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Computer Simulation in the Acquisition Life Cycle using the WRENCH Simulation Model

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Abstract

Computer simulation can be used throughout the defense acquisition life cycle in order to conduct analysis of alternatives and evaluate materiel solutions; assess risk reduction efforts; and aid in development test and evaluation activities. This use of simulation can be an innovative way for transitioning emerging technologies from research and development to defense acquisition programs of record, thereby helping the program successfully cross the valley of death. In this paper, we discuss how WRENCH, a computer simulation software developed at the Naval Postgraduate School's Center for Modeling Human Behavior, could be used in the acquisition life cycle to test the effectiveness of different proposed or prototype Intermediate Force Capability (IFC) weapons configurations. WRENCH simulates a security force (SF) managing a potentially hostile crowd, enabling the exploration of potential outcomes when the SF has IFC weapons of different configurations available for use. In WRENCH, different scenarios can be tested, providing outputs to inform a variety of metrics of interest. Here we demonstrate using WRENCH to explore the effectiveness of different Active Denial Device configurations on the achievement of mission objectives in a compound defense civil security scenario, discussing an experiment, and analyzing results. We then discuss implications for acquisition and future work.

Keywords: defense acquisition, acquisition life cycle, computer simulation modeling, intermediate force capabilities, non-lethal weapons

Introduction

Assessing performance characteristics and the potential effectiveness of emerging technologies during the acquisition life cycle is challenging, particularly when physical testing of the technology is dangerous or cost-prohibitive. Computer simulation provides a method of testing that can reduce testing costs and risk. In addition, it enables testing of products at any stage in the development process from initial concept to final product. Use of simulation modeling can also expand what is possible in testing, whether the restriction on what's possible is due to high testing costs or due to the high risks of testing, such as the risk of harm to humans. In this paper, we address the use of computer simulation models tools to assess, test, and evaluate something that is being acquired. Alternate uses of M&S in acquisition may include the simulation of the acquisition process itself, as addressed in Wirthlin et al. (2011), and simulations or simulation models that are part of what is being acquired such as training simulations, as addressed in Vila (2010).

In order to provide a context for our discussion of how simulation capabilities can be useful in the acquisition life cycle, we focus on the acquisition of Intermediate Force Capability (IFC) non-lethal weapons (NLWs). Due to the fact that "NLWs and simulants carry a very real risk of permanent damage to [human] subjects" (Mezzacappa, 2014), this is a prime context for the use of simulation modeling. In their article on the importance of characterizing the human effects in NLW acquisition, Burgei et al. (2015) state that characterization of these effects is critical, as warfighters face complex engagement scenarios. The authors state "the warfighters must have confidence in the effectiveness of a NLW and understand the risk of adverse effects." The characterization of human effects in NLWs is guiding the development of these weapons in the earliest stages of the acquisition process, focusing first on warfighter needs as expressed by combat developers. The authors also argue that continually improving the human effects characterization process is key to improving NLWs (2015).

Even with the use of computer simulation, it is particularly difficult to assess the potential effectiveness of weapon systems for which non-kinetic effects can be as important as kinetic effects, and effectiveness measures pertain to human behavioral responses. In this research we explore the use of recent computer simulation modeling advances in human behavior modeling, as evidenced in the WRENCH simulation model developed at the Center for Modeling Human Behavior in the Naval Postgraduate School. We present an experiment conducted using WRENCH to demonstrate how simulation can provide insights into the relative effectiveness of different NLW configurations on the management of a dynamic, potentially-hostile crowd. Experimental results discussed here give a brief glimpse into the possibilities of using a simulation model such as WRENCH in the acquisition process.

The paper proceeds as follows. We first identify key phases in the acquisition life cycle, and then provide a brief literature review. Following that, we provide an overview of the WRENCH simulation model and describe an experiment and results analysis that demonstrates some of the capabilities of WRENCH for assessing the effectiveness of different IFC weapons. We then discuss how WRENCH could be used during different phases of the acquisition life cycle, and conclude with recommendations for using WRENCH as an innovative tool in transitioning emerging technologies from R&D to a DoD program of record and thus successfully crossing the "valley of death."

Background: The Acquisition Life Cycle

Here we provide relevant highlights of the acquisition life cycle, establishing the framework for our discussion on how modeling and simulation (M&S) can be used in the acquisition life cycle. We focus specifically on the Major Capability Acquisition (MCA) pathway, which is used to acquire and modernize military unique programs that provide enduring capability where there is a need to use a structured acquisition life cycle approach for analyzing, designing, developing, integrating, testing, evaluating, producing, and supporting the weapon system or complex capability (DoD, 2022).

The first life-cycle phase in the MCA pathway is the *Material Solutions Analysis (MSA)* phase. In this phase, activities to choose the product to be acquired (the material solution) are conducted. These activities include an analysis of alternatives (AoA). It is in this phase where validated capability gaps are translated into system-specific requirements, and planning is conducted to support an acquisition strategy for the product.

The next life cycle phase is the *Technology Maturation and Risk Reduction (TMRR)* phase. The purpose of the TMRR phase is to sufficiently reduce technology, engineering, integration and life-cycle cost risk so that the program can advance to the next phase in the life cycle.

The *Engineering and Manufacturing Development (EMD)* life cycle phase includes the development, building, testing, and evaluating of the materiel solution, to verify that all operational and implied requirements have been met, and to support production, deployment and sustainment decisions. It is during EMD that developmental testing and evaluation (DT&E) activities are conducted to provide hardware and software feedback to the program manager on the progress of the design process and on the product's compliance with contractual requirements, effective combat capability, and the ability to achieve key performance parameters (KPPs) and key system attributes (KSAs). It is also during the EMD phase that operational test and evaluation (OT&E) will be conducted to provide initial assessments of operational effectiveness, suitability, survivability, and the ability to satisfy KPPs and KSAs. The successful completion of EMD life-cycle activities supports the decision to transition to the production and deployment phase.

The *Production and Deployment (P&D)* phase includes the activities needed to produce the product (e.g., weapon system) and deploy it to operational units. These activities include completing DT&E and initial OT&E. The acquisition may also include the production of low-rate initial production units to be used in initial OT&E activities.

The *Operation and Support (O&S)* phase is the final phase of the acquisition life cycle for the MCA acquisition pathway. During this phase, activities related to operating and supporting the newly acquired weapon system are performed. These activities are in support of sustainment of the weapon system and disposal of the system after it is removed from inventory.

Literature Review

In this section, we provide a brief look at examples from the literature pertaining to the use of simulation modeling in the assessment, testing, and evaluating activities within the acquisition life cycle, drawing from real-world defense acquisition programs, followed by a discussion of the use of M&S in product development iterative cycle activities. We also discuss literature pertaining to the simulation of IFC weapons.

M&S Use in the Acquisition Life Cycle

An example of using modeling and simulation in the requirements determination process (e.g., MSA phase) can be seen in the Army's Mechanized Infantry Combat Vehicle (XM30) program. The XM30 is the Army's planned solution to maneuver warfighters on the battlefield to advantageous positions for close combat. This vehicle is expected to allow for crewed or remote operation. The Army developed the vehicle's requirements using modeling and simulation and was informed by digital concepts from different contractors during the product development phase (GAO, 2024).

An example of using M&S activities in system design (e.g., EMD) can be seen in the Army's Extended Range Cannon Artillery (ERCA) program. ERCA is part of the Army's long-range precision fires portfolio of programs. The acquisition program includes an upgrade to the M109 self-propelled howitzer that will improve lethality, range, and reliability. It will also add armament, electrical systems, and other upgrades to the existing vehicle. The Army used M&S in its iterative product development approach (GAO, 2024).

An example of M&S in reducing risk in manufacturing and testing (e.g., EMD) can be seen in the Navy's Hypersonic Air-Launched Offensive Anti-Surface Warfare Weapon System (HALO) program. The Navy's HALO acquisition program focuses on developing an anti-ship missile. HALO will address long-term capability needs for longer-range missiles with increased survivability to target heavily defended ships from near-peer competitors. The HALO program plans to leverage M&S to help address the challenge of the limited manufacturing industrial capacity to serve multiple hypersonic programs. M&S will be used by HALO contractors and their subcontractors to identify potential choke points in the manufacturing process. The program plans on using M&S in ground and flight testing in other related hypersonic programs (GAO, 2024).

Simulating Intermediate Force Capabilities

The rapid evolution of modern conflicts has highlighted the critical need for Intermediate Force Capabilities (IFCs) as a necessary element of modern military strategy. NLWs, in particular, provide options in force escalation and enable military units to disperse crowds, disable threats, and enhance force protection with reduced collateral damage (Grocholski et al., 2022). These capabilities are especially vital in addressing hybrid threats, gray zone conflicts, and unconventional warfare. In recognizing these capabilities, NATO's Military Committee has actively sought to refine IFC applications for mobility and counter mobility threats, especially in population dense environments (Afara et al., 2024).

To assess and analyze the tactical and strategic effects of IFCs, both NATO and the DoD have increasingly turned to agent-based simulation modeling. Early examples are the incorporation of unspecified NLW systems in the ModSAF simulation environment (Peters et al.,1998) and the modeling of a Long Range Acoustic Device (LRAD) in the COMBATXXI combat simulation (Grimes, 2005).

A more recent example is Gray (2017), who used an agent-based simulation model coded in Pythagoras to study the effects of a U.S. Marine patrol using a marking, blunt trauma NLW when moving through a civilian area. And just recently, Afara et al. (2024) used the Map-Aware Non-Uniform Automata (MANA), a New Zealand developed simulation tool, to study IFCs in urban mobility and counter mobility scenarios, modeling the use of "directed energy (DE) weapons such as acoustic hailers, laser warning devices, as well as microwave, millimeter wave or radio-frequencies devices" to address people blocking the advancement of a military vehicle or convoy.

Using WRENCH to Simulate ADT Effectiveness of Active Denial Technology

In this section we provide a brief overview of the WRENCH simulation model. We then discuss active denial technology (ADT), how an ADT device is modeled in WRENCH, and describe the design of an experiment of ADT effectiveness using WRENCH.

Brief Overview of WRENCH

WRENCH is an agent-based simulation model, coded in NetLogo that simulates a security force (SF) engaged in civil security operations, addressing potential threats through the use of non-lethal and lethal weapons. The mission scenario currently modeled in WRENCH is compound defense, where the SF is comprised of stationary gate guards and mobile patrol squads that can come to the aid of the gate guards during active defense of the compound. Figure 1 provides a snapshot of the compound area as depicted in WRENCH, showing the compound in the center with three designated entry points, roadways, other buildings, and also people, guards, and patrol vehicles magnified in the view for better visibility.

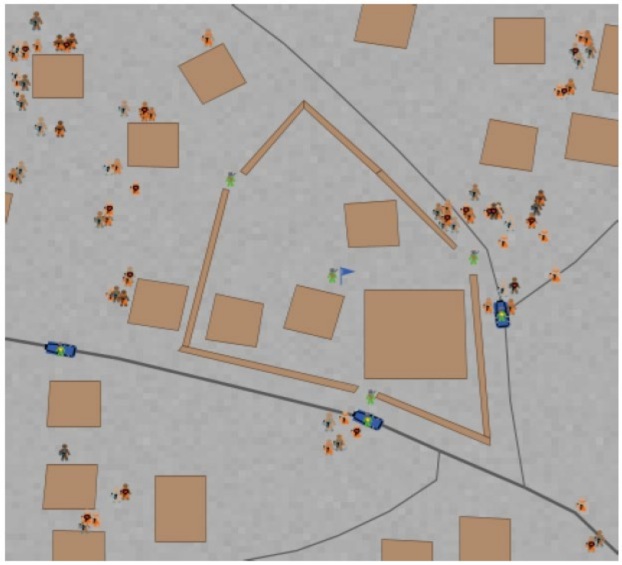

Figure 1. Snapshot of Compound and Other Simulated Elements in WRENCH (Aros & McDonald, 2023a)

Each person in the population, SF member, and patrol vehicle is modeled as an individual agent, such that each can interact with the environment and other agents autonomously. Individual agents can also be in groups (SF agents grouped within the command structure, and people agents in family or social groups). WRENCH models dynamic details for each agent such as its emotions, beliefs, needs, objective, physical state, and group influences, that will affect its cognitive decision-making and behavior.

Within WRENCH, the simulation user can specify a variety of characteristics about the SF and how they operate, the most relevant for this paper being the IFC(s) available for use, the tactical rules of engagement, and the SF's inherent stance toward the population, all of which will be explained in more detail in the experimental design section below. The user can also specify quite a few different aspects of the population, which will also be explained further within the experimental design section.

WRENCH runs with a 1-second simulated time-step, and is typically run for minutes to a few hours of simulated time in order to capture in detail the rapid changes that can occur with a potentially hostile crowd. WRENCH can be run using an interactive mode, where the emergent changes can be observed over time, or in a "headless" mode that enables large-scale experimentation of a wide variety of settings, producing a wealth of data for analysis. More details about WRENCH can be found in Aros et al. (2021) and Aros and McDonald (2023b).

Overview of Active Denial Technology

An active denial technology system is a directed energy weapon "that uses non-ionizing millimeter wave radiation to heat moisture just below the skin's surface, creating a sensation of heat" (Buch & Mitchell, 2013). Because this directed energy penetrates only a few millimeters or less into human tissue, its primary effect is limited to surface heating (Wang et al., 2020). Two active denial system (ADS) were produced under the DoD under the Advanced Concept Technology Demonstration Program. System 1 is "mounted on a modified High Mobility Multi-Purpose Wheeled Vehicle (HMMWV); and System 2 is a self-contained, box shaped model that is transportable via tactical vehicles larger than a HMMWV" (Buch & Mitchell, 2013). An ADS can project the millimeter wave beam over long distances. Safety concerns regarding overexposure are addressed by automatic shut-off mechanisms that deactivate the beam as soon as the trigger is released or when a pre-set time expires. Additionally, a laser rangefinder adjusts the output power according to the distance of the target, ensuring that safety thresholds are not exceeded (LeVine, 2009).

The ADS garnered significant media attention during and after its initial deployment, with reports discussing both its benefits and drawbacks. Some positive reported aspects of the ADS system includes the potential to minimize civilian casualties, effectively disperse large crowds, and limit collateral damage. However, negative reports on the ADS focused on the system's capacity to cause pain from far distances and numerous unforeseen and untested health risks (Buch & Mitchell, 2013).

Simulating Active Denial Technology in WRENCH

The WRENCH simulation software includes a weapons database that provides detailed specifications of various non-lethal and lethal weapons such as each weapon's range, the size and shape of the impact zone, whether it is designed for use against people or equipment, and, if it is designed for people, whether it is designed to use on a single person or multiple people in a single firing. Impacts of weapons on humans are categorized into one of seven severity levels: Psych-impact levels 1 through 3 (representing mild, moderate, or high psychological effects), Pain-impact levels 1 through 3 (representing mild/transient pain/injury, significant injury, or severe injury), or death. Any significant physical injuries or effects that alter their movement capabilities are also explicitly modeled, allowing for different patterns of impact to be modeled depending on the type of weapon.

In WRENCH, active denial devices (ADDs) are modeled as having a broader cone-shaped impact zone (possibly hitting multiple people) or a very narrow impact cone (hitting one person), with a long possible range of use, and with possible resulting impact levels ranging from Psych-2 through Pain-1. For this experiment, different ADD configurations were tested that combined differences in breadth of the impact cone, the ability to use the ADD at different power/impact levels. All but one of the tested ADD configurations were assumed to be mounted at the compound gates, one per gate, while one configuration was assumed to be hand-held; the hand-held option had a lower max range, a lower max severity level, and could be carried by a patrol squad member and a gate guard. The no-ADD case is termed "voice only" because the SF members can, in all cases, use their voice in a limited range to address hostilities. And, although the user can specify in WRENCH that the SF can have multiple different types of weapons available, this experiment limited their weapons to only the specified ADD and their voice.

A summary of the four different ADD configurations is given in Table 1. The rows specify the specific characteristics of each different numbered ADD configuration, and the columns distinguish differences when the given ADD is used at different severity levels. We emphasize that these are hypothetical weapons configurations designed to demonstrate the use of WRENCH for comparing the relative effectiveness of different weapons configurations.

Table 1. ADD Configurations Tested (Treece, 2024)

	ADD-1 (Mounted)	ADD-1 (Mounted)	ADD-1 (Mounted)
Range	1000 meters	1000 meters	300 meters
Cone Degree	30	20	10
Impact Level	Psych-2	Psych-3	Pain-1
Target Type	Multiple People	Multiple People	Multiple People
	ADD-2 (Mounted)	ADD-2 (Mounted)	ADD-2 (Mounted)
Range	1000 meters	1000 meters	300 meters
Cone Degree	15	10	5
Impact Level	Psych-2	Psych-3	Pain-1
Target Type	Multiple People	Multiple People	Multiple People
	ADD-3 (Mounted)	ADD-3 (Mounted)	ADD-3 (Mounted)
Range	1000 meters	1000 meters	300 meters
Cone Degree	0.1	0.1	0.1
Impact Level	Psych-2	Psych-3	Pain-1
Target Type	Single Person	Single Person	Single Person
	ADD-4 (Handheld)	ADD-4 (Handheld)	
Range	300 meters	300 meters	
Cone Degree	0.1	0.1	
Impact Level	Psych-2	Psych-3	
Target Type	Single Person	Single Person	

Experiment Design

To assess the relative effects of different active denial technology, a simulation experiment was conducted within WRENCH. The experiment focused on evaluating the ADD configurations just described. We also varied several additional parameters (i.e., factors) in the experiment in order to explore whether the relative effectiveness of the weapons configurations could differ when characteristics of the population and the SF were different. A summary of the experimental design parameters and levels is provided in Table 2, with discussion of each provided below.

Table 2. Experimental Parameters and Levels (Treece, 2024)

Parameter (WRENCH)	Levels (options within parameters)
Rules of Engagement (ROE) ruleset	{IH, LH, LD}
Intermediate Force Capabilities (IFC)	{ADD1, ADD2, ADD3, ADD4, Voice-Only}
Security Force Stance	{Nurturing, Cautious, Repressive}
Population Scenario	{Protest_SIG, Protest_indiv, Market}

Within WRENCH, the tactical rules of engagement are highly customizable, detailed sets of rules. The ROEs specify the basis of threat assessments (individual hostility (IH), locational hostility of clusters of people in a small area (LH), or the density of people in a small area (LD)) and the prioritization of areas and hostility levels to address first, among other details. For this experiment, the ROEs were designed to be identical, except for differing in the basis of the threat assessment. As for the available IFCs, each different ADD configuration was tested, as was a "no ADD case" where the SF were only able to use their voices. (Note that the SF members were able to use their voice in addition to the specified ADD under each ADD option as well.) The SF stance parameter provides a way to specify how the SF will interpret the observed behaviors of the people.

In WRENCH, the SF members observe the behaviors of the people and deduce a range of likely hostility levels for each person based on these observations. The Stance then specifies what level of hostility, within the range deduced from observed behavior of each person, the SF will respond to. Under the Nurturing Stance, the SF "assumes the best," or lowest hostility level in the range; under the Repressive Stance, the SF "assumes the worst," or highest, hostility in the range; and under the Cautious Stance, they assume the mid-range hostility level.

The configurable population characteristics within WRENCH include, but are not limited to, the population demographics, distribution of initial objectives across the people, initial hostility levels, how many people "arrive" in family groups, of what size ranges, and how many people "arrive" in social groups, of what size ranges, and what basis of social group identification. In order to reduce the number of parameters and levels required to test the ADD effects on different populations, we adopted the three sample population designs first introduced in Aros & McDonald (2023b):

- Market – with a higher percentage of children and families, and fewer adults beginning with an objective to protest, and lower average initial hostility levels
- Protest – with a lower percentage of children and families, and most adults beginning with an objective to protest, with a small number of adults beginning with the objective to Attack (invade), and higher average initial hostility levels, with
- two Protest sub-types: "individual" where all people show up as individuals (except children are with mothers), and "SIG" where many people show up in social groups

The experiment conducted was a full factorial experiment across the parameters and levels summarized in Table 2, testing every possible combination of levels across parameters. This experiment approach, while inefficient, has the advantage of allowing the separation of data into subsets based on different parameters without introducing bias. The experiment included a total of 135 design points (i.e., 135 unique combinations of levels of the parameters), with 100 replications run for each design point; yielding a total of 13,500 simulation runs.

Results and Analysis

The central question guiding the analysis of results was, "Which ADD configuration produces the most favorable results?" WRENCH can produce outputs toward a wide range of performance metrics. In this analysis we focus on two: the number of intruders (a primary metric of mission success for compound defense), and the amount of escalation in the average hostility level of the crowd (a potential consequence of the use of force that has implications on the mission going forward). We also discuss how examining the influence of other experimental parameters, particularly the characteristics of the population, can provide more insight into the effectiveness of different ADD configurations. In this section, all averages were taken across all replications with the stated data subset, unless otherwise specified. And in the bar charts, the "whiskers" indicate 95% confidence intervals.

Number of Intruders

As can be seen in Figure 2, the average number of intruders was quite high under each IFC option. Considering that no weapons were in use that could significantly injure anyone or cause death, this makes sense. The results also show that there was not a great deal of variation in the number of intruders under each IFC option, although a one-way ANOVA test confirmed significance at the $p < 000.1$ level. The ADD-1 configuration resulted in the lowest average number of intruders (24.8), ADD-2 resulted in the most (29.6), and the other three options resulted in a moderate number of intruders, with a small amount of variation among them (27.8, 27.4, 28.3, respectively).

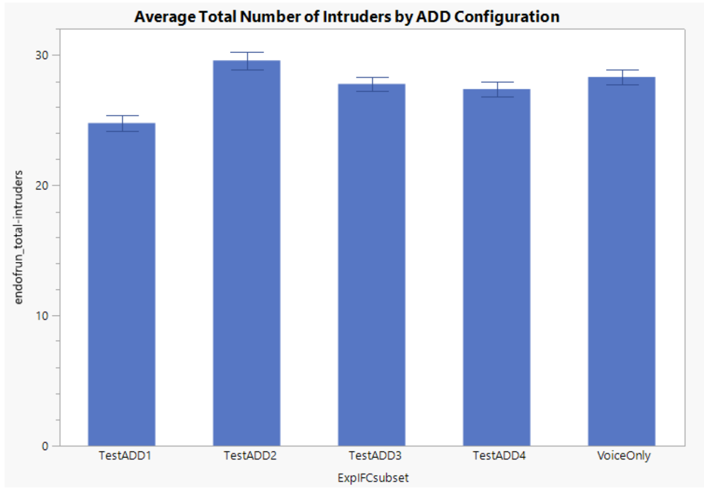

Figure 2. Average Number of Intruders by ADD Configuration (Treece, 2024)

Crowd Hostility

In WRENCH, hostility is measured on a [0,6] scale, where 0 is completely compliant and 6 is deadly hostility. And, while a person doesn't automatically act on their hostility, it is a significant driver of behavior; it can cause them to begin protesting, or to aggressively move toward the SF while protesting, or even decide to attack (attempt to invade the compound), which also has ripple effects through groups and the crowd.

Figure 3 shows the average hostility level of the people (averaged across the people within each replication, then averaged across the replications). As can be seen, ADD-1 and ADD-2 greatly escalated the average hostility of the people, while the other three options minimally escalated hostilities. And when comparing Figures 2 and 3, there appears to be somewhat of a trade-off between intruders and average hostility. Notably, while ADD-1 is the best according to the intruders metric, it is actually the worst on the hostility metric. This shows the importance of using a simulation model that can provide outputs on multiple metrics of interest, and of considering performance on all of those metrics when determining what IFC configuration option is "best."

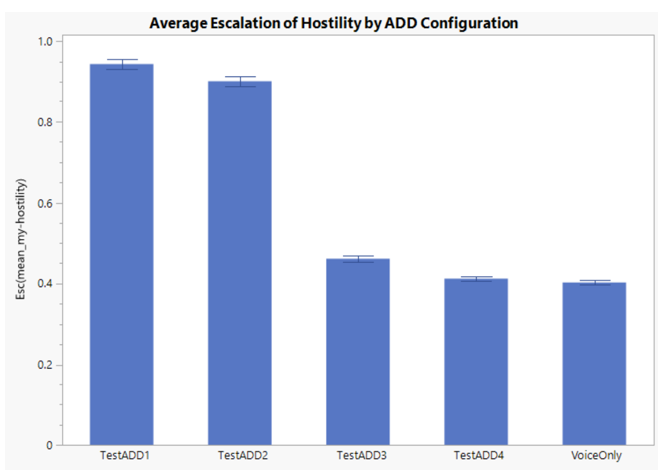

Figure 3. Average Escalation of Hostility by ADD Configuration (Treece, 2024)

Why Population Matters (how above "answers" regarding "best" ADDs may differ based on population type)

When aggregating data, such as was done in the averaging of the results across all replications as seen in the above analysis, important information can be lost (Aros & McDonald, 2023c). A primary benefit of conducting a full-factorial experiment is that it is possible to split the data into subsets based on different parameter values without introducing bias, allowing for disaggregation of the data for further analysis. In preliminary exploration of results, it became clear that the outcomes differed greatly based on population type, with the largest differences being between the Market population as compared to each Protest population. So here we discuss the results separated by population type, looking at the Market population results separately from the aggregate of both Protest populations on the two metrics of interest.

Figure 4 shows these results for the average number of intruders metric. Not surprisingly, the average number of intruders in Protest populations is much higher than for the Market population, across all IFC options. We also see that ADD-1 did achieve the best results, (i.e., lowest intruders) under both the Market population (5.6) and the Protest populations (34.4), consistent with the fully aggregated results discussed above. However, upon closer examination, some differences become clear. For example, we see that, for the Protest populations, ADD-2 gives the worst outcome (40.4 intruders), whereas for the Market population the ADD-2 gives the second-best outcome (8.0 intruders).

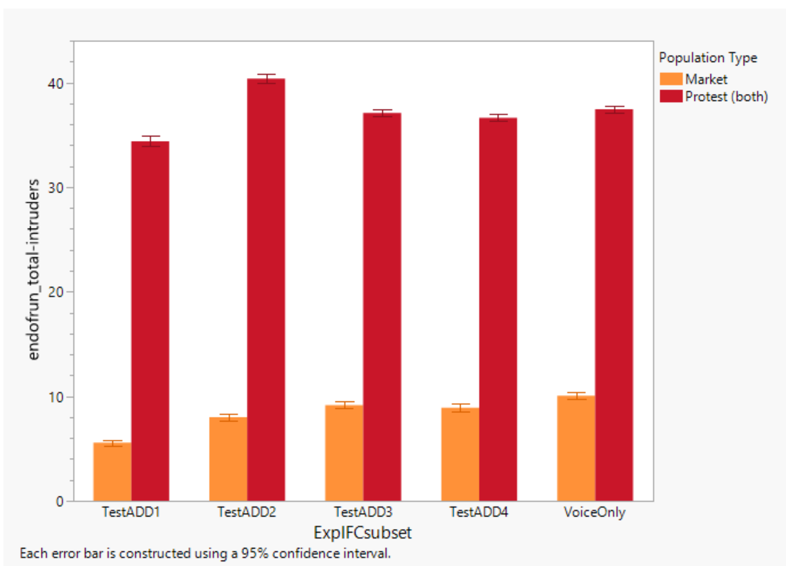

Figure 4. Average Number of Intruders by ADD Configuration, Split by Population Type

Figure 5 provides the hostility escalation results, split by population. Here we can see that, for the Protest populations, the ADD-1 and ADD-2 options result in an average of 138% higher hostility escalations than result from the other three IFC options, averaged. But for the Market population, ADD-1 and ADD-2, averaged, only result in only 56% more hostility escalation than the other three IFC options, averaged.

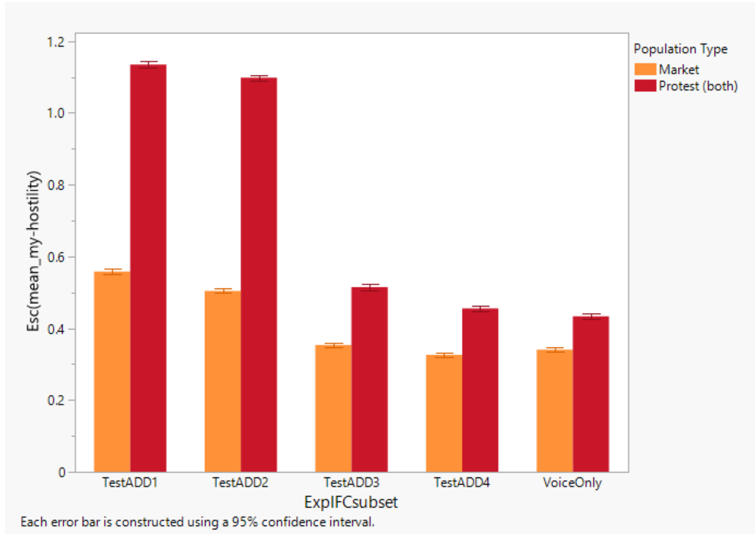

Figure 5. Average Escalation of Hostility by ADD Configuration, Split by Population Type

Overall, this examination of results over different populations, and across two different performance metrics, shows that what had appeared to be the clear dominance of ADD-1, based on the intruders performance metric over the fully aggregated dataset, is actually not so clear. The very high escalation of hostility caused by the ADD-1 should also be considered. Also, the fact that the escalation of hostilities caused by ADD-1 and ADD-2 in the Protest populations is so high, relative to the other IFC options, may indicate to decision-makers that it may be worth considering one of the options that was not optimal on the intruders metric. A full analysis of the results that examines difference in results across other parameters, and across other important metrics such as the escalation in the number of protesters and attackers, would further highlight important nuances in the trade-offs between ADD configuration options. While the new insights from this second-level analysis by population type are few, Aros & McDonald (2023b) demonstrate to what extent the combination of parameter values that produce the most desirable outcomes can be quite different for different populations.

Discussion

Here we discuss how WRENCH can support the acquisition process in different phases. We also discuss important limitations of using simulation modeling in the acquisition process.

How WRENCH Can Inform the Acquisition Process

In the AoA activities of the MSA phase, and in various TM&RR phase activities, WRENCH could be used to simulate the use of different types of theoretical NLW systems, capabilities, or proposed weapons designs, enabling the analysis of the relative effectiveness of different options. This analysis could also provide insights into what factors, whether of the weapons themselves or of the situations or methods of use, most contribute to different effectiveness outcomes. These insights could then be used not only in the selection among alternatives, but also to inform the exploration of theoretical alternatives not yet considered.

During the EMD life-cycle phase WRENCH could be used in DT&E activities to test different design specifications or characteristics of the NLW system to see which is most effective, similar to what was presented in this paper. In addition, these design options could be tested across broad ranges of potential use scenarios to see if the relative effectiveness across the design options differs significantly in different scenarios. And as a part of OT&E activities, WRENCH could be used to test different ways in which the new technology could be used in conjunction with existing non-lethal and lethal capabilities. This can highlight any synergies of challenges in integrating the new technology into the SF force continuum, but can also be used to aid in the development of guidance for how to best use the new technology.

During the P&D phase, once the technology design has been finalized and is ready to be produced, WRENCH can be used to explore different deployment strategies for the new technology such as which force members should be issued the technology. Also, once the technology has been finalized, further exploration of the most effective use strategies can be explored as well.

Limitations of Simulation Modeling

When using any type of simulation, it is important to keep in mind that a simulation will never fully replicate reality, even “live” simulations. Therefore it is important to consider the purpose of the simulation and determine if it is “good enough” for that stated purpose, being careful not to use simulation to inform decision-making that it was not designed to support. For WRENCH, the stated purpose is to evaluate the relative differences in the metrics of interest across realistic scenarios; it was not designed to predict actual outcomes for specific situations. Extensive efforts have gone into the verification and validation of WRENCH, though, and these efforts are ongoing.

Conclusions

This paper discussed the use of computer simulation modeling to assess, test, and evaluate NLW systems. Specifically, we demonstrate how the WRENCH simulation model can be used to explore the effectiveness of different NLW configurations on the achievement of mission objectives in a compound defense civil security scenario. We discussed the design of the experiment, analyzed the results, and provided recommendations. Though our experiment was based on a hypothetical ADS, our findings and discussion indicate that WRENCH could be used throughout the acquisition life cycle for the development of NLW, especially during the MSA AoA activities, and the TM&RR, EMD, and P&D phases.

Our work also serves as a demonstration of how the DoD can leverage simulation capabilities throughout the defense acquisition life cycle for the assessment, testing, and evaluation of products. This would require the selection or development of simulation models suitable for the specific weapons and testing environments, as WRENCH is suitable for exploring NLW effectiveness. The use of computer simulation throughout the acquisition life cycle can be an innovative way for transitioning emerging technologies from research and development to defense acquisition programs of record and thus help the program successfully cross the valley of death.

The experiment and analysis presented in this paper give just the smallest glimpse into the capabilities of WRENCH for testing NLW during the acquisition life cycle. WRENCH can generate outputs on a wide variety of metrics of interest, and can be used to test the effectiveness under a wide variety of conditions and weapon configuration differences, providing a wealth of data for analyses that can shed light on what factors contribute most to the effectiveness of the weapons toward different metrics of interest. WRENCH can also easily be updated to model any new NLW type or new NLW configuration for testing, whether existing or in the planning stages of development. WRENCH currently supports simulation of compound security missions, but could also be extended to modeling other civil security situations such as border patrol and humanitarian aid distribution.

We have a number of ongoing research avenues pertaining to the use of WRENCH. Most immediately, we are continuing to analyze the dataset from the experiment presented in this paper in order to provide more insights into the combinations of different parameters, and which of the specific differences between ADD configurations most affect the results.

We also have multiple efforts underway in the ongoing improvement, verification, and validation of WRENCH. In addition, a future avenue of work just begun is to explore how the simulation advancements made with WRENCH could be leveraged and adapted to construct a similar type of simulation for modeling the use of IFCs in the maritime gray zone. WRENCH is fully DoD owned and developed, leaving the door open for limitless further development and adaptation.

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