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Does Computer Based Training Impact Maintenance Costs and Actions? An Empirical Analysis of the U.S. Navy's AN/SQQ-89(v) Sonar System

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Panel 19. Toward Cost Reductions in Ship Design and Maintenance

Thursday, May 15, 2014	
1:45 p.m. – 3:15 p.m.	**Chair: RADM David Lewis,** USN Program Executive Officer, SHIPS ***Potential Cost Savings for Use of 3D Printing Combined With 3D Imaging and CPLM for Fleet Maintenance and Revitalization*** David Ford, Texas A&M University Tom Housel, Naval Postgraduate School ***A Proposal for Reducing Work Content in Early Stage Naval Ship Design*** Robert Keane, Ship Design USA Inc. Laury Deschamps, SPAR Associates, Inc. Steve Maguire, First Marine International ***Does Computer Based Training Impact Maintenance Costs and Actions? An Empirical Analysis of the U.S. Navy's AN/SQQ-89(v) Sonar System*** Robert McNab, Naval Postgraduate School Diana Angelis, Naval Postgraduate School

Does Computer Based Training Impact Maintenance Costs and Actions? An Empirical Analysis of the U.S. Navy's AN/SQQ-89(v) Sonar System

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Abstract

Traditional training for Navy technicians is labor intensive, removes skilled sailors from the fleet, requires capital infrastructure, and may require more time than alternative means of acquiring knowledge. The U.S. Navy decided in the early 2000s to replace traditional, instructor-led schoolhouse training with Computer Based Training (CBT). Anecdotal evidence suggests that CBT failed to sufficiently prepare new sailors for on board maintenance and operations. To determine the validity of this claim, we examine data for the AN/SQQ-89(v) sonar. We analyze whether the U.S. Navy's introduction of CBT significantly affected fleet maintenance costs, actions, and training requirements. Preliminary results suggest that CBT adversely impacts costs, actions, and maintenance hours for the sonar system, suggesting that the reduction in training costs experienced with the use of CBT may have been transferred to fleet operations costs, supporting the anecdotal evidence.

Introduction

The majority of specialized skills training (known as class "A" and "C" schools) in the United States Navy has traditionally been provided in a classroom setting by instructors in Navy schoolhouses. The growing cost of training and concerns that future training demand would exceed capacity, led to an Executive Review of Navy Training (ERNT) in 2000. The ERNT group recommended using new training technologies to meet future demands while reducing training costs and time (United States Navy Chief of Naval Operations, 2001).[1] Based, in part, on these recommendations, the U.S. Navy implemented Computer Based Training (CBT) in 2003, expecting that CBT would increase training capacity and reduce the time and cost of training, while maintaining training quality.[2]

While it seems reasonable that CBT may lower costs and maintain quality for relatively simple tasks, it may not be as effective for specialized, knowledge-intensive skills. In 2009, the Naval Inspector General found that although CBT did reduce training time relative to the A and C schools, it may not have adequately prepared sailors for their initial duty assignments. Anecdotal evidence suggested that sailors trained with CBT did not

[1] Part of the navy's new strategy included use of new training technologies such as, distributed learning, computer based training, collaborative learning, and computer-mediated learning.
[2] CBT is defined as "individual or group self-paced instruction using a computer as the primary training medium, to include web-delivered Navy E-Learning (NEL)" (Naval Inspector General 2009, ii).

possess the required Knowledge, Skills, Abilities, and Tools (KSATs) to perform their duties effectively (Ewing, 2009; Naval Inspector General, 2009). Initial evidence also suggests that the use of CBT may have transferred these costs to the operational fleet (Gibson, 2012). To understand the operational cost impact of CBT we need to know whether CBT reduced the overall cost of operations and maintenance, including on-the-job training, unscheduled maintenance actions, and the length of repairs for systems requiring intensive education and training.

In this study, we examine the impact of CBT on a single system, the AN/SQQ-89(v) sonar[3], to determine whether CBT significantly altered fleet maintenance costs, actions, and training requirements for this system. If CBT has effectively trained personnel, then costs, labor hours, and corrective maintenance actions should either remain constant or decline. On the other hand, if CBT is an ineffective replacement for traditional 'hands-on' training, then, after controlling for other factors, costs, labor hours, and corrective maintenance actions should increase. We recognize that focusing on one system will limit the inferences about CBT's effect, however, we maintain that these inferences will still of be interest to practitioners and policymakers alike.

The next section briefly discusses the Navy's traditional and computer based training. The third section describes the AN/SQQ-89(v) sonar system and the data used in this study. The fourth section analyzes whether CBT has affected maintenance costs, actions, or time. The last section concludes and offers directions for future research.

Navy Training

U.S. Navy sailors receive training throughout their careers. Once a recruit has completed basic training, he or she will attend specialized skill training in an occupational specialty or "rating." In-rate training begins in a class "A" school,[4] then, depending on the rating, a sailor may also attend additional in-rate training in a "C" school.[5] After completing school training, the sailor is assigned to an initial duty station, where training will continue "on-the-job" as he or she gains real world experience in their specialized skill. Additionally, sailors can expect to receive general military training in topics ranging from electrical safety to suicide prevention.

Until the early 2000s, the navy had conducted in-rate training in a traditional schoolhouse setting using more experienced sailors (subject matter experts) to instruct new sailors. These instructors have practical experience with the work and responsibilities of newly rated sailors and can supplement classroom material with anecdotes and tips from their own career experiences (Hall & Freda, 1982; Naval Inspector General, 2009).

In addition to lectures, sailors reinforce their understanding of the material through hands-on practice on the same equipment they will use and maintain in the Fleet, and are

[3] The AN/SQQ-89(v) surface ship Anti-Submarine (ASW) Warfare combat system is an integrated network of sonar systems designed to search, detect, classify, and engage ASW threats (Lockheed Martin, 2009)

[4] For further information on qualifications for and assignments to class "A" schools, see MILPERSMAN 1306-618, 'Class "A" School and Rating Entry Requirements.' Available at http://www.public.navy.mil/bupers-npc/reference/milpersman/1000/1300Assignment/Documents/1306-618.pdf

[5] A submarine Fire Control Technician, for example, attends a 27 to 33 week A school course on basic skills, followed potentially by a C school course on advanced maintenance topics, including computer language skills and maintenance of specific weaponry.

asked to troubleshoot malfunctions in a controlled environment. Because the instructors are observing and interacting with the students in person, the delivery of material (lecture or practical application) can be tailored to improve the students' level of comprehension.

The introduction of CBT in the class A schools has considerably altered the nature of instruction. Using a personal computer, sailors can progress through learning modules at their own pace or work together in groups to complete the course material (Barker, 2010). There are periodic knowledge assessments throughout the module, followed by a comprehensive evaluation at the end. In both self-paced or group-driven CBT, the navy has replaced instructors with facilitators who are primarily concerned with maintaining order in the classroom, monitoring student progress, and providing technology assistance. Facilitators do not provide instruction or answer questions related to the course content. The removal of instructors from the classroom may have a detrimental effect on learning for those students who cannot grasp the material on their own.

In 2010 GAO noted that the fleet had concerns over the level of knowledge that sailors and officers have received through CBT (GAO, 2010). In fleet interviews, some commands reported that specialty qualification time was nearly double what it had been before the CBT's introduction (Naval Inspector General, 2009). Unfortunately, the navy has focused on the cost of training and has not developed metrics to examine training outcomes, potentially reducing readiness (GAO, 2010; Novak, 2010).

The AN/SQQ-89(v) Sonar System

In this study we examine the effect of CBT on a single navy system, the AN/SQQ-89(v) sonar system. We selected the AN/SQQ-89(v) sonar system because it is fielded throughout the operational fleet before and after the implementation of CBT with relatively consistent manning. The AN/SQQ-89(v) surface ship Anti-Submarine (ASW) Warfare combat system is an integrated network of sonar systems designed to search, detect, classify, and engage ASW threats (Lockheed Martin, 2009). The system is currently installed on CG-47 class cruisers, DDG-51 class destroyers, and FFG-7 class frigates. The AN/SQQ-89(v) employs a variety of sensors that can transmit and receive acoustic data to detect and classify threats (Johns, 1998).

The AN/SQQ-89(v) is maintained and operated by sonar technicians (STGs). All sailors selected for this duty attend STG A school. At A school they learn the basic principles of oceanography and sound. Following A school, STGs who are strictly operators report to a Sonar Operator course, while maintainers attend C school, where they learn the technical skills required to maintain the equipment present on their reporting ship (Navy Personnel Command, 2012).

Analysis & Results

To test the hypothesis of whether the introduction of CBT significantly influenced system maintenance and operation we define three dependent variables of interest: Organization Parts Costs (*OrgParts*), Corrective Organizational and Intermediate Maintenance Actions (*OrgActions*), and Organization Labor Man-Hours (*Orghours*). If CBT does not detract from sailor ability, then CBT should have no (or negative) impact on the dependent variables. If, however, CBT fails to adequately prepare sailors for operating and maintaining these systems to the degree of traditional training, then there should be an increase in parts costs, maintenance actions, and man-hours.

We define Computer Based Training (CBT) as a dummy variable that is 0 before 2004 and 1 afterwards and introduce several control variables: billets authorized for enlisted grades E-1 to E-6 (*BAE)*; the Navy Manning Plan for enlisted personnel in grades E-1 to E-6 (*NMPE*); number of enlisted in grades E-1 to E-6 currently on board (*COBE*); and the number of days underway in a given fiscal year (*UW*). A matrix Z includes the radar variant, radar's installation year, type of ship, and homeport location. We employ panel data and thus specify the general estimation form as follows:

$$y_{it} = \alpha + \beta_1 CBT_{it} + \beta_2 BAE_{it} + \beta_3 NMPE_{it} + \beta_4 COBE_{it} + \beta_5 UW_{it} + \varphi Z_{it} + \mu_i + \lambda_t + u_{it} \quad (1)$$

where μ_i and $\lambda_t$denote the unobservable individual ship and time effects, respectively. The term uit is a random walk. The subscripts i and t denote ship and time period, respectively.

To examine the hypothesized influence of CBT on AN/SQQ-89(v) parts costs, maintenance man hours, and maintenance actions, we select those variants on board prior to and following CBT's introduction into the A and C schools. Of the 15 possible variants, we utilize data on five variants for the empirical analysis from FY 1999 through FY 2010. Our final data set contains 526 observations on 68 ships from FY 1999 to FY 2010. Table 1 presents the 68 ships that have these variants onboard.

We present results from pooled Ordinary Least Squares (OLS) estimators, explicitly assuming that CBT is exogenous to the dependent variables; as CBT is a policy decision, this is a reasonable assumption. We find that CBT's use has ***adversely*** influenced the parts costs, actions, and labor hours associated with operating and maintaining the AN/SQQ-89(v). This result is consistent when we control for the type of ship, radar variant, homeport, and unobservable ship and time characteristics. These results suggest that the navy has traded an explicit training cost for an obscured cost in terms of parts, maintenance actions, labor hours, and readiness.

Our analysis suggests that using CBT increases Organizational Parts Costs by approximately $4,971 per year at the 1% level of significance (Table 4). For a given system on a ship, this suggests a 20 to 50% increase in maintenance costs over time. We also find that CBT increases Corrective Maintenance Actions by approximately 32 per year at the 1% level of significance (Table 5). For a given system on a ship, this suggests a significant percentage increase in maintenance actions. Finally, we estimate that introducing CBT inflates the number of Organization Labor Hours by 730 hours at the 1% level of significance (Table 6).

Our results support the anecdotal arguments that CBT negatively impacts sailor performance on ships, affecting parts costs, maintenance actions, and maintenance labor hours. While limited to one system, this result suggests that the navy has reduced the cost of labor and equipment in schoolhouses at the expense of operational cost and effectiveness (parts, maintenance, and labor hours) on board ships. Further research is important to understand whether these adverse impacts are present in different systems.

Conclusions and Future Research

In 2001, ERNT released its report, *Revolution in Training: Executive Review of Navy Training Final Report*, which led to a major overhaul in the U.S. Navy's training practices, including the use of CBT in A and C schools. Anecdotal evidence from the Fleet suggested that the quality of training received by sailors through CBT was not as good as the training received in traditional schoolhouses.

In this study, we focus on a single navy system, the AN/SQQ-89(v) sonar system, to examine the effects of the conversion to CBT on maintenance. Controlling for the navy's planning for manning the system, the number of billets authorized, and the number of personnel on board, we find that CBT adversely impacted costs, actions, and maintenance hours. These preliminary results provide, for the first time in the literature, empirical evidence CBT's negative impact with respect to the U.S. military.

The estimation of (1) raises several econometric issues including serial correlation, heteroskedasticity, and the possibility of ship and time-specific effects. We will explore whether our results are fragile to the choice of estimator in future research. Future research should also explore whether CBT has affected other systems in a similar manner. This question is of direct policy and financial interest to the navy; navy expenditures may rise from increases in costs and actions.

Table 1. List of Ships and AN/SQQ-89(v) System Variants[6]

(V)2	SHIP	HOMEPORT
CG 55	LEYTE GULF	Norfolk, VA
FFG 8	MCINERNEY	Mayport, FL
FFG 28	BOONE	Mayport, FL
FFG 29	STEPHEN W GROVES	Mayport, FL
FFG 32	JOHN HALL	Mayport, FL
FFG 33	JARRET	San Diego, CA
FFG 36	UNDERWOOD	Mayport, FL
FFG 38	CURTS	San Diego, CA
FFG 39	DOYLE	Mayport, FL
FFG 40	HALYBURTON	Mayport, FL
FFG 41	MCCLUSKY	San Diego, CA
FFG 42	KLAKRING	Mayport, FL
FFG 43	THACH	San Diego, CA
FFG 45	DE WERT	Mayport, FL
FFG 46	RENTZ	San Diego, CA
FFG 47	NICHOLAS	Norfolk, VA
FFG 48	VANDEGRIFT	San Diego, CA
FFG 49	ROBERT G BRADLEY	Mayport, FL
FFG 53	HAWES	Norfolk, VA
FFG 55	ELROD	Norfolk, VA
FFG 56	SIMPSON	Mayport, FL
FFG 57	REUBEN JAMES	Pearl Harbor, HI
FFG 58	SAMUEL B ROBERTS	Mayport, FL
FFG 59	KAUFFMAN	Norfolk, VA
FFG 60	RODNEY M. DAVIS	Everett, WA
FFG 61	INGRAHAM	Everett, WA

(V)3	SHIP	HOMEPORT
CG 56	SAN JACINTO	Norfolk, VA
CG 57	LAKE CHAMPLAIN	San Diego, CA
CG 58	PHILIPPINE SEA	Mayport, FL

(V)4	SHIP	HOMEPORT
DDG 51	ARLEIGH BURKE	Norfolk, VA

(V)7	SHIP	HOMEPORT
CG 66	HUE CITY	Mayport, FL
CG 67	SHILOH	Yokosuka, Japan

(V)9	SHIP	HOMEPORT
FFG 37	CROMMELIN	Pearl Harbor, HI
FFG 50	TAYLOR	Mayport, FL
FFG 51	GARY	San Diego, CA
FFG 52	CARR	Norfolk, VA
FFG 54	FORD	Everett, WA

(V)6	SHIP	HOMEPORT
CG 68	ANZIO	Norfolk, VA
CG 69	VICKSBURG	Mayport, FL
CG 70	LAKE ERIE	Pearl Harbor, HI
CG 71	CAPE ST GEORGE	San Diego, CA
CG 72	VELLA GULF	Norfolk, VA
DDG 52	BARRY	Norfolk, VA
DDG 53	JOHN PAUL JONES	San Diego, CA
DDG 54	CURTIS WILBUR	Yokosuka, Japan
DDG 55	STOUT	Norfolk, VA
DDG 56	JOHN S. MCCAIN	Yokosuka, Japan
DDG 57	MITSCHER	Norfolk, VA
DDG 58	LABOON	Norfolk, VA
DDG 59	RUSSELL	Pearl Harbor, HI
DDG 60	PAUL HAMILTON	Pearl Harbor, HI
DDG 61	RAMAGE	Norfolk, VA
DDG 63	STETHEM	Yokosuka, Japan
DDG 64	CARNEY	Mayport, FL
DDG 65	BENFOLD	San Diego, CA
DDG 66	GONZALEZ	Norfolk, VA
DDG 67	COLE	Norfolk, VA
DDG 68	THE SULLIVANS	San Diego, CA
DDG 69	MILIUS	San Diego, CA
DDG 70	HOPPER	Pearl Harbor, HI
DDG 71	ROSS	Norfolk, VA
DDG 72	MAHAN	Norfolk, VA
DDG 73	DECATUR	San Diego, CA
DDG 74	MCFAUL	Norfolk, VA
DDG 75	DONALD COOK	Norfolk, VA
DDG 76	HIGGINS	San Diego, CA
DDG 77	O'KANE	Pearl Harbor, HI
DDG 78	PORTER	Norfolk, VA

[6] For further discussion of the ship types and sonar types, please see (Gibson, 2012).

Table 2. Variable Definitions

Name	Definition	Units of Measurement	Source
Organizational Parts Costs	Cost of repair parts used by the ship's personnel in system maintenance and alterations	Constant FY 11 Dollars	Naval Visibility and Management of Operating and Support Costs (VAMOSC)
Corrective Maintenance Actions	Number of corrective maintenance actions performed onboard ship	Actions	VAMOSC
Organizational Labor Hours	Corrective maintenance hours performed onboard ship	Hours	VAMOSC
Authorized on Board, E1 through E6	Sailors authorized on a ship for a fiscal year	Individuals	Navy Personnel Command
Navy Manning Plan, E1 through E6	Sailors planned for a ship a fiscal year	Individuals	Navy Personnel Command
Currently on Board, E1 through E6	Sailors on board a ship at end of a fiscal year	Individuals	Navy Personnel Command
Days Underway	Days spent at sea	Days	VAMOSC

Table 3. Descriptive Statistics

Series	N	Mean	Standard Deviation	Minimum	Maximum
Organizational Parts Costs	802	8439.80	9434.82	0	65839.71
Corrective Maintenance Actions	793	75.10	54.05	4	447
Organizational Labor Hours	801	1012.60	1029.57	7	12079
Authorized on Board, E1 through E6	808	12.66	3.66	6	18
Navy Manning Plan, E1 through E6	812	12.8	4.09	5	20
Currently on Board, E1 through E6	811	12.92	4.13	4	24
Days Underway	543	135.80	48.77	24	281

Table 4. Estimates for the Impact of CBT on Organizational Parts Costs

(Constant FY 11 Dollars)

	Pooled OLS
$Parts_{t-1}$	---
Computer Based Training	4971.45** (1894.62)
Billets Authorized	581.46 (373.73)
Navy Manning Plan	-226.72 (338.25)
Currently On Board	-332.35+ (188.27)
Constant	8159.01** (2789.05)
F	7.58**
R^2	0.20
Observations	790
M1	3.24**
M2	1.95*
Number of Instruments	---
Sargan test	---
Difference-in-Hansen	---

Note. **, *, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 5. Estimates for the Impact of CBT on Corrective Maintenance Actions

	Pooled OLS
$Parts_{t-1}$	---
Computer Based Training	32.86** (11.51)
Billets Authorized	5.18* (2.53)
Navy Manning Plan	-3.53 (2.22)
Currently On Board	-0.12 (0.85)
Constant	57.75** (19.80)
F	16.11**
R^2	0.27
Observations	779
M1	4.37**
M2	2.26*
Number of Instruments	---
Sargan test	---
Difference-in-Hansen	---

Note. **, *, + denote significance at the 1%, 5%, and 10% level, respectively.

Table 6. Organizational Maintenance Hours

	Pooled OLS
$Parts_{t-1}$	---
Computer Based Training	730.21** (170.17)
Billets Authorized	-33.35 (45.09)
Navy Manning Plan	4.85 (39.24)
Currently On Board	17.34 (19.12)
Constant	954.13 (384.28)
F	9.55**
R^2	0.22
Observations	787
M1	3.72**
M2	1.73+
Number of Instruments	---
Sargan test	---
Difference-in-Hansen	---

Note. **, *, + denote significance at the 1%, 5%, and 10% level, respectively.

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