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Anti-submarine Warfare (ASW) Capability Transformation:
Strategy of Response to Effects Based Warfare.

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**Anti-submarine Warfare (ASW) Capability Transformation:
Strategy of Response to Effects Based Warfare.**

Responding to the World War I emergent submarine threat forced an acknowledgement regarding our intellectual ignorance of the environmental domain which hides the operations of the elusive, unseen threat which would destroy commerce from the depths of the world's oceans and seas. The early scientific investigations gave birth to the efforts of the "Allied Submarine Detection Investigation Committee" (ASDIC) and those of the "Operations Evaluation Group" (OEG). These efforts sought to better understand and document scientifically the maritime undersea environment and the associated affects upon Antisubmarine Warfare (ASW) in order to develop capabilities and refine tactics to counter the threat posed by submarines.

ASW is prosecuted as a "system of capabilities". Each capability represented as a platform based system of sensors designed to support undersea domain awareness through a process to search, detect, classify, localize and, when permitted, attack a threat submarine. This paper proposes an Undersea Domain Awareness (UDA) strategy that merges quantifiable sensor or system level performance analysis of platforms capabilities within the modern application of effects-based operations to optimize the system of capabilities "kill chain". Employing ASW as a case study, the paper proposes that quantified sensor performance analysis is critical to achieving the proposed benefits of effects based warfare.

Anti-submarine Warfare (ASW) Capability Transformation: Strategy of Response to Effects Based Warfare.

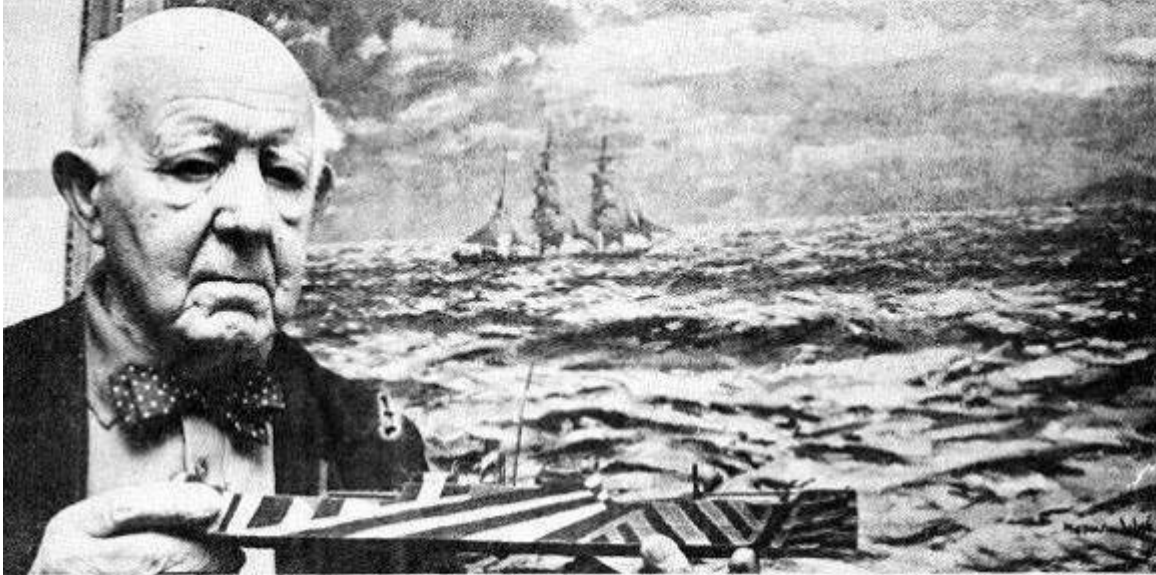
“The story of the contest between our war-ships and their new enemy, the submarine, is the story of a most remarkable and successful adaptation.”
Sir Henry Newbolt 1919

“We must look at ASW as an overarching system, analyzed and procured with a mind toward overall capability vice that of individual platforms. The best ASW system is one that can detect, target and neutralize well outside of the adversary submarine’s sphere of influence on our forces afloat or ashore.”
Littoral Anti-submarine Warfare Concept, Naval Doctrine Command 1998.

Since the inception of Anti-submarine Warfare (ASW) we have played catch-up, chasing an unseen elusive submarine threat. Our actions were by necessity responsive to the initiation of unrestricted submarine warfare¹ upon allied shipping and our ability to forward project control of the seas. Sir Henry Newbolt describes the World War One adaptations that our forces implemented in response to the new enemy. He summarizes the “six principle methods of defence, three old and three new, as a striking proof of the scientific ability to reconsider and adopt obsolete measures”². The three old methods of defence were highly responsive, adopting anti-torpedo netting, employment of surface armament against surfaced or partially submerged submarines or torpedoes and finally the employment of ramming tactics to run down submarines. The new methods employed to defeat submarines incorporated the use of “Dazzle Paint”, use of “Deceptive Targets” and a construction technique to defeat a successful torpedo attack which Sir Henry Newbolt eludes to permitting HMS Marlborough to rejoin the fleet very quickly after being torpedoed at the Battle of Jutland.

¹ Unrestricted submarine warfare is a type of naval warfare in which submarines sink merchant ships without warning as opposed to attacks per prize rules. While such tactics increase the combat effectiveness of the submarines and improve its chance of survival, they are considered by many to clear breach of the rules of war, especially when employed against neutral country vessels in a war zone.

² Submarine and Anti-submarine, Sir Henry Newbolt; New York: Langmans, Green & Co, 1919; Chapter 7 page 95.



Norman Wilkinson – credit as the artist inventor of Dazzle Camouflage

The early scientific investigation mentioned by Sir Henry gave birth to the efforts of the Anti-submarine Detection Investigation Committee (ASDIC) and perhaps more importantly, those of the “Operations Evaluation Group” (OEG). These efforts sought to better understand and document scientifically the maritime undersea environment and the associated affects upon anti-submarine operations in order to develop capabilities and refine tactics to counter the threat posed by submarines. Under the pressures of WWII, the efforts matured as a compilation of a “systems of capabilities” approach. Electronic and signals intelligence supported convoy screening and routing and importantly the development of anti-submarine hunter killer capabilities by ships and maritime patrol aircraft. “The Allies used tactics, intelligence, electronic devices and weapon systems to fight the Battle of the Atlantic... the fruits of communications intelligence and electronic devices were useless if either side lacked or misused weapon systems such as ships or aircraft in a convoy battle.”³ The efforts served to lay the foundation of our current oceanographic and maritime understanding governing modern ASW operations.

ASW operations exploit defence-in-depth supporting tenets of *Homeland Defence* and *Forward Engagement*, both predicated upon control of the seas. Modern ASW operations attempt to be pre-emptive and interdict unseen undersea threats which directly challenge our ability to control the seas in the defence of world commerce and the health of the sea lines of communications or commerce, euphemistically referred to as the SLOCs. As learned during the World Wars, ASW today is a system of capabilities. “There is no single or inexpensive answer to meeting the problem. It requires the close teamwork of all ASW forces – surface, subsurface, air and space – served by an effective worldwide network of intelligence and communications,”⁴ supporting operational capabilities composed of sensors to search, detect, classify, localize and respond to

³ The Defeat of the German U-Boats; The Battle of the Atlantic; David Surett; University of South Carolina Press 1994, Preface XI

⁴ Burke, Arleigh; House Appropriations Committee hearing 86:1:1, 23 January 1959, pp. 661, 691

elusive unseen threats. Each system component must be balanced with the other composite capabilities to achieve the desired outcome of effects oriented response to known undersea threats. Modern ASW itself reflects these concepts. For the system to function effectively and efficiently, it is critical to understand the system components to better manage the associated risk if a portion of the system is not available when required.

This paper proposes an Undersea Domain Awareness (UDA) strategy that merges quantifiable sensor or system level performance analysis of platforms capabilities within the modern application of effects-based operations to reshape the perception of elusive submarine operations. The paper specifically examines ASW, a prescribed mission set of UDA, as the lens to investigate the application of effects-based operations (EBO) to ASW sensors, systems and platform capabilities. It begins by making some key definitions to describe sensor level performance process of search to detection to classification to localization, culminating in ASW engagement. The ASW sensor process architecture is then presented as a “Markov Chain”⁵ pictogram, an operational “Cue to Kill” chain, to examine the effects-based operations nature of ASW. The suggested paradigm is examined to determine critical points yielding an ASW strategy model with decisive effects shaping the behaviours of our national and allied ASW postures as well shaping our adversaries’ employment of submarines to achieve desired aims and outcomes.

ASW battles have always been about “out thinking” your adversary, while employing the available ASW systems to affect the behaviours of our own forces and those of the adversary. ASW is arguably the most difficult area of naval warfare since as the, “Behavioural science has proven, it is hard to cognitively trust sensed data that can not be verified through visual or optical means.”⁶ In a sense, the mission of ASW is a tactical derivative of the strategically premised EBO based observe, orientate, decisions and action process against another “man-in-loop” thinking system, another system with self prescribed means of agility and unpredictability. ASW systems have not yet been able to develop the algorithms required to replace the human component of the system, unlike the time constrained, counter-Mach, anti-missilery, functional automation to replace man-in-loop systems employed to conduct surface and anti-air warfare. ASW is a slow to develop chess match. The stealth afforded submarines or other undersea platforms by the cloak of the world’s oceans enables submarines to obtain “check and very often a check-mate” position at very little risk.

The Threat

Perceptively, ASW as a warfare discipline reached its zenith during the Cold War. Although the threat of hostile ballistic missile submarines and submarine attacks on commerce has declined since the end of the Cold War, the threat posed by foreign submarines never truly receded. In fact, the global proliferation of submarine capability

⁵ Markov Chain is a sequence of stochastic events (based on probabilities instead of certainties) where the current state of a variable or system is independent of all past states, except the current (present) state.

⁶ JOT Canadian Navy Celebrating 100yrs. Vol 5 Special Issue – Canadian Navy: ASW to UDA.

has escalated since nations understand the strategic value of possessing a capability which permits the unobserved conduct of operations which, even if detected, can remain unattributed with plausible deniability. Conducting surveillance of an adversary's coasts, sea lanes, naval facilities, ports, harbours and shipping; exploring for undersea resources in Exclusive Economic Zones (EEZ); and landing illegal's and contraband remain valid mission for undersea capabilities. Worldwide, since the end of the Cold War, there has been a shift towards increased emphasis on the threat posed by diesel-electric submarines operating in littoral waters, as opposed to nuclear submarines operating in deep waters. Design improvements in submarines have increased their endurance and speed, made them more difficult to detect, and have increased the effectiveness of their sensors, communications systems and weapons systems. Air Independent Propulsion (AIP) systems generate electrical power to recharge the batteries of diesel-electric submarines while the submarine is submerged, thus enabling longer periods of submerged operations. Dived endurance of state-of-the-art AIP submarines is between two weeks and a month at slow speeds.⁷ Several countries have successfully introduced AIP into operational service. Improvements in submarine weapon systems have resulted in a requirement to detect and classify submarines at greater ranges, more quickly, and with greater accuracy. A complementary asymmetric threat is the use of Unmanned Undersea Vehicles (UUVs) by foreign nations to conduct surveillance of an adversary's coasts, sea beds and harbours and the use of small submersibles and semi-submersibles by non-state groups for criminal activities such as smuggling contraband or as carriers of improvised explosive devices.






SCUBACRAFT – Asymmetric Undersea Capabilities

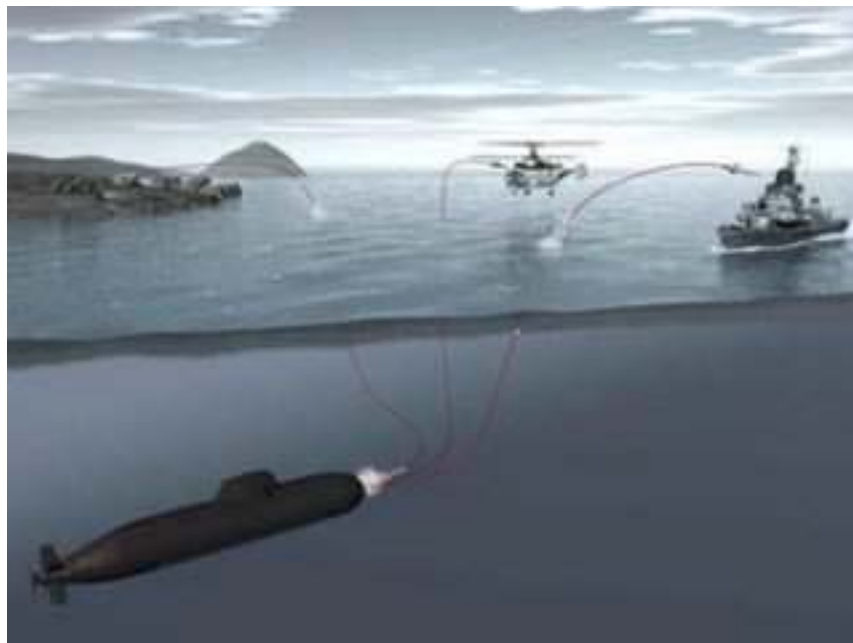
The importance of our ability to achieve a traditional ASW deterrence posture was recently reinforced with the sinking of the ROK Cheonan destroyer by a probable PRK submarine. Despite the authoritative findings of an International team that forensically examined the evidence of the sinking implicating PRK, North Korea continues to maintain its innocence and deny any involvement, especially since there is

⁷ Dalhousie University Centre for Policy Studies, “*Backgrounder: Victoria Class Submarines, Northern Operations and Air Independent Propulsion*”, October 2007

no eye witness to attribute their involvement in the event. Less obtrusive but no less confrontational was the sighting of a previously undetected Song Class Chinese diesel submarine within potential weapons range of an US Navy Aircraft Carrier in 2006. The resurgence of the Cold War adversary was noted in 2009 with a tandem deployment of Russian Akula attack SSN's to positions along the North American coastline that positioned them well within range of likely cruise missile weapons loads of major North American centres.⁸

<p>EDITORIAL The Sinking of the Cheonan Published: May 20, 2010</p>	<p>Chinese Submarine Fleet Is Growing, Analysts Say By DAVID LAGUE Published: February 25, 2008</p>	<p>Russian Subs Patrolling Off East Coast of U.S. By <u>MARK MAZZETTI</u> and <u>THOM SHANKER</u> Published: August 4, 2009</p>
		
<p>North Korean Submarine</p>	<p>Song Class Submarine</p>	<p>Akula Class Submarine</p>

Submarine capability and emergent UUV technologies enable nations to leverage the inherent stealth of the platform to force reactive defensive measures. As witnessed with the Koreas incident, the stealth and plausible deniability of undersea actions is of Strategic value to the nation willing to apply the capability to achieve national objectives.



The Stealth – Unattributed Attack

⁸ New York Times extensively covered the three submarines events. <http://www.nytimes.com>

Effects-Based Operations (EBO) Stratagem

The philosophical construct supporting EBO “aims to link sensors and shooters within an information loop that accelerates the decision-making cycle by following critical information faster to apply force in an ever more effective manner.”⁹ EBO describes the physical, functional or psychological outcomes, events or consequences that result from specific actions as a consequence of intelligence and sensed derived situational awareness. “It is no longer sufficient for military forces to be able to “fight and win” the wars. The potential impacts and fallout from conflicts in such highly linked globalized world will be so great that fighting and winning could be too little to late. Globalization will shift the focus of military efforts to strategically preventing wars from occurring, containing those conflicts that do occur, and discouraging the emergence of hostile competitors.”¹⁰ Strategically, an EBO strategy attempts to build persistent awareness of global events to support deterrence in the global environment creating stability of homeland defence and forward engagement through visible presence and crisis response. The strategy of employing persistent surveillance as a principle of the engagement model relies upon Satellites or Space sensing resources to sense the air surface and near surface domains. Unfortunately space sensing has not yet developed the technology to sense in the undersea domain. The cloak of stealth provided potential undersea threat technologies remains, necessitating other technological means to conduct persistent undersea sensing.

Persistent sensed situational awareness supported by means to respond to the detected threat is the lynchpin to achieving the desired outcomes of preventing ASW events from occurring and obtaining tactical victory if they do come to fold. The information awareness of the subsurface undersea domain seeks to render the unobserved water column from seabed to the surface transparent and observable, illuminating the activities of potential threats and eliminating the perceived stealth of the characterized threat of submarines. The Strategic, Operational and Tactical decisive goals of an ASW stratagem are captured in Figure 01:

Strategic	Eliminate perceived stealth of Submarines Transparency of World’s Oceans to detect adversary platforms while maintaining freedom of manoeuvre and stealth for own subsurface capabilities
	Persistent Undersea Domain Awareness
Operational	Prevent Submarines from obtaining position of influence maximizing: sensor surveillance effectiveness; weapons effectiveness.
	Deployable, Rapidly deployable UDA sensing, regionally supporting persistent infrastructure

⁹ Rethinking the Principle of War, Anthony D. McIvor editor, Naval Institute Press Annapolis Maryland 2005, p 145

¹⁰ Globalization & Maritime Power: Edited by Sam J. Tangredi: Institute for National Strategic Studies, National Defence University 2002; Effects Based Operations, p 309

Tactical	Achieve FC solution on threat submarine
	Ability to counter threat weapon systems if fired upon
	Self Defensive sensing of Deployable Platforms
Unifying Objectives	
<ul style="list-style-type: none"> • Detect, locate threat/adversarial undersea platforms • Development of tactical procedures to permit decisive ASW manoeuvre • Integrate ASW systems enhance probability of neutralizing UDA threats • Increase operator proficiency • Incorporate leading edge technologies • Leadership decision making processes to optimize capitalization and employment of UDA equipment 	

Figure 01 – Decisive Goals and Unifying Objectives

ASW is a myriad of ever changing, interdependent variables whose course can never entirely be predicted because of the integrated nature of the man-in-the-loop. The strength of an effects-based approach to operations is that it squarely addresses these complexities by concentrating on their most nonlinear aspects: humans, their institutions and their actions. The effects-based approach is ultimately about shaping human perception and behaviour. The central tenet of an effects-based approach to operations is that we can somehow purposefully shape the interactions of the actors in the complex security environment.¹¹ At the Strategic level an effects-based approach to ASW seeks to convince Nations that the conduct of submarine operations is not risk free, that submarines operations can not take place unobserved. This is achieved if submarine movements are observed enabling irrefutable attribution of action. Remove the stealth from submarine operations and the cost – risk – reward equation is dramatically altered, affecting the National will to develop, train, and maintain a submarine capability. During the Cold War, Strategic ASW concentrated upon SSN marking SSBN in order to render the BN fleet ineffective just at the moment that it was to be called to service. Strategic ASW was also executed by means of long range persistent acoustic sensing that cued deployable forces to subsequently redetect, classify and localize a potential threat to engagement criteria. A surveillance, localization and engagement continuum tied to EBO is illustrated in Figure 02, the EBO – Systems Performance Model.

¹¹ Complexity, Networking, & Effects-Based Approaches to Operations. Edward A. Smith, CCRP, July 2006

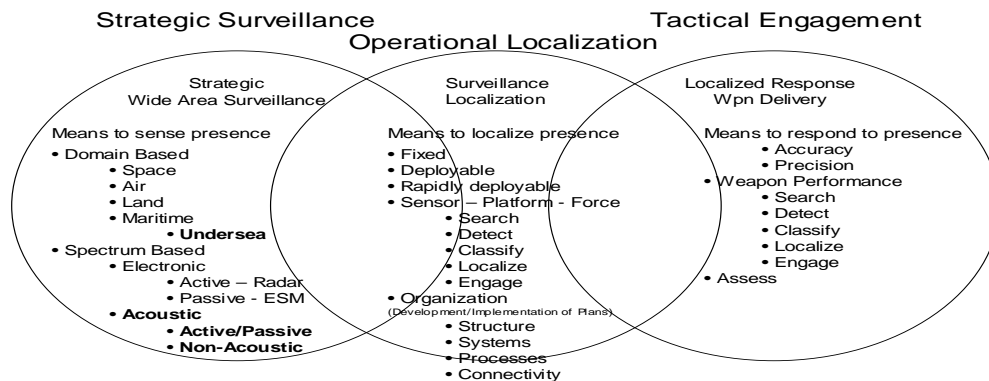


Figure 02 – EBO – Systems Performance Model

Sensing – Sensor level Performance

All maritime undersea domain sensors, active or passive acoustic and non-acoustic, are employed through a search, detect, classify, localize to attack [when permitted], concept to observe and orientate situational awareness. Anti-air warfare sensing, also employs the same sensor paradigm, has by necessity of threat based Mach inherent time constraints become highly automated. Undersea domain sensing encounters environmental constraints which has precluded the successful incorporation of automated sequences to attribute sensed information into resolved target data. Undersea domain awareness and the mission of ASW is a slow to develop, man-in-the-loop warfare. Undersea domain awareness is a team effort employing integrated means to network deployable, rapidly deployable and fixed surveillance systems to maximize detection, tracking and engagement opportunities of unobserved undersea threats. Undersea domain integration is multitier and multiphase. It takes place at a platform level, collating the data from multiple sensors collocated within the single platform, and at multiple force levels, collating the data from multiple platforms, whether maritime surface, subsurface, air or space based and multiple operational centres each coupling outcomes from platform based networks. At the force level information integration is represented regionally designed for specific mission objectives and cumulatively integrated to develop a global understanding of undersea awareness. Cueing, tracking and engagement of undersea threats is executed through a coordinated and integrated operations cycles enhanced by common operational and tactical procedures to permit precise targeting and weapons employment. Quantification of individual system performance and the corresponding determination of that systems ability to search, detect, classify, localize to enable engagement when integrated with the quantified performance attributes of other platform collated sensors determine the Platform

Capability to affect undersea awareness information superiority and effects-based capabilities.

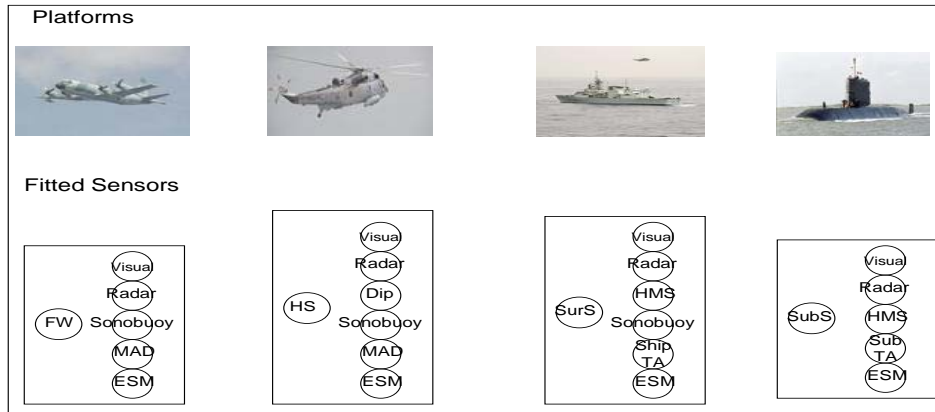


Figure 3 (above) - Platform Capability Integration of Systems
 Note: other development sensors can be included – example Lasers
 And Spaced Based Sensing

Figure 4 (below) – Task Force/Group Integration of Platform Capability



Efforts to quantify system level performance permitting an aggregation of platform performance and Force capabilities relating to ASW is not a new undertaking.

The OEG REPORT No. 51, reporting on the conduct of ASW in WW II¹², published in 1946, accomplished that very objective, although in a rudimentary means relating to the current understanding of EBO methodologies. Other efforts like the USN Ship ASW Readiness Effectiveness Measuring [SHAREM] formalized the lead of the OEG ASW report by establishing repeatable and constant Measures of Effectiveness and Measures of Performance [MOE and MOP]. Each measure is supported by data collection regime as well as articulated statistical analytical methodologies to permit data compilation and aggregation of a singular system through time or from system to platform to force. The SHAREM effort is specifically related to ASW. The Canadian Naval Operational Effectiveness Analysis attempted to replicate the ASW methodological discipline across all maritime warfare areas to comprehensively quantify platform capability across multiple warfare areas. The construct of standardized force or platform MOEs through system MOPs has permitted the quantification of ASW system performance and permitted statistical aggregation to platform and force and capability assessments. The use of standardized, repeatable MOEs and MOPs facilitates information exchange and a relational correlation of multiple systems within a single platform or force by establishing a common language, actual or simulated, from a common perspective. The establishment of this common understanding has enabled improved effectiveness and efficiencies involving hardware and software procurement, tactical development, and training optimization to improve ASW capabilities holistically. The common understanding also advances the EBO principle of linking sensor to shooter within an accelerated knowledge informed decision-making cycle.

¹² OEG REPORT No. 51 ANTISUBMARINE WARFARE IN WORLD WAR II, Charles M. Sternhell and Alan M. Thorndike, Operations Evaluation Group Office of the Chief of Naval Operations Navy Department, Washington, D.C., 1946 THIS volume embodies the results of some of the statistical and analytical work done during the period 1942-45 by members of the Anti-Submarine Warfare Operations Research Group of the U.S. Navy, later the Operations Research Group and, since September 1945, the Operations Evaluations Group.

The group was formed and financed by the Office of Scientific Research and Development at the request of the Navy, and was assigned to the Headquarters of the Commander in Chief, U.S. Fleet. The group has been of assistance in:

- a. The evaluation of new equipment to meet military requirements.
- b. The evaluation of specific phases of operations from studies of action reports.
- c. The evaluation and analysis of tactical problems to measure the operational behaviour of new material.
- d. The development of new tactical doctrine to meet specific requirements.
- e. The technical aspects of strategic planning.
- f. The liaison for the Fleets with the development and research laboratories, naval and extra-naval.

This book consists of a statistical review of the anti-submarine war in the Atlantic from 1941 to 1945, together with a unified analysis of the tactics which proved most useful in this combat. It is believed that this material will be of considerable help in providing basic understanding of this extremely important branch of naval warfare.

The USN SHAREM program and the Canadian Navy Analysis Requirements and Methodology Guide (ARMG) for Operational Capability Analysis (OCA) have structured Forces level ASW MOEs and system level MOPs, Figure 5, through analytical regimes to quantitatively examine an individual systems ability to search, detect, classify, and localize an undersea domain target to enable engagement if and when required, supporting an EBO system performance assessment. The regimes inform and assess the ASW Team decision making process. Critically the measures also assess own vulnerability to attack by an adversary as well as our material readiness and reliability to conduct ASW operations when required. For ASW, the two standard force level ASW MOEs are:

- A. The probability that ASW forces accomplish their ASW Mission; and
- B. The probability that submarines fail to accomplish their missions.

In many scenarios the two situations addressed by these MOEs, ASW success and submarine failure, are identical. For example, if the ASW force mission is to protect a screened carrier from submarine attack, and the submarine mission is to attack the carrier, the values assigned to these two MOEs must be equal. Other situations are less straightforward. If the ASW force and the submarine intend to destroy one another, it is unlikely that both will succeed. It is entirely possible that each will fail. Finally, if the ASW mission is to destroy all the submarines in an ocean area, it may succeed in destroying only a fraction of them. Similarly, a submarine may sink only some rather than all of its potential targets. Because of these ambiguities it is desirable to quantify system/platform level MOPs, which can then be statistically managed to assign values to the MOEs for a specific scenario, ASW mission or submarine mission.

Measures of Effectiveness
1. Probability that ASW forces accomplish their ASW Mission 2. Probability that submarine fail to accomplish their mission
Measures of System Level Performance
ASW Detection
1. Probability of detection as a function of lateral range 2. Cumulative probability of detection as a function of range
ASW Classification
1. Probability that a contact classified POSSUB is valid 2. Probability of correct classification given a valid contact 3. False contact rate 4. Time from detection to correct classification
ASW Localization
1. Probability of successful localization given valid contact 2. Time form detection/classification to localization 3. Probability of localization as a function of lateral range 4. Cumulative probability of localization as a function of range
ASW Attack

<ol style="list-style-type: none"> 1. Probability of successful attack 2. Time from localization to attack
ASW Vulnerability
<ol style="list-style-type: none"> 1. Probability of counter detection versus lateral range 2. Cumulative probability of counter detection versus range 3. Cumulative probability of torpedo detection versus range 4. Cumulative probability of torpedo classification versus range 5. Cumulative probability of torpedo hit versus range
ASW System Material Reliability
<ol style="list-style-type: none"> 1. Operational availability 2. Reliability 3. Maintainability 4. Operation to specification

Figure 05 – Standard ASW MOE/MOP

Balanced against the EBO Decisive Goals, Figure 01, it is apparent that the force level MOEs and system level MOPs, Figure 05, are directly linked to Operational and Tactical outcomes and enable achievement of the strategic objectives. Psychologically the Strategic EBO decisive goal is reached with an adversary’s acceptance that our forces can achieve the Operational and Tactical desired outcomes. The affect is manifested when an adversary reconsiders the risk to reward equation associated with possessing submarine platforms. The ROK Cheonan incident as well as an undetected SONG Class diesel submarine reaching a position of weapon advantage suggests that we are far from achieving the strategic EBO goal let alone the operational and tactical outcomes. A means to holistically assess and determine desired outcomes is required to move forward our ability to better represent our ASW capability. Analytically, OEG 51, SHAREM and the Canadian Navy OCA efforts suggest the analytical employment of a MARKOV Chain, operationally described as the “Queue to Kill Chain,” analysis methodology could achieve this requirement.

MARKOV – “Cue to Kill” - CHAIN

Development of the MOP premised analytical methodology permits system performance quantification and examination of the derived probability of success and clearer insight to which equation components have the greatest impact on the desired outcome. To illustrate this concept a MARKOV “Cue to Kill” chain can be employed, Figure 06, to visually and statistically represent capability derived “Cue to Kill” from system performance analysis, as well to inform outcomes for a simulated scenario.

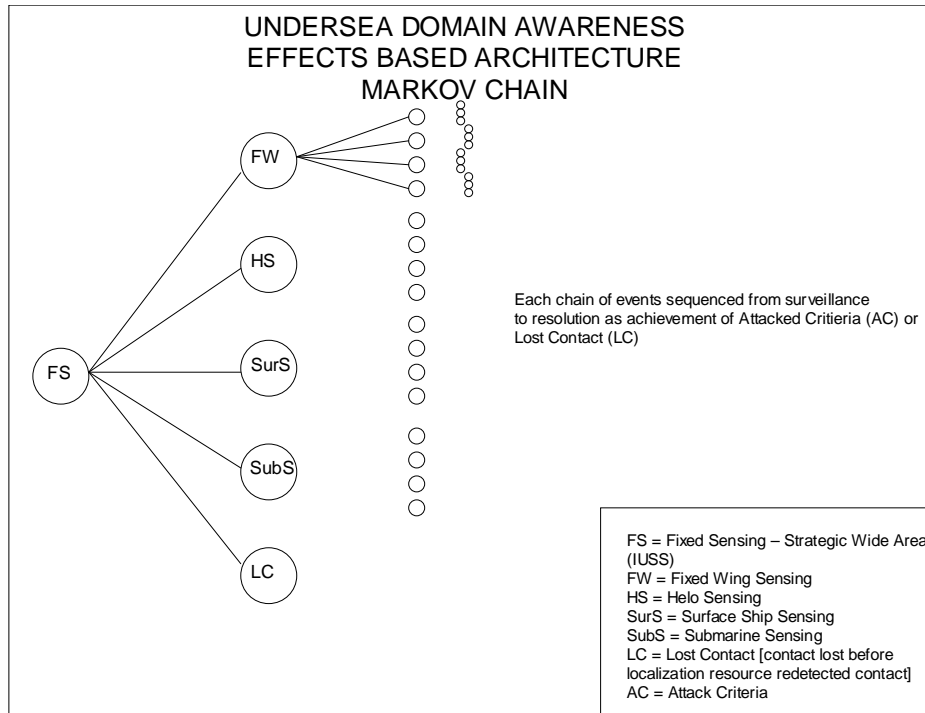


Figure 06 – UDA EBO Architecture

The Force or Platform level ASW MOEs are determined from quantifying the MOPs of each sensor which can be utilized to support ASW prosecutions. Underpinning each platform is a number of sensors which require individual quantification assessments to determine the platform capability and in turn the force capability to deal with a particular problem, in this case ASW. Figure 07 reinforces the concept that a Fixed Wing Maritime Patrol Aircraft has a number of sensors, acoustic and non-acoustic, which can be employed singularly or in combination to search, detect, classify and localize a threat submarine to engagement (attack) criteria. Some systems, Fixed Surveillance (FS) an example, typically are unable to localize a target to attack criteria since it does not possess or control the launch of precision weapons. FS must handoff contact data to a localization platform possessing the capability to localize to attack criteria.

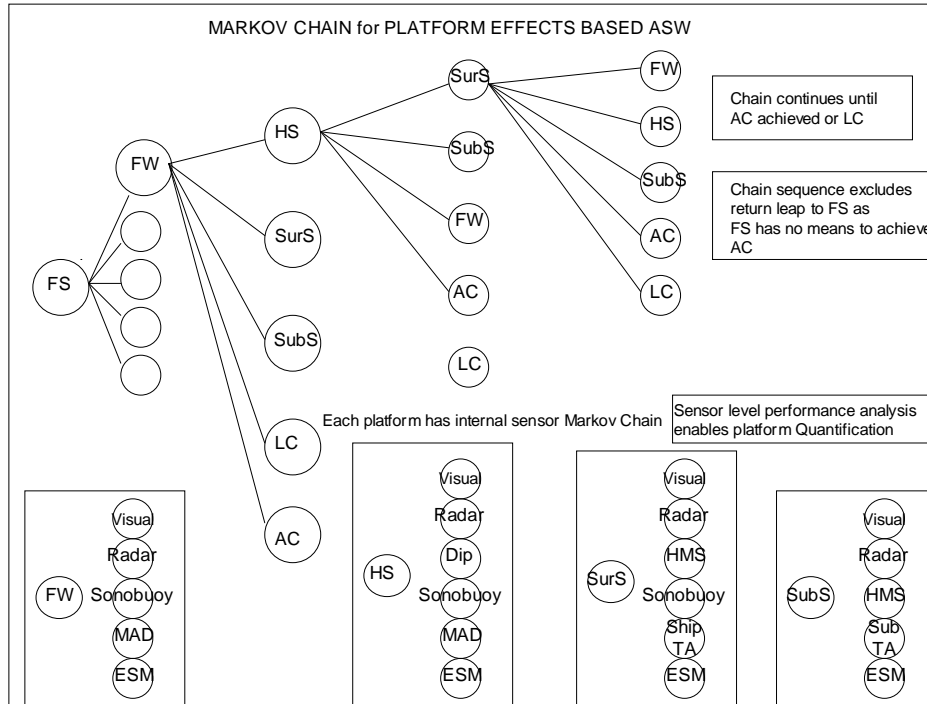


Figure 07 – Markov Chain for Platform Effects Based ASW

Historically five ASW systems, resident within four different platforms have demonstrated a significant ability to begin a successful localization process. The five systems include: Fixed acoustic systems [IUSS or its forerunner SOSUS], and deployable Ship Hull Mount sonar, and Towed Array sonar, Active dipping Helicopters, and Passive Sonobuoys employed by Fixed Wing aircraft. Excluding IUSS and fixed sensing, these systems can be illustrated by four initial platforms detectors; active ship – Hull Mounted Sonar [HMS], passive ship – Towed Array Sonar [TA], passive air – Maritime Patrol Fixed Wing Aircraft, and Active dipping air – Helicopter sonar. Figure 08, illustrates the eleven different forms that a localization process beginning with a Towed Array contact may take. An initial Surface Ship Towed Array (TA) contact, left side of the figure, may result in one of four events: passing the contact to a fixed wing aircraft; passing the contact to an active dipping helicopter; passing the contact to a submarine; or lost contact. This sequence assumes that a towed array platform will not develop or affect a fire control solution itself since the platform is not likely to include a long range ASW weapon. Successful handoff of the contact to a localization platform creates a new status preventing lost contact. The development of fire control solution by a platform capable of an engagement with a precision weapon or sequential handoff to other platforms with similar capability maintains the process chain with desired positive termination once localization to attack criteria is achieved, or the undesired negative termination with lost contact. Tactical implications of the sensor level performance quantification are illustrated in Figure 08.

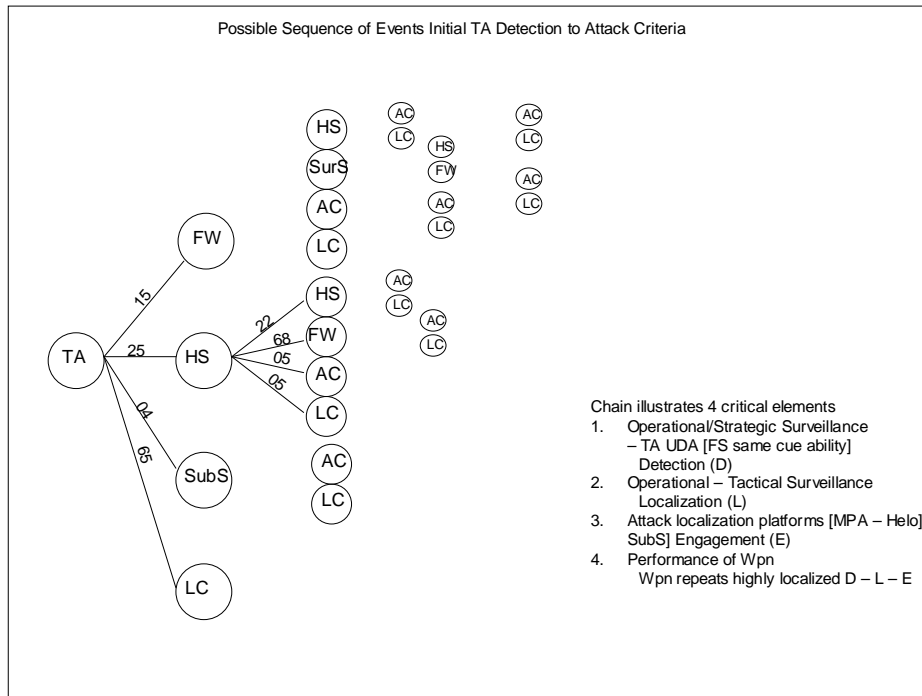


Figure 08 – Possible Sequence of Events TA Initiate Sequence Tactical Implications

Tactically, the numbers corresponding to the vectors between the TA to FW, Helo, Sub and lost contact (LC), Figure 08, indicate that approximately 65% of towed contacts in the late 80's and 90's were lost before the information could be passed to another localization platform and sensor package. At the time, further analysis indicated that the majority of TA contacts were lost due to the tactical manoeuvre procedure required to determine array bearing ambiguity. If a means could be developed to resolve ambiguity without alteration of course, a greater number of the contacts would potentially be maintained longer, better enabling hand-off to localization platforms and thereby have a positive affect on the total number of submarines localized to attack criteria. The strength of the Cue to Kill Chain is the statistical analysis to quantitatively calculate the desirable probability of achieving AC or undesirable probability of LC from actual systems performance assessments. Performance which then feeds training programs, simulations efforts, tactical development and system capability architectural enhancements to improve undersea domain awareness and our ability to respond to emergent threats.

Operational and Strategic Effects Based Analysis

Quantification of actual system performance enables the determination of the various success probabilities and insights to the means to improve performance vectors. "ASW as overarching system analyzed and procured with a mind toward overall capability vice that of individual platforms..." can be quantitatively assessed strategically through the use of the cascading effect of detection through to Lost Contact or development of Attack Criteria. Removal of one component of the overarching system will stress the other components in the delivery of desired outcomes. Maritime patrol

aircraft are more widely known as “ASW aircraft” as they were a critical enabler to defeating the WWII “German Wolf Pack” during the Battle of the Atlantic. During the 70’s and 80’s MPA gained the rightful reputation as ASW weapons delivery systems of exceptional capability.¹³ The elimination of an ASW capability component, as the Dutch did when they sold their P3 MPA capability without replacement and the British have proposed with the elimination of the MR4 Maritime Patrol Capability, affects the ability of the ASW System to achieve the desired tactical attack criteria, as illustrated in Figure 7. Quantification of associated probabilities by system and platform to achieve desired ASW outcomes would permit system performance computations with the removal of one component. “If competence in this mission area is permitted to erode, it will be very difficult to reconstitute,”¹⁴ and would affect the strategic ability to remove stealth as decisive point in the conduct of ASW operations. Figure 09 illustrates the non-statistically implications of eliminating a critical component of the system of capabilities.

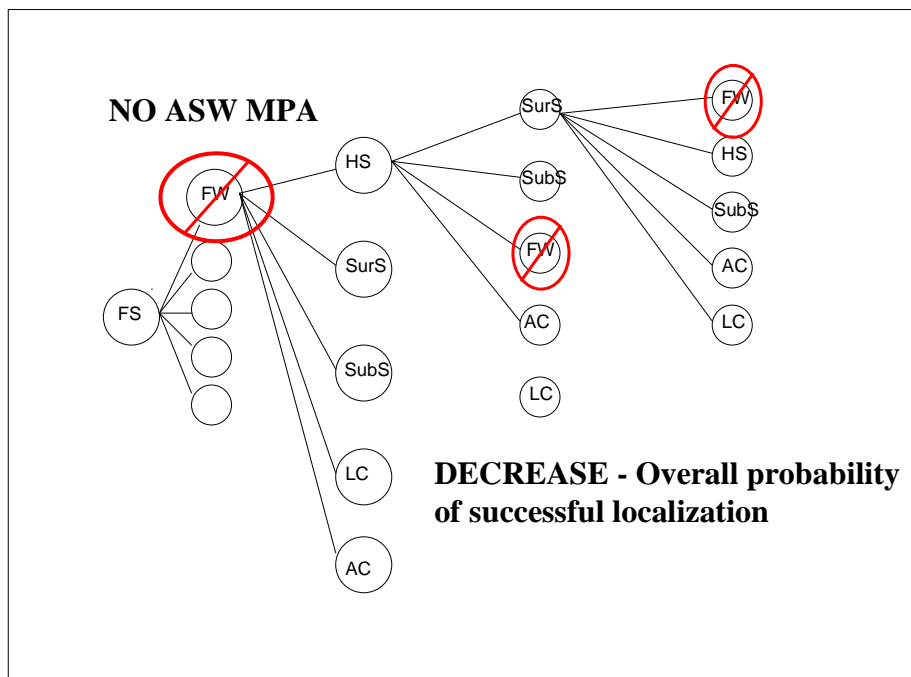


Figure 09 – Effects implied by elimination of MPA Capability

Conversely, the application of netcentric processes and structures through advances in Multistatic Low Frequency Active (LFA) operations would potentially improve “Cue to Kill” chain. LFA and Multistatics theorize simultaneous enhanced performance of a wide variety of ASW System performance vectors, illustrated non-statistically in Figure 10.

¹³ <http://www.globalsecurity.org/military/systems/aircraft/mpa.htm>

¹⁴ 1993 Executive Research Project S7; Development of Future Allied Maritime Patrol Aircraft (MPA); Captain William G. Bozin USN; The Industrial College of the Armed Forces, National Defense University Fort McNair, Washington, D.C. 20319-6000

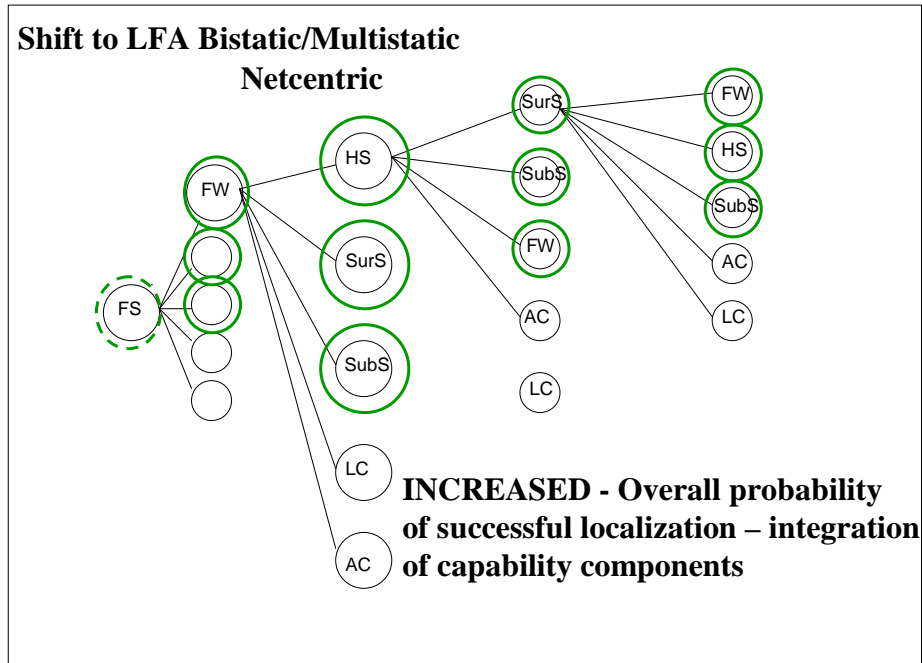


Figure 10 – Enhanced System Capability Performance

Both the degraded and optimized chains require quantifiable data developed through system level MOEs and MOPs to replace speculation with fact.

The ASW MARKOV Chain also illustrates the operational principles and force attributes supporting acoustic processing, data networking and sharing, rapid manoeuvre, collaborative planning and execution to support precision engagement. Strengthening these tenets allow friendly forces to take the fight to the undersea adversary. The representations also permits identification for technological agility with architectural enhancements maximizing effect whether processing, human integration or by technological insertion. Importantly the chain illustrates the critical nature for considering ASW and UDA as a “system of systems” architecture. The loss of one component dramatically determines the ability or inability of the “system” to prosecute UDA threats.

Force Level Sensing (Decision Support Matrix)

At the sensor level some measures of performance specifically monitor or assess the critical influence of the man-in-the-loop operating the individual sensors. Yet other measures attempt to quantify aspects of Command Team or Group effort to derive POSSible - PROBable - CERTain submarine classifications and required localization to attack criteria. Other measures are required to proactively assess the impact of the Force Level OODA Loop decisions nodes, such as a platform’s Command Team, and successive levels of Task Force Command nodes composing the network and the Command and Control structure and methodology supporting 21st Century warfare and ASW specifically. As indicated at Table 1 – Engagement Strategy Models, the conduct of Undersea Domain Awareness and the mission of ASW can not be conducted in

isolation from the engagement pillars and the associated man-in-loop interactions. “The 21st century mission space has expanded to include a wide spectrum of mission challenges, ranging from providing support to multi-agency disaster relief operations to complex coalition efforts within political-military environment involving a large variety of military and non-military actors, representative of complex endeavours.”¹⁵ The NATO model has developed a Network Centric Value Chain to examine the cumulative affect of the four Information, Cognitive, Social, and Physical domains structured within the model to programmatically investigate and understand complexity and our ability to account for it in the undersea domain, Figure 11.

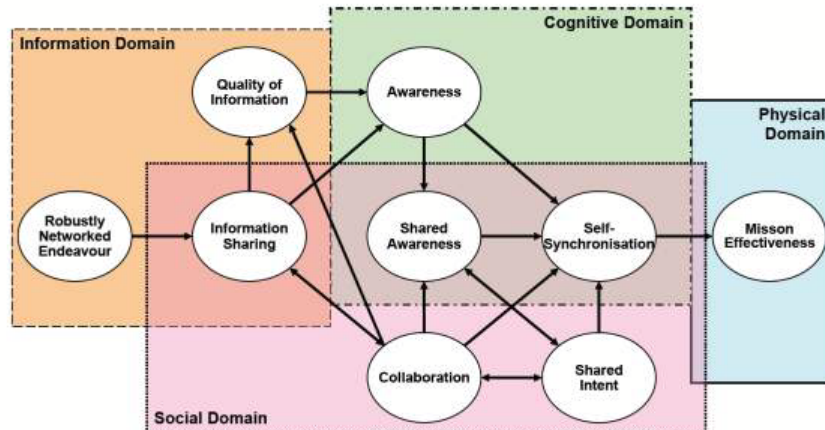


Figure 11 – NATO NETWORK Centric Value Chain

System performance critically informs and measures aspects of each of the interconnected domains illustrated by the NATO Network Centric value chain. NATO Code of Best Practices for C2 Assessment¹⁶ provides a hierarchy of measures to permit the measurement of performance across decision making processes. A similar outcome is achieved through a methodology developed by the Australian Defence Force for the performance evaluation of Operational Level Headquarters. The ADF methodology developed standardized MOEs and MOPs to examine a HQs human capital employed within structure, systems, process and connectivity to produce and or execute plans. Both concepts seek to assess the quality and quantity of information available or required to support decision making, situational awareness and decision agility of the human-in-the-loop linking sensor to shooter outcomes. Sensor system performance remains the lynchpin to subsequent efforts to orientate decision and action tactically, operationally and strategically.

Conclusion

Undersea Domain Awareness and the supporting mission area of Antisubmarine Warfare remains a difficult task. Arleigh Burk’s 1959 statement to the House Appropriation committee, that “there is no single or inexpensive answer to meeting the problem. It requires the close teamwork of all ASW forces – surface, subsurface, air and

¹⁵ NATO NEC C2 Maturity Model, SAS-065, Executive Summary, page XV.

¹⁶ NATO Code of Best Practices for C2 Assessment, Washington, DC: CCRP Publication Series. 2002: page 92.

space – served by an effective worldwide network of intelligence and communications,” remains a truism. The US Naval Doctrine Command applied the truism codifying that, “We must look at ASW as an overarching system, analyzed and procured with a mind toward overall capability vice that of individual platforms. The best ASW system is one that can detect, target and neutralize well outside of the adversary submarine’s sphere of influence on our forces afloat or ashore.”

Success has only been achieved when an integrated system of capabilities is committed to the surveillance and localization of undersea threats to inform application of limited response capabilities. ASW must be understood as a system of capabilities to prevent one component of the system from being played against another system component when budgets and resources are limited. The system component balancing can only be achieved by developing an understanding of overarching integrated system capability vice that of individual sensors and corresponding platforms. The goal of the system is to search for, detect, classify localize and neutralize potential threats well outside of an adversary’s sphere of influence upon our forces afloat or ashore. Stipulating the overarching desired effects based tenet, aligned with quantified system performance metrics would enable a better visualization of attempts to achieve the balance amongst ASW System Components.

	EBO Tenet	System Performance (S-D-C-L-A)	Balanced Platform Capabilities
Strategic	Eliminate perceived stealth of Submarines	S – D	Fixed Sensing - IUSS, ELINT/SIGINT
Operational	Prevent Submarines from obtaining position of influence maximizing: sensor surveillance effectiveness; weapons effectiveness.	S – D – C – L	Localization capabilities with means to achieve attack criteria
Tactical	Achieve FC solution on threat submarine	A	
	Ability to counter threat weapon systems if fired upon	A	

Figure 10 – EBO – System Performance – Balanced Capabilities

Achievement of Effects Based decisive goals provides a means to shift behaviours and remove the advantage of undersea stealth. Achievement of this desired goal further potentially affects National Will to pursue systems which until now have permitted plausible deniability through the conduct of adversarial operations which could not take place in the observed realm on or above the world’s oceans and seas without direct repercussions. ASW System performance provides the means to quantitatively assess the full spectrum of ASW mission requirements, from acquisition to training of

individual systems, to integration of fixed, deployable and rapidly deployable sensors closely netted surface, subsurface, air and space platforms to achieve the aim to affect an adversary's national will to fundamentally pursue ownership and projection of undersea threats.