AUTONOMOUS SYSTEM SIMULATION TO IMPROVE SCENARIO AWARENESS AND CAPABILITIES TO PROTECT MARINE, OFF-SHORE AND COASTAL CRITICAL INFRASTRUCTURE

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ABSTRACT

This paper proposes and integrated approach to address maritime security respect the use of innovative autonomous systems operating within the extended maritime framework. Indeed the paper addresses the vulnerability of ports as well of off-shore and coastal critical infrastructures. The paper outline the advantage to use interoperable simulation to address this context by a global approach combining industrial, homeland security and defense point of view. The authors propose the scenario definition and the main objects and variable to be considered. The paper proposes the process to develop a simulation framework able to be reused and to serve as reference point of the different stakeholders

Keywords: *Autonomous Systems, Interoperability, Modelling and Simulation, Joint Naval Training, Tactical Decision Aid*

INTRODUCTION

Maritime Security is a major issue that represent a strategic context for National and International interests. Indeed these aspects are even overstressed by the evolution of the socio economic scenario; the constant trend in world merchandise traffic is a very consolidated phenomena continuously growing along 2010-2013 ranging from +12.9% to +2.2% yearly for world traffic; the western developed economies are characterized by lower values that in any case confirm positive trends for USA (Import +15.9% down to +2.6%, Export +14.8% down to +0,9%) while some recession effect is present in Europe (Export from +11.6% to +1.4%, Export from 9.4% down to a minimum 2.5% that is recovering to 1.2% in 2013), these figures are cumulative and reprent a very significant overall increase as proposed in figure 1 (Rogers 2014). Indeed the logistics of the raw material flows and goods is mostly based on shipping lines, so ports represent the strategic entry gate for being able to maintain industrial activities and sustainability of the large majority of existing economies; figure 2 provide an interesting overview of world sea traffic increase just between 2013 and 2013. In addition to these aspects, 44% of world population is located on coastal area and this rate is increasing year by year (Choen et al. 1997); a large quantity of critical infrastructures are located within coastal areas (e.g. power plants, fuel storages, refineries, water treatment, waste treatments, etc) due to the population density and/or the need to logistics and technological benefits arising from facing the sea. In addition to these aspects the off-shore resources for power (e.g. oil rigs, gas rigs, wind farms) are normally located not so far from the coast up to 200 NM (Matrangelo 2005). It is important finally to outline that very strategic world assets are concentrating near the coast representing critical infrastructures such as Underwater Pipelines and Communication Cables.
Based on all these elements it is evident the necessity to study how to improve the security of the assets located in

this context and due to the complexity of this framework it is evident the necessity to use M&S as investigation tool.

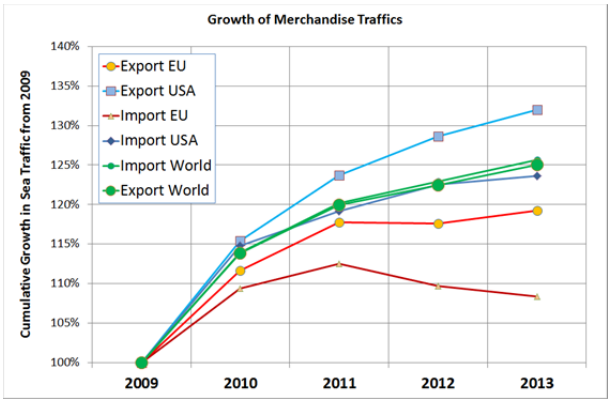

Figure 1 –World Traffic Cumulative Increases

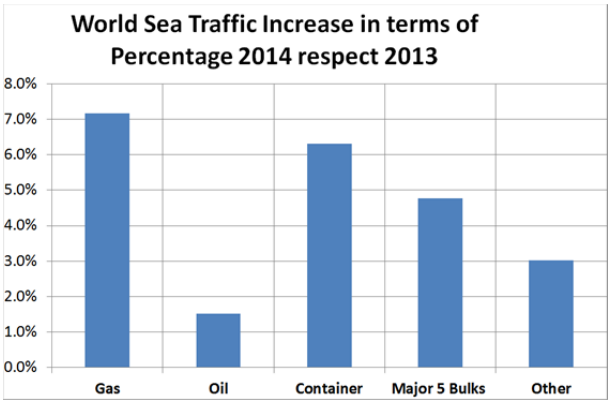

Figure 2 –World Sea Traffic 2013-2014 Trends

2. MODELING AND SIMULATION FOR MARITIME SECURITY

In many of these context the defense policies need to be reviewed considering the very dynamic nature of emerging threats as well as the necessity to protect wide infrastructures with very high vulnerabilities; from this point of view the use of autonomous systems and heterogeneous sensor network could allow to develop new sustainable solutions for improving security and reducing vulnerability, but it is still necessary to define the architecture of these new solutions, the technological requirements, the utilization policies and procedures as well as their reliability and efficiency (Been et al. 2008); for all these purpose the simulation represent a promising approach able also to support the development of innovative training equipment for promoting the diffusion and service (Waite 2001).

So considering all these elements it is fundamental to develop simulators able to consider marine infrastructures and address these issues and to dynamically adapt themselves to the evolution of these scenarios (Longo, 2010; Bruzzone et al. 2013c; Bruzzone et al. 2013e). Indeed, historically Modeling & Simulation (M&S) has been already extensively used in the maritime domain, mostly to support decision making, education and training (e.g. Longo et al. 2013; Longo et al. 2014). Therefore the potentials of M&S in this area has been widely proved and this fosters the use of M&S to support cutting-edge research to protect marine, off-shore and coastal critical infrastructures.

Due to these reasons the authors are considering interoperable simulation based on state of art technology as the best approach and are working to establish initiative in this fields through excellence networks and international organizations and institutions.

This initiative is currently addressing the development of an interoperable simulation environment to study the combined use of Autonomous Systems and Traditional Assets within the Extended Maritime Framework (i.e. Sea Surface, Underwater, Coast, Air, Space, Cyber) to protect related critical infrastructures (Bruzzone 2015).

Indeed the concept of Extended Maritime Framework (EMF) was developed to consider the strong correlation among the different domains and the necessity address them within a common simulation framework (Bruzzone et al. 2013b); EMF represents a very critical mission environments where the interoperability importance is over stressed by the nature of this battlespace and the complexity of the specific heterogeneous networks among the related assets.

In addition to these elements, as anticipated, very critical infrastructures are present in this context including among the others strategic resources, such as cables, underwater pipelines, ports, as well as off-shore and on-shore plants, LNG, terminals, etc.

The use of autonomous systems to protect these critical infrastructure results very promising for reducing their vulnerability in this multi domain environment; therefore it is evident the importance to investigate these solutions by quantitative models, extensive experimentation; it is also critical to be able to study the interoperability of the autonomous systems with traditional assets (e.g. helicopters, boats, ships, MPA etc) in this framework.

Probably simulation is the only methodology able to develop this investigation capability and to evaluate a priori the most effective strategic solutions to face these challenges.

Currently the authors are developing an initiative in joint cooperation among Simulation Team, CMRE, M&S COE, NATO MSG for promoting the development of this research within leading institution in M&S: this initiative is defined as SA3C4 and should investigate the most effective approaches, as well as their capability, to augment the scenario awareness and the capabilities to protect marine, littoral and Coastal Critical Infrastructure by using a mix of autonomous systems and traditional assets

This idea is strongly relying on the solid experience and background in the sector of interoperable simulation, marine M&S and operational simulation acquired by Simulation Team, CMRE and the other NATO Entities supporting this initiative (e.g. NMSG, NATO M&S COE) in strong liaison with excellence centers (e.g. M&S Net, McLeod Institute, VMASC, Genoa University, etc.) in worldwide leading Institution (Bruzzone et al 2011c).

It is important to outline that this research is addressing also the need to extend NATO capabilities in Joint Naval Scenario Simulation and should benefit of existing activities such as Exploratory Team MSG-ET-036 "modelling and Simulation of Autonomous ASW capable vehicles to Augment surface and maritime air Capabilities"; this previous research was devoted to identify the available simulation resources to develop an interoperable simulation able to reproduce the combined use of autonomous and traditional assets for operational naval scenario (e.g. Anti Submarine Warfare); the preliminary results achieved by this Exploratory Team by interacting with different centers are currently confirming the potential of this approach by interactive demonstration on an HLA federation of simulators (High Level Architecture) that provide guidelines and references for further developments in this context (NATO 1998, 2012; Bruzzone 2014c).
In addition to HLA the idea to use this simulation to support education and training as well as table top exercise suggest to adopt the SaaS (Simulation as a Service) paradigm experienced already with DVx2 simulator (Bruzzone et al. 2014b).

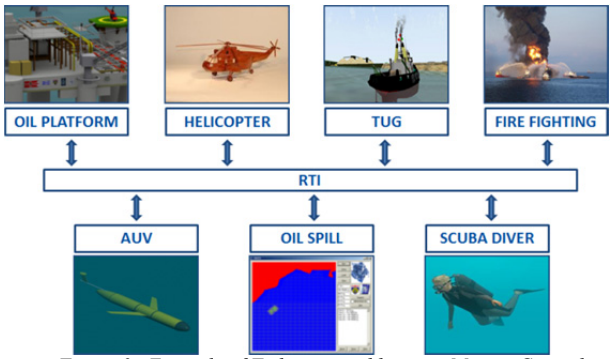

Figure 3 –Example of Federation addressing Marine Critical Infrastructure Protection

3. OBJECTIVE IDENTIFICATION

The goals of this Interoperable Security Simulation for extended Maritime framework (ISSEM) is to establish a M&S reference on combined used on Autonomous Systems and Traditional Assets able to combine behavioral models and resource simulation (both platforms and networks) with the simulation of the critical infrastructures to assess the effectiveness of solutions devoted to protect of Strategic Assets within the Extended Maritime Framework (i.e. Sea Surface, Underwater, Coast, Air, Space, Cyber).
Obviously several of these models will need to be created ad hoc to reproduce new elements (e.g. autonomous systems swarms) and many legacy systems will require major revision to be usable within this context; therefore the creation of this ISSEM federation, represents the opportunity to develop a strategic capability in modelling and analyzing the Extended Maritime Framework for protection of littoral, coast and related infrastructure. A major step forward supported by ISSM is the possibility to couple the critical infrastructure simulation dealing with the effects resulting from compromising their security with the simulation of new autonomous systems as well as that one of traditional solutions.
ISSEM concept is based on multi layer simulation already applied for industrial and natural disaster (Girbone et al.1994; Bruzzone & Massei 2006; Bruzzone et al. 2014d); indeed this context requires to be able to estimate not only the vulnerability reduction, but also to evaluate the damage resulting from the attacks respect different target functions including the strategic role of the assets, its costs, its implication within society; so it means that if a power plant fails this correspond to an heavy impact on urban activities, while attacks to oil and gas process plants could lead toward the generation of direct and indirect on population and environment (Bruzzone et al. 2014a). An example of ISSEM federation addressing these issues is proposed in figure 3.
An important aspect to focus is the identification of interoperable simulation requirements for the creation of distributed collaborative simulation amongst potential users; indeed by this approach it becomes possible to assess the benefits provided by unmanned systems when integrated within existing surface and maritime air capabilities in protecting marine, coastal and littoral critical infrastructures (e.g. cables, underwater pipelines, ports).
ISSEM final goal is the creation of an HLA Federation of simulators and related guidelines to further extend it in respect of standards for interoperability; the decision on using the reference interoperability standards for M&S is also motivated by the availability of multiple simulation framework and experiences for marine environment based on HLA (Massei et al. 2010; Longo 2012; Bruzzone et al. 2013a; Bruzzone et al. 2013b; Bruzzone et al. 2013d).
In order to achieve valuable results and create an effective demonstration with limited resources it is crucial to define the boundary of the scenario to be simulated by ISSEM federation; this means that the demonstration should focus on a specific scenario to be defined as common agreements among the different partners and by analyzing specific case studies strategically relevant for maritime Security; in this context the threat modeling as well as the simulation of resource coordination results critical dealing with maritime asymmetric scenarios (Mevassvik et al.2001; Bruzzone et al. 2011a); in order to succeed in this case it is fundamental to federate elements introducing intelligence within the scenario; in this case the idea is to use the IA-CGF (Intelligent Agent Computer Generated Forces) already used in marine security over other scenarios (Bruzzone, Tremori, Massei 2011b).
It is important to define this scenario in a way that allow ISSEM to demonstrate its general purpose capabilities in relation to dual use (defense and civil application); from this point of view it is suggested to combined the identification of the kind of critical infrastructures to study (e.g. oil rigs, commercial ports) with the expectations from business the sectors related to crucial industries and plants (e.g. oil & gas, shipping, terminal operations) in this context.

The development plan should be based on a synergy among leading entities in simulation community; currently the authors have already developed some example of these concepts and are in contact with Simulation Team, CMRE, NMSG, NATO M&S COE for activating an joint initiative using ISSEM as basic for further developments.

4. ISSEM FEDERATION

A preliminary configuration ISSEM federation was create to investigate the concepts proposed and to validate them (Bruzzone 2002); the case was finalized in relation to scenario dealing with an off-shore platform and the use of some autonomous vehicles (e.g.AUV and Gliders) devoted to patrol the area versus opposite autonomous systems and cooperating with a surface vessel as proposed in figure 4 ().

The architecture proposed is based on HLA and several different marine simulators have been evaluated for the interaction as Habitat, ST_VM, Jeans, MCWS, COLA2, DVx2 and MSTPA; an example of execution of current ISSEM is proposed in figure 5; ISSEM Federation uses time management and is able to operate fast time and real time and was tested also including SIL (Software in the Loop) related to AUV Navigation in a basic MCM patrol scenario (Mine Countermeasures); the virtual representation

The simulation mission is to guarantee a patrolling by three AUV (Autonomous underwater Vehicles) while an UAV (Unmanned Aerial Vehicle provide air coverage; a frigate in the area is in charge of recovery and deploy the AUVs taking care of recharging the batteries, full data download; the procedure for bordering the ship is based on approaching the stern gate usually devoted to handle a large RHIB (Rigid Hull Inflatable Boat); this mission was activated as example for testing interoperability within JEANS Simulator (Join Environment for Advanced Naval Simulation) using discrete event stochastic simulation for the events and threats; Jeans allows to visualize green capsules and orange pyramids, on demand, over the AUV to simplify the awareness on the situation and immediate identification of underwater assets even from surface virtual representation (see figure 5).

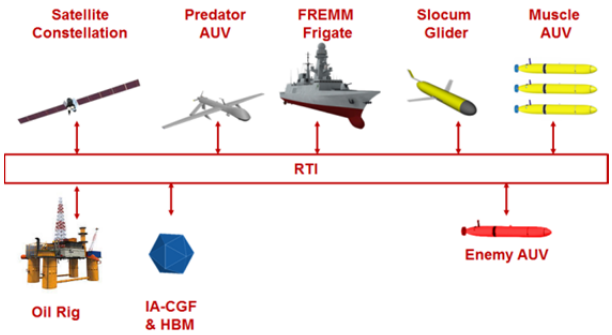

Figure 4 –Example of ISSEM Federation configured for Patrolling the Oil Rig

Obviously this case is just an example that could be further extended to other cases, indeed the modeling standard and guidelines for this Interoperable Simulation are a good reference for further developments within marine environment; in particular the authors are working in order to couple ISSEM federation with models reproducing the impact of actions versus the marine critical infrastructures.

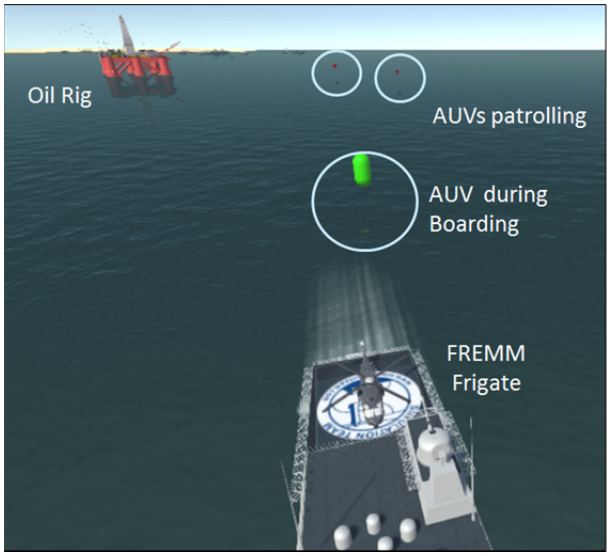

Figure 5 –Virtual Simulation federate presenting dynamic evolving situation within ISSEM Federation

ISSEM could be used for education and training in these new kind of operation (Bruzzone et al.2009); therefore it could be also applied for supporting decision making on maritime security dealing with strategic assets.

5. DEVELOPMENT PLAN

As anticipated ISSEM represents a first step also in relation to the activation of a Maritime Security initiative within NATO; in this case the general objectives are dealing with industrial application and homeland security, therefore it could be necessary to address more specifically the defense; in this case it should be tailored a special version of ISSEM federation addressing the related detailed scenario. This defense scenario should require a development plan to guarantee the involvement of stakeholders and the exploitation of the results; this could be achieved by activating different activities including among the others:

- Survey on Available interoperable models and simulators available for being integrated in the Federation
- Detailed Definition of Federation Objectives, Mission Environment & Scenario, Architecture
- Definition of Federation Configuration for the 1st Experimentation devoted to test, present, and exploit interactively the Augmented Capabilities provided by the interoperable simulation

In addition it will be necessary to plan proper the ISSEM Demonstration & Networking. The Federation

Demonstration is devoted to finalize on a specific defense scenario relevant for protection of littoral, coast and related critical infrastructures; this demonstration could become an important support to diffuse the use of the related FOM and federates as reference for interoperability in maritime security within the extended maritime framework.
Currently the author plan to demonstrate the ISSEM Federation on a specific workshop organized ad hoc to interact with Stakeholders and Subject Matter Experts and to exploit the result of the project; in addition, ISSEM could be presented within major Technical/scientific Conference such as I/ITSEC, ITEC and/or UDT, NATO CAX Forum and I3M/DHSS.
In general, the Prospective Stakeholders of ISSEM are the National and Alliance Decision Makers, the National Navies, the Extended Maritime Framework Stakeholders, the Autonomous System Community, the Simulation Community, the Coast Guards, the Homeland Security Agencies, elements from industry (e.g. Defense Industry, Oil & Gas Industry, Commercial Ports, Shipping). This activity should be devoted to exploitation and engagement of different entities, Nations and SME. Indeed the proposed Federation of Simulators could be demonstrated during in several communities representing the interested subjects. In addition it could be possible based on available resource and support to exploit the ISSEM results by interacting with scientific community in major conference and exhibitions (i.e. NMSG, I/ITSEC, ITEC and/or UDT, NATO CAX Forum I3M/DHSS).
The tailored ISSEM Federation and/or a specific release for defence could be finalized in synergy among existing projects and in cooperation with partners; this could be made available as a new tool for improving marine investigation capabilities for the Alliance and Nations. Different examples of ISSEM federation are currently operational within different simulation Labs (i.e. CMRE SimLab, Simulation Team Labs in Savona Campus); these examples could be further developed to be made available for evaluating solutions as well as to be used for table top exercises and further analyses.

CONCLUSIONS

This paper combines previous researches carried out in maritime security with the innovative concepts such as interoperable simulation and Saas. The preliminary runs carried out on the oil rig patrolling platform confirmed the potential for combining existing models and for completing experimental tests; currently the authors have completed technological integration and they are working forward for integrating also other simulators.
Future developments involve the engagement of SME in using ISSEM for analyzing maritime security scenarios and identifying specific additional models that should be added.

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