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Sensors As Confidence Building Measures: A Demonstration Using a Combat Simulation

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Preface

Numerous combat simulations have been developed and used to study the consequences of alternative force structures, analyze weapon performance, and train combat force commanders. These same simulations can, with minor modifications, be used to study a suite of arms control issues. To demonstrate this point, a modification of the LLNL Joint Conflict Model (JCM) was used to explain the utility of unattended ground sensors (UGS) as confidence building measures (CBMs) in the context of a regional arms control situation.[†] It was shown that existing simulations (in particular, JCM) have the functionality necessary to easily and readily address regional arms control issues in a meaningful fashion.

Introduction

Efforts are underway to encourage and support CBMs that could, in principle, reduce the potential for future regional conflict. An example of such a measure is the introduction of technology that could permit a significant reduction in military presence at border areas without loss of national security. This task explores the utility of a constellation of UGS to replace the early tactical warning function provided by troops monitoring a border area. The exploration involves using a combat simulation, modified appropriately, to illustrate the viability of the concept. Such a simulation tool could also be used to examine sensor suite effectiveness issues and broader questions about sensor suite architecture.

The demonstration is sited at a portion of the UN-patrolled demilitarized zone (DMZ) between Israeli Frontier Forces and Syrian forces in the Israeli-occupied Golan Heights. A constellation of UGS composed of seismic, magnetic anomaly, and imaging infrared sensors was deployed in and around the DMZ. For the purpose of the demonstration,

an attack by a Syrian force is postulated, one reminiscent of the attack during the 1973 Arab-Israeli War. The demonstration illustrates that military traffic can be distinguished from commercial traffic and that using a sensor constellation rather than frontier forces provides at least as much tactical warning.

It should be noted that the situation in the Golan Heights today is different from that of 1973. There were no UN troops on the Golan Heights until after the 1973 war. Also, in 1973 Syria had the backing of the Soviet Union and was fighting in coordination with Egypt. The current quiet on the Golan Heights could lead Arabs and Israelis to conclude that the military situation is stable and that there are more important problems to address. Nevertheless, the scenario, which was chosen to illustrate the utility of a combat simulation to show the potential utility of UGS deployments as CBMs, is founded on historical fact.

This paper describes the sensors chosen, why they were selected, and how they were modeled in the simulation code. Results of test demonstrations are described. Finally, suggestions for further work are offered.

Purpose

History suggests that disengagement of forces is often the first step along the path to normalization of relations and ultimately to peace. A dilemma is that often after the cessation of hostilities, both parties mistrust each other and are motivated to maintain military forces along border or armistice lines. Unwillingness to eliminate the tactical warning provided by these forces is a strong factor. The premise of this work is that appropriate sensors can provide adequate tactical warning and thus remove one important consideration for frontier force retention. Thus such a sensor deployment could be considered a confidence building measure. A necessary condition to such a deployment, however, is to convince decision makers on both sides of the border that the suggested sensor deployment could actually work as advertised. The purpose of the work reported here is to use a high-resolution sim-

[†] Funding for this work provided by the U. S. Department of Energy, Office of Nonproliferation Policy.

suggested sensor deployment could actually work as advertised. The purpose of the work reported here is to use a high-resolution simulation to illustrate how such a sensor deployment might work by showing how tactical warning can be retained with an appropriate deployment and also to illustrate how difficult it would be for either side to evade the sensors.

Methodology

The JCM combat simulation was modified to model a set of UGS reporting to a data center.[†] The modified simulation was dubbed the Sensor Simulation Model (SSM). A combination of seismic, magnetic anomaly, and imaging infrared sensors was used. Simple engineering models that represent sensor performance were developed and incorporated into the simulation. The scenario was sited in the occupied Golan Heights where Israeli Frontier Forces and Syrian forces face each other across a narrow DMZ, which is patrolled by UN forces (see Figure 1). It was postulated that both countries would know where the sensors were deployed and either both would receive identical reports from the sensors or they would jointly man the center where the sensors would send their reports. Any sensors used in the scenario would be those either commercially available now or in the immediate future—no advanced sensors would be considered.

SSM was used to examine several questions:

- Can deployed sensors provide tactical warning of a military attack at least as quickly as could frontier forces?
- Can sensors distinguish between normal commercial traffic and a military attack?
- Would attempts by an attacking force to evade sensors significantly extend the time to initiate the attack, which would reduce the opportunity for surprise attack and increase the opportunity for

national technical means to detect the incipient attack?

Figure 1. Region of interest. The Blue and Red lines delimit the DMZ for the Israeli and Syrian sides, respectively.

Sensor Descriptions

The sensors assumed available for deployment are based on a suite of seismic, magnetic anomaly, and imaging infrared sensors connected through a neural net. The neural net is not modeled, but sensor detections displayed in the simulation reflect what would be reported if the neural network was functioning. These sensors are in the final stages of commercialization for deployment on the US-Mexican border. Performance data was provided by specialists.[†]

Seismic sensors detect vibrations in the ground and air. The sensors used in this ef-

[†] SSM is a variant of JCM Version 2.16.

[†] Dave Fuess and Dick Emmert, LLNL, private communication.

fort are able to discriminate between foot traffic, wheeled vehicle traffic, and armored vehicle traffic. Detection ranges vary with foot traffic detection being the smallest and armored vehicle detection being the greatest. Detector performance was modeled with a simple algorithm based on detection range. Timing is a consideration with these sensors. These sensors collect data over a specified period of time (50 seconds used), process data for a few seconds, and then transmit a report. If something is detected during the period, no report is made until the detection event ends. If the event does not end by the end of the report period, then a report is made.

In the simulation, whether a detection event reports one or many items detected is indicated by using different symbols to display the detection (refer to Figure 2). If a detection event identifies a single item, then an icon showing the silhouette of the type detection (foot, wheeled or armored) is displayed at the sensor location, and a circle is drawn about the sensor. The radius of this circle equals the maximum detection range for that type of detector. If a detection event reports more than one item, the icon displayed is the military symbol for the type detection with the greatest range. The circle is displayed as above. Each sensor reports every minute. If a sensor does not report, it is assumed destroyed and that fact is known. (The issues associated with sensor destruction were not examined and so a display for this possibility was not developed.)

Magnetic anomaly detectors sense the presence of magnetization and thus the presence of ferromagnetic materials, like iron. They cannot distinguish between a small magnetic source near the detector and a larger magnetic source much more distant and thus are not suited for providing range to detector information. These detectors are very good for indicating the presence of large amounts of metal, such as is found in large military vehicles. A single detector is not very good for indicating direction of movement, but several detectors working in conjunction can indicate direction. In this work, detections by magnetic sensors are displayed by a

ray drawn from the detector toward the detected target (refer to Figure 2). Only the ray is shown because the detector cannot tell how far the detected target is from the sensor or what has been detected.

Figure 2. Display of detections by individual seismic sensors. The example shown is the passage of the main Syrian force through the sensor band.

Infrared imaging detectors were straightforward to represent in SSM since they did not require a new algorithm. The detectors represented here are self-cued and can provide a crude image of the object passing through their field of view. Figure 3 shows what a tank looks like imaged by one of these detectors. Detections are displayed in the simulation using an icon showing the silhouette of the detected item where it was imaged. These detectors have very short detection range, on the order of 150 feet, and a narrow field of view (four degrees).

Figure 3. Infrared image of a tank.

During the simulation, detections by all sensors are displayed. To simplify viewing, the screen is erased every two minutes. Figure 4 shows the result of a single truck detected by the seismic sensor in the band that crossed the road (circle and silhouette) and several wheeled vehicles and tracked vehicles moving past the pair of imaging sensors located adjacent to the road.

SSM Modifications

Three key modifications were made to JCM to create SSM:

- Models for seismic and magnetic anomaly UGS were included in the simulation. The infrared sensor model was modified to support the specific UGS selected. The previous Sensor Description paragraphs discuss the capabilities of the sensors modeled.
- The displays were enhanced to include sensor reports. The previous Sensor Description paragraphs discuss the displays used to depict the sensor reports. The simulation was also modified to clear and update the report displays each reporting period.
- The simulation was modified so both sides in the simulation displayed the UGS locations and received and display all sensor reports.

The modifications described above were accomplished quite easily. Significant savings were realized by making modifications to an existing combat simulation rather than writing a new simulation:

- Software to describe terrain and manmade features (and accompanying editors) already existed. Using digitized elevation data, taken from Defense Mapping Agency (DMA) sources, is preferable to using a map background. Although map backgrounds sometimes look better on computer displays, they share no information with the simulation. An

Figure 4. Display of detections by seismic and infrared imaging sensors.

actual terrain representation explicitly accounts for elevation gradients, which affect mobility, and terrain and foliage shadowing, which affect sensor performance.

- Software to describe vehicles and other platforms already existed. This permits a highly detailed definition of such entities. Detailed definitions are important if the postulated sensors are to truly reflect expected performance. Physical models of sensor performance can not hope to succeed if the objects they are to detect do not possess the detectable attributes. Although one can easily draw a picture of a tank and direct it to move across the screen, without a detailed description behind it, it is just a picture and cannot provide a correct depiction of whether, when and where it would be detected.
- The architecture to accept sensor input and output already existed. Although algorithms for sensors not already included in the simulation needed to be developed, the basic architecture was already there, vastly simplifying the task of incorporating new sensor types.

Many other features of the combat simulation could be used intact, thereby minimizing

the amount of effort that needed to code software (new or modifications). A partial list of pre-existing software features includes: graphical displays, features to easily position sensors, features to define vehicle movements before and during simulation execution, and extensive data output for post-game analysis.

Demonstration Scenario

Early discussions with the sponsor led to siting this demonstration scenario in the Middle East. Specifically, the location chosen for the simulation is a 40-km by 40-km area centered on the town of Quneitra in the occupied Golan Heights of Syria. This location was chosen because it was an objective of a Syrian armored column during the 1973 Arab-Israeli War. Moreover, this terrain is well-suited to a deployment of the types of sensors discussed above because traffic is fairly well restricted to the Damascus-Quneitra road because of extensive lava outcroppings that make off-road travel (even by armored vehicles) very difficult. Sensors were deployed in bands of sensor strings covering an area about two kilometers wide and 100 meters deep. Figure 4 shows where the bands were located in the simulation. To simplify the demonstration, sensors were not emplaced on the Israeli side of the DMZ. For reference, the figure also shows the armored column.

Each band of sensors consisted of 12 strings in an overlapping pattern. Sensor strings themselves were composed of three seismic and four magnetic anomaly sensors interspersed (see inset in Figure 5). Pairs of imaging infrared sensors were located on both sides of strings that cross roads and are adjacent to the roads. JCM (and thus SSM) permits several "sides" or independent views from a side's perspective in the simulation. Each view shows the things owned by that view (*e.g.*, forces, sensors) and what is detected or seen by those things. Thus, for instance, a view that had a tank and an imaging detector would display on its screen the tank, the imaging detector, everything that the tank crew "sees" and everything

imaged by the detector. Four views were used in this scenario: one for the Israeli forces, one for the Syrian forces, one for the unattended ground sensors, and one for the civilian traffic. SSM had been modified so that whatever the sensors' detect would also be displayed on the Israeli and the Syrian views.

As suggested above, SSM permits the presence of noncombatants in the combat simulation. This feature was used to represent commercial truck traffic moving along the Damascus-Quneitra road intersecting the sensor fields. To clearly indicate what the detection of civilian traffic would look like on the screen, the Syrian force was artificially stopped (just outside of the reach of the sensor field) for the first five minutes of the demonstration. Thus only civilian traffic passed by the sensors.

In this scenario it was assumed that Syria sent an armored division into the occupied Golan Heights, ostensibly to regain control of the territory. The advance guard (a tank brigade) of a Syrian tank division was put astride the Damascus-Quneitra road, much like the case in the 1973 Arab-Israeli War. The movement of this tactical unit was modeled with sensors present and without sensors present. At the same time, civilian trucks were modeled moving along the road network. When sensors were not emplaced, a series of Israeli Frontier outposts were assumed to be manned along the Blue Line to provide tactical warning. These posts were located one kilometer apart. We assumed these surveillance posts were ten meters high and manned by soldiers with 8X field glasses.

An excursion was conducted where the sensors were emplaced as described, but the Syrian brigade, knowing where the sensors were located, avoided them by choosing a route of march north of the sensors and then south after passing through the DMZ. For this excursion, trafficability of the area north of the Damascus-Quneitra road was assumed identical to that of the road vicinity itself.

Figure 5. Location of the sensor bands in the simulation. The Syrian armored column is depicted as the red symbols at the top right (each symbol generally represents a company-sized element). This represents a 40-km by 40-km area. The inset is a schematic showing the arrangement of the seismic and magnetic sensors in each sensor string.

This is not correct. Consequently, the delay caused by taking this detour is shorter than it would actually be.

It is worth a few words to discuss the broad applicability of SSM and its ease of use for other scenarios. If one has already described

the sensors of interest, it is a simple matter to apply them to completely different geographic regions. Only three things differ from region to region: the terrain description, the "order of battle," that is, the representation of the activities the sensor are designed to detect such as tanks, trucks, factory emission

plumes, troops, drug runners, *etc.*, and the operation of the force to be monitored. Elevation data for the world is available from DMA on CD-ROM. The procedure of going from CD-ROM to a completed terrain file for SSM takes a few days (actual time depends on the amount of detail needed). In fact, the most time-consuming step is obtaining maps or photos so that foliage, rivers, and manmade features can be incorporated. Defining a new order of battle is often a matter of changing a few numbers in a data table. Incorporating the operations (orders) of the force to be monitored can generally be accomplished in a few days given that the operations are understood. Our experience is that a scenario can be readied in one to two weeks—and possess all the important physical fidelity. Simple scenarios or excursions from existing scenarios can be readied much quicker.

Scenario Results

Civilian traffic is distinguished from military movement by several features. The most dramatic is that the sheer number of vehicles, and therefore the number of detections, is significantly greater for the military movement. Civilian traffic is virtually restricted to the roads proper, but flank security elements associated with tactical military movements are often off the roads on both sides. Magnetic and seismic sensors can distinguish between wheeled vehicles and tracked vehicles and although there are some tracked civilian vehicles (*e.g.*, bulldozers) there are not many of them. Finally, the pictures from the imaging sensors are clear enough to be able to unambiguously identify many common military vehicles (*e.g.*, tanks, armored personnel carriers, artillery).

When sensors are not used, the vanguard of the invading Syrian brigade is detected at the Red Line at roughly 4.5 kilometers from the outposts on the Blue Line. This occurred at roughly 20 minutes into the simulation. When sensors are used, the brigade is detected at the first sensor line crossed. In this demonstration, that corresponded to a dis-

tance of roughly 12 kilometers from the Blue Line. This happened at five minutes into the scenario (*i.e.*, almost immediately upon the Syrian force being permitted to move), thus providing the Israeli forces with 15 minutes additional warning time. It must be noted, however, that the positioning of the sensor lines in this demonstration was arbitrary. Had sensors been located further east, the attack would have been signaled that much sooner.

In both of these cases, the Syrian force began to move at five minutes on the simulation clock. The force took approximately 20 minutes to reach the Red Line, some 15 minutes more to reach the Blue Line, and another ten minutes to reach the outskirts of Quneitra.

In the avoidance scenario, the Syrian force took approximately 35 minutes to reach the Red Line at the road heading east-west to the north of Quneitra. From that point it took ten minutes more to reach the Blue Line and another 15 minutes to reach the road heading south. The force reached the outskirts of Quneitra at roughly an hour and a half into the scenario. Thus, taking the route to avoid the sensor fields imposed (in this simulation) an additional 50 minutes of travel time.

It should be noted that this is an extremely conservative result. The tactical difficulty of turning a large military force from a road to travel cross-country, turning at a designated point to continue cross-country movement and turning again onto another road was ignored. In the demonstration, the force executed these turning maneuvers without missing a beat. Moreover, the speed of the force during the cross-country movement was not degraded compared to that of the force moving parallel to the road. Finally, in reality, the Syrian force **could not** maneuver off the road at this location. The difficulty of negotiating the terrain (lava outcroppings) is so severe that the Syrian force would be restricted to movement along the Damascus-Quneitra Road, the route actually used in 1973.

Finally, it is important to note that experts on the sensors reviewed how the sensors were deployed and modeled. They agreed that the representation was reasonable.

Conclusions

Although one can always write a new simulation specifically tailored to the application at hand, that is often an expensive and time consuming proposition. This work has demonstrated that existing LLNL simulations can be rapidly and economically modified to satisfy the simulation requirement.

The demonstration described in this report illustrates several points. A constellation of sensors can be deployed that will be able to detect large military movements and distinguish them from normal commercial traffic. Moreover, the sensors can accomplish this before Frontier Forces manning border outposts could. Furthermore, the sensors are largely unaffected by line-of-sight interruptions, which could significantly degrade what border outposts would be able to see. The types of sensors used in this demonstration are suited to regions where movement is fairly restricted. Otherwise a large number of sensors must be deployed to provide adequate coverage. Requirements for additional sensors impact installation and maintenance costs.

This work has illustrated one example where an existing, high-resolution combat simulation can be modified slightly for application to arms control issues. The example described in this paper is the examination of the utility of UGS in the context of a regional arms control situation. In this case, the combat features of the simulations were not necessary. Instead, the graphical interface, the high resolution terrain representation, and the ability to introduce and control forces (Syrian brigade and civilian truck traffic) were the important elements.

Future plans

Although there are no immediate plans to continue this work, a number of possibilities

exist. The simulation could be used to examine alternative architectures, in terms of sensor types and their combinations, for a sensor deployment to support the mission discussed in this paper. It also could be used to examine cost and effectiveness trade offs of the alternatives. For different scenarios, SSM could be used to illustrate the viability of garrison and portal monitoring for selected treaty regimes. A tool such as SSM also has application in examining the utility of several potential missions that could be assigned to unattended ground sensors, using UGS to cue airborne sensors, for example. Finally, SSM could be used to examine potential countermeasures to UGS.

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