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APPLICATIONS OF ADVANCED SENSOR TECHNOLOGY TO PEACEKEEPING MISSIONS

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Dennis F. DeRiggi
D. Sean Barnett

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INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) as part of a Central Research Project. It describes a series of simulated exercises, using ModSAF in the IDA Simulation Center, in which peacekeeping teams attempt to intercept infiltrators who attempt to penetrate a safe-haven boundary in the vicinity of Sarajevo.

The authors wish to acknowledge the technical support provided by Mr. Barron Gibson, Mr. Keith Green, and Ms. Karen Luigard of the IDA Simulation Center. Also, the authors wish to acknowledge Mr. Richard Carpenter who created the sensor simulation that was so central to this study and Dr. Jeff Grotte who performed the review of this document.

CONTENTS

Chart 1 - Background and Motivation

In the future, United States or allied military forces may engage more frequently in peacekeeping operations, or operations other than war (OOTW). Today, for example, U.N. forces are engaged in such operations in Bosnia. Advanced sensor technology can be utilized in peacekeeping operations to help maintain safe havens, guard borders against hostile infiltration, and enhance peacekeepers' safety. Sensors placed along boundaries and common thoroughfares can alert response teams to the presence of infiltrators and enable the response teams to be vectored to intercept the infiltrators and confront them from a position of tactical advantage.

The Defense Nuclear Agency has a particular interest in the use of advanced sensors in peacekeeping operations. It sponsored an earlier IDA effort which surveyed applicable technologies.[1] That study, which looked at the use of sensors in operations in Bosnia, motivated our effort and provided the scenario we used in the present investigation. IDA Central Research Projects have also investigated the use of sensors in peacekeeping operations as well.[2]

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1 Robert Zirkle and Ivan Oelrich, *Advanced Sensor and Information Processing Technology for Peacekeeping Operations*, IDA Paper P-3112, Institute for Defense Analyses, forthcoming.

2 Dennis DeRiggi, D. Sean Barnett, and Matthew Hersch, *SIMNET/DIS Applications to Peacekeeping Missions*, IDA Document D-1593, Institute for Defense Analyses, Draft, September 1995.

Background and Motivation

- Mission and geographic area relevant to US foreign policy
- Germane to issues and areas of interest in other IDA studies

Chart 2 - Objective

The objective of this CRP is to build upon the work of Zirkle and Oelrich (IDA Paper P-3112) and investigate the utility of remote sensors in peacekeeping missions. In particular, the study team was interested in investigating and quantifying the impact of multiple sensor belts, extended sectors of coverage (beyond those proposed by Zirkle and Oelrich), and the deleterious effects of false alarms.

As a secondary purpose, the study team wanted to demonstrate the utility of distributed simulation as an analytic tool. Until recently, distributed simulation at IDA has been used principally as a demonstration vehicle. It was our intent to show that certain facets of distributed simulation are sufficiently mature to yield plausible results in free-play, interactive engagements.

In particular, the terrain database that supported the simulation (ModSAF version 1.4) was believed to be of sufficient detail to provide a level of realism not available in other media. This perceived realism was critical in the team's decision to use distributed simulation in an analytic application.

Objective

- Further investigate use of remote sensors in peacekeeping missions; examine impact of:
  - multiple sensor belts
  - false alarms (robustness)
  - variable ground coverage requirements
- Demonstrate analytic utility of distributed simulation

Chart 3 - Methodology

This task was conducted in a series of steps. First, a scenario that would be the basis for the simulation trials was constructed. (This scenario will be discussed in the next slide.) Next, several pilot test trials of the scenario were conducted using ModSAF and the sensor simulator. Results from the pilot test were analyzed, leading to some modifications of the basic scenario.

A matrix of trials for the "full-up" test was constructed after the pilot testing was complete. The test design specified a series of 16 ModSAF trials to be conducted in the IDA Simulation Center (see Chart 8, Test Design).

Next, test trials was conducted. Finally, the results from those trials were analyzed and a set of observations and conclusions were drawn.

Methodology

- Design scenarios based on DNA task
- Conduct pilot tests using distributed simulation (ModSAF)
- Analyze preliminary results from pilot test.
- Design “full-up” test
- Conduct matrix of trials
- Analyze results
- Draw conclusions regarding use of sensors
- Make observations about testing
- Draw conclusions regarding analytic utility of distributed simulation

Chart 4 - Pilot Tests

Before finalizing the design of our experiments, we conducted pilot tests to gain insight into mission issues and to learn the mechanics of conducting the experiments with SIMNET/DIS. The pilot tests simulated Red (attacking) infiltrators, represented by a squad of infantry, attempting to penetrate a 10-km-wide sector of a 30-km diameter perimeter around Sarajevo, Bosnia (see Chart 6, Scenario). The sector was located due west of the city, in mountainous terrain, with a road running north-south along the sector perimeter. A sensor belt was assumed to be emplaced parallel to and 400-m west of the road. A Blue (defending) mechanized infantry platoon was located at the center of the sector.[3] It moved along the road to intercept the Red infiltrators once the sensor belt detected them. The Blue platoon dismounted when it came within sight of the infiltrators, chased them down, and captured them on foot. We performed about 10 tests of this type. In addition, after observing Red infiltrators firing with little effect at the M-2s carrying Blue infantry, we also conducted some tests in which we used HMMWVs to intercept the infiltrators to investigate the effect of Red fire on unarmored vehicles.

In addition to the tests, we investigated Blue's use of airmobile infantry to intercept the Red infiltrators. We used a 20-km-wide sector of the Sarajevo perimeter adjacent to the south of the sector we used for the mechanized/motorized infantry tests. The sector largely consisted of mostly barren, rolling hills but contained no roads. Zirkle and Oelrich postulated the use of airmobile infantry to cover the same sector in their study.[4] The Blue force consisted of a dismounted infantry platoon and two utility helicopters.[5] The Red force consisted of the same dismounted infantry squad. All of the above tests allowed us to observe the interactions of forces that would occur during our full-up tests and to learn how to operate the ModSAF simulator better.

3 Zirkle and Oelrich used a motorized (truck-mounted) infantry platoon. Zirkle and Oelrich, pp. 92–93. We initially used a mechanized (M-2 mounted) platoon because truck-mounted infantry is not yet available in the ModSAF simulator.

4 Ibid., pp. 99–103.

5 We had to mock up an airmobile platoon because helicopter-mounted infantry is not yet available in ModSAF. In our tests we simulated mounting and dismounting by creating or deleting the infantry platoon at the location of the helicopters whenever the helicopters landed or took off.

Pilot Tests - Purpose

To gain insight into mission issues

To learn the mechanics of conducting distributed simulation tests

Chart 5 - Pilot Tests - Lessons Learned

We learned a number of lessons from the pilot tests which helped us conduct our full-up tests. First, Blue should not use soft-skinned vehicles or dismount to confront Red. Red fire was highly effective against the HMMWVs we used to simulate soft-skinned vehicles, to the point that Blue HMMWVs rarely survived for more than 30 seconds after Red detected and began to fire at them. Also, even when Blue confronted Red with a 4:1 advantage in dismounted squads, all of which were qualitatively superior to Red, Blue often took casualties, and on a few occasions Red eliminated the entire Blue platoon. Thus our results suggest that in an operation similar to our simulations, Blue should remain inside their armored vehicles and should engage Red with their vehicle-mounted weapons to minimize Blue casualties.

Second, we found that the Blue response team could cover more ground than predicted by Zirkle and Oelrich.[6] This was mostly because the Blue teams could detect the Red infiltrators at a much greater range than predicted, and because Blue had much better cross-country mobility with the M-2s we used in the mechanized infantry tests than with the trucks Zirkle and Oelrich postulated in their study. Thus it took longer for Red to escape by moving out of the range of Blue's sight, and Blue could reach the vicinity of the sensor that detected Red more quickly. This in turn meant that Blue could start farther away from Red and still intercept them.

In the airmobile tests, we also found that Blue could cover much more ground than predicted, primarily because of the speed of the helicopters.[7] Blue helicopters easily moved to a position along the sector boundary opposite the Red infiltrators before Red had even covered the distance between the sensor belt and the boundary (400 m). This suggests that airmobile infantry might cover a perimeter better than other type of forces. Airmobile infantry, however, still has the problem of confronting Red without the benefit of armored vehicles and thus is vulnerable to sustaining casualties as described above.

The third lesson we drew from the pilot tests was that two people could operate ModSAF (one commanding Red and one commanding Blue). We had assumed earlier that one additional person would be required to operate the ModSAF sensor simulator. Finally, we learned how to operate ModSAF better in terms of relating ModSAF unit orders to real-world movement and firing—essentially getting the ModSAF units to do what we wanted.

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6 See Zirkle and Oelrich, p. 97.

7 It should be noted, however, that Zirkle and Oelrich may have limited the sector covered by airmobile infantry to the area that contained no roads. They cite potential problems with relying on helicopters, and may have preferred ground units for covering the perimeter where practicable. See Zirkle and Oelrich, pp. 100–102.

Pilot Tests - Lessons Learned

Vehicle and personnel casualties

Red/Blue mission capapbilities

Number of operators required to conduct test

ModSAF operational realism and idiosyncracies

Database realism

Chart 6 - Scenario

The study team developed, as the basis for its study, a scenario consisting of an attempted infiltration of a hypothetical safe-haven boundary surrounding Sarajevo (roughly, a circle with a 30-km radius centered in Sarajevo). The scenario entailed a vehicle mounted peacekeeping team (mounted in four Bradley Fighting Vehicles) positioned along a 5- to 10-kilometer sector of the safe-haven boundary south of Sarajevo. One or two sensor belts, running the length of the sector, supported the peacekeeping operation. (The sensors were offset 400 m beyond the boundary in the case of one belt and 400 m and 1400 m in the case of two belts. Each sensor had nearly a 100 percent probability of detecting any target within 30 m. Sensors were deployed 60 m apart, essentially making it impossible for an infiltrator to pass through a belt undetected.). One infiltrator, a simulated dismounted infantry squad, and up to two false alarms (unarmed trucks or HMMWVs) attempted to penetrate the sensor belts and boundary and make their way toward Sarajevo. The objective of the peacekeeping team was to capture the infiltrator.

The geographic region in which the scenario took place differed from that in the pilot tests (approximately 25 km to the southwest of the earlier experiment). The reason for selecting a different setting was to take advantage of rougher terrain in which there was an absence of modern roads (in order to stress the capabilities of ground vehicles). If time had permitted, a second series of tests would have been conducted in the same area as the pilot tests for comparative purposes.

Scenario

- 30 km south of Sarajevo on safe-haven boundary
- Sensor belts deployed beyond boundary
- Infiltrator (dismounted infantry) attempts to penetrate boundary and approach Sarajevo
- Vehicle-mounted peacekeeping team uses sensor belt to detect and intercept infiltrator

Chart 7 - Full-Up Test

Each trial in the exercise consisted of two players, in the roles of opposing commanders, controlling simulated units on networked ModSAF workstations. One player (Blue commander) controlled the peacekeeping team from one workstation, while the second player (Red commander) controlled the infiltrator and false alarms. Each operated independently without knowledge of the other's intentions or position. A third workstation housed the sensor simulator's graphical interface and gave visual cues to the peacekeeper commander (Blue) whenever a detection occurred. (A fourth workstation, connected to the graphical interface, executed the sensor software.) The only other means for the peacekeeping team to detect the infiltrator was through visual contact as determined by the underlying simulation.

Trials began after the Red commander had chosen a penetration route and initiated movement of units (the infiltrator and, possibly, false alarms). The Blue commander would then activate the sensor belt or belts and begin monitoring the sensor workstation for some indication of the infiltrator.

When the sensor simulation indicated a detection (by a visual prompt on a map image), the Blue commander would give an order to his forces to proceed to a point where he estimated the penetrating unit would most likely be intercepted. The Red commander then began evasive maneuvers in an attempt to keep his infiltrator from being intercepted. The play of the game became the interaction of these two commanders to outwit each other using only ModSAF provided visual cues or prompts from the sensor screen.

All action in the simulation was recorded by software running on a fifth workstation.

“Full-up” test

- Setup
  - 2 players (opposing “commanders”)
  - 5 workstations
- Execution
  - placement of forces and selection of movement routes
  - activation of sensor belts (overlays)
  - initiation of intruder movement
  - peacekeeping team response
  - real-time data recording

Chart 8 - Test Design

The experimental plan was a 2^3 factorial design in which the principal factors were the number of sensors belts, sector width, and number of false alarms. Each factor had two test levels, referred to as 'high' and 'low.' The high level of factor 1, sensor belts, was 2, while its low value was 1. The high and low values of factor two were 10 km and 5 km, respectively. These values correspond to 200 percent and 100 percent of the widths recommended by Zirkle and Oelrich[8] for peacekeeping missions in the geographic area where the test was conducted. High and low values for the number of false alarms per trial were 2 and 0, respectively.

Each combination of the principal factors was tested twice, once with operator A playing the role of Blue Commander and once with operator B as Blue Commander. Since there are 8 representations of main effects, and 2 operator choices, a complete block of trials consisted of 16 tests.

8 IDA Paper P-3112, Chapter IV, *Safe Areas and Barriers.*

Test Design

- 2 levels of sensor belts
- 2 sector widths
- 2 levels of false alarms (multiple intruders)
- 2 operators/commanders switching roles
- 16 trials

Chart 9 - Test Design Matrix

The order in which the trails were conducted was selected by a pseudo-random number generator. For operational reasons, trials 1 and 13 were reversed. The sequence of trials was: {6,4,16,15,3,9,8,14,2,12,11,5,7,10,13,1}.

Test Design Matrix

Trial #	Belts	Sector (km)	False Alarms	Blue Cmdr
1	2	10	2	A
2	2	10	0	A
3	2	5	2	A
4	2	5	0	A
5	1	10	2	A
6	1	10	0	A
7	1	5	2	A
8	1	5	0	A
9	2	10	2	B
10	2	10	0	B
11	2	5	2	B
12	2	5	0	B
13	1	10	2	B
14	1	10	0	B
15	1	5	2	B
16	1	5	0	B

Chart 10 - Underlying Model

An analysis of variance was performed to test various hypotheses related to the principal factors and their interactions. The goal of this analysis was to determine the combination of levels of the principal factors that yields the most effective safe-haven barrier.

The statistical model[9] used in this analysis was:

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \varepsilon_{ijkl},$$

where y represents the measure of interest, μ,an overall mean, and τ, β, and γ are, respectively, the principal factors (main effects): number of belts, sector width, and false alarms. The error term ε_{ijkl} is assumed to be normally distributed, with zero mean and unknown standard deviation. the indices i,j,and k, assume two values (1 and 2) to indicate low and high levels of the main effects. The index l varies from 1 to 2 m, indicating observation number.

9 D.C. Montgomery, Design and Analysis of Experiments, Third Edition, John Wiley and Sons, 1991.

Underlying Model

- Model description
- Standard normality assumptions
- Hypotheses expressed in terms of model (mathematically)

Chart 11 - Test Results

Test results are summarized in the next series of charts. Measures recorded were the number of infiltrators captured and the length of time the infiltrator was pursued. As one infiltration took place per trial, the average number captured corresponds in some sense to a rate of mission success.

Test Results

- Captures (successes)
  - infiltrators caught by peacekeeping team
  - displayed by level of each factor
- Length of time required for capture
  - median time to intercept
  - displayed by level of each factor

Chart 12 - Average Captures (success rate)

When one sensor belt was deployed, the intruder was captured in five out of eight opportunities, or 62.5 percent of the time. When two belts were used, the success rate increased to seven out of eight, or 87.5 percent.

Similar results were recorded for the other factors. Namely, when sector width contracted 10 km to 5 km, the success rate also changed from 62.5 percent to 87.5 percent. Similarly, when false alarms dropped from two to zero, captures again increased from 62.5 percent to 87.5 percent.

Of course, these are not independent events. For example, the capture rate for the low level of sensor belts (one belt) is averaged over both sector widths and false alarm rates. Taking this into account, a standard factor analysis calculation shows that the changes in capture rate for these three principal factors is not statistically significant, at least not at the 10 percent level.

Average Captures (success rate)

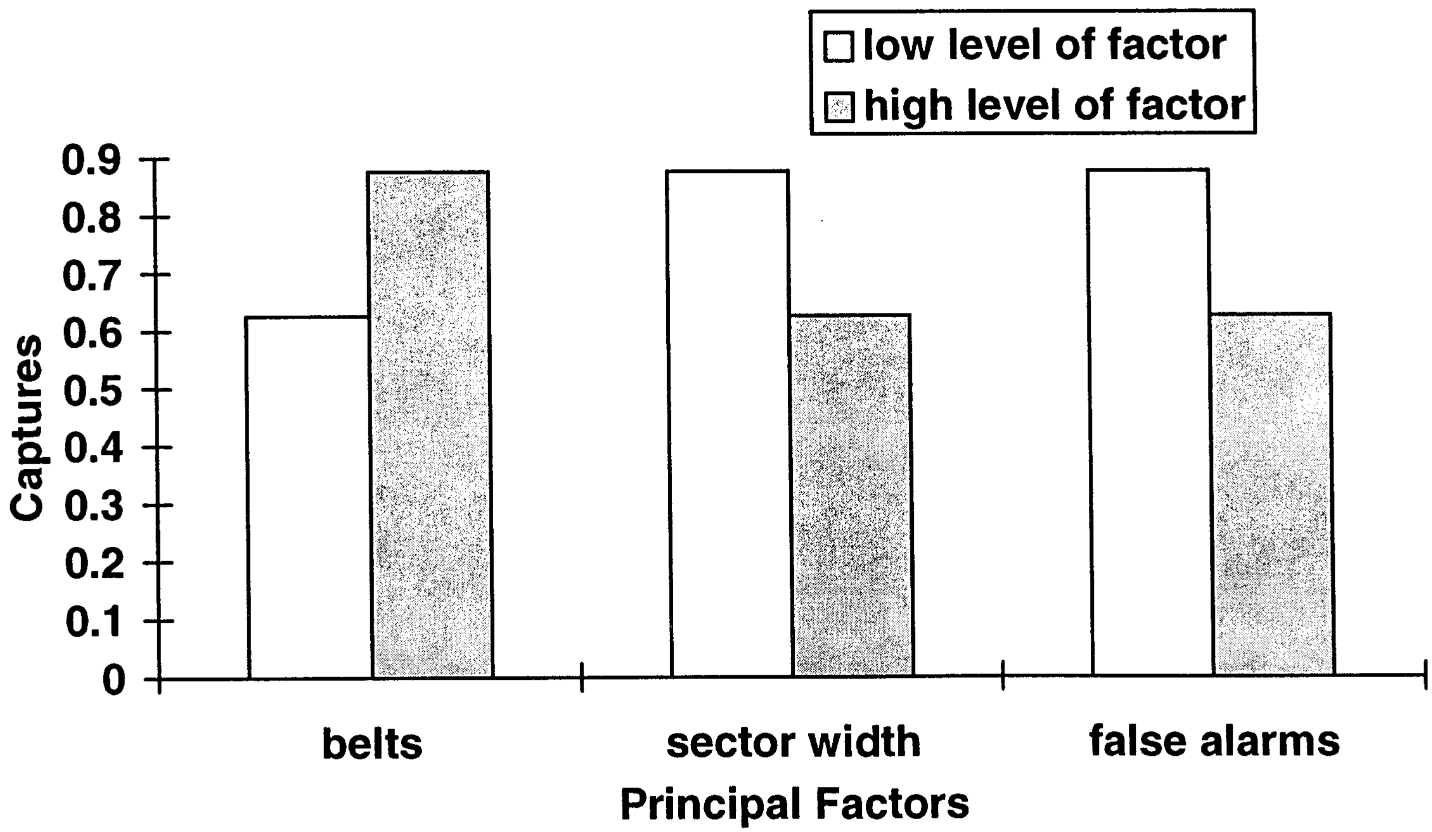

Chart 13 - Sector Width-False Alarm Interaction

Interactions between the principal factors—number of sensor belts, sector width, and number of false alarms—often provides insight into how outcomes are driven by combined effects or synergy. The first set of interactions examined are sector width and number of false alarms. The test design prescribed four trials with a 5-km sector and no false alarms, four with a 5-km sector and two false alarms, four with a 10-km sector and no false alarms, and four with a 10-km sector and two false alarms.

In the 12 trials comprising the first three pairings, the infiltrator was captured in all but one trial. However, in the last pairing, a 10-km sector and two false alarms, the infiltrator was captured only once. Thus, there appears to be a combined effect of a wide sector and a modest number of false alarms that causes the peacekeeping mission to fail. This is, of course, quite intuitive.

What is surprising, however, is that this effect is the only statistically significant interaction. Other pairings, such as sector width and number of sensor belts or sensor belts and false alarms, do not appear to have as great an impact on the capture rate.

One ramification that may be important to keep in mind is that a wide sector and a low false alarm always resulted in a mission success. This suggests that sector widths as originally designed may be conservative.

Sector Width-False Alarm Interaction

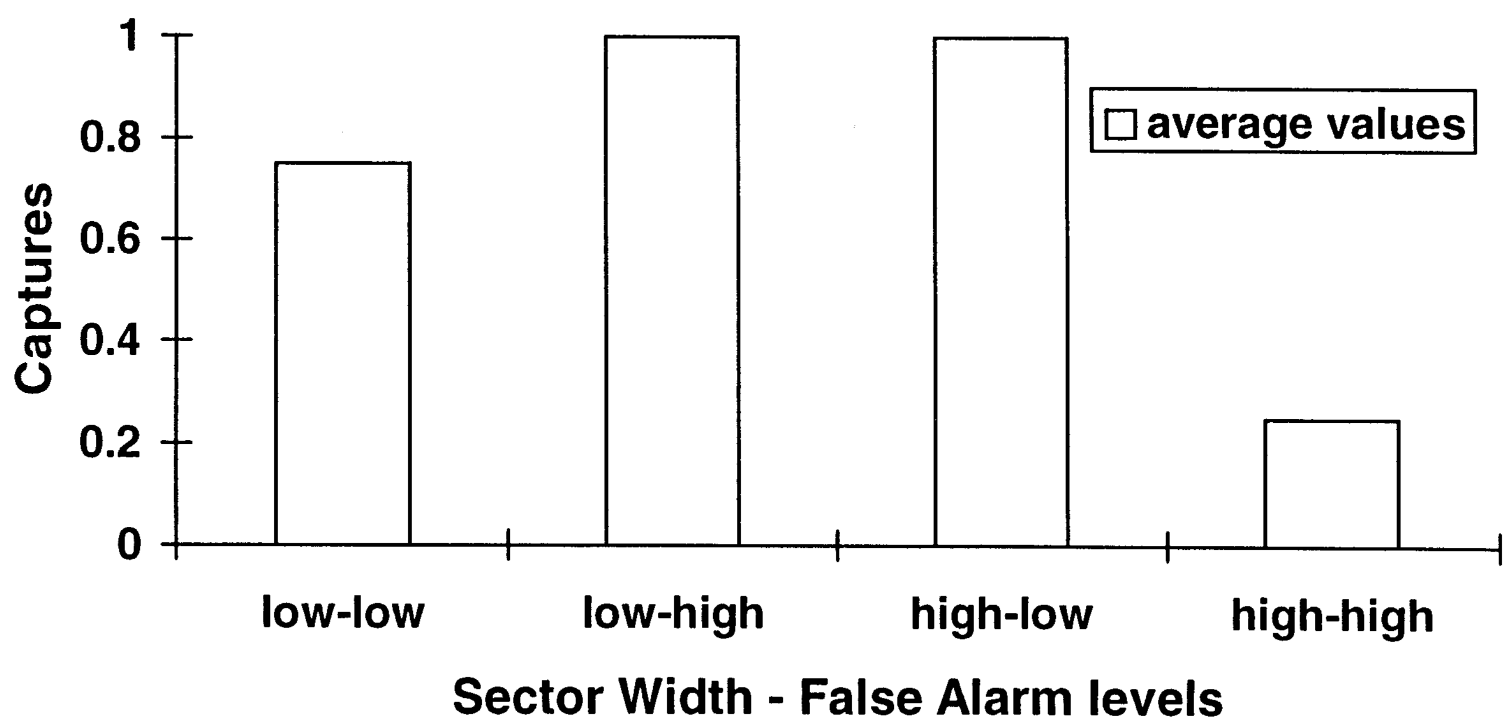

Chart 14 - Sector Width- Sensor Belt Interaction

When the sector width was 5 km, it was difficult for the intruder to pass through the sensors and avoid capture. This was true no matter whether one belt or more were deployed. The speed of the M2s, although variable depending on terrain, generally averaged 30 km per hour, while the dismounted infiltrator rarely exceeded 5 km per hour. This disparity in speed made captures a virtual certainty, despite the rugged terrain and limited visibility.

A point that should be kept in mind, however, is that the infiltrator did not always react in ModSAF in a way one might expect in real life. Instead of hiding in the grass, or climbing a tree to escape detection, for instance, the infiltrator would remain standing and, on occasion, give away his position by engaging the peacekeeping team with small arms fire or rockets. This aspect of ModSAF made the 'end game' less realistic than desired and probably introduced a certain bias.

Returning to the graph, wide sectors with one sensor belt only produced a 50 percent success rate. Because of the small number of trials, the factor analysis did not indicate that this was significant. Given the large change from small sector-two belts to wide sector-one belt, one cannot help but suspect, however, that further testing is likely to show a trend.

Sector Width-Sensor Belt Interaction

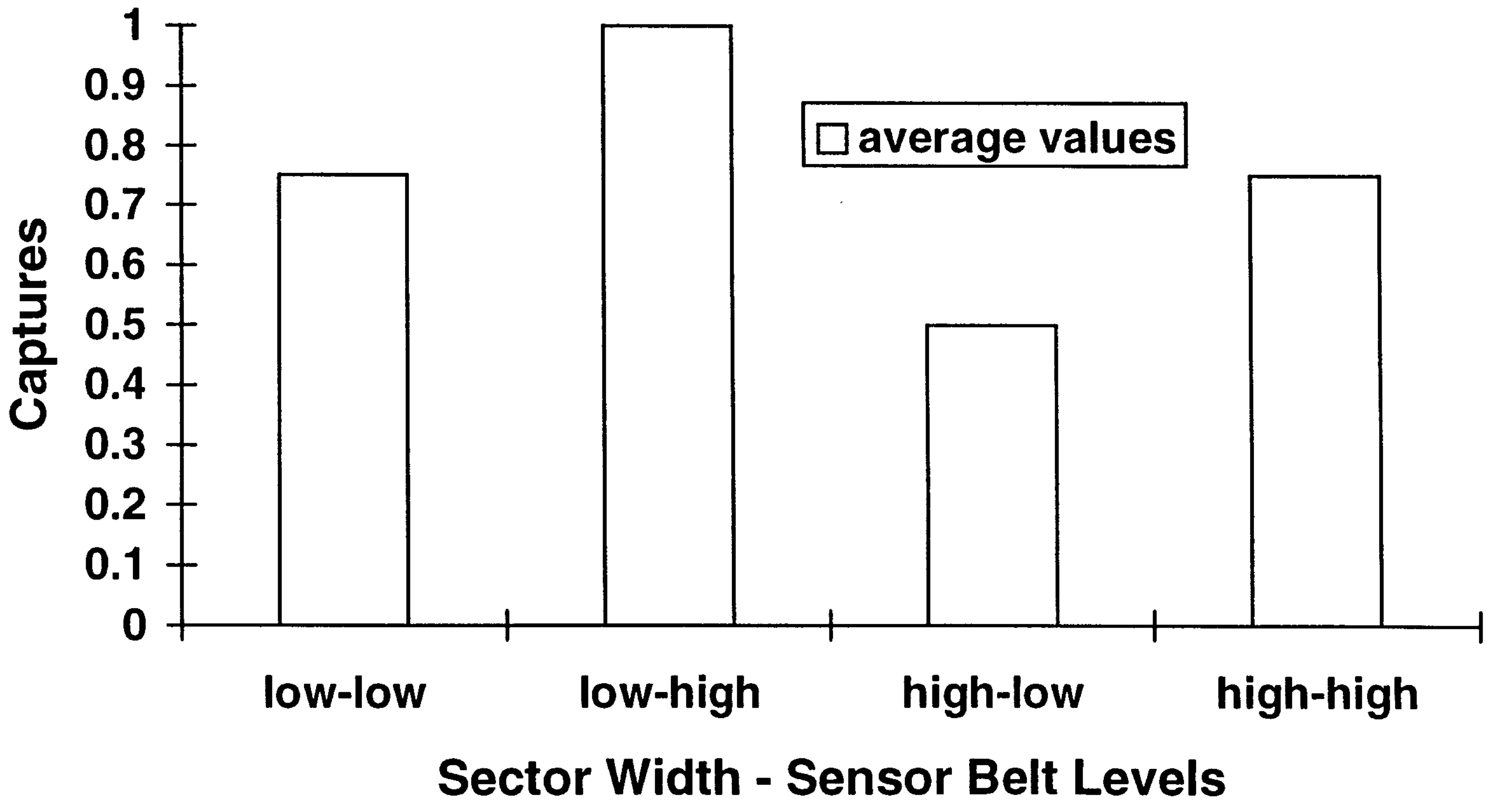

Chart 15 - Sensor Belt-False Alarm Interaction

The accompanying graph is similar to the preceding chart. It shows some variation and suggests the presence of trends that coincide with intuition. Namely, more belts and fewer false alarms produce better results (100 percent success when two belts are deployed and no false alarms occur, compared with 50 percent success when only one belt is deployed and two false alarms occur). However, as in the previous chart, the variations are not wide enough and the samples are too few to suggest that the interaction between sensor belts and false alarms is statistically significant.

Sensor Belt-False Alarm Interaction

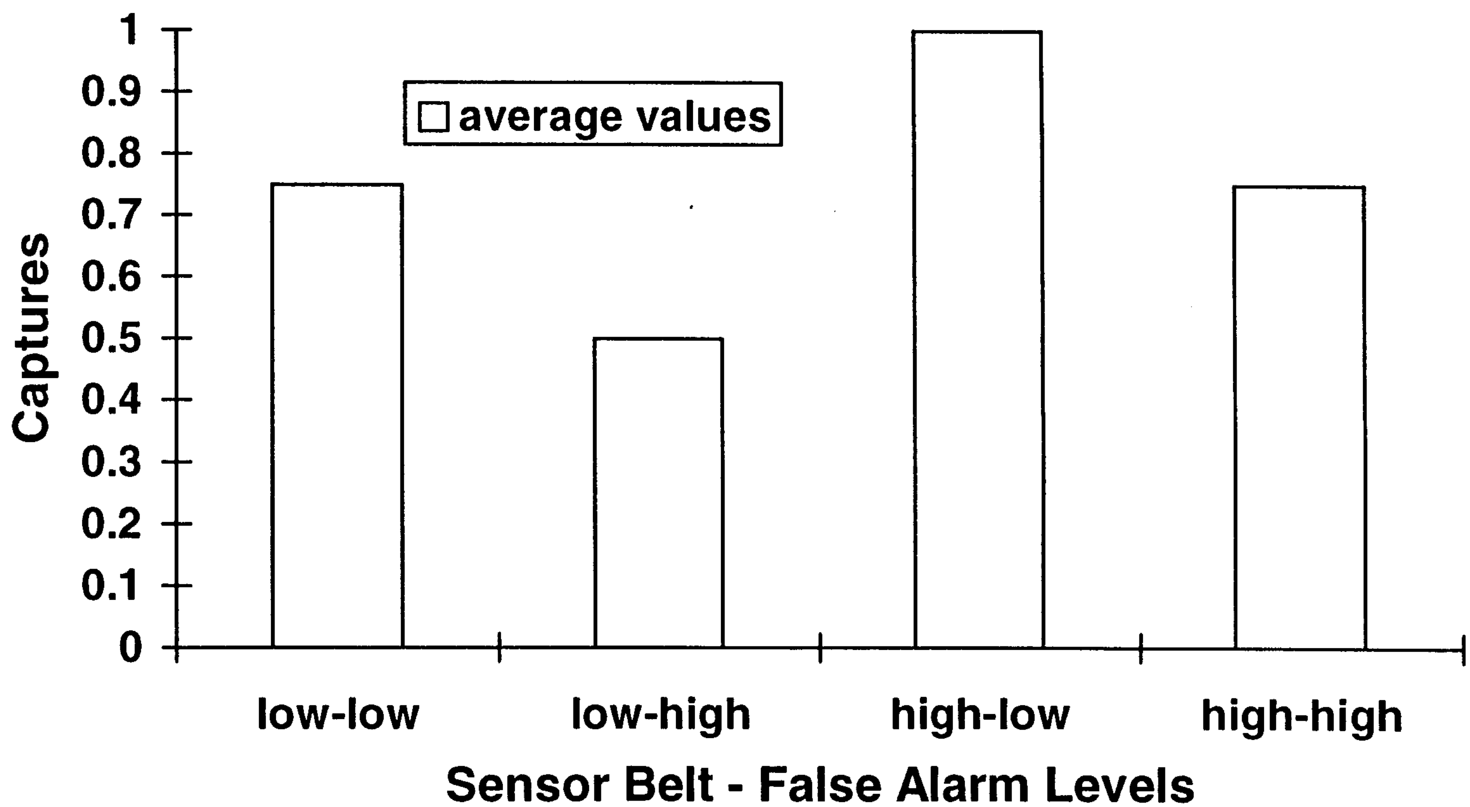

Chart 16 - Median Time in Pursuit

Another quantitative measure recorded was the amount of time required to capture the infiltrator. This measure is somewhat imprecise because the beginning of the pursuit was not sharply defined. Generally it was the time at which the infiltrator operator verbally informed the Blue Commander that his forces were "on the move." While this procedure undoubtedly introduces some variation in measurement, it is most likely less than one minute in magnitude.

From the graphs, it appears that the number of sensor belts induces only a marginal difference in median pursuit time. Indeed, the difference is only 1.5 minutes. On the other hand, median pursuit time increases 11 minutes when sector width increases from 5 km to 10 km. This is in keeping with a 30-km-per-hour vehicle having to travel an extra 5 km.

Similarly, pursuit time increases 8.5 minutes when the number of false alarms increases from zero to two. The numeric connection between the time increase and the number of false alarms is somewhat unclear, however. False alarms tended to precede the intruder and often were confined to the edges of the sector being played. This suggests that the time increase should be greater than the observed value.

Median Time in Pursuit

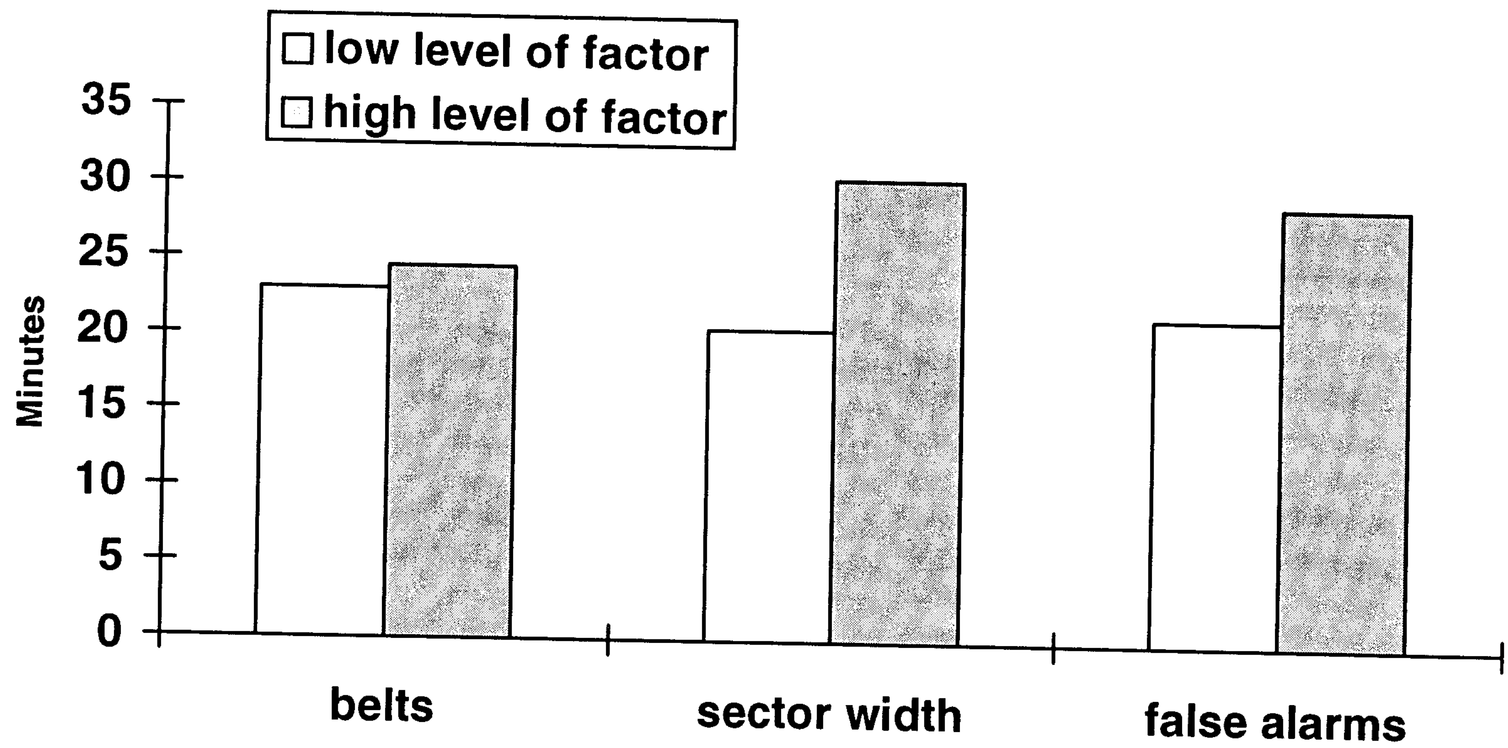

Chart 17 - Data Analysis

To summarize the results of the previous data slides, some improvement occurs when the number of sensor belts is increased from one to two; however, the amount of improvement is not great enough to assert that the observed increase is anything other than a random fluctuation. A similar statement holds for the other two factors, sector width and number of false alarms.

A somewhat more interesting story appears when one examines the interactions among the principal factors. The success rate associated with narrow sectors does not show much sensitivity to false alarm rates or the number of sensor belts deployed. While there is some apparent interaction between the number of belts and the false alarms, it, too, is not statistically significant. On the other hand, these trials do indicate a strong deterioration in mission success when a large number of false alarms occur across the wider sector. This appears to hold whether one or two sensor belts are played. One might suspect that it is too easy for an infiltrator acting in concert with, or merely taking advantage of the presence of, other penetrators to time his incursion in such a manner that the peacekeeping team will be too far to one end of the sector or the other to capture someone in such hilly and forested terrain.

Indeed, the presence of additional belts may not help under these circumstances. A belt placed a significant distance from the team's initial position gives the infiltrator a mechanism with which to deceive the peacekeepers (and may also add to the number of false alarm detections). For example, since infiltrators in these trials knew the approximate location of the sensor belts, it was possible for the infiltrators to cross the outer belt, then travel parallel to the belts for some distance before crossing

the inner belt. This sequence of detections would give the peacekeeping team both a false start and an ambiguous indication of the number of penetrations taking place. (Was it the same infiltrator, or had an earlier detection gone unnoticed, and was this an indication of a second crossing?)

Increases in pursuit time were noticeable for larger sectors and higher false alarm rates. Pursuit time was not affected by number of sensor belts, however. This may have resulted because of the effect mentioned in the above paragraph, or, possibly, because the Blue commander was aware that he was vulnerable to this sort of deception. Consequently, he may have held his forces in reserve until he was more certain of the infiltrator's path as indicated by a second detection.

Data Analysis

- Sensor Belts
  - inconclusive: slight indication of some benefit in adding additional belt
  - requires further testing
- Sector Width and False Alarms
  - indication of strong interaction when false alarm rate is high and sector width is large
  - further testing may provide insight

Chart 18 - Conclusions Regarding Use of Sensors

While we performed a limited number of trials, we can draw some general conclusions about the usefulness of sensors in a barrier or safe-haven peacekeeping missions like the one we simulated. First, we found that the sensors did, indeed, allow Blue to intercept Red most of the time. Only in the cases with wide sectors, and in few of those, did any infiltrators escape. Furthermore, the sensors enabled Blue to cover much more ground than they could have if they had relied on visual detection alone. Blue covered 10-km sectors fairly effectively and covered 5-km sectors very well. They would not have been able to cover either very well without the sensor belts.

Second, the tests suggest some force employment strategies that might be effective for Blue. In particular, in the cases in which false alarms occurred, splitting the Blue infantry platoon to enable Blue to confirm sensor detections as real or false would probably have enabled Blue to intercept all of the Red infiltrators. Typically, where Red escaped, false alarms would draw Blue off to one end of the sector, and even though Blue moved much faster than Red, Blue could not get back to the other end of the sector in time to catch the Red infiltrators, even though the sensors had detected them. Because Red fire was almost totally ineffective against the Blue vehicles, Blue could have confronted a Red squad with a single vehicle and still killed them or kept them in sight until the rest of the platoon had arrived to kill them.

Conclusions Regarding Use of Sensors

- Utility in Peacekeeping Operations
  - impact on captures
- Response Team Deployment Strategies
  - splitting teams may be an efficient strategy against small numbers of infiltrators
  - splitting teams may help ‘filter’ false alarms

Chart 19 - Observations on Testing

During our experiments we observed elements of ModSAF and SIMNET/DIS behavior that might be areas for future improvement. First, some elements of ModSAF behavior were simplistic or unrealistic. In particular, we observed a few instances where units detected each other at ranges over 3 km and where units "saw through" patches of woods to detect units inside or on the other side, at ranges over 1 km. We believe that given the nature of the terrain we were using, such results were unrealistic. We did not identify the cause of the behavior, but we do know that patches of woods in ModSAF are represented as "canopies," under which units can observe each other without interference from intervening "trees." Nevertheless, if a future ModSAF user is performing a simulation where unit detections at extreme ranges could lead to incorrect conclusions, he or she should be aware that such "detections" may not represent reality.

Second, we found that while the sensor simulator we used to represent the sensor belts was reliable, it was cumbersome to operate. In particular it was impossible to de-activate a sensor belt after it had been activated. Thus, when the test matrix called for a "one-sensor belt" trial to follow a "two-sensor belt" trial, it was necessary to completely terminate the sensor simulator and then restart the simulation "from scratch." Also, it was not possible to transfer electronic overlays between ModSAF and the sensor simulator. This made it difficult to display precisely the same information (safe haven boundaries or sensor belt locations) on both workstations.

Finally, we found the SIMNET/DIS network to be problematic at times; occasionally the workstations we were using to run the simulations would shut down or lock up without explanation, and sometimes the workstations were slow to respond to user commands. While the slow response was explained by IDA SIMCENTER personnel as being caused by the heavy load placed on the network by all of the users, both problems made it difficult to run simulations quickly. The lock up problem in particular caused us to waste a number of ModSAF sessions repeating simulations that had been interrupted.

Observations on Testing

- ModSAF behavior
  - simplistic
  - long-range detection/engagements unrealistic
- Sensor Simulator
  - reliable
  - cumbersome
- Network traffic and responsiveness
  - sometimes unworkable

Chart 20 - Conclusions Regarding Utility of Distributed Simulation

Our experimental results and our experiences with ModSAF and SIMNET/DIS show that DIS can simulate small unit missions and can enable operators to repeat simulations to explore mission options or to obtain statistical validity. We successfully simulated a potential real-world small unit mission and varied the conditions under which the mission was carried out, to estimate the effects of the conditions on the outcome of the mission. Our statistical analyses show that even with the limited number of tests we ran, we obtained statistically significant results. Thus DIS could be valuable as a tool to use in future analyses involving small unit actions.

In addition to enabling one to determine the effects of previously identified conditions on mission outcome, the use of DIS may illuminate phenomena previously undiscovered through qualitative or quantitative theoretical analysis. Because the simulators contain highly detailed models of unit interactions with other units and with terrain, one may observe phenomena that a less detailed analysis might not predict. This is not a critique of theoretical analyses, but merely a recognition of the capabilities one can build into computer simulations. In our experiments, this happened when we discovered that Blue units could cover more ground than Zirkle and Oelrich had predicted. The intervisibility model in ModSAF showed that Blue could detect Red at longer ranges and thus had more time to move to intercept them, therefore covering more ground.

On the other hand, a lack of accuracy in the simulation may, in some cases, limit the extent to which one can draw conclusions about the real world. Before confirming the identification of new phenomena, one should be sure that the phenomena are representations of reality and not artifacts of the simulation. Our tests illustrated this point when we observed units detecting each other at extreme ranges and through patches of woods. Those events were not realistic, so we are not reporting them as findings of our study, although we are identifying them as evidence of potential shortcomings of ModSAF. Nevertheless, if one takes a hard look at any counterintuitive events that occur during a simulation, one should be able to filter out the results of artifacts and still find the simulation to be a valuable analytic tool.

Conclusions Regarding Utility of Distributed Simulation

- DIS can simulate small unit missions and can enable operators to repeat simulations to explore mission options or to obtain statistical validity
- Use of DIS may illuminate phenomena previously undiscovered through qualitative or quantitative theoretical analysis
- On the other hand, a lack of accuracy in the simulation may, in some cases, limit the extent to which one can draw conclusions about the real world

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Dennis F. DeRiggi, D. Sean Barnett

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Institute for Defense Analyses
1801 N. Beauregard Street
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Small peacekeeping teams patrolling remote sectors of a proposed safe-haven boundary have a substantial likelihood of mission success under a variety of conditions. In particular, when the sector width is approximately 5 kilometers wide, a vehicle-mounted team assisted by one or two sensor belts deployed beyond the safe-haven boundary is virtually assured of intercepting infiltrators even in the presence of a modest number of false alarms. However, extending sector width to 10 kilometers leads to mission failure even in the presence of a second belt of sensors.

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