This product is part of the RAND Corporation monograph series. RAND monographs present major research findings that address the challenges facing the public and private sectors. All RAND monographs undergo rigorous peer review to ensure high standards for research quality and objectivity.

DDG-51 Engineering Training

How Simulators Can Help

Roland J. Yardley, James G. Kallimani,
Laurence Smallman, Clifford A. Grammich

Prepared for the United States Navy
Approved for public release; distribution unlimited

RAND NATIONAL DEFENSE RESEARCH INSTITUTE

The research described in this report was prepared for the United States Navy. The research was conducted in the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Department of the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community under Contract W74V8H-06-C-0002.

Library of Congress Cataloging-in-Publication Data is available for this publication.

978-0-8330-4729-8

Cover photo courtesy of Finn Kilsgaard/Naval Air Warfare Center Training Systems Division, Surface Systems

Published 2009 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213-2665
RAND URL: http://www.rand.org
To order RAND documents or to obtain additional information, contact
Distribution Services: Telephone: (310) 451-7002;
Fax: (310) 451-6915; Email: order@rand.org

Summary

U.S. Navy surface combatant ship crews require extensive and rigorous training. The training demands are many on ships of the DDG-51 class. Among DDG-51 crew members, some of the most rigorous training is required for ship engineers responsible for maintaining, operating, and repairing main propulsion and auxiliary equipment.

The basics of engineering training consist in developing watchstander proficiency in two different skill sets. The first required skill set is the ability to respond to engineering casualties. This training consists of executing a series of engineering drills, coordinated by the ship's Engineering Training Team (ETT), during which the watchstanders must respond to the symptoms of the casualty, take the correct controlling and immediate actions from memory, and then restore the plant to its normal operating configuration. This training is time-consuming and repetitive. All members of the watch section must function effectively as individuals and as a team. It takes repeated exposure to understand the casualty and to learn and memorize the actions needed to correct, control, and recover the engineering plant. The use of simulators has great value for this skill set.

The second required skill set is the ability to conduct routine plant operations or engineering evolutions[1] (i.e., starting and stopping various pumps, motors, and engines and aligning systems for use). During evolutions, the watchstander is required to have and refer to a written procedure while conducting the event. Evolutions can also be practiced

[1] *Evolutions* are events performed during the normal operation of the engineering plant.

on available engineering simulators—both on the desktop and on console trainers. Because evolutions are essentially "open book" tests, evolution proficiency is easier to achieve than proficiency in responding to engineering casualties.

Ships progress through a sequence of training events before being assigned to operational missions. Ships begin first with unit-level training (ULT), during which the ship's crews are assessed, trained and certified in the missions that the ship was designed to perform. After ships complete ULT, they are ready for tasking (RFT) as individual units and progress to intermediate and advanced training, where they train and operate with other ships and units. Upon completion of advanced training, ships are ready for deployed operations. Ships must sustain the training readiness achieved during ULT throughout the operational cycle. Our research focuses on the engineering training requirements and proficiency of engineering watchstanders.

Previous RAND research found that much of the ULT is conducted underway but that a great deal of it could be done in port.[2] Although underway training is arguably the best method for training a crew, it is expensive. While underway, ships burn large quantities of fuel and incur equipment wear and tear that may increase maintenance demands. The average DDG burns a minimum of 500 barrels (21,000 gallons) of fuel per 24-hour underway day. At an optimistic price of $50 per barrel, one can see that fuel costs of $25,000 per day per DDG are easily achieved.[3] Time constraints and other factors also limit how much underway training a crew can do. By contrast, simulated training could expand training opportunities. The use of a shore-based engineering simulator console could improve watchstanders' proficiency throughout the length of their tour on the ship, reduce the necessary ULT underway training days required for them to achieve satisfactory proficiency and thus saving fuel, reduce equipment

---

2 Roland J. Yardley, Harry J. Thie, Christopher Paul, Jerry M. Sollinger, and Alisa Rhee, *An Examination of Options to Reduce Underway Training Days Through the Use of Simulation,* Santa Monica, Calif.: RAND Corporation, MG-765-NAVY, 2008.

3 When the fully burdened cost of fuel to the Navy is considered, the fuel costs per underway day dramatically increase. Fully burdened fuel costs include costs to transport fuel to the fleet.

wear and tear, and potentially result in the ship being RFT earlier in the training cycle.

Recognizing these issues and the potential of simulated training to supplement underway training, the Director, Assessment Division (OPNAV N81) asked RAND to examine the training requirements for DDG-51 engineering watchstanders—specifically, how available simulation technology might be adapted for use by DDG-51–class ship engineers and what policies and resources could help increase the use of simulated training. Accordingly, this monograph reviews the ways that simulators can boost training proficiency as well as the changes needed to support their widespread adoption.

Current Training Challenges and How Simulators Could Meet Them

Subsequent to a maintenance period and before undergoing advanced training and deploying, ship crews—including ship engineers, the focus of this study—go through ULT to assess their readiness and mastery of drills and evolutions they are expected to handle in the conduct of routine plant operations. Typically, most ship engineering teams do not start at the required level of mastery during the initial assessment of these drills and must begin a period of mobility–engineering (MOB-E) training. Most ships entering MOB-E training complete it within three to four weeks, but a few in recent years have taken as many as six weeks or more to complete this training. Ships typically have three teams of engineering watchstanders, with the third team consisting of members of the Engineering Training Team (ETT) who are responsible for evaluating the other two.

Our research has shown that ship crews perform a majority of their training underway but that many training exercises could be done in port. This monograph discusses how simulator use could improve engineering watchstanders' proficiency before ships go to sea, so that time at sea could be used to fine-tune the training. Furthermore, given constraints on underway training—including other tasks that a ship must accomplish at sea as well as the resources needed to be at sea—

there is a limit to the drills a ship can practice at sea. In addition, the requirement that a third team train and evaluate the other two leaves little opportunity for it to conduct its own drills.

Simulation technology is currently available in three forms for a DDG-51 destroyer: a desktop trainer, a full mission console, and an embedded training capability (onboard and integrated into the ship's engineering consoles). The desktop trainer and full mission console use the same software, developed exclusively for the DDG-51. The full mission consoles include exact duplicates of the consoles onboard DDG-51 ships and provide training for watchstanders in normal startup, operations, shutdown, and casualty control procedures of a DDG-51 engineering plant. The desktop trainer can be operated either individually—to train operators on the seven DDG-51 engineering consoles to align, start, operate, or stop equipment—or in a local area network to provide watch team training. The embedded training capability is installed only on the newest ships of the class (DDG-96 and above), but plans are being made to backfit the embedded trainer on the older ships (DDG-51–DDG-95). The embedded training capability allows operators to train onboard their ship, on their own ship's consoles. The consoles are put in a training mode and an instructor inserts casualties via a laptop connection to the console, to evaluate the watchstander's responses.

Simulators, both onboard and ashore, can help increase an engineering watchstander's proficiency by allowing the ship's company to practice more drills and to practice each drill more frequently with fewer time constraints and less manpower.

Current simulators allow practice on 35 of 40 casualty control drills. Simulators on shore at Fleet Concentration Areas (FCAs) would also provide more-accessible training opportunities. The only current DDG-51–class engineering simulators ashore are those at the Surface Warfare Officers School in Newport, Rhode Island, and therefore they are not used by the enlisted personnel most likely to stand engineering watches. The Navy is currently backfitting embedded simulators on DDG-51–class ships but, at the current rate, will not complete this process until 2025.

Benefits and Drawbacks of Simulator Training

In addition to providing more training opportunities, simulators offer many unique advantages that do, in fact, provide for more-effective training. Their replay capability allows engineers to pinpoint the exact point at which a drill failed. The "freeze" capability allows an instructor to stop a drill when needed and provide instruction. They allow engineers to practice multiple or cascading casualties more easily than underway training would allow. They allow more repetitions of a single drill in much less time than is required underway, improving the pace of learning. More-qualified engineers can maintain their skills on simulators; less-experienced ones can gain experience and proficiency prior to underway training. Training via a simulator is a safer way to train. The impact of a trainee's incorrect actions or inactions will not harm equipment, personnel, or the ship.

We compared and contrasted the conduct of engineering casualty control drill training as it is done on the ship at sea, on the ship pierside, or in a shore-based simulator. Table S.1 compares these methods using a stoplight format—green being good or best, yellow being neutral, and red being poor or least attractive—by variables such as cost, training constraints, and cohesiveness.

We do not weight these variables, but we understand that some, e.g., cost, are more important than others. The table shows that shore-based simulators offer many training options that compare favorably with training done either onboard at sea or pierside in port. Advantages include lower cost, better cueing of watchstanders, better trainee feedback, reduced energy use, and increased training safety. These advantages do not suggest that a shore-based simulator is the single best option for conducting drills. Rather, such simulators could be part of a balanced approach to improving training.

Although simulators can offer some advantages over underway training in cost, scheduling of training, and trainee feedback, their use can be affected by several factors. Among the most important factors that support increased use of simulation are the close proximity to ship's engineers, high fidelity of simulator exercises compared with actual operating conditions, flexible times for use, and an adequate

Table S.1
Factors to Consider in Using Shore-Based Simulators or Shipboard Equipment for Training

Factor/Location of Training	At Sea	Pierside	Shore-Based Simulator
Cost	High fuel costs plus wear and tear	Lower cost, but wear and tear	Lower cost, no wear and tear
Operate own ship's equipment	All engineering equipment can be operated	Some can be operated, but not all	Ship's equipment not operated
Cueing of watchstanders	Some cueing by training team on drill imposition	Some cueing by training teams on drill imposition	No cueing
Number of ECC drills than can be done	All 40	32 of 40	35 of 40
Time available by crew for training	Dedicated crew underway, but underway time is decreasing	Maintenance demands in port are high. CCS is hub of activity in port—conflicts will arise	No conflicts, but competes with other unit's training needs
Training constraints	ECC drills normally done underway on a not-to-interfere basis with other training needs and/or impact bridge operations or ship's ability to navigate	Some conflicts with in-port maintenance demands and other ship events	Trainees must leave ship for training. Must trade off what they would be doing if they stayed on board, and what doesn't get done
Who gets trained	2 of 3 Engineering Watch Teams composed of CCS and in-space watchstanders	2 of 3 Engineering Watch Teams composed of CCS and in-space watchstanders	3 of 3 CCS watchstanders but not in-space watchstanders
Personnel involved in training	ETT and all watchstanders	ETT and all watchstanders	CCS personnel
Impact on nonengineering watchstanders	Electrical load limitations for combat systems, navigation and bridge equipment	Small impact	None
Usefulness to utilize for varying skill levels	Good for experienced and inexperienced personnel, but expensive and potentially hazardous if incorrect actions taken	Good for experienced and inexperienced personnel and less expensive; potentially hazardous if incorrect actions taken	Good for experienced and inexperienced personnel and least expensive over time; good for continuation training
Impact of watchstander errors	CCS personnel and in-space watchstanders – potential for being costly and dangerous	CCS personnel and in-space watchstanders—potential for being costly and dangerous	Trains CCS personnel only— no hazard to personnel or equipment

Table S.1—Continued

Factor/Location of Training	At Sea	Pierside	Shore-Based Simulator
Feedback mechanism to trainees	In-space watchstanders stopped for safety violations. CCS watchstanders will perform immediate and controlling actions—graded as effective or ineffective based on observation and written comments about their actions	In-space watchstanders stopped for safety violations. CCS watchstanders will perform immediate and controlling actions—graded as effective or ineffective based on observation and written comments about their actions	Program can be "frozen" to provide instruction to watchstanders. Printout of time and sequence of actions offer ability to trace actions and timeline and provide objective feedback
Time it takes to conduct training	Longer. Must be approved by commanding officer and deconflicted with other training events onboard	Long. Deconfliction is required with ongoing maintenance and other shipside training	Short. Provides list of drills and runs training events. Events may be repeated to ensure proficiency
Maintenance of Engineering Training Team (ETT) Casualty Control Proficiency	Proficiency of ETT is unknown and untested	Proficiency of ETT is unknown and untested	Good. ETT members receive proficiency training as well as 1st and 2nd watch teams; ECC drill proficiency can be maintained in a shore-based simulator
Engineering watchstander's cohesion	Good. All are trained and communicate together	Good. All are trained and communicate together	Good for CCS watchstanders only
Physiological—heat, sound, sight, smell, ship movement, stresses	The real thing	Fewer stresses in port	Simulated environment
Realism of drill imposition	Some impositions different from an actual casualty, e.g., grease pencil used to indicate a high tank level	Simulations and deviations exist	Casualties alarm and occur to CCS watchstanders as they would underway
Effectiveness standard	Underway demonstration standard is 50%	Onboard demonstration standard is 50%	Can be trained to a higher effectiveness standard
Energy savings/carbon footprint	High energy use	Reduced energy use	Little energy use
Safety	Proficiency gained on operating equipment	Proficiency gained on operating equipment	Safe. Can train and gain proficiency before getting underway

return on investment offsetting the costs of equivalent underway training. By contrast, a simulator at a removed distance that offers low or poor fidelity to actual operations and a limited range of exercises at high cost will hinder or limit simulated training. Overall, our research indicates that simulators should be used as a training alternative when they can sustain readiness, enhance a capability, save resources, or reduce risk.

Resources Needed to Increase Use of Simulators

We recommend installation of engineering full mission consoles at FCAs, such as Norfolk and San Diego. A DDG-51 engineering console trainer, such as the one used at the Surface Warfare Officers School, costs $1.6 million to procure and $300,000 to install. Sustainment costs include an operator, a technician, and updating the software as needed. The software for the desktop trainer can be loaded onto ship computers today at negligible cost to the Navy. Such software can be used to practice many console operations.

The payoff for installing full mission consoles at FCAs depends on the cost of resources and the number of underway days of training the console saves. For example, DDG-51–class ships burn a minimum of 500 barrels (21,000 gal) of fuel per day. If fuel were to cost $50 per barrel, then it would cost approximately $25,000 per 24-hour steaming day per DDG-51. A console that saves a total of 120 steaming days of training over the course of a decade would save $3 million in fuel costs alone ($25,000 × 120 = $3 million). These savings would pay for the simulator's acquisition and sustainment costs. In addition, there would be reductions in necessary ship maintenance, repairs, food costs, port costs, etc. We estimate that approximately 50 Norfolk-based ships and 39 San Diego–based ships (without an embedded training capability) will undergo ULT from fiscal year (FY) 2009 to FY 2018. Even if fuel were just $40 per barrel over the next decade, an engineering simulator in Norfolk would pay for itself if it saved only about three days per ship of underway training over a ten-year period, while one in San Diego would pay for itself if it saved only about four days per ship.

We recognize that, when a DDG is underway for MOB-E training, engineering is not the only training the ship conducts. However, our discussions with Afloat Training Group (ATG) representatives on both coasts indicate that MOB-E training, when it is in a ship's Plan of the Week for an underway week, is normally the preponderance of the effort. MOB-E training is a major driver for underway training, and simulators will reduce that requirement.

Policy changes could further encourage use of simulators for training. To fully realize the benefits of the engineering simulator, its use should be a mandatory part of the training process. To increase engineering training through simulators, the Navy should, among other steps, establish console trainers at FCAs, using them for training during extended maintenance periods and repetitive training requirements; use desktop trainers as lead-in trainers for advanced console operations; load the engineering training software onboard ships or ashore and at homeports without console trainers; and perform alignment, starting/stopping, and master light-off checklist plant operations on the desktop trainers.

The DDG-51 community could consider utilizing simulators to qualify/requalify senior enlisted personnel who are reporting back to sea duty from a shore-duty assignment. A refresher course would allow personnel to arrive at their new commands ready for qualification. It would free up senior engineering talent to focus more on monitoring material condition and training and mentoring subordinates.