run the scenario and parameters of the foundation model and the output will be analyzed. A determination will be made regarding the acceptability of any discrepancies or unexpected outcomes, followed by a decision to further invest or not invest into the technique or model.

## V. Product Development

**Purpose:** *To develop crowd control models and tools that are available for use by trainers, weapons developers, and strategic planners.* Crowd control models found in the literature today that include human behavior modules have not been validated by scientific research. This effort will accept models that meet the requirements set in Modeling Techniques #1 and support the further development of these models in a manner that can be scientifically supported and validated.

**Description:** It is anticipated that at the end of each FY, an existing tool will be updated, and a new tool will become available. The training module for crowd control M&S is expected to be the first tool available as significant investment is already being made in that area. This module would be upgraded as new information on human behavior becomes available. The second area in which a useful tool would become available is for weapons developers to use in trade-off or comparison studies. Initially a paper guide would be available, followed by a computer model possibly in the FY06/07 timeframe. The third area anticipated is in strategic planning, and/or force on force computer gaming. This module is expected to be available in FY09, and will require significant work in integration with existing real-time computer force gaming models.

All of these modules, whether paper models or computer generated graphical models, will require annual review and revision. The body of knowledge and understanding of crowd behavior is still growing and shows no signs of coming to closure in the foreseeable future. These models must be designed in a fashion that allows them to accept new information and adapt to new or evolving concepts without significant investment in redesign.

## CONCLUSION

To realize the full potential of NLWs in crowd control situations, commanders and soldiers will need to understand how and when to employ the weapons, as well as, how to mix the different technologies to achieve a desired goal. The M&S tools must be developed in a manner that will allow the JNLWD to educate the user community, to build trust in the technology, and ensure proper use of the systems.

There are a number of existing models that claim to be able to predict or simulate crowd behavior. Typically these models do not have experimental behavioral data and are based on unknown or ill-defined assumptions of how the crowd or individual will react. The use of these models will likely result in incorrectly assessing the effectiveness of a NLW system in crowd scenarios. Validating an approach to modeling crowd situations is critical to advancing the ability to quickly assess technologies, as well as training the soldier and commander in the use of these systems.

Models and simulations that predict or describe crowd behavior currently do not exist in a form that could be used describe the dynamics of crowds and how the use of NLWs will impact their behavior. There is a significant amount of research that is still required to understand these dynamic interactions. The JNLWD will be able to develop a set of usable tools in a shorter time period, and at a lower cost, if a coordinated plan is

maintained and executed that leverages research currently being supported by the JNLWD and other agencies.

## APPENDIX A

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