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Security Modeling for Maritime Port Defense Resource Allocation

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Summary

Redeployment of existing law enforcement resources and optimal use of geographic terrain are examined for countering the threat of a maritime based small-vessel radiological or nuclear attack. The evaluation was based on modeling conducted by the Savannah River National Laboratory that involved the development of options for defensive resource allocation that can reduce the risk of a maritime based radiological or nuclear threat. A diverse range of potential attack scenarios has been assessed. As a result of identifying vulnerable pathways, effective countermeasures can be deployed using current resources.

The modeling involved the use of the Automated Vulnerability Evaluation for Risks of Terrorism (AVERT®) software to conduct computer based simulation modeling. The models provided estimates for the probability of encountering an adversary based on

allocated resources including response boats, patrol boats and helicopters over various environmental conditions including day, night, rough seas and various traffic flow rates.

Introduction

Redeployment of existing law enforcement resources and optimal use of geographic terrain are examined for countering the threat of a maritime based small-vessel radiological or nuclear (Rad/Nuc) attack within maritime port areas. The evaluation was based on modeling conducted by the Savannah River National Laboratory (SRNL). The focus is on the maritime domain, namely the inlet or harbor approach to strategic port facilities. Current security tactics include a show of force through routine security patrols. However, more efficient Rad/Nuc interdiction relies on targeted areas for security patrols to encounter, detect, and identify the illicit transport of Rad/Nuc materials.

Various tactical, deterrent, and mitigation strategies to counter a terrorist Rad/Nuc attack within a maritime port were evaluated for effective defensive resource utilization. Normal maritime baseline operations as well as surge defense strategies were modeled using the AVERT® computer based simulation software (Automated Vulnerability Evaluation for Risks of Terrorism) [1].

AVERT® is commercial simulation software from the ARES (Applied Research and Engineering Services) Corporation that is used by security specialists to quantify risk and evaluate mitigation strategies for land based high value facilities. AVERT® is being used by the Defense Human Resources Activity (DHRA) within the United States Department of Defense to aid in identifying and preempting security threats to enhance the protection of critical assets and facilities.

Baseline operations occur when the perceived risk of attack is low and there is no actionable intelligence indicating an increased threat. Surge strategies are executed at heightened security levels indicating a need for increased vigilance. The metric used in this report is the probability of encountering an adversary which is based on the adversary's capabilities and the operational tempo for allocated defensive resources. Defensive resources include response boats, patrol boats and helicopters during various environmental conditions that include day, night, reduced visibility, sea states and various traffic flow rates.

Background

In April 2008, the United States (U.S.) Department of Homeland Security (DHS) released the Small Vessel Security Strategy [2] describing the "immense" challenge of distinguishing between legitimate vessel operators and those engaged in illicit activities. A small vessel is any craft that weighs less than 300 tons. There are nearly 13 million

registered recreational vessels, 82,000 fishing vessels, and 100,000 other commercial vessels contributing to the U.S. small vessel population.

Rad/Nuc detection strategies that exploit the natural geography of the maritime domain and optimize the use of assets are needed to improve maritime security. Strategies such as placing patrols at chokepoints resulting from narrow passages and optimized sweep patrols for large open water bodies can be deployed using existing resources.

AVERT® is commercial simulation software from the ARES Corporation that has been used by security specialists over the past ten years to identify risks and evaluate mitigation strategies by quantifying risk reduction for land-based, high value facilities. The software is used by the Defense Human Resources Activity (DHRA) within the Department of Defense to identify and preempt security threats thereby enhancing the protection of critical assets and facilities worldwide. The modeling serves as a primary tool in analyzing security systems to support the agency in the implementation of its optimal security posture.

Previous AVERT® models have focused on facilities in small geographic areas that contain military bases and security buildings rather than the much larger maritime regions up to 200 square nautical miles considered in this report. The application of AVERT® in this report is unique because of its maritime basis and the much larger geographic areas involved in the simulations.

To customize AVERT® for the maritime applications in this report, a scripting code was developed by ARES and SRNL that runs within AVERT®. The code modifies patrol behavior to allow for a security related encounter with the release of non-threatening, compliant pleasure traffic after a random hold time for maritime Rad/Nuc detection logistics.

An “encounter” in this research is defined as a radiation detection enabled patrol vessel coming in close physical proximity to a potential adversary vessel. Once within this range, the encounter time, in reality, could turn out to be a relatively short duration "rendezvous" (5-15 minutes), a longer duration "rendezvous and nest" (15-30 minutes) or the longest duration a "rendezvous, nest, and board" (30-75 minutes).

A rendezvous occurs when a law enforcement boat comes alongside an operating vessel with the proximity depending on sea state and weather conditions. The officer may address the vessel operator and will observe the operator’s behavior and assess the vessel’s on-board equipment. During this stage, the small vessel is viewed for its compliance with laws – i.e., fishing licenses, proper equipment, etc. If the law enforcement boat is equipped with a Rad/Nuc detector, scanning for Rad/Nuc material may take place. Nesting occurs when a State or Local law enforcement officer (Coast Guard does not nest) requires additional information from a vessel operator. Nesting is done while both the vessel and law enforcement boat are dead in the water and tied to

each other. Boarding occurs when a law enforcement officer goes over the gunnels and is physically present on the small vessel.

The probability of detection is the product P(Encounter) x P(Detection | Encounter) where P(Encounter) is the probability of encountering the adversary and P(Detection |Encounter) is the probability that any illicit Rad/Nuc source is detected on the encountered vessel.

There are four necessary constructs for an effective Rad/Nuc detection and deterrence program: Encounter, Detect and Identify, Engage, and Defeat [3]. An encounter occurs when a Rad/Nuc detector equipped Law Enforcement vessel comes within sufficient proximity of an illicit Rad/Nuc device or material for sufficient time such that detection is possible. The P(Encounter), evaluated using AVERT®,corresponds to the first construct. The probabilities corresponding to the remaining constructs are beyond the scope of the research presented.

The focus of this report is on vulnerability reduction through evaluating operational tempo alternatives that provide a high probability of encounter and, therefore, reducing the risk of a successful maritime attack. The AVERT® simulations allowed the direct comparison of the effectiveness of different strategies that vary operational tempo, traffic patterns, and other parameters related to patrols. A primary factor is the size of the patrol area since it relates to traffic density. The probability of encounter was estimated for normal and surge operations. In addition, these probabilities provided a quantitative basis for evaluating the effectiveness of defensive postures for various threat scenarios and enabled the comparisons of alternatives that could lead to decreased risk.

Every U.S. port has unique geographic attributes. The results for patrol areas of various dimensions developed in this study and through further research could provide the building blocks to evaluate the effectiveness of preventive Rad/Nuc detection patrols within any maritime port. The simulation provided a quantitative basis for recommending various defensive postures that could lead to decreased risk and enhanced deterrence strategies.

The simulations were conducted making use of parallel search patrol areas as well as chokepoint patrols that can be used generically, for any port area. The evaluated search areas can be combined to represent a much larger geographic area. In doing so, the vulnerabilities and resources required for baseline normal and surge operations can be evaluated for any U.S. port.

Terrorism in the Port Environment

Maritime ports are “sprawling”, intermingled with sophisticated transportation networks and, in most instances, in close proximity to densely populated areas which are easily accessible. Ports facilitate exceptional freedom of transportation of goods, while allowing freight, vessels, and people to travel with relative anonymity. Due to their accessibility, ports can be vulnerable to a vast array of attacks. Potential avenues for smuggling

weapons of mass destruction or other harmful materials into the U.S. include large vessels carrying containerized or non-containerized cargo and small vessel recreational and commercial traffic. Moreover, ports contain numerous types of facilities that could be targeted by terrorists, including administration buildings, military bases and vessels, cruise ships, pedestrian ferries, terminals, factories, power plants, and sports complexes [4].

Despite the operational challenges that terrorist groups face, maritime terror attacks against the U.S. have occurred in the past. Past terrorist attack scenarios include the use of rowed boats, inflatable crafts, dinghies, and floating debris, to more sophisticated approaches such as high-speed boats, deceptive fishing vessels, and commercial vessels [5]. Small vessels (less than 300 gross tons) may be the type of watercraft with the highest potential to be used by a terrorist to attack a port. Small vessels were defined in this report to be those less than 100 feet in length.

Some believe that small vessels pose a greater threat for nuclear smuggling than transporting material in shipping containers [6]. Small vessel size and high maneuverability lend to a greater probability of a successful terrorist attack [7]. According to the October 2007 General Accounting Report on the *Small Vessel Security Summit* [8], many believe that it would not be difficult for terrorists to obtain a small vessel to execute an attack against the U.S.

Historical data and past maritime terrorist attack scenarios may not be particularly useful in predicting future attack scenarios. The challenge is dealing with the fact that the risk of terrorism is dynamic. Understanding the contributors to the risk of terrorism is fundamental to being able to adequately prepare for an attack.

Risk Considerations

Risk is generally considered to have three main components: threat, the probability that a particular target will be attacked; vulnerability, the probability that an attack will cause damage; and consequences, the magnitude of the damage [9]. Risk is expressed loosely as *Risk=Threat x Vulnerability x Consequences.*

An issue that should be taken into consideration is whether Rad/Nuc detection is a primary or secondary mission with regard to patrol operations. If Rad/Nuc detection is a secondary mission, Rad/Nuc detection equipment may not be active during a large portion of patrol time. During this time, Rad/Nuc materials may only be detected when a vessel is searched. Reasons to search would include suspected transport of illegal paraphernalia, other suspected illicit activity, fisheries inspection, safety violation, search and rescue, or simply a need to reach a particular quota of “inspected” vessels. However, if the Rad/Nuc detection is a primary mission, this equipment would be used during all or almost all of the patrol time periods. The determination of whether Rad/Nuc detection is a primary mission or a secondary mission may depend on decisions based on the Marine Security (MARSEC) level [3]. The impact of Rad/Nuc detection as a secondary mission

was not fully explored because of the difficulties inherent in assessing the impact of the deterance effect.

Modeling Specifics

The simulations make use of parallel search patrol areas of various sizes that can be used generically, in defining any maritime port landscape. Patrol areas up to 10 nautical miles (nm) by 20 nm were considered (Fig. 1); also called a grid in this report. Multiple grids of various sizes can be combined to estimate vulnerabilities and resources required for normal and surge operations in any maritime port.

Fig. 1. 10 nm by 20 nm Grid for Parallel Path Patrol

The grids used in this study can provide the preliminary building blocks in evaluating defensive postures when overlaid on strategic areas within a port.

Girds up to 10 nm by 20 nm were used in simulating the impact of patrols conducting sweep operations. However, the grids could also be used to represent an area in open water for directing and perhaps escorting traffic past a Rad/Nuc monitoring station before entering a port.

A “shift” in this report corresponds to a six hour period of time for response or patrol boats and four hours for H60 helicopters. Time was provided in the simulation for the defenses to exit the grid within their normal shift hours. Nighttime hold times were 20% greater than those used for daytime operation because of reduced visibility. Vision distances and vessel speeds were also reduced during night operations.

Various numbers of recreational vessels were released into the 10 nm by 20 nm grid (Fig. 1), with each vessel’s release time following a uniform distribution over a six hour shift. Each incoming recreational vessel was assigned a destination at the extreme opposite side of the grid for directing traffic flow. The traffic flow was along the major and minor axes

of the grid with traffic uniformly distributed along the edges. Various numbers of vessels and sizes were randomly released into the grid with release time following a uniform distribution over time. The traffic entered the grid stochastically and flowed across the grid with speed following specified distributions. The vessels were released into the grid randomly over a typical six hour shift. In the simulation, the incoming vessels follow the shortest path to their target. In addition, the recreational vessels would not attempt to evade an encounter with a maritime patrol vessel. Combat, an option in AVERT®, was not considered in the simulations since estimating the probability of encounter was the main objective.

The simulation provided an evaluation for various defensive postures that can lead to decreased risk. An understanding of patrol effectiveness was gained through the modeling. In addition, the simulation results provide an indication of the tactical resources needed at chokepoints during surge operations.

Simulation Scenarios

An "encounter" within the simulation was defined as the law enforcement vessel coming in close physical proximity (within several hundred feet) to a potential adversary vessel. In reality, a patrol would have to be closer to conduct an encounter but this choice for modeling was practical since the simulation was based on discrete time steps.

The encounter time could take from 5 to 75 minutes depending on the type of encounter (rendezvous to a boarding). In this report, P(Encounter) is the probability that there will at least be a rendezvous (an encounter of the shortest time duration) with a potential adversary.

The patrol type (Federal, State, Local, helicopter, response boats) and operational tempo were considered in the simulations to produce realistic results. Small vessels less than 40 feet (ft) are not typically on the water during rough sea conditions. Rough seas conditions include 6 ft. waves, 10 ft. swells, or winds at 20 knots. The patrol boats can be on water up to 6 hours/day several days a week in normal operations. The helicopters considered in this report (H60) were on patrol for four hours. The P(Encounter) is only applicable to the time that the patrol is active. A zero probability of encounter was taken into account during the hours when the patrols are not active when estimating the detection probability over time.

The number of patrols was a parameter that was varied in the scenarios. The patrols could be either from Federal, State or Local agencies enforcing port security. Parameters that were varied according to probability distributions include the vision, vessel size, boat vessel speed, pursuit speed, evasive speed, and encounter time. The patrol path, patrol area size, and number of recreational vessels (traffic rate) were also varied. Vision/radar was assumed to have a 360 degree view.

In the simulation, a patrol will deviate from its patrol path if a potential adversary is seen. After completing an encounter, the patrol will return to its patrol path if no other vessels

are seen. A patrol that has a path along the minor axis of a grid will be referred to as a fence, or chokepoint, patrol (FP). Vessels were not detained more than once in the simulations.

Probability of an Encounter (P(Encounter))

The P(Encounter) was estimated for normal baseline operations as well as surge operations through simulations using AVERT®. Maritime surge strategies are executed when intelligence or a heightened security level indicates that there is a need for increased vigilance. Conversely, baseline normal operations are in effect at the lowest security levels.

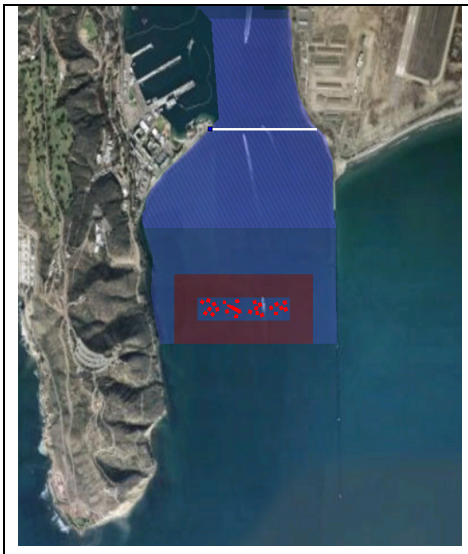
The results show that a helicopter on patrol substantially increases the P(Encounter). This was due to its far-reaching sight and its maximum speed (e.g.: vision 10 nm, speed 120 knots during daylight and good weather conditions). In the simulation, the helicopter was equipped with a stand-off radiation detector. If the stand-off detector alarmed, the patrol boats were directed by the helicopter to intercept the suspect vessel. For low traffic flows, doubling the resources did not lead to doubling the P(Encounter). The marginal impact on the P(Encounter) became less as additional law enforcement boats were added.

The P(Encounter) for a helicopter on patrol is high relative to that for patrol boats during rough sea conditions (no small vessels are on-water) assuming that wind conditions for flight are within acceptable ranges. The P(Encounter) is 0.70 for one helicopter at 40 vessels/shift vs. approximately 0.13 when only two patrol boats are on-water. The P(Encounter) is 0.93 for two helicopters on patrol at 40 vessels/shift during rough sea conditions.

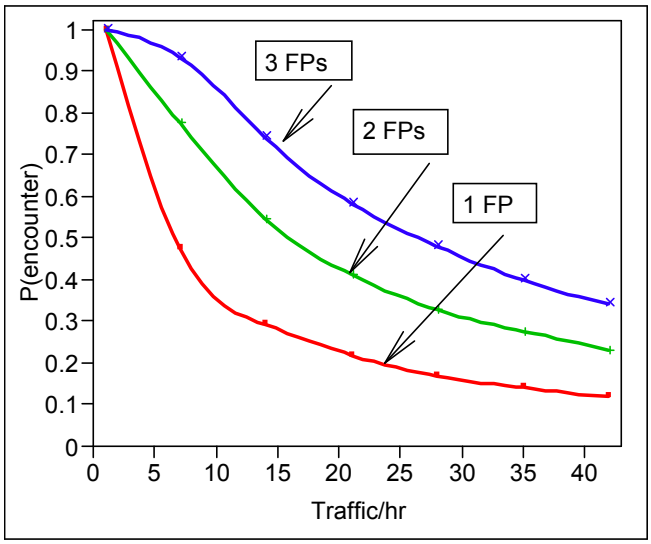
Simulation Results

For chokepoint operations, the P(Encounter) was estimated through the AVERT® simulation for increasing chokepoint patrols. Chokepoint lengths ranged from ¼ nm to 6 nm. There was a significant increase in P(Encounter) when additional patrols were added.

The ¼ nm fence line could be deployed at narrow chokepoints (Fig. 2) while the 3 nm fence line could be deployed at an inlet to a maritime port. Encounter time was randomly distributed from 10 to 15 minutes that could allow for the rendezvous and then escorting the incoming vessel past a Rad/Nuc screening station. In addition, a 6 nm fence line was used to determine the number of patrols necessary when deploying this particular strategy in open water for directing traffic past a Rad/Nuc screening station.



Chokepoint patrol



Probability of encounter versus incoming traffic flow. *(10-15 min random encounter time)*

Fig. 2. Chokepoint Patrol

The simulation revealed that an adversary's evasive path of least detect is typically along the outer edge boundaries of each patrol area. A patrol that is constantly moving was preferred over a stationary, in-waiting patrol. One zone of coverage leads to a higher P(Encounter) than separate zone segments of coverage when multiple patrols are allocated to the same chokepoint.

Allocating fence patrols at a chokepoint is most effective in conducting encounters. However, the chokepoint may be uncomfortably close to a population center or high value targets. An option was evaluating P(Encounter) for a patrol region further out from the chokepoint for directing traffic past a Rad/Nuc screening station before the port's entrance.

There was a decreasing benefit of additional fence patrols at a chokepoint especially with low traffic levels. This same effect was not observed for high traffic levels. Therefore additional patrols were included in the simulations to determine the point at which there was a diminishing return on the number of encounters per patrol.

Normal patrol operations were modeled on a 10 nm by 20 nm grid with a parallel path patrol area (Fig. 3). The grid contained a mix of various sized small vessels with variable speed conditions. The patrol pattern in Fig. 3 was a sweep operation done during daylight, calm sea conditions. The boundaries of the patrol area as well as all nodes within the patrol area are viewed along the patrol path. The patrol speed for the response boat was significantly greater than for the patrol boat. In addition, the pursuit speed for the response boat was substantially greater than that for patrol boats.

The simulation results are presented in Fig. 4 was for a clear day, calm sea conditions. The P(Encounter) for a response boat was greater than that for a patrol boat under day calm sea conditions and even more so for low traffic flows.

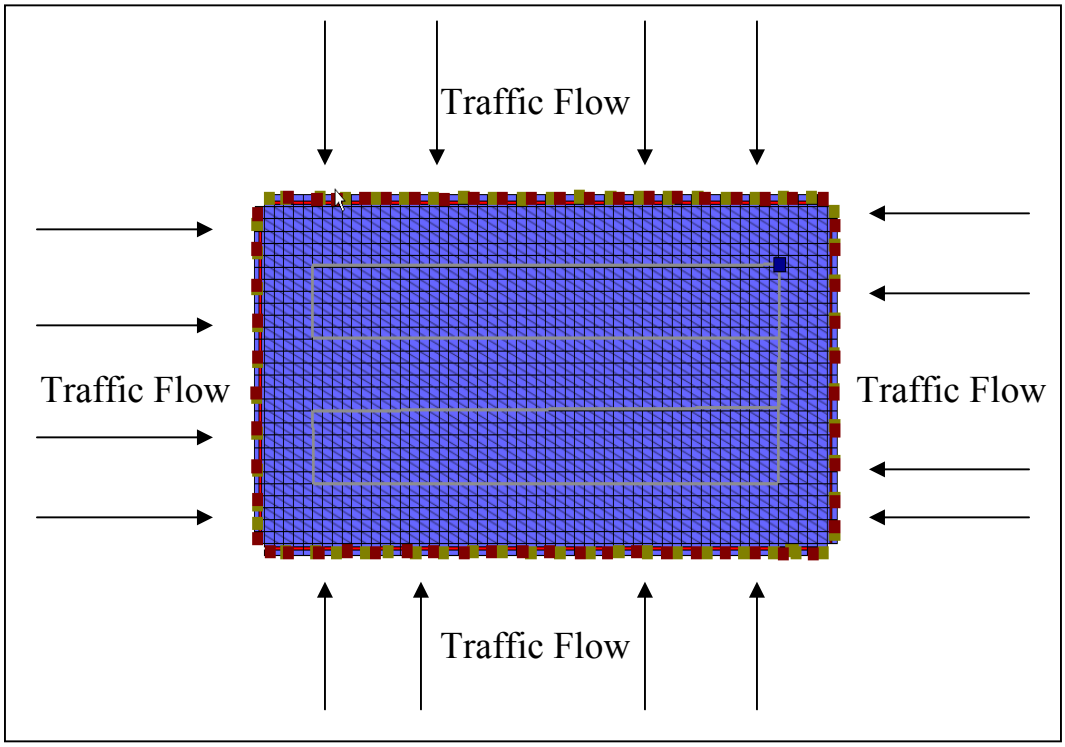


Fig. 3. 10 nm by 20 nm Grid with Parallel Search Path

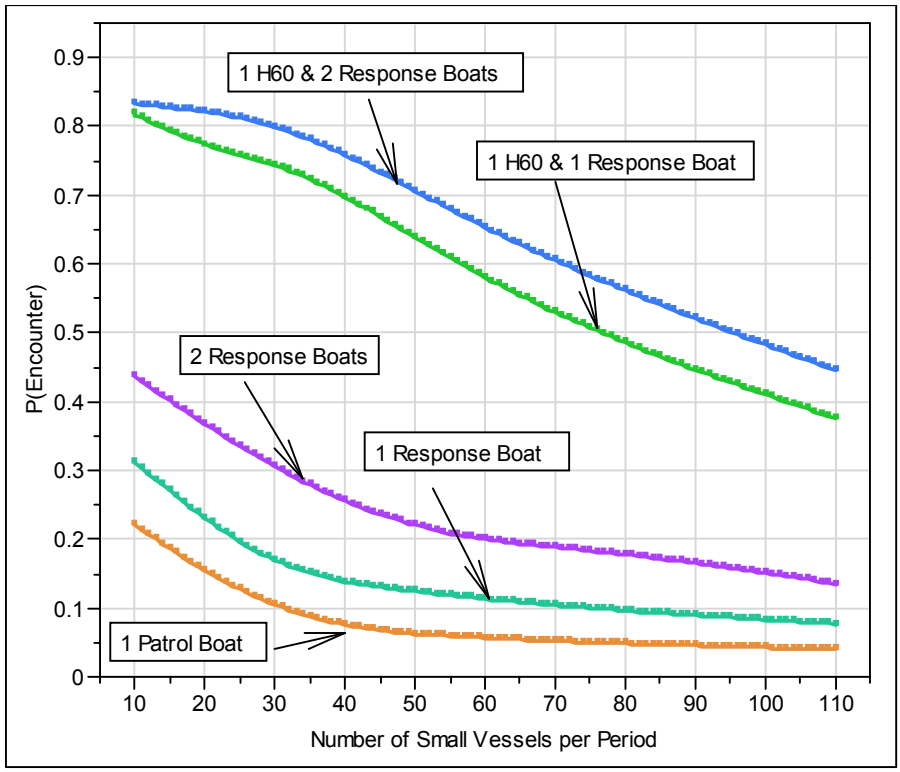


Fig. 4. Comparison of P(Encounter) for response boats, patrol boats, and response boats with support of a H60 helicopter during daytime hours with calm sea conditions on a 10 nm by 20 nm grid.

Support of a H60 helicopter when a response boat is on patrol substantially increased the P(Encounter) while adding an additional response boat further increased the P(Encounter). In the simulation, the patrol boat remained on patrol approximately six hours with time allocated to return back to home base.

The patrol speed and vision followed random distributions for various environmental and sea state conditions. The encounter type (Rendezvous; Rendezvous & Nest only; Rendezvous, Nest and Board) was treated as a stochastic event. Adversary Speed Distributions were varied. A random mix of various sized small vessels (small, <40', medium 40-60', and large 60'to100') was active in the simulation. During reduced visibility conditions, the ability of resources to perform operations is greatly reduced.

Vessel size distribution on the water is dependent on the sea state. Under good weather conditions, 60 to 100 foot vessels accounted for 5% of the traffic. Vision and speed was assigned according to environmental conditions. The type of encounter was a stochastic event in the simulation. The rendezvous occurred 30% of the time, rendezvous and nest only 56% of the time and a full boarding 14% of the time. Federal patrol or response boats do not nest. They can "Rendezvous only" 70% of the time or "Rendezvous and then Board" 30% of the time. The distribution of encounter times (Rendezvous, Nest, Board) was built into the simulation according to the size of the vessel encountered and type of encounter.

Conclusions and Recommendations

Computer simulations using the AVERT® software have been conducted under normal baseline and surge operations to estimate the probability of encountering an adversary possessing Rad/Nuc materials or devices. Defensive resources include helicopters, response and patrol boats equipped with various Rad/Nuc detection devices. Patrol and intercept effectiveness for various traffic flow rates was evaluated under various environmental conditions such as day, night, rough seas and reduced visibility. The results provide a basis for the tactical resource allocation that could lead to an increase in the probability of encounter. Greater fidelity can be built into the models and larger scale simulations can be conducted as computational time becomes quicker through hardware improvements and software upgrades.

Law enforcement use of helicopters results in a high probability of encounter in the maritime environment. However, helicopters are not able to hover near vessels less than 30 ft in length especially during rough sea states. A helicopter with Rad/Nuc monitoring capability could be used to screen vessels 30 ft to 60 ft in length during surge operations. Law enforcement patrols could attempt to encounter these vessels only when the detector alarms. As a result, the patrols would be able to provide greater coverage for the smaller vessels.

Simulations were conducted making use of grids (parallel search patrol areas) of various sizes that can be used to model any area of response. In addition, multiple grids can be combined to represent a much larger area within a port. Other sizes and general shapes (e.g.: Funnel) could be considered in the future so that the simulation results can be tailored to any port. Multiple grids of various sizes can be combined to estimate spatial vulnerabilities and resources required for normal and surge operations.

Simulation results from this study and further research can be used to evaluate defensive postures within any port area. The simulation results provide a quantitative basis for evaluating various defensive postures and enable the comparisons of alternatives that can lead to decreased risk. Further simulations could be done to provide an understanding of enhanced mitigation strategies during surge operations.

Greater fidelity can be built into the models and larger scale simulations can be conducted as computational time becomes quicker through hardware improvements and software upgrades.

Terrorists can strike at any given place at a port at any given time. As evidenced earlier, the chance of maritime and port terrorism is both prevalent and complex. While it is important to keep the challenges inherent in preventing a port terrorist attack in mind, it is also vital to understand that if proper security measures are in place, maritime pathway vulnerabilities can be recognized and risks of terrorism can be reduced.

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