Scythe

Proceedings and Bulletin of the International Data Farming Community

Issue 6 - Workshop 18

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 *sixth* prototypical issue. Articles, ideas for articles and material, and any commentary are always appreciated.

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International Data Farming Community Workshop 18 Program Committee

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.

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IDFW 18: Dynamic Truths

by Gary Horne
Naval Postgraduate School

The Naval Postgraduate School was excited to host International Data Farming Workshop 18! It was held from March 22nd through the 27th, 2009. Our theme was "Dynamic Truths," and the goal, as usual, was to use our data farming methods to continue to explore our important questions. The plan continues to be 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 18.

This issue, our sixth, of The Scythe contains a summary of each work team effort. And 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.

Now looking ahead, our Data Farming community will be in Auckland, New Zealand for our next workshop, International Data Farming Workshop 19. I would like to invite you to participate, starting with the opening dinner on Sunday 1 November 2009 and continuing through the week with the closing session on Friday 6 November. Our theme for IDFW 19 is... ***"Mana."*** In the Maori culture, having *mana* means to have influence, authority, effectiveness, power, usefulness, and prestige.

We hope to see you there (with all of your ***mana***)!

Gary Horne

Team 1: Maritime Force Protection Study using MANA and Automatic Co-Evolution (ACE)

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INTRODUCTION

This study investigated maritime protection using the Automated Co-Evolution (ACE) framework developed in Singapore. The scenario examined involved a frigate having to defend a high-value but poorly protected target vessel (HVT) from pirate or Fast Intruder Attack Craft (FIAC). The outcomes for the study were to determine whether ACE could come up with feasible tactics for both Blue and Red forces, and as a secondary objective, to gain insights into the scenario itself.

Additionally, a new version of the MANA model was used and evaluated for the work. This version, MANA 5, uses continuous coordinates and vectors to determine the position and movement of the agents in the scenario, rather than the cellular paradigm used in previous versions of MANA. This allows the model to represent both the long-range and short-range interactions in the scenario, without artifacts caused by coarseness of scale that would have occurred if earlier versions were used.

DESCRIPTION OF SCENARIO

In this scenario the Blue Force consists of a generic frigate and a troop carrying vessel with limited armament. In addition, Blue Force was given a group of Rigid Hull Inflatable Boats (RHIBs) for some excursions. While not well armed, the intention was that the RHIBs could act to determine Red Force's intent early. The Red Force consists of a group of seven FIACs, three of which are suicide bombers, and the remaining four armed with RPGs.

Additionally, neutral vessels were added as a scenario variation. These vessels could not be distinguished from the FIACs beyond visual range, and so served to confuse the Blue Force's situational awareness at long range.

Critically, the Red Force is not a conventional military threat, so its intention must be determined before Blue Force may engage it.

The version of the scenario used for the ACE runs included both the RHIBs and the neutral vessels, though it turned out that these did not play a large role in the tactical outcomes.

KEY ASSUMPTIONS

The critical assumptions for this scenario concerned the Rules of Engagement. Two factors would be at play for an actual operation of the type depicted in this scenario:

1. Under what conditions would Blue Force be allowed to begin engaging Red Force?
2. Given the presence of non-combatants, which weapons would be available to the frigate to use? (i.e. Is collateral damage an issue?)

For this analysis, it was deemed that Red Force's intent could be gauged if it came within 500m of Blue Force. Furthermore, no restrictions were placed on the weapons systems that could be used by the frigate, except as a later excursion.

We further assume that the Red Force is deemed successful if it causes any kind of damage to the HVT (i.e. it does not necessarily have to sink it).

Here we do not contend that these assumptions are realistic, rather the intention is to determine what each side should do given these assumptions.

KEY MODELING PARAMETERS

Blue Force. For the ACE runs, the Blue Force consisted of the frigate, HVT, and two RHIBs. The characteristics for these vessels were:

- HVT. The HVT was assumed to be lightly armed and could reach a top speed of 28 knots.
- Frigate. The frigate was modeled to be well-armed with a 5 inch main gun at the bow, a rear Phalanx CIWS 1B, as well as port/starboard stabilized 50cal guns. The frigate was assumed to be positioned randomly within 2km of the HVT. The frigate could also reach a top speed of 28 knots, with some inertia modeling.
- RHIBs. Two RHIBs were modeled as fast moving boats with light arms. Their main use was to scout for

adversarial presence and to inform the HVT and frigate early.

A summary of the key specifications of the Blue Force is listed below:

	HVT	frigate	RHIBs
Maximum Speed (knots)	28	28	35
Detection Range (m)	20000		
ID Range (m)	500		
Weapon Range (m)	1000		

Table 1: Specifications of Blue Force

Note: Detection for the RHIBs is assumed to be supplied by a comms link to the frigate. To save computational overhead, this was represented by giving the RHIBs the same sensor as the frigate.

Red Force. The Red Force consisted of seven FIACs. Four FIACs were armed with RPGs capable of launching attacks within 100m range while three FIACs were close-range suicide bombers. The FIACs were assumed to have a maximum speed of 35 knots. A summary of the modeling parameters used is listed in Table 2 below.

Maximum Speed (knots)	35
Detection/ID Range (m)	500
RPG Range (m)	100

Table 2: Specifications of Red Force FIACs

Neutral. More than 30 neutral ships were added to model the difficulty faced by the RHIBs in identifying hostile craft along a busy shipping channel.

METHODOLOGY

Refinement of Baseline Scenario

The team members first started with a round of discussion to fine-tune the baseline scenario. Several quick Red-Teaming runs were initially conducted on ACE to evaluate the modifications before arriving at the finalized baseline for Red and Blue force plans (illustrated on Figure 1 below).

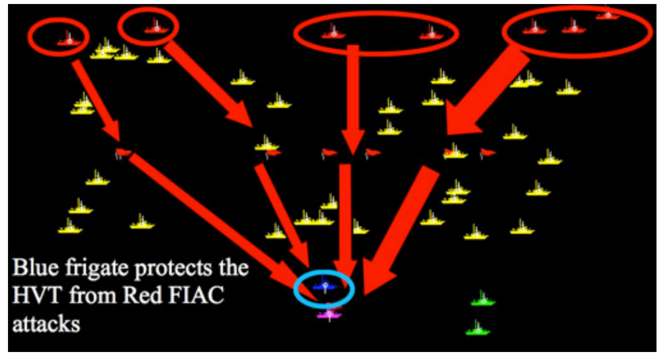


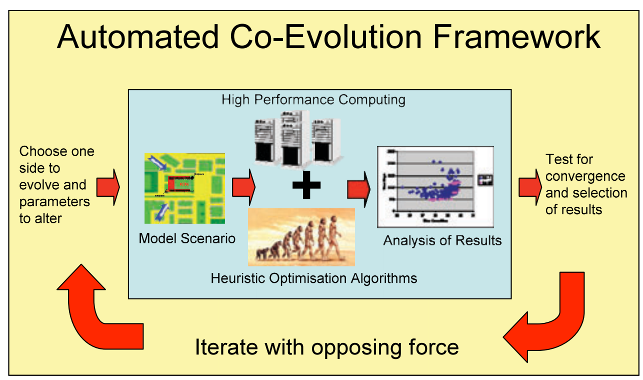
Figure 1: Baseline Blue/Red force plans

Automated Co-Evolution (ACE)

ACE[1] was developed by DSO National Laboratories, Singapore. It is a two-sided competitive co-evolution algorithm, which provides a vehicle for understanding the dynamics of competition in a military context.

The key benefit of this framework is to complement the manually intensive process of developing plans of action by automatically generating plans that perform well and are relatively robust even in the face of an adaptive Red adversary. Potential applications of ACE include supporting of military doctrine/tactics development, operational plan evaluation and acquisition programs.

An overview of ACE is shown below:



Applying ACE

A total of 5 co-evolutions, each constituting one round of Blue Teaming vs. Red Teaming, were conducted automatically using ACE. The two tables below show the ACE run settings, and the ranges for the MANA parameters that were to be evolved.

Co-Evolution Settings	Co-Evo Gen	5
	Comparison Size	1
EPGA Settings	Max EPGA Gen	6
	Max Individual	40
	Parents	10
Model Settings	Replicates	20
Total Runs		~28000
Time Taken	Condor Cluster	~ 20 hrs

Table 3: ACE run settings

[1] "A Co-evolution Approach for Military Operational Analysis" by Choo et. al, *2009 World Summit on Genetic and Evolutionary Computation*.

Blue Parameters	Min Value	Max Value
Dispersion of RHIBs	-100	100
Aggression of frigate against FIACs	-100	100
Cohesion of frigate with HVT	-100	100
Red Parameters	**Min Value**	**Max Value**
X-position of start point for each FIAC	1000 (Left boundary)	19000 (Right boundary)
X-position of waypoint for each FIAC	1000 (Left boundary)	19000 (Right boundary)

Table 4: Red and Blue Parameters for Co-evolution

MEASURES OF EFFECTIVENESS

As required by the heuristic optimization function within ACE, objective functions involving the MOEs were designed. Based on the scenario, it was decided that the function would depend on the following MOEs:

- Mean HVT attrition (Primary Objective)
- Mean Red Force attrition (Secondary Objective as a tie breaker)

Hence Blue Force would seek to minimise mean HVT attrition and maximise Red Force attrition. In contrast, Red Force would seek to maximise mean HVT attrition and minimize Red Force attrition.

RESULTS AND ANALYSIS

Baseline Scenario

Table 5 below shows a cyclic outcome from the 5 co-evolution cycles of Blue Teaming vs. Red Teaming.

No.	Pop Name		RedCas	HVTCas
1	BlueCoEvo	1	1.65	0
2	RedCoEvo	1	2.15	0.95
3	BlueCoEvo	2	2.35	0
4	RedCoEvo	2	5.3	0.85
5	BlueCoEvo	3	6.6	0
6	RedCoEvo	3	5.8	0.35
7	BlueCoEvo	4	5.25	0
8	RedCoEvo	4	2.5	0.35
9	BlueCoEvo	5	3.05	0
10	RedCoEvo	5	6.25	0.4

Table 5: Baseline Scenario MOEs

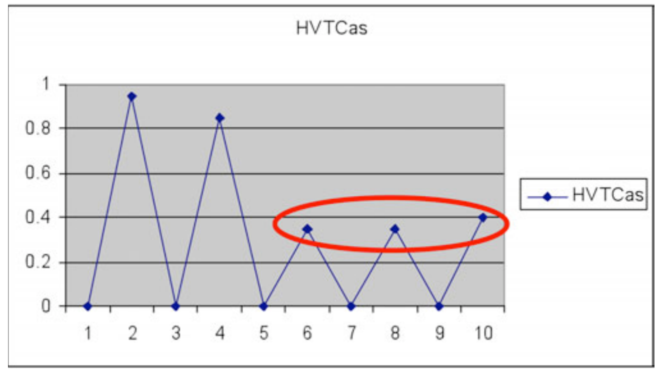


Figure 2: Evolution of Mean HVT Attrition

Cyclic outcome. Zooming in on the results for MOE 1 (Figure 2 above), the team observed that Blue Force could successfully evolve stable defensive tactics (after the 2nd co-evolution cycle) that resulted in less than 50% success for the Red Force counterattacks. MOE 2 (mean Red Force casualties) did not produce meaningful correlation to MOE 1 as it was included mainly as a tie breaker. The team observed surprising maneuvering tactics which saw the frigate purposefully following behind the HVT's escape trail. In addition to maintaining a constant watch and safety buffer distance for the HVT, this strategy successfully created open spaces for the frigate to separate the FIACs and to achieve higher kills against individual FIAC targets as illustrated in Figure 3 below.

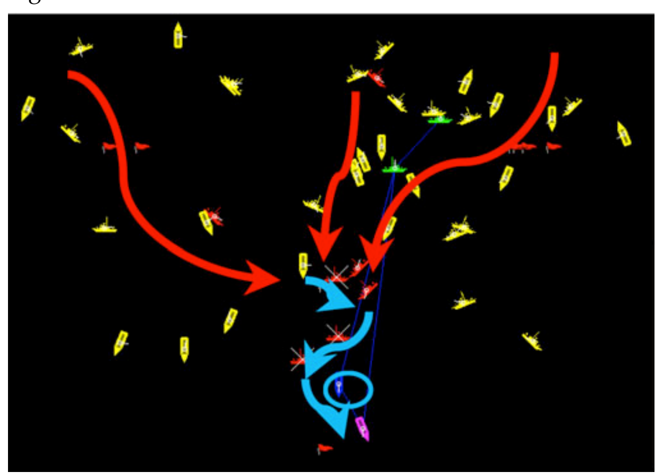
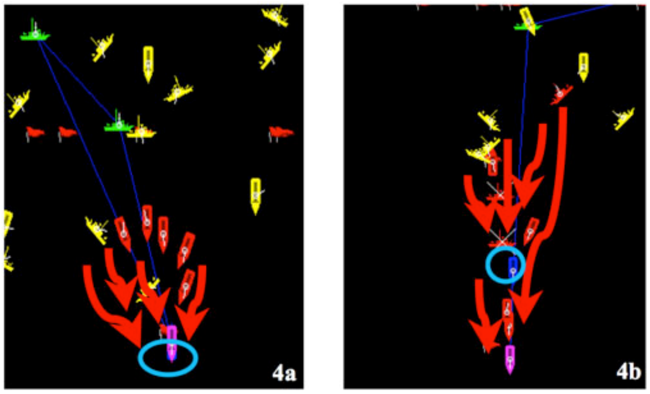


Figure 3: Co-evolved Blue plan

To counter this Blue Force tactic, Red Force's co-evolved plans were to launch synchronized saturation assaults. FIACs were observed to simultaneously swarm so that the HVT had little reaction time and space to escape (See Figure 4a). Another possible tactic would be to send waves of en masse attacks to overwhelm the frigate and thus creating possible openings for at least one FIAC to slip through and to charge towards the HVT (See Figure 4b).



Figures 4a & 4b: Co-evolved Red Force plan

Additional Scenarios

To further explore these findings, the team decided to create two variants of the baseline scenario to study the impact of splitting the FIACs so that they can attack from both North and South directions ("Split FIACs"), and to weaken the weapon effectiveness of the frigate to understand whether there can be tactical solutions for Blue Force to overcome this reduced performance ("Weaken frigate"):

		(a)Split FIACs		(b)Weaken frigate	
No.	Pop Name	RedCas	HVTCas	RedCas	HVTCas
1	BlueCoEvo 1	6.85	0.1	2.5	0.8
2	RedCoEvo 1	4.85	0.9	0.35	1
3	BlueCoEvo 2	6.45	0.35	0.85	0.85
4	RedCoEvo 2	3.25	1	0.15	1
5	BlueCoEvo 3	5.3	0.05	1.75	0.85
6	RedCoEvo 3	1.65	1	0.7	1
7	BlueCoEvo 4	6.8	0.1	1.45	0.9
8	RedCoEvo 4	4.4	1	0.55	1
9	BlueCoEvo 5	5.6	0.2	1.1	0.95
10	RedCoEvo 5	2.2	1	0.05	1

Table 6: MOEs for Split FIACs and Weaken frigate

(a) Results for Split FIACs scenario

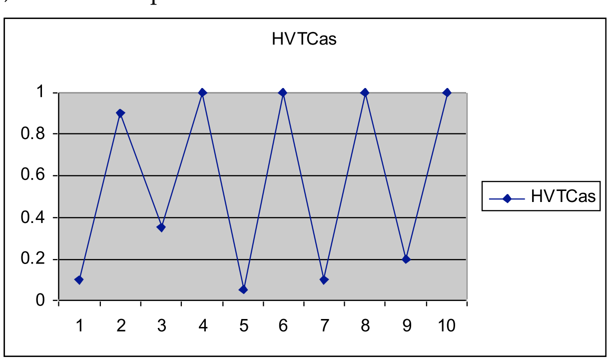


Figure 5: Evolution of Mean HVT Attrition (Split FIACs)

Cyclic outcome. With four FIACs coming from the north and three from the south, the results now showed a significant deterioration in the situation for Blue Force. For every Blue Force evolved tactic, Red Force was always able to find successful countering tactics to ensure close to 100% HVT attrition (seen in Figure 5 above). For every Red Force evolved tactic, Blue Force was unable to find countering tactics to ensure 100% HVT survivability. While the Blue Force's evolved tactics were similar to the baseline scenario, the FIACs' plan was to first draw the frigate towards the north to face the higher density of FIACs. Pre-occupied with the engagements, the frigate would likely lose contact with the fleeing HVT, thus allowing the remaining FIACs to easily flank the frigate and attack the unprotected HVT, as shown in Figure 6 below.

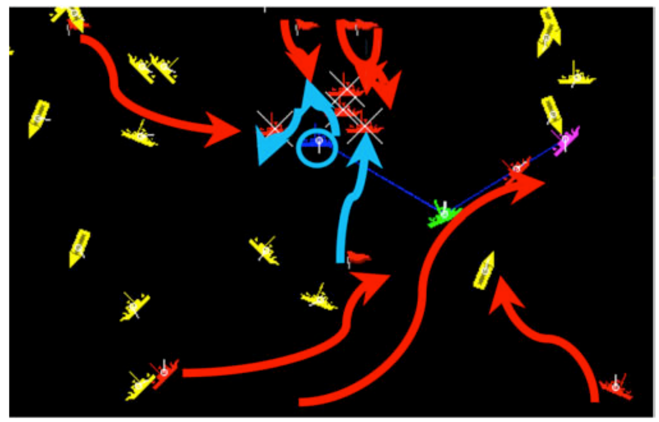


Figure 6: Co-evolved Red Force plan for Split FIACs

(b) Results for Weaken frigate scenario

Red Force dominant outcome. The team observed that the weakened frigate, without the 5-inch gun, was unable to perform the task of protecting the HVT. This could be seen from the trend of mean HVT attrition evolving towards the 100% level in Figure 7 below. Even though the frigate tried to remain close to the HVT, the frigate was regularly overwhelmed by the FIACs when the FIACs chose to attack in numbers. The results show that Blue Force was unable to develop good strategies to counter the Red Force, and even more so when the FIACs split up.

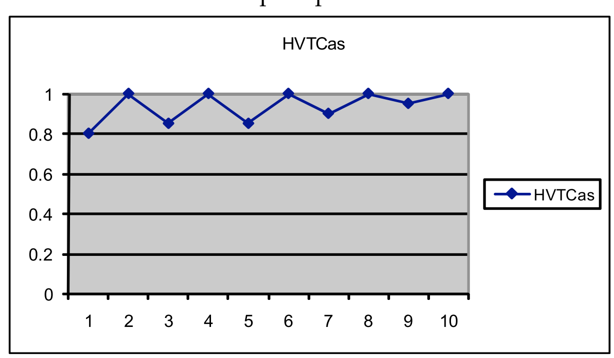


Figure 7: Evolution of Mean HVT Attrition (Weaken frigate)

SUMMARY OF FINDINGS

One-sided compared to Two-sided attack. The results show that the additional degree of freedom given to the FIACs in attacking from two sides rather than just a single side will pose a much greater challenge to the Blue Force. Instead of just trying to saturate the frigate (in the one-sided case), the FIACs can attempt to lure the frigate away from the HVT and then attack an unprotected HVT easily.

Performance of frigate weapon systems. The team assumed a rather optimistic weapon performance for the frigate against the FIAC class of targets. In the scenario of the weakened frigate, we noticed immediate dominance by the Red Force. This finding suggests that if sea trials show that the frigate's weapon systems have limited performance against FIACs, additional Blue Force capabilities may need to be introduced. Note however that the weakened frigate case reflected a much lower level of firepower than a frigate could potentially have (this was achieved by removing the frigate main gun and CWIS, as if these weapons could not be used due to the potential for collateral damage).

CONCLUSIONS

This work successfully demonstrated that ACE was able to generate sensible and optimized tactics for both the Red and Blue forces using MANA 5. This reinforces the findings of Workshop 14 where Singapore's Automatic Red Teaming (ART) was used to establish the feasibility of using evolutionary algorithms to develop tactics; on that occasion for a single side.

In short, the best tactics for the Red Force were to split up and attempt to lure the frigate away from the HVT. Alternatively, if possible the Red Force could attempt to overwhelm the frigate by launching a swarming attack. Conversely, Blue Force's best tactic was for the HVT to move away from the Red Force, but for the frigate to move more slowly, so as to become relatively closer to the Red Force, but when not engaging the Red Force to move back towards the HVT.

We note that this was an abstract scenario and did not necessarily represent accurately the true firepower of the frigate or FIACs. Furthermore, our assumptions about Rules of Engagement, acceptable tactics and objectives of each side may not be representative of actual situations in current operational theatres.

Nonetheless, they still provide some interesting insights into maritime force protection scenarios, and a good starting point for more detailed analysis. It is therefore believed that ACE results would make a useful contribution to mission planning and acquisition analysis.

Team 2: Final Report: Unmanned Casualty Evacuation (CASEVAC) in the Distributed Environment

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INTRODUCTION

The current battlefield is changing rapidly. Combat operations against irregular forces are set in a dispersed, non-linear battlefield. Vast distances between small units such as the infantry squad and the distances from these small elements to their supporting organizations pose unique challenges. Casualty evacuation is one of these challenges.

The goal of casualty evacuation is to transport an injured Marine from the point of injury to life saving surgical care quickly. The first 60 minutes after a traumatic injury is referred to as the "golden hour." The chances of survival for critically injured trauma patients depend on immediate surgical care. Increased dispersion results in longer distances from the point of injury to medical care facilities with a corresponding increase in the delay between the time of injury and life saving surgical care. The non-linear aspects of this battlefield increase the threat to aircraft crews and platforms conducting casualty evacuation. Aerial CASEVAC, executed with manned assets, places additional lives at risk.

Unmanned aerial systems (UAS) offer an alternative means of air casualty evacuation. This alternative may provide time-critical response while reducing threat to aircraft crews.

The specific objective for Team 2 at IDFW 18 was to determine which performance factors of a UAS has the greatest impact on CASEVAC.

Ineffective CASEVAC Can Cost Lives

During CASEVAC, the patient is stabilized before transport because, unlike medical evacuation (MEDEVAC), emergency care may not be provided en route.

Treatment time lost en route, and greater distances from the point of injury (POI) to life-saving surgical care, creates a need for faster reaction and reduced travel times.

Boeing's Unmanned Little Bird (ULB) Provides a Unique Opportunity for Live Force Experimentation

With a maximum speed of 134 mph, a range of 379 miles, and flight ceiling of 7,300 ft, the ULB is well suited for use as an experimental aircraft in the context of unmanned CASEVAC. Its small size (23-ft length, 26.35-0ft width, and 8.14-ft height) allows for entry into landing zones that would otherwise be impractical for larger aircraft. The ability to take off with a maximum weight greater than 3,500 lbs provides the flexibility to deliver supplies and transport casualties.

Figure 1: Boeing's Unmanned Little Bird

SCENARIO

There are three platoon locations, separated by over 50 miles. Casualties are experienced over a 96 hour time window. UAS(s) is dispatched to retrieve casualties. The forward operating base (FOB) is centrally located with UAS support and surgical care. Casualties are evacuated between 5 and 45 miles from the FOB. Any casualties inside of 5 miles will be evacuated via ground transportation.

A casualty-causing event where there is no longer a threat present near the POI is modeled. There are, however, three threat cases.

- **High Threat** - The high threat case models a casualty-causing event in which the threat is located in close proximity to the POI and along the route of flight of the UAS.
- **Area Threat** - The threat is near the POI.
- **Route Threat** - The threat, in this case, is located along the flight route.

Basic Assumptions for CASEVAC Model

- All casualties were properly stabilized and triaged before transport.
- Patient status did not degrade during the evacuation flight.

- Surgical care was collocated with the ULB launch and recovery site.
- All radio communications were reliable.

Agent Descriptions

Five agent types are used in this simulation: the casualty, the UAS, the Direct Air Support Center (DASC), the surgical care facility, and the threat.

- The UAS agents used in the model were constructed with location, speed, survivability, capacity, and route characteristics.
  - CASEVAC – When casualty notification is received, the UAS flies to the location of the casualty, retrieves the casualty, and then moves to the drop-off location.
- The surgical care facility was the finish line for evacuated casualties.
- The DASC received and processed all CASEVAC requests.
- The enemy combatants were given a location, sensor range, probability of detection, and probability of kill characteristics.
- Casualty agents are characterized by instances and location.

DESIGN OF EXPERIMENTS

The MOE for this model was mission completion time (MCT).

Factor	Value Range	Explanation
Casualties	1…18	The number of casualties sustained
UASs	1...4	The number of UASs available
Speed (m/s)	46.3...115.7	Airspeed (meters per second)
Litters	1...8	The number of rescue litters that are carried by each UAS
Altitude (m)	304.8...1524	The cruise altitude of the UAS
Load (s)	300...420	Time for UAS to descend, land, and climb to level flight
Enemy Sensor Range (m)	0…4828	Sensor range of the enemy
Probability of Detection	0.65...0.95	The probability the enemy detects the UAS within sensor range
Probability of Kill	0.05…0.03	The probability that the enemy shoots down a UAS

Table 1: Situational factors are in blue, aircraft characteristic factors are in green, mission process time factors are in yellow, and enemy capability factors are in gray.

The conditions of the distributed environment influenced the choice of experimental factors, which were grouped into four categories: situational, aircraft characteristics, mission process times and enemy capabilities. Aircraft characteristics and mission process times are controllable factors. Situational and enemy capabilities are uncontrollable by the decision maker. Table 1 summarizes the input parameters and ranges used in the experiment.

MODELS

The Joint Test and Evaluation Agent Model (JTEAM) and Pythagoras models were the programs chosen to model UAS interaction in the distributed environment. JTEAM is a farmable ABM; time-stepped, and three-dimensional. Pythagoras provides the ability to model the terrain of the operating environment.

RESULTS AND ANALYSIS

The first runs with the JTEAM model were done without mission process time delays. This provided the same MCT for each design point.

The model was updated and a second batch of runs was executed. In this iteration, the enemy threat was too robust. The model was run approximately 1000 times. Of those, the unmanned asset was shot down 331 times. Presently, JTEAM is being updated to account for this. Results of the JTEAM model are forthcoming.

Pythagoras Output

Analysis of the initial output proved speed was only important in instances of one casualty. As the output was further analyzed, there seemed to be some confounding between the speed of the UAS and the distance of the casualty from the FOB.

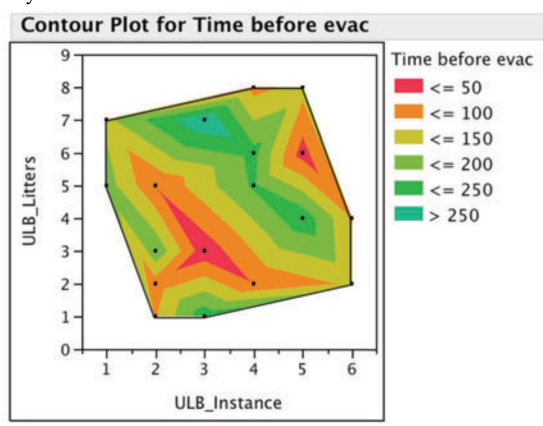

Figure 2 shows the contour plot of the MCT as a function of the number of litters and the number of UASs.

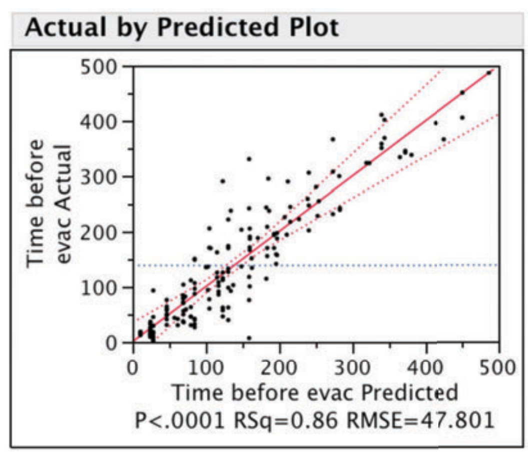

Figure 3: Actual vs. Predicted plot for MCTs

The most important factors for shorter mission completion times in unmanned CASEVAC is the interaction of the number of litters with the number of casualties followed by the number of UASs available. Speed is a factor, but not important as initially expected.

Team 3: Total Life Cycle Management: Automated Model Development

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Tom Turner (Concurrent Technologies)
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INTRODUCTION

Total Life Cycle Management (TLCM) is the process which enables program managers to make life-cycle decisions across all phases of the acquisitions process. Life-cycle sustainment, operational performance issues and requirements are system dependant. Relevant issues arise from early in the process during the Material Solutions Analysis Phase, all the way through Operations and Support. Adaptive and modular modeling and simulation tools have been developed to address these complex issues throughout the life-cycle the Marine Corps weapons systems.

Previous work from Naval Postgraduate School students has focused on the Total Life Cycle Management – Assessment Tool, from Clockwork Solutions. This technology has been successfully used in numerous studies in support of program managers and logistics decision makers throughout the Marine Corps. Marine Corps Systems Command and Headquarter Marine Corps, Installations and Logistics have also pursued a more scalable approach to life-cycle modeling and simulation using EXTENDSIM 7.0.

During the International Data Farming workshop both simulation environments were explored using readily available, organic, Marine Corps availability and maintenance data. Data extraction and model build times were drastically reduced with the use of an interface developed by Captain Shawn Phillips. The ability to link Marine Corps data repositories and life-cycle simulations will give decision makers the ability to produce relevant, timely and cost-effective solutions to system operational effectiveness issues.

PROVIDING RELEVANT SOLUTIONS

In addition to providing analytic rigor to standard system reliability, availability and maintainability assessments, modeling and simulation can provide the program manager insight into a myriad of TLCM process areas.

- <u>System Performance Requirements</u>: What level of future system performance is required in order to meet/exceed the desired capability? What availability is required or attainable in order to meet/exceed the desired capability?
- <u>Depot Maintenance Planning</u>: Which Principal End Items (PEIs) would best benefit from overhaul? Which sub-systems are driving low reliability or availability numbers?
- <u>Product Upgrade</u>: What is the most cost-effective solution to upgrade the capability of a system? Is continued investment in sub-system reliability or availability improvement worth the capital investment, or should extra spares be purchased?
- <u>Product Support Plans</u>: What are the potential tradeoffs when considering different product support plans? How do overarching process improvements affect material availability and mission readiness?

These and many other TLCM questions are potentially addressed using TLCM-AT and EXTENDSIM 7.0, but the process of data manipulation and model building is often time consuming and cumbersome. While accurate results continue to be paramount, timeliness of analysis was the focus at IDFW 18.

BRIDGING THE GAP

The Bridging Operational Logistics Tool (BOLT), designed and implemented by Captain Shawn Phillips, enables the model builder to rapidly extract data from an Excel source file, change the model input parameters and implement design of experiments (DOE) for TLCM simulations. In order to assist in the verification of the two modeling environments the following factors were determined to be of interest and were varied using DOE:

- Maintenance Times
- Operational Tempo (expressed in total miles and average miles/hour driven in a year.)
- Vehicle Population
- Percentage of parts found to be un-repairable upon inspection.
- Shipping Time
- Scale of failure distribution

The levels of these factors were set using data sources and technical manuals. Without the aide of BOLT, these variations to the models could have possibly taken days or weeks to implement. During IDFW 18, team 3 was able to set up the parameters, analyze the input data, agree upon the validity of assumptions, run the simulation, and verify the accuracy of the results, in a single afternoon.

In order to determine the accuracy of the results and the importance of the factors of interest the team used the following methodology:

1. Use a time period in which data is known
2. Determine historical parts usage for the entire period
3. Input the parameters into the simulation for the first half of the period and then predict the parts usage for the second half.
4. Use root mean square error to measure the difference between simulation predictions and actual parts usage.
5. Determine factors of interest using statistical software.

RESULTS AND ANALYSIS

The analysts using TLCM-AT and EXTENDSIM 7.0 both implemented the same methodology and experienced similar results. Mean time between failure, vehicle population and operational tempo proved to be the most significant factors overall. Several interactions between maintenance and shipping times were also noticed, but at a lower level. The analyst's ability to use BOLT and DOE to explore the entire decision space, when parameters are unknown, replaces the need to solely rely on subject matter expertise. The increased knowledge that is derived from using DOE empowers the program manager to focus data collection efforts on the factors of most importance in order to improve a models output and predictive capability.

Operational usage of ground combat systems is an especially difficult metric to capture. In order to more fully explore BOLT and the two modeling platforms, a real-world operational scenario was explored in which a ground commander would have had some prior knowledge of a pending deployment. Using the IDFW developed methodology, the team was able to accurately predict the observed increase in system part usage with a corresponding projected increase in operational tempo and vehicle population. Solely based on simulation results, the operational commander would have only been short 17 total parts over the period of the deployment. This is especially important when planning austere contingency operations where parts and logistics assets are limited.

CONCLUSIONS

IDFW 18 provided a unique venue for a team of Government and industry simulation and data management professionals to combine their expertise in the pursuance of a common goal. With the implementation of BOLT, the TLCM insight that modeling and simulation provides is now more accessible to Program Managers and decision makers. Days and weeks of complex data manipulation and model development have been successfully reduced to several hours of an experienced analysts time.

The two simulation platforms exercised were similar in their results and modeling methodology, but their actual implementation will vary significantly. The Marine Corps plans to use them both as complementary capabilities to provide both rapid and more detailed analysis. The path forward should include a detailed and documented validation of both simulations, by the utilizing agencies, in accordance with the approved DoD instruction.

For detailed explanation of TLCM modeling and simulation efforts in the Marine Corps and actual results from IDFW 18, please contact Major Stephen Mount, stephen.mount@usmc.mil or 703-432-3868.

Team 4: Evaluation of electro-optical sensor systems in network centric operations using ABSEM 0.2

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INTRODUCTION

The German Federal Office of Defense Technology and Procurement (BWB) is interested in analyzing the influence of networked sensors and effectors on military capabilities in network centric operations.

On behalf of the BWB, about one year ago representatives of EADS started developing a new agent-based model that addresses the BWB-specific requirements.

The agent-based sensor effector model (ASBEM) concentrates on modeling complex technical aspects in NCO and to do so, it integrates detailed physical theories when it comes to simulating the output of various sensors and when determining the effect of different weapon systems.

ABSEM has continuously been enhanced since IDFW17 so that ABSEM version 0.2 could be released at IDFW18.

Using a camp protection scenario, the team's objective was to investigate the effect of different electro-optical sensor systems (human view, infrared, residual light amplifier) in combination with the use of direct fire weapons in network centric operations.

Objectives

In Data Farming experiments the team's main intention is to examine the performance of some given sensor and effector systems under varying conditions (e.g. different weather-dependent atmospheric conditions, time of day, varying number of hostile units,…). To evaluate the implemented sensor- and effector systems various MoEs will be recorded, e.g. the time needed for detection / classification / identification as well as the attrition rates for both blue and red forces.

Overall, the team had the following goals:

- Review and face validate ABSEM version 0.2
- Conduct experiments with different designs analyzing the effect of parameters such as different seasons, different weather conditions, distinction between day and night, deployment of different sensor and weapon systems
- Identify needs for further work.

Scenario

The IDFW18 scenario dealt with the threat posed by adversary invaders. The military camp is guarded by several watch towers occupied with soldiers equipped with electro-optical sensors and small arms. An UAV is deployed for airborne reconnaissance. The sentry reports any detected, classified or identified unit to the command centre, which, in turn, decides how to proceed. In addition, the camp is protected by armored motorized ground patrols.

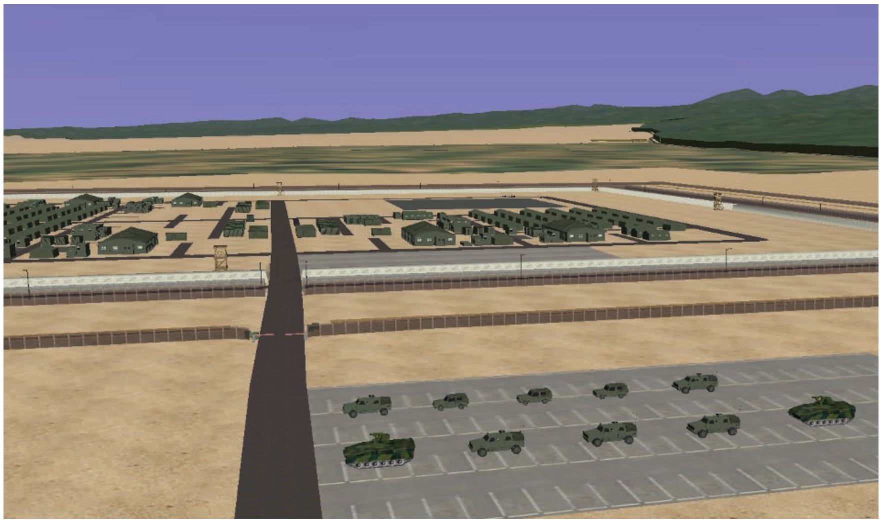

Figure1: Camp protection scenario

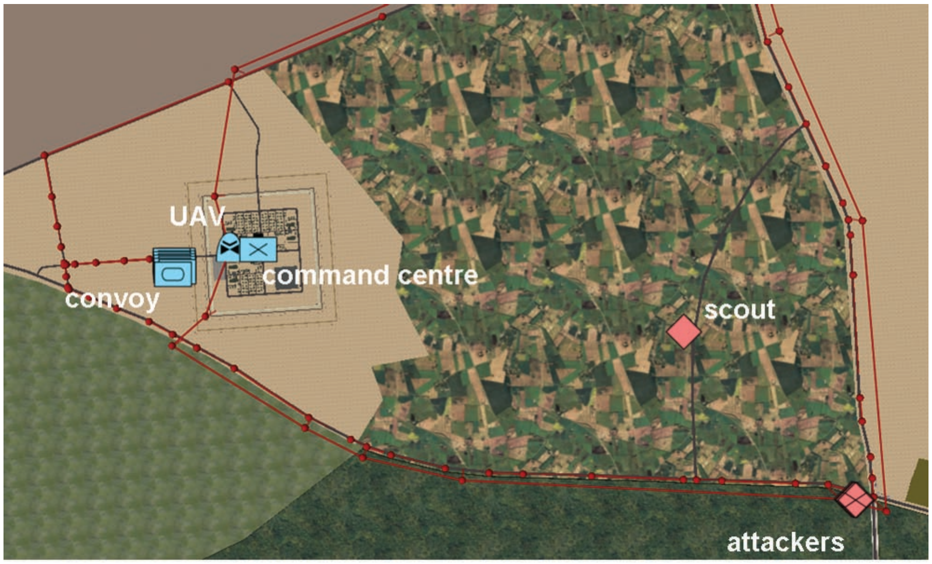

Figure 2: IDFW18 Basecase scenario

In case any opponents were classified or identified by the UAV, a heavily protected and armored convoy will be sent out to patrol the area. If no enemies were detected, only a slightly protected convoy will be sent out.

The attackers, in turn, hide in a forest right next to the convoy's patrol route.

In two different scenario vignettes we distinguish whether the attackers do have a scout reporting in advance when the UAV or convoy approximates the attacker or whether they don't. If it's the case, the attackers may better hide and therefore detection becomes much more difficult.

Depending on the scenario setup (and the user-defined agent behavior), the blue forces will fight the detected red entities as soon as they were classified or wait for an identification.

TEAM ACTIVITIES

What we are interested in, is if the attackers may be detected early enough and defeated so that any blue losses can be avoided.

Though, firstly, we wanted to compare the performance of different available infrared systems regarding the overall mission success and secondly, we were looking at the significance of NCO-aspects. Do the red forces profit from their scout? How does the reconnaissance UAV affect the MoE?

Data Farming Experiments

We were executing a series of data farming experiments, looking at the following parameters:

- deploying the UAV for airborne reconnaissance: yes / no
- UAV speed [30m/s; 60m/s]
- existence of scout: yes / no
- time of the day: noon / midnight
- season: summer / winter
- weather: foggy / clear
- type of sensor system used by attackers: binoculars
- type of sensor system used by blue forces: binoculars / middle wave infrared device 1 and 2 / long wave infrared device

As MoEs we were mainly looking at the damage state of the blue and red forces and the detection / classification / identification times and distances

All of our experiments were successfully executed on the 32node German cluster owned by BWB.

Data Farming Results

In a first analysis we distinguished between day and night and summer and winter times.

There were hardly any differences between summer and winter, but, as expected, at night it is advisable to use infrared devices. The long wave and uncooled infrared device 3 performs best (see figure 3).

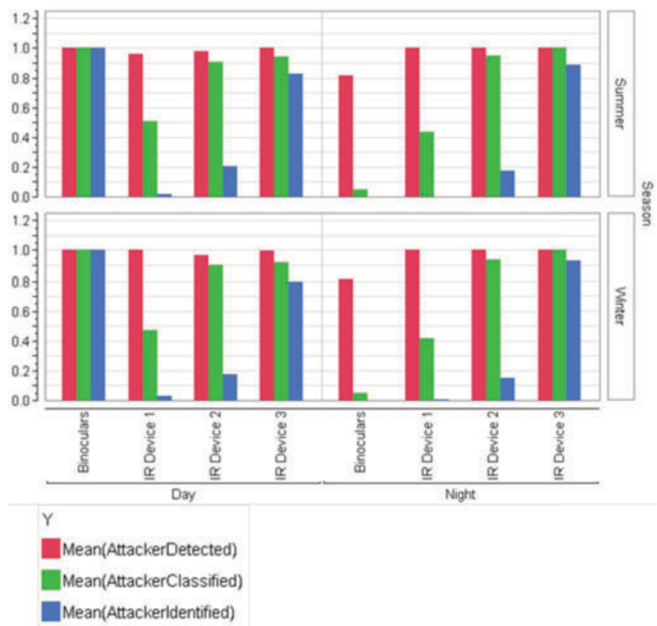

Figure 3: Comparing the detection times of different sensors

In a second analysis, we distinguished between foggy weather and clear sky and the existence of a scout or not. Since the use of infrared devices is not affected by fog, the following figure 4 only shows the detection distances when binoculars are used.

We could observe that the existence of the attackers' scout actually leads to higher blue losses (see figure 5). The reason for that is that due to the existence of the scout, the attackers can better hide within the forest. Therefore it's much harder to detect them. And if the UAV couldn't perceive them, the lightly armored convoy is sent out and of course stronger damaged.

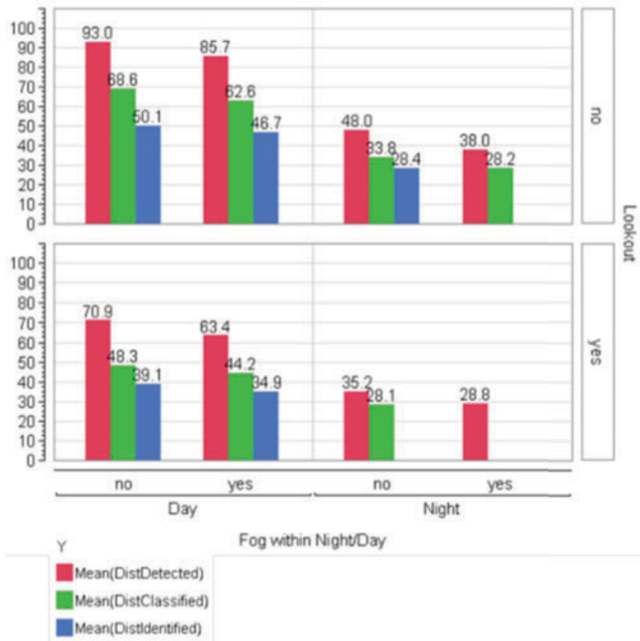

Figure 4: Comparing the binoculars performance for foggy weather and clear sky.

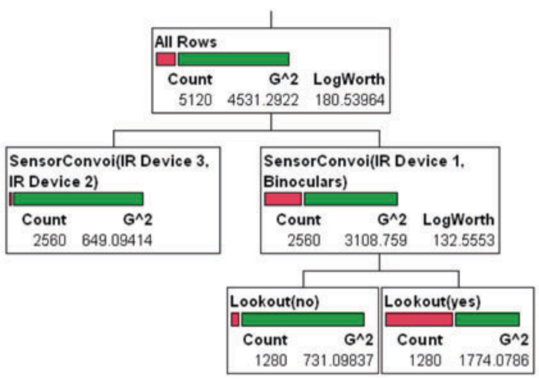

Figure 5: Attackers profit from scout

Finally, we compared the deployed sensor systems with regard to the overall mission success (avoiding any blue losses). Use of infrared devices seems to be rather counterproductive in the daytime. At night, however, again infrared device 3 performs best.

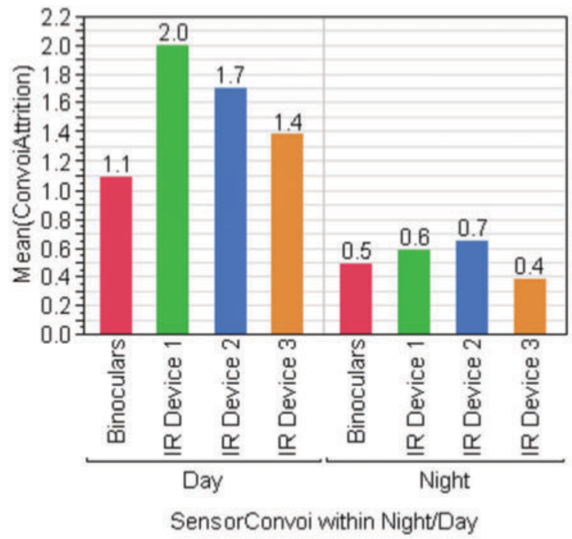

Figure 6: The sensors' performance regarding the overall mission success

SUMMARY AND WAY AHEAD

Overall we are happy, the model itself works very well. We succeeded in setting up an interesting scenario during the week. Analyses of the conducted data farming experiments showed that the results are consistent with our expectations and understanding of the real world scenario.

We succeeded in verifying the modeling approach we chose for physically modeling electro-optical sensors and direct fire weapons. With the implemented optical sensors, the terrain features and atmospheric conditions are adequately considered.

Despite the more advanced features ABSEM version 0.2 contains by now, the model performance is still more than sufficient for ABSEM being used within the data farming process.

In future activities we first of all want to extend and complete the effector modeling taking into account indirect fire. Furthermore we plan to integrate radar systems.

Team 05: PAX3D Refugee Camp Scenario Calibration of the Adapted PAX Model

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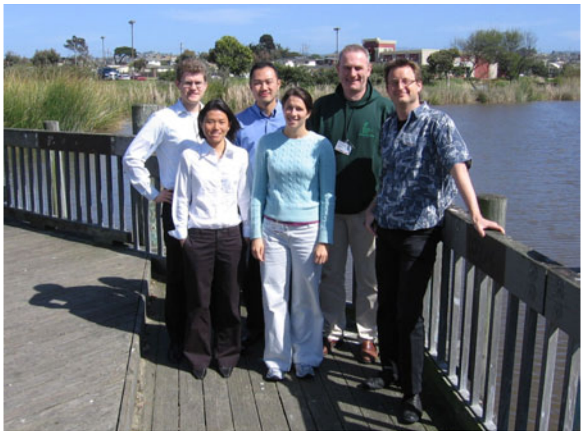

Figure 1: Team Members

INTRODUCTION & MISSION

The Bundeswehr Transformation Center is exploring concepts how M&S can effectively support CD&E projects related to Peace Support Operations (PSO). Human Factors and Human Behavior analyses have shown to be highly relevant in this context. One study specifically examines possibilities to model a PSO with PAX in which military is tasked to assist in building and operating refugee camps, and especially to ensure order and security. PAX is to be used to support decision makers in assessing and evaluating TTP (Tactics, Techniques and Procedures) and ROE (Rules of engagement). Therefore, a high degree of validity in the model and data is required.

Since IDFW17, PAX has changed significantly, including a revised tactical behavior of the soldiers, adjustments to other major model effects and a 3-dimensional simulation and visualization.

The team's primary goal during IDFW18 was to calibrate selected parameters in order to achieve a realistic behavior of the soldier agents with a specific focus on ROE. This calibration follows the methodology developed at IDFW17 and prepares the validation of the new soldier agent model in PAX. Underlying questions for investigation are:

1. Are the ROE effective for the military and the given mission of operating a refugee camp?
2. Can a secure environment for both refugees and camp operators, e.g. military, NGO, be established by applying these ROE?

The team's mission at IDFW18 was as follows:

Calibrate the simulation inputs so that the target ranges of the MOE derived from the underlying ROE are achieved.

SCENARIO

The team examined a situation in the refugee camp where members of one group (B) have already received food packages and are heading back to their tents. Members of another group (A) do not have their rations yet and attempt to steal packages from B.

Figure 2: Examined situation in the refugee camp scenario

Two vignettes ("micro scenarios") were chosen as the basis for calibration, referred to as the low-escalation vignette and the high-escalation vignette. In the low-escalation vignette a civilian CivA1 from Group A verbally threatens civilian CivB in order to obtain his packages. A soldier witnessing the threats tries to stop the packages being stolen and to prevent escalation of the situation while obeying the ROE, the relevant extract of which is shown in Figure 3. In the high-escalation vignette, CivA1 attacks CivB with a knife in order to obtain the food as opposed to a verbal threat.

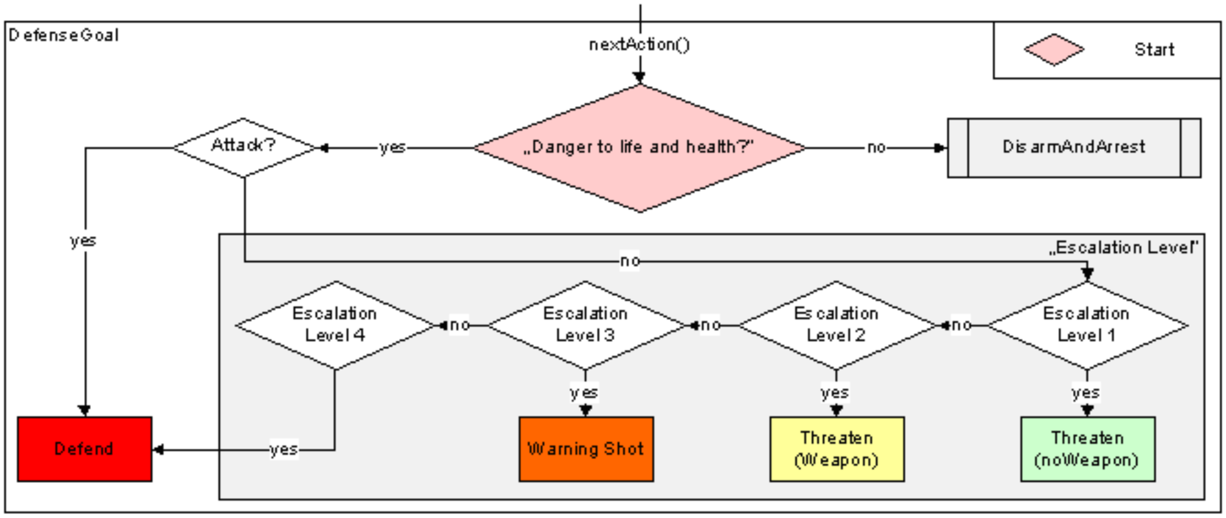

Figure 3: Soldier's ROE when defending another agent

CALIBRATION METHODOLOGY

Usually, we define calibration of a simulation model as an iterative process comprising two main activities: comparing the model to the real system and making adjustments to reduce ascertained discrepancies.

Due to a lack of "real system data", however, the team was relying on subject matter expert (SME) opinion as to what should happen in a particular situation. For this reason, it was desirable to perform the calibration on a very small scale situation.

The calibration of these vignettes was done in several phases[1]:

- **Pre-experimental phase**: Determine and classify input factors, define the desired MOEs and identify related model output factors.
- **Develop understanding end exclude unrealistic settings**: Evaluate the model and scenario doing broad range experiments.
- **Calibration**: Achieve realistic MOEs by adjusting input factors or even the model itself.

STUDIES & ANALYSIS

Pre-Experimental Phase

The most important step of the pre-experimental phase was to define the MOEs. The refugee camp scenario can be declared as calibrated when the MOEs, which were determined by SMEs, are met (see Table 1). For example, Table 1 indicates that the SME expectation was that in the low-escalation vignette the soldier would successfully prevent the packages from being stolen in more than 90% of the cases.

During team discussions, the inputs of interest in the refugee model were found to fall into one of three categories. Internal factors are those which are to be calibrated to fixed values[2]. Advanced factors are psychological and behavior traits, which should be recalibrated by a model expert for each scenario and should not usually be visible to the OR analyst. Model variables are those input factors which will be varied by the OR analyst in the specific scenario. Thus the calibration goal for the model variables is to identify valid variable ranges to be used by the OR analyst. Examples of factors identified in each of the three categories are depicted in Table 2.

MOE	Calibration Goal
Low-escalation vignette	
Soldier's success in preventing stealing	> 90%
Use of weapons by CivA1	0%
Use of weapons by Soldier	0%
High-escalation vignette	
Soldier's success in preventing stealing	≥ 90%
Soldier's success in preventing subsequent attacks	≥ 90%

Table 1: MOEs and respective calibration goals

Develop Understanding and Exclude Unrealistic Settings

The goal of this phase was to develop a better functional understanding of the behavior of the scenario and to narrow down the ranges of all factors to reasonable intervals. For this purpose, several broad range experiments were done on a Data Farming cluster. One of the results, for example, was the finding of an appropriate level of the threshold below which a motive is considered irrelevant in the PAX behavior model (see second parameter in Table 2). This was found through a regression tree analysis of the results of one

1 These phases are intended as a guideline only, with the possibility to add, skip or repeat single phases or steps as necessary.
2 Note that in the case of PAX, this requires a combined effort of model experts, psychologists and SMEs.

experiment and a visual study of unexpected model results via animation and graphs of human emotions over time.

Calibration Phase

The calibration phase encompasses the actual comparison of the experiments to the MOEs defined through subject matter expertise as well as adjustments to reduce ascertained discrepancies.

For this purpose, an NOLH design with 15 factors was created and run for each vignette, based on the experiments in the previous phase and the parameters and ranges finally selected. Table 2 exemplarily depicts a selection of those parameters with their respective value or parameter range.

Model factor	Category	Range in NOLH DoE
Thresh. insignificance of a motive	Internal	*fixed to 20*
Persuasiveness of attacks	Advanced	*fixed to 100*
Thresh. for handing over package	Internal	*fixed to 2*
Persuasiveness of pacifying	Advanced	[20;50]
Persuasiveness of threats	Advanced	[30;60]
Civilians' anger factor	Variable	[0.01;0.3]
Civilians' arousal factor	Variable	[1.0;3.0]

Table 2: Categorization of parameters and their ranges in the NOLH design of calibration experiment Exp 01

Figure 4: Detailed analysis of a single run in PAX3D GUI

The results from the first calibration experiment (Exp 01) are presented in Table 3. Exp 01 indicated a straight success for the high-escalation vignette – MOEs achieved and calibration declared.

Exp 01 for the low-escalation vignette resulted in a surprise: the soldier performed extremely poorly in preventing CivA1 from stealing the packages of CivB. More precisely, he was successful in only 3% of the cases! Analysis of the results indicated that this was due to the factor threshold for handing over package, which was subsequently fixed to a value of 1 for Exp 02. While this re-calibration already resulted in an improvement to 43% (see Table 3), further investigation warranted changes on the implementation side that are needed to handle this particular type of situation.

MOE	Goal	Exp 01	Exp 02
Low-escalation vignette			
Soldier's success in preventing stealing	> 90%	3.01%	43.26%
Use of weapons by *CivA1*	0%	0%	0%
Use of weapons by soldier	0%	0%	0%
High-escalation vignette			
Soldier's success in preventing stealing	≥ 90%	95.29%	-
Soldier's success in preventing subsequent attacks	≥ 90%	97.64%	-

Table 3: Calibration results

The team also studied the animation for several single runs (see Figure 4) and tracked behavior variables as a function of time to verify that the calibration results were not achieved arbitrarily or due to random effects.

SUMMARY AND CONCLUSIONS

The two main outcomes of the week were the further refinement of the calibration methodology defined at IDFW17 and a partly calibration of the new PAX3D model with a focus on the new soldier agent model.

The main objective of the workshop was to calibrate the simulation inputs so that the MOE thresholds derived from the underlying ROE are achieved. This could be achieved for the high escalation vignette. Analyzing the low escalation vignette, the team discovered that the model has to be adapted with respect to underlying parameters. In summary, there was high confidence that the ROE basically were executed properly.

The distinction of the model factors into three categories – internal, advanced and variable – in the preparation phase makes the calibration process more targeted since the different types of parameters need different types of calibration as well: Internal factors are the "deepest" in the model and are to be calibrated to fixed values, ideally never touched again. Advanced factors are also calibrated to fixed values or ranges, but based on the scenario and thus requiring recalibration when the scenario changes. The variable factors finally represent the parameters visible and available to the OR analyst and should be calibrated to a reasonable range depending on the scenario. This categorization is considered an important finding of the workshop and an essential step for future calibration work.

To sum up, the general methodology defined and the calibration performed especially with the new soldier agent model and scenario during IDFW18 lay the foundation for the validation and application of PAX3D.

Finally, the interdisciplinary, international and collaborative atmosphere during IDFW18 again guaranteed great work with valuable results! Special thanks to all team members for bringing in their expertise, work and time during the week – and fun!

Team 6: Data Farming in Netcentric Systems Test Planning

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INTRODUCTION

There is a need to conduct testing in a complex joint mission environment across the acquisition life cycle to improve a program manager's ability to deliver joint capabilities to warfighters. For a joint mission environment with many interdependent systems, assessing individual system and system-of-systems (SoS) contributions to joint mission effectiveness becomes extremely challenging. A change in one system may have cascading effects across the mission environment and, furthermore, many of these systems may be at different points in development and acquisition. This complex adaptive SoS environment makes it nearly impossible to plan efficient tests using current test methods and capabilities. Cogent planning for the tests of these complex adaptive systems involves a very tedious, almost impossible, test planning process for determining what and how exactly to test. To do this efficiently, new test and evaluation (T&E) tools, methods, and processes are needed and data farming has been identified as one tool that may help in this process.

For this workshop, our team continued work in exploring the use of data farming in the netcentric systems test planning process. Our objectives were to:

- Continue to gain a fuller understanding of the challenges in planning Netcentric Systems Tests;
- Continue to explore areas in Netcentric Systems Tests where data farming may be complementary to other techniques and tools;
- Continue to gain an appreciation for the state-of-the-art experimental design techniques and algorithms for exploring a large possibilities landscape; and,
- Test the capability of our prototype JTEAM (Joint Test and Evaluation Agent Model) framework in data farming a Joint Fires Scenario, focusing on the C2 system parameters. The scenario was developed to support the InterTEC (Interoperability Test and Evaluation Capability) Spiral 2 System Integration Test Plan (STIP).

To guide our discussion, as well as illustrate the data farming process, we conducted two notional experiments using a standard Nearly-Orthogonal Latin Hypercube (NOLH) design and a newer Resolution VII Fractional Factorial (R7FF) design. The system-of-systems under consideration in these experiments was based on a Time-Sensitive Target (TST) scenario vignette, which was partially implemented in JTEAM prior to the workshop, and a subset of the larger Joint Fires scenario. The next sections give a brief overview of the scenario, the JTEAM simulation, the experiments, and their resulting analyses. The article concludes with a summary and discussion of our future work.

SCENARIO

The scenario was a simplified variation of the TST vignette that was developed to support the InterTEC (Interoperability Test and Evaluation Capability) Spiral 2 System Integration Test Plan (STIP). On the Red side, the TST is a Red Convoy moving down a road. Protecting the convoy is a Red Air-Air (RedAA) aircraft, equipped with an Air-Air missile, providing defense against Blue's aircraft. On the Blue side,

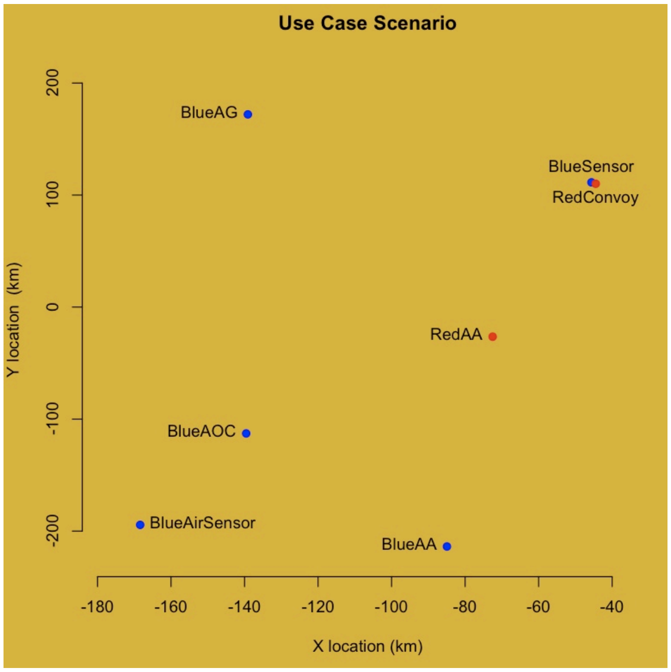


Figure 1: Use Case Scenario

there is a Blue Sensor (ground) that can detect and track the Red Convoy; a Blue Air-Air aircraft (BlueAA), equipped with a Blue Air-Air missile; a Blue Air-Ground (BlueAG) aircraft, equipped with a Blue Air-Ground missile; a Blue AirSensor that can detect the Red Air-Air aircraft; and a Blue AOC (Air Operations Center), which makes decisions on which resource to attack the TST. The scenario laydown is shown in Figure 1.

The scenario proceeds as follows: the Red Convoy begins moving down the road at simulation start; when within range of the Blue Sensor, the Blue Sensor sends a Call For Fire message to the Blue AOC; the Blue AOC decides which resource to send based on target priority, resource availability, weapon matching and fires area deconfliction, and sends a message to the first matching resource to conduct the mission. For this example, the only resource available is the BlueAG aircraft, which then proceeds to the target location indicated in the Call for Fire message. When nearing the TST (based on onboard sensor range), the BlueAG aircraft launches its AG missile and returns to its base.

Happening concurrently is a similar process on the Air-Air side. When the Blue AirSensor detects the RedAA, it determines which resource is available to attack that target (similar to the AG situation, the Blue AA is the only Anti-AA resource), and sends a message to the BlueAA to proceed to the target location. When the BlueAA nears the RedAA, it launches its AA missile. If the RedAA sensor's range is sufficient, it can also detect the Blue AA and launch its Red AA missile. Mission success is based on whether or not the Red Convoy is destroyed.

In the current implementation, the Air and Ground interactions are independent, e.g., the Blue AG can proceed to its target though the Red AA may still be a threat. Future work will focus on integrating these aspects.

JTEAM OVERVIEW

JTEAM (Joint Test and Evaluation Agent Model) is a prototype Agent-based simulation being developed as part of the JMEDF (Joint Mission Effectiveness support using Data Farming) project, supporting the Netcentric Systems Test Program. The goal of JTEAM is to help test designers in developing test designs for joint systems of systems tests by providing an easy-to-use, fast-running tool, and combined with state-of-the-art experimental design techniques, to explore a wide variety of test scenarios.

JTEAM is a discrete-event, three-dimensional, farmable agent-based model built on top of a composable and extensible framework. Farmability of the model enhances computational experiments by allowing users to easily vary input parameters associated with the agents. Composability allows users to build up or construct agents using software components specific to the domain. Extensibility allows users to develop their own software components to extend functionality provided by the basic framework.

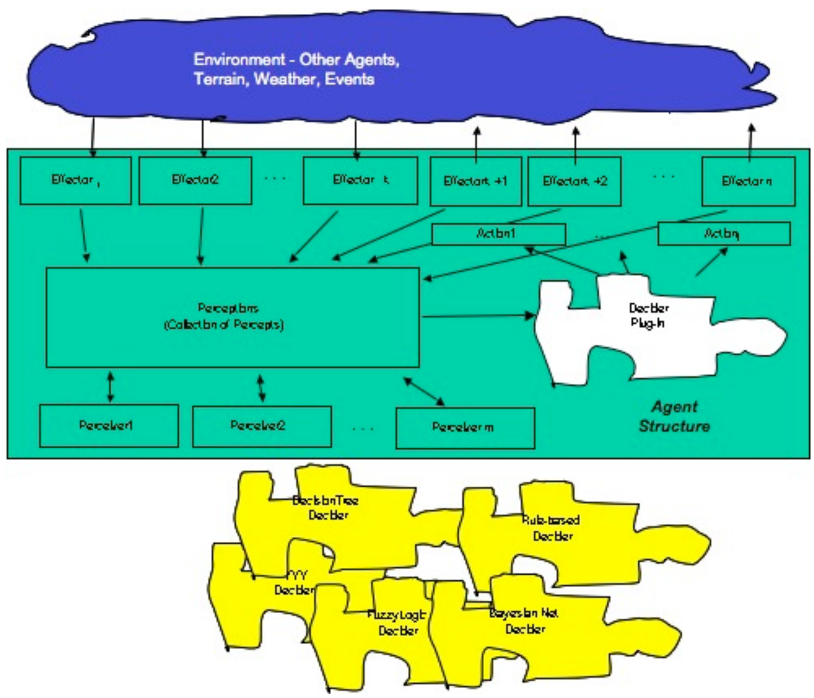


Figure 2: JTEAM Agent Structure

The JTEAM model is composed of a collection of agents and an underlying world model where the agents interact, which currently is a 3-dimensional spatial world with flat terrain. Each Agent has a basic structure that is common to all agents, with functionality added by including specific Decider, Effector and Perceiver components. In addition to these components, Agent's have a name, a side, an observableClass, and a targetClass, all of which can be set to arbitrary values. Finally, Agent's have a PropertyHandler that can handle a set of user-defined properties (through Effectors). The agents, and their components, are specified in an XML-formatted scenario file.

Each Decider, Effector, and Perceiver can have a set of farmable parameters associated with that component. Common structure includes communications, action, effector, damage, and perception handling mechanisms, and common properties such as target and observable class.

As depicted in Figure 2, each agent can have one or more Effectors, one or more Actions, one or more Perceivers, one Decider, and a Perceptions or "knowledge" base, which is a collection of Percepts that characterize the Agent's situational awareness.

Briefly, Effectors provide the Agent a means to observe or influence its external environment, through Actions, such as sensing, movement, or shooting. Effectors also provide Percepts, which are placed in the Perceptions base to be used by other Effectors or Perceivers. The Agent's set of Percepts constitutes what the Agent "knows" about the environment and itself. Perceivers work with Percepts in the Perceptions base, and provide additional, sometimes "higher-level" Percepts, or by filtering and removing Percepts to model such things as memory or operator overload. A Decider then uses those Percepts to "decide" on the set of Actions to take, and tasks the Effectors to carry out those Actions.

JTEAM is written in the Java language and uses the MASON agent-based modeling framework (specifically version 12) for its underlying simulation infrastructure, in addition to a number of other supporting open source packages that provide additional functionality.

Farming Parameters	Min	Max
Blue Sensor call for fire out process time	5 sec	30 sec
Blue Sensor comm link reliability	0.7	1
Blue Sensor sensor range	2 km	10 km
Blue Sensor probability of detection Red Convoy	0.7	1
Blue AOC call for fire in process time	5 sec	30 sec
Blue AOC comm link reliability	0.7	1
Blue AOC decision time	30 sec	2 min
Blue AOC range of the Blue AG resource	10 km	300 km
Blue AirSensor call for OCA out processing time	5 sec	30 sec
Blue AirSensor OCA out processing time	5 sec	30 sec
Blue AirSensor sensor range	200 km	400 km
Blue AirSensor probability of detection for Red AA	0.7	1
Blue AirSensor decision time for the mission	30 sec	2 min
Blue AirSensor range of the Blue AA resource	100 km	300 km
Blue AA OCA in process time	5 sec	30 sec
Blue AA speed	280 m/s	320 m/s
Blue AG JFIRES in process time	5 sec	30 sec
Blue AG speed	250 m/s	280 m/s
Red AA speed	280 m/s	320 m/s
Red Convoy speed	10 m/s	20 m/s
Blue AAM pk	0.8	1
Blue AAM speed	700 m/s	750 m/s
Red AAM pk	0.8	1
Red AAM speed	700 m/s	750 m/s
Blue AGM pk	0.8	1
Blue AGM speed	280 m/s	320 m/s

Table 1: Data Farming Parameters

DISCUSSION AND EXPERIMENTS

The group discussed several areas where data farming could potentially be useful in the Net-centric systems test planning process. The group also became more familiar with the NST planning process in order to understand where the challenges lie. The team used JTEAM with the TST scenario and focused on the associated C2 parameters, particularly time to make a decision as to what asset or platform to assign to the TST based on a priori known capabilities of the Blue agents.

Using a modified version of the initial TST scenario, the team developed a list of 65 potential factors that could be used in a design of experiments (DOE). In order to use the standard NOLH, in addition to one of the newer designs, we down selected from 65 factors to 26 factors. We then picked minimum and maximum values that seemed reasonable given the construct of the scenario. The parameters and their minimum and maximum values are listed in Table 1. We constructed a 26 factor NOLH of 257 design points, and ran JTEAM on the new SEED cluster, reaper, using 30 replications for each design point. We then conducted an initial analysis, demonstrating to the team members the types of analysis and information that can be obtained using primarily regression trees. Our primary MOE was the mean time to kill the convoy.

Following the NOLH runs, we generated a 26 factor, Resolution VII Fractional Factorial (R7FF) design, which resulted in 16384 design points. The R7FF is one of the new designs developed as part of the JMEDF project. We ran this experiment, again using reaper, with 5 replications for each design point.

RESULTS AND ANALYSIS

Our initial analysis using the 26 factor NOLH indicated that the AOC decision time was the most important factor, which was the factor the group "guessed right". Also, the mean time to kill was close to the "actual" 10 minutes, i.e., the time observed during the actual field test. However, while conducting the analysis using data from R7FF runs, we noticed that the initial NOLH results did not include output from the runs where the Red Convoy was not killed; the Red Convoy had survived 66% of the time. When the analysis was conducted by reweighing the effects of the non-kills, the AOC decision time was no longer a factor in any of the statistical models.

The results for the probability of kill for the TST ranged from completely ineffective to nearly perfect with just a few factors and splits of the regression tree, as can be seen in Figure 3. Similar results were obtained for the mean Time To Kill MOE. It appears that further work will be needed in JTEAM post-processing tools to capture the relevant output data more effectively!

FUTURE WORK

One of our objectives for the workshop was to arrive at a way forward for the project. After discussion and seeing what data farming could do, the group decided on several items to accomplish by the end of year review, which is to occur this September. The tasks that lie ahead include:

1. Implementing a sequential design, such as the R7FF, so that it could be used by lay persons.
2. Implement a JTEAM Decider component that would focus on modeling some aspect of the AOC.
3. Expand the scenario to incorporate other agents and complex decision-making for the AOC agent.
4. Include the Decider component as a factor in the upcoming analyses.

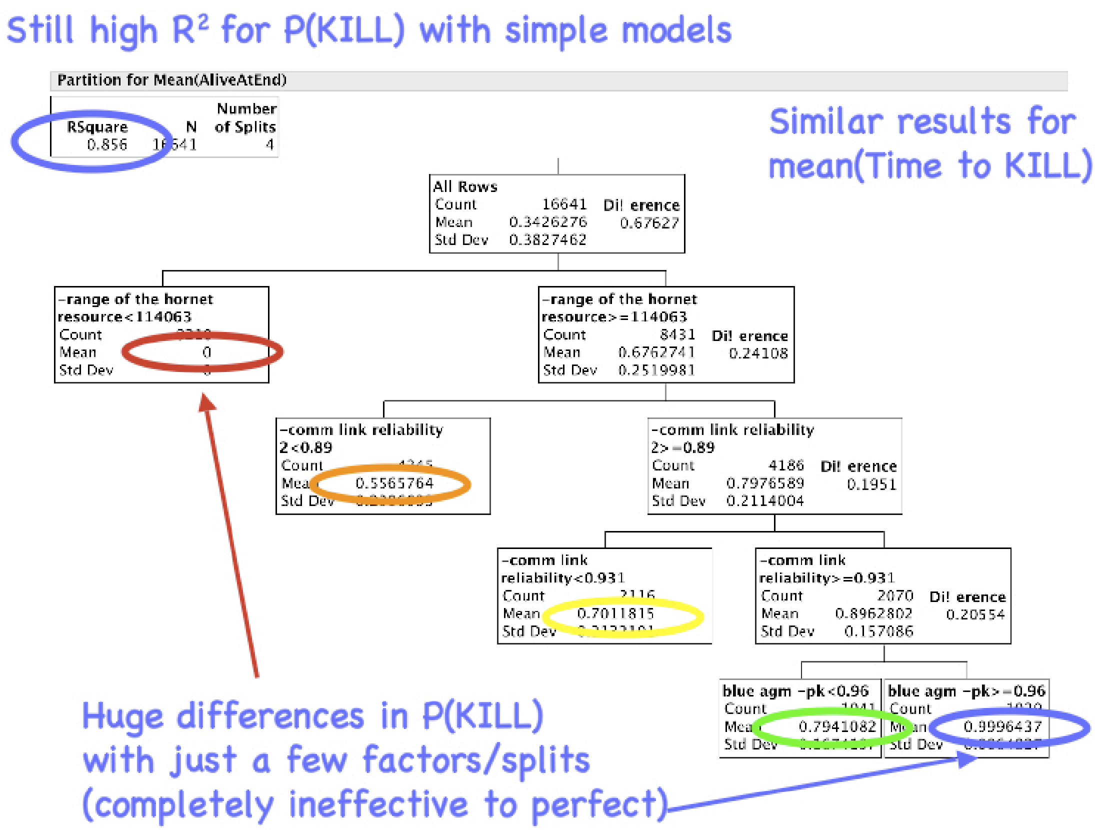
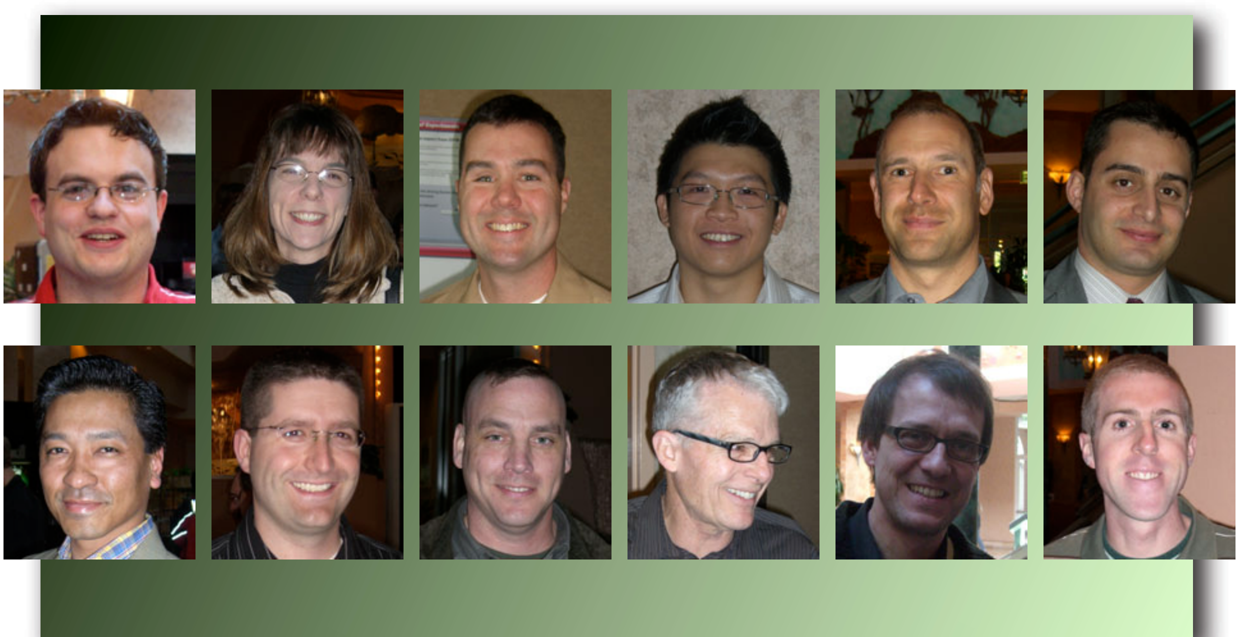


Figure 3- Partition tree for P(Kill)

SUMMARY

To accomplish our workshop objectives, our team conducted two notional data farming experiments in order to gain a better understanding of the potential applications of the data farming process, techniques and tools to the test planning process. We used a TST scenario, implemented in our prototype JTEAM model, and made over 89,000 runs, using both a standard NOLH design and one of the newer R7FF designs. We conducted an analysis of that data, illustrating several standard analysis products. Finally, we discussed the way forward for our project's end of year review.



IDFW 18 Plenary Sessions and Focus Groups

Tuesday

Data Farming for New Members – Gary Horne

Data Farming Tools – Steve Upton and Ted Meyer

MANA – Michael Lauren

Pythagoras – Edd Bitinas, Donna Middleton, Brittlea Sheldon

Wednesday

Design of Experiments and Paul Sanchez – Susan Sanchez, Tom Lucas and Paul Sanchez

Comparing Designs for Simulation Experiments – Rachel Johnson

Demo of Automated Co-evolution Framework – Spencer Low and Ng Ee Chong

NATO Data Farming Exploratory Effort – Gary Horne and Susan Sanchez

Thursday

Update on efforts to model human intangibles – Sim Mong Soon and Spencer Low

Influence of individual differences on vigilance performance – Evania Tan

Modeling Urban Insurgencies Using Systems Dynamics Methods – Anna Gordon

Cost Effectiveness Analysis of Indirect Fire Systems – Esa Lappi

Exploring the use of UAVs and other Assets in Border Protection – Bahri Yildiz

Team 7: Investigating the Use of Simulation Tools for Mass Casualty Disaster Response

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INTRODUCTION

Koti ei ole koti ilman saunaa.

- Finnish Proverb

The focus for Team 7 at IDFW 18 was the investigation of modeling requirements for simulating mass-casualty disaster response scenarios and the investigation of how existing simulation packages could meet these requirements. We began with a brainstorming session of possible events that could result in mass-casualty disaster situations. To provide a framework for our thinking, we developed a basic scenario to consider while discussing what types of features a modeling software package would need to have to build a useful simulation model for this type of scenario. This discussion inherently included consideration of both the discrete-event simulation (DES) and the agent-based simulation (ABS) methodologies. The list of features was used to evaluate several simulation software packages for suitability. Next, details were specified for the scenario and team members attempted to build simulation models using four different packages: Arena, NetLogo, Pythagoras and Sandis. In addition, we interviewed experts in additional packages: MANA, PAX, and Extend. With the results of this investigation and experience, we drew some conclusions about simulation modeling of mass-casualty disaster response scenarios.

MASS-CASUALTY DISASTERS

For the purposes of our investigation, we defined a mass-casualty disaster as some event that resulted in a number of victims that exceeded the number of responders. Our brainstormed list of potential events that could result in a mass-casualty disaster included:

- Tornado
- Earthquake
- Boat sinking
- Train crash
- Auto / bus crash
- Plane crash
- Explosion
- Chemical release / spill
- Biological release
- Fire

Each of these disaster events has different characteristics that will affect the modeling features a simulation package must have to be able to model a scenario of that type. Therefore, we generated a list of dimensions that would cover the primary characteristics of a mass-casualty disaster scenario.

Dimensions of Scenario Characteristics

- Disaster time frame:
  - Time span (minutes, hours, days)
  - After disaster cause has finished, as disaster cause is continuing, or both
- Physical area
  - Dispersion of victims
  - Traversability of terrain
  - Potentially unsafe scene due to
    - chemical contamination
    - biological hazard
    - unstable structure(s)
    - continued threat due to attack or continued cause of disaster
- Size and severity
  - Number of victims
  - Distribution of injury severity level
- Responder characteristics
  - Authority structure(s)
  - Number and skill level of responding individuals
  - Number and type of responding equipment / vehicles
  - Prior plans in place / drills done
- Scope of focus
  - On-site treatment
  - Evacuation
  - Medical facility management
  - Combination of above

Recognizing that we would have difficulty evaluating the software packages for their usefulness in modeling all characteristics on all dimensions, we defined a specific scenario to consider.

Specific Scenario Chosen

We chose to consider a four-car passenger train crash in a small town with a city nearby. The scenario begins immediately after the crash so there is no on-going disaster event. The accident scene is considered safe and the area traversable but some of the victims are trapped and will need to be extricated. There are 200 passenger victims with varying injury levels, either still in the train or within the immediate vicinity.

The responding organization has a clearly defined authority structure with an established response plan so there are no inter-organizational issues to be modeled. There are responders with medical skills as well as unskilled volunteers and an extrication team with necessary equipment. Three ambulances will be available to transport victims to a local hospital and seven ambulances will be able to transport the most severe victims from the local to the city hospital.

The Measure of Effectiveness (MoE) chosen was the change in the distribution of victim injury levels from the initial injury distribution to the injury distribution at the end of the scenario (when all patients were treated and released, had died, or remained at the city hospital). The scope of the focus would be on-site treatment as well as evacuation and medical facility management. On-site activities are the triage of victims, the extrication of trapped victims, the movement of victims from their initial locations to a common location, stabilization of the patients, transportation of victims to the local hospital, and transportation to the city hospital. Over time, the injury levels of the victims become more severe, but when some type of care is given, the injury levels improve. Other necessary parameters for initial injury level distributions, injury degradation functions and improvement jumps, number and arrival times of resources, travel times, etc. were chosen later to facilitate actual model construction.

SIMULATION METHODOLOGY AND SOFTWARE EVALUATION

We chose to evaluate several different software packages for their suitability for modeling this type of scenario. These packages included ones primarily developed for DES modeling and ones primarily developed for ABS modeling. To have a general terminology, we used the term "agent" to refer to entities, resources, or agents wherever possible. The full list of software packages we were able to consider included: Arena, Extend, MANA, NetLogo, PAX, Pythagoras and Sandis.

Required Features

When considering our scenario, we developed a list of features or modeling capabilities necessary for building an effective model. These included:

- tracking of location of agents
- tracking of continuous changes in injury level
- agents having different roles
- agents moving together (e.g. a worker carrying a victim)
- agents able to perform more than one task
- modeling of processes that require specific combinations of agents and take time

In addition, we realized that our basic scenario did not explicitly appear to require certain features, but these features would increase the usefulness of a model of this scenario. These include:

- communications to increase the number of available agents or to redirect agents
- human-in-the-loop capabilities

When evaluating the software packages, it did become clear that our scenario description was biased towards DES methodology. Therefore, Arena and Extend seemed to be a better fit, with Extend being a little better due to the ability to explicitly track and animate agent coordinates. However, for more realistic modeling of the scenario we would likely want to use agent-based features such as behavior changes based on internal states of the agents. In addition, investigation of important response organization coordination issues would require the ability to model agent interactions. With this consideration in mind, the ABS packages became more attractive. To further investigate a few of the most promising packages, we chose to try to build a simulation model for the scenario in each of four different packages: Arena, NetLogo, Pythagoras and Sandis.

Model Construction

Attempting to build a model for the scenario in each different software package simultaneously was informative. We experienced unexpected challenges, found an occasional bug, and sometimes were surprised at how we could use the existing features in a package to model something that the software wasn't designed for. The experiences of each member working on a different model are described below.

Arena

Modeling this scenario in Arena initially seemed to be an easy proposition, since several sequential processes needed to be modeled and this is what Arena was designed for. However, the modeling became more complicated when trying to model the changing injury levels for each victim. Arena seems to have some ability to track continuous variables but it is not readily apparent, so the model was designed to update the injury level information for a victim each time it received treatment. This, however, means that the injury levels are not really continuously tracked and acted upon. In addition, it was determined that an agent performing triage should always move to the next closest victim agent. Since Arena does not provide any mapping capability, the coordinates of each agent had to be recorded as attributes. Each time a worker agent needed to move to another victim, the queue of victims had to be iteratively searched, with each distance recalculated, to find the next closest victim. Further modeling was needed to delay for the correct travel time and update the worker's coordinates. This was a cumbersome way to consider locations in Arena. Overall, Arena handles basic processing well, but is not able to easily accommodate the more complex aspects of the scenario.

NetLogo

NetLogo is a free, agent-based simulation development environment based on Logo, a computer language designed for ease of programming. No one on the team had previous NetLogo experience, but the team was able to build enough of a model to ascertain the capabilities of this language and environment.

Unlike the other tools tested, NetLogo does not provide a graphical programming environment; rather, it is purely coded in a high-level language. Nevertheless, the language has several features well suited to the chosen scenario.

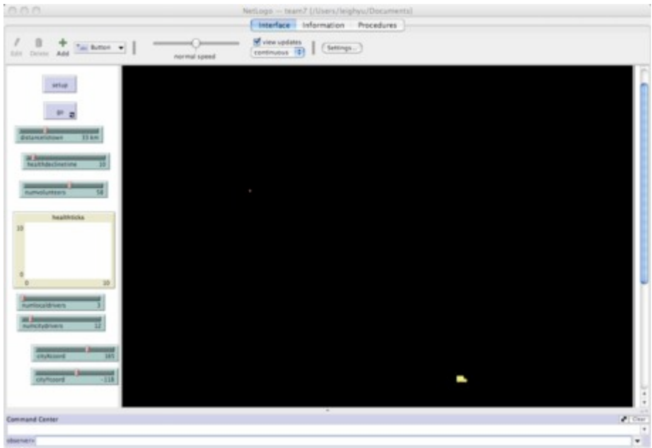

Figure 1. NetLogo train crash simulation in start position. Yellow truck "turtle" represents ambulance starting location. Sliders control simulation parameters.

NetLogo agents are called "turtles" and they can interact through explicit links. The programmer is able to define types of agents ("breeds") - for our scenario the passengers, medical personnel, and vehicles were all different types. Different sets of attributes could be defined for each type of agent, such as the health state for the passengers or the number of passengers assigned to each transport vehicle. NetLogo also has the ability to change agent types (for example, passengers who become volunteers), and to collect summary statistics on subsets of agents ("agentsets") to be used for decision-making (for example, don't send an ambulance to the accident site if there are no passengers needing transport).

NetLogo does not appear to have a good capability for travel via specified paths (i.e., roads); we were able to assume straight line paths in this case, but additional logic would be necessary for turtles to follow a line. NetLogo can import a graphic map and assign color values to map coordinates; this may allow agents to stay within certain boundaries (for example, the transport area).

Pythagoras

Pythagoras has various features that provide an advantage in modeling a disaster scenario. As stated previously, in the initial discussion the scenario set-up was biased towards DES methodology, which would involve a package such as Arena. Therefore, some of the data we chose for the scenario had to be interpreted into a form more suitable for Pythagoras.

Pythagoras agents have the ability to interact amongst each other as well as be affected by the environment. These two capabilities allow for a model to show the scene of a train crash with the communication between volunteers and victims, as well as the challenges of getting through the debris.

The Terrain feature can model the visibility and mobility challenges faced at the site of the crash. The terrain may slow agents down, so that it is more difficult for the volunteers to reach the victims. Communication devices can show the unique interactions amongst agents. Agents may also be set with leadership properties to create an organized response system. Agent attributes may be used to show the level of an agent's injury, with recurring changes each time step. Agent triggers may cause a change in agent behavior due to an altered state. (For example, if an agent's health improves to a certain level, it may be redirected to a different location).

Pythagoras is not set up to model queuing type processes as in Arena. Although it can be used to convey these concepts, it is in most cases better to use Arena if the interest only lies in modeling processing. However, Pythagoras would allow for a more detailed analysis of interactions between agents and the challenges faced in a disaster response environment.

Sandis

Only the medical evacuation model of the Sandis tool was used for this scenario. In general, the input of the Sandis tool is 1) weapon and communication characteristics, 2) units and their weapons, 3) fault logic for units and operation success, 4) geographical map, and 5) user actions for units in company or platoon level.

The output is 1) the operation success probability for each minute time step, 2) the probability of being beaten for each unit, 3) unit strength distributions, 4) average combat losses and the killer-victim scoreboard, 5) ammunition consumption, 6) radio network availability, and 7) medical evacuation logistics and treatment capacity analysis.

In the medical evacuation model of Sandis, the victims are grouped into four categories: minor injury, mid-state injury, major (critical) injury, and dead or hopeless. This classification system is based on triage classes.

Medical units are grouped in either connection type evacuation units or treatment units. Every medical treatment unit has three slots for the classes of combat casualties: 1) waiting for treatment, 2) in treatment, and 3) waiting transport to the next level. The medical unit's parameters are the number of patients it could handle for each level of injury and average treatment time. A queue forms, if the number of wounded exceeds the capacity of the treatment unit or the capacity of the evacuation unit transporting the wounded to the next level of treatment. Evacuation connections have parameters for transporting time and number of wounded the connection can transfer.

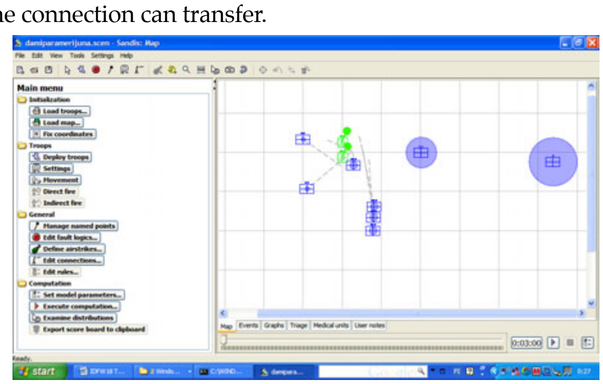

Figure 2. Sandis train crash simulation in start position. Casualties in units with green push pins.

There are state transition parameters for wounds getting worse without treatment during the evacuation and treatment process. Thus the difference in number of dead can be compared with different evacuation alternatives. The distribution of casualties in four triage categories was easily created using the "divine hand" weapon. The medical units were modeled as military squads or platoons with medics and vehicles. Their ability to give treatment was given as a parameter value. The average values of casualty flows and treatment facilities could be modeled.

The trapped victims were modeled as a separate group. The extrication team was modeled as a treatment unit with the average treatment time set to the average time for freeing a victim.

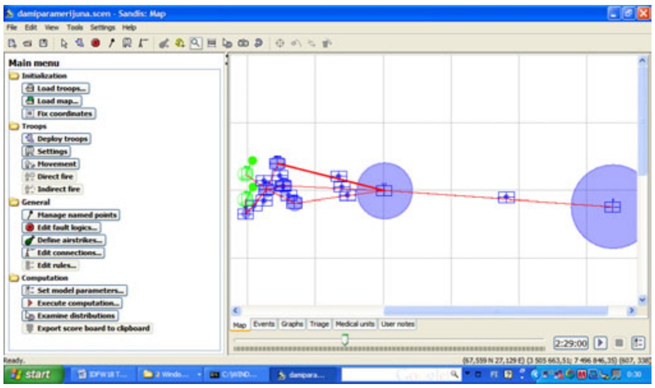

Figure 3. Medical units are at the train and connections from train to triage sorting area and further to medical facilities are operational.

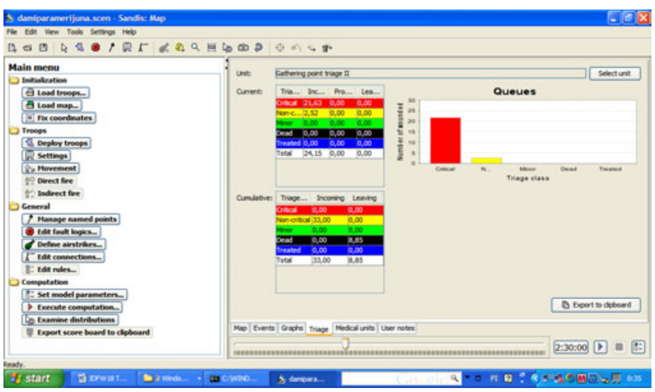

Figure 4. Built-in feature shows a bad queue during the simulated evacuation process

The transportation gave only average values, but was also rather easy to model. The results were shown by graphs and written to a data file.

The modeling difficulties lay in more detailed analysis. For example, the action of individual first aid workers or casualties is practically impossible to model using Sandis. Also all casualties with same triage class had the same statistical parameter data.

CONCLUSIONS AND RECOMMENDATIONS

Overall this team accomplished a great deal in terms of defining requirements for modeling mass-casualty disasters and evaluating a variety of simulation software packages. We discovered that, although different software packages had quite different origins and features, all of them could be manipulated to model the scenario well enough to be useful. On the other hand, it was clear that none of the packages we investigated could model all aspects of the scenario well. Since different packages have different strengths, we developed some recommendations for packages to use when focusing on different aspects of a disaster response scenario. Overall we recommend:

- Arena or Extend for focusing on queueing of agents and resource usage and allocation
- Pythagoras for modeling the interactions of individuals with others and the environment
- Sandis for focusing on evacuation routing and tracking triage levels most accurately
- PAX for modeling group relationships and interaction dynamics

In addition, we realized that ABS and DES methodologies each have strengths and weaknesses but may complement each other well. Since DES more readily models queueing and resource usage and allocation, a DES model of a scenario could be used to determine expected queueing times as victim agents wait for limited resources agents. These waiting time distributions could then be incorporated into an ABS model as additional delays or travel times. On the other hand, an ABS model could be used to see how agents are redirected to move toward a different goal or perform a different functions or call for additional resources over the course of the scenario. This information could then be incorporated into a DES model using timed triggers or probabilities to simulate this emergent behavior.

Since it is already well known that DES and ABS methodologies have different strengths, software packages are now available (e.g., AnyLogic), and others are under development, that are advertised to have both DES and ABS functionality. Since it is clear that effective modeling of disaster-response scenarios could benefit from both types of functionality, a next step in this research direction would be to evaluate these multi-purpose software packages.

Given that no single platform can satisfy all requirements, one additional possibility is the development of a more comprehensive modeling environment that allows easy access to a portfolio of simulation-based platforms, including the ones surveyed in this report (see [Plale et al 2005][1] for an exemplar of this approach). This integrated modeling environment would ideally provide a meta-level interface which would aid users in configuring data sets, models, and solvers within one environment regardless of modeling approach or paradigm.

1 Plale, B., Gannon, G., Huang, Y., Kandaswamy, G., Pallickara, S.L., Slominski, A. 2005. Cooperating services for data-driven computational experimentation. Computing in Science and Engineering (7,5), 34-43.

Team 8: Force Protection With ITSim: Base Protection Against Ballistic Weapons

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INTRODUCTION

ITSim is a newly developed agent-based simulation environment designed to analyze operations within the broader range of tasks of the Federal Armed Forces, the Bundeswehr.

Modern warfare scenarios are dominated by asymmetric threats with complex non-linear interdependencies and interrelations that traditional techniques of analysis are insufficient to capture. For example, it is often hard to determine whether located humans are opponents (Red) or just civilians (neutral). This distinction can often only be made, when suspicious behavior is observed. Especially, when protecting a base, the response time to suspicious behavior is important to prevent attacks.

The investigated scenario analyses exactly that aspect by using 3D terrain provided by the German Armed Forces.

One of our goals is to investigate the influence of the given terrain. The expectation without terrain is that the red units can be detected as soon as they start to prepare their missile attack. If the terrain data base is used we expect areas in which the opponents cannot be detected, e.g. in a valley. Thus, the existence of opponents can only be determined after they have started the attack by detecting the trajectory. The second goal is to analyze the efficiency of different base defending strategies, which will be defined later on.

SCENARIO

Figure 1 depicts a possible excerpt of the investigated scenario. A blue base is located in 3D terrain. Dark regions mark high terrain elevation whereas bright areas denote lower terrain elevation. Thus, the blue base is located on a hill. It is protected by four guard towers. Two additional towers equipped with cameras are used to observe the surrounding area. They are visualized by tactical icons in the upper part of figure 1. During the course of the scenario, some Red will approach the base in order to attack it with ballistic weapons. Depending on the strategy, a blue unit will try to prevent the attack as shown in figure 1.

The key idea is that the opponents cannot be detected as Red until they start to prepare their attack. Thus, the whole approach time cannot be used to prevent the attack. After the configured preparation time, the opponents launch n missiles and flee afterwards.

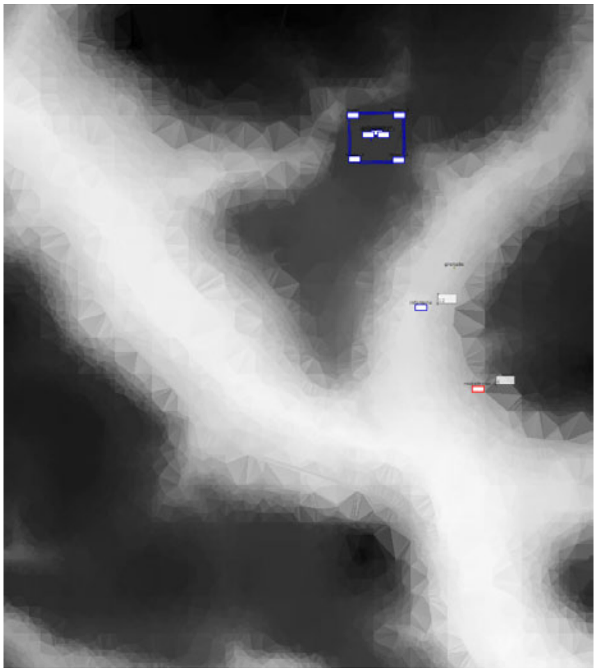

Figure 1: Base in 3D terrain

The scenario's analysis is divided into two phases. The first one is a static classification and the second one is a simulation capturing the dynamics of the strategies.

Static Classification

Before the scenario is simulated dynamically, a static classification is performed. Two important measures are vital for the strategies: ballistic threat and line-of-sight. Areas from which the base can be attacked by ballistic weapons are called ballistically threatening. The muzzle velocity of the weapon defines its maximal distance. The terrain defines if there exists an angle that results in a flight trajectory such that the base is hit. The line-of-sight denotes which areas can be observed by the cameras in the base. These cells are called observable. Note that both measures strongly depend on the given terrain: if there is none, every point inside a maximal sight range is visible and any point between a given minimal and maximal shoot range is ballistically threatening.

In order to perform the classification, the area around the base is gridded. Afterwards, every cell, i.e. grid element, is checked if it is ballistically threatening and observable. Note that the terrain itself is not gridded but based on precise vector data. According to that classification, three cases exist:

- A cell is not ballistically threatening, i.e. the base cannot be attacked from that cell. The Blue don't have to worry about that cell. Therefore, the cell is colored green.

- A cell is ballistically threatening and not observable. Thus, the base can be attacked from that cell and there is no line-of-sight to the base. The attackers cannot be identified while they prepare their attack. This is the worst case for the blue forces and the cell is colored red.
- A cell is ballistically threatening and observable. Thus, the base can be attacked from that cell and there is a line-of-sight to the Blue. The attackers can be detected while they prepare their attack. The cell is colored yellow.

The result of the classification of the base-case scenario is depicted in figure 2. Each grid cell has an edge length of 11 m resulting in 12,315 cells. 38.9% of the cells are green, 26.8% yellow and 34.3% red. Considering the ballistically threatening cells, only, the majority is not observable. This classification is the base for the simulation.

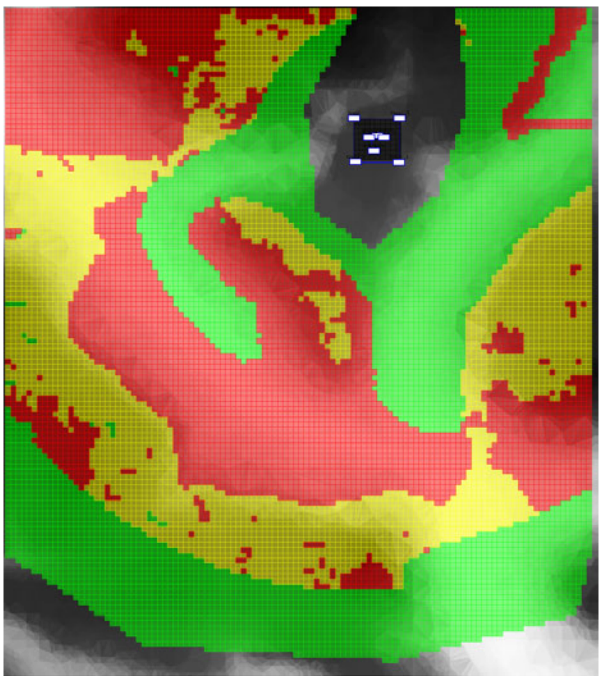

Figure 2: Result of Classification

Simulation of the Strategies

Our second goal is to evaluate different blue strategies against a given red behavior. This kind of analysis may give interesting hints to support the defending of the base. The red strategy is fixed in all experiments. It consists of the following steps:

5. **Generation**: the units are generated uniformly distributed outside the base. Their affiliation is neutral, i.e. they cannot be detected as hostile.
6. **Approach**: a yellow or red cell (i.e. a ballistic attack is possible from that cell) is selected and moved to. The unit is still not detectable as hostile.
7. **Preparation**: two cases exist. If the attacker can detect any blue unit it gets discouraged and flees. Otherwise it starts to prepare its attack. From that point in time, it can be detected as hostile by the Blue. As soon as a blue force is detected by the red unit, it aborts its preparation and starts to flee. Thereby note that the cameras' sight range is much higher than the one for regular ground troops including red attackers and blue defenders. For our experiments, we assume a preparing time of five minutes.
8. **Attack**: the Red starts to fire a previously defined number of projectiles at the base. From this point in time, the attacker is detected as hostile by the blue defenders if it has not already been. Between the shots, the attacker has to reload. Afterwards, it flees.

The two Measures of Effectiveness (MoE) of this scenario are: The primary one is the number of prevented shots at the base. This happens if the attacker is neutralized or discouraged before the attack is started. The secondary MoE is the number of neutralized attackers.

Currently, the Blue have three different strategy options to prevent ballistic bombardment at their base:

- *Pursue from Base (PfB)*: a blue Quick Reaction Force (QRF) is located inside the base and pursues as well as attacks the Red as soon as they have been detected. The attacker can be observed by the cameras or they reveal themselves by shooting projectiles at the base.
- *Camouflaged Emplacements (CE)*: camouflaged spotters are located outside the base. They can detect the Red but not vice versa. As soon as the red units are located, their position is reported to the base and the QRF starts the counterattack at the Red.
- *Show of Forces (SoF)*: patrols move around the base. They can detect the Red and can also be detected by these. If any red force is located, the nearest patrol starts a counter attack. Note that there is no QRF in the base as in the other strategies. If the Red detect any approaching patrol, they flee.

Figure 3 shows the classification of the strategy CE, where two emplacements are located in the valley. The circles denote their maximal sight range. Many cells inside these circles turned yellow since they became observable. The green cells remain unchanged since the ballistic threat depends on the terrain, only. 34.2% of the cells are yellow and 26.9% red. This is an improvement of about eight percent. The majority of the ballistically threatening cells are observable by the Blue.

The initial situation of strategy SoF is as follows: two patrols are located in the valley. The first one patrols between two waypoints northward of the base. The second one patrols southward. The QRF is no longer inside the base, because the patrols can pursue and attack the Red directly.

Note that the camera towers inside the base always support the detection of the Red. As mentioned above, the red units can only be detected after they have started preparing their attack. The QRF has limited time to reach the attackers before they can fire their rockets.

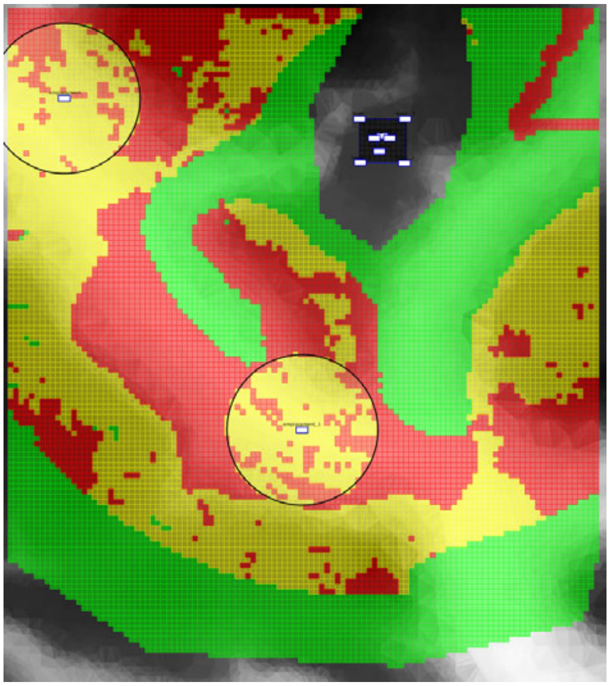

Figure 3: Classification of CE

We expect the following results having strategy PfB as basis for our comparison:

CE: when the emplacements are positioned such that a large area becomes visible that has not been before (e.g. many cells turn from red to yellow), more attacks can be prevented since the *QRF* can act earlier. Thus, we expect more success for the Blue.

SoF: if the patrol points are selected wisely, the patrols can also cover many of the invisible cells and attack the Red earlier. Another advantage is that the distance from the patrol to the red attackers might be shorter than the one from the base to the Red. A third positive effect for Blue is that the Red might have to flee more often since they can detect the patrols by themselves and get discouraged. Thus, we expect this strategy to be the best.

The influence of omitting the terrain (i.e. the whole area being flat) on the three strategies is expected as follows:

PfB: the success rate will rise since the red units can always be detected as soon as they start to prepare their attack. Thus, the *QRF* always has the maximum time for its reaction. Note that this does not necessarily mean that the attack can always be prevented.

CE: this strategy will not improve the MoE of *PfB* since it only enlarges the visible area that is already maximal anyway (the cameras' sight range is larger than the range of the red ballistic weapons). Thus, we expect similar results as for *PfB*.

SoF: the advantage of the enlarged visible area drops since the whole area is visible. But the advantage of discouraging the Red stays. Additionally, the approach distance to the attacking enemies might be shorter since the patrols are outside the base. Thus, we expect this to be the best also if the terrain is omitted.

We present the analysis of our results in the following section.

RESULTS AND ANALYSIS

As already mentioned in the introduction, we want to investigate two main questions during the evaluation of this scenario:

- What is the influence of the terrain?
- How effective are the different strategy options of the blue base defenders?

To answer these questions, we have determined a primary and a secondary MoE. The former one is the percentage of prevented attacks and the latter one is the number of neutralized attackers.

We have performed more than 170,000 simulation runs with different parameter variations. The variation covers the terrain, the velocities of the Red and Blue, as well as the different strategies.

Influence of the Terrain

In order to determine the terrain's influence on our MoE, we have evaluated the strategy PfB with blue velocities b1, b2 and b3 km/h as well as red velocities of r1, r2, r3 km/h, respectively. All nine experiments were performed with and without terrain resulting in 18 experiments.

Table 1 contains the results of the strategy Pursue from Base. We can easily confirm that both MoEs prevented shots and prevented all shots do not depend on the velocity of the Red since the variation caused by the red velocity is less than one percent given the blue speed.

Blue Speed	Red Speed	Prevented Shots	Prevented All Shots	Neutralized Attackers
b1 km/h	r1 km/h	21.02 %	18.14 %	57.79 %
b1 km/h	r2 km/h	20.96 %	18.14 %	40.07 %
b1 km/h	r3 km/h	21.02 %	18.14 %	36.89 %
b2 km/h	r1 km/h	26.17 %	21.06 %	75.37 %
b2 km/h	r2 km/h	26.16 %	21.05 %	53.05 %
b2 km/h	r3 km/h	26.09 %	20.96 %	46.09 %
b3 km/h	r1 km/h	31.10 %	25.32 %	86.21 %
b3 km/h	r2 km/h	31.10 %	25.32 %	65.50 %
b3 km/h	r3 km/h	31.10 %	25.32 %	51.82 %

Table 1: PfB with terrain

This can be explained by considering that a shot can only be prevented if the Quick Reaction Force arrives at the attacking unit while it is preparing its attack or if the Red recognizes a blue unit during its preparing phase. Clearly, the former event only depends on the blue velocity while the latter one does not depend on any velocity. However, the red velocity is important for our secondary MoE, since the number of neutralized attackers significantly rises when the Red get slower or the blue defenders become faster. The reason is simply the fact that more attackers are able to escape when they are faster.

Note the difference between prevented shots and prevented all shots: the former one denotes the number of prevented shots, whereas the latter one denotes if the base attack has been prevented completely throughout one simulation, i.e. if the red attacker has been discouraged or neutralized while it was preparing its attack. Thus, the latter one is a more strict measure. This explains why its percentage is less then prevented shots in all variations and strategies.

Blue Speed	Prevented Shots	Prevented All Shots	Neutralized Attackers
b1 km/h	48.15 %	46.85 %	84.58 %
b2 km/h	64.84 %	61.83 %	93.78 %
b3 km/h	78.76 %	74.67 %	98.29 %

Table 2: PfB without terrain

Table 2 contains the results of strategy PfB without terrain. Since the red attacker can be seen as soon as it starts to prepare its attack, the blues success is significantly superior. Note that this does not result from a better strategy itself but it is just the lack of realism that raises Blue's success. The average gain factor of prevented shots and prevented all shots is about 2.5. The number of neutralized attackers is also higher in all cases than without terrain as can be seen in table 1. We compared the influence of the terrain only with respect to the strategy PfB. This is sufficient since it is clear that the terrain has an influence. We can quantify this influence with respect to our two MoEs.

However, the terrain's influence can also be seen by the static classification discussed above. If there is no terrain, there exists no red cell, i.e. no cell is ballistically threatening and not observable at the same time. The number of green cells decreases from 3,299 to 2,273 since all cells can be attacked within the given minimal and maximal range of the ballistic weapons (defined by its muzzle speed). All remaining 10,042 cells are yellow compared to 4,215 yellow cells if terrain is given. Thus, the static classification also supports the claim that there is a significant influence of the terrain.

Of course, this quantification is limited to this scenario with this strategy. But in the real world there is terrain and we cannot simply omit it in data-farming since this distorts the analysis significantly. The results of the strategy comparison are presented next.

Comparison of the Strategy Options

We run the scenario with all three different strategies. Each run was performed with terrain and the same velocity settings for the units as above: b1, b2 and b3 km/h for blue defenders and r1, r2 and r3 km/h for red attackers. Table 1 from above provides the results for the strategy PfB, which serves as base-case. We compare the other strategies with respect to PfB.

Blue Speed	Prevented Shots	Prevented All Shots	Neutralized Attackers
b1 km/h	23.24 %	19.00 %	54.06 %
b2 km/h	31.19 %	23.75 %	69.04 %
b3 km/h	37.89 %	29.32 %	76.26 %

Table 3: Results of strategy CE

Table 3 shows the results of the second strategy Camouflaged Emplacements. Similarly to PfB, the red velocity is not important for the MoEs prevented shots and prevented all shots. Due to the earlier detection in the areas that are covered by the spotters (see figure 3), the blue QRF can start earlier. Since the number of yellow cells rises from 26.8% to 34.2% because of the additional spotter (see figures 2 and 3), one might expect that the primary MoE also rises by eight percent. This is not true. The MoE rises with respect to the blue velocity. If blue moves with b1 km/h, the MoEs prevented shots and prevented all shots rise by 2 and 0.8 percent, respectively. When the blue speed is b2 km/h the MoEs rise by 5 and 2.5 percent, respectively. The largest gain occurs if the blue speed is b3 km/h: 6 and 4 percent, respectively. The reason therefore is the distance between the base and the additional observable cells (see figure 3). The distance is so large that the QRF cannot prevent all attacks although it starts earlier. The faster the QRF moves, the more attacks can be prevented.

The gain of strategy CE with respect to the MoE neutralized attackers compared to PfB is linear. Roughly 9 percent more attackers are neutralized than with strategy PfB.

Blue Speed	Red Speed	Prevented Shots	Prevented All Shots	Neutralized Attackers
b1 km/h	r1 km/h	67.35 %	64.95 %	68.31 %
b1 km/h	r2 km/h	69.22 %	66.18 %	64.01 %
b1 km/h	r3 km/h	71.63 %	68.74 %	58.55 %
b2 km/h	r1 km/h	73.88 %	70.81 %	67.27 %
b2 km/h	r2 km/h	72.91 %	70.27 %	68.05 %
b2 km/h	r3 km/h	74.84 %	72.19 %	65.28 %
b3 km/h	r1 km/h	82.11 %	78.97 %	62.55 %
b3 km/h	r2 km/h	78.17 %	74.88 %	69.38 %
b3 km/h	r3 km/h	78.35 %	75.04 %	68.47 %

Table 4: Results of strategy SoF

The results of the last investigated strategy Show of Forces can be seen in table 4. First of all, we notice that the red velocity has influence on the MoEs prevented shots and prevented all shots. However, the blue velocity dominates the red one, i.e. the higher the blue velocity is, the superior are the MoEs. The faster the Blue move, the larger is the area they can observe in a certain time frame. Additionally, they can reach an observed red attacker in shorter time. If the blue speed is constant, the red velocity has an influence on the MoEs, but there is no unambiguous trend. The reason therefore is the timing of the parallel movements of the red attackers and the blue patrols. For example, if the velocities are set such that a blue patrol prevents an attack by discouragement, a faster as well as a slower red attacker might not be discouraged or might be detected later or earlier.

Another interesting result is the reason for the high percentages of prevented attacks. The number of attackers that got discouraged before they started the preparing of their attack is much higher in this strategy as can be seen in table 5.

Strategy	Prevention by Discouragement
PfB	1.38 %
CE	1.29 %
SoF	69.20 %

Table 5: Percentage of Prevention by Discouragement

Prevention of Discouragement denotes the percentage of the discouraged red attackers, i.e. the ones that detect a blue immediately before starting their preparation, with respect to all attack preventions. This rate is low and similar for the strategies PfB and CE. But it rises dramatically in strategy SoF. Thus, the main reason for its success is that the Red can detect the blue patrol and flee before they attack. Transferring this result to reality might become difficult since no one can count this number. Thus, in reality this strategy might be underestimated, because the correct MoE cannot be determined in the real world.

Summary of the Results

Figure 5 depicts a summary of the MoE prevented *all shots* with all strategies. Comparing PfB with terrain, CE and PfB without terrain, we can see that the blue velocity is more important if more cells can be observed. The following statements can be derived by our analysis:

- Terrain information has a huge impact on the investigated MoEs. This statement is supported by the static classification as well as the simulation of the strategy PfB. Thereby note that the strategy *PfB* without terrain has a higher MoE than *PfB* with terrain and CE. Only SoF is superior. The main reason is the high rate of discouraged enemies.
- *Camouflaged Emplacements* help to raise the success of the blue defenders in comparison to *PfB* due to an enlargement of the observable area. The Blue have to assure that these additional yellow cells can be reached in time by the *QRF* in order to realize the potential advantage. The impact of emplacements is supported by the classification and simulation.
- *Show of Forces* is the best strategy option. It outperforms all other strategies, even *PfB* without terrain. The main reason is the fact that it is able to discourage the attackers before they start their preparing.

Given these results some common hints for the defenders can be derived. Due to the success of SoF it might be useful to substitute camouflaged emplacements by visible emplacements that can also discourage the enemy. It is important to note that the number of discouraged attackers cannot be determined in reality. Another option is to raise the speed of the QRF, e.g. by using helicopters instead of ground troops.

Limitations of the Strategy Comparison

The performed strategy comparison is just a starting point. Basically, one instance of each strategy has been evaluated.

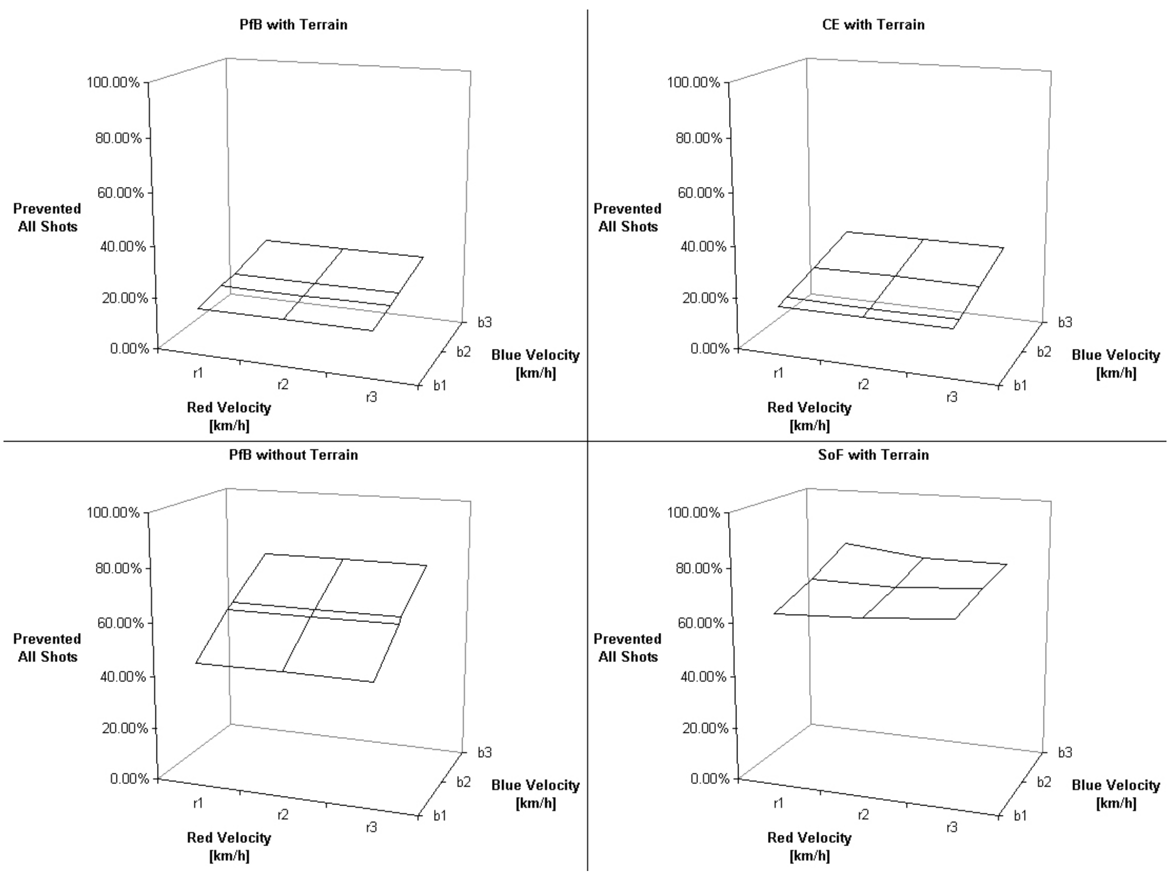

Figure 5: Summary of Results

This is useful if several existing strategies have to be compared with each other.

With the help of the static classification, we would like to answer the following questions in future:

- How many emplacements are needed to cover all cells?
- How can n emplacements be distributed such that most cells are covered?
- What is a good ratio between covered cells and used emplacements?

The first question is academic since there will not be enough resources available in practice. But it gives an upper bound for the resource planning. The answer to the second question requires an optimization of the application of available resources. The third question is very interesting if there is a base protection to be planned. We expect a double bend curve if we map the emplaced units to the covered cells. Then, there would be a point from which any additional emplacement merely raises the number of observed cells.

Analogously, the answer to the following questions could be given using the strategy simulation:

- How many emplacements/ patrols are needed to avoid any attack?
- How can n emplacements/ patrols be placed such that most attacks are avoided?
- What is a good ratio between avoided attacks and used emplacements/ patrols?

These questions are very similar to the ones above. But note that their answering is much more complex since the dynamics (especially the movement of the Red) have to be captured. Additionally, a patrol cannot simply be placed at a certain coordinate but its waypoints related to the arrival times are also important.

In order to answer these questions at least semi-automated, we have to extend our current approach with optimization techniques which are able to derive strategy settings automatically. Such a system could use evolutionary algorithm combined with data-farming similar to Automated Red Teaming (ART) and Automated Co-Evolution (ACE).

Another limitation of the performed analysis is the restricted variation of the parameters. We just changed the velocity of the units and the position of the attackers. Additional parameters can be varied in order to confirm the analysis. These parameters are sight range for the camera towers and standard units, number of attackers and defenders, initial position and waypoints of the blue patrols, range of the weapons of Red and Blue, duration of the attack preparation of the red attackers, reload time of defenders and attackers, number of shots of the Red before their fallback, etc. Considering all these parameters, the number of required experiments grows exponentially.

CONCLUSIONS

The presented analysis is a first approach of incorporating terrain information into our agent-based simulation system ITSim. It enables the analysis of many interesting and promising scenarios that might give some decision-support to leaders of the German Armed Forces. Especially the possibility to evaluate different strategies under real-world constraints is an enormous step into that direction.

As expected, the terrain information complicates the base defending task for the blue forces. But it is vital to consider all parameters that influence the MoE of given scenarios significantly. A realistic model of scenarios is important for the transfer of gained knowledge to the real application.

From an analytic point of view, military operations are highly non-linear processes in which a wide variety of factors can have an impact on what is going to happen. Even small-scale decisions can have serious effects and cause an operation to take very different courses. The key to success is the appropriate modeling of the planned operation. To achieve this, the model must be scaled such as to generate sufficiently general statements that are valid for a wide range of operations. Thus, a satisfactory analysis of the blue strategies is future work since several parameters of each strategy (e.g. number of units, position of units/ waypoints etc.) have not been investigated yet. We only have analyzed one representative of the strategies CE and SoF, respectively, since only one number of units and one patrol way have been investigated. Note that PfB can be considered as sub-strategy of SoF, because there is only one patrol that is placed inside the base. The reason for this insufficient analysis is the required computing power. Over 170,000 simulation runs have been performed after the workshop in order to generate the presented results. During the workshop, we were able to perform several hundred runs per design point, only. We calculated two design points for the strategy CE and omitted SoF completely.

Additionally, other strategy options for the blue forces can be imagined, e.g. a mixture of the strategies CE and SoF. The red strategy can also be changed although we consider it as very plausible and realistic. A change of a unit's behavior is quite simple to manage since ITSim is designed to provide the best possible support to the modeler and therefore has a completely agent-based structure. All the entities of the simulation (terrain, units, technical elements, weather, communication, etc.) are simulated by autonomous agents. This technology provides the possibility to adapt the system to the requirements of the given operation model in spatial (cancellation of the operation area, aggregation of units), temporal (time model) and functional terms (behavior of units, technical and environmental elements). The scaling of the model can be adjusted to the simulation runtime so that uninteresting phases can be simulated in time lapse mode or low resolution. Additionally, all behaviors of the agents are built following a service-oriented approach. Thus, the existing services can be reused when developing new strategies.

Another future work might be the development of a system similar to Automated Red Teaming (in this case Blue Teaming) and Automatic Co-Evolution (ACE) aiming in automatic evaluation and comparison of the different strategies. One core requirement for such a system is the integration of experiment design, cluster control and result analysis. Additionally, the strategies (technically: parameter variations) must be guided heuristically in order to avoid a possibly infinite search.

Team 9: Logistics Battle Command Model

TEAM 9 MEMBERS

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INTRODUCTION

Several joint and service concepts recognize that the future Joint Force may need to be supported from the Sea Base. Furthermore, the future Joint Force envisions routine delivery of supplies and equipment from the Sea Base by unmanned aerial assets. Currently, unmanned aerial systems (UAS) provide an array of aerial sensors and a means of delivering munitions to distant targets with no risk to operators. However, there is very few cargo UAS developed and deployed on operations that are able to distribute commodities. Since they could contribute to improving force protection and enable the reduction of inventory for certain commodities, there is merit in developing the capability further. To address this required capability, the Marine Corps Combat Development Center (MCCDC) is exploring various options for future USMC needs for aerial logistics to support sea based distributed operations, essentially, to identify the system design requirements for future cargo UAS.

IDFW18 OBJECTIVES

This working group overall objective for IDFW18 was to explore the use of the Logistics Battle Command (LBC) model, a new battle command simulation developed by TRAC-Monterey, combined with experimental design techniques to identify significant factors and provide insights for the assessment of various options for future USMC needs for aerial logistics support. Essentially, the intent was to determine the types of operational insights that LBC can provide—specifically, in terms of quantifying the impacts of cargo UAS capabilities on sea based distributed operations.

Particularly, the specific objectives of Team 9 sessions during IDFW18 included:

1. Implement the scenario in LBC.
2. Choose the input parameters and measures of effectiveness (MOE).
3. Develop the experimental design to examine factors of interest to issues of analysis.
4. Execute model production runs.
5. Analyze the simulation output.

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.

LBC model uses nodes and arcs to represent the different networks of the distribution system. LBC model accomplishes this through three layers of network representation are 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.

Due to time constraints of IDFW18 and for simplicity, the vignette for this effort was implemented in LBC taking advantage of some LBC functionalities, essentially implicit representation of the transportation network and planning network.

VIGNETTE

The vignette modeled is one of sea based distributed operations in support of maneuver forces. These operations support persistent sustainment deliveries of class I, III, and V from the Sea Base to forward operating bases. The vignette assumed a 30 day operation with random consumption of the aforementioned classes of supply. The vignette built on LBC was designed to assess the ability to support maneuver forces given two different alternative or platforms to deliver commodities.

The two alternatives of interest are: ground convoys (base case) and cargo UAS (cargo UAS case). The base case represents ground resupply convoys of all commodities required by maneuver forces to increase their stock levels to the desired level of three days of supply (3DOS). Conversely, the cargo UAS case aerial represents aerial resupply missions of a single type of commodity required by the maneuver forces to increase its stock level to the desired level of 3DOS.

MEASURES OF EFFECTIVENESS

The second objective addressed was the development of MOEs. The three primary MOEs of interest developed are velocity, capacity, and rate. Velocity is expressed as the mean time to resupply maneuver units which includes requisition time and receiving resupply for each option of delivery platform. Capacity describes the limits of capabilities that can be supported from the Sea Base and is driven by the functional limitations of each option of delivery platform. Rate represents the rate of the resupply mission that flow from Sea Base for each option of delivery platform. These MOEs were derived directly from the concept specific attributes listed in the Joint Logistics (Distribution) Joint Integrating Capabilities (JIC) (2006) and Seabasing JIC (2005).

low level		1	5	150	0
high level		12	12	4000	1
decimals		0	3	0	3
factor name	DP	Platforms Available	Platform Endurance (hrs)	Platform Payload (lbs)	P(Successful Resupply)
	1	4	12	3278	0.375
	2	2	6.75	3519	0.563
	3	2	8.063	391	0.25
	4	3	9.375	1353	1
	5	9	11.563	1834	0.125
	6	12	7.188	1594	0.813
	7	8	6.313	4000	0.313
	8	7	11.125	3038	0.938
	9	7	8.5	2075	0.5
	10	9	5	872	0.625
	11	11	10.25	631	0.438
	12	11	8.938	3759	0.75
	13	10	7.625	2797	0
	14	4	5.438	2316	0.875
	15	1	9.813	2556	0.188
	16	5	10.688	150	0.688
	17	6	5.875	1113	0.063

Table 1: NOLH Design

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 five factors. The factors considered are platforms available for resupply missions, platforms endurance, platform payload, and probability of successful delivery of goods. For simplicity, the factors were considered continuous and integer.

RESULTS

Examination of the data sets revealed that the simulation did not provide meaningful insights to address the issue of analysis. One clear observation is that it would be required to utilize the three networks of LBC (i.e. transportation network, communications network, and planning network) in order to refine the vignette, which in turn would provide a better level of abstraction of distributed operations in accordance with the two JICs aforementioned. In addition, is recommended to explore additional factors for the assessment of cargo UAS and their impact on operational logistic support.

CONCLUSIONS

The work accomplished throughout IDFW18 was valuable. Team 9 participants developed a scenario, MOEs, and DOE to measure the impact of cargo UAS using LBC to support of MCCDC research. Further, throughout the working week substantial revisions and expansions of LBC were accomplished to improve the functionality and usability of the model as a data farming and analysis tool for the operational vignette of interest.

Team 10: Peace Support Operations Model

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INTRODUCTION

As the focus of the United States military shifts from conventional warfare toward irregular warfare, interest has grown in the development of models that can simulate social behavior as it pertains to military operations. The contemporary operating environment, as reflected in Iraq and Afghanistan, shows the critical role the population portrays in modern combat. Populations, whether broken into smaller social groups, granulated into individuals, or studied as an aggregate of social groups, are often the determinate of success in modern combat. Therefore, the military's interest in modeling social cognition has grown out of necessity. The military uses models for course of action analysis, training and rehearsal, and evaluation for acquisition. If these models are not indicative of contemporary operations, they are not only lacking in utility, but are potentially harmful.

One new model which combines conventional warfare with the modern focus on the population is the Peace Support Operations Model (PSOM). PSOM is a simulation-based war game which portrays the populace and displays the effects military and political actions have on the populations. During preliminary use, PSOM has shown potential as an analytic and training tool; however, to date the model has not been taken through any sort of VV&A process. This can prove detrimental due to the tremendous risk inherited from using a model that has not been thoroughly evaluated. Our working group quantifiably analyzed PSOM using data farming to measure the limitations and constraints of the model.

Methodology

- Our goal for IDFW 18 was to use quantitative analysis to explore the capabilities of PSOM. Because the parameter space in a campaign level model such as PSOM is quite large, the basis of our work was to leverage high performance computing and efficient design of experiments to run the model many times. This process allows for the exploration of a very large parameter space in a limited amount of time. Efficient design of experiments and statistical analysis permit us to determine which parameters and interactions are significant in PSOM.

The scenario used to test the model is the ongoing war in Iraq as of 2004 (figure 3). This scenario was developed by DSTL in 2008. For the workshop we focused primarily on those regions of Iraq which are inhabited by the Sunni Population. This limits the focus to about 30% of the population, 37 coalition combat maneuver battalions, and the faction of the Sunni Nationalists. The designs of experiments focus on the underlying assumptions about the Iraqi population, the capabilities and attributes of coalition and insurgent forces, the operational courses of action taken by coalition forces, and the systematic settings of PSOM. The responses analyzed are primarily the changes in security in the nation and the population's consent towards its own government and coalition forces (when needed, other outputs are taken into account). The resulting statistical analysis is then used to gain insight into the vast space of possible PSOM inputs and their resulting outputs.

Factor	Level 1	Level 2	Level 3	Level 4	Description
Coalition Stance	Combat Units Attacking Sunni Nationalists–Sub Stance Clear	CBT Units Securing Sub Stance Patrol	CBT Units Providing Humanitarian Aid – Sub Stance Build Infrastructure	CBT Units Withdrawn	37 Coalition maneuver BN's in Sunni inhabited regions take this stance.
Sunni Nationalist Stance	Attacking U.S. Sub Stance Ambush	Attacking Iraqi Government Sub Stance Destroy Infrastructure	Withdrawn		75 Sunni Nationalist Units (AQI and Militia) in Sunni inhabited regions take this stance.
IGO Stance	Withdrawn	Provide Humanitarian Aid			47 IGO's throughout Iraq take this stance
Coalition Shares Intelligence with Sunni Nationalist	Yes	No			Determines if the coalition and Sunni Nationalist share information

Table 1. Categorical Factors Explored

Factors explored

During the International Data Farming Workshop we chose a set of parameters from the scenario file of PSOM. These factors represent many of the assumptions specific to the scenario being simulated. For this experiment these factors are applied to either the coalition forces, Sunni nationalists, or the Sunni population of Iraq. Table 1 displays the categorical variables manipulated in the DOE. Table 1. Categorical Factors Explored

Table 2 is an explanation of the continuous variables used in the experiment.

Factor	Experimental Range	Description (Jon Parkman, 2008)
Coalition ROE Level	1-5	1 (Loose) and 5 (Tight) representing the degree to which the unit is willing to cause civilian casualties in order to complete its task.
Coalition Force Protection Level	1-5	An integer between 1 (Low) and 5 (High) representing the degree to which the Unit is willing to suffer its own casualties in order to complete its tasks
Sunni ROE Level	1-5	See above
Sunni Force Protection Level	1-5	See above
Sunni Political ideology	0-100	This is a value between 0 and 100, which give the Faction's Ideology based on its views on Personal freedom, through the Nolan chart system, as shown below
Sunni Marginal Gains	0-1	These values, one for each Good Type, control the level of importance that the Group places on the provision of that Good Type
Sunni Marginal Gains Security	0-1	This value controls the level of importance that the ethnic group places on Security
Sunni Initial Consent Coalition	2-8	These values set the initial levels of Consent towards each Faction that are possessed by the generated Agents at the start of play
Sunni Initial Threat toward coalition	2-8	This value sets the initial level of threat that a population agent feels toward each faction
Coalition Casualty tolerance	0-100	Casualty Tolerance value, which controls how many casualties the unit will bear each turn before the Deterrence function begins to have an effect.
Coalition Leadership	0-100	The level of competence in the leadership of the Unit
Coalition Experience	0-100	The level to which the Unit is trained and experienced in conducting operations in a PSO type situation
Coalition Reputation	0-100	The degree to which the Population perceives that the Unit is unwilling to conduct offensive operations against them

Table 2. Continuous factors explored.

Description of Scenario

The scenario is Iraq 2004+ created by the developers of PSOM. Figure 3 is a general Description of the population and anti-Iraqi force lay-out used in the scenario.

Design of Experiment and Metrics

We used a full factorial design for the categorical variables crossed with an NOLH for the continuous variables resulting in a DOE with 3120 design points covering a multitude of possible combinations of the factors. We then ran each excursion 5 times in order to account for the very limited stochastic influence within PSOM.

The resulting design points were then analyzed using quadratic least squares regression models with two way interactions where the response variables are either the mean Sunni Population's consent toward the coalition or the mean Security across Iraq.

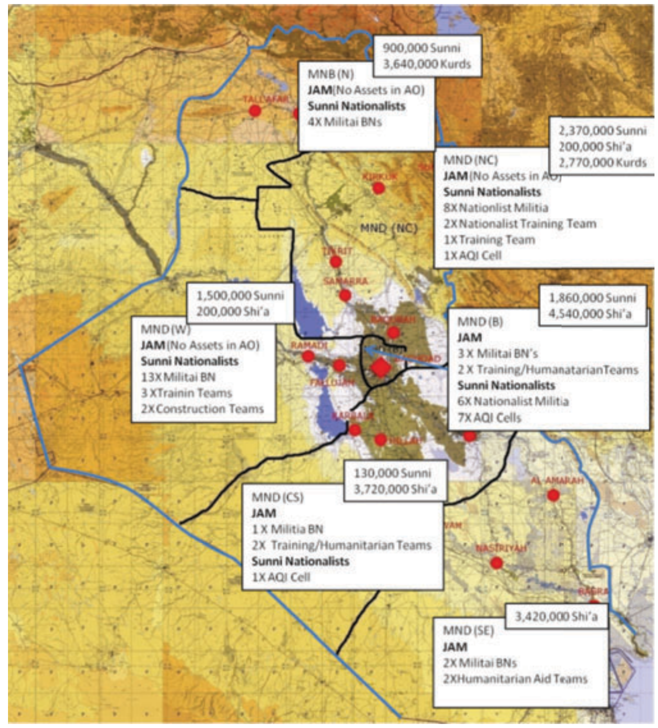


Figure 1. Iraq Scenario

Results and Analysis

Our resulting meta models proved accurate enough for further analysis. (Figure 2)

Summary of Fit

RSquare	0.938032
RSquare Adj	0.937792
Root Mean Square Error	0.588595
Mean of Response	-4.03833
Observations (or Sum Wgts)	3120

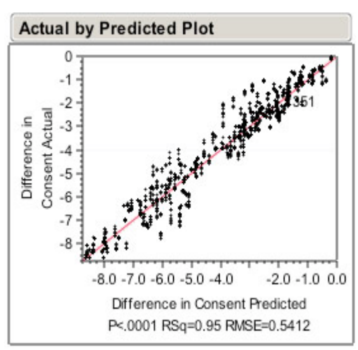


Figure 2. Consent toward coalition meta-model.

Looking at the scaled effects we found that the initial value for consent and the parameter Sunni Marginal gains for Security are the most significant factors examined in determining consent. The contour plot (Figure 3) shows the significance of these factors with respect to consent.

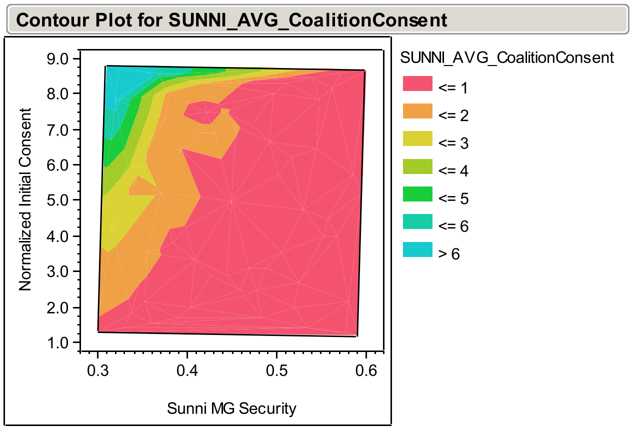


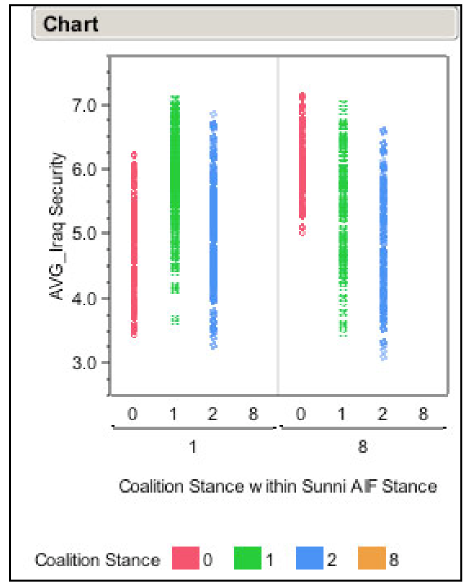
Figure 3. Contour plot of Sunni consent toward coalition with respect to Marginal Gain Security and Initial Consent.

We also found that coalition stance is a significant factor in respect to Sunni Consent for the coalition.

Looking at the response of security we had similar success with our meta model. With an R squared of .76 we found the Rules of Engagement setting for factions to be particularly significant toward security. We also found that the factions' stances and the interactions of the stance of competing factions is particularly significant in the model as can be seen in figure 4.

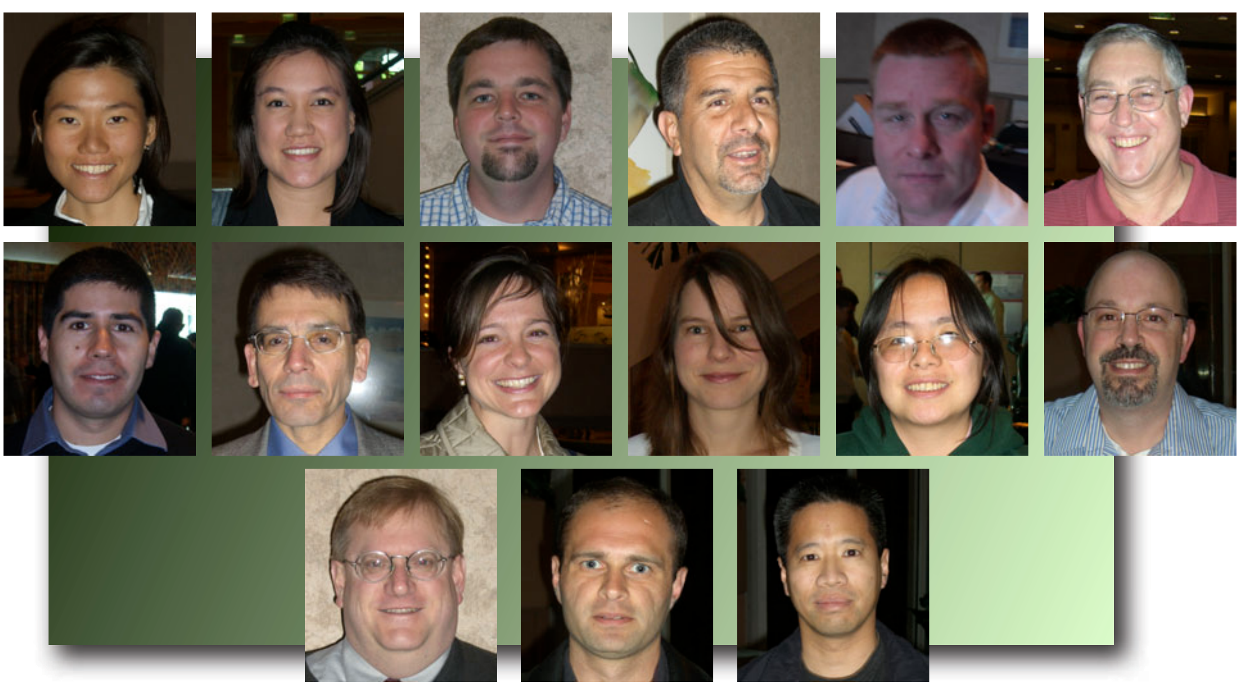
Conclusions

The team's main objective was to jointly agree on a set of parameters within PSOM which should be interesting and then use data farming to determine which of these factors truly are influential to both the consent metric and the security metric within PSOM. Our hasty analyses conducted during the last day of the workshop proved positive toward PSOM potential uses. Clearly the underlying assumptions about the population have tremendous implications on the model. Also, we gained tremendous insight about the effects player decisions have toward both security and consent. We clearly met our main objectives and in doing so have displayed the power of data farming in regards to the VV&A process for contemporary combat models.



Stance
0 - Provide Humanitarina Aid
1 - Attack
2 - Provide Security
8 - Withdrawn

Figure 4. Line chart showing effects of stance with respect to security.



Team 11: Frigate Defense Effectiveness in Small Craft Green Water Engagements

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INTRODUCTION

Both traditional and asymmetric threats continue to pose challenges to any combatant commander in a Stability, Security, Transition, and Reconstruction (SSTR) Operation. Limited threats that were once confined to littoral and brown waters now extend to the green water theater. Many NATO countries operate frigates in green water SSTR missions, typically as a single unit scouting vast areas. In the calm waters of the Mediterranean and Gulf of Aden, small, agile, fast and usually cheap small craft are often encountered.

In this study we investigate the question of whether a swarm of 4 - 8 small vessels, armed with hand-held weapons, can attack and achieve a mission kill on a typical NATO FFH operating in a SSTR mission. In this context our primary goals for IDFW18 were to examine the factors driving the model and create a suitable experimental design. Our secondary goals were to create inputs based on the selected design, conduct runs on the SEED Center's cluster computer, and analyze the output of the model for any interesting results.

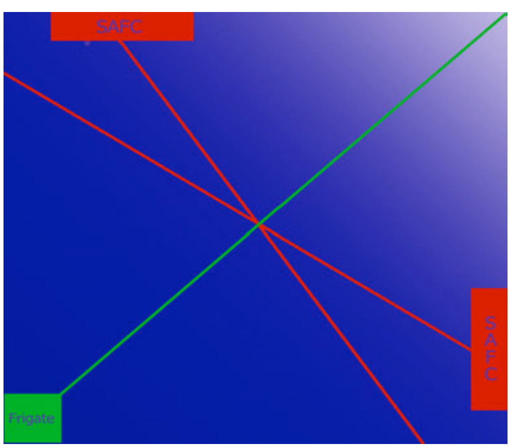

Figure 1: Frigate and Attacker (SAFC) placement map

Modeling

The scenario consists of a single frigate, sometimes accompanied by a helicopter, operating in open waters (Fig. 1). The frigate is attacked by four or eight small agile and fast craft (SAFC) of varying types and armament. The measure of the defenders effectiveness is whether or not the frigate survives this engagement. The frigate will be considered to have 'lost' the scenario when it is hit as many times as it has allocated hit points. This approach allows us to model the frigate as a single entity, rather than modeling all compartments, personnel and machinery.

Factors

Many factors affect the outcome of an encounter. Some of these factors, such as frigate armament and Tactics, Techniques, and Procedures (TTPs), are controllable by NATO forces. Other factors, such as the number of SAFCs or their weaponry, cannot be controlled by NATO forces. Because of this, we chose to analyze the model using robust design techniques. Factors are classified as controllable or uncontrollable. The latter are referred to as "noise factors." The noise factors are varied to see how much impact they have, but are not used as independent variables in the analysis. Instead, we calculate a measure of "loss" for each design point in the controllable factor space. The loss function is based on both the expected performance and the variance at each point, calculated over the noise factors.

For the controllable factors, a 22 factor NOLH design was chosen. The total number of factors for the frigate was 47, so several groups of related factors were "lockstepped," i.e., all elements within a group were varied in identical fashion based on a common scale factor. Consider the main gun of a frigate as an example. The lower the inter-firing time, the more ammo it will carry. Probably it will also be designed with a wide firing arc since it represents a modern weapon system. All three of these factors were therefore varied in unison.

Since the objective is to induce variability with the noise factors rather than directly estimate their impact, a much sparser design can be used. We chose a Hadamard matrix of size 20 to vary noise factors between their minimum and maximum values. The NOLH and Hadamard designs were then crossed to create a study file with 2480 design points.

Item	Minimum	Maximum
Max speed	14 kt	35 kt
Main Guns	1 x 76mm	1 x 127mm, AP-Round
Auxiliary Guns	None	2 x 30mm, targeting computer
Small Guns	2 x 7,62 MG	2 x 12.7 mm, computer stabilized
CIWS	None	30 mm full auto gun / missiles
Heli Max Speed	120 kt	190 kt
Helicopters	None	1
#AGM-114N (if Helicopter)	2	8

Table1: Main blue design factors

Tactics

All weapons exchanges were modeled using a step function for hit probabilities. Each weapon was assigned a minimum and a maximum effective range. This has three reasons. First, the level of abstraction chosen dictates some abstraction on the hit probabilities. The second reason is to prevent the model from wasting ammunition on extremely low hit probabilities, due to MANA constraints. The third reason is that it is actually not possible to calculate even a remotely true P(hit) based on factors such as wind, target speed, size and facing. Instead, these are subsumed within the randomness, and should average out over the effective range of the step function.

Actual Rules of Engagement do not allow for the frigate to shoot at an approaching SAFC until the hostile intent of each individual SAFC is determined, either by firing upon the frigate or closing to within a reaction range despite warnings. Variations in the reaction range and reaction type will represent the use of non-lethal weapons as well as ROE reaction distances. The frigate must assume that all approaching vessels are in fact neutral. One of our research questions is to see if reaction distances to these threats actually make a difference.

As mentioned before, the Frigate, SAFC, and Helicopter robustness and skills were modeled using hit points. For the SAFC the variation in hit points reflects not only their inherent survivability, but also their agility and sea-state influences.

DATA ANALYSIS

Two replications over the design space were performed. The loss function was calculated by collapsing each replication over the noise factors and calculating the mean and standard deviation of the frigates killed. We used a squared-error loss function, which is constructed by summing squared deviations from the ideal outcome (zero frigates killed) with variance. Low loss values are achieved by consistently having a low expected number of successful attacks against the frigate. Loss will increase if more attacks are successful or if the observed results are inconsistent, i.e., highly variable.

Sorted Parameter Estimates

Term
HeliNum
FrigateHP
AGhitP
(AGhitP-4850.02)*(HeliNum-0.62791)
MGHitP
(FrigateHP-22.5039)*(HeliNum-0.62791)
ROERefuelRange
(HeliNum-0.62791)*(ROERefuelRange-17.5078)

Figure 3: Sorted parameter Estimates

The first analysis was done using partition trees. Most important splits were on HellfireAmmo>2, AuxGun HitProbability, Frigate Hit points and ROE Engagement Distance>900yards.

The second analysis was done using a multiple regression analysis. All main effects, two-way interactions, and quadratic effects were considered for the controllable factors. Most of the terms were not statistically significant, and our final model yielded an R2 of 0.86 with five main effects and three interaction terms (Fig. 3).

CONCLUSIONS

The results using partition trees and regression analysis both indicate a set of capabilities needed for successfully defending against small swarms. Both show that in this setup, the Hellfire equipped Helicopter is paramount. This was expected and validating, as other studies had shown comparable results. It is also noteworthy that the Helicopter is a cofactor in all interaction terms in the regression analysis. Both of the frigate's organic damage sustainment capabilities are also important. Whether these are in the form of specially designed compartments, armor or damage control, the survivability of the frigate is an important factor. Of equal importance are auxiliary guns with a high probability to hit. Hit probability for this type of weapons is achieved by good weapon characteristics and either a lot of training, or a computer controlled weapon mount. These mounts are common sights on new vessels, and should be refitted on older ones. An ROE engagement distance of 900 yards or more is important, as the main weapon of the attackers, the RPG-7, has an absolute maximum range of 940 yards. Nonetheless it is interesting to note that after the small craft passed the 900 yard threshold, it does not matter if the frigate begins to defend at 800 or at 200 yards distance. This is reassuring both for the use of non-lethal weapons, and for typical ROEs.

An interesting observation is that there are no important quadratic terms in the regression model. The observed outcomes are well predicted using only linear terms and their interactions.

Both the main gun and the CIW Systems had no significant role in this model. This may be explained by the fact that both have, in these scenarios, a relatively long minimum attack distance, and both have a relatively high inter-target time. As MANA does not allow us to model inter-target time explicitly, it is included in the inter-firing times. This results in quite a slow rate of fire for both weapon systems.

The small guns modeled were also not significant. We infer that the other defense systems were too dominant for these guns to show up as a contributing factor.

Some of the lockstepped factors showed up as significant. Future research should therefore use a new design of experiments so that the lockstepped factors will not be confounded. Influential factors such as hit points should be investigated further, to determine whether the results are based on design, armor or crew capability. Of highest interest should be the crew's performance, as it is the only factor changeable for contemporary designs. Finally, a red teaming/ red tactics approach should be used to determine which changes may be employed by the SAFC to counteract any of the frigate's new tactics and armament.

Team 12: Cultural Geography Modeling and Analysis for IDFW 18

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INTRODUCTION

This report describes the primary effort of the Cultural Geography team to produce a scenario, experimental design and analysis using the prototype Cultural Geography (CG) agent-based model of civilian population in stability operations. This report provides a brief model overview, a summary of the scenario, a description of the experimental design and the emerging analysis results.

In addition to the Cultural Geography modeling and analysis described in this report, the team engaged in the following major activities during the International Data Farming Workshop: (1) Cultural Geography model and data ontology development, (2) Irregular Warfare metrics crosswalk between doctrine and model, (3) Senturion modeling and analysis briefing by Brett Marvin (Sentia Group), and (4) Tactical wargame Task-Event-Outcome (TEO) integration with Cultural Geography modeling methodology.

MODEL, DATA AND SCENARIO

The model, data and scenario are described below.

Model Overview

The purpose of the CG model is to explore the response of the civilian population to insurgent, government and coalition force actions in a stability operations context. The model represents a "conflict ecosystem" as described by Dr. David J. Kilcullen in his "Counterinsurgency in Iraq: Theory and Practice, 2007" (Kilkullen, 2007) report:

1. Multiple independent but interlinked (by social network) actors (i.e. agents);
2. Each seeks to maximize their own survivability and advantage;
3. Actors collaborate or compete and are often combative and destructive;
4. Coalition forces are not outside this ecosystem, but are players in it; and
5. Coalition forces intend to control the system's destructive, combative elements and transform to a "normal" state where normal is from the perspective of the population.

The Cultural Geography prototype implements an agent-based modeling approach. An agent-based model (ABM) simulates the actions and interactions of autonomous entities in order to assess the effect of their actions on the system as a whole. ABM implementations combine elements of game theory, complex adaptive systems, emergence, computational social science, multi-agent systems, and evolutionary programming. Monte Carlo methods introduce randomness into the model and allow for systematic exploration of the effect of inputs on outputs using experimental designs.

The environment modeled includes agents, objects and events. Agents are the actors in the simulation. These include representative members of society and other individuals or groups that influence the society. Infrastructure objects in the model provide goods and services. These goods and services are questions of public interest. Events are effects as well as information about goods and services that influence agents.

Internally, agents process information about events based on their beliefs and attitudes toward other agents involved in the event or agents considered responsible. Agents maintain and adjust a set of beliefs and positions on issues. Externally, agents transact and take physical actions. Simulation rules mediate the interactions among agents and between an agent and things in the environment. These rules govern how information is transmitted, media are exchanged and physical actions affect agents and things.

Scenario Description

The scenario is unclassified and loosely based on the city of Amarah in Iraq circa 2008. It represents a battalion area of operations (AO) as a brigade combat team conducts stability operations to improve security and infrastructure while supporting local elections.

Among the early tasks in the scenario development is to determine the population of interest in the AO and develop associated socio-demographic, socio-cultural & social-economic data. Demographic data are selected population characteristics such as ethnicity, age, income, mobility, educational attainment, home ownership, employment status, and location. Cultural data includes the set of shared attitudes, values, goals, and practices that characterize an institution, organization or group. Examples of cultural data are networks, religion, ethnic distinctions, personal motivators, information and persuasion. Economic data concerns the production, distribution, and consumption of goods and services. Examples are production, consumption, supply, demand, employment, and wages.

This data guides the determination of the most important identity dimensions in the population, which may include factors such as age, religion, education, tribe, ethnicity, region, etc. From those dimensions we produce population segments by identity and then partition the population by stereotype composites. A critical part of the process is to produce a narrative for each identity dimension and then to produce a narrative for each stereotype. Army and Marine Corps doctrine indicates that the most important cultural form for counterinsurgents to understand is the narrative (Department of the Army, Headquarters, 2006).

The social data is also used to develop the social network, which links population entities in the model. We determine the strength of relationship between agent Stereotypes applying the concepts of homophily and propinquity. Homophily is the tendency to bond with like others, while propinquity refers to the opportunity for interaction. We determine the associated level of trust and influence, which correlates with the strength of relationship and varies depending on the culture. These levels are driven primarily by tribal affiliation in this case. We finally determine the density (connectivity) of the social network; this also varies depending on the culture and is a strong candidate for data farming since it is not easily estimated. We then use social network software (e.g., ORA or UCINET) to analyze the network.

Also included in the entity and social network development are the many groups that often play critical roles in influencing the population in a conflict environment, but are largely beyond the control of military forces or civilian governing institutions. These include local leaders, informal associations, religious groups, families, tribes, as well as some private enterprises, humanitarian groups and media. During scenario development, the team determined which groups have influence over the population; group beliefs, values, interests and positions; and each groups' behaviors and events.

Concurrently, we determine what issues are salient to both the population and to the operation. Examples are security, essential services, legitimate authority, social justice, jobs, infrastructure and economics. We state the issues as questions:

- Is security in Amarah adequate?
- Are you satisfied with efforts to improve basic services provided by the infrastructure in Amarah?
- Will upcoming elections produce a legitimate government for Amarah?

We then determine what positions on issues are advocated by influence groups and sectors of the population and determine from the narratives which values, beliefs and interests influence issue positions. We conceptually determine the beliefs, values & interests that influence the population on the issue and construct Bayesian networks for each. We then develop case files that represent opinion samples for each population stereotype. Finally, we use the case files to estimate the probability data for the stereotypes' Bayesian networks.

We next determine the set of relevant behaviors in the population. Candidate behaviors include communicating and influencing, economic activity, political activity, and support to various actors. We determine the related factors that influence behavior including attitudes toward the behavior, social norms about the behavior, and perceptions of behavioral control. We conceptually model the behavior with a Bayesian network and develop case files that provide the probability information for the Bayesian network. This approach applies the Theory of Planned Behavior (Ajzen 1991), which is used to determine how the actor forms intentions to act—especially on a recurring basis.

Completing the scenario requires definition of events, which occur at a headline level because scenarios typically run over the course of six months to several years. Events are only relevant in the model if they produce an effect, change the functioning of an entity or object, or influence behavior or beliefs, values, interests and positions. Typically, the information surrounding the event is as important as or more important than the event itself. We define the possible events in the scenario, develop methods to implement event outcomes, and develop case files for the influence of events.

RESULTS AND ANALYSIS

The Cultural Geography team produced a scenario, experimental design and analysis using the prototype Cultural Geography agent-based model of civilian population. The results produced and analysis of this prototype provides the team insights into model calibration and validation requirements. The following sections present the experimental design and emerging analysis results.

Experimental Design

A five factor, 17 design point Nearly Orthogonal Latin Hypercube experimental design was used for this proof of principle work. Three decision factors and two noise factors were used in the design. These factors were chosen because of their impact on issue stance within the model. By varying these factors in a systematic way through our experimental design, the intent was to show that these factors did, in fact, impact the issue stance of entities within the model, confirming that the model functioned as intended.

Decision Factors:

- Mean time between Coalition Force Activity: The time between potential execution of coalition force events.
- Mean time between JAM Activity: The time between potential execution of JAM events.
- Mean time between AAH Activity: The time between potential execution of AAH events.

Noise Factors:

- Delay in Message Passage: Delay in transmission of knowledge of an event through the social network by an entity.
- Max Number of Recipients of Message: Maximum number of recipients of a message through the social network.

DP	Mean Time between Coalition Force Activity	Mean Time between JAM Activity	Mean Time between AAH Activity	Delay in Message Passage	Max Number of Recipients of Message
1	4.44	14	11.39	6.25	2.25
2	0.97	3.58	12.26	8.88	1
3	1.84	6.18	0.97	4.5	4.12
4	2.71	8.79	4.44	15	3.81
5	10.52	13.13	6.18	2.75	2.56
6	14	4.44	5.31	12.38	1.31
7	8.79	2.71	14	5.38	5.38
8	7.92	12.26	10.52	14.12	5.06
9	7.05	7.05	7.05	8	3.5
10	9.66	0.1	2.71	9.75	4.75
11	13.13	10.52	1.84	7.12	6
12	12.26	7.92	13.13	11.5	2.88
13	11.39	5.31	9.66	1	3.19
14	3.58	0.97	7.92	13.25	4.44
15	0.1	9.66	8.79	3.62	5.69
16	5.31	11.39	0.1	10.62	1.62
17	6.18	1.84	3.58	1.88	1.94

Table 1: Experimental Design.

Analysis

The model outputs are configurable to the needs of the analysis. In this proof of principle work, the primary outputs were the issue stances of each entity on each of the three issues represented in the model over time. As discussed earlier, the three issues were 1) satisfaction with security, 2) satisfaction about infrastructure, and 3) belief that elections would produce a legitimate government. This data was reduced and aggregated to show the change in issue stance over time for each design point for each of the 48 population stereotypes and each of the 11 demographic categories.

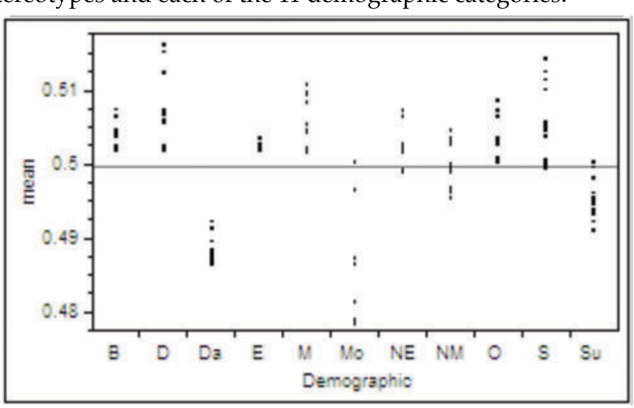


Figure 1: One way analysis of mean 'end of run' satisfaction with security in Amarah by demographic subtype.

The analysis here focuses on the issue related to satisfaction with security. Figure 1 shows the mean change in security issue stance for over all runs for all demographic subtypes. Noteworthy is the narrow range of all values from 48-52% satisfied for all demographic subtypes for all design points. This small range of changes indicates that no one subtype experiences large changes to issue stance. However, changes did, in fact, occur over the course of the run. This indicates a need for further calibration of the model, specifically focusing on the magnitude of the effect of events on issue stance.

Figure 2 illustrates the maximum observed level of satisfaction with security in Amarah by demographic subtype. The maximum observed satisfaction levels range from 55% for members of the Bani Lam tribe to near 80% for members of the educated class in Amarah.

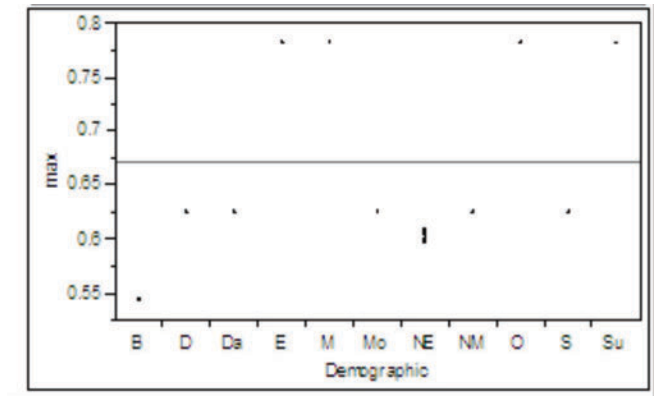


Figure 2: One way analysis of maximum observed satisfaction with security in Amarah by demographic subtype.

Similarly, Figure 3 shows the minimum level of satisfaction with security in Amarah experienced by each of the subtypes. Taken together these three graphs illustrate that over the course of a year, as represented in the model, the educated citizens of Amarah's level of satisfaction with security spanned a range from 38-77% satisfaction before settling near 50% by the end of the year. This confirms that the model is behaving as expected. Further analysis is required to trace the full path of public opinion through the model over time and to further explore the causal mechanisms behind these changes in issue stance.

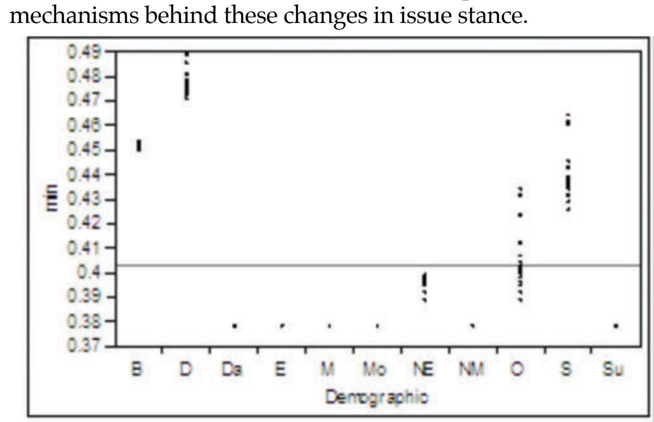


Figure 3: One way analysis of minimum observed satisfaction with security in Amarah by demographic subtype.

Regression analysis using the five factors from the experimental design as predictors for the mean response of the population as a whole was conducted considering out to third order interactions to identify the factors that most influence the model. Not surprisingly, this model accounted for only a small portion of the variability in the response of the entire population of Amarah, RSq= 0.14. This is not surprising since each subgroup within the model responds in a unique manner to events based on their internal beliefs. Also, not surprisingly, the most significant contributors to the mean satisfaction of the population with security were the level of JAM activity and coalition force activity (as a third order term). Again this is consistent with what one would expect as these actors both initiate events that impact civilian population issue stances. Surprisingly, the level of AAH activity was not a significant contributor, but the delay in transmission of information across the social network did have a significant impact. AAH was a significant actor within the model, but with a smaller base of support within the overall population. Thus, one might expect that a detailed analysis of subgroups would reveal a larger impact from AAH initiated events within the model. The delay in message traffic showing as a significant factor in the mean issue stance of the overall population shows that this portion of the model is functioning correctly.

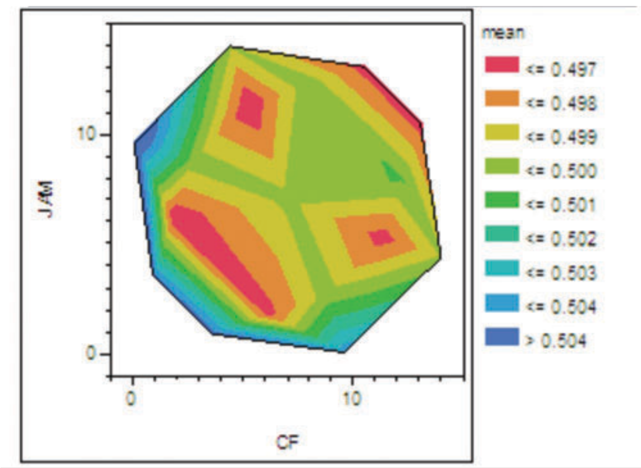


Figure 4: Contour plot of impact of the interaction between JAM and coalition force activity on mean satisfaction on security for the overall populace.

Figure 4 illustrates the relationship between JAM and coalition force activity within the model. The scale represents the mean time between the execution of events within the model by each actor.

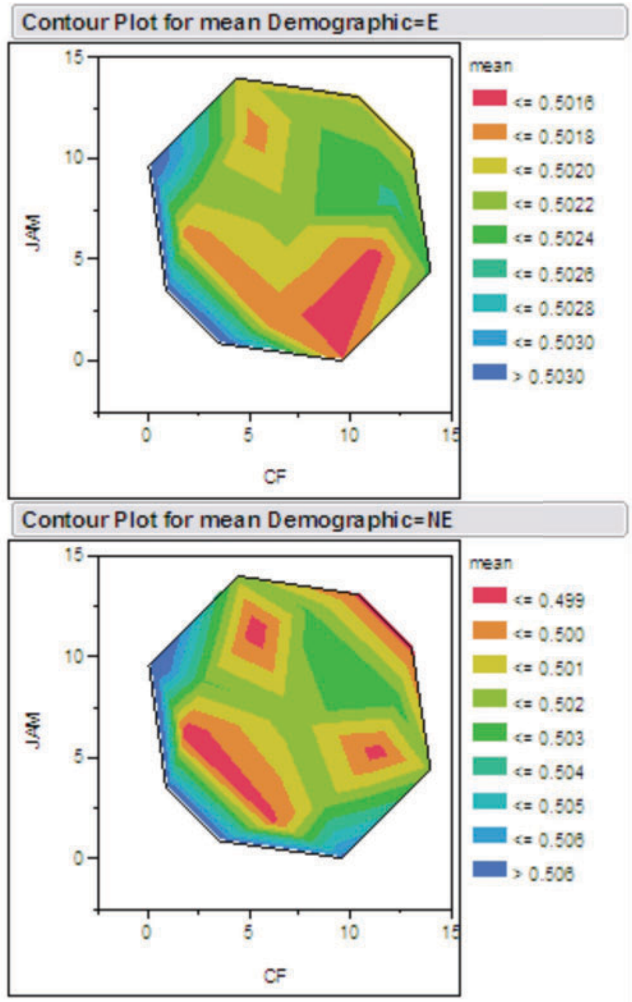
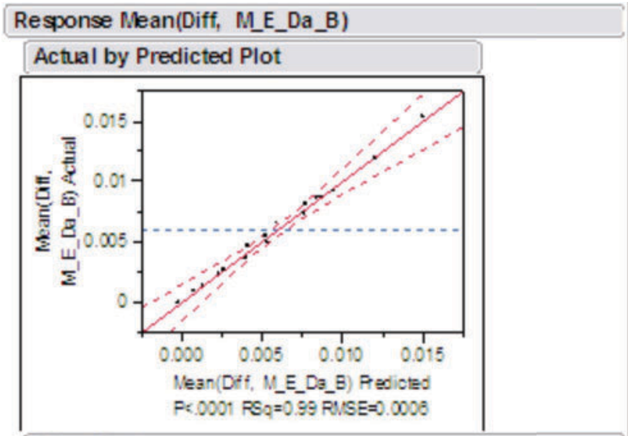


Figure 5: Interaction of JAM and coalition force rates of activity with mean satisfaction with security for educated and non-educated subtypes.

Figure 5 shows the difference in the response to varying levels of JAM and coalition force activity for the educated and non-educated segments of the population.

As an initial step to a more detailed analysis, a regression model was fit for the subgroup consisting of military age, educated members of the Dawa party and the Bani Lam tribe using the mean change in satisfaction on the issue of security as the response, in Figure 6 below.



Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
CF	1	1	4.2624e-10	0.0013	0.9725
JAM	1	1	0.00009959	306.1553	<.0001*
CP*JAM	1	1	0.00001007	30.9484	0.0026*
AAH	1	1	0.00003026	93.0320	0.0002*
Delay	1	1	1.57596e-9	0.0048	0.9472
JAM*Delay	1	1	0.00001813	55.7393	0.0007*
Recipients	1	1	0.00000341	10.4943	0.0230*
CP*Recipients	1	1	6.23328e-8	0.1916	0.6798
JAM*Recipients	1	1	0.00002079	63.8995	0.0005*
CP*JAM*Recipients	1	1	0.00001881	57.8333	0.0006*
Delay*Recipients	1	1	0.00000577	17.7254	0.0084*

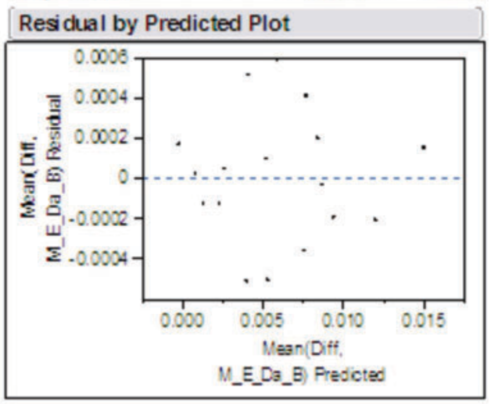


Figure 6: Stepwise regression model of the mean change in military age, educated members of the Dawa party and Bani Lam tribe.

Note that the model accounts for a much greater portion of the variability in the response, as expected given the uniqueness of each particular subgroups' interpretation of the events within the model. The analysis shows that the greatest contribution to the change in the mean level of satisfaction for this subgroup came from the level of JAM and AAH activity. Coalition force level of activity only becomes significant in the response as an interaction with JAM level of activity.

The contour plot below illustrates the impact of the interaction between JAM and coalition force activity on this population subgroups satisfaction with security within the model. The scale of this change highlights the need for further model calibration. In general, the greatest change occurs when the rate of JAM activity is less frequent. [FIG 7 HAS JAM/CF ON DIFFERENT AXES THAN FIG 5]

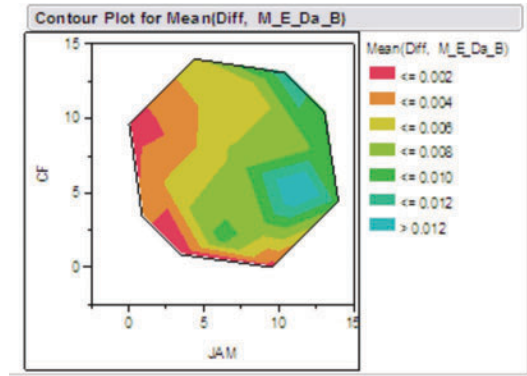


Figure 7: Contour plot of impact of JAM and coalition force actions on mean change in satisfaction on the issue of security for military age, educated members of the Dawa party and Bani Lam tribe.

SUMMARY OF FINDINGS

The team collected data for each agent throughout each of the model runs. Analysis of this data provided emerging insights for further exploration:

- Assess model calibration based on population stereotypes and their unique narratives.
- Trace population opinion over time to understand causal relationships of events with issue stances.
- Expand experimental design to better understand social network configuration.
- Continue analysis of other issues in the model (infrastructure and elections).

CONCLUSIONS

The International Data Farming Workshop provided an opportunity to prepare, present and collaborate about the current state of the CG model. The team successfully executed an experimental design using the proof of principle Cultural Geography model. The scenario is loosely based on the city of Amarah in Iraq circa 2008 and represents significant population elements, influencing groups, their social networks, infrastructure, and events. The team collected dynamic data about agent stances enabling emerging insights about the model. Analysis of the collected data demonstrates that many functions of the model are operating as designed, while also providing insights into model improvements, data collection and analysis needs, and validation possibilities. The CG team will continue to explore the data from the scenario described above and improve the CG model.

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IDFW 18: Start to Finish

Keynote Speaker – Dean Karl van Bibber

Keynote Speaker – LTC David Hudak

Keynote Speaker – Mr. Rob Heilman

International Data Farming Workshop 19

When: 1 - 6 November 2009

Where: Spencer on Byron Hotel, Takapuna, Auckland, New Zealand

Room rates are $160 NZD for a Studio and $180 NZD for a Suite per night and include 12.5% GST. Please go to http://harvest.nps.edu/ at the IDFW 19 link for additional information and registration.

The workshop fee will be is $800.00 NZD.

IDFW 19 2009 Tentative Agenda

- **Sunday, November 1:** Opening reception and dinner
- **Monday, November 2:** Opening briefs and team poster sessions in the morning, then begin work in teams
- **Tuesday - Thursday, Novemeber 3 - 5:** Work in teams (optional plenary sessions in the mornings)
- **Friday, November 6:** 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.

Theme:

Our theme for IDFW 19 is "Mana."
In the Maori culture, having mana means to have influence, authority, effectiveness, power, usefulness, and prestige.

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