Agent Based Simulation of Terrorist Attacks "Protection of Potential Targets"

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Mr. Bertsche is a project leader in the military OR-Section of EADS – Germany (a company of European Aeronautics Defense and Space Corporation, EADS). He has completed the development of an ASW planning tool called "ASW–Missionplanner" for the German Navy this year which considered area search and barrier operations. This work followed the development of an analysis tool for the development of Anti Submarine Warfare Screens called the "Screenplanner" for the Fleet Command of the German Navy which has also been introduced into NATOs allied tactical procedures this year. He also contributed in many other military OR – studies for the German Army Engineers but also assisted in the promotion of agent based modeling as an alternative OR analysis method within his department. He is presently working on an army engineer study considering inhibiting enemy mobility by investigating the implementation of other weapon systems other than conventional land mines. He was previously a nuclear engineer at Babcock & Wilcox in Virginia, U.S.A. He has a Masters of Engineering Degree in nuclear engineering from New York University.

Mr. Gunther Schwarz has recently been promoted to team leader for all German Army OR Studies concerning the area of agent based modeling and 3D OR – Simulation studies within the military OR-Section of EADS – Germany (a company of European Aeronautics Defense and Space Corporation, EADS). He is also the project leader for all agent based modeling studies for the German Army within EADS and was primarily responsible for the model development of the agent based model PAX, which is presently being used to analyze non combat scenarios in peace support operations. He graduated from the University of Passau and obtained a masters equivalent in computers science in the year 2000. For his master's thesis Gunther developed an agent based model called ADAM that simulates human behavioral characteristics such as needs, fears, and motion.

ABSTRACT

As a part of the Project Albert Emergency Working Session on Terrorism held in the Maui high performance computing center, MHPCC in January 2002, the German Working Group analyzed the scenario: "Protection of Stationary Potential Terrorist Targets." This scenario was developed to be used in the agent-based distillation program "MANA."

In this generic scenario, one or more objects of high value are endangered by terrorists' activities. Those stationary objects can have a different value for the goals of the terrorists. The stationary objects could be churches, bridges, tunnels, stock exchanges, governmental or cultural buildings or any other form of high value targets. There is also the possibility that the value of the objects is different to the protectors and the attackers.

The terrorists (RED) try to destroy one of these targets. The security personnel (BLUE) attempt to capture terrorists and try to prevent damage to any of the buildings. RED agents are well camouflaged – looking like civilians – and can not be easily identified as a terrorists. BLUE agents can also be camouflaged, but are identified by the RED terrorist agent much easier than vice versa.

If the BLUE security agents are able to detect the RED terrorist agent, the BLUE agents will attempt to capture the terrorist agent. If these efforts are unsuccessful, BLUE agents will focus their attention in guarding the potential stationary targets by moving in close to these targets. BLUE will always try to capture the RED terrorist agent, after they have been detected. BLUE agents usually capture at least one RED agent. But other terrorist agents still have the possibility to reach the target.

RED agents do not attack BLUE agents; they attempt to hide to avoid contact. Once RED terrorist agents have identified BLUE security agents, they stay hidden until they reach their goal. The stationary target is the only point of attack for the RED agents: They attack the target at short range with highly effective explosive charges.

BACKGROUND

Since the mid 1990s the U.S. Marine Corps and the MITRE Corporation have promoted the use of agent based analysis for operations research. This new analysis approach was first presented at the second Cornwallis Workshop "Analysis for and the Resolution of Conflict" in 1997.

The presentation showed that the traditional OR analysis methods such as Lanchester models of combat and Monte Carlo statistical methods only yield answers (loss exchange ratios) to extremely well defined boundary conditioned problems. But combat in itself is all but well defined. Here so many intangible factors such as persistence, courage, cowardice amongst others were never considered in the traditional OR combat analysis approach. Here agent based models seems to offer a solution to this problem.

One important criterion of agent based models is that the model remains simple and transparent in its behavior. This is important for the validation of the individual agents' behavior model to react appropriately to a number of different situations. After having developed acceptable agent behavior model a large number of parameter variations are required in order to determine the emergent behavior of the agents for a given combat scenario. One of the most important analysis methods associated with agent based models and a vast number of parameter variations is the so called Data Farming Method. With data farming it is possible to identify solution landscapes, which leads to combat success but moreover it also yields answers of how combat failures can still occur despite an alleged optimized force ratio (determined by traditional OR analysis methods).

Dr. Alfred G. Brandstein (Chief OR Analyst USMC) and Dr. Gary E. Horne (MITRE) further promoted agent based analysis method in the Second Infantry Workshop held at DORNIER GmbH in Friedrichshafen in July 1999. Here the possibility of using 3D visualization tools to visualize selected agent-based scenarios with the Dornier Model IRIS, were also being considered. This finally led the German Army to participate in the Project Albert International Workshop.

After September 11, 2001 an emergency workshop was initiated by the Dr. Brandstein called the "Project Albert Emergency Working Session on Terrorism." This workshop was conducted from January 18 – 24, 2002 in the MHPCC facilities on the Island of Maui.

OBJECTIVES

The general objective of this paper is to present an overview of the workshop activities conducted from January 2002 at the MHPCC. The activities were the following:

- Determination of the Objectives of the German participants.
- Familiarization to the available general analysis environment.
- Familiarization to the overall Data Farming Methodology.
- Coordination of the planned workshop analysis activity.
- Coordination of presenting the overall results.
- Developing an analysis proposition "Protection of Potential Targets."
- Alternate Analysis: "Protection of Potential Targets" in Project Albert International Workshop 5.

PROCEDURE AND RESULTS

This will explain how the above mentioned objectives were met using a systematic and analytic approach.

DETERMINATION OF THE OBJECTIVES OF THE GERMAN PARTICIPANTS

By participating in this international workshop the German participants identified a number of objectives for themselves in order to make a meaningful contribution to this workshop. First of all they needed to construct their own input parameters for the available agent-based models in order to properly simulate the phenomenon counter terrorism. In order to perform this activity appropriately, more knowledge about the agent based simulation models and

their associated distillation tools and data farming methods was necessary. Foremost of importance is a basic understanding of terrorist actions, which can be derived from their basic objectives and their available means of destruction. In order to implement the agent based models in an appropriate fashion requires the development of an adequate scenario. Only through this very analytic and systematic approach was it possible for the German participants to demonstrate their competence within Project Albert.

FAMILIARIZATION TO THE AVAILABLE GENERAL ANALYSIS ENVIRONMENT

The preparation of an appropriate scenario started at home several weeks before the workshop commenced in January 2002. One of the primary activities was to identify the available input parameters for the simulation models. Even though the parameters may seem clear in their function, detailed knowledge about their effectiveness in the simulation may not be readily understandable. Therefore, the U.S. Marine Corps supported the international participants with OR specialists, who were knowledgeable about the agent based models that would be used during the workshop. The agent-based models that were used during the workshop were the following:

- MANA.
- SOCRATES.
- ISSAC.

The available infrastructure to perform the enormous amounts of analysis capability was access to the GILGAMESH Network, which consisted of about 20 PCs with dual processors and access via network to 512 nodes of the MHPCC super computer.

FAMILIARIZATION TO THE OVERALL DATA FARMING METHODOLOGY

To properly use the available data farming tools required an adequate understanding of their inputs and functions. In order to perform any kind of data farming one has to know what parameters are available and how these parameter values should be varied in the agent based analysis. This task can only be performed in a logical fashion if the model is available on a local PC. This allows the user to experiment with the different available parameters and can judge and evaluate their influence of the individual parameter variations. This by no means will cover all variation possibilities, but certain sensitivities to parameters can be determined before the large parameter variations are performed on a super computer or on GILGAMESH type of network.

Once the influencing factors have adequately been determined, the large scale parameter variation can be launched. This large amount of analyses will of course produce an enormous amount of data set results that must be evaluated. The evaluation process cannot be performed manually in a reasonable amount of time; therefore so-called data farming methods

were developed to quickly visualize the results of data variations. Based on preliminary variation results will define the total scope and step size of the variations. This is an iterative process that increases the understanding of the scenario, but also gives insight and limitations of the fidelity of the agent based model itself.

COORDINATION OF THE PLANNED WORKSHOP ANALYSIS ACTIVITY

The German team began developing the scenario "Protection of Potential Targets." In order to perform this activity required the use of an agent based model. A decision was made to use the New Zealand developed agent based combat model MANA. The results produced by MANA were than interpreted by the 3D visualization tool which had previously been developed by the US Marine Corps within Project Albert. The primary objective was to determine the primary influencing factors and developing correlations between the chosen parameters. In addition the step size of the parameter variations were also determined.

COORDINATION OF PRESENTING THE OVERALL RESULTS

The general results obtained was that the scenario "Protection of Potential Targets." This scenario still needed further development, which could not be performed during the limited time frame of the workshop. The obtained MANA results were visualized with the 3D visualization and an interpretation of the differences in the results was possible. This led to better understanding of the applied methodology within Project Albert in particular the application of the data farming methods in conjunction with the results generated by the supercomputer.

Another result was an overall better understanding of the applied analytical tools, especially the agent based simulation tool MANA (version 0.97) and of course of the Project Albert Visualization Tool (Version 2.5.3). But most of all a much better understanding of the mechanisms of terrorism was obtained.

DEVELOPMENT OF AN ANALYSIS PROPOSITION "PROTECTION OF POTENTIAL TARGETS"

The German team was successful in developing an analysis proposal called "Protection of Potential targets". This actually meant formulating a number of general questions that needed to be answered. These general questions were the following:

- How can terrorist attacks be prevented in general?
- How can high valued targets be protected from terrorist attacks?
- How can terrorists be identified and eliminated?

BOUNDARY CONDITIONS/LIMITATIONS

One of the limiting factors which made the analysis somewhat cumbersome was the high level of abstraction within the agent based model to simulate this type of problem "Protection of Potential Targets" which needed to be solved. Here several tasks for both terrorists and security forces were identified:

- Terrorist (RED) aim is to destroy the target; the terrorist target could include churches, bridges, tunnels, stock exchange, government or cultural buildings.
- The security forces (BLUE) attempt to discover and eliminate the terrorists but at the same time provide protection for the high valued targets.
- Because BLUE has two Goals: Object protection and terrorist identification/elimination, this generates a conflict in strategy.
- Within MANA the BLUE forces recognize the primary terrorist target.

These activities lead to a number of more detailed questions, which must be answered. These questions are the following:

- What capability is required of BLUE to prevent RED terrorists to carry out their plan?
- What is the best strategy for BLUE security forces to protect high value targets in high threat situations?
- What is more important search/elimination of terrorists or protection of the high valued target?
- What are the most important characteristics/capabilities of RED terrorists?
- What is the best strategy for RED terrorists to achieve their goal?

In order to solve the above defined questions, the following solution scheme was used to answer the above detailed questions: First of all a selection of the significant parameters for the data farming process was necessary.

A PC Notebook was implemented to perform initial Simulations with MANA to obtain datasets in order to determine model and agent behavior. Group discussions finally led to the parameter ranges and parameter increments for the data farming process using GILGAMESH and supercomputer applications.

The data farming process included 500 to 1000 solution points with approx. 30 to 100 variations. The data was then evaluated with the data visualization tool where the minima averages and maxima were analyzed in detail.

Another point of interest was to be able to reproduce particular solution points that gave interesting results which could be interpreted. To expedite the evaluation of the data certain

criteria needed to be defined for the evaluation of the landscape results and those of the trend analysis of a simulation tracking runs.

In the first analysis with MANA the following agents were modeled: one group of security personnel, one group of terrorists and one target. For this first analysis some performance related questions arose:

- How effective must BLUE security forces be in detecting terrorists (percentage to detect terrorists while having contact) in order to prevent acts of terrorism?
- What is the best strategy mix to protect the targets? (detect and destroy terrorists vs. guarding the target).
- What is the best strategy for RED?

The initial analysis of the scenario: "Protection of a Potential Target" consisted of the security group patrolling in an attempt to detect and neutralize terrorist agents as presented in Figure 1.

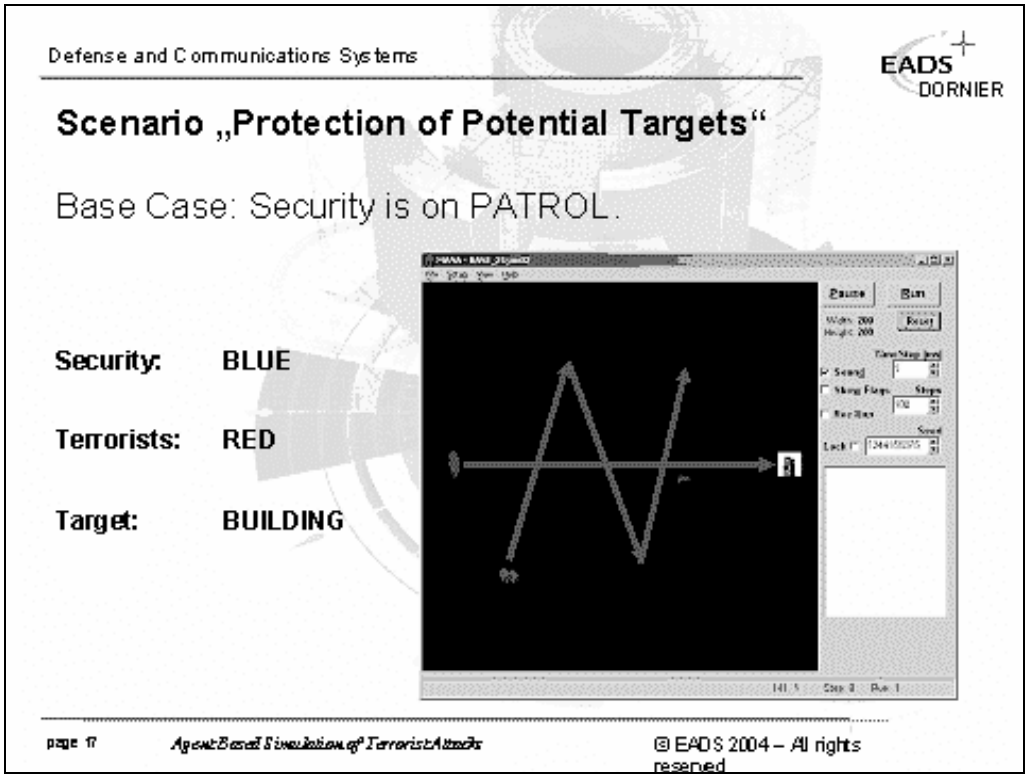

Figure 1: Base Case Security Forces are on Patrol.

The MANA simulation shows that this scheme of patrolling may detect terrorist agents; however, the security group may not detect all terrorists and as Figure 2 shows, the target is destroyed.

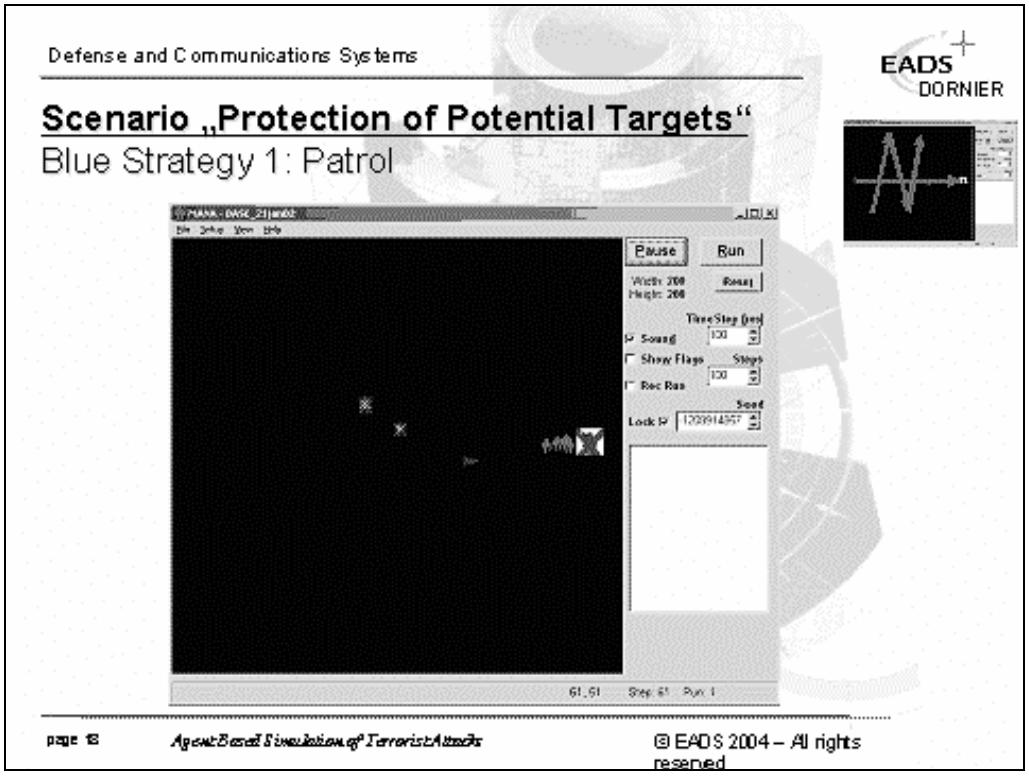

Figure 2: Results of the 1st Strategy.

A second strategy had as its goal to protect the target. All security forces were committed to protect the target as shown in Figure 3.

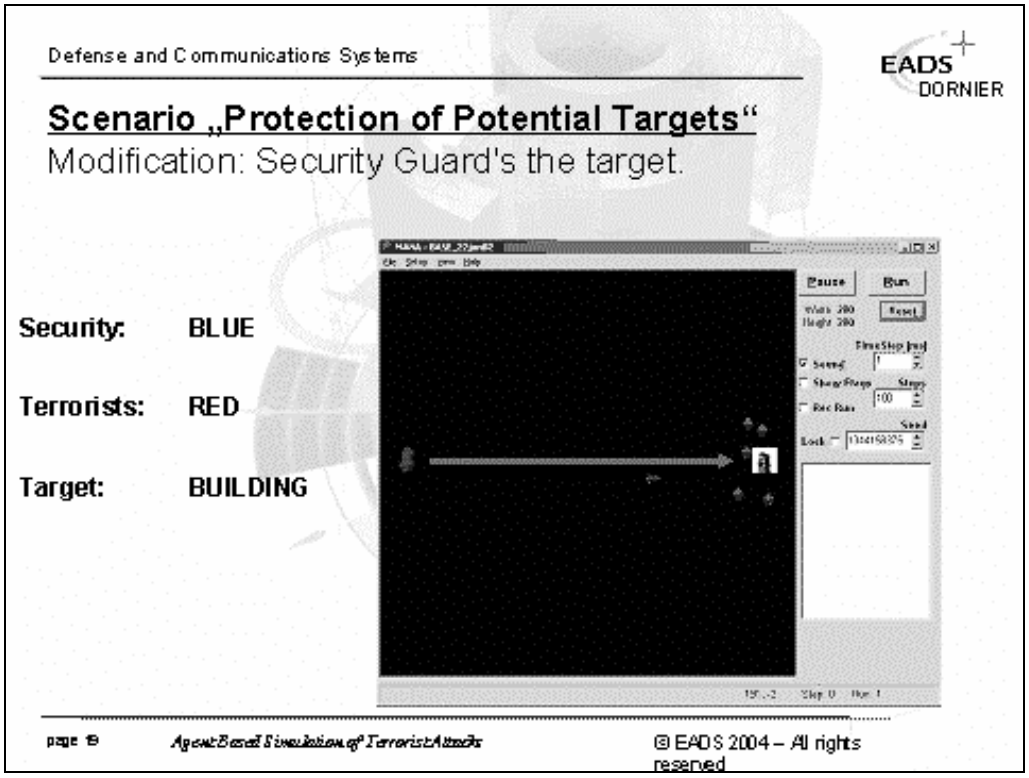

Figure 3: Security Forces Guard Target.

The results are shown in Figure 4, indicating that all terrorists are neutralized before they were able to destroy the target building.

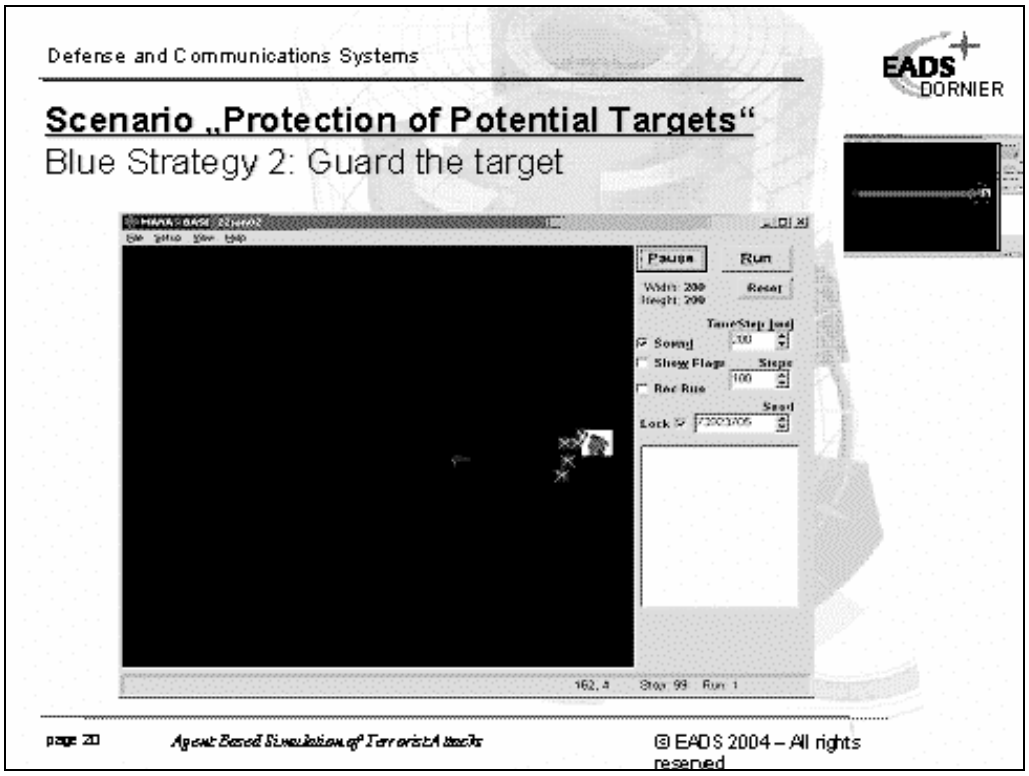

Figure 4: Guarding the target.

The main influencing parameters of both security forces (BLUE) and Terrorist group (RED) are the following:

Terrorists Group (RED)	*Security Forces (BLUE)*
Stealth	Stealth
Movement Speed	Movement Speed
Sensor Range	Sensor Range
Weapon Range	Weapon Range
Hit Points	Fire Power (SSKP)
Movement weights:	Movement weights:
w2, w10: Avoid BLUE contact	w 2: Move towards RED
w 5: Move straight to the target	w 6: Move closer to high value target

Based on these parameters a number of variations were determined. The first variation considered was the speed of the security forces BLUE, but also as a function of their sensor range and their movement tendency to move toward the high value target which will be called “tendency to guard target.” All other remaining parameters were kept at their pre defined average values. The plot in Figure 5, Figure 6, and Figure 7 show the probability of the terrorist group to destroy the high valued target as a function of sensor range, “tendency to

guard target" for various values of speeds (degree of mobility) of the security forces. If the security forces are extremely slow the high valued target can practically always be destroyed by the terrorist group no matter how well the security forces are able to detect the terrorist or their "tendency to guard target."

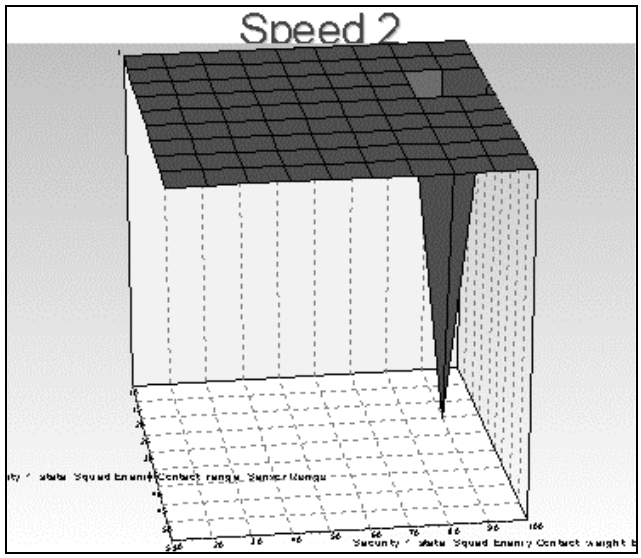

Figure 5: Low Speed.

In simple terms this just means; if the security forces are quite immobile they won't be able to position themselves properly in order thwart the impending terrorist attack. This trend for the terrorist to destroy the high value target, change appreciably at moderate speeds (mobility) of the security forces associated with a high sensor range and a high "tendency to guard target." Under such favourable conditions BLUE security forces become very effective in thwarting the terrorist attack that is shown in Figure 6.

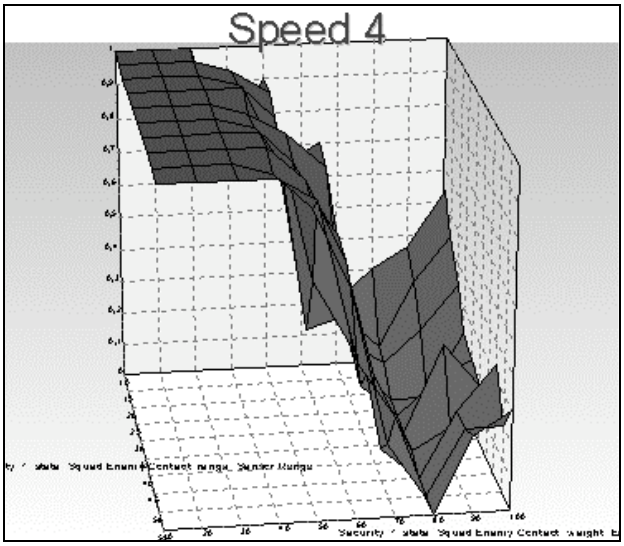

Figure 6: Medium Speed.

However, at high speeds (high mobility) of the security forces a counterproductive tendency seems to occur in association with a high detection probability of terrorists. Since there

is also a tendency for the security forces to move towards the terrorists, the high sensor range seems to act as a distracting factor for the security forces and lower sensor range lead to somewhat better results in protecting the high value target as Figure 7 seems to show.

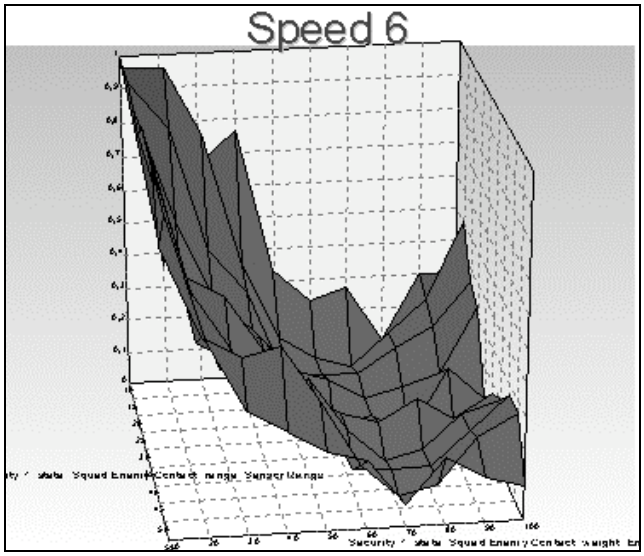

Figure 7: High Speed.

The second variations of parameters looked at the probability of the terrorist group to destroy the high valued target by varying speed of the security forces, but also varying firepower as well as the "tendency to guard target". The result of this variation is presented in Figures 8 through 10.

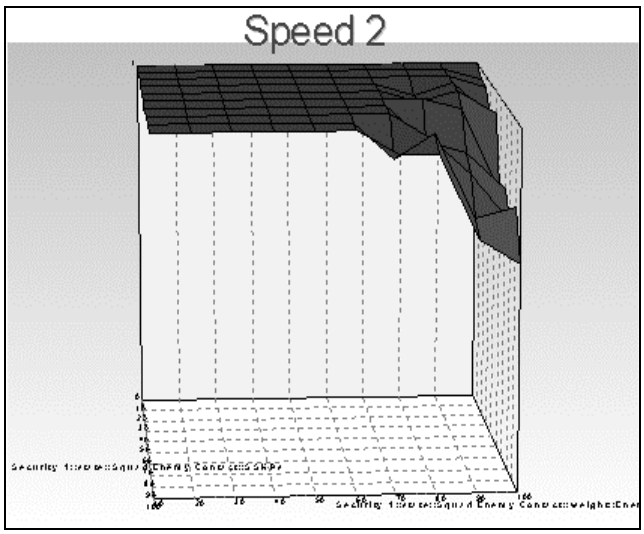

Figure 8: Low Speed.

As the figures show high speed associated with high fire power but also with a high "tendency to guard target" will prevent the terrorist for destroying the target. But it is also evident for all speeds if there is little "tendency to guard target" the destruction of the high valued target is at extremely high risk of being destroyed.

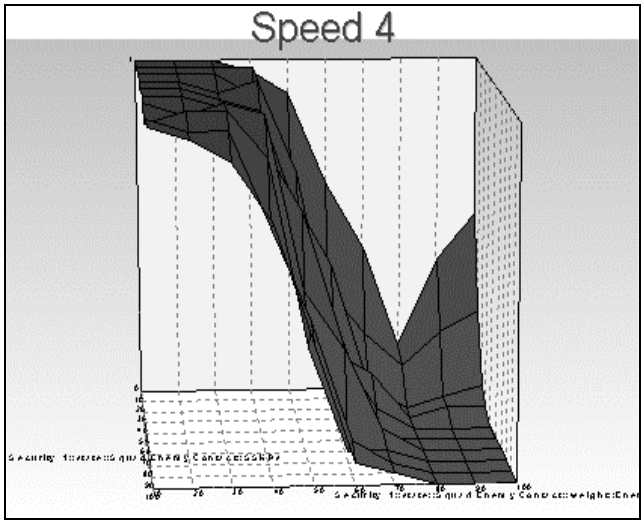

Figure 9: Medium Speed.

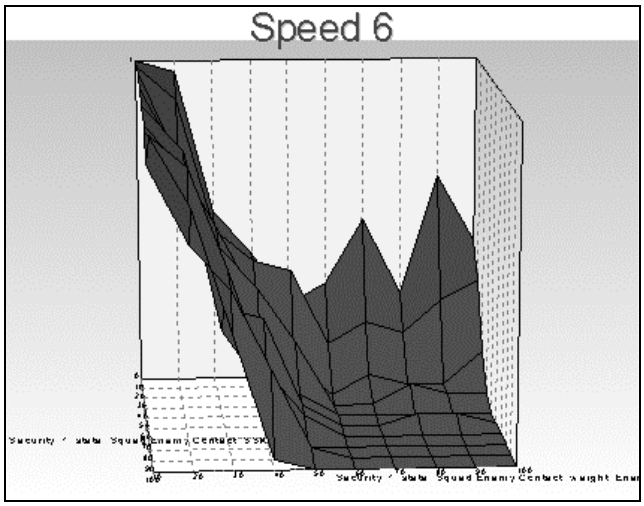

Figure 10: High Speed

The third analysis looked at the guarding scenario as described in Figures 3 and 4. In this third analysis the parameters variation that were looked at were firepower, sensor range, and speed/mobility of the security forces. Here, the impacts of these variations were being evaluated with respect to the probability of destruction of the high value target by the terrorists. The results of the analysis are shown in Figures 11 through 13.

By guarding the high valued target appreciably reduces a successful assault by the terrorist in all respects in comparison with the patrolling scenario. By looking at Figures 11 through 13, only small variations of the results can be observed when speed/mobility of the security force is considered. This is a reasonable result since the security forces do not require very much mobility in order to fulfil their task in guarding the target.

The results achieved for the patrolling and guarding scenarios partially completed the analysis work of the German working group for the Analysis of "Protection of Potential Targets" within the Project Albert Emergency Working Session on Terrorism held in January 2002 at the MHPCC.

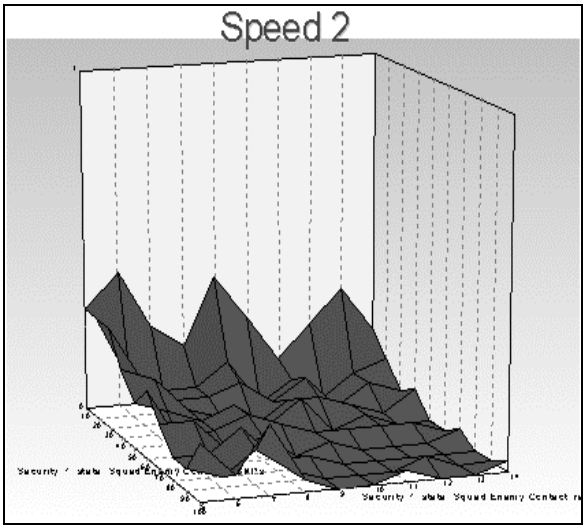

Figure 11: Low Speed.

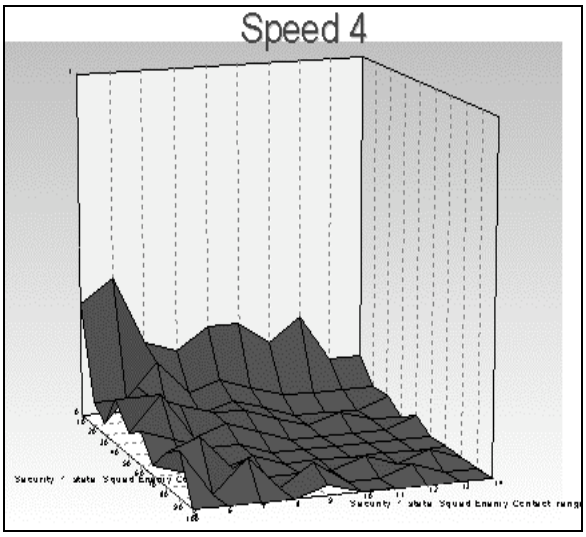

Figure 12: Medium Speed.

The partial results achieved showed that even with a high level of abstraction of the agent based model it was still possible to generate plausible results. The objective of the workshop had therefore been met. Laptop farming was effectively used to generate preliminary results to better understand the agent based model behavior.

The group had learned the main methods for generating data with agent based models by interpreting the data, selecting sensitive parameters and improving intuition of the models behavior.

The Data Farming Method was implemented to visualize the results of the mass of generated data by the agent-based model running on the supercomputer with all parameter combinations to better understand the relationships and influences of different parameters. By analyzing the landscape results unexpected behavior could be identified and proper model behavior can be confirmed.

Due to the limited time of the workshop not all necessary analysis could be performed and therefore additional work was still required to complete the analysis for the scenario "Protection of Potential Targets." The results of this analysis were then presented in the Project Albert International Workshop 5 which was hosted by EADS Dornier GmbH in Überlingen on July 1 through 4, 2002.

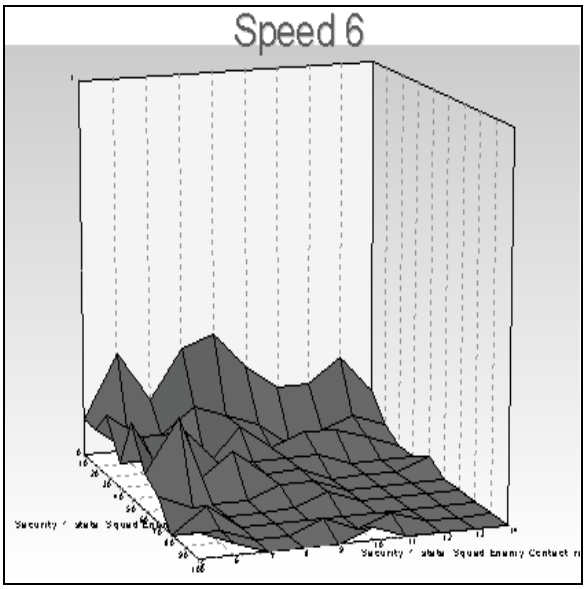

Figure 13: Maximum Speed.

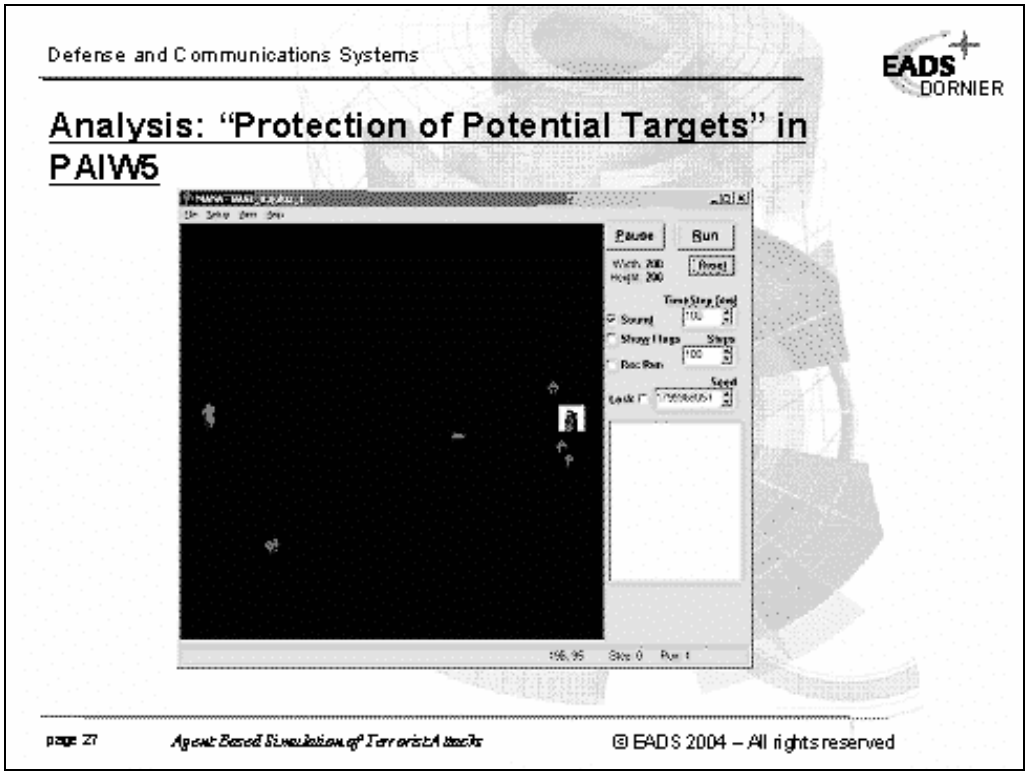

Figure 14: Analysis of Potential Targets in PAIW5, Vignette 1.

ADDITIONAL ANALYSIS: "PROTECTION OF POTENTIAL TARGETS" IN PROJECT ALBERT INTERNATIONAL WORKSHOP 5

The analysis which was performed in the Project Albert Emergency Working Session on Terrorism had only one type of activity for all BLUE security agents at anyone time. Since the results showed that not only guarding the high valued target is important but also patrolling activities of the security forces some distance away from the high value target also have a significant effects. In this follow on study a combination of agents some guarding the high value target and others patrolling some distance away from the target was investigated.

The first vignette which was analyzed for the scenario "Protection of Potential Targets" had three security agents assigned to guard while two security agents were out patrolling some distance away form the high value target. This initial situation is shown in Figure 14 which shows the terrorist group on the extreme left the two patrolling security agents in the lower left side of the screen and the three guarding agents on the right side of the screen.

The results obtained was "Probability of Target Destruction" by the terrorist group for the parameters "single shot kill probability" SSKP and the "tendency to guard target" of the security forces. These results are shown in Figure 15.

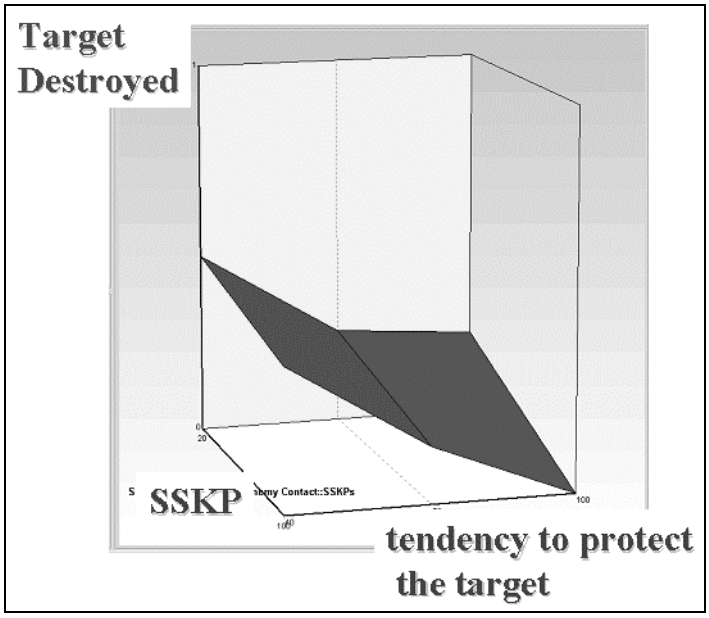

Figure 15: Results 3 Security Guards guarding, 2 Security Guards Patrolling.

The Figure 15 shows that for a high single shot kill probability SSKP and "tendency to protect target" the probability of terrorists destroying the high valued target is very low. However if the "tendency to protect target" is low and SSKP is low the terrorists become much more successful in achieving their goals.

In the second vignettes the three security guards were performing patrols and only two security guards were assigned to guard the high value target. The initial situation for this vignette is shown in Figure 16.

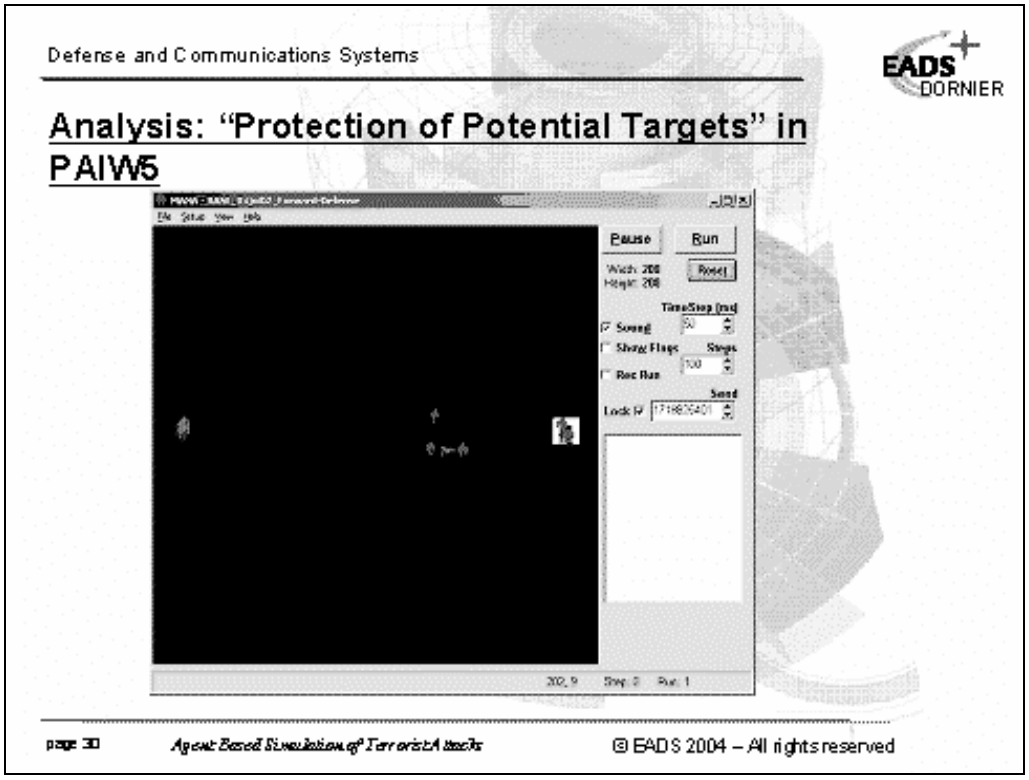

Figure 16: Analysis of Potential Targets in PAIW5, Vignette 2.

The results obtained was the "Probability of Target Destruction" by the terrorist group for the parameters "single shot kill probability" SSKP and the "tendency to guard target" of the security forces. These results are shown in Figure 17.

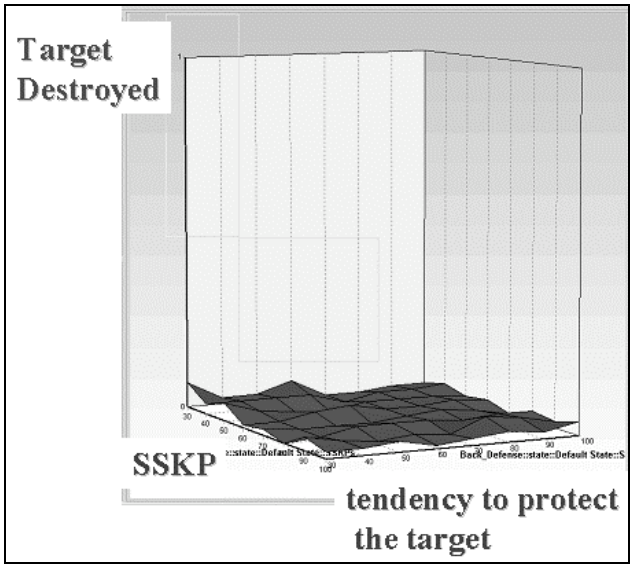

Figure 17: 3 Security Guards guarding, 2 Security Guards Patrolling.

The Figure 17 shows, by increasing the number of patrolling guards and reducing the number security guards guarding the high value target, the results are almost independent of the single shot kill probability or tendency to protect the high valued target by the BLUE Security forces.

Several other interesting results were obtained one of them being an analysis of the neutralization of terrorists. Here two parameters were considered single shot kill probability and the "Tendency to Protect Target." The results are shown in Figure 18.

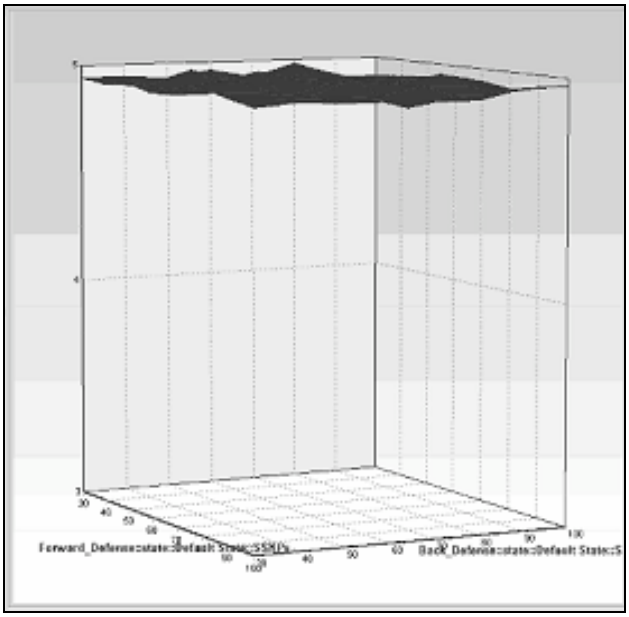

Figure 18: Neutralization of terrorists.

Because the BLUE security forces have been split into two groups, it seems that either the patrolling security forces or the guarding forces are capable of neutralizing nearly all RED terrorist. However, if the terrorists group is capable of camouflaging themselves more effectively the casualties of the terrorists do decline and a latent threat to the high value target does remain. This is shown in Figure 19.

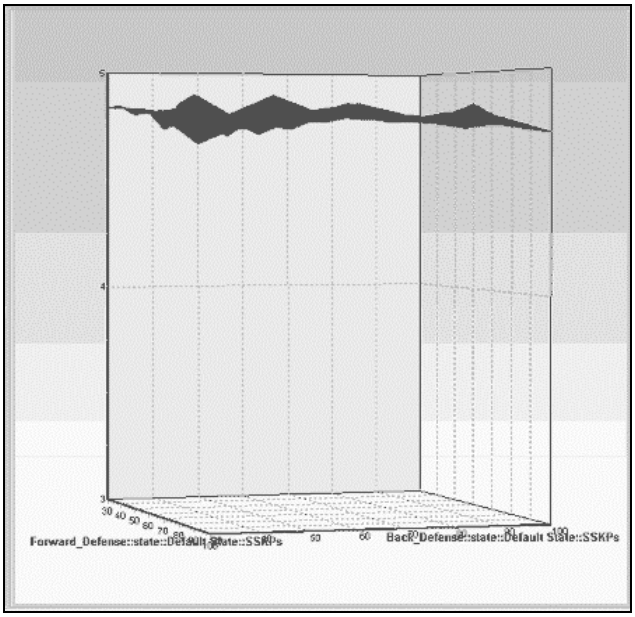

Figure 19: Neutralization of terrorists considering camouflaged terrorists.

CONCLUSIONS

Even though the level of abstraction of the agent based model MANA version 0.97 is high for simulating the basic scenario "*Protection of Potential Targets*," it still gave plausible acceptable results for all of the vignettes considered. The most interesting results were the splitting of the security force into a patrolling group and a guarding group. The level probability of terrorists destroying the high value target was the lowest. On the other hand if terrorists camouflage themselves effectively, will lead to a higher survivability and a latent threat does remain.

ACKNOWLEDGEMENTS

We would like to take this opportunity to thank the German army office for financing this investigation and also thank the US Marine Corps for their overall personnel support as well as the use of their tools and models.