MODELLING SWARMS OF UNMANNED AUTONOMOUS FIGHTERS FOR IDENTIFICATION AND ANALYSIS OF NEW STRATEGIES AND TECHNOLOGICAL ENABLERS

Agostino Bruzzone[(a)], Alberto Tremori [(b)]
Simonluca Poggi[(c)], Luciano Dato[(d)], Angelo Ferrando[(e)], Antonio Martella[(f)]

[(a)] [(b)]DIME University of Genoa (ITA)
[(a)]agostino@itim.unige.it, [(b)]tremori@itim.unige.it

[(c)(d)(e)(f)] Simulation Team
[(c)]simonluca.poggi@simulationteam.com, [(d)]luciano.dato@simulationteam.com, [(e)] angelo.ferrando@simulationteam.com, [(f)] antonio.martella@simulationteam.com

ABSTRACT
This paper presents preliminary results of ongoing researches devoted to use agent based simulation to investigate political, military, economical social infrastructural and informative effects of new underwater tactics based on swarms of autonomous unmanned underwater vehicles attacking cargos and tankers with a single or a group coordinated approach.

The basic idea is to use relatively cheap UAFs (Unmanned Autonomous Fighters) bringing small economic torpedoes or mines to create consistent threats to international commercial trades' routes and to critical infrastructures or to mount a blockade to a hostile country.

To investigate such innovative tactic a discrete event, stochastic agent based simulator has been created and preliminary on going experimentations are summarized.

Keywords: agent based stochastic discrete even simulation, unmanned autonomous vehicles, underwater warfare.

1 INTRODUCTION

During the Second World War two main categories of tactic for submarines were adopted: defensive and offensive. In the first case submarines were used to protect harbors and other critical infrastructure. Offensive tactics can be, as well divided in two main typologies: attack to military or merchant ships. This is the area of interest of the studies described in this paper. With the evolution of submarines with bigger, faster and much more expensive vehicles and torpedoes and with the development of more efficient anti-submarine warfare the usage of modern submarines for attacking merchant ships has almost disappeared. In this paper it is described an innovative tactic based on the usage of unmanned submarine devoted to attack, damage and if possible sink cargos and tankers both sailing alone and on convoy.

This is a preliminary work and the goal is mainly to describe basics of the approach considering historical events that inspired authors. Authors developed a simulator to test hypothesis and concept related both to tactics and vehicles catachrestic and the effectiveness. This work is divided in the following phases:

- Study of historical data about *Rudeltaktik* and current an analysis of economical impacts deriving from such kind of potential threats
- Development of conceptual models of new family of economical underwater unmanned vehicles, torpedoes or mine and related tactics
- Description of the stochastic discrete event simulator developed to provide preliminary experimental results.

2 HISTORY AND PRESENT OF UNDERWATER WARFARE

The submarine warfare in past conflicts introduced new aspects in Naval Warfare and represented a strategic issue; the use of submarine indeed introduce many new aspects including technical, operational, ethical, diplomatic etc.

In this chapter are summarized historical events and tactics used adopted during World War II, when submarine warfare was split into two main geographical theaters areas - the Atlantic and the Pacific. In the Pacific theater US submarines represented a minority of the US fleet, nevertheless sank more than 30 percent of Japan's navy, including eight aircraft carriers. Furthermore US submarine fleet contributed to weaken Japanese economy by sinking almost 5 million tons of ships, about 60 percent of the Japanese merchant marine. Japanese submarines were initially successful, destroying two U.S. fleet aircraft carriers, a cruiser, and several other ships but on the long term they proved to be ineffectual due to a doctrine that concentrated attacks on warships instead on weaker merchant ships.

US submarine tactics were mainly based on lonely ambushes to Japanese cargos, with a maximum of three submarines that operated in the *coordinated attack group.*

Different was the approach of the Kriegsmarine (German Navy) on the Atlantic *the Battle of the Atlantic*. This is considered the longest continuous military campaign in Second World War. Being an island, United Kingdom was highly dependent on imported goods. Britain required more than a million tons of imported (about one million tons per week) to survive and fight. In essence, the Battle of the Atlantic was a tonnage war where Allied struggle to supply Britain and the Germany and Italy attempted to stem merchant shipping flows.

This campaign was based on convoy and submarine warfares based on the so-called Wolf Pack or "Rudeltaktik" that was a tactic used by Kriegsmarine (German Navy), and made famous by Karl Donitz. The Wolf Pack had the goal to defeat the convoy system created by Alleys during the First World War and then extensively re adopted to bring goods across the Atlantic Ocean to support UK and was to have a devastating impact on allied shipping.

U-boat movements requested a high level of coordination by the Befehlshaber der Unterseeboote (BdU; English translation: "Commander of Submarines"). The idea was to form a pack of U-boats (Rudel) and to wait for other U-boats until all boats were in position to conduct a massed attack, so a Rudel consisted of as many U-boats as could reach the scene of the attack with strong possibility to overwhelm the escorts. The first boat to make contact was the "shadower" – whose job was to remain invisible, to maintain contact and to report the convoy's position back to BdU. When enough boats have converged with the convoy, BdU would give order to attack, usually in the night.

This had devastating effects and attacking in groups easily overwhelmed escort ships. When a destroyer detected and attacked one U-boat, another would attack at a different location, bringing confusion and chaos.

With the exception of orders and coordination given by the BdU, when the attack started U-Boat commanders were free to chose the best tactic and the attacked as they saw fit.

Once Wolf Pack operations began U-boats inflicted heavy losses until the allies developed new technology to counter the threat. One of the most famous Wolf Pack attacks took place between the nights from October 16th to the 19th, 1940. Convoy SC7 was attacked by a pack of seven boats, sinking 20 of 34 ships in the convoy. The next night, convoy HX79 was attacked with 14 ships further losses, making a total of 34 ships in 48 hours.

Allies developed countermeasures to turn the U-boat organization against itself. Most notably was the fact that wolf packs required extensive radio communication to coordinate the attacks. This left the U-boats vulnerable to a device called the High Frequency Direction Finder (HF/DF or "Huff-Duff") which allowed Allied naval forces to determine the location of the enemy boats transmitting and attack them. Also, effective air cover, both long-range planes with radar, and escort carriers and blimps, allowed U-boats to be spotted as they shadowed a convoy (waiting for the cover of night to attack).

Wolf packs fell out of use after the Second World War, modern submarines have better weapons and underwater speed than those of Second World War. These boats could operate faster, deeper and had much longer endurance. They could be larger and so became missile launching platforms. Furthermore the cost of each single submarine and modern torpedoes respect the value of a single merchant ships and the capability for escorts to attack and sink it by helicopters has made not economically convenient to attack cargos or tankers. However, the importance of the submarine has shifted to an even more strategic role than the disruption of merchant shipping, with the advent of the nuclear submarine carrying nuclear weapons to provide second-strike capability.

3 ECONOMIC SCENARIOS

It is still pretty controversial the real impact of the U-boat Arm and if it came close to winning the Battle of the Atlantic with the Allies almost defeated, and Britain close to starvation it. At no time during the campaign were supply lines to Britain interrupted and the German never succeeded in mounting a comprehensive blockade.

In only four out of the first 27 months of the war did Germany achieve the target of 350,000 tons that was calculated as necessary to isolate Great Britan, while after December 1941, when Britain was joined by the U.S. merchant marine and ship yards the target effectively doubled. Such target was achieved in only one month, November 1942.

By the end of the war, although the U-boat arm had sunk 6,000 ships totalling 21 million grt, the Allies had built over 38 million tons of new shipping.

These are figures of the Battle of Atlantic and the impact of Wolf Pack tactic. Nevertheless, today economical mechanisms that are ruling our world are much more complex and even fragile respect the situation dramatic situation of the Second World War. Furthermore the scenarios we are envisioning and studying are completely different from a global war scenario. It must also be considered that with the US entrance in War forces inequality bocame considerable. The ideas presented in this paper are focusing on a more symmetric scenario with two countries in war. It could be also applied to a completely different scenario with terrorist organization wit the goal to threat global trades but this will be studied in further analysis.

Considering global economical situation we have to focus on some figure related to extended supply chain and maritime transportation. Delocalization of production sites, continuous request of raw materials import and export flows that are continuously changing based on a high dynamic richness allocation are some of the most relevant elements of an extended logistics process that is more and more complex.

In figure 1 and Table 1 are summarized statistics of ports container traffic. These figures measure the flow of containers from land to sea transport nodes, and vice versa, in Milion of twenty-foot equivalent units (TEUs).

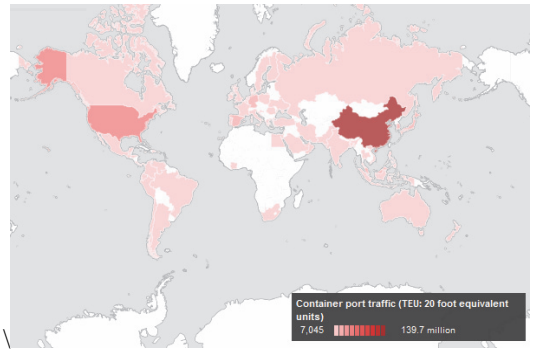

Figure 1: geographical distribution of container traffic

Data refer to coastal shipping as well as international journeys. Transshipment traffic is counted as two lifts at the intermediate port (once to off-load and again as an outbound lift) and includes empty units. (Years 2006-2011 Source Word Bank).

Table 1: container traffic by nations

Country	2006	2007	2008	2009	2010	2011
China	85	104	116	109	130	140
India	6	7	7	8	10	10
Italy	10	11	11	10	10	10
Japan	18	19	20	16	18	19
Netherlands	10	11	11	10	11	12
UK	8	9	8	8	9	9
USA	41	45	42	37	42	43

In Figure 2 are described shipping routes and it illustrates the relative density of commercial shipping in the world's oceans. For instance in 2011 about 39 million TEUs passed through the Suez Canal.

Table 1 shows that, despite last years international crisis, maritime traffic trend is still positive with a growing number of TEUs shipped from and to the three main areas: China and Far East, Europe and USA as shown in Figure 1.

There are several countries or areas where a naval blockade based on the submarine tactics could be effective. In the Middle East there are countries higly dependant from sea traffic with few ports located in areas that could be easily interdicted. Also in Far East and South Asia there area with a growing trend of more than +150% from 2006 to 2011 in container flows but with coasts, and of course ports located in areas that could be easily controlled by hostile countries. The world is plenty of countries with such conditions and complex international political relations and looking at Figure 2 we could easly imagine several critical areas: in fact such figure depicts the level of concentration of routes in some "hot spots" which represent, with the areas around the main ports in the world, a set of ideal areas for any kind of military or terroristic operations aiming to create threats to international trades and global economy or targeting a specific country as well.

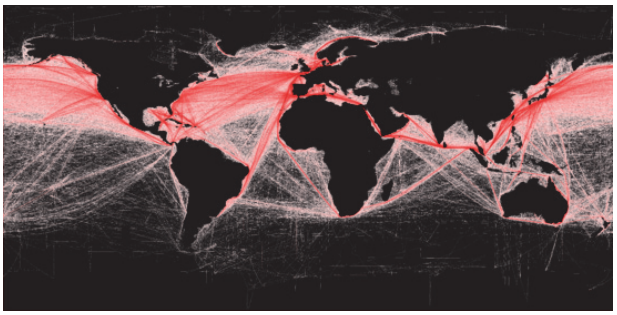

Figure 2: shipping routes and relative density of commercial shipping

4 TACTICS AND CONCEPTUAL MODELS OF UAFS

In the last paragraph of previous chapter elements summarizing some basic concepts underling potential success factors of a submarine tactic based on unmanned vehicles. Indeed a stealth flotilla or swarm of UAFs (Unmanned Autonomous Fighters) bringing torpedoes could create such a threat to international trades able to mount a comprehensive blockade of an enemy country; the models proposed in this paper are devoted to address both the analysis of possible strategies and tactics as well as to identify the technological enablers and requirements that are most sensitive to the impact of using these innovative systems; these kind of analysis are addressing a very complex mission environment affected by many stochastic factors and interactions, so it emerges evident the necessity to use modeling and simulation and the potential of this approach to identify drivers and critical elements of the whole problem.

In this chapter are described the hypothesis considered to define UAFs and are also described tactics and variables to be investigated of this submarine warfare; obviously the use of such autonomous systems will affect many sectors, including regulations as well as diplomacy and are expected to introduce complex operational modes, caveats and strategic decision making related to the rule of engagement, tactics and modes to be applied during the operations.

The UAF should copy some basic elements characterizing Second World War submarines, respect

modern ones. They should be relatively cheaper vehicles bringing cheaper torpedoes and these elements should make economically convenient attacking cargos and tankers. But respect II World War submarines UAF are unmanned so smaller, with more autonomy and, consequently more difficult to be detected by anti-submarines systems and ships. Furthermore no men on board means, of course, no cost (direct and indirect) related to human losses.

Such kind of vehicles and the tactics under evaluation could be used both by country, with no capability to deploy a navy fleet or a terrorist organization.

Since our aim is to design an underwater unit having at least the same operational skills of the German U-Boot during the II World War, made more efficient thanks to the modern technologies and weapon systems, in order to represent a real threat for cargo or, based on coordination and swarm artificial intelligence algorithms, even a merchant convoy, itself composed by naval units built with advanced construction techniques, we have to consider different aspects.

First of all the autonomous propulsion underwater vehicle, provided with a propeller and thrusters for the horizontal asset, will get power supply from fuel cells batteries and accumulators fed by solar panels placed on the UAF surface. This represents a limit for the maximum operative depth: to use cells also diving it's important not to exceed 10-15 meters of depth, where the sunlight is about the 10% than over the surface.

Since the UAF can operate autonomously , that is without crew on board, it can have very limited dimensions in relation to conventional submarines. Moreover there are other annexed benefits: no acoustic emissions caused by human activities, no heat produced by heating plants for the crew, fewer necessity to ventilate and cool spaces, no more delays in the execution of offensive and defensive maneuvers other than the time necessary to make decision about actions to be taken.

Limited dimensions permit to hold the needed electronic equipment: sensors for the underwater passive detection (hydrophone), radio for sat communication (VHF or UHF), and active sonar (beacon) for underwater transmission, GPS for position identification, echo sounding.

The payload the UAF must have is strongly related to the methods of use. Since the UAF is quite complex and provided with communication and detection systems, we may imagine the simultaneous employ of UAF s with restricted detection capability, placed in proximity of the Command UAF, the only one with payload and with the required propulsive power to keep the speed to silently follow the target. One kilogram of TNT explosive charge brought near the propellers or the rudders could restrict the ship ability to maneuver. Thus exposing it to assaults on the part of other UAF s, let alone the fact that possible supply vessels would expose themselves to further attacks.

There are other mission typologies that could considered: such as surveillance of sea areas to control surface navigation, sea bottom mapping, identification through acoustic tracking, navigation interdiction, communication between air and water taking advantage of sound canalization phenomena, coordination between UAF s.

In other words this is to present a possible evolution of submarine warfare: less expensive units, compared to submarines, able to seriously damage merchant and military navigation. Supposing the presence of autonomous propulsion mines, with low probability to be detected, behind enemy lines, becomes a nightmare for who has to organize a convoy escort and keep navigation safe.

Among the variables and operational modes that could be investigated by the model concerning vehicles characteristics and different tactics it is worth to mention:

- Autonomy, supplying procedures and maintenance politics of UAFs
- How to deploy in and recover from theater of operations UAFs
- Coordination and Communications among UAFs, in particular to use a wolf pack approach to mass assault convoys or critical infrastructures.

In fact invisibility of UAFs is, probably, the main advantage of such vehicles and tactics and all the above mentioned issues are related to this element. Another area that it is worth to be investigated is focused on Command and Control and to the related concept of agility.

5 SIMULATION AND UUVs, STATE OF ART

Unmanned vehicles is an area of great interest in the defense sector with researches from the beginning of the Twentieth Century.

The US Navy began experimenting with radio-controlled aircraft during the 1930s but battlefield Unmanned aerial vehicles (UAV) would not come into their own until the 1980s. For what concerns underwater the first Autonomous Unmanned Vehicle (AUV) was developed at the Applied Physics Laboratory at the University of Washington in 1957. It was named SPURV that stays for “Special Purpose Underwater Research Vehicle”, or SPURV and was used, as name suggests, to study diffusion, acoustic transmission, and submarine wakes.

Typical military missions are to monitor and an area to detect mines or unidentified objects. AUVs are also employed in anti-submarine warfare.

Long-Term Mine Reconnaissance System (LMRS) and its successor, the Mission Reconfigurable UUV (MRUUV) are systems imagined as torpedo tube-launched and tube-recovered underwater search and

survey against mines and are supposed to be roughly the size of a 21-inch torpedo. Futuristic concepts, such as Naval Undersea Warfare Center's MANTA vehicle, would approach, or even exceed, the dimensions of today's Advanced SEAL Delivery System (ASDS) – 65 feet long and 55 tons. Vehicles of that dimension could carry a variety of full-scale weapons – conceptually, MANTA could launch heavyweight torpedoes and – depending on future rules of engagement – might even be unleashed to wield lethal force against enemy ships, submarines, and shore installations. Such kind of platforms could represent a sample, or a starting point of a vehicle used to apply tactics described in this paper.

Typical missions for such kind of unmanned vehicles are reconnaissance, Search and Survey and supporting communications/navigation of submarines. Most of these roles are motivated by the unique advantages of underwater stealth and the need to manage risk, but there are many missions in which using unmanned underwater vehicles could complement crewed platforms providing a significant force-multiplier or simply a more cost-effective approach. The concept of cost-effectives is one of the reference point.

Considering the interest of the military, homeland security and industry communities for such kind of platforms there are several samples of researches and patents in this area. An interesting survey from RAND Corporation (Button et al. 2009) describes most promising missions for unmanned undersea vehicles. Another interesting work from Zhu et al. recently published describes how to control a team of AUVs to reach all appointed target locations for only one time on the premise of workload balance and energy sufficiency while guaranteeing the least total and individual consumption. As an application of simulation in this area we can cite a paper that describes the capability, design and application of the generic underwater warfare simulation environment called ODIN. The model was developed by QinetiQ (Robinson T., 2001)

6 SIMULATOR AND PRELIMINARY EXPERIMENTATIONS

Simulation represents the ideal methodology to test a tactic that is completely new with no real experimental data to be used or analyzed. This is the situation of UAF approach, so a simulator has been developed and, in this chapter are summarized the characteristics of the simulator and preliminary experimental results.

Based on authors' long experience an agent based simulator has been developed. Intelligent agents provide autonomous behavior to the following agents:

- UAFs: for the this experimental scenario the number of UAFs is set to 50; every UAF boards up to a maximum 20 torpedoes
- Military Frigates and Destroyers with helicopters: there are 18 vessels in the area devoted to patrolling and ASW (Anti Submarine Warefare)
- Cargo traffic in the area: there is a daily flow of about 250 cargos per day
- Scenario: it is a square of 1,000 by 1,000 Nautical miles located in Deep Sea

The simulator detects successful attacks (sunken cargos) from UAFS to cargo and from anti-submarine vessels in the area to UAFs. UAFs failures, overall costs and other parameters are also tracked.

UAFS and Frigates/Destroyers operate autonomously and attack their targets based on condition; obviously both need refueling, reloading and support activities based on their use. Cargos navigate in the area following assigned routes.

For this first phase of the analysis a scenario with no convoys has been created, so UAFs operate independently with no particular coordination and C2 with exception to the support, logistics and service operations.

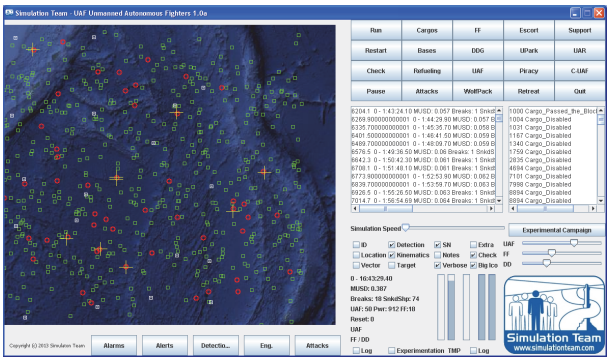

Figure 3: Simulator GUI

In Figure 4 is represented the Mean Square pure Error (MSpE) analysis to define the simulation duration, that confirms the possibility to obtain after a number of simulation days a pretty reliable estimation of the confidence band for the different target functions.

Preliminary experimentation, mainly to complete the V&V phases, generated some encouraging findings about effectiveness of this approach.

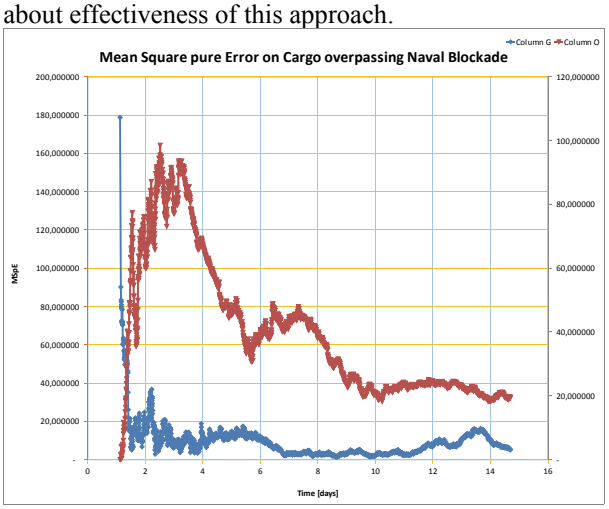

Figure 4: MspE of Cargos passing blockade

In Figure 5 are depicted three observed target functions:

1. Disabled cargos [%]
2. Cargo able to break the Naval Block created by the UAF respect the overall flow [%]
3. Availability of UAFs's weapons respect initial maximum capability [%]

From this figure it is emerging that about 18% of cargos crossing the blockade area are hit and disabled by UAFs' attacks and the UAFs flotilla is able to operate with acceptable losses, but requires proper support and logistics.

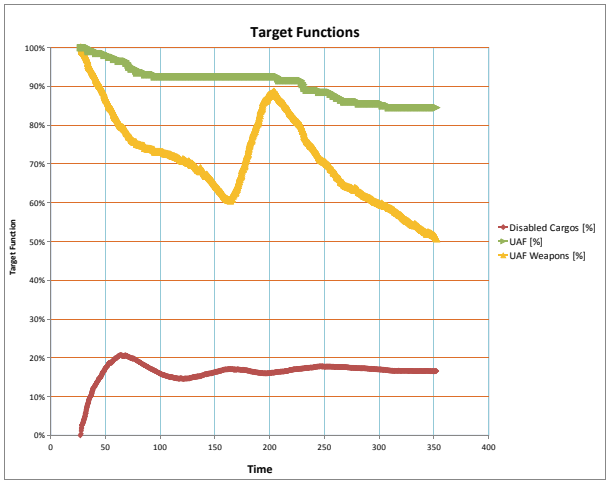

Figure 5: Disabled Cargos and UAFs Fire Power

7 CONCLUSIONS

This paper describes on going researches to define innovative strategies and tactics as well as critical technological aspects related to the development of innovative UAF; the paper address specifically the submarine warfare based on unmanned vehicles and presents some preliminary result from experimentation based on the usage of a agent based discrete event simulator developed ad hoc.

The general idea is to attack merchant routes or mount a blockade to a country or an area by an innovative stealth submarine force based on unmanned vehicles (named Unmanned Autonomous Fighters - UAFs) even if readapt tactics from World Wars. In the analysis and in the development of the conceptual models and scenarios, the authors have considered the economical trade off between results of attacks to cargos and potential losses, considering cost of the vehicles and of mounted weapons.

Preliminary results based on the developed agent based simulator are encouraging about the effectiveness of such approach and provide useful insight about the UAF technical characteristics, requirements and features.

Actually authors are creating an international team of subject matter experts to complete the accreditation of this model and to support future researches and developments. Among these are the study of new tactics with more coordination capabilities, the definition of a detailed plan based on costs and an analysis of direct and indirect impacts of such kind of attacks and further experimentation to define procedures and variables such communications or autonomy of UAFs.

REFERENCES

"Political, military, economic, social, Infrastructure, information (PMESII) Effects forecasting for course of Action (coa) evaluation", AFRL-RI-RS-TR-2009-160 Final Technical Report, June 2009

Benedict, JR (2000) "Future Undersea Warfare Perspectives" Johns Hopkins Apl Technical Digest Volume: 21 Issue: 2 Pages: 269-279

Bocca E., Pierfederici, B.E. (2007) Intelligent agents for moving and operating Computer Generated Forces, Proc. of SCSC, San Diego July

Brooks, John (2007) "Anti-submarine warfare in World War I: British naval aviation and the defeat of the U-boats" Mariners Mirror Volume: 93 Issue: 1 Pages: 115-117, Feb

Brown, Gerald; Kline, Jeff; Thomas, Adam; et al. (2011) "A Game-Theoretic Model for Defense of an Oceanic Bastion Against Submarines", Military Operations Research Volume: 16 Issue: 4 Pages: 25-40

Bruzzone A.G., Cantice G., Morabito G., Mursia A., Sebastiani M., Tremori A. (2009) "CGF for NATO NEC C2 Maturity Model (N2C2M2) Evaluation", Proceedings of I/ITSEC2009, Orlando, November 30-December 4

Bruzzone A.G. Tremori A., Massei M. (2011) "Adding Smart to the Mix", Modeling Simulation & Training: The International Defense Training Journal, 3, 25-27, 2011

Bruzzone A.G., Fadda P, Fancello G., Massei M., Bocca E., Tremori A., Tarone F., D'Errico G. (2011) "Logistics node simulator as an enabler for supply chain development: innovative portainer simulator as the assessment tool for human factors in port cranes", Simulation October 2011, vol. 87 no. 10, p. 857-874, ISSN: 857-874, doi: 10.1177/0037549711418688.

Bruzzone A.G., Massei M. Tremori A., Longo F., Madeo F., Tarone F, (2011) "Maritime Security: Emerging Technologies for Asymmetric Threats", Proceedings of European Modeling and Simulation Symposium, EMSS 2011, Rome, Italy, September 12 -14

Bruzzone A., Tremori A., Longo F., (2012) "Interoperable Simulation for Protecting Port as Critical Infrastructures", Proc. of International Conference on Harbor, Maritime and Multimodal Logistics Modeling & Simulation, HMS 2012, Wien, September 19-21

Bruzzone A.G., Tremori A., Merkuryev Y. (2011) "Asymmetric marine warfare: PANOPEA a piracy simulator for investigating new C2 solutions" Proceedings SCM MEMTS 2011, St.Petersburg June 29-30

Button R. Kamp J. Curtin T.; Dryden J. (2009) "A Survey of Missions for Unmanned Undersea Vehicles), RAND National Defense Research Inst Santa Monica CA ADA503362

Changjun Pan, Guo Yingqing (2013), Design and simulation of ex-range gliding wing of high altitude air-launched autonomous underwater

vehicles based on SIMULINK, Chinese Journal Of Aeronautics Volume: 26 Issue: 2 Pages: 319-325

Chu, PC; Perry, MD; Gottshall, EL; et al. (2004) "Satellite Data Assimilation for Improvement of Naval Undersea Capability" Marine Technology Society Journal Volume: 38 Issue: 1 Pages: 12-23

Coy, Peter (2008)"Anti-Submarine Warfare", Mariners Mirror Volume: 94 Issue: 4 Pages: 496-497

Dingman, Roger (2010) "Execute Against Japan: The US Decision to Conduct Unrestricted Submarine Warfare" Pacific Historical Review Volume: 79 Issue: 2 Pages: 308-309

Dönitz K., (1958) Memoirs: Ten Years and Twenty Days, World Publishing Company, NYC

Dorwart, JM (1992) "Diplomatic Ramifications of Unrestricted Submarine Warfare, 1939-1941", Journal of American History Volume: 78 Issue: 4 Pages: 1505-1505

Franklin, George (2006) "The Royal Navy and anti-submarine warfare, 1917-1949", Mariners Mirror Volume: 92 Issue: 4 Pages: 520-522 Nov 2006

Gardner,WJR, Channon, RF (1997) "Anti-Submarine Warfare", Mariners Mirror Volume: 83 Issue: 1 Pages: 120-121

Guo, Rui; Zhao, Xiaozhe; Yu, Hayang (2006) "One application case of artificial life approach in the simulation of surface ship's anti-submarine warfare" Dynamics Of Continuous Discrete And Impulsive Systems-Series B-Applications & Algorithms Volume: 13 pp. 610-614

Hamilton, Michael J.; Kemna, Stephanie; Hughes, David (2010) "Antisubmarine Warfare Applications for Autonomous Underwater Vehicles: The GLINT09 Sea Trial Results", Journal Of Field Robotics Volume: 27 Issue: 6

Higgins, TM; Turriff, AE; Patrone, DM (2002) Simulation-based undersea warfare assessment, Johns Hopkins Apl Technical Digest Volume: 23 Issue: 4 Pages: 396-402

Horcicka, Vaclav (2012) "Austria-Hungary, Unrestricted Submarine Warfare, and the United States' Entrance into the First World War", International History Review Volume: 34 Issue: 2 Pages: 245-269

Jethi, SC; Jain, RK (2004) "Simulation of naval wargames" Defence Science Journal Volume: 54 Issue: 3 Pages: 407-415

Maas P., (1999) The Terrible Hours: The Man Behind the Greatest Submarine Rescue in History, HarperCollins New York

Massei, M., Tremori, A., Poggi, S. and Nicoletti, L. (2013) 'HLA-based real time distributed simulation of a marine port for training purposes', Int. J. Simulation and Process Modelling, Vol. 8, No. 1, pp.42–51

Milner, Marc (2006) "From Nelsonic to Newtonian: The development of anti-submarine warfare in the North Atlantic 1939-45" Mariners Mirror Volume: 92 Issue: 4 Pages: 465-476

Morgan, JG (1998) "Networking ASW systems: Anti-submarine warfare dominance - The direction for US Navy operational primacy - To remain the most formidable ASW force in the world" Sea Technology Volume: 39 Issue: 11 Pages: 19-22

Potter E. B. and Chester W. Nimitz, 1960; Sea Power: A Naval History, N.J.: Prentice-Hall, Englewood Cliffs

Robinson, T. (2001) "ODIN - an underwater warfare simulation environment ", Simulation Conference, 2001. Proceedings of the Winter (Volume:1) ISBN 0-7803-7307-3, Arlington (VA) 09 Dec 2001-12 Dec 2001

Sea Technology, (2010) "Anti-Submarine Warfare", Sea Technology Volume: 51 Issue: 10 Pages: 31-32 Published: Oct 2010

Steffen D. (2004)"The Holtzendorff memorandum of 22 December 1916 and Germany's declaration of unrestricted U-boat warfare", Journal of Military History Volume: 68 Issue: 1 Pages: 215-224

Sturma, Michael (2009) "Atrocities, Conscience, and Unrestricted Warfare US Submarines during the Second World War", War In History Volume: 16 Issue: 4 Pages: 447-468

Todd, Jonathan (2008) "The Royal Navy and anti-submarine warfare, 1917-1949", Journal of Strategic Studies Volume: 31 Issue: 4 Pages: 665-667

Tremori A., Massei M., Madeo F., Reverberi A., (under publication), "Interoperable simulation for asymmetric threats in maritime scenarios: a case based on virtual simulation and intelligent agents" International Journal of Simulation and Process Modelling (IJSPM).

van Vossen, Robbert; Beerens, Peter; van der Spek, Ernest (2011) "Anti-Submarine Warfare With Continuousiy Active Sonar TNO Tests the Principle of Continuously Active Sonar With the Interim Removable Low-Frequency Active Sonar System", Sea Technology Volume: 52 Issue: 11 Pages: 33-35

Vigliotti, V. (1998) "Demonstration of Submarine Control of an Unmanned Aerial Vehicle" Johns Hopkins Apl Technical Digest Volume: 19 Issue: 4 Pages: 501-512

Volkert, Richard; Jackson, Carly; Whitfield, Cecil (2010) "Development of Modular Mission Packages Providing Focused Warfighting Capability for the Littoral Combat Ship", Naval Engineers Journal Volume: 122 Issue: 4 Pages: 75-92

Zhu DQ; Huang H.; Yang, SX (2013) "Dynamic Task Assignment and Path Planning of Multi-AUV System Based on an Improved Self-Organizing Map and Velocity Synthesis Method in Three-Dimensional Underwater Workspace", IEEE TRANSACTIONS ON CYBERNETICS Volume: 43 Issue: 2 Pages: 504-514 DOI: 10.1109/TSMCB.2012.2210212, Published: APR 2013