SIMULATING THE MARINE DOMAIN AS AN EXTENDED FRAMEWORK FOR JOINT COLLABORATION AND COMPETITION AMONG AUTONOMOUS SYSTEMS

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ABSTRACT
The paper presents the objective and characteristics of an integrated architecture devoted to develop a new generation of simulators able to reproduce joint interoperability among Autonomous Systems over the marine domain. The authors analyze the requirements for such simulation solution in order to address the needs of the applicative context considering different needs: engineering, operations, training and supervision. The paper proposes the general architecture and an approach for integrating different models within this federation; the description of the mission environment is proposed as test case, as well as the preliminary activities for validating these concepts as well as the simulation architecture.

1 . INTRODUCTION

This research aims at developing conceptual models and simulators devoted to support the definition of technical and operational requirements for developing a new generation of interoperable UAS (Unmanned Autonomous Systems) operating over the different domains (Air, Sea Surface, Underwater, Land). The result of this activity is expected to be an HLA Federation that will allow to conduct virtual tests of new UAS configurations and to examine the interoperability related requirements in order to obtain a robust solution able to satisfy mission requirements. Indeed the UAS need to embed and implement interoperability principles to be able to act as a system of systems; currently UAV (Unmanned Aerial Vehicles) are quite advanced in this form, while the operational use of UGV (Unmanned Ground Vehicles) is still quite limited and AUV (Autonomous Underwater Vehicles) and USV (Unmanned Surface Vehicles) are in development phase.

Therefore it is crucial to proceed in this direction to guarantee operational interoperability; indeed this approach will be a support for AxS (Autonomous Surface, Underwater or Aerial Systems) operating for long periods and on multiple tasks over different areas. This paper focuses on operational scenarios running over the Maritime Extended Framework that includes Sea (surface and underwater), air, coastal areas, cyberspace and space; the paper pays special attention to modeling USV, AUV and UAV interacting with traditional assets over a coastal scenario for multiple operations, for instance intelligence surveillance and reconnaissance (ISR). In this context USV and AUV could drastically increase their capability through interoperability among their selves and with other traditional assets with examples in the interaction among Autonomous surface and underwater Vehicles (AxV in Nad et al. 2011); indeed it is evident the potential of considering them as resource able to interoperate with submarines, vessels, aircrafts, underwater docking stations etc.

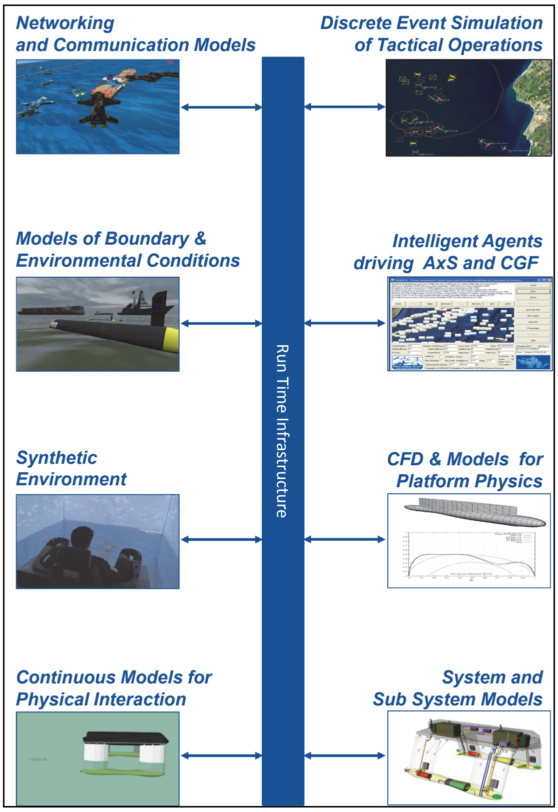

Figure 1: SEAVIT Federation architecture including different federates

2 . OPERATIONAL INTEROPERABILITY AND SIMULATION: SEAVIT FEDERATION

The goal of this research is to create a simulation framework to virtually experiment new interoperable AUVs, USVs and UAVs in order to measure the effectiveness of their interactions with other systems. Indeed the different kind of autonomous vehicles are currently characterized by improvements in capabilities, missions.

This evolution introduces the opportunity to assign more sophisticated roles to AxSs and to pass from single system task to multi system cooperation as well as to collaborative missions. At the same time it results evident the opportunity to investigate the capabilities of AxSs in terms of addressing competitive roles: indeed these systems have already kinetic capabilities (i.e. Reapers and Predators with Hellfire as Unmanned Combad Aerial Vehicles).

Therefore in the future these capabilities are expected to increase as well as to provide the AxSs with systems able to direct not-kinetic actions against opposite forces (i.e. cyber-attacks).

These aspects confirm the opportunity to use AxSs for contrasting and engaging opposite drones as part of a system of systems and the necessity to start investigation in these swarm combat scenarios by using modeling and simulation. In general, considering all the above mentioned elements, operational scenarios are evolving requiring to address AxS interoperability for improving their capabilities and extending their missions to new areas; obviously simulation is the crucial technology also for investigating in advance the alternative configurations, requirements, polices and doctrines related to these phenomena (Bruzzone et al. 2005).

This objective implies that many aspects need to be investigated, such as operational efficiency, costs, reliability, resilience and readiness. Currently the authors are working to create an innovative simulation environment for capability assessment and to develop the requirements for this new generation of interoperable AxSs.

By this approach it becomes possible to simulate in advance the impact of alternative solutions and standardization approaches considering different platforms and concepts (e.g. compare AUVs deployment from a surface platform or from a submarine).

Since the simulation should address different elements, the High Level Architecture interoperability standards (HLA) is considered by the authors the most appropriate and effective computational solution to adopt (Massei & Tremori 2013); the authors used Object Oriended Design and Analysis approach and creates objects for each entity for being shared among the federates (Zacharewicz et al. 2008;Ramos et al. 1999).

Figure 2: Example of Virtual Framework for Marine Simulation of Scenarios involving use of Autonomous Systems

This architecture allows to combine different models into a federation and to keep it open for further developments including HIL and SIL (hardware and software in the loop); this federation is defined as SEAVIT (Sea Environment for Autonomous Vehicle Interoperability Testing) depicted in figure 1. Physical aspects related to specific elements should be modeled and federated within the SEAVIT federation of simulators: examples are the mechanical simulation of the docking/recovery devices or the simulation of marine inductive recharge solutions for AUV; most of these models will be continuous deterministic models. SEAVIT Federation integrates also different models addressing tactical and operational issues in order to investigate the impact of the different alternative solutions; in this case the models are combined stochastic simulators including discrete event and continuous components (Piera et al. 1996; Zachariewicz 2008). Following this structure, SEAVIT has the capability to simulate multiple AxSs and different platforms operating on selected scenarios (i.e. target, suspicious objects, vessels, support devices etc). Due to the complexity of underwater communication system with respect to other environments it becomes crucial to be able to model also these elements; indeed such systems represent a critical issue to guarantee interoperability of existing systems and operational efficiency.

3 BENEFITS FROM SIMULATION OF MARINE UAS OPERATIONAL INTEROPERABILITY

Autonomous Underwater Vehicles (AUVs) have numerous advantages that, potentially, could make them a suitable solution for many military applications including ports surveillance and protection, mines searching, submarines operations support, etc. However, their current development status suggests that it is time to move towards a new generation of AUVs; such new generation of UAS should have in the interoperability with other systems its major point of force. For this reason, since nowaday's AUVs cannot be considered as fully operational vehicles in real missions. Indeed to deploy the AUV is not simple and in addition there are significant problems related to their recovering and recharging operations, collection of the data recorded, sensors replacement etc. Most of these problems could be addressed through standardization problems able to reduce the UAS interoperability capabilities (sensibly increasing the cost of their use and reducing the operative potentials over long time). As far as the recovering operations are concerned, there are different ways to recover AUVs; however often this is a time consuming and expensive operation; much more should be done to design AUVs that have the capability to be recovered in quickly and in standardized way. Similarly recharging operations should be simplified and standardized in order to increase the AUV availability. The data link used to retrieve the data recorded by the AUVs sensors should be simple and effective as much as possible and the replacement (or the change) of some parts of the UAV (i.e. replacing the actual sensors with new ones) should be done with a minimum effort and time.

As matter of fact, most of the problems of AUVs are related to their "physical" interoperability with other systems including other AUVs and/or USV, but, above all, submarines, vessels, aircrafts, underwater docking stations should be remarkably improved. Solving all the above mentioned problems would transform the idea of UAS: from experimental vehicles (as currently they are) to fully operative vehicles (as potentially they could be). The "physical" interoperability with other entities and the standardization procedures require the definition of new technical and operational requirements. To this end the SEAVIT federation is devoted to support the Simulation Based Design of a new generation of interoperable AUVs and USV.

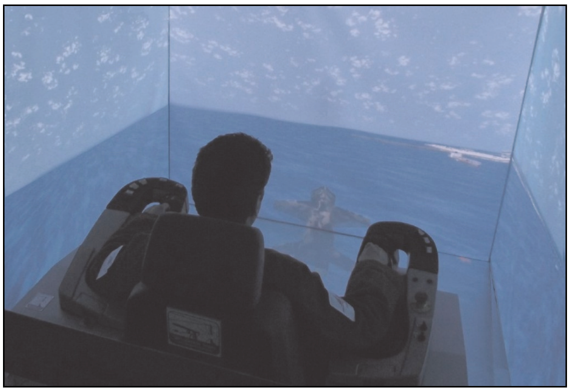

Figure 3: Example of Virtual Manned Cave for directing collaborative Swarms of UAV operating over the Sea

Aspects such us AUS requirements and deployment and recovering methods could be investigated in a safely virtual environment (see figure 2).
Multiple options for recharging operations may be considered in terms of operational efficiency, times and costs. In order to improve the design of the new generation of UAS, SEAVIT environment will provide the possibility to integrate in its HLA federation also real assets and equipment; providing the unquestionable advantage of testing the virtual UAS when interacting with real assets and entities. In addition, the simulation environment will give the possibility to carry out what-if analysis fully supporting and aiding in the design of the new UAS. New standardized components could be tested by simulation without committing resources to their acquisition; at the same time new operating procedures could be explored: i.e. compare AUVs deployment from a surface platform or from a submarine, gaining insight into the importance of those factors and parameters that may significantly affect the performances of the AUVs during their interactions with other entities. To this end the SEAVIT environment will be also able to study and reduce delays and to identify those constraints which pose a limit to the operative use of UAS.
The design of the new AUVs generation would be costly if carried out with real experimentation and prototypes; the SEAVIT environment may strongly support the identification and reduction of risks as well as of the development time. Furthermore the SEAVIT environment may strongly reduce field testing (cost reduction) and supporting – as a consequence – realistic requirements definition, development process and operational testing. In the following some scenario is proposed for applying SEAVIT simulation.

3.1 Collaborative Approach as Enabler for New Capabilities and Performances

The UAS have currently significant limitations on several aspects including autonomy, fire power, resilience and decision making. Some of these aspects could be addressed acting on a single entity design. Collaborative tasks could be improved taking into account the overall performance: from this point of view it is expected that an heterogeneous network of UAS could be assigned to collaborative tasks; in 2012 falls it was possible to complete the Air Refueling, therefore in maritime domain there are several aspects where collaborative assignments could be of interest for being assigned among swarms of UAS and/or mixed group including traditional assets and UAS (Wiedemann 2013); for instance the following actions could improve the performance as well as to introduce new capabilities:

- Joint Patrolling
- Multi Sensor & Multi Platform Data Fusion
- Multi Static Acoustics
- Mobile & Dynamic Heterogeneous Networking
- Command and Control
- Cooperative engagement

In addition to these aspects the following issues are devoted to an operational interaction among similar and/or different UAS or traditional assets such as:

- Deployment
- Refueling and/or Recharging
- Reloading and/or Re-Configuring
- Recovery
-

In particular the above mentioned cooperative tasks are important to enhance the AUV capabilities.

3.2 Autonomous System Competition: New Needs and Concepts To Be Investigated

In the future UAS are expected to assume an active role with a competitive behavior against others drones and/or traditional assets; from this point of view it could be interesting to consider both kinetic actions and not-kinetic activities dealing with

jamming (i.e. Electronic Warfare), Cyber warfare, etc. The competition among drones will require the development of new solutions and systems able to support this activity considering that most of existing weapons and techniques could be neither cost/effective nor able to deal with such targets.
The fight among swarm of drones represents a scenario that could be experienced only by M&S (Modeling and Simulation).

3.3 Examples of Joint Operations over Surface, Underwater and Air within Marine Framework

In the context of maritime extended framework, it is evident the potential to use different drones working on common operations; currently the scenario investigated in this case involves among the others the following assets:

Vessels:
- Frigate and Destroyers
- Patrol Boats
- Cargo Ships
- Submarines

Drones:
- AUV - Underwater Drones
- UAV – Aerial Drones
- USV – Surface Drones
- UGV – Ground Drones

Aircrafts:
- ASW Helicopters
- Patroling Planes

Ground Units
- Coastal Battery
- Company
- HQs

Weapons:
- Torpedos
- Missiles

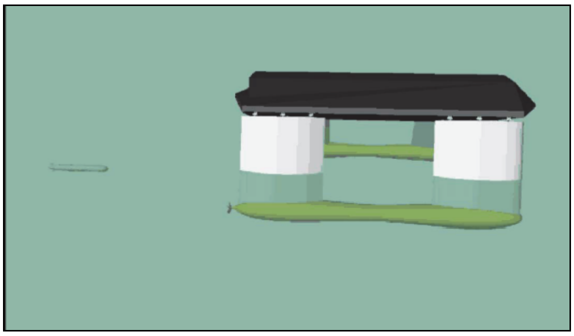

Fig.4 - Model of the AUV approaching the SWATH-USV

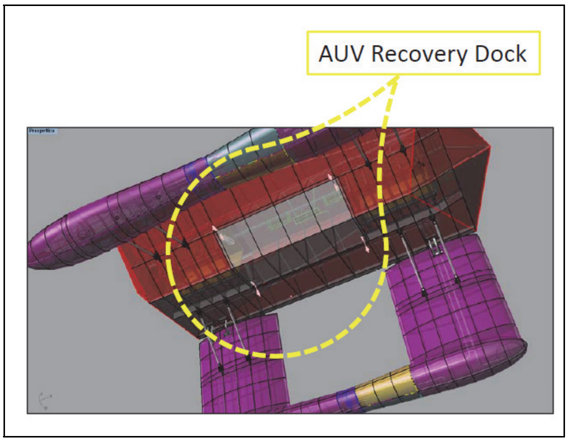

Figure 5: Detailed Model of the AUV Recovery Dock in the USV

Sensors:
- Hydrophones
- Active Sonars
- Sources for Multistatic Acoustics
- Radars
- EO/IR (Electro Optical/Infra Red)

The scenario was developed as ISR operation conducted in hostile waters near the coast; the zone was subjected to commercial and private traffic in some areas while the OPFOR (Opposite Force) involved ASW (antisubmarine warfare) capabilities, sensor networks and infrastructures and defensive drones; in addition in coastal area there are ground units able to activate anti-ship operations. The Blue Forces vice versa operates within the area just through a submarine, multiple AUV, USV and UAV. It is evident that the boundary and environmental conditions (i.e. sea, wind, temperature, fog, etc.) could heavily affect the performance over the same operational scenario and require proper models; it could be interesting in the future to develop integrated representations that could support this approach (Sanz 2008). In the proposed simulator, the USV might have kinetic and not kinetic capabilities, while in this scenario the AUV don't have kinetic weapons, but could produce jamming and other not-kinetic actions; the UAV carry multi sensors and weapons. In comparison with electric drones, the AUV was modeled with capability to communicate in RF in surface and through acoustic modems underwater; vice versa the USV used for this scenario was inspired to SWATH (Small Waterplane Area Twin Hulls) USV characterized by Superior

Operability over wide spectrum of sea states and able to provide support AUV (Brizzolara, Curtin, Bovio, Vernengo 2011; Brizzolara and Vernengo 2011).

Interaction AUV-USV

The simulator is modeling the interactions among AUV and USV; the USV is able to Deploy and Recovery AUV (see figure 4). The USV is also able to carry several AUV; so it becomes interesting to evaluate the dimensions of AUV and USV in terms of storage capability and characteristics (i.e. speed, autonomy, payload, visibility/detectability, etc) as proposed in figure 5. The USV could recover the AUV through an intelligent interactive device and to recharge it; data link is available, while it is possible to set up possibility to change the AUV payload on board. The improvements provided by using USV with capability to recharge the AUV through innovative inductive charging solutions are going to be tested thanks to this simulator. USV are modeled to be source for multistatic acoustics by emitting active pings and supporting fusion with AUV, hence the USV includes models of passive and active sensors and also weapon systems.

3.4 Interaction UAV-USV-AUV

The use of UAV within the heterogeneous network of drones, introduces new interaction capabilities. The model allows to deploy the AUV launched with a parachute; in addition UAV have possibility to reinforce communication and sensor network; these drones could proceed in cooperative targeting and engagement respect USV as well as AUV for ASW.

4. STATE OF ART WITHIN MARINE DOMAIN

The introduction of autonomy within unmanned vehicles creates opportunities for new roles and activities; in particular it becomes necessary to address new complex operational roles involving collaborative and competitive tasks. A great challenge is the involvement of different disciplines, such as computing science, mechatronics, artificial intelligence and to consider the needs for operational interoperability; in addition it will be soon necessary to address in a new way the aspects related to interactions among AxSs and humans moving from traditional direction and driving to high level supervision (Bocca and Longo 2008; Bruzzone et al.2013); these concepts were investigate in several cases and represent a critical issue for UAS research field (Cooke et al.2006) where interesting research are on-going (see figure 3). In addition, a corner stone for succeeding in this sector is the capability to generate some form of applicative intelligence able to direct robot cooperation in complex scenarios (Fernandez et al. 2013). This intelligence will need to be clearly defined by fixing capabilities and features able to measure and verify the ability AxSs (Bruzzone 2010); many techniques could be applied in this sector including IA (Intelligent Agents), AI (Artificial Intelligence), Swarm Intelligence, Fuzzy Logic, Genetic Algorithms, game theory, theoretical biology, distributed computing/control and artificial life; the authors of simulation team obtained interesting results in this sector by combining different techniques (Bruzzone et al. 2008; Zacharewicz 2008; Affenzeller et al. 2009); interesting results in directing collaborative and competitive assets within simulation were achieved by the development of IA-CGF (Bruzzone 2008; Bruzzone 2010 et al.); indeed it is evident the importance to adopt simulation interoperability standards to create frameworks to check a priori the interaction among the different systems and to test prototypes in a virtual scenario (Zini, 2012). Obviously the evolution of the potential scenarios for UAS (unmanned autonomous systems) was investigated along the years (Ross et al. 2006; Tether 2009; DARPA 2012; Lundquist, 2013) addressing a series of projects and examples on a wide spectrum of applications involving different levels of complexity over the different paradigms.

The use of the new generation drone within collaborative competitive mission is evolving as an important research area, therefore the scientific works in literature related to interaction of heterogeneous swarms driven by agents over all domains, such as fleet of UAVs, UGVs, AUVs and SUVs, are fairly limited. However there is an interesting scientific production addressing the problem of developing frameworks for the coordination of multiple vehicles belonging to the same single class: examples are available about multiple UAVs (Vail 2003) and multiple AUVs (Richards et al. 2002; Stilwell et al.2004).

In sea environment it is interesting the research conducted on joint operations involving a single UAV coordinating multiple AUVs while performing oceanic exploration missions (Sujit et al. 2009).

Some of these aspects were already investigated for marine environment creating a multi robot system

involving an aerial (UAV), a surface (ASV) and an underwater vehicle (AUV) within the same team (Shkurti et al. 2012).
These research are evolving along the last year to more operational roles; for instance another interesting case of collaboration is related to MCM (mine countermeasures) and it was investigating the collaborative use of an AUV and an autonomous kayak (USV) (Shafer et al. 2008); another in case related to detection and targeting in hostile environments it was studied by coordinating ground and aerial unmanned vehicles (Tanner 2007).
Scalability and Flexibility are major aspects to be investigated in these applications to support future mission environments; these aspects were addressed in relation to detection and tracking of unknown forces by using UAS over air and ground domains as well as a network of low cost sensors (Grocholsky et al. 2006); in this field there is also another example where two groups of mobile agents (UGVs and UAVs) were simulated to estimate their potential in terms of intelligence surveillance and reconnaissance (ISR) missions (Tanner et al.2007).
Studies related to the cooperation among different kinds of UAV and AUV over a port environment for security were investigated by using interoperable HLA Simulation (Tremori, Fancello 2010). An effective approach has been followed by Simulation Team; namely a stochastic simulator of joint operations involving UAV and other assets such as ground units, attack helicopters and planes, called IA-CGF U-COIN (Intelligence Agent Computer Generated Forces UAV and Counter-Insurgency) (Bruzzone et al. 2010).

5. MODELING & EXPERIMENTATION

The SEAVIT architecture is designed in order to be open; so it becomes possible in the future to federate and to simulate real assets (i.e. aircrafts, vessels, submarines, ground units, satellites, HQs) interacting with virtual ones creating a live, virtual and constructive framework addressing the whole problem.
In general, these different models and elements are expected to become part of the same simulation framework and the SEAVIT Federation will allows to estimate metrics through application of design of experiments (DOE) in order to identify most influent design parameters and most effective operative alternatives for maximizing the overall performance (Montgomery 2000; Andronov & Merkuryev 2000; Longo et al. 2012). The study is expected be conducted applying design of experiments (DOE) over a complex scenario affected by stochastic elements (i.e. detection probability, false alarms, kill probability, etc.).

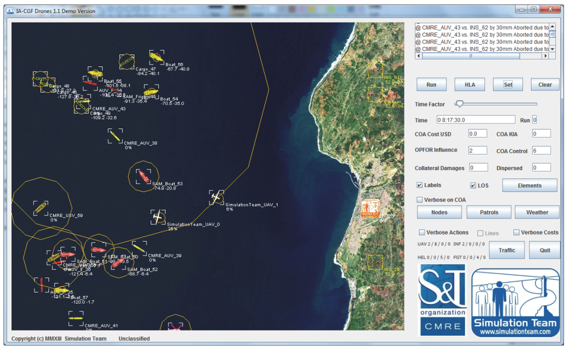

Figure 6: Tactical interoperable Simulation including AUV, USV and UAV as well as conventional platforms in the SEAVIT Federation

In fact the SEAVIT main goal is to investigate requirements and solutions to be adopted for Interoperability of Autonomous Underwater Vehicles; this goal should be achieved by creating a simulation framework able to carry out experimental analysis at “virtual sea” for supporting design and re-engineering.
The advantage of the proposed approach is the possibility to conduct tests over complex scenarios including operational issues and specific environmental conditions with a large number of assets and UAS; following this approach the configuration and alternative solutions are evaluated in the virtual environment under stressing characteristics and in reference to their interactions with other assets in ways that are impossible to reproduce during live exercise at sea or could not be applicable during design phase of new AUVs that are not yet existing.
SEAVIT Federation will address the verification and validation processes for this case and the architecture description in order to enable the possibility to federate in this system.
Even if AUVs are a specific narrow niche, their interoperability will be a real breakthrough advance extending opportunity of use, increasing the number of applications and the quantities of available devices. This will bring opportunities for new designs

and re-engineering processes as well as for further developments.

6. SEAVIT FEDERATION DEVELOPMENT PHASES

This paper is introducing the modeling approach and initial design phase of SEAVIT Federation; indeed the SEAVIT federation is organized in three major phases; the initial activity focuses on identifying all the main issues related to AxSs requirements engineering and operative scenarios as well as to define the operative and performance metrics and critical parameters to be used to re-engineer the requirements during the simulation; this phase is especially focused on AUV and their interaction with USV.

Some specific scenarios need to be identified to develop an initial configuration of the SEAVIT Federation able to demonstrate the potentials of this approach; obviously it is also necessary to define verification and validation processes of the simulation framework by providing a first set of design criteria and operative evaluations for the virtual experimentation.

The second phase aims at providing details for the conceptual design of SEAVIT models and of SEAVIT federation. To this end, the HLA standard for interoperable simulation enable the integration of new models as well as the adoption of legacy systems (if required existing models). The authors are currently designing the federation for an extensive use of IA-CGF (Intelligent Agent Computer Generated Forces) integrated within the SEAVIT federation in order to reproduce the intelligent behavior of autonomous systems as well as traditional assets.

In addition, in the future, the SEAVIT Federation could include also HIL and SIL, MIL (man in the loop) as well as real assets and systems.

The last phase of this research is expected to focus on the implementation of SEAVIT Federation and in its extensive experimentation; this allow to experience in a virtual environment the effects of different alternatives for AxS configurations, with special attention to operational interoperability requirements; by this approach it could be possible to quantify for each solution the costs/benefits ratio.

As additional results, SEAVIT federation is expected to provide a summary of the experimental results about interoperability and operative issues affecting new AUVs, USVs generations. The SEAVIT federation represents an innovative resource for identification of operational interoperability requirements and for developing new solutions for an operative use of AxSs as standard interoperable elements operating on field side by side with traditional assets.

Furthermore the SEAVIT federation demonstrator could be available for further extensions and for analyzing additional issues and new scenarios.

7. GENERAL ARCHITECTURE PROPOSED

SEAVIT is an interoperable simulation based on HLA (High Level Architecture) able to run in different configuration combining both detailed models for engineering as well simplified meta models for real-time and fast time simulation devoted to support capability assessment and eventually in future training. The general architecture is proposed in figure 1.

SEAVIT models are stochastic considering the influence of several important factors (i.e. probability to detect, probability to hit, probability to kill, operation durations, mean time between failures, etc). Among the federates it was possible to identify the following models:

- Discrete Event Simulation of Tactical Operations
- Intelligent Agents driving AxS and CGF
- Models of Boundary & Environmental Conditions
- Networking and Communication Models
- CFD & Models for Platform Physics
- System and Sub System Models
- Continuous Models for Physical Interaction
- Synthetic Environment

7.1 Different Interoperable Models

The interaction among the different models should be defined in SEAVIT federation in order to address specific simulation goals; in fact the computational models devoted to reproduce system physics (i.e. Computational Fluid Dynamics, Partial Differential Equations) are important to address single platform performance and details about their interactions.

Therefore the discrete event simulation and the intelligent agents represent the corner stone to run complex scenarios and to evaluate at high level the operations, doctrines and policies as well as the overall characteristics and configuration of different drones. By this approach it becomes possible to analyze different hypotheses about the drones and the operations as well as the most effective characteristics to address a specific mission environment.

Synthetic models could be effective in proposing the results of the simulation both for Verification and Validation as well as to present to user the different solutions and their operational modes.

All these models and simulator should be developed in consistency with HLA standard in order to be interoperable, so it becomes possible to couple a detailed physical model with a constructive simulator as well as with a communication network simulator; therefore it is evident that these models could be characterized by different time characteristics.

The authors are currently planning to develop SEAVIT by adopting conservative time management, so it means that when a slow time simulator is joining the federation all the processes slow down; for this reason it is important to develop simplified meta-models able to approximate the models within a well-defined analysis range; so it becomes possible to run fast time simulators by substituting the detailed federates by meta models and to conduct the experimental analysis by applying DOE over a large number of experimental runs; therefore when the best solution is identified it is possible to run back the simulation including detailed models to test and verify that configuration; in this way the approach guarantee maximal flexibility and efficiency at once.

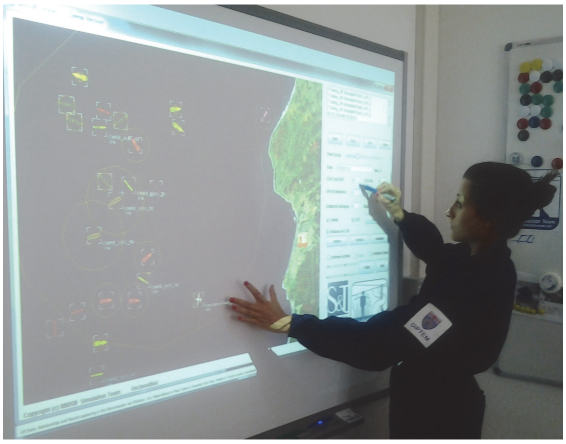

Figure 7: Testing and Experimentation of the SEAVIT Federation in DIME University of Genoa M&S Labs

7.2 Network Issues for SEAVIT Federation

Future concepts for network-enabled systems will involve the operation of mobile ad hoc networks to enable the integration of heterogeneous Autonomous systems with larger scale networks and Command and Control (C2) systems. The need of providing self-configuration, to handle dynamic topology changes in the absence of pre-deployed infrastructures, clashes against the practical difficulties of communicating in the maritime and underwater domains. The main challenge follows the fact that radio propagation is severely impaired underwater, leaving acoustic communication as the foundational technology to interconnect Autonomous Systems operating below the sea surface. Propagation of sound in the water occurs with a speed that is five orders or magnitude slower than above-water RF (1.5 x 10^3 m/s versus 3 x 10^8 m/s) in a time-varying bandwidth-limited channel that is severely impacted by environmental conditions and subject to frequent disruptions. Additional constraints derive from the fact that vehicles are exposed to the risk of being detected, captured and compromised. Threats against confidentiality, integrity and availability, such as denial of service, node displacement, false data injection, have to be countered using limited resources on battery-powered platforms. In addition to that, information exchange processes are normally served using shared/public communications media, which translate in exposure to passive and active attacks, such as eavesdropping and jamming. To make things more complicated, failures and manumissions could remain unnoticed, especially where connectivity between control centre and vehicles are intermittent.

The delivery of a joint interoperable framework for Autonomous Systems in the marine Domain drives therefore the need of encompassing several integrated elements, such as vehicle-to-vehicle communication using acoustic media (or radio, for surface operations), vehicle-to-C2 communication using satellite communications (for command and control and telemetry), data messaging standards (to enable interoperability with existing capabilities that consume data produced by autonomous systems deployed in the field), and cyber-security, as a cross-cutting component of all the above-mentioned sub-systems. Simulation approaches, essential to support the development and evolution of such complex capabilities, need to be founded on reasonable representations of the challenging environment in

which the agents will be called to cooperate (or compete), This could be tackled from different complementary approaches, ranging from accurate modeling of, e.g. acoustic propagation, taking into account environmental factors such as bathymetry, water column temperature, salinity, etc., to higher level synthetic models providing a compact representation of system states, where network-enabled systems can deliver their function only when the networking function is capable of operating as needed: failures in communication due to environmental factor or hostile activities such as cyber-attacks will have an adverse impact on the whole of the application that has to be delivered.
Eventually, Monte-Carlo approaches could be envisioned as the best mathematical tool to run experimental analysis. everal agents, representing collaborating and competitive autonomous vehicles, are operated in the context of a pre-defined scenario, to include the networking sub-systems, to gather useful statistics on overall system effectiveness and resiliency. Those statistics could be further analyzed with data farming techniques to identify the key parameters that need to be controlled in order to maximize system performance.

7.3 SEAVIT Execution and Experimentation

The proposed scenario related to ISR over a coastal area where drones are collaborating to complete their mission in a hostile environment where OPFOR are acting with traditional assets and other drones. The scenario was tested over a Mediterranean environment and several experimental runs were conducted using simplified meta-models for detection and directly tracking integrated within the Discrete event tactical interoperable stochastic simulation; the UAS as well as traditional assets were driven by IA-CGF derived from IA-CGF UCOIN previous simulator. The simulator is currently involved in dynamic, statistical and integration testing as presented in figure 7.

8. CONCLUSIONS

This paper presents the initial study for the development of a new federation related to AxS involved in collaborative and competitive missions; indeed in this paper it is proposed the definition of objectives, architecture and general configuration for this innovative Federation, titled SEAVIT, that addresses the creation of an interoperable stochastic simulation able to analyze requirements of future UAS. The focus on marine environment and ISR mission, allowed the authors to define bounds for such federation and the Models' characteristics needed to conduct preliminary tests and to verify and validate the approach: it has clearly emerged the importance to use interoperable agents as driver of the objects and entities.
Currently the federation development is in initial phase and it is expected to be extended in next year.
Therefore it is important to outline that this research initiative is an opportunity to create a trans-disciplinary team for autonomous system simulation involving people from Institutions, Academia and Companies that interact with final users and subject matter experts. So SEAVIT federation will enhance the possibility to create a pool of people and institutions with proved experience in the strategic sector of the new generation interoperable UAS. The project team, with strong modeling, simulation and engineering capabilities and a soundly technical background, will enable virtual experimentation and the investigation of new concepts, solutions and policies within complex and realistic mission environments over the maritime extended framework.

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