INTEROPERABILITY REQUIREMENTS FOR DEVELOPING SIMULATION SOLUTIONS FOR INNOVATIVE INTEGRATED SYSTEMS

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ABSTRACT

This paper aims at describing an innovative approach to simulate the interaction among sensors, antennas and electronic equipment; the paper focuses on the case study of an innovative mast integrating different sensors and systems to be adopted by modern military vessels.
In particular, requirements and reference architectures to be adopted in order to support interoperable simulation are proposed for the models related to vessel board systems. Such approach is developed in order to ensure interoperability of the different models (i.e. communications, radars, Optoelectronic and Infrared sensors etc.) considering mutual interferences as well as interaction with other vessel systems; this approach allows evaluating the overall effectiveness, electromagnetic interferences, compatibility and operational procedures respect operations.
The authors present a technological solution based on HLA (High Level Architecture) simulation enabling interoperability and leading to the creation of a federation for evaluating and validating results achieved during the experimental analysis; the latter is led over the proposed innovative integrated mast in order to understand the effectiveness of this solution with possibility to conduct comparison with other vessel configurations.

Keywords: Modeling & Simulation, HLA, Interoperable Simulation, Electromagnetic Interference, Integrated Mast, Vessel Virtual Prototyping, Radar & Naval Sensors, Electronic Warfare Systems

1. INTRODUCTION

Sensors, Communication, Control Systems and all the ICT resources represent the core of most modern complex systems including trains, planes, cars, military system; it is evident that their integration is often critical due to the interaction and interference among the different subsystems; in addition these systems often requires to guarantee simultaneous use of the different elements and subsystems often generating a very large spectrum of operational modes and configurations, pretty hard to predict and regulate. This introduces the necessity to develop solutions for addressing these aspects by creating a joint technical comprehensive representation of the new systems even considering the functions and operational scenarios to be faced (e.g. failures and emergencies).
From this point of view it is evident the potential to use interoperable simulation enabling the possibility to consider even stochastic factors and to integrated multiple elements in the (e.g. Man-in-the-Loop, Hardware-in-the-Loop, Software-in-the-Loop).
The authors in this paper address this problem with special attention to the case of modern military vessel; indeed, today, a frigate or a destroyer is fully equipped with a large number of antennas and devices that need to be properly designed and located around to support the different functions. These functions are strongly referring to the operational procedures and modes (i.e. Fire Control Problem) and need to be combined in order to guarantee reliability, effectiveness and efficiency (Kaempf 1996; Chalmers 1993).
This research is especially motivated by on-going researches related to the development of new solutions for military vessels able to integrate almost all the sensors in a compact and effective mast infrastructure.
The proposed approach is based on interoperable simulation and the paper identified in the High level Architecture (HLA) the most suitable technological infrastructure; obviously it becomes fundamental to define the related requirements for giving directions to model developers of different systems/subsystems.
This approach allows developing a technical comprehensive simulation integrating the board devices models (i.e. communication systems, radar, shooting range); this simulation aims at optimizing the characteristics and the design related to the systems, subsystems and whole vessel platform, keeping into account different operational modes and configurations.

2. DESIGN AND INTEGRATION THROUGH INTEROPERABLE SIMULATION

From this point of view there are different approaches devoted to support the design of these components in reference to naval military vessels; traditionally each single system was designed by itself (e.g. surveillance radar) and located over the ship just considering its weight and volume for guarantee space availability and ship stability (Salvesen et al.,1971); after completing this preliminary draft design studies are carried out in order to check also electromagnetic compatibility with ship infrastructures and other elements (Maiuzzo et al., 2005). Therefore in vessel design, the process should be much more integrated and the whole military ship should be considered by itself as a weapon system (Panchal 2005;Cao, Du, Zeng 2007).

Therefore usually new vessel design involves many different actors representing different companies with specific interests on diverse components (e.g. propulsion, ship building, weapon systems, combat systems, etc.); in addition the stakeholder list includes also different Institutions and Authorities including the branches of the Navy such as Acquisition Directorate, Warfare Development Command, etc. (Cebrowski, Garstka, 1998).

However this process is affected by a high risk to fail due to the high number of factors to be considered (i.e. line of sight, interferences, unexpected procedures, etc.), when this happen it is necessary to redesign the solution (e.g. moving a sensor) or to accept an operational limitation (e.g. incompatibility to carry out some simultaneous actions); these case are involving very high extra costs and could provide problems in operations (Moyst, Das, 2005); so it is evident the benefit provided by creating a technical comprehensive interoperable simulation.

By this approach, it becomes possible to provide a guideline to the different stakeholders to develop new system models in order to be ready for being federated in an interoperable simulation and to conduct the above mentioned analysis and test (Wang et al., 2009).

Indeed it is pretty common to have simulator for the different sensors and systems, however often these models are designed for specific purposes and lack in terms of interoperability; for instance there are radar simulator designed to evaluate the coverage of the antennas that don't have the capability to consider the interference with communication systems (Jin, Liu, Yu, 2013).

The possibility to create a joint simulation of new vessels in operational conditions, considering realistic interactions among different systems and subsystems, represents a major advantage to support design, engineering of the ship along its development life cycle.

For guaranteeing this result it becomes evident the necessity that the models of the different systems should be interoperable for being ready for integration within the vessel simulation for testing concepts as well as functions (Bruzzone et al., 2013; Bruzzone et al., 2003). Interoperability guarantees the possibility to combine the models also with real equipment in integration phase and evaluation of new technological solutions (Bruzzone et al., 2012); even the capability to federate such models with training equipment and/or operational multi resolution simulators provide an useful support to test the effectiveness of the new vessels in complex scenarios or versus new Concept of Operations (Bruzzone et al.,2013b; Gilman, 2004; Longo et al. 2013-a, Longo et al., 2013-b).

3. INTEGRATED MAST AS SOLUTION EXAMPLES

Actually one of the most important issues that affect the equipment of modern military vessels are those related to electromagnetic interferences and competition among different devices for their best position on the ship, for example in terms of line of sight, radiation hazard (RADHAZ), signal covering and accessibility for maintenance (Orem 1987).

This is mainly the reason why there are several recently developed integrated masts: these configurations allow overcoming the traditional approaches, based on trade-off solution, which inevitably lead to a reduction of sensors performances. Often the hollow structure is based on external allocation of sensors and antennas, while cables, electronic devices cabinets, necessary power sources and supporting systems are located internally; often the whole system is built in composite materials with a snub-conic shape on its top as well as a radome hosting the antenna for satellite communications (SATCOMs), while at the base normally the Identification Friend or Foe (IFF) with circular configuration are located (Van Werkhoven and Van Achen, 2010).

These solutions are divided by levels and could include planar sensors, rotating sensors such as navigation radar, navigation lights and passive sensors (an electro-optical system that allows panoramic patrolling and Electronic Surveillance Measure), multifunctional radar, communication systems for net-centric skills and 3D radar for aero-naval patrolling. In some other configuration the mast cabinet hosts IFF, electronic devices for radar sensors and systems for radar communications and data links (Mouritz and Gardiner 2001). The system also includes radar with planar sensors for volumetric searches, radar with the same characteristics, but devoted to sea surface patrolling and a passive thermal camera that, combined with an electro-optical passive sensor, provides panoramic patrolling. In particular an example of devices and sensors composing an integrated mast is summarized in the following list:

- Satellite communication systems: LRIT, TT 3000 E, Immarsat Standard C, Immarsat Standard Mini-M, Capsat Fleet, Fleet 77, Fleet 33, Jue 85, Immarsat Standard Mini-C, Immarsat Regional BGAN, Immarsat GAN, SCANSAT Sailor SC 4000 Iridium
- Communication Systems in several kinds of bands: SSAS, Radiotelefoni VHF, Radiotelefoni SSB
- Optical and laser communication systems: MM-fiber, GaAs-Laser, LED, MM & SM-fiber, InGaAsP FP-laser, InGaAsP DFB-lasermplifiers, WDM-Systems
- Thermal cameras; cool thermal imagers and uncool thermal imagers
- Laser Range Systems: fixed or mobile laser systems

- Fire detection: Electro-Optical Fire Control System (FCS)
- IFF Systems
- FLIR (Forward Looking Infrared) Systems: long wavelength systems, mid-wavelength systems, short-wavelength systems
- Active radars
- Electronic Support Measures (ESM)
- Flare detectors
- Electronic warfare systems

Due to the the growing density of electrical and electronic systems onboard contemporary military vessels, that need to coexist with detection sensors emitting signals in the same electromagnetic spectrum, several studies and researches have already been led about devices electromagnetic compatibility: in 1998 Dixon described an innovative electromagnetic compatibility (EMC) approach developed in order to mitigate risks deriving from the relaxation electric field emission requirements aboard naval platforms (Dixon, 1998). One year later a powerful evaluation technique referred to military vessels inductive equipment was invented paying particular attention to high power HF transmitter (Sispal et al. 1999). Furthermore in 2002 it was developed a software devoted to design radiating systems onboard and even to test their EMC combining Method of Moments and Physical Optics techniques (Obelleiro et al., 2002), while in 2003 Raghu described requirements for the correct implementation of EMC practices (Raghu, 2003). A survey about ultrawide-band radar was led in 2004 (Mokole et al. 2004) and one of the first techniques for simulating EMC on naval units was presented in 2005 (Zhou and Xie, 2005).

More recently in 2006 Dymarkowski formulated an electromagnetic interference (EMI) matrix related to an Hydro-acoustic system and a Radio-location in order to organize the whole vessel devices test plan (Dymarkowski et al., 2006). One year later he continued his work describing disturbances affecting ship weapon control system, underwater surveillance system and passive defense system, also identifying their electromagnetic noise resistance and their standardization (Dymarkowski et al. 2007).

The exploitation of data-mining technology for predicting electromagnetic compatibility on naval ship systems and improving anti-jamming measures was introduced in 2007 (Yu-Feng et al. 2007), while in the last year a powerful instrument to reduce marine VHF (Very High Frequency) communication band radiation was provided by an electronic field simulation software (Jim et al. 2013). Finally some researchers have recently measured radiated emissions of ultra wide band surveillance radar (Johnk R.T. et al. 2013).

Technological innovation has also allowed improvements in marine warfare electronic systems through a softkill effectiveness analysis, such as that developed by Lancon in 2011.

Furthermore, the increasing quantity of electronic devices that have to coexist on modern military vessels has recently determined the design of an integrated mast combining the whole onboard equipment. The Advanced Enclosed Mast Sensor System, developed at the end of the nineties, gathering vessel antennas and other onboard equipment, allowed to reduce maintenance and life-cycle costs and even radar signature (Benson, 1998). Few years later some researchers created the model of a four side cone shaped mast in order to test the its structural answer in a wind tunnel at the variation of the wind pressure (Yao et al. , 2002). Steps forward of technology have allowed to improve integrated mast system: in particular in 2010 a mast characterized by multifunctional material and composites technology was installed on UK aircraft carriers (Kane et al., 2010). In the same year an inverted model method was developed to test mast structure stress in case of ship sway: such analysis was devoted to improve the system shape design (Yao et al., 2010). In parallel the system shock resistance was also evaluated under air explosion thanks to high order, monotone and finite element algorithm which is called Flux-Corrected-Transport (Li et al. 2010).

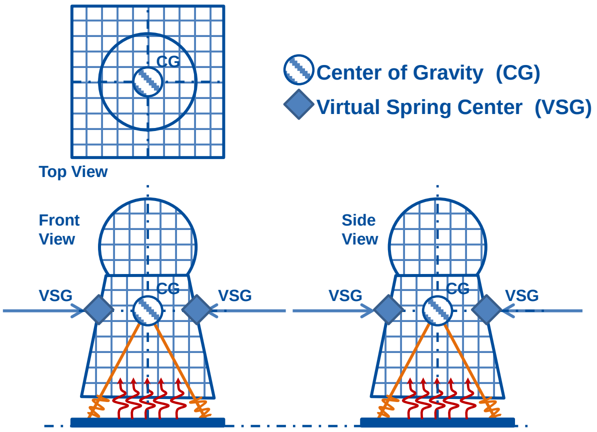

Figure 1: Drawing of Apparatus for mechanically isolating integrated sensor arrangement module above cabinet module of a ship

Integrated mast designed by Thales Nederland represents an important example of this technology solution: it includes communication antennas, radars and electro-optical sensors (Van Werkhoven and Van Achen, 2010) and since the following year it has been provided with an “Apparatus for mechanically isolating integrated sensor arrangement module (ISAM) above cabinet module (CM) of the ship” where the ISAM is proposed with several spring dampers headed to a point in horizontal plane containing its centre gravity (patent owned by Hogeman et al. 2011) as proposed in figure 1. In addition radar cross section of naval vessels mast platform has been recently reduced thanks to a technological solution based on a wedge structure (Ho L.J., 2013).

Among detection sensors gathered by such innovative vessels masts there are infrared sensors, acoustic sensors, laser sensors, radar, sonar and thermal cameras. At the end of the nineties, for example, it was designed an innovative Staring Infrared Panoramic Sensor

(SIRPS) in order to detect low-flying targets (Barrios et al., 1997). Few years later some researchers invented a powerful infrared sensor system combining new focal plane arrays with effective signal processing algorithms (Brusgard 1999). In addition the first active array multifunctional radar to be used for tracking, detection and even illumination of low-flying anti-ship missiles was introduced in 2003 (Fontana, Krueger, 2003). Other systems guaranteeing information to be integrated from different sources and then distributed in a secure manner or identifying surface threats were developed respectively in 2004 (Shaw et al., 2004) and 2007 (Stottler et al., 2007). In the same years Thales developed a new infrared system for search and track (Grollet et al., 2007). Fire detection and situational awareness, instead, represented the goal of new multisensory equipment to be installed on the Navy vessels (Minor et al. 2007). In particular fire detection was improved one year later using multicriteria technology (Hammond et al., 2008). Furthermore unexpected variations in data collected by others sensors could be identified by using a integrated Position, Navigation and Timing system (Woodward, Webb, 2009). Detection referred to naval vehicles since 2010 has been performed through electro-optical sensor systems (Van Valkenburg, Van Haarst, 2010) or thermal imaging (Akula et al., 2011). About electro-optical sensors, the problem of their integration in ship combat management system has been addressed in this context (Ten Holter et al., 2011). In addition in 2012 researchers have developed a model of complex event detection in shipboard surveillance (Liu et al., 2012), while a simulation model has been created in order to evaluate onboard wireless sensor network performance (Kdouh et al., 2012). Finally a possible approach for facing issues related to surface and underwater detection has been addressed using passive acoustic sensors technology (Sutin et al., 2013).

4. INTEROPERABILITY APPROACH AND STANDARDS

As already anticipated the use of interoperable simulation allows considering interferences and interactions among the different systems; from this point of view the first step is to identify the interoperability standards to be adopted. In this case the authors identified High Level Architecture (HLA) as the most appropriate solution for this context even considering the long experience in applying it in several sectors including marine domain (Bruzzone, Bocca 2006; Massei, Tremori, 2011).

Indeed it is important to state there are other existing approaches in this area including previous DIS standards (Distributed Interactive Simulation) and approaches such as Test & Training Enabling Architecture (TENA), Common Training Instrumentation Architecture (CTIA); therefore it is evident that DIS approach for distributed simulation is focusing on data exchange among different simulation providing not a very effective approach for addressing the current problem where the issue is not to connect simulators, but to define guidelines for developing new models and guarantee real interoperability among them; from other point of view the other distributed approaches are currently often used mostly by proprietary and specific applications. It is evident that the use of HLA is currently the unique simulation approach addressing interoperability for our application context that benefits from modern concepts, solid standard (recently updated in 2010) and strong directive from major customers (e.g. NATO STANAG 4603).

Indeed the HLA was originally promoted by US Modeling and Simulation Office since 1996 (at that time Defense Modeling and Simulation Office) and it was presented in several contexts both nationally and internationally for guarantee maximum diffusions (McGlynn, 1996; Ratzenberger, 1996). HLA was used in several applications and it further evolved consolidating its releases in 1.3 and NG; the RTI (Run Time Infrastructure) was distributed through DMSO, while some company developed commercial releases in international markets (i.e. Pitch Technologies). In 2000 the Institute of Electrical and Electronics Engineers (IEEE) emitted the first version of the actual standard (IEEE 1516) as extension of the original DoD Documentation by addressing HLA frameworks and rules, Federate Interface Specifications and Object Model Template (OMT) specifications.

In addition additional support documents were developed such as IEEE 1516.3-2003, “Recommended Practice for High Level Architecture Federation Development and Execution Process (FEDEP)”, followed in 2007 by IEEE 1516.4, “Recommended Practice for Verification, Validation, and Accreditation of a Federation an Overlay to the High Level Architecture Federation Development and Execution Process”. Recently, in 2010, it was published the latest 1516 standard version that introduce some significant advance in terms of dynamic models and incrementally growing federations and it represents the most appropriate approach for the integrated mast modelling and technical comprehensive ship simulation; indeed NATO STANAG 4603 was introduced after 2006 in order to evolve from previous DIS (Distributed Interactive Simulation) standard (STANAG 4482 and IEEE 1278).

Hence HLA standard represents a philosophical approach to Modeling and Simulation (M&S) and it includes HLA rules, Object Model Template (OMT) and Interface Specifications, so it requires that modelling experts adopt this approach; therefore through Object Model Templates it becomes possible to define the structure to develop Federation Object Model (FOM), Simulation Object Model (SOM) and Management Object Model (MOM).

Indeed, the proposed research is focused on FOM definition since it is devoted to identify specifications and reference architectures related to onboard systems models: the final goal, indeed, consists of integrating such models in a federation composed of different interoperable simulators and then testing their effectiveness, their interactions with each other and with vessel platform systems (for example in terms of interferences) and their compatibility with naval unit configuration in different operative modes.

5. INTEROPERABLE SIMULATION AND MODELING REQUIREMENTS

Therefore while technological interoperability aspects are fundamental it is important to outline that HLA approach don't requires to know details about internal structure of the different federate models; this aspect is pretty important to guarantee confidentiality of sensitive information related to technologies of the different system and subsystems that often belong to different companies with different industrial and commercial interested. By other point of view it is evident that interactions and interference in our context deal with different physical aspects that need to be addressed in the models such as:

- Electromagnetic Compatibility: the different emission could generate interferences with corresponding degeneration on radar and communication performances; in addition power supply or distribution could generate peak charges and/or interference, under specific conditions, creating problems to other systems
- Line of Sight in Different Spectrum (Optical Line of Sight, IR Line of Sight): EO/IR sensors (Electro Optical and Infrared) are stabilized and move to detect and track sensors, in their motion during operation it is fundamental that they could explore and track assigned areas and targets, so this aspect need to be addressed and it is necessary even to consider the influence of the different aspect to verify interference (e.g. ship emissions could deteriorate IR system performance, launch of flares could blind FLIR in some conditions).
- Physical Dynamics (Motion, Sea Keeping, Vibrations): for instance a large rotating radar antenna located at the top of the integrated mast could influence motion and introduce vibrations.

Do these issues the proposed Federation Object Model should enable to faces different aspects including electric and electromagnetic components; indeed it is necessary that the models should include algorithms able to consider the devices and sensors dynamic mutual compatibility (Groves 2014).

It is important to consider the interaction with other naval platform systems and its infrastructures: this aspect should be analyzed with reference to real operative conditions in the maritime environment, corresponding to operations while the instruments are working simultaneously to carry out specific tasks.

It is also necessary to be able to simulate dynamically the physical aspects, related to onboard masses static, dynamic stability and vibrational effects (Chen et al., 2006); indeed masses disposition and rotation over the vessel platform even influences the whole ship motion and vibrations. The optical elements are also strongly influenced by the infrastructures, but also by the different modes and actions carried out dynamically during the operations; this affects sensor effectiveness in different vessel configurations and operative modes and it is necessary to include these elements in the simulation; in similar way the laser communications and tracking are affected by line of sight and boundary conditions related also to the on-going operations for instance due to smoke (Alam, Bal, 2007). In addition the IR sensors are also affected by these aspects and they result even more sensible to objects overheating or high temperature emissions that could make neighboring device effectiveness to decrease drastically (Powell et al., 2000).

Based on these considerations it is suggested to adopt the architecture proposed in figure 2; this CVIF includes potentially several simulators including among the others:

- Sensor Simulators
- Communication System Simulators
- EW (Electronic Warfare) System Simulators
- ESM (Electronic Support Measures) System Simulators
- Weapon System Simulators
- Vessel System Simulators
- Vessel Sub-System Simulators
- Vessel Infrastructure Models
- Environmental Models
- CMS (Combat Management Systems)
- CGF (Computer Generated Forces)
- Ship Simulators (e.g. training equipment)
- Electromagnetic Simulation Models
- Optical Simulation Models
- IR Simulation Models

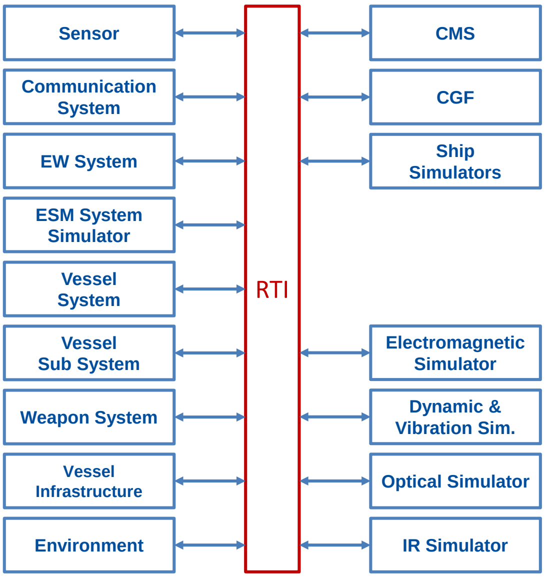

Figure 2: Technical Comprehensive Vessel Interoperable Federation

It is interesting to outline that the adoption of HLA allows conducting simulation experiments by federating models as well as real equipment. The use of CGF and the inclusion of CMS are fundamental to create realistic scenarios; for instance it is suggested to adopt Intelligent Agents such as IA-CGF (Intelligent Agents Computer Generated Forces) to create dynamic stochastic complex scenarios (Bruzzone, Tremori, Massei, 2011). In the federation it should be defined who is in charge of addressing transversal analysis; this activity is defined as I3S (Interactions and Interferences Interoperable Simulation); there are multiple possibilities such as:

- Each Federate is evaluating in its own model, internally, capabilities deriving from other element dynamic configuration and operation mode; for instance the FLIR (Forward Looking Infrared) system detects its capability to track a specific CGF considering internally the impact of the ship dynamic geometry and emissions.
- Some System Federate is in charge of managing specific aspects; for instance the Vessel Infrastructure Model is computing line of sight of each sensor versus each target
- Specific Interaction Simulation Models (SISM) are developed to address crucial aspects affecting interference and interaction; the IR simulation model addressed all the aspects related to capability estimation within IR Domain

The authors suggest keeping the structure flexible to avoid problems in adapting the federation to the integration of different models, but to respect interoperability requirement compatibility as proposed by the FOM presented in the following; therefore the authors recommended that if applicable the use of specific simulation models should be adopted to guarantee more effectiveness during the VV&A (Verification, Validation and Accreditation) procedures and testing. In any case the FOM proposed structure provides the requirements that guarantee to properly simulate this context by introducing into the different models the attributes and capabilities to handle the interactions; indeed this corresponds in adopting the following approach in defining the FOM; each Federate should include at least the following objects with corresponding attributes representing their system (e.g. Light Detection And Ranging LIDAR):

- ***Physical Object***
  - Name: for example Laser Range Finder
  - ID: code that uniquely identifies the object
  - Type: for example detection sensor, communication system etc.
  - Status: for example active, full power, etc.
  - Mass
  - Position expressed in meters of its barycenter from father object (the vessel) barycenter in terms of three-dimensional Cartesian coordinates x, y, z, and aeronautics angles α, β, γ. If the object is composed of more components it has to be defined the position of all such components split up
  - Inertia moment along axes x, y and z. If the object is composed of more components it has to be defined the moment of inertia of all such components split up
  - Current translation speeds and rotations along/around axes x, y, z respectively or the first derivatives of three-dimensional Cartesian coordinates x^1, y^1, z^1 and first derivatives of aeronautics angles α^1, β^1, γ^1
  - Current Accelerations identified by the second derivatives of three-dimensional Cartesian coordinates x^2, y^2, z^2 and by the second derivatives of aeronautics angles α^2, β^2, γ^2
  - Vibration spectrum over the three different axis
  - Vibrational Absorption
  - Electromagnetic Absorption
  - Current Shape/Configuration including cubicles affected by the current configuration (e.g. smoke)
  - Temperature
  - Emissions in IR Spectrum
  - Electromagnetic absorption

- ***Electromagnetic Object***
  - Operational Conditions: tracking, scanning, etc.
  - Mode (e.g. line of sight, sky wave, etc.)
  - Power
  - Frequency
  - Carrier
  - Pulse width
  - Pulse Repetition Frequency

Federation Object Model also includes the definition of interactions among different entities within the Federation; an important interaction class is represented by ICCR (interaction class communication request). The interactions parameters and related definition are reported as follows:

- Time: when the communication happens
- Source: What object transmits the communication
- Destination: What object receives the communication
- Content: content of the communication, for example a message
- Specific Communication mode: characteristics of the communication, for example in terms of frequency and signal power
- Configuration and operative mode: configuration and operative mode of the communication system at that time instant

The following interaction class is related to the possibility of two objects located on different vessels to see the one the signal of the other; this is defined as ICSR (Interaction Class Sensor Request). The interactions parameters and related definition are reported as follows:

- Time: when the signal is sent
- Source: What object is looking
- Destination: What is looking to the object

- Specific Looking Mode: characteristics of the sensor, for example in terms of power and frequency
- Configuration and operative mode: configuration and operative mode of the sensor in that time instant

The entity in charge I3S will react to these interactions through the following interaction class defined ICRR (Interaction Class Request Response):

- Time: when the signal is received by the entity
- Entity: getting this information
- Original Source: original source of the request
- Destination: original target of the request
- Perception type: the type of the signal received by the entity (e.g. directional ESM, visual light signal, radar detection).
- Type of request (e.g. IISR, IICR, Reactive IISR and Reactive IICR)
- Success: the target is correctly seen by the sensor or not (probability of success is determined)
- Failure reason: for example too long distance, sensor carrying out another operation, other devices obstructing view field of the sensor, other devices electromagnetic interferences or too high functioning temperatures damaging the sensor under exam
- QoS: Quality of the service in percentage between 0 and 1

Based on this approach the I3S in charge for the specific aspect (e.g. means that based on Electromagnetic SISM) will generate a set of interactions corresponding to the moments when this actions is perceived by the different players interested on this element; for instance if the originating sensor of the ICSR is a Radar, it will get back a ICRR from the Electromagnetic SISM confirming success or not of his action on a target and it will inform other potential systems interested with other ICRR (e.g. the target ESM system will receive a ICRR about this contact if it is active).

6. CONCLUSIONS

The proposed approach allows developing an interoperable simulation able to federate different models for addressing interference and interactions among systems and subsystems; the use of HLA guarantees technological and conceptual interoperability as well as solid standard base; in addition the modelling approach for managing the interactions is flexible and could integrate multi resolution simulators for multiple applications.

The introduction of a joint comprehensive simulation over these technical aspects provides a strategic advantage in development of new vessels; considering the interests demonstrated by different users, this approach could lead to the evolution of legacy simulators to become really interoperable, reducing vessel development costs and times.

The authors are currently working on implementing a solution for the case study related to an integrated mast in order to validate the proposed approach and to conduct integration testing activities.

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