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Using System Simulation and Wargaming to Examine The Threat of Maritime Improvised Explosive Devices (MIEDs) In U.S. Ports

Richard Jimenez
Systems Engineering Department
Naval Postgraduate School
Monterey, CA 93943
mailto:rjimenez@nps.edu

Bobby Rowden
Systems Engineering Department
Naval Postgraduate School
Monterey, CA 93943
mailto:bjrowden@nps.edu

Eugene P. Paulo
Systems Engineering Department
Naval Postgraduate School
Monterey, CA 93943
mailto:eppaulo@nps.edu

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Abstract

This study examines the use of interactive wargaming and computer modeling and simulation in assessing the overall performance of system of systems (SoS) alternatives in conducting critical functions concerning to defeat the threat of Maritime Improvised Explosive Devices (MIED) in a U.S. port. The geographic area of concern is Puget Sound, principally Elliot Bay and Commencement Bay. The wargame involves an attack against the Seattle Passenger Ferry System and the Maritime Transportation System (MTS) using MIEDs. A unique element of this scenario was that it combined an interactive wargame, which required crisis management actions, planning and coordination, with a series of closed-form simulations. This highlighted both the necessary actions and considerations that must be taken by military and civilian leadership in order to adequately prepare for and counter MIEDs in U.S. Ports, and focused on side-by-side analysis' of proposed solution alternatives were performed.

1. INTRODUCTION

World trade is highly dependent on worldwide maritime transportation systems for sustaining the expeditious and efficient flow of commerce on the sea. In the U.S., the major hubs for all domestic shipping via ground transport originate in major ports such as Seattle, Los Angeles, Chicago, Houston and New York. If any of these ports are compromised and the supply stream interrupted, the down-stream effects would be felt all along routes stemming from these ports. In 2003, the Organization for Economic and Cooperation Development (OECD) conducted a study and concluded that a coordinated attack on the national MTS would be measured in the tens of billions of dollars.[1] Should a terrorist organization seize on this critical vulnerability and want to strike a crippling blow to the US economy, attacking—or even feigning an attack on—a major port could prove disastrous and is not without merit.

Our project team was tasked with designing a system of systems that rapidly and efficiently mitigates the effects of a MIED attack to the MTS using a procedural-based approach known as the Systems Engineering Development Process (SEDP). As part of the SEDP, a modeling and simulation effort using Joint Conflict and Tactical Simulation (JCATS) was designed to perform the following tasks: 1) analysis of SoS alternatives, 2) provide an infrastructure to validate the project problem statement, operational concept and scenario, and 3) serve as a knowledge-generating tool giving insight toward the main task and the additional complexities and issues that would encompass a Maritime Homeland Defense (MHD) MIED scenario.

2. THE M&S APPROACH

The M&S approach we chose to allow for a thorough examination of these system-of-system alternatives in an MIED scenario consists of four phases. These phases are:

-Requirements: determine the purpose for conducting the simulation and identify the training audience

-Conceptual Design: scenario planning, constraints, player cells and overall design of experiments

-Model Implementation: translation of conceptual model into a computerized simulation and testing

-Experimentation and Revision: execution of the wargame and simulation for the purpose of understanding the behavior of alternative systems

3. REQUIREMENTS

As part of the SEDP, the project team required a method of testing the solution alternatives. Many of the solutions proposed were comprised of notional systems for which performance data was unknown or unavailable. Computer modeling and simulation became an attractive option for ascertaining data based on our best estimates input parameters, physical characteristics, etc. Based on our systems engineering design efforts, the primary "MIED defeat" functions of Search, Detect and Neutralize became the focus of our M&S efforts. A second area of emphasis was to gather insight on the important factors in reducing the effects of an MIED attack on the Maritime Transportation System. A live exercise such as LEAD SHIELD exercise in the Port of Los Angeles was too costly and not well suited for the purposes of our study. Therefore, the project team sought to design our own model and scenario to assist in our analysis of both the problem formulation and proposed solutions.

4. CONCEPTUAL DESIGN

4.1. Scenario

A fishing vessel has inconspicuously planted MIEDs in Elliot Bay in a planned attack against a passenger ferry that makes routine transits to a nearby island across Puget Sound. The terrorist attack is successful and imposes over 200 casualties when the ferry is struck. A US Coast Guard first response unit becomes the next victim as it attempts to render aid. Simultaneously, a cargo vessel that has been targeted is enroute to the loading docks in the Port of Tacoma. As part the coordinated attack, as second terrorist cell towing a submerged kayak laden with explosives places the improvised bomb in the traffic separation lane directly in the path of the cargo vessel. The cargo vessel is rendered immobile requiring an extensive ship salvage operation. At this point an anonymous call is placed with persons claiming responsibility for the attack exacerbating the threat of additional mines in the area. This portion of the wargame was not amendable and introduced the scenario to the response cell in a coherent sequence with the purpose of prompting the operational commander to secure port operations and force crisis mitigation actions. Figures 1 and 2 show the affected areas.

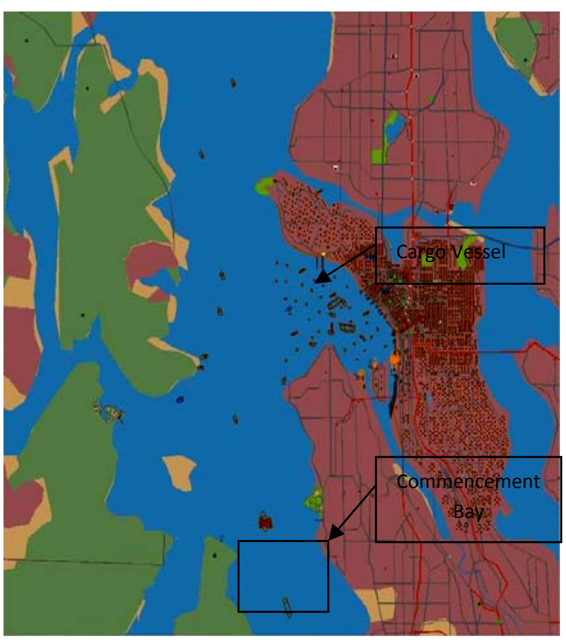

Figure 1 - Elliott Bay

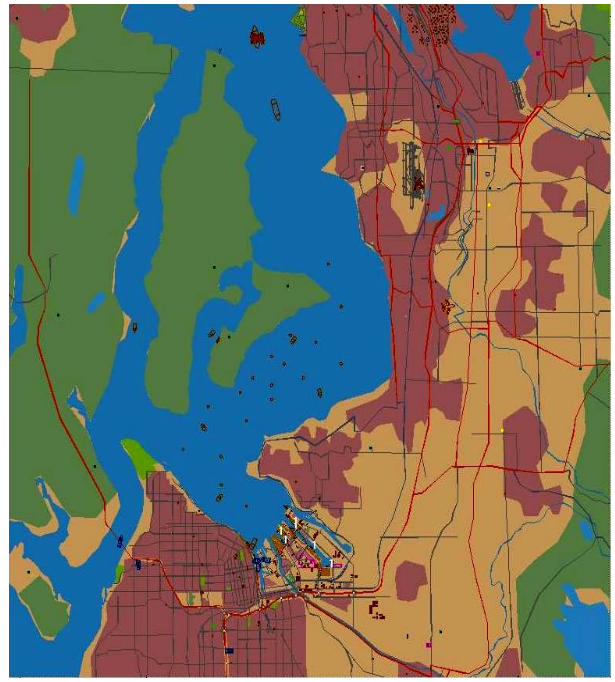

Figure 2 - Commencement Bay

4.2. Force Plan

The exercise controller coordinated the actions of the opposition forces and neutral forces in the wargame while the response cell was decomposed into the following elements:

-Joint Harbor Operations Center (JHOC): Operational commander/decision maker responsible for the actions of all supporting elements and assets.

Key Tasks:

- Maintain C2 of the operation and coordinate the actions of supporting elements
- Make the determination to implement Maritime Security (MARSEC) levels.

-Coast Guard: Lead element responsible for search and rescue (SAR) operations and emergency first response to a crisis in and around the harbor.

Key Tasks:

- Evacuation of ferry passengers to triage collection stations
- Establish secure zone around the ferry, first response unit, and cargo vessel
- Enforce MARSEC levels and make reports to JHOC

-Navy Region Northwest (NRNW): Responsible for mine hunting and mine clearance operations in the Puget Sound area of operations (AO).

Key Tasks:

- Conduct area sweep of designated search areas.
- Ordinance disposal of localized MIEDs.
- Provide assistance during SAR operations.

-Local Authorities: Comprised of law enforcement, fire department, Emergency Medical Services (EMS) and Seattle Port Authorities.

Key Tasks:

- Setup triage collection stations
- Account for all evacuated persons
- Enforce secure zones
- Firefighting
- Ship Salvage Operations

4.3. Wargame Constraints

The actions of the response cell were not entirely scripted but certain sequential activities needed to be completed within the specified constraints. The first of these constraints was that once the attack took place and authorities were notified of additional mines in the harbor, response cell elements would not transit the bay until areas were cleared. Therefore, SAR operations could only be accomplished using helicopters that would operate during daylight hours with a maximum capacity of two passengers per transit. Unmanned underwater vehicles (UUVs) could operate at any time. All searches/neutralization actions had to be in accordance with Naval Mine Warfare doctrine and vehicle endurances needed to be adhered to.

4.4. Design of Experiments

The first goal was to collect baseline data on current—use systems measuring the search rate, probability of detection (Pd) and time required for neutralization of MIEDs. Figure 3 shows a depiction of the current—use system. This system alternative was comprised of REMUS 100 UUVs and EOD teams to conduct the functions of Search/Detect/Classify/Identify/Neutralize. A secondary objective was to understand the determining factors that significantly affect re-opening a port once an MIED attack has occurred. The closed-form simulations were intended to gather performance data on the proposed system alternatives that would later be used in a comparative analysis of alternatives with respect to the current—use system. The data logger feature in JCATS allowed for replay of an executed scenario in which all actions from the simulation could be reviewed and analyzed.

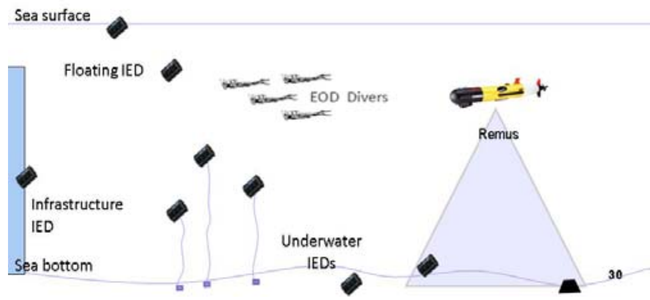

Figure 3 – Current—Use Baseline System

5. MODEL IMPLEMENTATION

5.1. From Concept to Executable Model

Model implementation involved building a virtual environment, dynamic moving objects and their behaviors, forces structures and constraints. These features were built into the JCATS database known as VISTA. Sensor, physical and mobility characteristics for most vehicles in the model were obtainable. However; vehicles used by some proposed system alternatives were notional or classified posing an obvious limitation. In such cases, best estimates based on open sources and legacy systems where used to fill the missing data.

Before creating a virtual map of Puget Sound in JCATS, field research was conducted to gather sufficient data about the terrain, port infrastructure, vessel traffic, military and civil authority locations. Features that would be used in the model also included ferry routes, transit times to and from nearby islands, average number of passengers per transit and commercial and non-commercial vessel traffic that would act as background noise in the simulation.

5.2. Building the VISTA Database

Each of the vehicles was constructed in the Systems Editor of the Vista. The Systems Editor is used to build the basic attributes of an object, specifically the mobility type and the symbols used for classification and identification during the game. In addition to the physical dimensions and passenger/cargo capacities, the Systems Editor allowed for design of detectability, vulnerability and survivability attributes. For each element in the simulation, a pairing was established for how it would interact with other objects and the environment. For example, a surface vessel could not detect submerged MIEDS, but had a vulnerability to them. Vulnerabilities were set using inherent PH/PK tables built into JCATS. An element's detectability was designed in a similar way with sensors contained by those objects.

Once the attributes for each object were set, they were aggregated by mobility class. For example, surface vessels as mobility classes were vulnerable to MIEDs, with their physical dimensions dictating the various degrees of damage. The sensor for each surface vessel was standard sight, called Direct View Optics (DVO). The is sensor had a range of 0 to 2000m, 2 second scan interval and a horizontal field of view of 20 degrees. Helicopters were also fitted with DVO and an enhanced range of 0 to 4000m, 2 second scan interval and a 135 degree horizontal view based on a 300ft ceiling. REMUS 100 UUVs were given an operating range from 0 to 50 meters and a 90 degree horizontal field of view, with continuous scan active sonar as their primary sensor. The active sonar detection is a pairing algorithm that allows the database manager to enter the types of platforms that the sonar can detect and then uses JCATS probability tables based on user inputs. Dismounted persons used "unaided eye" with a range from 0 to 1000m, 20 degree horizontal view and continuous scan. This process was repeated for the objects that comprised the SoS alternatives, many of which were classified systems.

5.3. Force Lay-down

Location of each object and element group was determined from research conducted in Seattle, WA. The neutral forces were randomly placed throughout Puget Sound. The goal here was to re-enact a typical day in the Port of Seattle prior to the attack. Asset placement also served as a venue for conducting functional tests of the objects used in the model. The operational testing was conducted at the individual, force and game levels. At the individual level each object was tested for functionality of behaviors programmed in VISTA. Force level testing was done for the purpose of determining the efficacy of the elements and how well they worked together. The final test was done to demonstrate all elements of the simulated wargame functioning together, a pre-trial of the free play portion of the game and insight on how the closed form simulation would be set up and executed. Figure 4 shows the force lay-down at the start of the wargame.

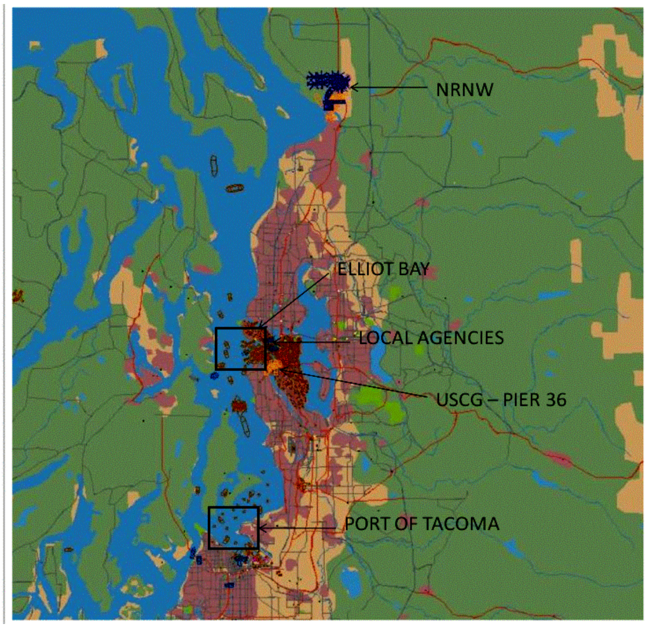

Figure 4 - Initial Force Layout

5.4. Preparing Player Cells for the Wargame

The project M&S team presented the scenario to US Coast Guard Sector Seattle, Contingency Plans and Force Readiness (CPFR) office. The scenario captured the attention of key persons within the organization and an extensive table top exercise (TTX) followed in which the response actions of each agency was discussed. The TTX was extremely useful in that it provided the M&S team with validated sequences and response actions to incorporate into the wargame. The TTX included a discussion of the following:

-The use a Unified Command Center (UCC) from which to maintain command and control of crisis management actions and a list of participating agencies.

-Priority search and clearance areas

-Actions required to resume port activities

-Civilian authority integration with NRNW

-Sequence of actions

-Timeline requirements for each action

The conclusion form meeting with CPFR was an understanding of each force's roles and responsibilities, information crucial to executing an accurate, meaningful, interactive wargame. CPFR added that the maritime rescue operation (MRO) and SAR operations added a high level of complexity to the scenario and would delay progress in hunting for MIEDs.

6. WARGAME/SIMULATION EXECUTION

6.1. Wargame

The wargame was executed over a period of two, eight hour days using a 2:1 ratio simulation speed. On the first day, the first 6 hours were devoted to crisis management in which the response cell was prompted to take actions in controlling the scenario, conduct MRO using airlift evacuation and establishing cleared routes (Q-routes) for CG vessels. The UCC established its priorities for overcoming the situation and conducted planning for MIED searches. The first six hours (12 hours in simulation time) tested the ability of the command and control element to deal with the complexities of the scenario. The JCATS program was ideal for supporting a "commander-in-the-loop" simulation through the use of command and control (CAC) files. CAC files are graphical overlays projected onto the JCATS map that provide situational awareness functionalities that focus on the human user. Figure 5 demonstrates the JHOC priority search areas which includes Q-routes.

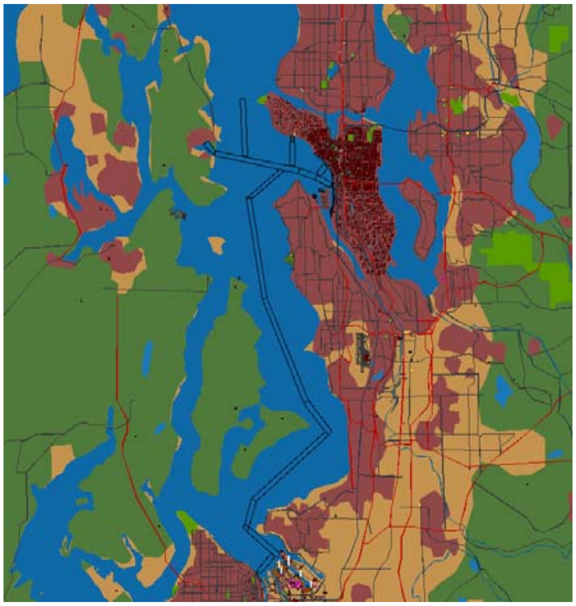

Figure 5 - JHOC Designated Search Areas

The second day of wargaming was devoted to conducting area searches and secondary crisis management actions. The searches were accomplished using REMUS 100 UUVs at a simulation speed of 15:1. Objects detected by the REMUS vehicles were treated as new contacts based on the assumption that a harbor bottom-survey was completed within the last six months. A total of 6 mines were placed in Elliot Bay, however; searches were conducted in all designated areas in Figure 4. Once the determination was made that an object was a MIED, an EOD team was mobilized to conduct neutralization, which required 2.5 hours (simulation time) for each MIED. The detect-to-engage sequence used in the wargame did not account for the time required to conduct post mission analysis (PMA) of a suspected MIED or the set-up times for the REMUS vehicles and EOD teams.

6.2. Wargame Results

The response cell was able to conduct an evacuation of all dead and injured personnel on the ferry within the 16 hours of simulation time. According to the TTX with CPFR, this would not have been possible due to the limited capacity of triage centers, difficulty involved with helicopter SAR and the likelihood of having to search for drowned victims. This would have inevitably delayed the time in which MIED searches could begin other than establishing Q-routes. In the wargame NRNW required only 30 minutes to deploy assets from Everett Naval Station to Seattle. The realistic expectation would have included approximately two hours to arrive and three hours for the UUV platoon and EOD team to set-up at the insertion point. In addition the neutralization time for each mine would have exceeded 2.5 hrs in a real MIED scenario because of the unconventional nature of MIEDs. The wargame did provide highly accurate results for area searches using the 15:1 ratio. The three UUVs deployed simultaneously required 148 combined operating hours (simulation time) at a search rate of 460-550 m^2/s with a 30 meter swath. The baseline AFP also had a probability of detection (Pd) between 85%-95% and 2-3 hours for neutralization. This search time was relatively close to what was calculated using an exhaustive search model given the platform speed and sensor ranges. The Pd was also reasonably within the parameters indicated by Hydroid Inc., manufactures of REMUS UUVs.

6.3. Closed Form Simulations

Closed form simulations were conducted using the wargame template at the point in which area searches would begin. Rather than running current—use systems, the simulations were conducted using objects from the Adaptive Force Packages (AFPs). These assets were operated individually over the measured areas shown in Figure 5 in order to obtain detection probabilities and area search rates. The data collected from each SoS alternatives from the simulation was verified with same exhaustive search model.

6.4. Closed-Form Simulation Results

Performance analysis was conducted using closed form simulations to determine the effectiveness of system alternatives in countering a MIED threat. The performance data sought were area search rate, probability of detection, and time required to neutralize. The various alternatives were evaluated and analyzed with reference to the current MCM system as the baseline model and threshold for the other alternatives. Only some of the details of the proposed systems are addressed here. See Rowden, et. al. 2008, for complete description of the proposed systems.

6.4.1. Adaptive Force Package 1

The first closed form simulation was performed for AFP 1 which was an adaptation of the baseline system but included an enhanced sonar suite. The key performance differences were an enhanced search rate of 630 m^2/s, and higher Pd (88%). AFP 1 still featured EOD divers for neutralization which on average required 2-3 hours for each MIED.

6.4.2. Adaptive Force Package 2

AFP 2 consisted of the all elements in AFP 1, with exception of the EOD divers, but also included airborne (via helicopter) a laser mine detection system, a mine clearance system and a mine neutralization system. With this upgrade, AFP 2 achieved a Pd of 95% and a significantly faster search rate (6650m^2/s). The neutralization times decreased to .5 hrs, since these systems are both aircraft deployed and remove the man from the minefield. Although these neutralization systems were extremely effective at neutralizing submerged threats and those near the surface, they required detonation of an MIED. This could potentially pose significant damage to existing infrastructure.

6.4.3. Adaptive Force Package 3

This alternative consisted of a multi-role underwater unmanned vehicle (UUV) capable of carrying search sensors and four single shot mine neutralizers. The notional search sensor suite on the advanced UUV includes synthetic aperture array sonar with a Pd of 95%.

6.4.4. Adaptive Force Package 4

This option featured the notional systems in AFP 3, but also uses a Joint Architecture for Unmanned Systems (JAUS) that inter-links all of the autonomous systems. A closed form simulation was not performed for this alternative and therefore shared the performance figures with AFP 3. The added value of this option is that the search, detection and neutralization can be done autonomously using multiple vehicles vs. one multi-purpose, but slow and expensive platform.

7. MODEL RESULTS

The project team's M&S efforts demonstrated that the functions of search, detect, classify, identify and neutralize are each necessary to counter MIEDs but not in the conventional sense. These separate processes, require a variety of equipment, time and skills to be effective. The grand challenge is to streamline these processes with the use of a single system or to increase the rate at which these processes are conducted. The AFPs were designed with this in mind due to the unavailability of traditional MCM ships. The wargame provided insight into the likely progression of events that would occur in an MIED scenario. Planning for such an attack is crucial and priority search areas need to be built into contingency plans for an MIED attack.

The use of alternative systems to counter MIEDs and enhance port security requires the use of smaller, easily mobile, easily deployed systems vice conventional MCM ships. The comparison of 4 AFPs in closed-form simulation showed that for presently available technologies and systems, AFP 2 is the most effective SoS to counter a MIED threat. With its high resolution, probability of detection and speed of the MH-60 as the employment platform, Alternative 2 gives a much higher measure of effectiveness to Alternatives 1 and 3. As a nominal option AFP 4 provides equivalent search and detection performance as the ALMDs but offers the non-explosive neutralization method coupled with the capabilities offered by JAUS. Table 1 summarizes the performance comparison between the alternatives.

Table 1 - Comparison of All Alternatives

Evaluation Criteria		**Baseline**	**AFP 1**	**AFP 2**	**AFP 3**	**AFP 4**
Search	Area search rate (m^2/s)	460	630	6650	184	644
Detect	Probability of Detection (%)	85	88	95	95	95
Neutralization	Time required to neutralize (hours)	3	3	0.5	0.5	0.5

8. CONCLUSIONS

The use of wargaming in the campus-wide, integrated capstone projects had not been attempted by previous Systems Engineering Cohorts at the Naval Postgraduate School. The advantages of M&S in a System Engineering project involved taking two distinct processes and using them toward achieving the project team's goal. M&S provided the ability to generate realistic measures making it a useful knowledge gathering and training tool in developing strategies and plans for Homeland Defense scenarios. The wargame and closed form simulations supported the SEDP as tools for comparing system solution alternatives and JCATS was an ideal program and well suited for the purposes of comparing the proposed system alternatives.

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Author Biographies

Rich Jimenez is a Lieutenant in the US Navy and graduate from Naval Postgraduate School with a MS in Systems Engineering and Analysis.

Bobby Rowden is a Lieutenant in the US Navy and graduate from Naval Postgraduate School with a MS in Systems Engineering and Analysis.

Eugene P. Paulo, Ph.D., is an Associate Professor of Systems Engineering at the Naval Postgraduate School. His research interests include modeling and analysis of combat systems, systems engineering, and system simulation.