Scythe

Proceedings and Bulletin of the International Data Farming Community

Issue 4 - Workshop 16

Proceedings and Bulletin of the International Data Farming Community

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It is appropriate that the publication supporting the International Data Farming Workshop is named after a farming implement. In farming, a scythe is used to clear and harvest. We hope that the “Scythe” will perform a similar role for our *data* farming community by being a tool to help prepare for our data farming efforts and harvest the results. The Scythe is provided to all attendees of the Workshops. Electronic copies may be obtained from harvest.nps.edu. Please contact the editors for additional paper copies.

Please let us know what you think of this *fourth* prototypical issue. Articles, ideas for articles and material, and any commentary are always appreciated.

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International Data Farming Community Overview

The International Data Farming Community is a consortium of researchers interested in the study of *Data Farming*, its methodologies, applications, tools, and evolution.

The primary venue for the Community is the biannual International Data Farming Workshops, where researchers participate in team-oriented model development, experimental design, and analysis using high performance computing resources... that is, Data Farming.

Scythe, *Proceedings and Bulletin of the International Data Farming Community,* Issue 4, Workshop 16, Publication date: July 2008

IDFW 16: Landscapes of Possibilities

by Gary Horne
Naval Postgraduate School

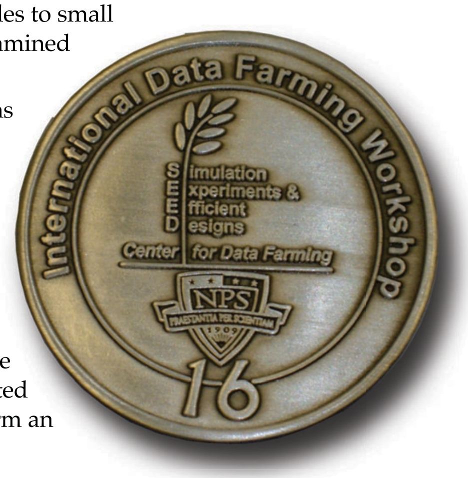
International Data Farming Workshop 16 (IDFW 16) took place from April 13th through the 18th, 2008 in Monterey, California, USA. Seventy-six participants from seven countries worked in eleven different teams exploring questions using Data Farming methods. The theme was "Landscapes of Possibilities," and the goal was to use our Data Farming methods to continue to explore our important questions.

Like IDFW 14, the workshop was hosted by the SEED Center for Data Farming at the U.S. Naval Postgraduate School in Monterey, California. The plan for future workshops is to continue to hold even-numbered workshops once a year in Monterey with odd-numbered workshops taking place at international venues.

As the executive director of the Center, it is my pleasure to work with many from around the world to develop the methods of Data Farming and apply them to important questions of our day. And on behalf of the co-directors of the SEED Center for Data Farming, Professors Tom Lucas and Susan Sanchez, I would like to express our thanks to the team leaders, the plenary speakers and all of the participants in IDFW 16.

This issue, our fourth, of The Scythe contains a summary of each work team effort as well as the plenary sessions. As always, the plenary session materials, in-briefs, and out-briefs from this workshop are available online at http://harvest.nps.edu along with electronic copies of this issue of The Scythe. (Attendees will find an attached CD with this material as well as a collection of photographs from the week of the workshop.) And now I would like to briefly outline the work of the eleven teams and invite you to examine the details of their efforts later in this issue of The Scythe.

Team 1 used Pythagoras to explore the contribution of small-unmanned ground vehicles to small unit combat effectiveness. The team developed a building-clearing scenario and examined different SUGV capabilities such as speed, sensor range, and vulnerability.

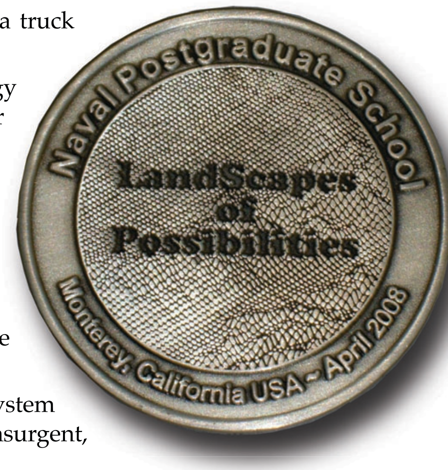


Team 2 built on the work of a completed NPS thesis, which examined questions regarding the new Littoral Combat Ship (LCS) using MANA. The team illustrated the power of Data Farming by conducting over 40,000 replications to help understand the implications of a variety of possible red tactics.

Team 3 was an internationally co-led team, which used both the PAX and MANA models, and applied Automated Red Teaming to investigate different aspects of the same problem involving peace support operations. The scenario used in this team's Data Farming was based on a crowd control situation in a stabilization operation.

Team 4 used the opportunity to participate in IDFW 16 to begin an effort using the agent-based sensor-effector model (ABSEM) recently developed in Germany. They presented the main ideas of the ABSEM to learn from the available expertise and they plan to data farm an ABSEM prototype at IDFW 17.

Team 5 used the Logistics Battle Command model and experimental design techniques to assess the impact that Soldier level network enabled capabilities have on cargo operations at a truck terminal node within a sustainment base supporting a joint force.



Team 6 was led by personnel from the Joint Test and Evaluation Methodology program. This team applied design of experiments and Data Farming using MANA for developing evaluation strategies for testing in a joint environment.

Team 7 not only won the best poster competition, but also used Data Farming to explore parameters and assumptions using the Total Life Cycle Management-Assessment tool on a Marine Light Armored Vehicle.

Team 8 continued its uninterrupted IDFW string of advances in examining combat identification and fratricide. At IDFW 16, they conducted Data Farming experiments using their agent-based model, which represents situational awareness and the cognitive process to combine new sensor input with it to make identification decisions.

Team 9 used Pythagoras and a scenario developed for a prototype multi-agent system model of a civilian population to explore the response of the civilian population to insurgent, government, and stability force actions in a counterinsurgency environment.

Team 10 used the Joint Dynamic Allocation of Fires and Sensors (JDAFS) model, which is being reviewed as a tool to support Joint Starting Condition data development. They explored a joint battlespace scenario in a Data Farming environment to identify possible improvements to JDAFS.

And finally, Team 11 built on research started in Canada on a systems dynamics model used to explore the use of non-lethal weapons in crowd confrontation situations. They used Data Farming and design of experiments approaches to help determine the most sensitive parameters and develop a robust set of rules of engagement.

IDFW 16 was our third workshop in Monterey and it was once again a forum for abundant international collaboration. A special thanks to our technical lead from the SEED Center for Data Farming, Steve Upton, as well as the many efforts of our administrative lead Debbie Sandoval and her assistant Richard Sanchez. And two more thank yous for a job well done goes to Ted Meyer for his expert work in putting together this issue of The Scythe and to Richard Mastowski for a great job editing. Please note that Ted and I can be contacted at datafarming@verizon.net with questions, comments or suggestions.

Now, looking ahead, our Data Farming community will be back in Germany, where workshops 5 and 12 were held, for our next workshop: International Data Farming Workshop 17. It will take place in Garmisch-Partenkirchen, starting with the opening dinner on Sunday, 21 September 2008 and continuing through the week with the closing session on Friday, 26 September. We hope to see you there!

Gary Horne

Team 1: Small Unmanned Ground Vehicles (SUGV): Contribution to Small Combat Unit Combat Effectiveness

TEAM 01 MEMBERS

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INTRODUCTION

As part of the Army's current transformation, robots are being integrated into force structure to reduce human risk. These mechanical "battle buddies" are being used for a myriad of tasks; however, there are currently no established standards for measuring and evaluating their contribution to force combat effectiveness. This research attempts to establish some metrics using essential elements of analysis (EEA), a SUGV functional decomposition hierarchy, Measures of Effectiveness (MOEs) and Measures of Performance (MOPs). Using these metrics, we will determine if the increased situational awareness provided by SUGVs and attached sensors improves combat effectiveness and mission accomplishment. The primary SUGV functional capabilities (Figure 1) modeled were Gain Information (detect/identify agents), Move (speed), Survive (vulnerability), and Employ Effects (sensor ranges). The MOEs measured were the number of friendly forces killed (separating SUGVs and Soldiers), the number of enemy forces killed, and the overall combat effectiveness of the Small Combat Unit (SCU). Pythagoras, an agent-based modeling program was used to develop the simulation. The scenario was based on a dismounted infantry platoon conducting building clearing operations as part of a larger company level cordon and search mission in an urban environment. For comparison, excursions either included one SUGV or none. It is our hope that results obtained will be beneficial to the U.S. armed forces for subsequent research or implementation into any military tactics, techniques, or procedures (TTPs) involving our new "battle buddies".

Problem

Future Combat System projects that 40% of the military fleet may eventually be robotic. Current modeling and simulation studies on the performance of SUGVs are insufficient. Recognizing that doctrine and TTPs will have to evolve, more research is needed.

Research Question

What SUGV capabilities contribute the most to improving a SCU's combat effectiveness during building clearing operations in an urban environment?

SUGV Functional Decomposition

The SUGV functional decomposition hierarchy was developed from requirements found in the Future Combat Systems - Unit of Action Design Concept Baseline Description. These requirements were used to create the six primary capabilities seen in Figure 1. Each of the primary capabilities is decomposed to SUGV MOPs for building clearing operations. Based on the results we will transform these MOPs into MOEs in order to evaluate against our research question.

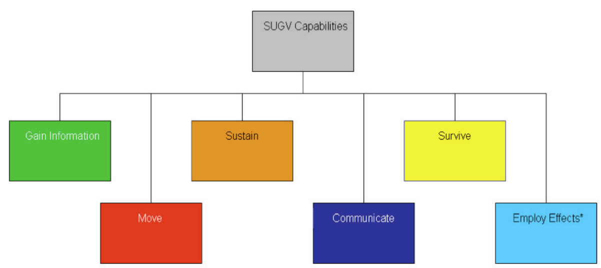

Figure 1: SUGV Functional Decomposition

Measures of Effectiveness (MOEs)

MOE 1: Combat Effectiveness

$$\frac{\text{(Initial Number Red Alive – Final Number Red Alive +1)}}{\text{(Initial Number Blue Alive – Final Number Blue Alive +1)}}$$

The higher this ratio the more effective the SCU is.

MOE 2: Blue Force Mission Accomplishment

$$\frac{\text{(Initial Number Blue Alive)}}{\text{(Initial Number Red Alive)}}$$

This MOE is determining the probability that the blue force wins given the above initial force ratio.

Scenario Description

A Future Force Warrior (FFW) Light Infantry Platoon (Fig 2) was tasked to clear two buildings within the center of a small, urban, desert town and to observe a third building to the north.

The platoon leader, tasked 1st Squad to clear the primary objective (Building 1), tasked 2nd Squad to clear Building 2, and tasked 3rd Squad to observe Building 3. On order, one team from 3rd Squad will provide additional support to 1st and 2nd Squads. The weapons squad will establish support by fire positions south of Building 1 (Fig 3).

Each squad has its own SUGV to provide initial reconnaissance along the routes to each building, as well as to perform initial reconnaissance of the respective buildings in order to detect the presence of any persons.

The enemy situation is unclear. Most recent intelligence reports place enemy elements within Buildings 1 and 2. However, this information is over 12 hours old at the time of the mission.

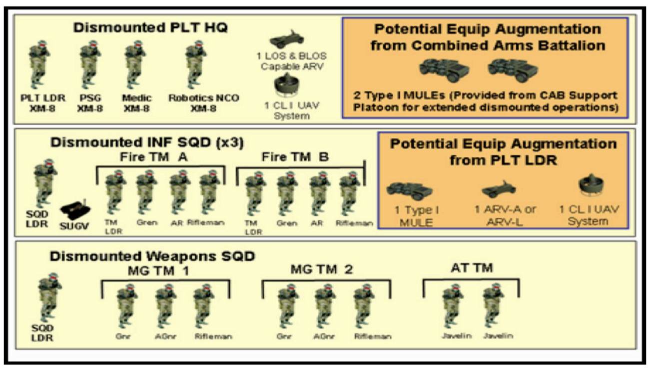

Figure 2: FFW Force Structure

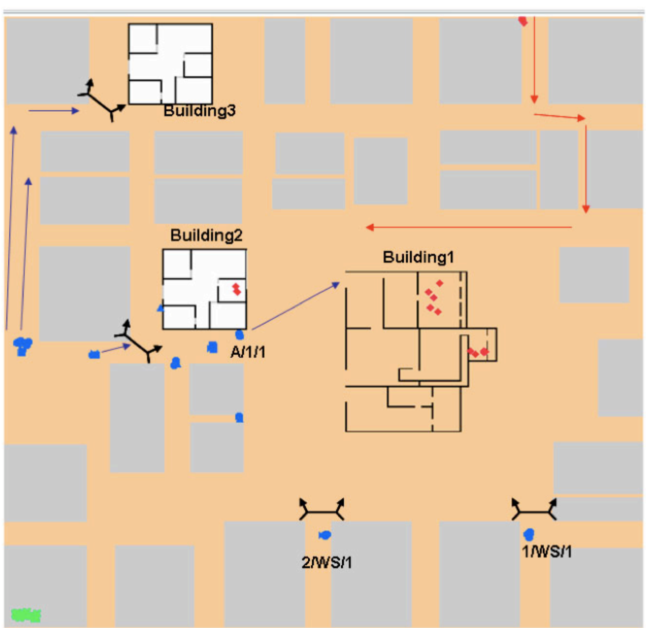

Figure 3: Force Operation Concept and Maneuver Plan

RESULTS AND ANALYSIS

Design of Experiment (DOE)

Using a Nearly Orthogonal Latin Hypercube (NOLH) design, 32 design points were analyzed based on 9 factors. In consideration of total running time and allocation of limited computer assets, only 15 replications were run for each design point. This produced a total of 1485 observations.

Design Factors	Min	Max
Number of SUGVs	0	1
SUGV Speed (kph)	3	6
SUGV Vulnerability	0.1	0.99
Blue Force Speed (kph)	2	8
Number of Enemy (enemy 1)	1	9
SUGV SWIR Sensor Range (m)	800	1200
SUGV Thermal Sensor Range (m)	1300	1700
SUGV Optical Sight Range (m)	250	450
Blue Force's Ability to Detect the Enemy	0.1	0.99

Table 1: Design of Experiment Factors.

Analysis of this experiment focused on the specific combat effectiveness and mission accomplishment of Team A, 1st Squad and its mission to clear Building 1. Using the MOE ratios, only enemy 1 was compared to Team A. Although the size of enemy 1 was varied between one and nine, the size of Team A remained constant at four for all runs.

MOE 1: Combat Effectiveness

Initial analysis of the data found that the mean combat effectiveness of the team to be 1.09 ± 0.95. Next, a regression tree was created to find out how the factors interacted.

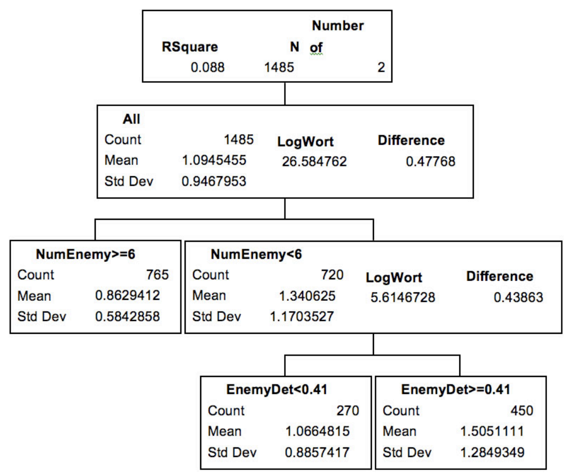

Figure 4: Regression Tree, Team A Combat Effectiveness

The upper portion of the regression tree shows that Team A has the highest mean combat effectiveness when it faces an enemy element that consists of fewer than six personnel. Furthermore, if Team A's ability to detect the enemy is greater than 0.41, then its combat effectiveness increases.

Using stepwise regression, the number of enemy, the blue forces ability to detect the enemy, SUGV speed, and SUGV's thermal sensor range were found to be the most significant factors (Figure 5).

Although the SUGV's speed and its thermal sensor range are significant, the number of enemy and blue force's detection of the enemy are the most significant factors in this model.

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio		Prob>|t|
NumEnemy	-0.076032	0.008804	-8.64		<.0001*
EnemyDet	0.5649415	0.080553	7.01		<.0001*
SUGVSpd	0.0337508	0.012966	2.60		0.0093*
ThermRnge	0.0003981	0.000198	2.01		0.0445*

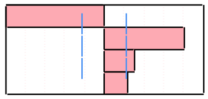

Figure 5: Significant Factors, Team A Combat Effectiveness

A least squares regression of the above four factors and two-way interactions between the four factors were calculated, but none of the interactions between the factors were significant.

MOE 2: Mission Accomplishment

For MOE 2, we wanted to see if the initial force ratio between blue and red forces, determined if the blue force was successful in completing its mission.

For evaluation of MOE 2, the blue force was successful if the final number of blue forces alive were greater than the final number of red forces alive.

Based on the factors varied in the experiment, a contour plot for Team A Mission Accomplishment was produced by looking at the blue force speed versus the number of enemy.

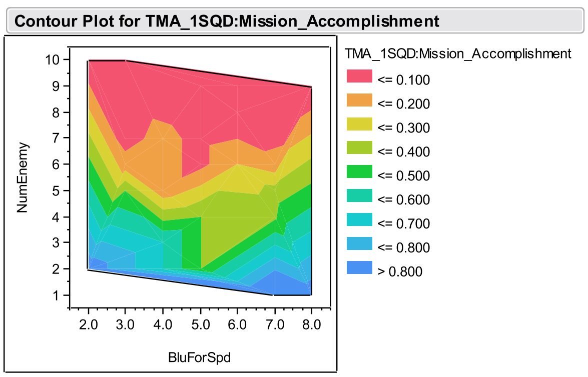

Figure 6: Team A Mission Accomplishment

This plot shows that the blue force is most successful when there are initially fewer than six enemy agents. Additionally, the blue force was more successful when they moved at speeds of 2 or 7 kph.

Further analysis using a stepwise regression found the number of enemy, the blue force's ability to detect the enemy, the SUGV's vulnerability, and the SUGVs infrared (IR) sensor and optical sight ranges to be significant (Figure 7).

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-1.8953702	0.7350499	6.65	0.0099*
SUGVVuln	0.93305944	0.2632043	12.57	0.0004*
NumEnemy	0.82863436	0.0446065	345.09	<.0001*
SWRRange	-0.0016444	0.0006251	6.92	0.0085*
OpticRnge	0.00152437	0.0007243	4.43	0.0353*
EnemyDet	-1.0763828	0.263253	16.72	<.0001*

For log odds of 0/1

Figure 7: Significant Factors, Team A Mission Accomplishment

Observation of a contour plot of the most significant SUGV factors versus the initial number of enemy showed Team A accomplished its mission most often when the SUGV's vulnerability was between 0.2 and 0.7 and when there were fewer than four enemy.

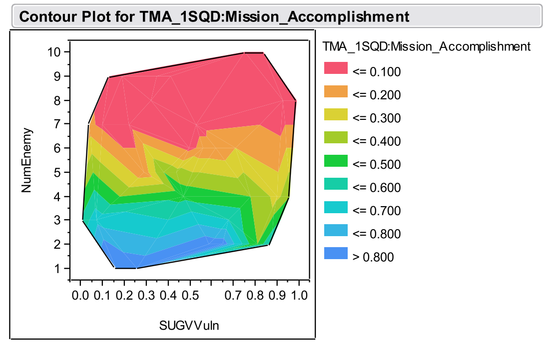

Figure 8: SUGV Vulnerability vs. Initial Number of Enemy (Team A Mission Accomplishment)

Finally we compared Team A's Mission Accomplishment against different initial force ratios. Team A does not begin to accomplish its mission until the force ratio is greater than 0.5 (Fig 9). For this scenario, Team A accomplished its mission less than 30% of the time.

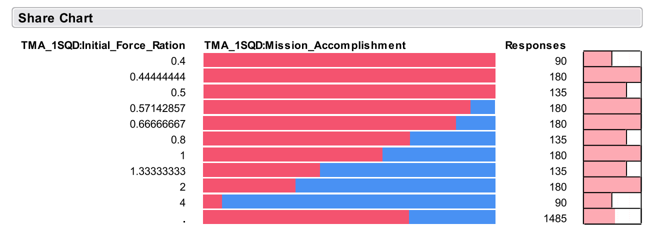

Figure 9: Team A Mission Accomplishment based on Initial Force Ratio

This chart shows that even with the SUGV as a combat multiplier a leader needs to know the number of enemy that his unit is going to be fighting against. If the unit is going to be outnumbered by more than 2 to 1 in a building clearing operation, then he will need an additional enabler.

CONCLUSIONS

Based on our analysis we concluded that a unit's combat effectiveness and probability of success for building clearing operations is most dependent on the number of enemy that are located within the building. However a close second is the enemy detection rate. This is where the SUGV can contribute the most while limiting the risk to Soldiers conducting building clearing operations. Our initial analysis found that the longer the SUGV is operational (vulnerability) the more persons it can detect in order to provide the unit leadership with the situational awareness needed to make critical decisions. Also, the type and number of sensors that the SUGV is equipped with can contribute to unit situational awareness. Both of these capabilities can contribute to the overall success of the unit in accomplishing its mission.

While this study was not conclusive, it shows that SUGVs can be a critical asset in close combat situations. More research and modeling are still needed to determine what combinations of sensors provide the best situational awareness capabilities for leaders.

	Baseline	Blue Plan		Red Plan		Blue ART	Red ART
		Manual	ART	Manual	ART		
Aggressiveness	-60	-60	74	-60	-14	-22	-4
Cohesiveness	-100	-100	-50	-100	-40	85	-16
Determination	60	60	9	60	33	-58	45
Red Mission Success	100%	82%	45%	100%	100%	2%	100%
Red Attrition	2.77	3.98	4.48	1.96	1.83	4.97	0.48
Neutral Attrition	2.21	1.06	0.52	3.05	3.15	0.03	4.52
% Drop (Red Mission Success)	-	16%	55%	0%	0%	98%	0%
% Increase (Red Attrition)	-	44%	80%	(29%)	(34%)	79%	(83%)
% Drop (Neutral Attrition)	-	52%	76%	(38%)	(43%)	99%	(105%)

Table 1: Summary of Results

Team 2: Littoral Combat Ship (LCS) Mission Packages: Determining the Best Mix

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INTRODUCTION

The threat facing the U.S. Navy is changing from engagement in blue water to combat in the littorals. In order to meet this threat, the U.S. Navy built the Littoral Combat Ship (LCS) — a high speed, shallow draft, focused-mission platform capable of operating independently, as a squadron, or as part of a Carrier/Expeditionary Strike Group (CSG/ESG).[1] As with every new platform, many questions regarding the employment of LCS are still unanswered. How many LCS should comprise a squadron? What mix of mission packages should be employed within the squadron? Previous research has addressed the above questions using data farming techniques (i.e., Nearly Orthogonal Latin Hypercubes (NOLH)) with an agent based model called Map Aware Non-uniform Automata (MANA). Simulating over 40,000 littoral engagements in three warfare areas, Surface Warfare (SUW), Antisubmarine Warfare (ASW), and Mine Warfare (MIW), LT Abbott showed that a squadron of six to ten LCSs and a compositional rule of thumb of five LCSs configured for the primary threat and two configured for a secondary threat produced lower blue casualties while increasing red casualties.[2] This research, however, did not take into consideration the use of tactics by the red force. Team 2 investigated the impact of red force tactics on the results found in LT Abbott's research.

Description of Scenarios

The three warfare areas analyzed in the original research were each given a scenario to model the use of an employed LCS squadron:

- In the SUW scenario, a squadron of LCS is used to clear a choke point of a missile boat threat in advance of a CSG; enemy submarines may also be present.
- In the ASW scenario, a squadron of LCS is used to clear a strait of submarines which may be protected by missile boats.
- In the MIW scenario, a squadron of LCS must detect and neutralize a mine field that is blocking a shipping lane and may be guarded by missile boats.

No alterations were made to the scenarios of the original research with the exception of placement of the red forces.

MODELING

In order to maintain integrity with the original work, design points meeting the recommendations (i.e., squadron size of six to ten, and mission package mix) were selected from each warfare area. This produced 16 design points for the SUW scenario, 14 for the ASW scenario, and 19 for the MIW scenario. Figure 1 shows the design points used for the SUW scenario. Since the focus is on tactics, the parameters of the design points were not changed nor were the personality weightings in MANA for the blue or red forces.

low level	1	0	5	1	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
high level	30	5	50	5	5	1	1	1	1	1	1	1	1	1	1	1
decimals	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	3
factor name	SUW LCS	ASW LCS	Red MB	Red Sub	Merchants	57 mm Pk	.50 Cal Pk	Ram Pk	LCS Pd	SUW H Pd	Hellfire Pk	NLOS Pk	30 mm Pk	ASW H Pd	Torp Pk	ASW O Pd
1	6	3	10	3	5	0.906	0.971	0.945	0.822	0.682	0.602	0.623	0.564	0.572	0.969	0.916
2	5	5	27	5	2	0.752	0.988	0.799	0.951	0.643	0.822	0.605	0.605	0.701	0.824	0.551
3	7	2	20	2	4	0.537	0.908	0.828	0.738	0.693	0.742	0.752	0.867	0.871	0.627	0.84
4	6	4	49	4	2	0.869	0.607	0.855	0.582	0.6	0.85	0.676	0.813	0.676	0.553	0.818
5	5	5	15	4	2	0.988	0.748	0.973	0.955	0.641	0.828	0.594	0.848	0.709	0.9	0.656
6	5	3	11	2	2	0.881	0.736	0.795	0.93	0.92	0.73	0.563	0.873	0.734	0.523	0.604
7	8	2	38	5	2	0.658	0.521	0.91	0.863	0.998	0.668	0.699	0.689	0.857	0.533	0.998
8	5	5	50	2	2	0.582	0.703	0.852	0.514	0.861	0.996	0.854	0.912	0.564	0.871	0.941
9	6	4	13	2	5	0.846	0.793	0.617	0.957	0.943	0.563	0.689	0.684	0.883	0.527	0.857
10	5	5	30	3	1	0.855	0.99	0.631	0.672	0.568	0.914	0.652	0.73	0.781	0.635	0.959
11	5	2	46	2	1	0.951	0.756	0.506	0.77	0.775	0.648	0.744	0.865	0.658	0.986	0.82
12	6	2	18	5	2	0.553	0.771	0.652	0.584	0.754	0.576	0.566	0.881	0.695	0.875	0.635
13	8	2	8	3	5	0.975	0.516	0.627	0.559	0.887	0.906	1	0.744	0.639	0.975	0.875
14	7	2	45	3	4	0.977	0.709	0.547	0.998	0.646	0.988	0.852	0.623	0.619	0.895	0.688
15	5	3	35	5	4	0.67	0.738	0.686	0.719	0.705	0.615	0.813	0.955	0.863	0.711	0.514
16	6	4	10	3	2	0.545	0.682	0.559	0.938	0.797	0.943	0.996	0.941	0.793	0.535	0.705

Figure 1: Design points used in the SUW scenario

[1] Commander Naval Surface Forces, Littoral Combat Ship Platform Wholeness Concept of Operations (Revision B), 2 Jan 2007.
[2] Abbott, Benjamin P., "Littoral Combat Ship (LCS) Mission Packages: Determining the Best Mix," M.S. in Operations Research, March 2008.

Placement of the red forces, however, were changed to simulate different tactics that a red force may employ. For each scenario, two tactics were created through red teaming by Team 2, which were then replicated 30 times across each design point. Table 1 summarizes the red tactics Team 2 created for use in the simulation.

Scenario	Red Tactic One	Red Tactic Two
SUW	Submarines form a barrier at the mouth of the choke point. Missile boats unchanged.	Missile boats are assembled in a U-shaped formation just south of the submarines. Submarines unchanged.
ASW	Submarines are placed in four separate boxes in a cross like pattern. Missile boats unchanged.	Missile boats are placed in the center of the channel to the north of the ubmarines.
MIW	Missile boats are placed in front of the mine field to prevent detection. Mines unchanged.	Missile boats are split into two elements, one placed in front of and one behind the mine field. Mines unchanged.

Table 1: Red tactics determined by Team 2

Figure 2 shows a screen shot of the MIW scenario at problem start with the original research placement and red tactics illustrated.

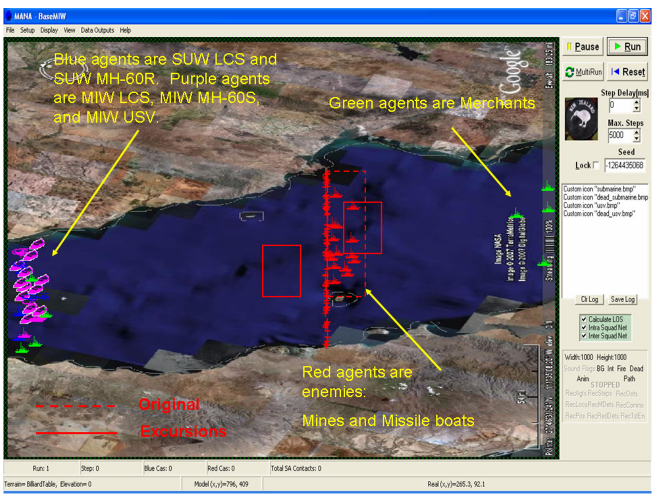

Figure 2: Screen shot of MIW scenario at problem start

RESULTS

After simulating over 1400 littoral operations, the results of each tactic per warfare area were compared to the data provided by the original research. In order to grasp the significance of red tactics, the Measures of Effectiveness (MOEs) chosen by the team are percent of LCS killed and percent of red killed. In the MIW and ASW areas, minor variations in the MOEs were observed and the results of the original work were confirmed—specifically LCS operating in areas where there are more than ten enemy submarines. Figure 3 shows the comparison of the results for ASW area.

The SUW area showed minor variations in percent of LCS killed, but instances of large increases in percentage of red killed. This was due to the ability of the SUW LCS to engage the missile boats while crossing the submarine screen. Figures 4 and 5 illustrate the impact of the different tactics on the blue and red forces for the SUW scenario.

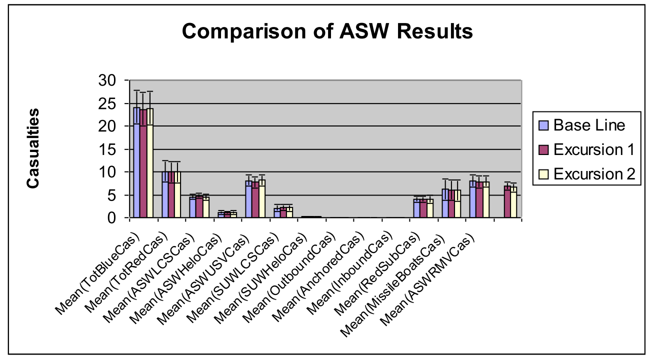

Figure 3: Comparison of the results for the ASW scenario

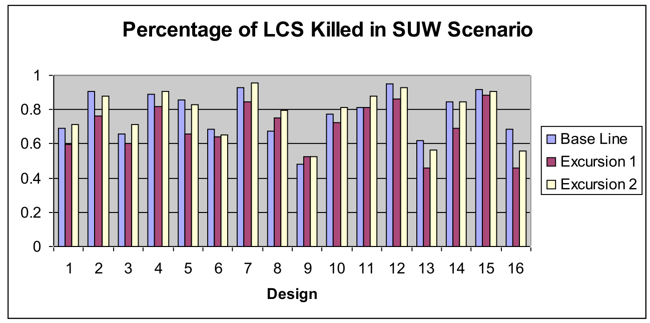

Figure 4: Minor variations in LCS casualties were observed in the SUW scenario

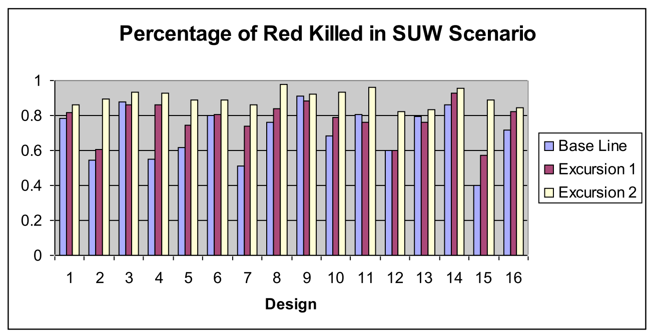

Figure 5: SUW scenario shows large increases in percentage of red killed

CONCLUSIONS

The results obtained by Team 2 solidify the original research and illustrates the power of data farming—conducting over 40,000 replications provides insight over a large spectrum. These results also suggest that MANA indirectly models tactics for both blue and red forces, when the agents are not assigned waypoints and required to follow them closely. This is due to MANA's re-seeding at each replication causing agents to start in different locations within their assigned home. As they follow their personalities they loosely apply many variations of tactics. Further research can be conducted on the impact of changing the personality weightings of both blue and red forces, as well as the use of Automated Red Teaming (ART) and other evolutionary algorithms in determining tactics for both forces.

Team 3: Operational Synthesis Approach for the Analysis of Peace Support Operations

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INTRODUCTION

The team's objective was to explore how an Operational Synthesis approach, i.e. making use of a variety of models and tools to investigate different aspects of the same problem, could improve the overall quality of the analysis. The scenario on crowd control in a stabilization operation used by Team 03 at IDFW 15 was the test case for this exploration. MANA and Automated Red Teaming (ART) were applied to identify the scenario with the most challenging demonstrator behavior. This "worst case" scenario was then represented in PAX[1] to investigate questions related to the effect of military Rules of Engagement (RoEs) on civilians and effects of escalation caused by civilians through the use of the PAX Analysis Toolbox.

OPERATIONAL SYNTHESIS

Operational Synthesis (see Figure 1) is a process which focuses on looking at the whole rather than reducing systems into parts. The goal of Operational Synthesis can be expressed as utilizing each individual tool for what it is good at, and combining the result in a manner that synthesizes the resultant wealth of information.

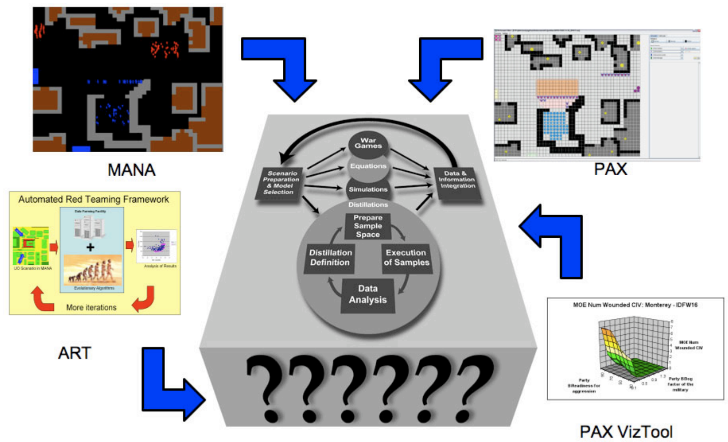

Figure 1: Diagrammatic Representation of Operational Synthesis

Scenario

The scenario examined during the workshop was based on a crowd control "Demonstration" situation in a stabilization operation, similar to the scenario examined by Team 3 during IDFW 15. The team's intention was to use this scenario as a test-case for exploring the process of conducting Operational Synthesis. (See Figure 2 for the geographical disposition of the various constituents of the scenario)

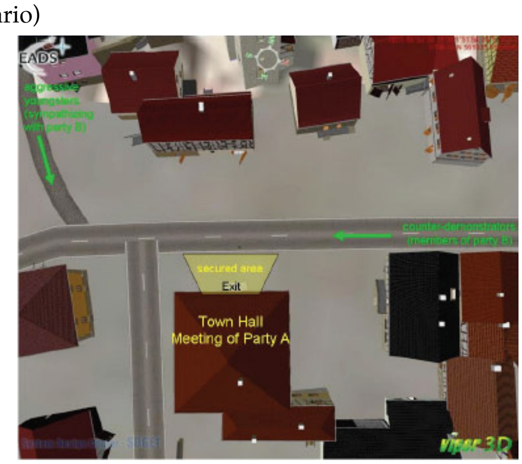

Figure 2: 3D view of the scenario layout

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[1] Note that a 1:1 representation of one and the same scenario in two different simulation models is *hardly ever* possible. Instead, the team captured the main features of the scenario, especially with regard to the aspects relevant and under observation with PAX.

In the scenario, an event organized by political-religious Party A was taking place in a town hall in a part of a town predominantly inhabited and controlled by Party B. When the event ended, Party A members had the intention to leave the town hall as soon as possible and return home via a road heading south. The Peacekeeping force PAXFOR received intelligence reports that a group of Party B members, known for their political disagreement with Party A and aggressive in behavior, had announced that a demonstration march would be carried out towards the location where Party A members were meeting. In addition, a small group of young Party B members, known for possible violent actions and persistent intent to cause harm to Party A members, were expected to join in this counter-demonstration. Party B members had the intent to hold the demonstration outside the town hall and confront Party A members when they were leaving the town hall. The PAXFOR identified the possibility that Party A and Party B members would be injured due to the confrontation and intended to separate the two groups by forming a separation line in front of the town hall.

Questions

"What would be particularly challenging situations that may arise, and the RoEs that would be helpful to the peacekeepers in these situations?"

The Process

Based on the questions and the scenario, and taking into consideration the strengths and limitations of MANA, PAX and ART, the team developed the proposed iterative process for an Operational Synthesis (see Figure 3).

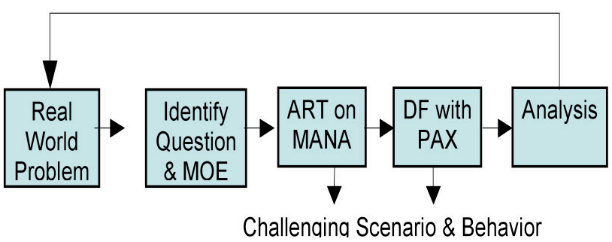


Figure 3: Iterative process for Operational Synthesis

Step 1: Identifying questions and defining an appropriate MOE to address the real world problem.

The team discussed the need to focus on a single common MOE that would be relevant to the question and ideally could be obtained from both the MANA and PAX models. However, as MANA and PAX are designed to study different aspects of operational problems, they naturally have different sets of MOEs. After some deliberation, "Wounded Party A members" was chosen as the "common" MOE.

Step 2: Developing and implementing the scenario in MANA; performing single runs and identifying parameters that are relevant to the study.

After the scenario was developed in MANA (see Figure 4), it was decided that a second line of Peacekeepers be included in the demonstration area to make the "blue" plan more robust and more effective in separating the Party A and Party B members. The intention of adding the second line of Peacekeepers would be to help deter and repel any Party B demonstrators who managed to penetrate through the first separation line. It was also decided that the scenario would be more challenging if the Party B violent youths were to mix within Party B demonstrators and approach directly from the front of the separation lines.

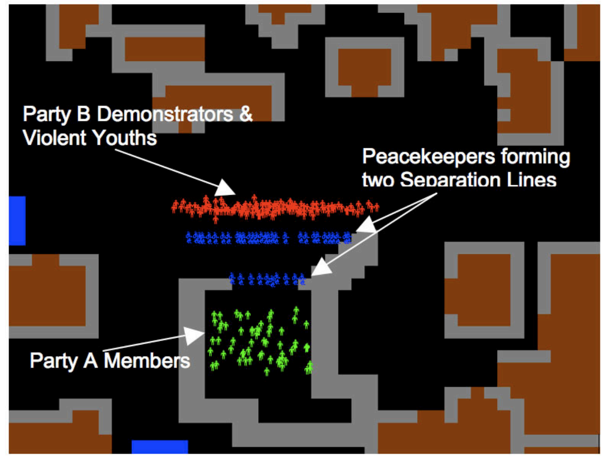


Figure 4: Geographical representation of MANA scenario

Step 3: Applying ART to the MANA scenario and evaluating the performance of the MOE based on generated changes to the parameters. Interpreting the parameter improvement with perspective of the real world problem.

The scenario developed in MANA was submitted for ART runs. The objective was to identify challenging movement and behavior emerged from Party B parameters that would maximize the number of wounded Party A members.

The following set of parameters was included to be varied within the specified range of values in the ART submission (Table 1):

Parameters submitted to ART	Parameter Values in MANA		
	Baseline	Min	Max
Party B Demonstrators			
Starting Location (along horizontal axis)	450 (centre)	300 (left)	700 (right)
Cohesiveness during Movement	-30	-40 (least cohesive)	40 (most cohesive)
Duration of Interaction with Peacekeepers (time steps), i.e. when will they back off.	100	10	200
Duration of Backing off (time steps), i.e. when will they come back to confront the PAXFOR again.	100	10	200
Party B Violent Youths			
Starting Location (along horizontal axis)	450 (centre)	300 (left)	700 (right)
Cohesiveness during Movement	-30	-40 (least cohesive)	40 (most cohesive)
Duration of Interaction with Peacekeepers (time steps)	100	10	200

Table 1: Submitted parameters and range of values

The ART submission was sent to the cluster in Singapore and the results presented in Table 2 were obtained:

Parameters submitted to ART	Parameter Values in MANA	
	Baseline	Best Results from ART
Party B Demonstrators		
Starting Location (along horizontal axis)	450	471
Cohesiveness during Movement	-30	33
Duration of Interaction with Peacekeepers (time steps)	100	64
Duration of Backing off (time steps)	100	35
Party B Violent Youths		
Starting Location (along horizontal axis)	450	445
Cohesiveness during Movement	-30	4
Duration of Interaction with Peacekeepers (timesteps)	50	194
MOE – Wounded Party A Members (Max 60)	25 42%	60 100%

Table 2: Comparing parameter values and MOE values of the best case with regard to Party B from ART run

It was evident that ART was able to increase the number of wounded Party A members from the original 25 out of 60 (42%) in the baseline to 60 (100%) in the ART scenario.

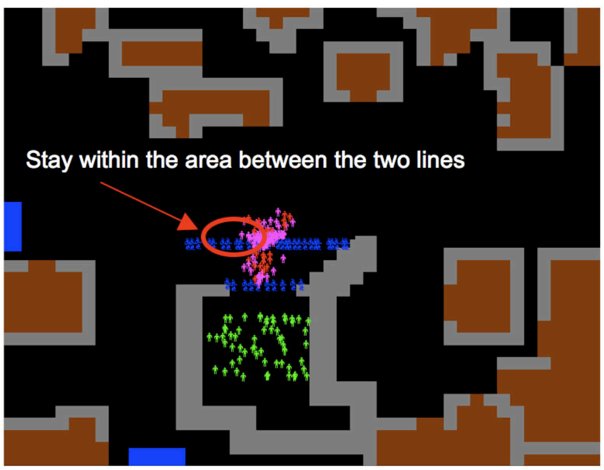


Figure 5: Emergent movement of the Party B members based on ART output

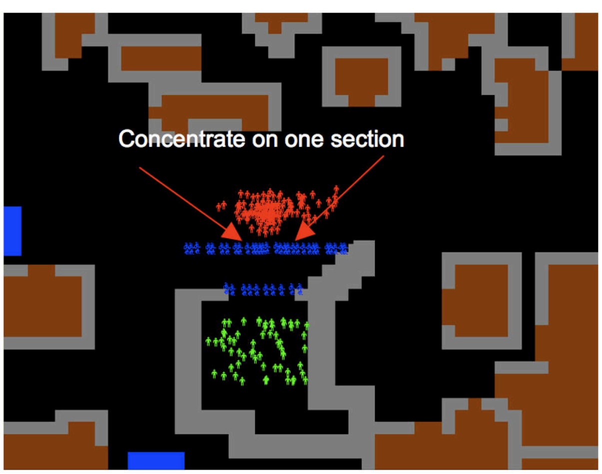


Figure 6: Emergent interaction behavior of the Party B members based on ART output

Two key points optimizing Party B's tactics were observed in the "ART-ed" scenario:

1. Concentrate demonstration on one section of the line to overwhelm the peacekeepers. (Figure 5)
2. Optimal interaction and back-off times that will keep large numbers of the Party B members between the lines. (Figure 6)

Step 4: Based on the interpretations of the ART results, deducing adaptations for the PAX and integrating them in the PAX scenario.

The resulting movement and behavior of Party B members identified from the MANA-ART effort were transferred to the PAX scenario, as applicable. Due to difference of the grid size in the PAX scenario only the group ratios were kept consistent across the MANA and PAX scenarios (Figure 7)

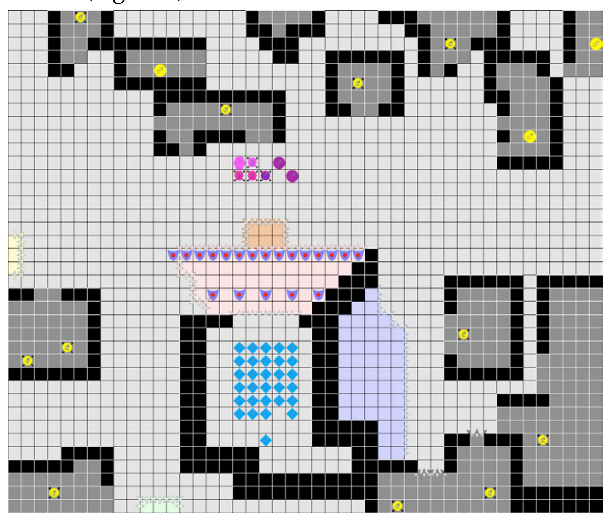
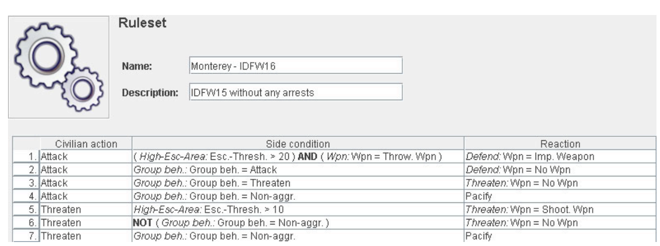


Figure 7: Geographical disposition of agents within PAX model

Step 5: Performing design of experiment and running data farming on PAX. Performing analysis on the PAX output.

With the challenging Party B behavior modeled in the PAX scenario, the team proceeded to address another aspect of the questions, which was on the possible RoEs that the peacekeepers could adopt to reduce the number of wounded Party A members. For this purpose, the team developed a new rule set, shown in Figure 8, which was based on the IDFW15 rule set but did not include any arrests, to compare this new rule set to the IDFW15 one as well as the "default" rule sets "PSO Manual" and "Gandhi."


Ruleset

Name: Monterey - IDFW16

Description: IDFW15 without any arrests

	Civilian action	Side condition	Reaction
1.	Attack	(*High-Esc-Area:* Esc.-Thresh. > 20) **AND** (*Wpn:* Wpn = Throw. Wpn)	*Defend:* Wpn = Imp. Weapon
2.	Attack	*Group beh.:* Group beh. = Attack	*Defend:* Wpn = No Wpn
3.	Attack	*Group beh.:* Group beh. = Threaten	*Threaten:* Wpn = No Wpn
4.	Attack	*Group beh.:* Group beh. = Non-aggr.	Pacify
5.	Threaten	*High-Esc-Area:* Esc.-Thresh. > 10	*Threaten:* Wpn = Shoot. Wpn
6.	Threaten	**NOT** (*Group beh.:* Group beh. = Non-aggr.)	*Threaten:* Wpn = No Wpn
7.	Threaten	*Group beh.:* Group beh. = Non-aggr.	Pacify

Figure 8: PAX rule set developed at IDFW16

In addition to examining the rule set, the team also decided to investigate two other factors that could not be represented in MANA, but were of interest with regard to the PSO aspects that can be modeled in PAX. Namely, the initial readiness for aggression of the Party B members and the deterrence effect by the presence of the peacekeepers (the so-called "dog factor") were selected as additional factors for the upcoming Data Farming experiment.

Finally a full factorial design of experiment as shown in Table 3, consisting of a total of 4480 runs (224 variations x 20 replicates), was submitted to the 128 node cluster of the Simulation and Test Environment of the German Bundeswehr.

Full Factorial Farming Parameters	Min	Max	Step Size
Party B counter-demonstrators readiness for aggression	30	90	10
Party B counter-demonstrators dog factor	0.1	1.5	0.2
Soldiers' rule set	1	4	1

Table 3: Parameters varied in full factorial design study

When analyzing this study, one of the immediate findings was that in the PAX scenario hardly any Party A member was actually ever injured (see Figure 9) as opposed to almost every one being injured in the respective MANA scenario. This confirmed the group's expectation that the "same" scenario, modeled in different simulation models, will almost certainly take a different course of events and hence the results will be different, even if the names of the MOEs under consideration may be the same. In this particular case, the reasons for this include, but are not limited to, the following:

- The criteria of when to consider a civilian "wounded" are different in PAX and MANA.
- The RoEs of the soldiers modeled in PAX were quite different from and comprised more detail than their reactions in MANA.
- The civilians' complex behavior model in PAX, especially with regard to emotional factors, was very different from the rather simplistic behavior of the civilians scripted in MANA.

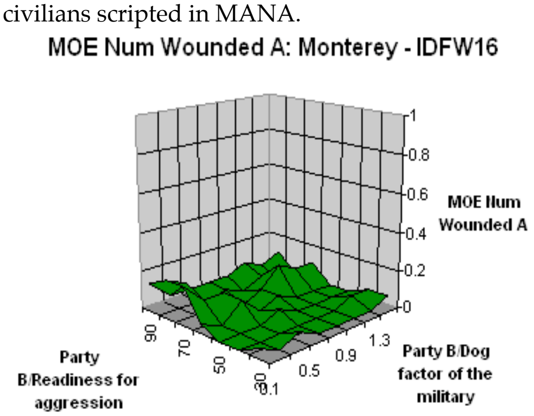


Figure 9: Number of wounded Party A members with IDFW16 rule set

One of the "lessons learned" the team drew from this was that, instead of comparing the two models and the course of events of the scenario in each, we should concentrate on the parameters and aspects the team had not even been able to model in MANA in the first place. This, in fact, complies with one of the team's key objectives: the ability to observe a problem from different perspectives using various tools and thus gain insights into various aspects of the problem at hand that could not have been obtained by using just one of the tools or models.

To point out one example, we will explain one of the team's findings with regard to the aggregated level of escalation caused by the civilians (i.e. aggressive actions performed by the respective civilians).

The group noticed that with the second line of soldiers the overall escalation shows a roughly *polynomial* decrease with respect to Party B's military dog factor as opposed to a roughly *linear* decrease observed with the original IDFW15 scenario (see Figure 10).

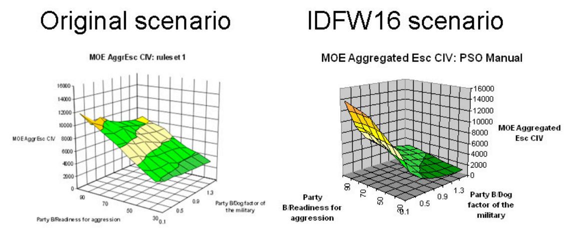


Figure 10: Comparison of the PAX scenarios with regard to the MOE "Aggregated Escalation by Civilians"

First of all, this confirms the rather obvious expectation that escalation can be kept low by either having more soldiers in the area or increasing the soldiers' deterrence effect by any means. In addition to this, however, the results of the PAX study suggest that with an increasing number of soldiers their individual deterrence effect, at least above a certain threshold, becomes even more efficient.

In other words, the analysis shows that with the second line of peacekeepers the PSO force is able to keep the escalation level *very* low even with a *rather reasonable* ability to deter the demonstrators. As a side-effect, this deployment is more robust with regard to the counter-demonstrators' readiness for aggression.

Further analyses, such as comparison of the different rule sets, were performed by the team but will not be described here for the sake of brevity.

Step 6: Applying the analysis result to gain insights to the questions identified for the real world problem.

This is essentially the final step. However, as the scenario was used as a test-case only rather than to examine a real operational problem, this step was not executed methodically. Although some very basic tendencies could be derived by using the respective strengths of both MANA and PAX, such as the introduction of a second line of soldiers and some possible conclusions as to the soldiers' RoEs, further actions would have to be taken to be able to perform this step.

To mention just a few, a much more detailed preparation of the scenarios, a more thorough analysis as well as further interpretation of the findings by military experts would certainly be necessary to draw conclusions with the confidence required for applying the results to a real-world problem.

CONCLUSION

Challenges of Operational Synthesis

Throughout the week, the team also discussed and noted the experiences with and the challenges of Operational Synthesis:

3. **Identifying questions and common MOE.** Identifying a common MOE that allows analysis to be conducted to address these questions was a challenge. Models like MANA and PAX would represent and measure effects of actions differently and hence certain MOEs, although named similarly, may not be measuring the same effects within the models. Hence if a common MOE is desired it would be important to establish what would be the relevant and common MOE(s) when dealing with different models to avoid confusion during the analysis stage.
4. **Representing common aspects of a scenario in different models.** Although it was possible to achieve cosmetic and physical similarity between different models like MANA and PAX, it is difficult to make different agent-based models function and emerge in a similar way to generate comparable results. One possible conclusion could be to put more effort on functional instead of parametric similarity so that similar effects would be represented in the two models. On the other hand, the team's experience has rather indicated that it is generally not even desirable to make two models behave exactly the same way since that eventually breaks down to having just one ("synchronized") model instead of making full use of the benefits of having different models to study different aspects and probably even different vignettes of a question.
5. **Transferring analysis findings between models.** Since MANA and PAX are different models, the results obtained from the ART runs on MANA would not be directly transferable to the PAX model, at least in the parametric sense. The main challenge would be to decide how best to represent these MANA findings in the PAX model.

Benefits of Operational Synthesis

6. **Better understanding of the models.** First of all, the use of different tools and models broadens the analysts' horizon and gives them insight into the models that goes far beyond simply using one and the other. Due to the necessity to carefully set up analyses and experiments with more than one model and then comparing their results a deeper understanding of the internal operation of each of them is required and obtained.
7. **More comprehensive analysis capabilities.** The Operational Synthesis approach enabled the team to look at the question set from different angles and on different operational levels. Thus the whole process and the combination of tools, models and methods thoroughly enhances the ability to develop, test and elaborate RoEs as well as Tactics, Techniques and Procedures (TTPs).
8. **Further applications.** Beside the advantages aforementioned, the methodology seems to be very well applicable to the calibration and validation of simulation models, for example. Using ART to "optimize" a scenario towards a result observed in the real world as well as the deep understanding of the model gained during the whole process of Operational Synthesis promise to be tremendously helpful during model calibration and validation.

Summary

As mentioned earlier, the team objective in this workshop was to focus on exercising and gaining insights on the process of Operational Synthesis, rather than examining a real operational problem. Through this exploration, the team discovered the key benefits of the Operational Synthesis approach. In particular, the approach allowed high-level as well as low-level resolution analyses. Deeper insights on the dynamics of the scenario and models could be gained. The team had also gathered many useful insights on the challenges of executing the Operational Synthesis process. Last but not least, the team had benefited greatly from a truly international collaborative effort as many useful ideas and insights were contributed by participants from Singapore, Germany, New Zealand and the United States.

In summary, the Operational Synthesis approach as performed by Team 3 promises to provide a new quality to the analysis of (Peace Support) Operations by enabling the analyst to take into consideration a variety of aspects and questions otherwise unaccounted for. Nevertheless, further work and research has to be done to improve the tool support and integration (e.g. providing Automated Red Teaming support for PAX) on the one hand but also formalizing the possibilities and limitations of the approach to make the best and most efficient use of it.

Team 4: Agent-based Sensor-Effector Modeling

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Team Proposal

During previous Data Farming workshops, different representatives of the German Federal Office of Defense Technology and Procurement and EADS were concentrating on the simulation of technical aspects in network centric operations (NCO). In the respective working groups, the main focus was on analyzing the influence of networked sensors and effectors on military capabilities and the operational outcome.

Those studies showed, however, that the existing agent-based models are rather limited in terms of modeling and simulating complex technical systems on a sound physical basis.

For this reason, the German Federal Office of Defense Technology and Procurement decided to develop a new agent-based model that fulfills the requirements to be used for analyzing the combination of various sensor and effector systems in NCO while taking into account the underlying physical theories. This model called ABSEM (agent-based sensor-effector model) is currently under development, a first prototype is planned to be presented to the international Data Farming Community at IDFW 17.

Team Activities

The team's main intention during IDFW16 was to learn from the available international expertise and experiences in building new models and designing a flexible and generic architecture for a data-farmable and modular multi-agent system for modeling sensor-effector physics.

For this reason, team 4 presented the main ideas and concepts of the ABSEM during a plenary session and put up the whole topic for discussion in a particular ABSEM focus group.

ABSEM Requirements

Particularly based on the work accomplished during the previous International Data Farming Workshops and looking on specific scenarios, a whole list of requirements could be identified that needs to be taken into account when building a new model for rather technical analyses of sensor-effector-systems. Those include for instance considering a three-dimensional representation of the terrain and the model entities, but also different types of terrain and accordingly the respective impact on both the agents' behavior and the sensor / effector systems. Apart from that, the model must provide a possibility to model different types of agents and entities (like soldiers, civilians, transport agents, vehicles, aircraft) by specifying the corresponding characteristics (e.g. speed, size, energy consumption,…).

However, the model's main goal is to analyze different sensor / effector systems within a dynamic environment. Therefore it is essential to allow for an arbitrary number of sensors and effectors that can be stored in templates to be reused by all agents and in any scenario. Possible sensor systems might be

- Human viewing (without any visual aids)
- Electro optical devices
- Night vision devices (residual light amplifier, infrared)
- Radar devices
- Sonar devices

The main focus in ABSEM will be to support different levels of abstraction and to allow for integrating sophisticated physical models when determining a sensor's range and detection / identification probability, but also when computing an effector's hit probability.

This implies that sensor parameters like the aperture angle, the resolution (spatial frequency), the sensitivity or also the search rate with respect to the field of view and field of search need to be considered. Regarding an effector's hit probability, influencing factors like the distance to the target, the terrain (line-of-sight, concealment) or the target size must be examined.

ABSEM Concepts

To be able to support different levels of abstraction, ABSEM allows for subsuming several real objects in one agent. After all, the model's efficiency and performance significantly depends on the number of agents involved.

There are three different types of model entities. Embedded systems are model elements that are attached to a certain parent object. They don't have any own, self-contained or dynamic behavior and only exist as long as their host entity exists. An agent, by contrast, is a completely autonomous system that is provided with its own dynamic behavior. An agent acts and reacts self-contained. It is not possible to directly change an agent's state. Instead, an agent perceives information from the environment, processes this information and then updates its own state and reacts if necessary. An aggregated entity finally is an agent that models the group behavior of two or more subordinate entities. Depending on the underlying scenario and the given question set, the sensors / effectors in ABSEM for instance may be either modeled as an embedded entity that is assigned to any other agent, or as an agent itself.

The agents' actual behavior results from a set of tasks or objectives the agent currently tries to pursue. Examples are various motion tasks, like patrol, follow, and escape, but, of course, also attacks or the task to defend or protect some area or other entities. Furthermore, ABSEM will consider communication and transportation tasks. Any task definition is always state-oriented. That is, the task only determines what has to be achieved, but it doesn't give any information about how. So, it's up to the agent to decide, how this task is going to be fulfilled.

Regarding the sensor and effector modeling, most existing simulation models use a very simplistic approach to determine the probability for detecting or hitting a target object, often not taking into account the terrain or specific characteristics of the sensor / effector. Within ABSEM, a rather detailed physical approach is to be used. The goal is to integrate parameters that are physically measurable—meaning that if you identify a certain model parameter within your Data Farming analysis that seems to be very important for a given MOE, this parameter can also be transferred to a specific real-world parameter.

ABSEM User Interfaces

In ABSEM both an online- and an offline-animation is to be supported. The offline-animation is often very helpful when analyzing single runs and if you want to jump back and forth in simulation time. Depending on the analysis objectives, a 2D- or alternatively a 3D-visualization is more appropriate. Apart from visualizing interactions between individual agents, information windows showing agent-specific information or technical information about the weapons or sensors in use will help in understanding what's going on and why the agents behave the way they do.

To realize all that, an integrated 2D and 3D visualization tool developed by EADS is to be used. This tool already fulfils part of the ABSEM requirements, at least regarding the visualization However, so far, no editing functionalities are supported, thus still need to be added.

Since ABSEM is also meant do be used within the Data Farming process, a link is to be created to the Data Farming GUI. In a few words, this Data Farming GUI enables the user to setup new Data Farming experiments in a very comfortable way. The progress of any experiment that is currently running on the connected computer cluster may be observed and the generated results may be analyzed using a corresponding analysis service. Altogether, this Data Farming GUI supports the three data farming phases experiment definition, experiment execution and experiment analysis and thus simplifies enormously the whole Data Farming process.

Summary

During IDFW16 team 4 got a lot of valuable feedback from the international partners that will be kept in mind in the following conceptual work.

The next step will be to implement a first ABSEM prototype that includes at least some of the described concepts and which will be available at the next International Data Farming Workshop 17 in September in Garmisch-Partenkirchen.

Team 5: Impact of Network Enabled Capabilities on Logistics Operations

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INTRODUCTION

Several joint and service concepts, logistics studies and analyses, as well as government sponsored studies recognize that the current distribution system is characterized by deficient in-transit visibility (ITV), networked communications, and information system that provide network-wide visibility of node and mode status in a shared logistics common operating picture (LCOP). These deficiencies jeopardize the ability to build a sustainment system that ensures that the right supplies and services will arrive on time and location when needed.

Because the current communications network does not support current force requirements, individual units and commands have supplemented their units with a myriad of commercial wireless technologies procured in an ad hoc manner with operational, discretionary, and supplemental dollars, to augment or replace tactical networks, despite interoperability, security, and spectrum issues. In fact, those commercial wireless technologies serve as systems and as network enablers to fill current network-enabled capability needs. Recent studies, anecdotal evidence obtained from operational needs, integrated priority lists, and collected operational lessons suggest that seamless integration of individual soldier-level wireless tactical networking devices prevalent in support operations areas require a comprehensive independent analysis. Consequently, TRAC-Monterey is conducting a Capability Based Assessment (CBA) to identify network-enabled capability gaps for CSS soldiers and to identify potential solutions to fill those gaps.

IDFW 16 OBJECTIVES

This working group's overall objective for IDFW 16 was to use the Logistics Battle Command (LBC) model, a new battle command simulation developed by TRAC-Monterey, and experimental design techniques to assess the impact that soldier level network-enabled capabilities have on cargo operations at a truck terminal node within a sustainment base supporting a joint force.

Particularly, the specific objectives of Team 5 sessions during IDFW 16 included:

1. Represent the different network structures and distribution of enablers in LBC.
2. Develop measures of effectiveness (MOE) and confirm that LBC can produce required MOEs.
3. Develop experimental design to examine factors of interest to issues of analysis.
4. Explore network-enabled capabilities and distribution of enablers through experimental design.
5. Run DOE for model on the cluster to determine how network-enabled capabilities affect performance.

LBC MODEL

The LBC model is a low-resolution, object oriented, stochastic, and discrete event model programmed in Java and incorporates Simkit. LBC functionality includes planning and decision support features to enable a simulated sustainment decision maker to monitor the LCOP, forecast demand for most classes of supply, and initiate and adjust missions to distribute supplies and perform sustainment functions. LBC model uses network architectures to represent the distribution pipeline to summon sustainment planning and execution representing the end-to-end flow of resources from supplier to point of consumption.

The LBC model uses nodes and arcs to represent the different networks of the distribution system. The LBC model accomplishes this through three layers of network representation: the transportation, communications, and planning networks. First, the transportation network links LBC model to the physical area of operations representing the geographical distribution of supplies, and allows for dynamic route planning. Second, the communications network represents an arbitrary complex communications network of the distribution system linking leaders and soldiers to all applicable stakeholders including the LCOP. Last, the planning network represents the data of the distribution system information network.

SCENARIO

The scenario selected focuses on operations at a terminal node of the theater distribution system: namely, a Centralized Receiving Shipping Point (CRSP). A CRSP is dock to dock distribution center, within an area of operations where cargo is delivered, sorted, shipped, and backhaul cargo is picked up 24/7. The objective is to continuously move cargo quickly and efficiently using regular sustainment deliveries from theater to a CRSP, employing the familiar "hub and spoke" concept. Typically, Army Transportation Soldiers operate the CRSP.

The scenario concentrates on Transportation Soldiers operating the CRSP different sections, especially the container lane, pallet lane, rolling stock lane, and the operations center to process cargo received from regular sustainment convoys composed of thirty trucks with different commodities.

Network Structures

Representing network structures on LBC is the first objective the workgroup addressed. The scenario built was designed to assess three network structures and the ability to accomplish the mission in the assigned scenario. Incorporating network-enabled capabilities in the scenario involves connecting various lanes as nodes in the communications network providing timely and accurate information. The three network structures implemented in LBC to explore network-enabled capability are Hierarchical, Star, and Fully Connected network structures.

First, the Hierarchical network structure represents a topology which outlines the interconnection of five network-enabled nodes through four communication channels in a hierarchical manner. Second, the star network structure delineates a topology in which each of the four nodes of the network within the terminal node are connected to the network central node, with a point-to-point link through four communications channels in a hub and spoke fashion. Finally, the Fully Connected network structure represents a type of network topology in which each of the five nodes of the network are connected to each of the other nodes in the network with a point-to-point link through seven communications channels or arcs making it possible for data to be simultaneously transmitted from any single node to all of the other nodes.

MEASURES OF EFFECTIVENESS

The second objective addressed was the development of MOEs. The three primary MOEs of interest developed are Velocity, Reliability, and Visibility. They were derived directly from the concept specific attributes listed in the Joint Logistics (Distribution) Joint Integrating Capabilities (JIC) (2006) in order to provide the linkage from the specific mission tasks to the estimated operational outcomes for each scenario. This approach clearly provides decision makers with the traceability of capability gaps to required capabilities. Below is a discussion of the MOEs of interest.

- *Velocity* is the speed at which convoys are processed in the terminal node. Convoys must be processed with the right resources at the right speed with reliability. Convoy wait time influences velocity. Wait time is defined, *Service Factor * Utilization Factor * Variation Factor*. As wait time decreased, Velocity increases.
- *Reliability* is the degree of assurance or dependability that cargo terminal operations will consistently meet convoy demands under established conditions to specified standards. Reliability measures the variance of the convoy wait time.
- *Visibility* is the capability to determine the status, location, and direction of flow of materiel. This MOE provide a measure of the impact of network-enabled capabilities. It quantifies the difference between the ground truth stock levels and the LCOP levels.

DESIGN OF EXPERIMENTS

A Nearly Orthogonal Latin Hypercube (NOLH) design was constructed (see Table 1) to develop several experiments based on a range of inputs for seven factors. The decision factors considered are ITV-available, ITV-accuracy, LCOP-update, latency, and probability of communications. These are the parameters that influence network capability for the scenario. The noise factors are resources available, and convoys per hour which allow examining the impact of network capability aspects on a broader base. These factors were derived directly from concept specific attributes listed in the Net-Centric Operational Environment (NCOE) JIC (2006). For simplicity, the factors were considered continuous and integer. Below is a discussion of the factors of interest developed by the workgroup.

- *ITV-Available* represents the probability to which personnel at the terminal node are provided with timely, reliable access to ITV data of cargo.
- *ITV-Accuracy* represents the likelihood of the ITV data of cargo transmitted matches received information given ITV-Available
- *LCOP Update* is the rate in hours at which nodes update the LCOP.
- *Probability of communications* corresponds to the probability of successful communication between nodes given point-to-point link.
- *Latency* refers to the message transmission delay in hours.
- *Resources available* accounts for the amount of materiel handling equipment available for operations at the terminal node.
- *Convoys per hour* are the amount of convoys arriving at the terminal node in an hour interval.

low level	**0.2**	**0.2**	**0**	**0.1**	**0**	**4**	**1**
high level	**0.9**	**0.9**	**1**	**1**	**0.25**	**8**	**3**
decimals	**3**	**3**	**3**	**3**	**3**	**0**	**0**
factor name	**ITV-Available**	**ITV-Accuracy**	**LCOP Update**	**P(Comms)**	**Latency**	**Resources Available**	**Convoys per hour**
	0.419	0.9	0.813	0.438	0.063	8	2
	0.244	0.375	0.875	0.606	0	5	2
	0.288	0.506	0.063	0.325	0.156	7	3
	0.331	0.638	0.313	1	0.141	5	3
	0.725	0.856	0.438	0.213	0.078	4	3
	0.9	0.419	0.375	0.831	0.016	7	3
	0.638	0.331	1	0.381	0.219	6	3
	0.594	0.813	0.75	0.944	0.203	7	2
	0.55	0.55	0.5	0.55	0.125	6	2
	0.681	0.2	0.188	0.663	0.188	4	2
	0.856	0.725	0.125	0.494	0.25	7	2
	0.813	0.594	0.938	0.775	0.094	5	1
	0.769	0.463	0.688	0.1	0.109	8	2
	0.375	0.244	0.563	0.888	0.172	8	1
	0.2	0.681	0.625	0.269	0.234	5	1
	0.463	0.769	0	0.719	0.031	6	1
	0.506	0.288	0.25	0.156	0.047	6	2

Table 1: NOLH Design

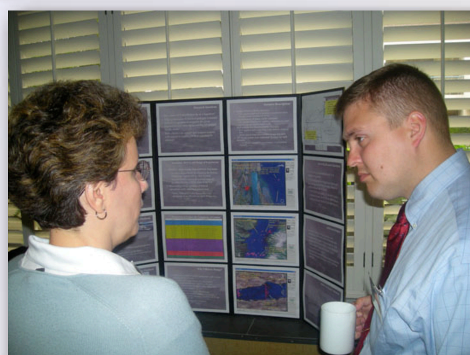
RESULTS

Due to limitations of the current configuration of the LBC simulation, examination of the data sets revealed that additional modifications and improvements were required by the LBC developers to improve model functionality and correct program anomalies.

CONCLUSIONS

The work accomplished throughout IDFW16 was valuable. Team 5 participants developed a scenario, network structures, MOEs, and DOE to measure the impact of network-enabled capability using the LBC model to support TRAC-Monterey's CBA. Further, throughout the working week substantial revisions and expansions of the LBC model were accomplished to improve the functionality and usability of the model as an analysis tool for the operational scenario of interest.

The way ahead is to develop the capability of LBC to handle an experimental design of a large amount of factors to provide analysts with the capability to conduct exploratory studies and develop credible response surfaces. Furthermore, continue to explore additional factors to identify network-enabled capability gaps and identify efficiencies in sustainment operations resulting from network-enabled forces.



Overview of Plenary Sessions

A Landscape of Knowledge Sharing

As is traditional, the members of the data farming community enjoyed and benefitted from sharing insights and knowledge gained through independent activities. IDFW 16 incorporated a full suite of plenary sessions that run the gamut of disciplines related to data farming.

Summaries of most of the plenaries are provided here. Besides the plenaries highlighted on this page, talks also included a session on **Data Farming for Newcomers** by Gary Horne and sessions on **Design of Experiments** and a **SEED Center Update** by Susan Sanchez and Tom Lucas.

Gudrun Wagner, Team 4, lead a session on **An Agent Based Sensor Effector Model** which is summarized in the Team 4 report in this issue. Ted Meyer and Steve Upton lead sessions on **Data Farming Tools: What We Have** and **Data Farming Tools: What We Need** which will be the subject of an article in an upcoming issue of *The Scythe*.

Human Intangibles

Choo Chwee Seng

The objectives of this focus group discussion were to share research knowledge on modeling the effects of human intangibles and to explore opportunities for collaborations. It started with a recap of the first meeting at IDFW 15 in Singapore, followed up quick updates and briefs by participants. The discussions were quite general though, and the group agreed to focus on specific topics at IDFW 17 in Germany. Members of the Data Farming Community from Singapore will be posting and administering an online discussion forum with a repository to share documents.

Naval Simulation System

Michael Atamian

The Naval Simulation System (NSS) is an object-oriented multi-sided, multi-warfare modeling and simulation tool originally sponsored by CNO N6M. An overview of the model history, capabilities, and use cases was presented. Specific attention was focused on the ability of the model to represent complex C4ISR and its potential ability to integrate within the data farming paradigm.

Statistical Aspects of Simulation Software

David Kelton

This plenary provided an overview of the needs for statistical analysis capabilities in simulation software. Input parameter analysis, random number generation, optimum seeking processes, are examples of the statistical tools that should be seamlessly integrated into our simulation tools and standard processes.

Data Farming GUI

Dr. Dietmar Kunde

The German IT Office of the German Armed Forces, in collaboration with EADS, is pushing its Data Farming environment and tools to the next stage. With the development of a service-oriented architecture for Data Farming, the user envisions a new level of user-friendliness. The typical phases of an experiment, that is, definition, execution and analysis, are manageable within a single GUI. The required input files for the farming process are generated within the application (agent-based model) and sent via remote access to the cluster. After model execution the generated data files will be downloaded and post-processed in the analysis phase.

During the plenary session the current GUI-architecture and the GUI were presented. The respective Data Farming services were remotely accessed from within the Data Farming GUI, a simulation experiment was defined and sent to a cluster for execution. Presenters included Dr. Dietmar Kunde and Thorsten Lampe.

Automated Co-Evolution: An Update:

Choo Chwee Seng

This plenary session was an update on the Automated Co-Evolution (ACE) project that DSO is currently working on. The objective of ACE is to explore a competitive two-sided co-evolution as a mechanism to understand the dynamics of competition in a military context through simulations. The brief touched on how ACE was evolved from Automated Red Teaming (ART), its key requirements in terms of algorithms, fitness functions and co-evolutionary solution concepts, and its design considerations. It ended with illustrations of the capability of ACE through some test cases. ACE will be ready for demonstration when the project ends in September 2008.

Visual Interactive Simulation and Data Farming: How Can They Coexist?

Francois Rioux

Data farming is a well-known approach that builds on formal statistical analysis for studying simulated systems. Alternatively, users of visual interactive simulation (VIS) systems base the changes that are brought to simulation parameters on their (intuitive or rational) understanding of the system and make decisions of whether or not some parameters should change at runtime. VIS analysis is therefore less formal than data farming. However, we claim that early phases of data farming such as parameter screening or exploratory analysis could benefit from using VIS. We argue that complex systems are particularly well-suited for VIS-based analysis due to characteristics such as discovery of emerging behaviors. In this context, we are currently developing a generic software framework called Multichronia, which implements several VIS features as well as a formal representation that tracks users' decisions regarding parameter changes during the execution of a simulation. In our work, we investigate how rich interaction metaphors with running simulations and data resulting from this interaction can assist users to better understand the simulated system. Our prototype implementation interfaces with a slightly modified version of Pythagoras that allows for an executing simulation to be saved in a file and be reloaded back into the simulation kernel. At IDFW16 we presented the methodology that was adopted for converting Pythagoras into an interactive simulator. We also discussed the added functionalities that our framework offers and discussed the relevance of such an approach in the context of data farming.

Health Care Applications of Data Farming

Lawton Clites

The purpose of this presentation was to bring the data farming community up to date on the medical modeling work being done by the University of Memphis Fedex Institute Center for Healthcare and Technology. The presentation began with a brief history of the medical modeling effort at Memphis, it's connection to the data farming community, and the previous models, namely the nurse reassignment model, the "day in the life of a paper chart" model, and the nurse-patient interaction model. The current project of incorporating data from real world observations taken by Memphis staff into the model was then discussed along with a brief description of the data collection process

Pythagoras User's Group

Gary Horne and Robin Marling

A Pythagoras user's group meeting was held during IDFW 16. LT Robin Marling from MCCDC and Dr. Gary Horne from NPS led the discussion, which was highlighted by reports from participants who are currently using Pythagoras. Many of the users are current NPS students working on their Master's theses. Also during the meeting Mr. Rick Clinger from MCCDC presented a Pythagoras demonstration.

Advanced Predictive Modeling - TLCM -AT

Hugh Saint

The Total Life-Cycle Management Assessment Tool (TLCM-AT) is a discrete-event simulator that uses the Monte Carlo method to perform holistic analysis of complex systems' logistics. It breaks down the components of a complex system (trackable by individual part number), how each platform is used, by location (e.g., varying op tempo, reliability, environmental impact, etc.), how it is maintained (up to three levels of maintenance), and how the logistics is supported and supplied. Each element is interrelated and the associated costs captured. Then, the technology allows a user to conduct Virtual Logistical Wargaming, running multiple scenarios to test the impact of varying operational and logistical factors; everything from the impacts of an operational surge, to changing your support structure (e.g., reducing shipping times, repair times, etc.), to the ROI of implementing ECPs (comparing their cost with their impact on availability, supply demand, potential logistical cost savings, etc.). All of the modeling outputs are available, via GUI, in the form of time-based charts, allowing visual comparative analysis of outputs for different scenarios.

The Role of Exploratory Experimental Designs in Informing System Requirements

Darryl Ahner

The development of requirements documents for new weapon systems may be improved through the application of broad exploratory experimental designs in conjunction with constructive simulation. The presented methodology informs the requirements development process by facilitating the efficient exploration of a large number of weapon system attributes and the examination of a broader range of potential performance parameters for these attributes. Used in conjunction with constructive combat simulations, the methodology provides the analyst with insights into the operational impact of attributes associated with a weapon system of interest. The methodology applies equally well to deterministic and stochastic models. The resulting analysis informs the requirements process of the potential impact of a given weapon system and the desired performance parameters, as well as the implications of building to less than the desired requirements. The presented methodology also aids in identifying the most critical performance parameters in a given weapon system or system of systems. This paper will provide a case study analysis using this methodology to examine performance requirements for unmanned systems.

Team 6: Enhanced Design of Experiment for Testing in a Joint Environment

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INTRODUCTION - TEAM 6

The intent of Team 6 activities at the International Data Farming Workshop (IDFW) 16 was to explore enhanced design of experiment (DOE) techniques and models relevant to developing evaluation strategies for testing in a joint environment (TIJE). This goal was met through the utilization of the Map Aware Non-uniform Automata (MANA) model to trace a "call for fire" (CFF) from the originator to the final weapon system, at the detailed level of an individual task thread. A capability-level evaluation strategy for battlespace deconfliction tasks was used as the scenario driver for the data farming runs. This evaluation strategy has been developed as part of the Joint Test and Evaluation Methodology (JTEM) project.

JTEM is developing and enhancing the Capability Test Methodology (CTM) as best practice methods and processes for designing and executing testing in a joint environment. Part of the problem space JTEM has discovered in developing this methodology is when moving from system to system of systems (SoS), or to capability-focused test and evaluation, the number of factors that are part of the test space grows significantly, even exponentially. Thus, part of the JTEM project is the mission to develop processes for refining this test space, based on DOE techniques for large factor; multiple response designs.

The planning, execution, and analysis of Team 6's data farming activities were completed within the context of the CTM's Develop Evaluation Strategy process. This process includes efficient DOEs, the use of computing clusters, and the iterative data farming process. Questions JTEM specifically wanted to focus on during IDFW 16 were:

- Given a critical joint issue (CJI) for battlespace deconfliction, which factors are the most important to examine for testing?
- What are some appropriate design of experiment techniques that could be applied to the test space?
- What data exploration and analysis methods would be appropriate to apply with so many factors?

Scenario

Prior to the actual execution of the workshop, Team 6 began to develop the use-case scenario shown in Figure 1. This scenario focuses on a joint forcible entry operation where friendly forces would be conducting joint fires, joint close air support, and close combat attack operations. These operations would expand a Blue (friendly) force lodgment and allow for control of key infrastructure in order to facilitate rapid force build-up in the joint operations area (JOA).

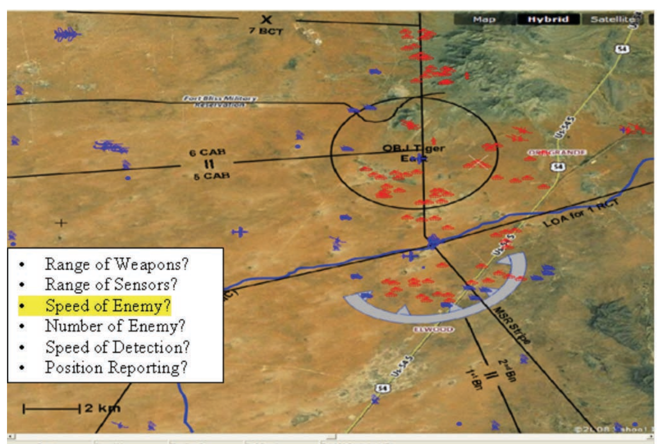

Figure 1: Team 6 Scenario

The developed mission desired effect was for threat forces to be destroyed or neutralized in the JOA. Once this scenario was developed, JTEM wanted to analyze different DOE techniques considered to be best practice, as well as look at promising new DOE techniques under development. The goal was to enhance the CTM methodology and incorporate the most current practices being applied in both industry and government laboratories. A screenshot of the MANA scenario shows the Blue (friendly) and threat forces with a list of potential influential factors. The general approach of Team 6 during IDFW 16 was to examine the developed scenario, apply appropriate DOE techniques, run thousands of iterations based on the applied DOE, and then analyze the results of the runs. By exercising this methodology, the team hoped to show data farming and DOE applications are extremely useful tools for test planning.

TIJE processes must develop critical evaluation issues to assess performance as it pertains to capabilities supporting joint missions. To address joint capability contributions to achieving desired mission effects, JTEM has developed the concept of a CJI. The CJI for a test should address the achievement of mission desired effects, the SoS' ability to accomplish joint operational tasks, and/or the SoS, system, or service attribute performance. The essential elements of a CJI include a capability's essential tasks, mission desired effects, Blue SoS aspects (across Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities--DOTMLPF), and conditions involving threat and environmental factors. These essential elements are contained in the capability crosswalk. A portion of the capability crosswalk for Team 6 is captured in Figure 2. It is important to state how the test issue contributes to achieving the desired mission end state outcomes in terms of mission desired effects. The CJIs should address the SoS capability to perform joint operational tasks and/or the SoS, system, or service attribute performance. CJIs can be of assistance to the appropriate authority when deciding whether to allow the SoS to advance to the next phase of development.

# MANA	Factors	MANA	MANA Parameter	Parameter Level
	Airspace Control		N/A	
	Assess the ability to perform battlespace deconfliction by Current/Future C2 SoS under a full range of military operations in order to achieve a destroyed or neutralized threat forces in the Joint Operations Area.	**Describe how will model the respective factor within the specific simulation**		
1	Current TBMCS/TAIS: Information not available for other Services	Inorganic SA commo links can be set up between any entity groups, thus allowing you to model which services can share information and who knows what. Can vary Inorganic SA Latency, Message Capacity, Buffer Capacity, Contact Type Accuracy (for friendly, enemy, neutral), Contact Location Accuracy (distance) and Reliability (of the message getting through) in order to get at the difference in solutions.	Range of SA for forward observer (Intersquad)	0 pixels (23.7 meters per pixel)
	Future JASMAD/JAMUS: Information available on all aircraft regardless of Service	Same as above		150 pixels
2	Current TBMCS/TAIS: Information not available for other Services	FO Current	Inorganic SA Fuse Time (Intersquad)	300 seconds
	Future JASMAD/JAMUS: Information available on all aircraft regardless of Service	FO New		0 seconds
		JTA C Current	Inorganic SA Fuse Time (Intersquad)	300 seconds
		JTAC New		0 seconds
		UAS Current	Inorganic SA Fuse Time (Intersquad)	300 seconds
		UAS New		0 seconds
3	Current TBMCS/TAIS: Information not available for other Services	FO Current	Contact Location Accuracy	50%
	Future JASMAD/JAMUS: Information available on all aircraft regardless of Service	FO New		90%
		JTA C Current		50%
		JTAC New		90%
		UAS Current		50%
		UAS New		90%
4	Current TBMCS/TAIS: Information not available for other Services	FO Current	Self- Intersquad SA (time steps)	60
	Future JASMAD/JAMUS: Information available on all aircraft regardless of Service	FO New		5

Figure 2: Part of Capability Crosswalk Developed By Team 6

An example CJI format which captures the essential elements would be: Assess the ability to perform Task X by SoS configuration Y under Conditions A to achieve mission desired effect Z. For this workshop Team 6 focused on the CJI of: *Assess the ability to perform battlespace deconfliction by Current/Future Command and Control (C2) SoS under a full range of military operations in order to achieve a destroyed or neutralized Threat forces in the Joint Operations Area.*

Design of Experiment (DOE)

Team 6 used an efficient DOE approach to screen for both continuous and categorical factors that were candidate key factors in influencing the SoS effectiveness. There is an evaluate-analyze-evaluate (EAE) iteration flow in the CTM used to refine the Evaluation Strategy as shown in Figure 3. Team 6 used this EAE approach to prioritize factor importance and compared the results to the expected factor performance to see if it was consistent with experience of team subject matter experts (SMEs). This process began by defining more than forty-seven different factors with levels that were summarized in the capability crosswalk. MANA was the agent-based simulation tool available to use for data farming runs.

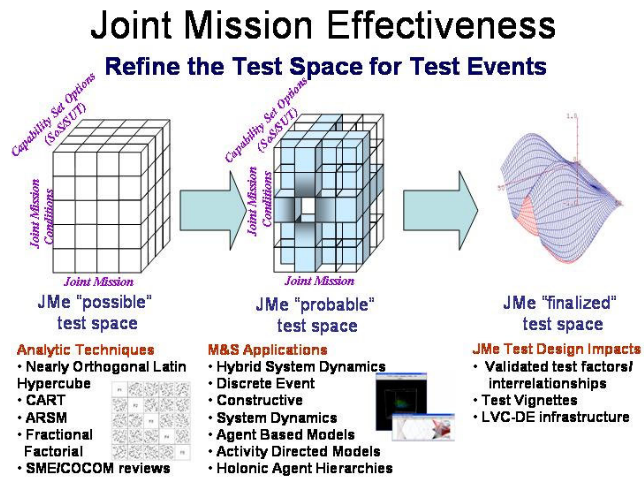

Figure 3: CTM Test Space Refinement

The capability crosswalk was mapped to a Nearly Orthogonal Latin Hypercube design and multiple iterations were run through the MANA model on the NPS cluster to provide results for further analysis and refinement of test factors. The team analyzed the responses to these runs to see if they were feasible and if expected factors were actually the most statistically significant. Throughout the week, daily replications of this process, each with numerous runs, were used to refine the test factors, based on a mission measure of effectiveness related to threat combat in a joint mission environment. The output from the initial test runs did not follow predicted factor importance. This outcome surprised many of the team members. However, further analysis of the MANA model highlighted possible limitations to the model, which were explored in subsequent DOE excursions. It was agreed that since the thrust of the week's effort was to exercise DOE processes within the CTM, the team could accept the apparent doctrinal, tactical, and performance inconsistencies in the output. The DOE process proved to be very valuable and supportive of the JTEM approach for including DOE in its methodology. Initially Team 6 had planned on running the scenario in both the MANA and Tester models. However, Tester was not available, which limited the scope of the analysis due to modeling constraints of MANA. Nonetheless, the team was able to achieve and exemplify a best practice of what could be done utilizing DOE with respect to test planning.

Analysis

Using MANA simulation results, data was processed and analyzed in order to assess SoS, threat, and environment factor importance relating to a mission measure of effectiveness. Some of the analysis outputs captured by the team are highlighted in Figures 4, 5, and 6. In Figure 4, the team applied classification and regression tree (CART) analysis output to analyze the Mission MOE concerning Proportion of Threat System Casualties. In this design, the most statistically significant factor was a forward observer (FO) "PassSelf" parameter, which turned Blue FO self reporting on or off. This PassSelf factor accounted for an R squared coefficient of determination of .587, implying that a least squares regression model relating PassSelf factor to the Mission Measure of Effectiveness (MMOE) can explain approximately 58% of the MMOE variation.

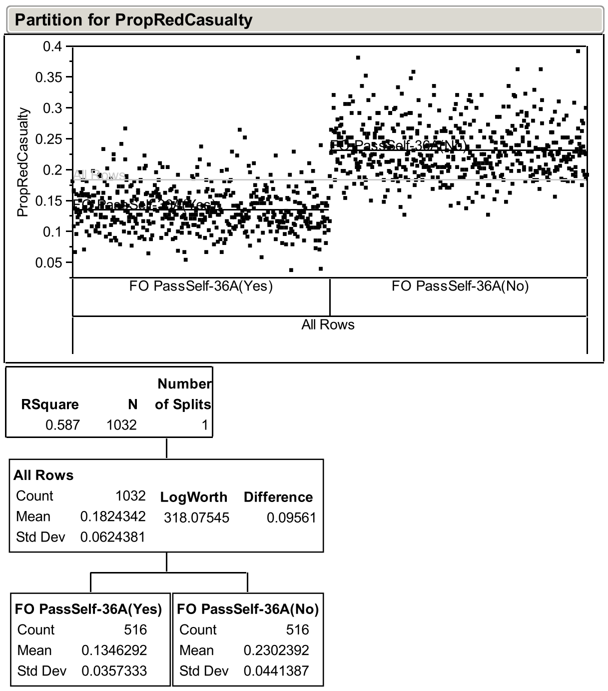

Figure 4: CART output for Red Casualties 1st Split (Left)

The partition plot in Figure 4 shows a No PassSelf parameter (no Blue FO self reporting) led to a better desired effect of threat system casualties. Similar analysis was completed to determine which variables had a smaller impact, such as the number of Red agents. Along with this analysis Pareto Plots (see Figure 5) and Prediction Profiler plots (see Figure 6) were used to model the factors that captured all main effects as well as stepwise effects chosen from all second order terms, with adjusted R squared values of .685 and .782 respectively. The adjusted R squared was essential for this analysis as it adjusts to the number of independent variables and sample size. While not as high of an R squared as preferable in smaller factor, controlled experiments, the analysis did inform the factor refinement of this large test space, which had a combination of 32 continuous and 3 categorical factors.

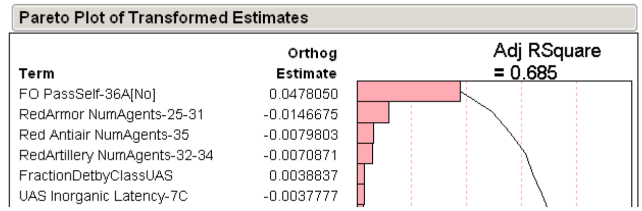

Figure 5: Pareto Plot of Model Terms of All Main Effects (Right)

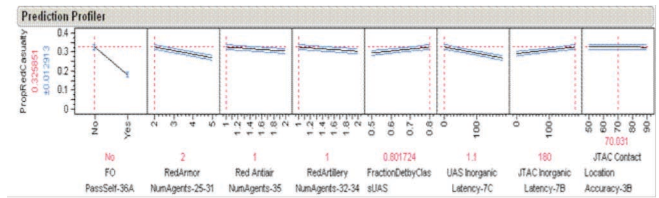

Figure 6: Profiler for 8 Most Important Factors

Insights and Issues for Further Investigation

Future data farming efforts would be more robust if they incorporated a comparison of data from both the MANA and Tester (or other models). Much of the situational awareness (SA) defined for this workshop utilizing MANA was modeled as the actual communications links both between and among entities. However the importance of C2 factors may have been underestimated. Further analysis of statistically significant C2 factors and refinement of model scenarios to better align with doctrine may provide more robust analysis. For example, if a tank battalion is down to 40% strength, and the 40% consists of the support platoon (ammunition and fuel), cooks, maintenance personnel, then that battalion has little to no fire power and would most likely not continue the offensive. The current MANA model treats many of the different elements as equal, which is not as realistic as MANA removing a unit (Blue or Red) from the fight when it reached a point of being combat ineffective. However a model is just a representation of the systems of systems "that should be used to try and gain some insights into the relationships among the various components or to predict performance under some new conditions being considered."[1]

For this analysis the attrition of Red and Blue forces was analyzed to assess the difference between the current and future SoS. Due to time constraints, this was the only MMOE or task measure of performance (TMOP) analyzed. Future investigations could expand the focus of the evaluation of this measure through an attack on the center of gravity for Red forces and then assess the impact of the loss of critical C2 nodes on Threat force attrition. However, due to the limited capabilities of Agent Based Models (ABMs), we should not throw out Red force losses and loss exchange ratios for MOEs. MOE enhancements can include weighting critical Red forces so all Red forces are not counted the same. For

[1] "Simulation, Modeling, and Analysis" Averill M. Law and W. David Kelton, p.1.

instance, the early elimination of Red air defenses could be deemed as an important desired effect achieved by joint fires and close air support tasks. Working with the MANA ABM provided an excellent opportunity to identify some needed capabilities to support MMOE and TMOP evaluations. It also provided the opportunity to identify new design aspects for the Tester model being developed. The developer for Tester was a Team 6 member and throughout the week's event he noted some critical aspects of C2 for future incorporation into future model enhancements. This immediate feedback to ABM developers is a key benefit which enhances future data farming workshops.

Having design of experiment expertise from Naval Postgraduate School, Research Development and Engineering Command (RDECOM) and TRADOC Research and Analysis Center allowed Team 6 to compare different designs to the same experimental space (NOLH, R5FF, others). This capability, combined with the application of different analytical techniques (e.g., linear regression, Kriging) allowed the team to gain valuable insights into the C2 SoS ability to perform battlespace deconfliction. Within the IDFW 16 venue, Team 6 began analyzing more than forty-eight different factors in the DOE. These factors were modeled in the MANA model and thousands of iterations were run to gain insights on the test factors and test factor interrelationships. The statistical output was then analyzed in order to validate the significance of test factors and interrelationships. This process allowed the team to indicate where models need to be changed, and where other factors or interrelationships may need to be modeled. Analysis of the data and utilization of analytic best practices such as sensitivity analysis, CART, and visualization/ analytical tools were applied to turn test data into insights including an evaluation of the overall joint mission effectiveness and the contribution a C2 SoS makes to the accomplishment of that joint mission. The IDFW 16 Workshop allowed all team members to apply a use-case focused on battlespace deconfliction to see how joint mission effectiveness test space refinement is accomplished by examining the test structures, identifying test factors and test factor interrelationships through the application of analytical techniques to identify factors of importance, factor levels of impact, and important interrelationships.

Team 7: Total Life Cycle Management – Assessment Tool: An Exploratory Analysis

TEAM 7 MEMBERS

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INTRODUCTION

The United States Marine Corps continually works to shape logistics plans and policies in order to sustain excellence in combat effectiveness. Total Life Cycle Management (TLCM) is a vital part of the Marine Corps' vision of developing a force that is capable of performing and successfully completing the vast array of missions expected to be performed during the 21st Century. In an effort to improve the life-cycle management of assigned weapon systems, the Marine Corps contracted Clockwork Solutions to develop a tool capable of simulating life-cycle sustainment costs and performance metrics of operations, maintenance and supply for new and legacy weapon systems. Clockwork Solutions developed such a tool and named it Total Life Cycle Management-Assessment Tool (TLCM-AT).

During the IDFW-16, we focused our efforts on exploring several parameters and assumptions using TLCM-AT on a Marine Light Armored Vehicle (LAV-25). Our analysis involved the employment of the Nearly Orthogonal Latin Hypercube (NOLH) to help develop several scenarios based on a range of inputs for five critical parameters. Each scenario was replicated using TLCM-AT and the results were later analyzed in search of significant factors.

TLCM-AT Tool and NOLH

TLCM-AT is a stochastic modeling and simulation analysis tool developed by Clockwork Solutions. The tool's main objective is to provide a simplified representation of a system at some particular point in time intended to promote the understanding of the real system. Using this tool could enable decision makers and logisticians to perceive in a matter of minutes interactions and behaviors that would normally unfold over a very long time.

Clockwork Solutions included in the delivery of TLCM-AT five models covering the following weapon platforms:

- Amphibious Assault Vehicle (AAV)
- Joint Light Tactical Vehicle (JLTV)
- Light Armored Vehicle-25 (LAV-25)
- Lightweight 155mm howitzer (LW155)
- Medium Tactical Vehicle Replacement (MTVR)

Each of these models is implemented using a Microsoft Access 2003 database file. TLCM-AT uses these files to control both inputs and outputs, which are saved into the same file. In the context of this report a database file representing a weapon system will be called a model.

Using the provided LAV-25 baseline model, we ran the simulation tool 30 times and collected the results to determine the top ten LAV-25 degrading parts. This process of determining problem parts is done using a formula provided by Clockwork Solutions on their LAV-25 final report. The process uses the output from the out Waiting time and Unavailability output table. The formula is used to create a degrader index for each part on the weapon system. The formula is:

*Waiting Time * Requests * (Unavailability+1)*

Later parts are sorted by decreasing degrader index to determine the top ten degraders.

Employing the NOLH tool to efficiently maximize our sample space, we varied the starting state of the top ten degrader parts by varying five initial input parameters of each degrader. The five parameters controlled for our experiment are:

- Spare Levels (Total number of spares at each location)
- Induction Quantity (A limit on the number of inductions that can occur in the given quarter and year)
- Capacity (Number of parts that can be processed concurrently)
- Service Times (Time to service the part)
- Unscheduled Removal Rates (Part failure rate)

The Measure of Effectiveness (MOE) used was Operational Availability (Ao). Ao is defined as the number of operational platforms divided by the total number of platforms available fleet-wide at the end of 20 operational quarters. Table 1 shows the list of experiments in NOLH design format. Each row in Table 1 defines one experiment; later we will describe how these values are implemented into a model.

low level	1	0	1	0.5	0
high level	33	32	33	1.5	10
decimals	0	0	0	4	4
factor name	Spare	IQ	I Cap	Deg	ST
	11	32	27	0.875	2.5
	3	8	29	1.0625	0
	5	14	3	0.75	6.25
	7	20	11	1.5	5.625
	25	30	15	0.625	3.125
	33	10	13	1.3125	0.625
	21	6	33	0.8125	8.75
	19	28	25	1.4375	8.125
	17	16	17	1	5
	23	0	7	1.125	7.5
	31	24	5	0.9375	10
	29	18	31	1.25	3.75
	27	12	23	0.5	4.375
	9	2	19	1.375	6.875
	1	22	21	0.6875	9.375
	13	26	1	1.1875	1.25
	15	4	9	0.5625	1.875

Table 1: NOLH Design

Design Implementation

Each design was implemented using Table 1 as a guide. The factor names are Spare for spare levels, IQ for induction quantity, I Cap for capacity at the I- Level, Deg for unscheduled removal rates and ST for service times. The value of spare levels, induction quantity and capacity were set to the value on the NOLH for each degrader part. In the case of service times and unscheduled removal rates the current values of those parameters were multiplied by the value on the NOLH.

Data Generation and Flow

Due to the cumbersome nature of manipulating Access files manually, we were forced to create a Java application that could do the job for us. Figure 1 describes the process of design development and data generation flow. We were able to implement a Java tool that copies our baseline model into a working model that TLCM-AT can recognize when launched from the command line. Once the working model is created, our Java tool modifies the model to reflect the next design on the experiment; it then launches TLCM-AT from the command line. Our tool completes the process by collecting the necessary output from the current working model so it can be saved before a new working model representing the next design is created.

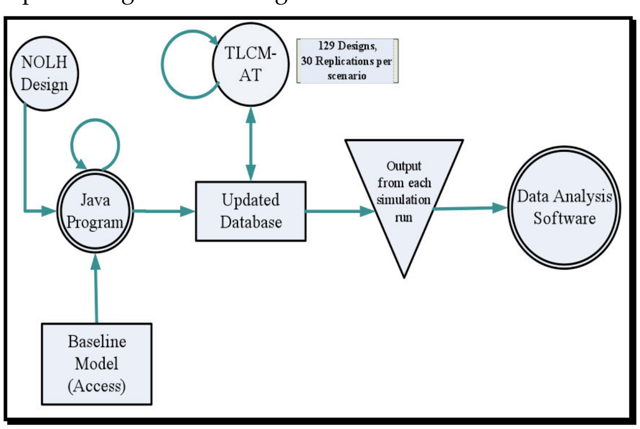

Figure 1: Data Generation and Flow

The output from our simulation is a CSV file containing every design value as listed on Table 1 and the achieved Ao for that design.

RESULTS AND ANALYSIS

Figure 2 shows how each design compares with respect to our MOE. The small difference range among all designs is explained by the fact that we only varied our parameters on ten parts. Limiting our analysis to only ten parts significantly improved the speed of our runs.

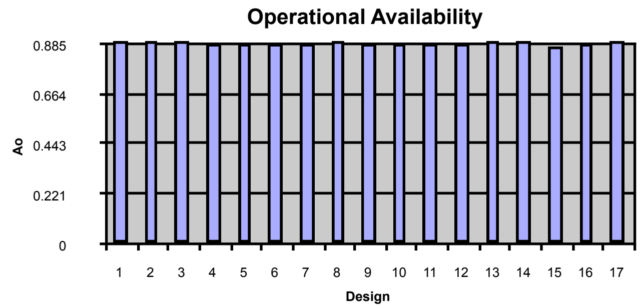

Figure 2: Operational Availability per design

Our initial analysis involved a main-factor-only multiple linear regression model. We expected to identify some significant main factors during this portion of the analysis, but surprisingly that was not the case. Figure 3 shows the parameter estimates for the linear regression model. The lowest p-value included on this model is 29 percent and the R-Squared equaled 17 percent strongly suggesting that this model is not adequate.

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.87646	0.005963	146.99	<.0001*
Spares	0.0001072	0.000127	0.85	0.4159
IQ	-2.79e-5	0.000127	-0.22	0.8299
Capacity	3.0247e-5	0.000127	0.24	0.8159
Degradation	0.0017899	0.004059	0.44	0.6678
ServTime	-0.000448	0.000406	-1.10	0.2929

Figure 3: Main Factors Regression Model

Our next step was to include second order interactions on our model perform stepwise regression to determine significant factors and interactions.

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.8693558	0.001984	438.16	<.0001*
Spares	0.0001072	3.452e-5	3.11	0.0267*
IQ	0.0001104	0.000041	2.69	0.0433*
Capacity	7.9242e-5	3.54e-5	2.24	0.0754
Degradation	0.0053867	0.001247	4.32	0.0076*
ServTime	-0.000356	0.000111	-3.20	0.0241*
(Spares-17)*(IQ-16)	-1.94e-5	8.777e-6	-2.21	0.0781
(Spares-17)*(Capacity-17)	8.8471e-6	4.588e-6	1.93	0.1117
(Spares-17)*(Degradation-1)	-0.000972	0.000208	-4.66	0.0055*
(Spares-17)*(ServTime-5)	0.0000504	1.233e-5	4.09	0.0095*
(Capacity-17)*(Degradation-1)	0.0013016	0.000283	4.60	0.0059*
(Spares-17)*(Capacity-17)*(Degradation-1)	-0.000138	2.223e-5	-6.22	0.0016*

Figure 4: Regression Model with Interactions

In this case it was discovered that the interaction among spares, capacity and degradation times was the most significant factor on the model. Figure 4 shows the Parameter Estimates for the regression model including second order interactions. The subsequent significant factors are interactions between spares and degradation times, capacity and degradation times and the main factor degradation times (significant in the presence of other factors).

Figure 5 shows the order of significance of all factors included on the model. R Squared for this latest model equaled 97 percent.

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
(Spares-17)*(Capacity-17)*(Degradation-1)	-0.000138	2.223e-5	-6.22	0.0016*
(Spares-17)*(Degradation-1)	-0.000972	0.000208	-4.66	0.0055*
(Capacity-17)*(Degradation-1)	0.0013016	0.000283	4.60	0.0059*
Degradation	0.0053867	0.001247	4.32	0.0076*
(Spares-17)*(ServTime-5)	0.0000504	1.233e-5	4.09	0.0095*
ServTime	-0.000356	0.000111	-3.20	0.0241*
Spares	0.0001072	3.452e-5	3.11	0.0267*
IQ	0.0001104	0.000041	2.69	0.0433*
Capacity	7.9242e-5	3.54e-5	2.24	0.0754
(Spares-17)*(IQ-16)	-1.94e-5	8.777e-6	-2.21	0.0781
(Spares-17)*(Capacity-17)	8.8471e-6	4.588e-6	1.93	0.1117

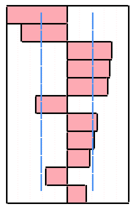

Figure 5: Parameter Estimates in Order of Significance

CONCLUSIONS

The results from this analysis are specific to the LAV model provided to us by Clockwork Solutions and it applies to the set of adjusted parameters and the way they were changed. The main conclusion is that investing in any one given resource in order to improve Operational Availability would not provide the best result if the underlying interactions among factors are not explored carefully. Running a base case scenario and comparing the results to those obtained by changing one factor at a time simply will not allow the analyst to estimate the interactions (synergies) among the many factors. From the initial results that were obtained during the workshop, one can clearly see that the interaction of the factors analyzed had the most significant impact on Operational Availability of the LAV. Decision makers need to consider the best mix of resources to maximize Ao; clearly the use of tools such as the TLCM-AT, combined with design of experiments, can provide insight into these interactions.

THE WAY AHEAD

During the previous months and during IDFW-16, a process has been developed to use DOE and the NOLH with the TLCM-AT. A simple scenario was used to test the mechanics of the Java implementation, and interesting results were obtained. The work accomplished here opens the door for researchers in the future to apply these techniques to real-world scenarios. Commonly, decision-makers are presented with several courses of action (COA) when trying to decide how to maintain material readiness of complex weapons systems. Each COA can be individually modeled in the TLCM-AT database, and design of experiments can be used to explore the significant factors that affect the desired end state for the fleet of a particular weapons system.

Team 8: Combat Identification and Fratricide: A Human Affair

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INTRODUCTION

Over the past two years TNO and Dstl developed an Agent Based Combat ID Model to support the research on factors influencing the success and failure of Combat Identification processes. During the International Data farming Workshop (IDFW) 15 in Singapore, we evaluated this model by conducting the first data farming experiments. The model represents Situation Awareness (SA) and the cognitive processes to combine new sensor input with SA in order to make identification decisions. A description of the model and the results of the Singapore experiments can be found in [ref 1].

A more general treatment about an architecture for placing the human at the centre of a constructive simulation, which also contains a more extensive description of this agent based Combat ID model, can be found in the ICCRTS 2008 paper [ref 2]

This paper describes the progress we made with the model development since IDFW 15 and the results from the data farming experiments we conducted during IDFW 16 in Monterey. In a few paragraphs an overview will be given of the new features, the objectives, the design of the experiments and the results. We will conclude this paper with lessons learned, conclusions and future developments.

New Features

Based on our "development master plan" and the results of IDFW 15, we enhanced the Combat ID model with a number of new features that are described below.

1. The new Combat ID model incorporates a much richer set of Measures of Merit (MoM). Each MoM is characterized by three dimensions:
    - decision (3 values: blue, red or green)
    - ground truth (3 values: blue, red or green)
    - object type (3 values: tank, car or person)

    These three dimensions result in 27 MoM that give an accurate and detailed picture of the successes and failures of identification for each type, e.g. the combination (decision=red, ground truth=blue, type=car) gives the number of fratricide incidents where cars are involved.
2. The identifying agent(s) use(s) the more realistic ACQUIRE sensor model, developed by Night Vision Laboratory (NVL). This model takes into account characteristics on:
    - Terrain
    - Weather
    - Sensor
    - Object

    Although in principle, all parameters can be dynamic or can be "data farmed on," the first three are held constant during IDFW 16. The last one is dependent on the type of object encountered. Apart from the characteristics mentioned, the output of the sensor model is dependent on the distance of the identifying agent to the object. The relation between distance and probability of detection, classification and identification take the shape of an "S-curve" as shown in Figure 1.

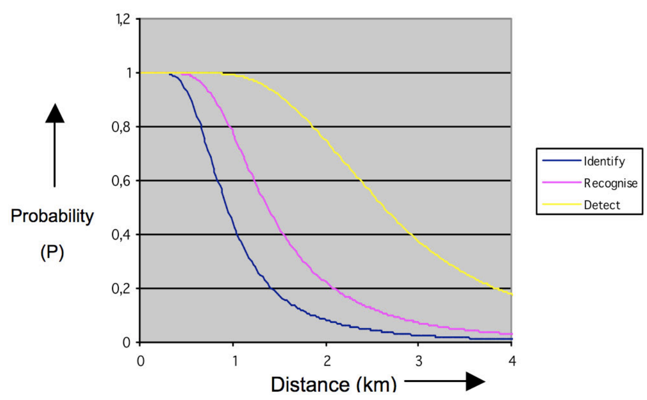

Figure 1: The probability curves for Detection, Recognition, and Identification.

3. The processing of sensor input has been changed. The following steps are involved.
    - The agent calls the ACQUIRE algorithm to get a probability of detection.
    - If the probability of detection is above a certain, data farmable threshold, a stochastic function determines whether the

agent indeed detects the object or "misses" it. This corresponds to the situation that the user does not pay attention to the sensor or simply overlooks the object. The probability for missing is inversely proportional to the probability of detection, but involves a "rolling the dice" mechanism.

- After detection, the agent makes a rough assessment how much closer it needs to go in order to make an identification. It makes a movement "on the safe side" of this assessment.
- After making the calculated movement, the agent uses the sensor data and the ACQUIRE algorithm to determine the probability distribution (blue, red, green) of the objects identity and combines this with its preconception distribution (situation awareness) in order to get the new belief distribution about the identity of the object. As in previous versions, it uses the information acceptance curves for this purpose. If the resulting value is below the decision threshold, the process starts again until either an identification decision can be made or the agent is as close as a hundred meters from the target. If the last condition is the case, the agent leaves the object alone and focuses on other objects.

As in previous versions of the model, the whole process also involves dynamic adaptations of the preconception grid of the agent and modification of the Measures of Merit if the agent takes a decision.

Objectives of IDFW 16

The objectives of the study during IDFW 16 are:

- Evaluate the new features described above
- Get insight on the effects and relative importance of influencing parameters and establish a foundation for further model improvements.

Design of Experiments

As the basis for our experiments, we use a Near Orthogonal Latin Hypercube (NOLH) with 16 parameters. These parameters deal with the number of objects for each type (3 parameters), the distribution of those objects on the screen (3 parameters), the distribution of the preconception (3 parameters), the shape of the information acceptance curves (2 parameters), the radius of the circle in which the agent tries to detect objects, the decision threshold, the size of the local SA grid, the size of global SA cells and finally the surprise level. Most of the parameters are explained in [ref 1], with the difference that we use different parameters for the distribution of preconceptions that make them relative to the ground truth.

In our current design we use data farmable parameters for the correlation between ground truth and perceived truth and for the mixture of objects. These parameters are not directly settable, but are derived from others like the centers of ground truth for red, green and blue and the parameters for the relative distance of perceived to ground truth. These dependent variables make sure that the results are based on variables that do not contain interdependencies anymore.

During IDFW 16, we performed three data farming runs with basically the same design, but with different data points in the hypercube of all possible design points. Also, we looked at the outcomes of the initial runs to fine tune the maximum delta of the perceived truth compared to the ground truth and to limit the maximum number of steps.

RESULTS

The description of the results in this paragraph is limited to two examples and is, by far, not exhaustive. Results are omitted because of limited space, the detailed nature of the results, and the lack of a clear graphical visualization of them. For those interested, more detailed analysis will be available later this year.

Figure 2 shows the relation between the fraction of samples and the percentage of objects that were correctly or incorrectly identified by the agent after 10.000 steps. The graph is based on results of the second experiment.

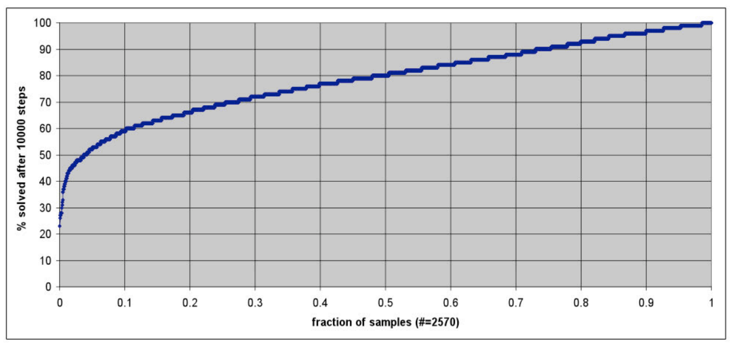

Figure 2: The fraction of samples related to the percentage of identified objects after 10000 steps.

The figure shows that for roughly half of the samples 80 percent or less of the total number of objects are identified. For the other half of the samples, 80 percent or more of the objects are identified. It also shows that the relation is almost linear. Regression analysis shows that the decision threshold is the most significant factor influencing the percentage of decisions. The second most important factor is the Y-intercept-indicator, a variable responsible for the shape of the information acceptance curve. A flatter curve caused more correct decisions. The flatter the curve the more the agent is open for new information in the case of extreme values of preconception (strong belief).

Figure 3 shows a regression tree for the third experiment, with the relationship between the importance of input parameters and the percentage of fratricide. The tree shows that the most important factor responsible for fratricide is the ratio by which an area with blue ground truth is misconceived as red (by the initial preconception).

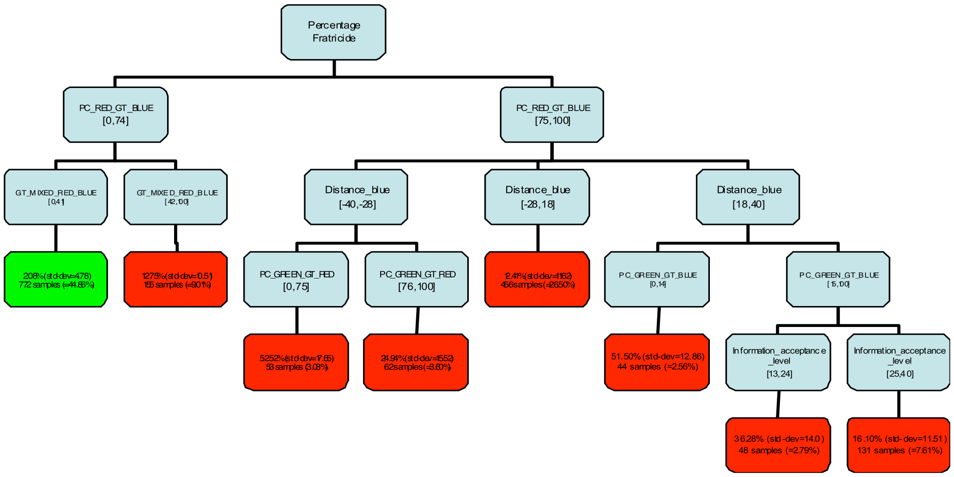

Figure 3: The regression tree for the fratricide measure of Merit. The R2 of this metamodel is 0.63.

LESSONS LEARNED AND CONCLUSIONS

IDFW brought us a step further towards a mature Combat ID agent based simulation model. Although the results still have to be analyzed in detail, our first impression is that our Combat ID model in combination with the data farming approach is a good method to get insight into the parameters that influence the success and failures in Combat ID processes. However, it is important to keep a close connection between the experiments and the customer questions and we feel that we need to take a number of measures to ensure this in the future. This is reflected in the lessons learned below:

The lessons learned from IDFW 16 are:

- Although data farming is a good approach to get quick results in an iterative way based on a large number of model runs, it is important to have a clear understanding of the questions that needs to be answered. In hindsight, we feel that we lacked a detailed enough and shared question to steer our process of discovery. Future workshops will need better preparation with respect to the questions to be answered.
- Good analysis tools are essential for data farming. Although we had tools available for data analysis, the lack of a good graphic representation of results made it hard to get quick insights in the meaning of the results. This hindered the depth of analysis during a workshop severely.

FUTURE DEVELOPMENT

During IDFW16 we started with the development of the next version of the Combat ID agent based model. Contrary to the current version, where an agent moves around in a world that is defined by parameters that determine, for example, the number of objects and their distribution, as well as the initial preconception, this new version will be scenario-driven and will focus on a limited number of data farmable parameters like decision threshold, situation awareness and information processing characteristics. The reasons to go to this model style are that a scenario driven model:

- is closer to the mental model of the customer,
- enables us to simulate historical incidents, and
- gives more control on the behavior of the model.

In the new version, the setup of the scenario will be handled in a separate "setup" application. The scenario can be stored and then imported into the "execute" application.

New features of this scenario driven version will be:

- Both the Ground Truth distribution and the Perceived Truth distribution can be defined manually in a separate "scenario" application.
- More than one identifying agent can be defined. Each agent will have its' own characteristics, SA and behavior. This includes levels of training and experience, and the consequences of this on the identification process.
- The route of agents and objects can be defined in terms of waypoints (instead of the current semi-random movement)
- The scenario can be written to a file with a specified name. This file can be imported by the Combat ID "execution" application.

We plan to develop and test this scenario driven version of our Combat ID model before September 2008 and use IDFW 17 in Garmish Partenkirchen to conduct data farming experiments with this model. We will develop two or three scenarios as the basis for our analysis.

References

[1] Scythe: Proceedings and Bulletin of the International Data Farming Community, Issue 3 - Workshop 15, pages 30 and 31. Publication Date: January 2008.

[2] 13th ICCRTS in 2008 "C2 for Complex Endeavors", paper "architecture for placing the human at the centre of the constructive wargame", David Dean, Alasdair Vincent, Beejal Mistry – Dstl, UK; Mink Spaans, Peter Petiet – TNO, NL.

Team 9: Representing Urban Cultural Geography in Stability Operations (RUCG-SO)

TEAM 9 MEMBERS

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INTRODUCTION

Representing Urban Culture Geography in Stability Operations concerns the representation of the civilian population in a conflict environment. This working group used a scenario developed for Pythagoras and a scenario developed for a prototype multi-agent system model of the civilian population to explore the response of the civilian population to insurgent, government and stability force actions in a counterinsurgency environment. The working group also examined potential measures of merit from recent work by an irregular warfare modeling and analysis working group.

This article describes the effort associated with the prototype multi-agent system model of the civilian populace with a focus on developing the data associated with a notional scenario to execute the model in a high performance computing environment with an experimental design. The ultimate motivation behind the multi-agent system model is to create a scenario and run the simulation model to understand how actions, information, perceptions and beliefs affect public opinion about the legitimacy of the host nation's government. This workshop was the first test of that emerging model.

MODEL

The version of the prototype used during the workshop had limited initial functionality consisting of civilian population entities, select beliefs and positions held by those entities, the social network connecting the population entities, and a set of actions influencing the population entities.

Civilian population entities represent typical members of the society. They may represent individuals, families, clans or tribes depending on the resolution desired and the data available during scenario development. Civilian population entities are cognitive agents in the multi-agent system. Most other agents like the stability forces, host nation entities, insurgents, and others are reactive agents consisting of relatively simple scripts to represent plans and simple behaviors to represent policies in response to actions.

Central to the civilian population entities are the positions they hold on matters of public importance and the underlying beliefs that support those positions. These agents process information about events in the model and about objects in the environment that they observe. This information influences their beliefs and positions.

Civilian population entities are directly influenced by action events and indirectly influenced by other agents in the social network. Action events take the form of positions on an issue along with beliefs associated with that issue. The social network connects the population entities and provides for the exchange of information among entities. When a population entity processes an action influence the agent may decide to pass it along to one or more agents in its social network.

SCENARIO

The scenario was derived from the Peace Support Operations Model (PSOM) Ginger Junction scenario used in the MORS Irregular Warfare (IW) Workshop in December 2007. That scenario is a disaster relief operation complicated by an active insurgency. The RUCG-SO Ginger Junction scenario follows the broad outline of that scenario with scripted behaviors and events for most actors and an enhanced focus on the civilian population's response.

In total there were 86 population entities distributed across four population groups: Northern Natives, Northern Others, Southern Natives and Southern Others. The social network represents affective ties in the population. The existence of a relationship is symmetric, but the strength of the relationship is not symmetric.

Issues identified in the Ginger Junction scenario include Southern Independence, Land Reform, Increased Crime, Distribution of Disaster Relief Aid, Distribution of Wealth, Representation in Legislature, Participation in Government, and Government Mismanagement of Budget. For this experiment two representative and related issues, Southern Independence and Land Reform, were examined.

The issue of Southern Independence has four possible positions: Status Quo, Federalism, Autonomy and Independence. This issue is influenced by three population entity beliefs: fairness of political participation, belief that southern natives (called Little Buddies) are inferior, and views on the role of government.

The issue of Land Reform has three possible positions: Status Quo, Minor Reform (e.g., making land available for ownership by the poor, squatters, etc.), and Major Reform (e.g., redistributing land or government control of land, etc.). This issue is influenced by two population entity beliefs: legitimacy of current land ownership and perceptions about the current plantation system.

Figure 1 is an example of the initial beliefs and positions of an agent depicted as a Bayesian belief net. We used Netica 4.02 by Norsys Software Corporation for this research relying on the graphical user interface for data development and using the Java Application Programmers Interface (API) in the multi-agent system implementation.

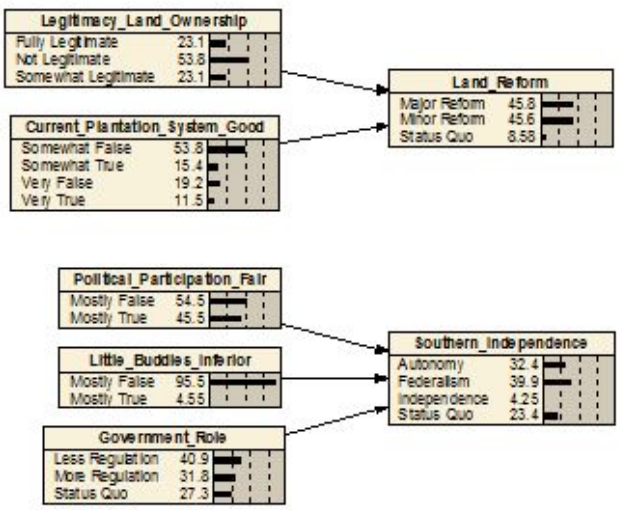

Figure 1: Southern Native #15 Initial Beliefs and Positions (using Netica 4.02 byNorsys Software Corporation).

The underlying data for this belief net was derived by taking a set of representative survey data for the individual agent's population group and randomly selecting a subset of the survey results for this agent. Each case in the survey data represents the response from a single member of the population surveyed on his issue position and related belief stances. This method of random selection from within an agent's population group produces agents representative of the group with a reasonable distribution of beliefs and positions.

It is important to note that the agent's position on issues and stance on beliefs is not like a single response to a survey. Instead one may interpret the internal representation of the agent's issues and beliefs in a few ways. First, you might consider the agent as an individual and view the weighting on issue positions or belief stances as his tendency to support that position. In a simple case like Southern Native #15's belief that Political Participation is Fair we observe that his initial belief is balanced between Mostly False at 54.5% and Mostly True at 45.5%. That agent leans slightly toward Mostly False.

Second, we might consider the agent as representing more than one individual with the weighting of each belief stance representing the proportion supporting that stance. As a practical matter, the model will use the data associated with beliefs and positions in the same way.

The events in the scenario are in the form of effects, which we call action influences because they translate actions in the scenario into their influence on population entity beliefs and positions. Each action influence supports one set of beliefs and one issue position. Table 1 is Action Influence #198 depicted as a data table in the form that is processed by the model. This Action Influence supports the status quo for land reform based on the belief in a fully legitimate system of land ownership and the goodness of the current plantation system. Note that this example has data for the issue position and stances on both related beliefs; however, the multi-agent system implementation can process action influences that consist of partial information.

Legitimacy_Land_Ownership	Current_Plantation_System_Good	Land_Reform
Fully_Legitimate	Very_True	Status_Quo

Table 1: Action Influence #198 as a Data Table for Processing by the Model.

The weight of the action effect depends on the strength of relationship between the influenced agent and the influencing agent in the social network. In the experimental scenario there are 200 candidate action influences. The number and type included in each scenario depends on the action influence factor setting. In Versus there are 140 action influences; in Neutral there are 144 and Equal there are 149.

An action influence is directed at one or more of the four population groups. Of the 200 candidate action influences, 27 target the entire population, 42 target the Northern Natives, 40 the Northern Others, 66 the Southern Natives and 25 the Southern Others. Forty-two action effects occur in only one design point; 83 in two; and 75 in all three. All Land Reform action influences occur in all three design points.

EXPERIMENTAL DESIGN

The experimental design had two factors each with three settings configured in a full factorial design as depicted in Table 3.

Design Point	*SI Action Influence*	*Social Network Density*
DP01	Neutral	High (Base)
DP02	Versus	High (Base)
DP03	Equal	High (Base)
DP04	Neutral	Medium
DP05	Versus	Medium
DP06	Equal	Medium
DP07	Neutral	Low
DP08	Versus	Low
DP09	Equal	Low

Table 2: Experimental Design.

The first factor was action influences for Southern Independence. We varied the distribution of action influences in the scenario. In the Neutral factor setting action influences support each of the four positions in the same proportion as was initially found in the overall population. In the Versus factor setting action influences supporting the two extreme positions, Status Quo and Independence, were increased to account for 90% of the influences in equal weight with the remaining 10% of the action influences supporting the two centrist positions, Federalism and Southern Autonomy, in equal weight. In the Equal factor setting action influences supporting each of the four positions were the same.

The second factor was density of the social network. The Base factor setting has the baseline social network, which is relatively dense. The Medium factor setting is about half as dense as the baseline social network. The Low factor setting is about a quarter as dense as the baseline social network. While a population entity is more likely to have more and stronger ties in the social network with members of the same population group, social ties cross population group boundaries.

RESULTS AND CONCLUSIONS

We successfully executed ten replications of each of the nine design points in the experimental design after making some fine tuning adjustments to the model and data. Data was collected on each state change for each agent. Analysis of the resulting data indicates that the multi-agent system model functioned as expected.

Varying the Action Influences related to Southern Independence resulted in significantly different issue positions on Southern Independence in line with the nature of the distribution of action influences. Neutral had only a minor impact while Equal and Versus had more of an impact and moved the issue positions toward the expected results.

Varying the Social Network Density resulted in significantly more state changes in the design points with a denser social network. The resulting movement in issue positions was more pronounced in dense networks than less dense social networks. We noted that the model was sensitive to the probability that an agent passed along an action influence in his social network.

Not varying the Action Influences related to the Land Reform issue served as a useful control on the experiment. The expected response occurred with little difference among design points with the same social network density and statistically significant differences between design points with differing densities.

This experiment is the first experience with the multi-agent system. It provides a sound basis for continued testing and development of analytical methods going forward. Over the next year, the multi-agent system will be significantly enhanced to better represent civilian populations in stability operations based on social science theory.

Team 10: Joint Dynamic Allocation of Fires and Sensors (JDAFS) Joint Starting Conditions Analysis

TEAM 10 MEMBERS

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INTRODUCTION

Joint starting conditions (JSC) are the generated set of initial conditions that are provided a combat model for its use within a study or analysis. These conditions include such data as starting Blue and Red common operational pictures (COPs), starting unit locations, starting unit statuses (force strength/attrition effects and current logistics state), etc. A particular scenario provides the context and the JSC apply to a specific starting point within that scenario (e.g., Day D+27). Currently JSC development is executed primarily using Subject Matter Expert (SME) input, discussion, and adjudication for spreadsheet tools and separate attrition and Intelligence, Surveillance, and Reconnaissance (ISR) models. The results are often not repeatable and can be driven by dominant personalities.

As part of the TRADOC Analysis Center's (TRAC's) structured scenario development process, the Joint Dynamic Allocation of Fires and Sensors (JDAFS) model is being reviewed as a tool to support JSC data development. JDAFS is a discrete event simulation that accounts for first-order combat effects using Army approved algorithms. It couples the dynamic, optimized allocation of resources (such as unmanned platforms and artillery assets) to a simulation in order to render better representations of network-enabled warfare. The process to use JDAFS has four main points of effort. First, identify the full range of stating conditions and associated factors that must be accounted for in the JSC process. Second, identify those JSC data that can be developed using model and simulation (M&S) support - clearly capturing and recognizing the interaction between M&S data and non-M&S supported data. Third, identify and execute appropriate M&S enhancements to support JSC data development. Fourth, develop an appropriate Design of Experiment (DOE) front end to support sensitivity analysis and alternative starting conditions.

APPROACH TO JOINT STARTING CONDITIONS

When using high-resolution ground combat simulations, scenarios often do not start running in these high-resolution simulations on D-day. For instance, if the high-resolution starts on D+10, then initial conditions for the high-resolution simulations must be developed. The process for setting these initial conditions often has relied on a single ISR expert to determine detection and identification percentages. Then, an air campaign expert determines the destruction percentage and dispersion of remaining enemy assets throughout the area of operation. This overall process is difficult to defend to an analysis review board which brings into question the results of the high-resolution runs due to the lack of traceability to certifiable algorithms and experimental performance data when setting these initial conditions. A repeatable, traceable process that is approved by the scenario, intelligence, threats, and Joint community is desired.

High-Resolution simulations use the JSC data to represent the intelligence preparation of the battlefield that all military units perform prior to major operations. By providing a traceable methodology of determining these initial starting conditions, the high-resolution simulations, which are already traceable and whose results are well accepted by senior military leaders, can provide defendable results to senior military decision makers.

The goals of Team #10 were:

- Refine and test a Joint battlespace shaping scenario that represents ISR asset allocation/trade-offs and kinetic effects in JDAFS.
- Develop a data farming interface (or at least requirements for one) that lends itself to analyst ease-of-use and provides a range of potential starting conditions.
- Identify and define appropriate improvements to JDAFS to better represent joint shaping assets and that result in traceable realistic Joint Starting Conditions for high-resolution ground combat simulations.

JDAFS

The JDAFS simulation is a publicly available, discrete event simulation that accounts for first order combat effects using Army-approved algorithms. It couples the dynamic allocation of resources, such as unmanned platforms and artillery assets, to a simulation to render better representations of network enabled warfare. The United States Army TRADOC Analysis Center has supported the development of JDAFS for the past several years.

JDAFS implements an entity-level, "low-resolution" approach to simulation modeling. Units are not modeled to the level of detail present in high-resolution models such as COMBATXXI. Algorithms, such as for detection and adjudication of weapons effects, are designed to capture first-order effects without the time-consuming detail present in the high-resolution models.

The starting condition input parameters that the high-resolution simulations require fall into three categories: unit, geographical and operating environment parameters. The problem of determining appropriate JSC is one of determining these parameters following an initial phase of the battle just prior to the operation of real interest. Therefore, traditional analysis with one, or a relatively few, number of output measures is not a good fit to this problem.

This output from this effort is different than the output that is typically obtained from a combat simulation in that it is the end state rather than measures of performance of entities within the simulation that is desired. It is important that a range of starting conditions is available so that expert judgment can be used to determine whether the follow-on, high-resolution simulation runs should begin with a best-case, a worst-case, or an average case situation.

The base-case approach taken was to identify some key measures and perform a simple frequency analysis on the results. For each measure, three output conditions were identified. These corresponded to the "best," "worst," and "most likely" cases. Specifically, the 25th, 50th, and 75th percentile runs are identified based on the frequency distribution of the measure, and these correspond to the "best," "most likely," and "worst" cases respectively.

DESCRIPTION OF SCENARIO

The scenario consisted of Blue, Red, and Neutral (Civilian) units. Blue assets included ground, air, and surface (Navy) units. Red assets included ground and air defense units. A notional display of the force locations at the start of the scenario is shown in Figure 1.

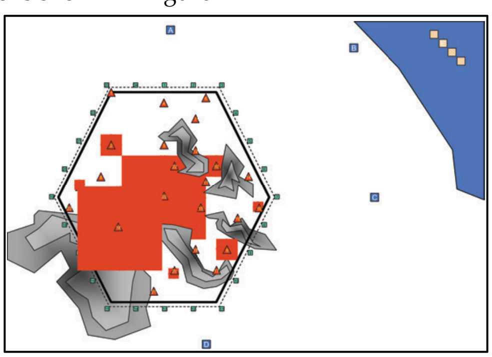

Figure 1: Joint Starting Conditions Scenario

A snapshot of the base case scenario implemented in JDAFS at the beginning of the run is shown in Figure 2. Red and Blue units are shown in their respective colors, while circles represent Civilian units.

The unit positions at the end of one replication are shown in Figure 3. The X's represent casualties.

Design of Experiments

In order to facilitate the execution of multiple scenarios according to an experimental design, a modular approach was developed. Two databases were processed by a Java program that generated the JDAFS input databases, as shown in Figure 4.

The Template database consists of a complete base-case scenario for JDAFS. The Design database consists of two tables. One identifies the factors in the Template database by table, column, and an optional value. The second table points to the particular designs, based on the quantity of parameters varied in the DOE.

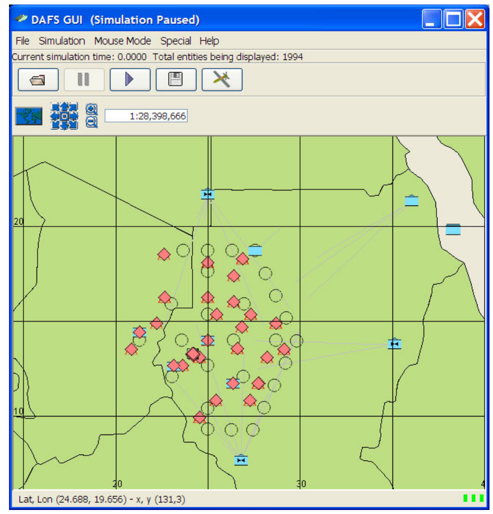

Figure 2: Joint Starting Conditions Scenario in JDAFS

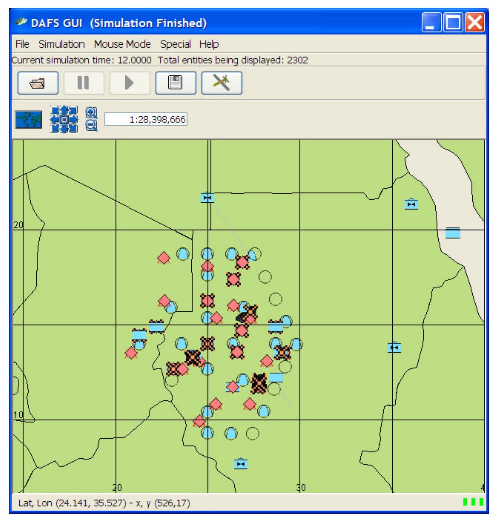

Figure 3: Base Case Scenario at End of Replication

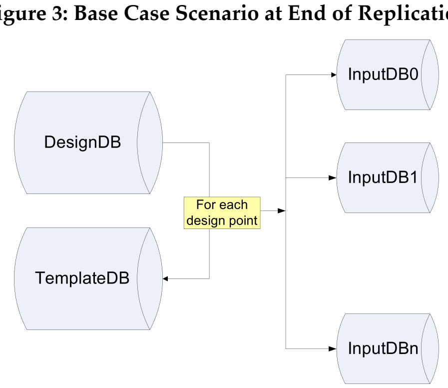

Figure 4: Generation of Input Databases

RESULTS AND ANALYSIS

Analysis of Base Case

As noted above, setting joint starting conditions does not lend itself to traditional analysis, since there are no Measures of Effectiveness (MOEs) that are ultimately of interest. Rather, the outputs of interest consist of the possible JSCs for the next phase of the operation. Thus, the outputs are highly multivariate, consisting of all unit positions, dispositions, and strengths as well as the perception of the enemy. That is, the output is a COP for the enemy and/or friendly forces.

The base case was replicated independently 100 times for the initial analysis. The measures chosen to examine were Blue casualties and Red casualties. The distribution of Blue casualties is shown in Figure 5. The distribution shows nothing particularly unusual. The mode is 8, occurring in 21 out of 100 scenarios.

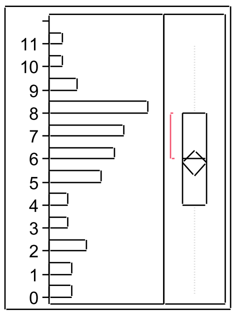

Figure 5: Distribution of Blue Casualties

The distribution of Red casualties is shown in Figure 6. This shows an interesting bimodal pattern. Although the mode is between 500 and 550 casualties, there are also many that were between 50 and 100.

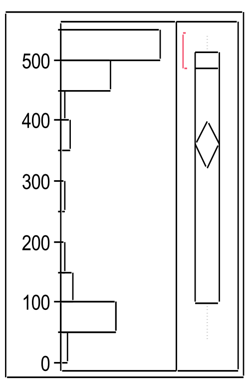

Figure 6: Distribution of Red Casualties

Examining the frequency of casualties by percentile is another way to identify scenarios of interest. This is shown in Table 1, which identifies the 0.25. 0.50, and 0.75 percentile replications. Additionally, the replication is captured so that the results for that condition can be traced.

Percentile	Blue Casualties (Replication)	Red Casualties (Replication)
0.25	4 (17)	98 (95)
0.50	6 (94)	234 (41)
0.75	8 (52)	511 (79)

Table 1: Percentiles of Casualties by Side

Design of Experiments

An experimental design was run with seven factors, three being the optimization intervals (used by the model to set the frequency of optimization for use by the fires, sensor, and unmanned scheduling algorithms) within JDAFS, and the remaining four being the maximum Electro-Optical (EO) sensor ranges for four different Blue platforms. This resulted in 17 design points, each of which had 30 replications. Each replication took approximately 2 minutes on a laptop computer, and the entire set of runs was executed overnight. In a high-performance computing environment (i.e., a cluster) the turnaround time would have been quite rapid.

SUMMARY OF FINDINGS

The analysis of the previous section could be used to identify a small set of representative or interesting scenarios for the next phase of the study. That is, the ending conditions of the JDAFS replication corresponding to the given scenarios would be used to set the JSCs for the next model's runs. Currently, it is straightforward to convert these dispositions into starting conditions for more runs using JDAFS. Thus, JDAFS could be a valuable tool for a panel of subject matter experts in adjudicating possibilities. This would be an improvement over the current approach

Several future improvements to the JDAFS simulation to better represent the setting of JSC were identified. These improvements included:

- Better representation of stand-off ISR missions.
- Implement enemy detection states (positional, functional).
- Better representation of aircraft refueling.
- Capability for units to first become available later in the simulation run.
- Initial Intelligence Preparation of the Battlefield for the JDAFS simulation run.
- Further refine Generalized DOE Interface.
- Finalize an input method to execute multiple DOE configurations.
- Merge output files into a common database to facilitate follow-on analysis.
- Execute final version of the joint starting conditions scenario.

Further Work

JDAFS shows great promise as a tool to enhance the setting of joint starting conditions. In addition to additional JDAFS function improvements, further work includes finalizing and testing the DOE capabilities and refining the user interface. Improved automation of output analysis is also desirable, especially formatting the output reports to be more amenable for use by statistical packages.

Team 11: Non-Lethal Weapons in Crowd Confrontation Situations

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INTRODUCTION

Crowd confrontations are a common occurrence. In the Free World, peaceful protest is a human right. However, when a crowd becomes violent, control forces need to step in to restore order. They should do this with minimum but sufficient force. The use of Non-Lethal Weapons has been promoted to ensure a continuum of force between the simple presence of the control forces and the use of lethal weapons. However, the strategy and tactics for the employment of Non-Lethal Weapons is not well developed.

The following study is part of a three-year project by the Centre for Operational Research and Analysis in Defence Research and Development Canada in cooperation with Laval University of Quebec City. The first year of the project was devoted to literature review on the socio-psychological nature of crowd behaviour. The second year of the project was devoted to modeling and simulation using agent-based methods by Laval University and the System Dynamics model by the Centre for Operational Research and Analysis. The project is currently in the third and final year and will concentrate on analysis of modeling results. This paper will discuss the analysis of the System Dynamics model using the Design of Experiments approaches promoted by the SEED (Simulation Experiments and Efficient Designs) Center at the Naval Postgraduate School.

GOALS

The goals of this analysis of the System Dynamics model of Crowd Confrontations and Non-Lethal Weapons are to:

- Determine the most sensitive parameters in the current model in order to potentially simplify the model or at least focus the data collection efforts for future application of the model.
- Develop a robust set of Rules of Engagement for the employment of Non-Lethal Weapons by applying the model to a diverse set of scenarios.

OVERVIEW OF THE MODEL

Following the approach suggested by Coyle [1], the problem statement was developed in some detail. The primary concern of the study was to determine the effective use of Non-Lethal Weapons from the strategic perspective. Namely, there are strategic and tactical decisions concerning both the benefits of controlling a crowd that becomes unruly, and the costs of either making the situation worse by not doing enough or being perceived as using excessive force through the employment of Non-Lethal Weapons.

After recognizing the complex nature of the problem, a qualitative model was developed to understand its important dynamic nature. Figure 1 provides an influence diagram that was generated early in the modeling effort.

The central feature of this diagram is the crowd aggressiveness level. The controllers have an accepted aggressiveness level that they will allow, while the instigator/leaders and the violent crowd members have a desired aggressiveness level that they are wishing to achieve. Based on the discrepancy between the actual crowd aggressiveness and the accepted aggressiveness, the controllers will determine their tactics. Similarly, the instigator/leaders and violent crowd members determine their actions based on the discrepancy between their desired crowd aggressiveness and the actual crowd aggressiveness.

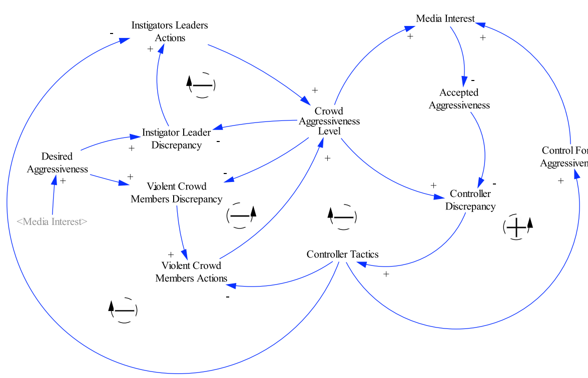

Figure 1: Influence Diagram of Crowd Confrontation Situation

These interactions lead to a series of negative feedback loops. There are also two positive feedback loops that involve the media. Control force tactics and crowd aggressiveness leads to media interest and this influences controller tactics and instigator/leader and violent crowd member actions.

The next step in the modeling process was to develop a series of quantitative models based on System Dynamics

Stocks and Flows. Quantitative models were developed to examine:

- The Crowd Dynamics with Bystanders/Pacifists, Violent Crowd Members, and Instigator/Leaders of various age categories and both genders.
- The Actions of the Violent Crowd Members and the Instigators/Leaders in terms of provocation, violence against property, or violence against the Control Force.
- The Tactics of Controllers with options to use such Non-Lethal Weapons as tear gas, plastic bullets, water cannons, etc.

These sub-models were interrelated by the various decision processes of the individual agents in the model. Thus, the actions of the crowd and the instigator leaders affect the crowd dynamics and the decisions of the controllers. The actions of the controllers affect the crowd dynamics and the actions of the violent crowd members and instigator/leaders.

The detailed documentation of the model is available in [2].

MODELING PARAMETERS

The philosophy of system dynamics is that it is better to have a crude estimate of an important parameter than to ignore the parameter because a good estimate of its value cannot be obtained. By not including a parameter, one is implicitly assuming that its impact is zero. However, in this model 227 parameters have been included and the goal is to determine which of these parameters are most important to the future analysis. There are four types of parameters that are explicitly modeled:

a. Observables – such as number of people in the various groups of various types, and actions carried out by these people of various types.

b. Change rates in the observables – such as number of people joining or departing the groups, the increasing or decreasing rate of actions by the people, the effects of the observables on the rates, etc.

c. Thresholds that determine tactics – such as the level of crowd aggressiveness that will trigger the use of various Non-Lethal Weapons by the Controllers, and the level of crowd aggressiveness that will cause the Instigator/Leaders to take actions.

d. Strategic targets – such as the acceptable level of crowd aggressiveness that the Controllers will allow, and the desired level of crowd aggressiveness that the Instigator/Leaders wish to achieve.

Some of these parameters, such as the number of Bystanders/Pacifists initially in the crowd, are scenario dependent. Some of the parameters are theoretically determined, such as the tactical effects of Non-Lethal Weapons on the crowd behaviour. Some of them are controllable by the agents, such as the Thresholds that determine the tactical use of Non-Lethal Weapons, and the strategic values related to acceptable and desired levels of aggressiveness.

Because of their importance to the understanding of the central feature of the model, namely the aggressiveness levels, Tables 1 and 2 are provided to show how the aggressiveness of the crowd and the controllers are categorized.

Aggressiveness Level	Majority Action Type	Minority Action Types	Description of Crowd
1	Passive	Passive	Passive Crowd
2	Passive	Provocative	Passive Crowd with Isolated Violent Actions
3	Passive	Provocative, Property Damage	
4	Passive	Provocative, Property Damage, Control Force Attack	
5	Provocative	Passive	Agitated Crowd
6	Provocative	Passive, Property Damage	Agitated Crowd with Isolated Violent and or Passive Actions
7	Provocative	Passive, Property Damage, Control Force Attack	
8	Property Damage	Passive, Provocative	Violent Crowd
9	Property Damage	Passive, Provocative, Control Force Attack	
10	Violent Against Control Force	Passive, Provocative, Property Damage	Violent Crowd

Table 1: Crowd Aggressiveness Categorization

Aggressi	Tactical Combinations
0	Presence
1	Communications
2	Defensive Move
3	Tear Gas
4	Defensive Move and Tear Gas
5	Water Cannon
6	Defensive Move and Water Cannon
7	Tear Gas and Water Cannon
8	Defensive Move, Tear Gas and Water Cannon
9	Plastic Bullets
10	Defensive Move and Plastic Bullets
11	Tear Gas and Plastic Bullets
12	Defensive Move, Tear Gas and Plastic Bullets
13	Water Cannon and Plastic Bullets
14	Defensive Move, Water Cannon and Plastic Bullets
15	Tear Gas, Water Cannon and Plastic Bullets
16	Defensive Move, Tear Gas, Water Cannon and Plastic Bullets
17	Offensive Move
18	Tear Gas and Offensive Move
19	Water Cannon and Offensive Move
20	Tear Gas, Water Cannon and Offensive Move
21	Plastic Bullets and Offensive Move
22	Tear Gas, Plastic Bullets and Offensive Move
23	Water Cannon, Plastic Bullets and Offensive Move
24	Tear Gas, Water Cannon, Plastic Bullets and Offensive Move

Table 2: Controller Aggressiveness Categorization

DESIGN OF EXPERIMENTS

To achieve the goals of the team, two experiments were run: one to determine the sensitive parameters in the model; and one to develop a robust set of rules of engagement.

The first experiment involved a two-level fractional factorial design, which required 512 simulation runs.

The second experiment involved a cross-design. For the 22 "controllable" tactical and strategic parameters, a nearly orthogonal Latin hypercube was used. This required 129 simulation runs. For the remaining 183 "uncontrollable" parameters, a two-level saturated design was required. This involved 256 simulation runs. Therefore, 129 times 256 or 33,024 simulation runs were required for the entire experiment.

RESULTS AND ANALYSIS

Sensitivity of the Parameters

The 512 runs for the two-level fractional factorial design took only five minutes on a laptop computer because the System Dynamics model is purely deterministic. Therefore, data farming was not required.

The aggressiveness of the crowd and the aggressiveness of the controllers were summed in the model to determine the overall level of aggressiveness that would be minimized in the ideal world. Two types of statistical analysis were conducted on the results of the 512 simulation runs: stepwise regression and a partition tree.

With the stepwise regression, 21 parameters entered the model and were able to account for 30% of the deviation in the results. Eleven of these were considered controllable (i.e., associated with factors influencing control forces strategies). Among them, five are used to determine the tactics of controllers (e.g., tear gas and plastic bullet thresholds). These controllable elements would need to be determined to reduce aggressiveness to a minimum. Ten parameters were considered uncontrollable (i.e., associated with factors influencing the crowd members). For example, the effect of "illegitimacy" is an important factor. The uncontrollable elements would need to be estimated accurately, based on the scenario or the theoretical foundations of the model. As predicted, many of the controllable factors (5 out of 10) made the top 10 list.

With the partition tree, again 21 parameters entered the solution. However, they were a different set of parameters, which included only 6 controllable parameters and 15 uncontrollable parameters. The model was able to account for 50% of the deviation in the results. Some elements, such as the effect of illegitimacy, come later in the order of importance in the partition tree than in the case of stepwise regression. However, one of the uses of the partition tree approach is the ability to develop rules of engagement directly from the results.

Robustness of the Rules of Engagement

The first thing that was done to evaluate the robustness of the rules of engagement was to develop a "loss function." This was not difficult—since the goal was to minimize the total aggressiveness in the scenario, the "loss function" that was chosen was the maximum aggressiveness in the scenario squared.

The mean loss was then determined for each of the 129 controllable parameter runs by averaging all 256 of the uncontrollable parameter runs.

Stepwise regression and a partition tree were applied to the 129 simulation results, with the independent variable being the mean loss.

A stepwise regression was conducted using all 22 main factors, all two- and three-way interactions and all quadratics. Thirty-eight variables entered the model: 15 main effects, 21 interaction effects and 2 quadratic effects. This model accounted for 90% of the deviation in the results. The results confirmed that the thresholds of soft tactics, such as communication and use of cameras, do not have a considerable impact on the aggressiveness of the event. Conversely, the use of plastic bullets and water cannons has a considerable impact. This model could easily be used to determine a robust set of tactical thresholds and strategic goals of the controllers over all possible scenarios that might be faced.

The partition tree results were somewhat less satisfying since only five partitions were possible, even though they represented only 78% of the deviation in the results.

FUTURE WORK

Using this model with an efficient design of experiments, it is hoped that a robust set of rules of engagement can be developed that will minimize aggressiveness of the crowd with minimum force applied by the controllers. There are two approaches that will be examined:

- A set of scenario-independent rules of engagement that can be applied to all possible situations.
- A two-player style measure-counter measure approach that adapts the rules of engagement to the developing dynamics of the situation.

The first set of rules might be useful for doctrinal documentation on Non-Lethal Weapons employment. The second, more dynamic rules, might be useful for training simulations and Red Team/Blue Team gaming.

The 2010 Winter Olympics will be held in Vancouver, British Columbia and the Canadian Forces are currently making plans to support the games with security capabilities. There have already been indications that attempts will be made to disrupt the games by anti-poverty protesters and native groups [3]. With the eyes of the world on Canada through the international media, it will be imperative to handle any disruptions expeditiously, but carefully. Therefore, the optimal use of Non-Lethal Weapons is currently of great interest to the Canadian Forces, and supporting the 2010 Olympic Games planners with doctrine and training could be one of the immediate benefits of this work.

In the longer term, the introduction of design of experiments to verify and validate models in the Centre for Operational Research and Analysis, Defence Research and Development Canada, the Systems Dynamics Society, and the modelling and simulation community through presentations of this work, would be an admirable goal for the Team 11 members.

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International Data Farming Workshop 17

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Hotel Information:
Mrs. Tatjana Fuchs (Tatjana.Fuchs@dorint.com); Tel.: +49 8821 / 706 - 603; Fax.: +49 8821 / 706 - 618

The room rates are: Single: € 117; Double: € 168. The Workshop Fee is € 410, and will be collected by the hotel. If you have any questions, please do not hesitate to contact Mrs. Tatjana Fuchs at the hotel or the SEED Center's administrative assistant, Debbie Sandoval either by email: dasandov@nps.edu or by phone: 831.656.2683.

Please go to http://harvest.nps.edu/ at the IDFW 17 link for additional information and registration.

Tentative Agenda
Sunday, September 21: Opening reception and dinner.
Monday, September 22: Opening briefs and team poster sessions in the morning, then begin work in teams
Tuesday - Thursday, September 23 - 25: Work in teams (optional plenary sessions in the mornings) at NPS
Friday, September 26: Outbriefs and closing ceremony in the morning.

Call for Team Leaders / Plenary Speakers:
Please email gehorne@nps.edu with your choice of teams and if you want to lead a team or present a plenary briefing.

Conference Fee:
The registration fee is €410
Registration pays for:

- Conference rooms
- Lunch, Break food and drinks
- New one-year membership card with quote
- Opening dinner
- CD & conference materials
- Fun

The Data Farming CD/DVD, if provided, will be attached here. For additional copies of the CD or of the Scythe please contact Ted Meyer (tedmeyer@mac.com)

Scythe - Proceedings and Bulletin of the International Data Farming Community

Seed Center for Data Farming
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