A Ship Defense Analysis Process

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Over the past 6 years an adaptable, efficient, and cost-effective process to analyze ship defense against hostile air threats has been developed in support of the Program Executive Office (PEO) Theater Surface Combatants and PEO Expeditionary Warfare to evaluate planned and proposed improvements to their ship defense combat systems. The Requirements and Analysis Working Group, which comprises personnel from the Naval Surface Warfare Center/Dahlgren Division, Naval Research Laboratory, and APL, developed the process and conducted these analyses. This process is also used to evaluate current combat system performance to support tactics development. (Keywords: Analysis, Anti-air warfare, Ship self-defense.)

INTRODUCTION

An adaptable, efficient, and cost-effective process has been developed over the past 6 years to analyze ship defense systems in support of Program Executive Office Theater Surface Combatants (PEO TSC) and PEO Expeditionary Warfare (PEO EXW). The process has been developed under PEO sponsorship through the Requirements and Analysis Working Group (RAWG) with representation from the Naval Surface Warfare Center (NSWC)/Dahlgren Division (DD), Naval Research Laboratory (NRL), and APL's Joint Warfare Analysis Department and Air Defense Department. A broad range of ship defense anti-air weapon systems and threats that require expertise in many fields has been modeled and evaluated. For the analysis process, the analyst must have a basic knowledge of all weapon systems being studied, access to experts on each key system component, and a modeling tool to automate effectiveness calculations. The analysis process relies on and, in turn, expands an extensive database of Navy weapon systems and threats. This article discusses the need for ship self-defense combat system analysis, describes the analysis process, and presents three examples of it.

THE NEED FOR COMBAT SYSTEM ANALYSIS

The analysis of combat system effectiveness is used by Navy leadership for system development and by the Fleet to develop system employment guidelines and tactics. The different user needs affect the analysis. Program managers and resource sponsors are interested in future threats, especially those that stress defensive capabilities. They also need a consistent representative environment. Fleet users are interested in near-term threats in their operating area.

Comparative Analysis

Typically, a program manager or resource sponsor may have several systems from which to choose. A comparative analysis is performed to evaluate one or more systems against a common threat set and various conditions. When this analysis is combined with estimated system cost, it is a cost-effectiveness analysis. The decision maker then selects the most cost-effective system. The analysis is not always a simple comparison of numerical results because other factors such as development risk may also be considered.

The Program Objectives Memorandum (POM) process analysis, conducted biennially to determine future weapon system procurement investment, is a comparative analysis. An example of it is discussed later in this article. Several configurations are analyzed against a common set of threats for 5 to 15 years in the future. The effectiveness of alternatives and their estimated procurement and total lifetime costs are compared. Specified measures of effectiveness (MOEs) are used to compare systems. Another example of comparative analysis is an analysis of alternatives, previously called a cost and operational effectiveness analysis.

Utility analysis, a type of comparative analysis, evaluates new systems in the same context as current or planned systems. It may not hold to strict government guidelines or have a set requirement that must be met as in other applications of comparative analysis. The High Energy Laser Weapon System (HELWS) Study, described in the Analysis Examples section, is representative of a utility analysis.

Operational Analysis

Operational analysis is conducted to evaluate ship self-defense systems against current threats in support of the Fleet. The Fleet uses these analyses to develop operational and experimental tactics and system employment guidelines, which may be evaluated during Fleet exercises. For example, the analysis results may aid a commander in allocating ships to various missions such as escorting other ships or in conducting offensive operations such as amphibious assault or shore bombardment. The operating area of the Fleet under evaluation dictates threat and environmental conditions considered, and can include the time phase of hostilities (e.g., prehostilities or hot war situation) as well as rules of engagement. Operational analyses can also aid a ship's crew in determining best defensive doctrines for different warfighting situations. In some cases, a Fleet commander wishes to understand his ship's capabilities in a potentially hostile situation. The Fifth Fleet Study, which is described in the Analysis Examples section, typifies this type of operational analysis.

ANALYSIS PROCESS TO SUPPORT RAWG

A six-step analysis process provides a flexible framework for resolving ship defense problems. Central to this process is an engagement model to automate effectiveness calculations. Two major goals of the analysis process (Fig. 1) are to develop data inputs needed to support the model, such as the Surface Anti-Air Warfare (AAW) Multi-Ship Simulation (SAMS) model used for effectiveness calculations, and to provide sufficient data for the analyst to interpret results properly.

The steps in the analysis are as follows:

1. Define the systems to be analyzed, the expected threat, and the operating environments
2. Modify the engagement model if necessary to ensure proper representation of the systems to be analyzed
3. Establish the MOEs to use
4. Collect data needed to model all components of the problem, potentially using results from high-fidelity simulations
5. Use the engagement model to obtain the MOEs
6. Analyze and present the results

Each step is further described in the following subsections.

Defining the Problem

Problem definition consists of identifying three components: (1) the ship defense systems to be analyzed, (2) the threat, and (3) the operating environment. Ship defense systems are determined jointly by the sponsor and the analyst. The sponsor will identify configurations based on existing or planned system developments. Inputs from industry may be used to identify potential system improvements or possible new systems. Several configurations of weapons, sensors, and control systems may be considered. Fleet users will specify the current systems on their ships.

The Office of Naval Intelligence (ONI) is responsible for defining likely near- to far-term threats to naval forces. The program sponsor is interested in future threats that stress defensive systems. ONI selects appropriate threats based on the program manager's needs, with input from the analyst about threat characteristics that stress the systems. Attack densities are chosen to reflect intended ship missions. Environmental conditions are chosen to stress the systems. These threat selections are made to avoid designing a system around a single criterion.

Such problem definition is sufficient for comparative analysis. Operational analysis, however, may require development of an operational situation, which includes the political evolution leading to an attack, daily

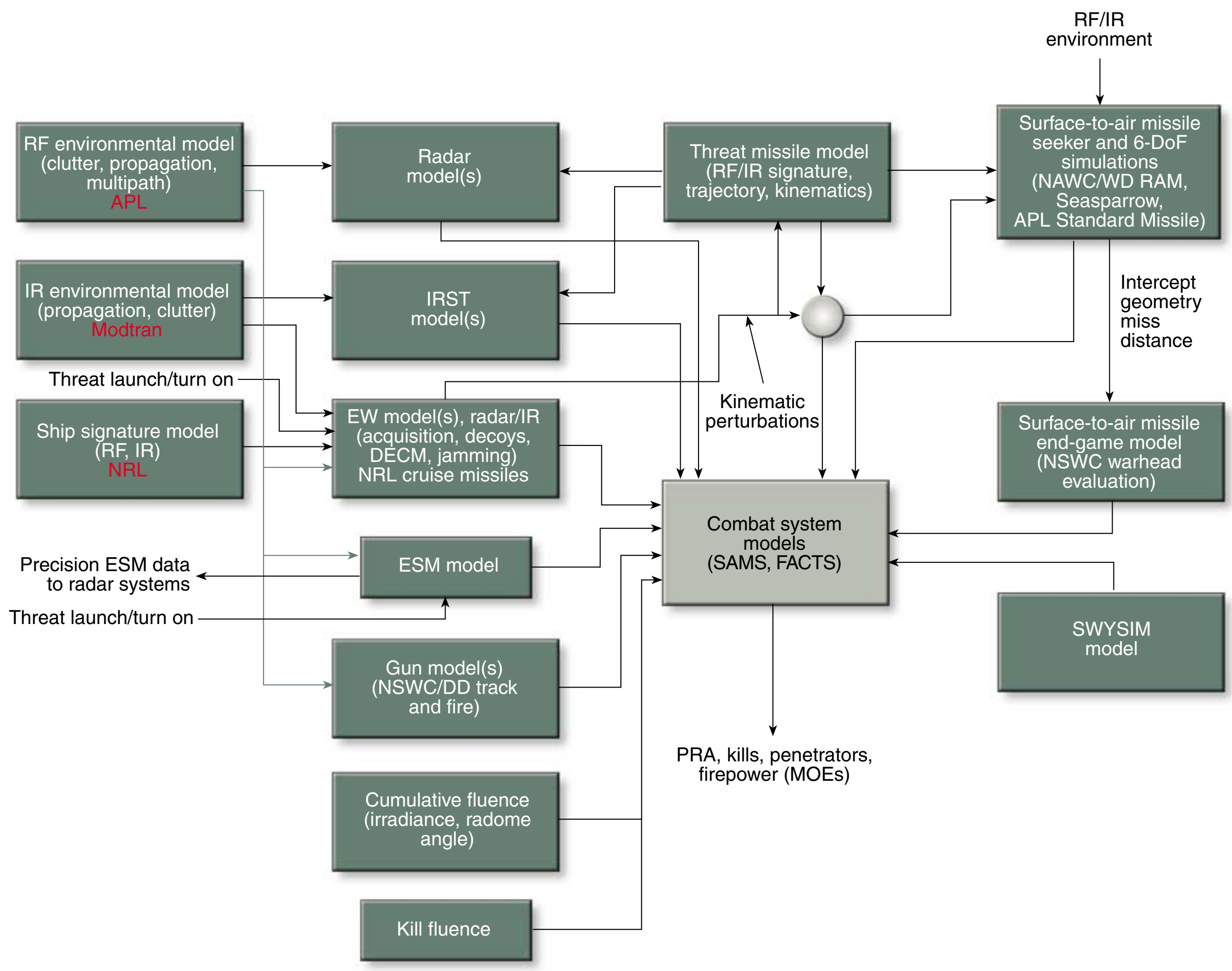

Figure 1. The RAWG analysis process involves the use of high-fidelity simulations to develop detailed weapon and threat data for the combat system models. The flexibility of the process allows the data inputs to be tailored to the type of analysis (operational or comparative) and to the needs of the end user. Not all analyses use each of the simulations or processes indicated in this figure. (DECM = deceptive electronic countermeasures, DoF = degrees of freedom, ESM = electronic support measures, EW = electronic warfare, FACTS = Fleet Anti-Air Warfare (AAW) Model for Comparison of Tactical Systems, FLIR = forward-looking infrared, IRST = infrared search and track, NAWC/WD = Naval Air Warfare Center/Weapons Div., NSWC/DD = Naval Surface Warfare Center/Dahlgren Div., PRA = probability of raid annihilation, RAM = Rolling Airframe Missile, SAMS = Surface AAW Multi-Ship Simulation, SWYSIM = SWY Simulation.)

description of scenario events, and environmental conditions appropriate to the operating area as well as the ONI-defined threat.

Representing the System in the Effectiveness Model

The second step in the analysis process is to ensure that the engagement model, e.g., SAMS, properly represents all aspects of the problem to the desired degree of fidelity. SAMS is a stochastic, discrete event model of surface-based AAW defense systems. Single or multiple ships, radars, and weapon systems can be simulated. Effectiveness against single or multiple attack elements can be determined. SAMS is one of two approved models used by the RAWG for conducting ship self-defense analysis for PEO TSC and PEO EXW. The other is the NSWC/DD Fleet AAW Model for Comparison of Tactical Systems (FACTS). FACTS and SAMS have been extensively benchmarked against each other to ensure consistent results for RAWG analyses.

SAMS evolves to support the analysis, providing new or enhanced capabilities. The simulation's object-based modeling structure facilitates changes in the nature of defensive weapons. This built-in flexibility allows users to adapt the model to new concepts or increase fidelity via model inputs, in many cases without changing the actual model.

SAMS emphasizes weapons control and use, especially weapon assignment and scheduling and coordination of engagements at the unit and force levels. Results from engineering models are used to model sensors and weapon performance.

Establishing MOEs

MOEs are numerical results used to assess the systems being analyzed. The traditional MOE for self-defense weapon systems is probability of raid annihilation (PRA), i.e., the probability that all targets in the attack are killed or deceived by some component of the ship's self-defense weapon system. This MOE is used by the Ship Defense AAW Capstone Requirement, a Chief of Naval Operations–approved set of warfighting requirements for ship self-defense, commonly referred to as the Capstone requirements.

Other MOEs may be used as well. If missiles are limited by magazine capacity, then the number of missiles fired is an important MOE to minimize while maintaining a high PRA. When not all weapon systems available to the ship are modeled, the expected number of penetrators can be used as an MOE for comparison with a threshold that is assumed to be handled by other weapon systems. The number of over-engagements (targets engaged by other weapon systems after the first weapon system has killed it) is often used as an MOE when analyzing several weapon coordination methods.

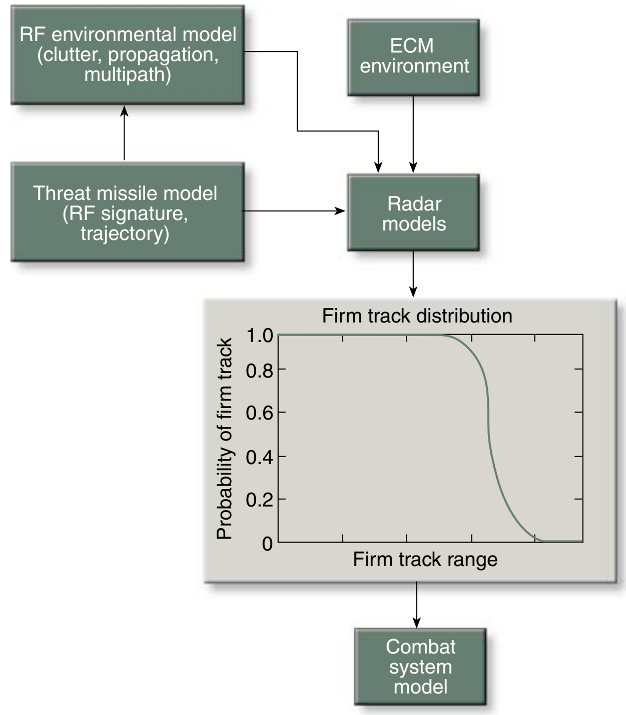

Figure 2. Firm track distribution for a radar system. This information is needed for each sensor that is evaluated. Similar data (threat parameters and environmental modes) are needed for electro-optical sensors. In either case, a probability versus range distribution is developed and used (ECM = electronic countermeasures).

Collecting Data

Once it is determined that SAMS properly represents all aspects of the problem being analyzed, its database is examined to determine what additional data are needed. Combat system performance data are developed for the air defense system elements from system requirements, test data, or high-fidelity computer simulations of components such as radars or missile systems.

SAMS model inputs describe the threat and the weapon systems engaging it. The threat is described in terms of launch times, seeker turn-on time, targeting, speed, time of flight versus range, and altitude versus range. Weapon systems description can be divided into detection, control, and engagement information.

Detection information is represented in SAMS by probability of firm track distributions for each sensor that may be used to support a weapon engagement. Threat characteristics and environmental data are input to high-fidelity radar models that produce cumulative probability of firm track versus range distributions that SAMS uses to establish the time at which the track is disclosed to the weapon system. An example of this process for radar data is shown in Fig. 2.

The weapon control system is represented in SAMS through a series of delays and queues. The major reaction time delays are time from firm track to weapon assignment, time from weapon assignment to missile or decoy launch, time between rounds, homing time (if using semi-active guidance), and kill assessment time. These times can be represented as cumulative distributions or as fixed delays.

Input parameters for an interceptor missile can include fly-out times, kill probability as a function of range, minimum and maximum intercept ranges, seeker homing time, illuminator slew and acquisition times, illumination pad times, and launcher slew and reload times for the trainable launcher. The delays depend on weapon type. These parameters are determined by the process shown in Fig. 3. Key elements of this process are the high-fidelity missile models that simulate missile fly-out and intercept.

NRL-developed models determine electronic attack weapon effectiveness using the process shown in Fig. 4. Electronic attack is either conducted using decoys (e.g., chaff) or electronic techniques (e.g., jamming) to deceive the attacking missile's seeker. These models provide probability of effectiveness versus deployment range distributions for each electronic attack system by threat, ship class, and approach angle. The distributions are used by SAMS to determine the probability of a threat missing the ship given that a decoy or electronic attack technique is deployed when the threat is at a specified range. These ranges are based on threat seeker turn-on and time for either the decoy to deploy or the electronic technique to become effective.

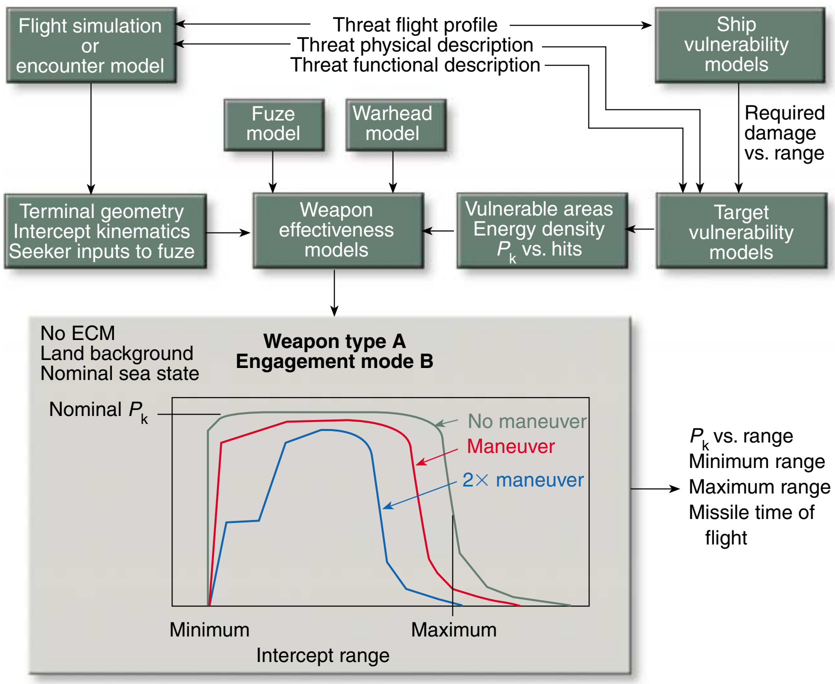

Figure 3. Process defining missile performance. The data required for a missile system are provided by a number of high-fidelity models that supply missile fly-out parameters and evaluate the ability of the missile to hit and destroy an attacking weapon. This process also relies on detailed models of the hostile weapon's vulnerability to the missile's warhead and fuze capabilities. (P_k = kill probability, ECM = electronic countermeasures.)

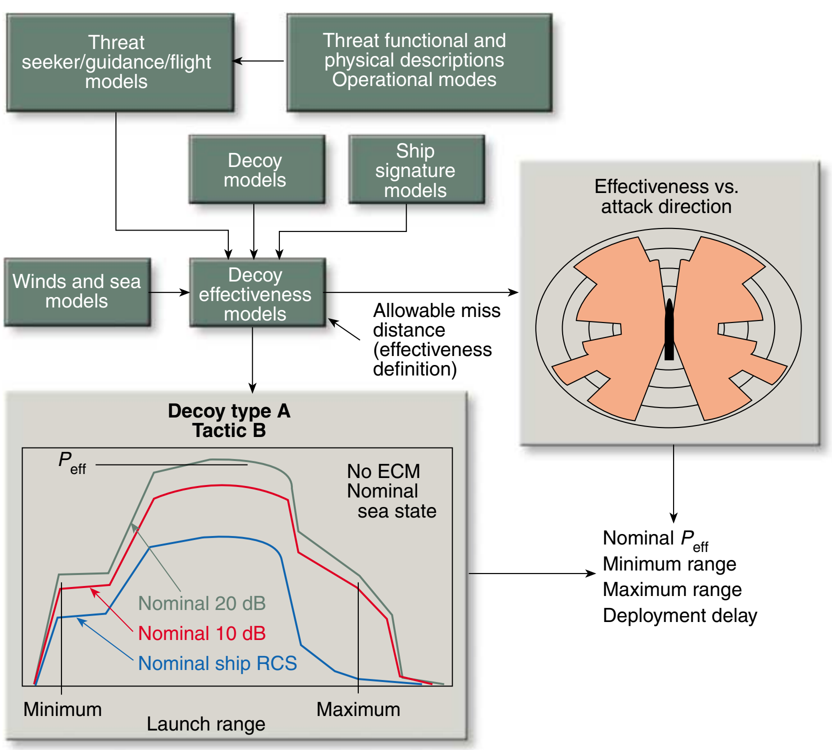

Figure 4. Process defining electronic attack weapon performance. A number of high-fidelity models are used to evaluate the effectiveness of electronic attack weapons (jamming, chaff, and decoys) on a hostile missile's ability to acquire and home on the defended ship. Ship signature models are needed to complete this assessment. (P_{eff} = probability of effectiveness, RCS = radar cross section.)

Determining Effectiveness Using SAMS

Once all components are properly represented in the model and all the necessary data have been gathered, SAMS is run to determine system effectiveness. The philosophy of the model requires the user to provide appropriate input and make key decisions regarding tactics, doctrine, and weapon employment. The model does not automatically decide which doctrine or tactic to use. The user must analyze the situation in advance and specify via input which method to use as well as appropriate threat and weapons performance data. This approach allows the model to be used as a research tool. Detection ranges, kill probabilities, or doctrines can be treated parametrically, and trade-off studies can be performed. SAMS produces both detailed and summary information for all aspects of each engagement. This information can be used to verify the validity of questionable results or compute additional MOEs.

Analyzing and Presenting Results

MOEs must be analyzed and displayed so that the sponsor can understand them and draw appropriate conclusions. The analysis performed to define the system and inputs gathered provide insight into SAMS results. MOEs for each system configuration are measured against a Capstone requirement, if available, or plotted against one another to determine relative values in a comparative study (i.e., the ability of the system to defeat the threat in an operational study). A standard set of output charts (Fig. 5) has been developed to display system ability to satisfy Capstone requirements.

Sensitivity analyses are often performed to provide a broader picture of ship or weapon system capabilities. Threat density may be increased to show weapon system

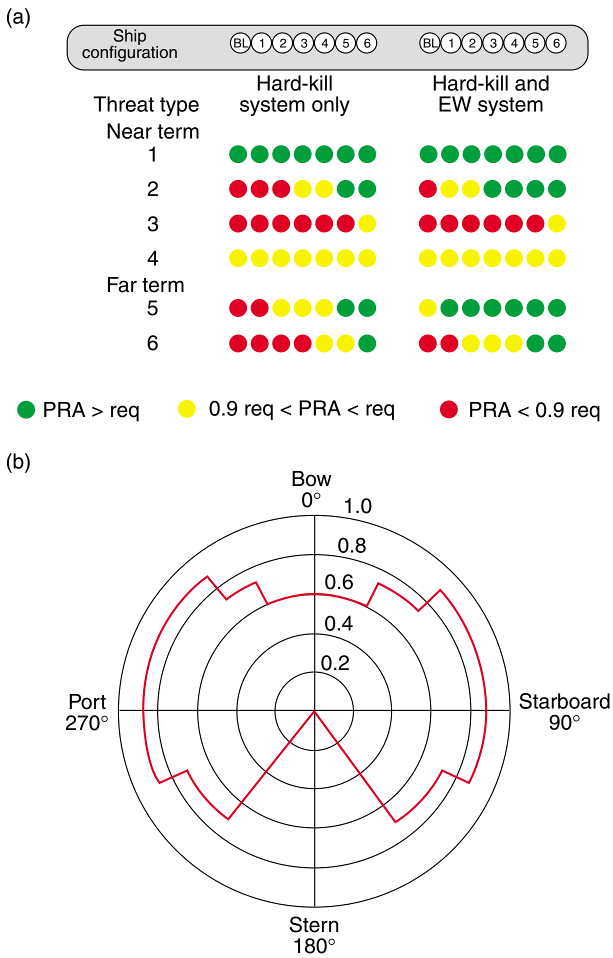

Figure 5. Standard probability of raid annihilation (PRA) output charts. An example of the combat system model and analysis results from the RAWG process is shown in (a). Results are compared to a hypothetical standard to assess if the combat system meets the goal requirement (green), meets a lesser requirement (yellow), or does not meet any requirement (red). Results may also be shown graphically, such as in a polar plot (b), to pinpoint possible vulnerable areas around a ship. (EW = electronic warfare, req = requirement.)

robustness. A weapon system may be omitted to show how much it contributed to total effectiveness. This technique provides better insight into the importance of certain weapon systems for the sponsor.

Availability of weapon systems is an important part of the analysis. If a system fails it could significantly degrade the ship's capabilities. Knowing which weapon systems are key to a ship's survival and knowing their reliability can determine whether a ship goes into a high-potential conflict area.

The database of element-level parameters and combat system results is also an important product of the analysis because it documents the study and makes data accessible for future studies. Questions posed following a study can often be answered quickly if the database is maintained during the study. For instance, the effect of adding a weapon system or changing the threat density is easy to determine by rerunning SAMS if the required data are readily available.

ANALYSIS EXAMPLES

Program Objectives Memorandum 2000

The six-step analysis process noted earlier helps Navy leaders who are selecting ship defense combat system configurations determine an investment strategy to develop future systems. As part of POM 2000, PEO TSC provided cost and effectiveness data to the Office of the Chief of Naval Operations on ship defense combat systems for all non-Aegis ship classes over the next 15 years. This analysis helped the Navy determine the optimal set of weapon systems needed to protect against current and future threats, given the cost constraints of each ship class. APL, as part of the RAWG, performed an effectiveness analysis using the six-step process. Other Navy organizations produced the cost analysis.

The PEO TSC, through the RAWG, defined a set of weapon system configurations for each ship class (e.g., Table 1). The analysis compared each configuration for three different time periods, weighting results by the likelihood of encountering each threat in each time period.

Data from previous studies (POM 1998 and Performance Review 1999) were used as input for SAMS in this study. Changes for POM 2000 from POM 1998 were the configurations on each ship class, which, in most cases, were narrowed to very specific sets of elements. The effectiveness of each configuration was computed using SAMS and compared with Capstone requirements to select suitable configurations for each ship class, ensuring their high mission effectiveness against current and future threats.

This analysis provided the Navy with a method to compare various sets of weapon systems in order to select the most capable and cost-effective way to protect its ships. It also gave the Navy an estimate of how effective certain weapon systems would be against existing and future threats and exposed some of the shortfalls of our current systems.

HELWS Study

A comparative analysis to investigate the military utility of HELWS for ship protection against anti-ship cruise missiles in conjunction with near-term missile systems was conducted. The first step in this utility analysis was to establish the POM 2000 anti-ship cruise missiles as the threat. The threat set was expanded to include technologically feasible, advanced anti-ship cruise missiles as well as rocket artillery with no guidance so that both ends of the technological spectrum were represented.

Table 1. LHD 1–7 class combat system configurations analyzed for POM 2000.

Baseline	Configuration 1	Configuration 2	Configuration 3
Detect			
Mk 23 TAS	Mk 23 TAS	SPQ-9B	SPQ-9B
SPS-48E	SPS-48E	SPS-48E	SPS-48E
SPS-49(V)5	SPS-48A	SPS-49A	SPS-49A
	CEC	CEC	CEC
SLQ-32(V)3	SLQ-32(V)3	AIEWS	AIEWS
Control			
ACDS Block 0	ACDS Block 1	ACDS Block 1	ACDS Block 1
SWY-3	SSDS	SSDS	SSDS
Engage			
NSSMS	NSSMS	NSSMS	NSSMS
RIM-7P	RIM-7P	RIM-7P	ESSM
RAM Block 0	RAM Block 1	RAM Block 1	RAM Block 1
CIWS Block 1	Mk 53 DLS	Mk 53 DLS	Mk 53 DLS
Mk 36 DLS	Nulka	Nulka	Nulka

Note: ACDS = Advanced Combat Direction System, AIEWS = Advanced Integrated Electronic Warfare System, CEC = Cooperative Engagement Capability, CIWS = Close-In Weapon System, DLS = Decoy Launching System, ESSM = Evolved Seasparrow Missile, NSSMS = NATO Seasparrow Surface Missile System (two directors/two launchers), RAM = Rolling Airframe Missile, SSDS = Ship Self-Defense System, TAS = Target Acquisition System.

This analysis used the combat system data including missile system parameters from the LPD-17 Cost and Operational Effectiveness Analysis. Because HELWS is new, a system concept was developed to describe how it might fit into the LPD-17 combat system and to establish its engagement process. The sponsor provided HELWS performance parameters. Laser kill criteria of the threat missiles were based on the Point Defense Demonstration Test and Army Nautilus tests.

The PRA was selected as the MOE for this study. Unlike POM 2000, no official Navy requirement exists for HELWS. The study looked for maximal PRA values among the weapon mixes considered. Before SAMS could be used for the effectiveness assessment, representation of HELWS in the SAMS model, a firing doctrine for the system, and a review of weapons coordination doctrines to determine their applicability to this new weapon were required. Several weapon coordination doctrines were developed during the course of this study.

HELWS is a directed-energy weapon system. Target kill is obtained by accumulating sufficient energy on the target to disable it in some manner. In this study, the assumed kill mechanism for the laser was to burn a hole in the target's radome, which would cause the missile to become aerodynamically unstable. SAMS was modified to incorporate a model of HELWS based on the defined system concept. Modifications to SAMS were verified by comparison with a spreadsheet model of HELWS and with results from an existing HELWS model from the Center for Naval Analysis.

Within SAMS, all weapons use a self-defense weapon coordination doctrine to engage targets. Such doctrines specify how shipboard weapons select targets for engagement based on set criteria. The criteria may include time-to-go (time for the target to reach the defending ship), the number of other weapons engaging the target, and the effectiveness of those weapons. The two primary SAMS coordination doctrines in this analysis were free fire, where all systems may engage the target, and first launch, where only the first available system engages the target.

Initial analysis of the weapon mixes indicated that no coordination was better than the first-launch doctrine. Two additional self-defense doctrines, "first launch plus" and "first launch plus plus," were developed for this study to further explore HELWS coordination with short-range missile systems. These doctrines expanded the first-launch doctrine to allow additional engagements to achieve a user-defined cumulative probability of kill (P_k) based on estimated weapon single-shot P_k's. Additional analysis was required to determine the robustness of each doctrine to changes in target type and spacing.

The utility analysis first determined a firing doctrine for HELWS based on maximum range to start lasing. The optimal range to begin lasing is a trade-off between battle space and total available lase time. Fluence (i.e., energy density in kJ/cm^2 of the laser beam on the target) accumulates on the target faster at short ranges than at long ranges, resulting in less time to gain the required fluence level. Thus, it is desirable to engage targets at the shortest range possible. However, if the HELWS maximum lase range is too close, its battle space may be too compressed for it to engage all threats in a raid before they reach the keep-out range, i.e., the range by which a target must be killed to avoid ship damage. The maximum lase range is therefore a trade-off between these two conflicting conditions. Assuming that an incoming target can only be classified based on speed, two maximum ranges were chosen, one each for subsonic and supersonic targets. The most effective ranges were chosen after computing HELWS effectiveness as a function of maximum lase range for all targets and raid densities.

HELWS utility to ship self-defense was evaluated using the firing doctrines established for subsonic and supersonic targets. Each of the four weapon coordination doctrines was used with six weapon mixes. The mixes included two types of short-range surface-to-air missile systems operating separately or together with and without HELWS. Two laser frequencies were considered for HELWS, and SAMS determined the PRA for each case. Sample results for one target are given in Fig. 6.

In addition to the base case, HELWS effectiveness against a technologically feasible threat and a rocket attack was evaluated. The sensitivity of HELWS utility to several assumed factors was analyzed, including keep-out range (increased for supersonic targets), hole size (increased for supersonic targets), and firm track range (reduced for stealthy subsonic and supersonic targets).

Results indicated that HELWS could provide significant complementary defensive capability. For the base case targets, HELWS with either self-defense missile provided effective defense against near- and mid-term anti-ship cruise missiles. The system had greater utility against higher threat densities where missile systems become saturated. No single coordination method performed best in every case. The most effective coordination method depended on raid density. This study was an initial step in investigating the applicability of HELWS for a wide range of force protection capabilities. Further analysis was recommended.

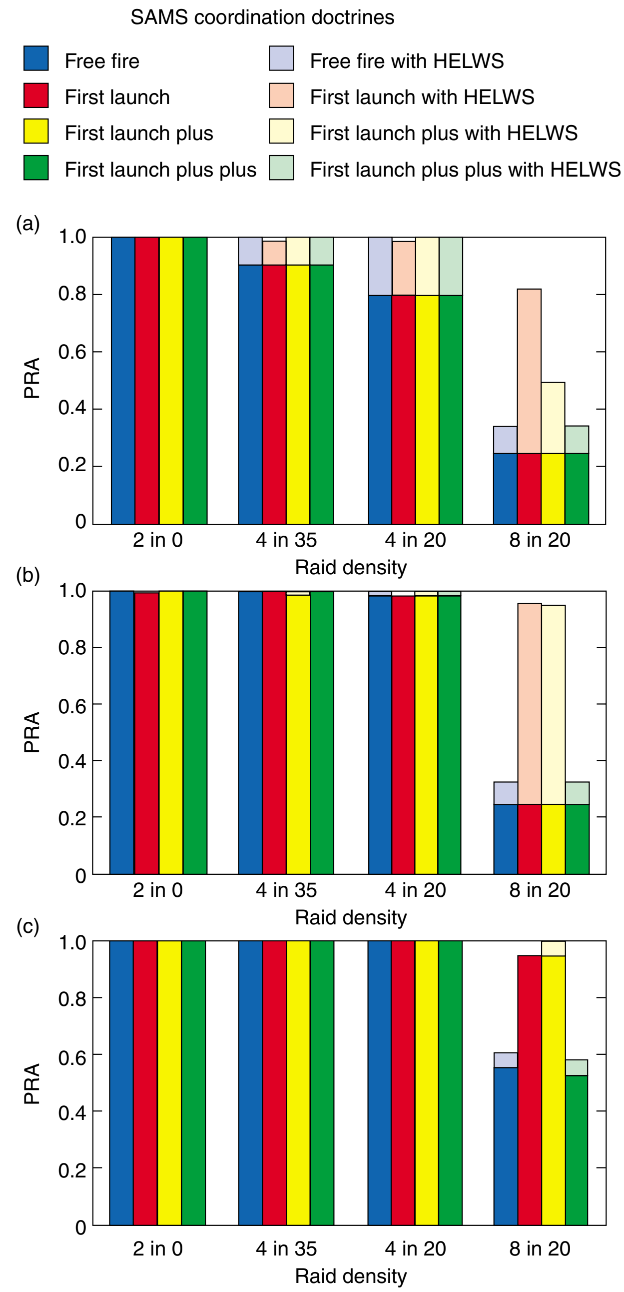

Figure 6. HELWS PRA results for a sample target. The HELWS utility analysis is designed to assess the relative contributions of a high-energy laser to a ship's combat system. The hypothetical results shown here represent the effectiveness of two types of surface-to-air missiles used both with and without HELWS against a typical anti-ship cruise missile: (a) missile type 1 used, (b) missile type 2 used, (c) missile types 1 and 2 used. See the text for discussion of the SAMS coordination doctrines.

Fifth Fleet Study

In 1995, Commander Fifth Fleet requested information on the capabilities of his ships in the operating environment. PEO TSC and Commander Surface Warfare Development Group (CSWDG) sponsored a study to provide ship defense effectiveness data to help develop new tactics for the Navy. APL, through the RAWG, participated in this study.

Again, the six-step analysis process was used. However, unlike the previous examples, there were no prior studies from which to draw data. Almost the entire process was used to generate study results. It included defining an operational situation, using high-fidelity simulations to get radar detection data, and using missile high-fidelity simulations to generate fly-out times, minimum and maximum engagement ranges, as well as kill probabilities.

The analysis was limited, addressing only two principal ship classes, DD 963 and LHD 1. Combat systems for these ships are shown in Table 2. Principal hard-kill weapon systems studied included SWY-3 and the Close-In Weapon System. SWY-3 is composed of the Mk 23 Target Acquisition System Radar and Weapons Control System, the NATO Seasparrow Missile System (NSSMS), and the Rolling Airframe Missile (RAM) Weapon System. Electronic attack systems (i.e., so-called soft-kill weapons), controlled by SLQ-32, were also part of the analysis and included chaff, electronic countermeasures, and jamming. The infrared decoy Giant was also evaluated.

In the first two examples (POM 2000 and HELWS), analyses were conducted using future threats and limited variation in operational environments. They compared combat systems or their components. For the Fifth Fleet analysis, current threats were examined. The operational environments were those of the Fifth Fleet, i.e., the Arabian Gulf and the Gulf of Oman. As with the other studies, ONI was tasked to provide threat estimates; however, these were expected threats for the region rather than the most stressing threat that could be encountered anywhere in the world. With information supplied by ONI, an operational situation was developed that included details on the geopolitical situation and conditions under which engagements would occur.

The operational situation was used to determine combat system doctrine, which specifies how SWY-3 (either RAM or NSSMS or both) selects targets for engagement. Combat system operating doctrine also impacts system reaction times in processing a target engagement.

The analysis considered environmental conditions such as proximity of land (land clutter) and varied radar propagation conditions (anomalous propagation) that occur in this region. This required that new radar calculations using a high-fidelity propagation model and detailed radar simulations be performed. Two operating regions were selected, and the land clutter received by radars was determined. Analysis results indicated good performance of radars for these locations and environments.

The study used a detailed system simulation called SWYSIM, developed at NSWC/Port Hueneme, which provides a high-fidelity model of SWY-3. It was used to evaluate changes made to SAMS to support this analysis and to provide electronic support measure data from SLQ-32 in support of RAM engagements.

NSSMS and RAM missile performance against the threats used in this analysis had not been evaluated previously. NSWC/China Lake ran each missile's six-degrees-of-freedom model to evaluate missile fly-out and kill probabilities against the threats. Kill probabilities were provided as functions of intercept range.

PRA was selected as the primary MOE. Analysis results showed that the ships had good capability against the expected operational threats. This outcome was expected because the ships' weapons had been designed to counter these types of threats. Excursions of the analysis were done to evaluate combat systems robustness. For example, an analysis was conducted to evaluate the impact of system availability on the results. Careful analysis of input data and SAMS results provided further insight into system operation, aiding CSWDG's development of tactics.

Table 2. DD 963 and LHD 1 class combat system elements for the Fifth Fleet Study.

Combat system type	System elements: DD 963	System elements: LHD 1
Detect	Mk 23 TAS	Mk 23 TAS
	SPQ-9A	SPS-48E
	SPS-40E	SPS-49(V)5
Control	SLQ-32A(V)3	SLQ-32A(V)3
	CDS	ACDS Block 0
	SWY-3/RAIDS	SWY-3
	R17.00/DDI	R17.00/DDI
Engage	RAM Block 0 (1 launcher)	RAM Block 0 (2 launchers)
	RIM-7P (1 launcher)	RIM-7P (2 launchers)
	CIWS block 1A (2)	CIWS block 1A (3)
	5 in./54 Mk 45 (2)	
	Mk 36 Mod 18 DLS	Mk 36 Mod 18 DLS
	SLQ-32A(V)3	SLQ-32A(V)3
	SLQ-49	Giant (infrared decoy)
	Giant (infrared decoy)	

Note: ACDS = Advanced Combat Direction System, CDS = Combat Direction System, CIWS = Close-In Weapon System, DDI = Distributed Data Interface, DLS = Decoy Launching System, RAM = Rolling Airframe Missile, TAS = Target Acquisition System.

SUMMARY

A six-step process was described that has proven to be an effective framework for analyzing ship self-defense systems. It can be used to support program managers and resource sponsors in evaluating systems for development and to support Fleet operators in evaluating the performance of their combat systems in an expected operational situation. The process starts by precisely identifying the problem and encompasses use of an engagement model with possible modifications. Other steps include establishing the MOEs, gathering the required data, and analyzing and displaying the results. This process, which has evolved over the past 6 years, has been used for a wide range of studies. Examples of three such studies—POM 2000, HELWS Study, and Fifth Fleet Study—were described. Each further developed the analysis process and expanded the database of Navy weapon systems and threats. This process and the models used to support it will continue to evolve in the future.

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