Distributed simulation deadlock

Jose-Ramon Martinez-Salio

Simware (NADS)

Madrid, Spain

jrmartinez@nads.es

ABSTRACT

During the last ten years there has been a growing demand for distributed simulation. Demand has evolved to ask for a permanent infrastructure where new and existing simulators can join with little effort. There has been a lot of theoretical talk about the nature of this permanent infrastructure and its demands. Certain consensus has been reached in the proposal of using High Level Architecture (HLA) as its possible backbone.

In these years, there have been a lot of national and NATO-supported experiences trying to build the basis of this infrastructure using HLA as the backbone; but still this goal is not yet in the immediate (5 years) horizon.

Furthermore, HLA as the proposed architecture for distributed simulation hasn´t achieved its "natural" position as the unique simulation architecture. Distributed Interactive Simulation (DIS) is still in use in old and, surprisingly, in newly built simulators. End users and operators prefer the simplicity of this NATO-retired standard to the use of HLA.

But the use of DIS, doesn´t come without drawbacks. E.g. the operators complain about the lack of services that are part of HLA standard.

This paper analyzes this discouraging situation. HLA, supported and promoted by the industry and main institutions (like NATO), is not able to demonstrate the capabilities that were promised and DIS, retired as NATO standard in 2010, is just not enough for all the demands.

As a solution, the convergence of existing simulation standards in one platform is proposed. The new Layered Simulation Architecture (LSA), now in the process of becoming a SISO standard, can combine the simplicity of DIS and the services of HLA providing at the same time a real time data-exchange backbone that allows full control of the network and complements the lacks of HLA in security and control of the communications.

ABOUT THE AUTHOR

Jose-Ramon Martinez-Salio is International Presales Director at Simware, a company of NADS group. He received its M.Eng in Industrial Engineering from the Polytechnic University of Madrid, Spain. He is vice-chairman of SISO LSA group. In the last few years has been involved in NATO groups related with interoperability and distributed simulation.

Distributed simulation deadlock

Jose-Ramon Martinez-Salio

Simware (NADS)

Madrid, Spain

jrmartinez@nads.es

1. INTRODUCTION

Distributed simulation is a mature market with more than three decades of history. In all that time, standards and architectures have born and evolved to cover new and challenging demands. Demand has passed from the creation of small clusters of isolated simulators to the creation of nets of simulators interconnected and, lately, to new concepts like Modelling and Simulation as a Service (MSaaS).

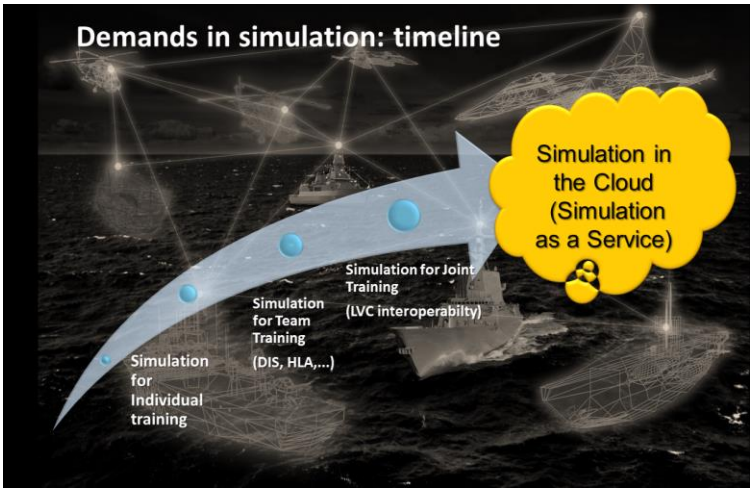

Figure 1: Simulation demand timeline

In this paper, we analyze, current situation of simulation standards and architectures comparing them with the latest demands. In the first section, we start by establishing a historical perspective of simulation standards. After that, we analyze current situation of standards and the pressure of the demands, both the new (e.g. MSaaS) and the old demands not yet covered. Second section centers on HLA (as the main reference for simulation) and its current challenges and also the relation of HLA with its competitors. At the end of this section, we will have established the scenario of what we call "the simulation deadlock". Third section presents Layered Simulation Architecture (LSA) as a way out of this deadlock situation.

2. HISTORICAL PERSPECTIVE OF SIMULATION STANDARDS

Simulation standards have come a long way from its starting point during the decade of 1980. During that time, both the simulators and the technologies involved have been steadily maturing. In this process, modelling and simulation (M&S) standards evolution follows the usual path for all technologies from the beginning to obsolesce and –future- retirement.

In the case of M&S standards and architectures, we can summarize this path in just three big periods (following Hollenbach, 2009) [1]:

Period	Generic Demand	Technologies involved
Emergency of standards	Going from one-time, one-effort simulators to simulators based on standards	Creation of DIS and ALSP
Islands of interoperability	From DIS/ALSP simulators to federations of simulators	Creation of HLA
Crisis of standards: multiple standards	HLA is good, but is not good enough for substituting DIS, industry need more.	Creation of TENA/CTIA Evolution of HLA

In the first period "Emergency of standards", the industry saw the emergence of the first real standards. During early 80´s and starting from Simulator Network (SIMNET), created in the Defense Advanced Research Project Agency (DARPA); the University of Central Florida's Institute for Simulation and Training (IST) created the Distributed Interactive Simulation (DIS). DIS is considered the first real "mainstream" standard for distributed simulation.

DIS and also Aggregate Level Simulation Protocol (ALSP) were adopted by the industry for creating distributed simulations. These distributed simulations usually consisted on small clusters of simulators running together. During the next decade (1990) this created the situation called "islands of interoperability". In this situation, there were simulators and clusters of simulators compatible with DIS and ALSP coexisting with other simulators not connected and not compatible with any standard. Some of these simulators could not be connected together using DIS due to different uses of time in the simulation, use of events and other issues.

HLA was born with the idea of going beyond DIS limitations and also integrate these simulators that were previously isolated. HLA was created by the US Department of Defense (DoD) and soon obtained strong support of the whole NATO. In 1998-2000, HLA was in the perfect position and with the necessary support to become the only standard for all the distributed simulation.

But in 2001, this model of "one standard for every simulator" entered in crisis with the creation, supported by the same US DoD, of new standards like Test and Training Enabling Architecture (TENA). Also HLA didn´t succeed in substituting the use of DIS in new simulators.

The situation in the mid 2000´s reached a point where multiple standards were coexisting at the same time: HLA as the "main standard" coexisting with DIS, still in use. At the same time, especially in USA, the architectures TENA and Common Training Instrumentation Architecture (CTIA). This is the period called "Crisis of standards" that reaches to this day.

Trying to analyze, understand and solve this situation, in 2007, the Office of the Secretary of Defense Modeling and Simulation Steering Committee commissioned the Live, Virtual Constructive Architecture Roadmap (LVCAR) study [2]. The objective of the study was to try to "develop a vision and a supporting strategy for achieving significant interoperability improvements in live, virtual and constructive (LVC) simulation environments" (Saunders, 2010) [3].

Situation of the standards today

In terms of standards, its real use and "wedges" [4] (to use LVCAR terminology), situation today is not different from the conclusions of LVCAR study:

- There is one "mainstream" standards supported by NATO and recommended in every single technical meeting and NATO group: High level Architecture (HLA).
- There is a "legacy" standard that is still in use in old systems and surprisingly in new simulators: Distributed Interactive Simulation (DIS)

- There are two "non-standardized" evolutions of HLA (that started from the HLA architecture) mainly used in the USA. These architectures have been promoted and are strongly supported in the US DoD. It is important to remember that HLA was originally created by Defense Modeling and Simulation Office (DMSO) of the same DoD. These are Test and Training Enabling Architecture (TENA) and Common Training Instrumentation Architecture (CTIA)

Centering in NATO, the situation shows a strong support for HLA use and possible evolution with the clear objective of making it the "solo" standard (see for example "NATO Modelling and Simulation Strategic Plan (2012)")[5]

This situation shows that, although there is a clear orientation and strong support (at least in NATO) towards the use and evolution of HLA, the reality is that, nowadays, there are four competing standards or architectures being used in the M&S world.

The new challenge of Modeling and Simulation as a Service (MSaaS)

Requisites and user expectations have evolved in parallel to M&S standards and technology. We cannot confuse user expectations with the final requirements of a real system, although the –initial- requirements of a new system usually reflect user expectations. User expectations depend on the perceived state of the technology but also of the state of the technological environment. E.g. mobile-phones have made the use of "Apps" popular, so now, user expects any download-under-demand element to connect seamlessly by using "plug & play", as a result, to have plug & play applications in now also demanded in personal computers (PC) and also in simulation; users expect to have the applications connecting that way.

In the last three years, a new challenge to M&S standards has appeared; NATO is now trying to create the so-called Modeling and Simulation as a Service (MSaaS) approach. MSaaS requirements come, in great part, from the user expectations about the way the simulation elements should behave and integrate. MSaaS is nowadays (see MSG 136 SG of NATO [6]) in definition, so it is still more a "wish list" than a reality, but we can talk about the requisites for an ideal MSaaS[7]

- Simulation services placed in a cloud. This could be a private and controlled cloud.
- Ubiquitous connectivity: Any device (computer, tablet, self-phone, etc) in any place have to be able to connect to the service cloud.
- Seamless integration: Any service that claims to be compatible has to be able to connect seamlessly with any other service also compatible of the same level.
- Full plug&play building: final user will create a new simulation under demand by connecting different services as "lego" pieces. This demands the services to be pluggable and capable to run immediately, ideally even during runtime.
- Security: too long to discuss and out of the scope of this paper, security in every possible aspect is key in the success of MSaaS

Current M&S standards and specially HLA, as the main standard, has to respond to these new requirements. Later in the paper, we will discuss about HLA and MSaaS demands.

3. HLA CURRENT SITUATION AND PERSPECTIVES

HLA, as has been mentioned, is the proposed standard (by NATO) to be the "solo" standard for the entire M&S industry including the new challenge of MSaaS (see NATO Modelling and Simulation Group (MSG) [8]).

HLA was created in 1996 with the idea of substituting DIS and the Aggregate Level Simulation Protocol (ASPL) standards and to "enable federating any combination of DoD simulations as a need arose and logic supported, regardless of the simulations' characteristics (e.g., level of abstraction; live, virtual, or constructive representation nature; time management approach)." (Hollenbach, 2009). With these objectives in mind, HLA created a data model structure starting from DIS protocol data units (PDU) and a full set of services. Since them, HLA has had three mayor evolutions called HLA13, HLA 1516-2000 and HLA 1516-2010 called HLA-evolved.

HLA current uses

Nowadays, HLA is mainly and successfully used for local clusters of simulators communicating in federations. Each HLA vendor has created its own approach for the network layer of communication (the so-called HLA Runt-Time Infrastructure or RTI) that guarantees a good and stable level of interoperability in local clusters. Also HLA capability is, routinely, a requisite and characteristic of many new simulators -planned to be connected to others or not-. In many cases, this theoretic characteristic (theoretic in the sense that was created for the simulator from the star but has never been used) probes to be impossible, or very difficult to use, when the necessity arises, due to the different interpretations of HLA that are possible.

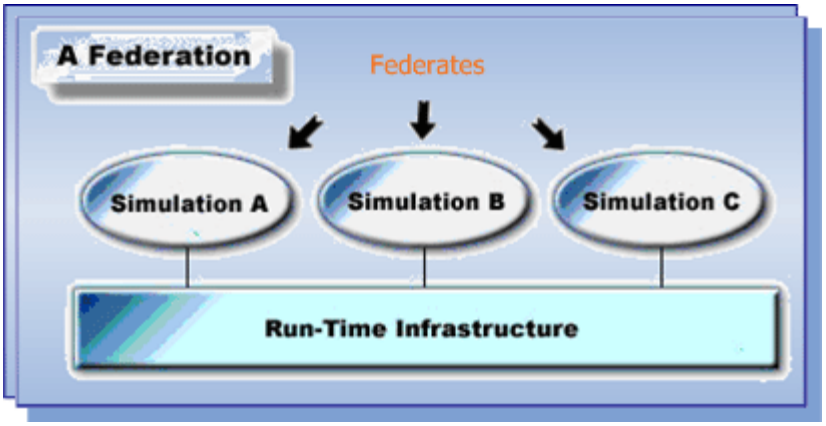

Figure 2: HLA federation

Centering in Europe and NATO-wide, the use of HLA for non-local clusters (remote connection) has always been made in a non-permanent base. In Europe, there is no known permanent implementation of a distributed network based exclusively in HLA. The situation in the USA is that there are some mixed permanent infrastructures based on DIS combined with HLA. It is not known (as far as the author knows) the existence of a "pure" HLA permanent wide-area-connection in the USA.

Historically, at least in Europe, HLA remote connections, has always been a "one-time" effort with the purpose of experimentation, demonstration or for some specific exercises. We can easily find examples of this kind of "one time effort":

- As typical example of one-time effort approach in a nation-wide level for a specific training, we have the Aozou live training exercise of 2015 in France [10].
- In a more academic level, as a pure demonstration, we have the "SISO simulation smackdown" in San Diego 2013 [11]

In Europe, nation-supported and specially NATO-supported there have been and currently are a strong interest in building an HLA permanent pan-European or pan-NATO infrastructure. For example this is one of the main objectives of MSG-128 "implement a persistent capability to support operational readiness" (from MSG 128 Objectives) [12]. The idea of this pan-NATO permanent infrastructure is to mimic the already existing Combat Air Forces Distributed Mission Operations (CAF-DMO) permanent infrastructure [13] and other national initiatives like the Defence Operational Training Capability (DOTC) in the UK. [14].

It is important to notice that, to this day, the only real permanent infrastructures for distributed simulation are based in the USA. We can mention:

- CAF-DMO in USA. This is the main infrastructure of reference. It is based mainly on DIS although it supports HLA and TENA endpoints on the network.
- Battle Lab Simulation Collaboration Environment (BLCSE) [15]. BLCSE is a "Multipurpose Platform for Simulation C2" that has a main DIS backbone combined with HLA.

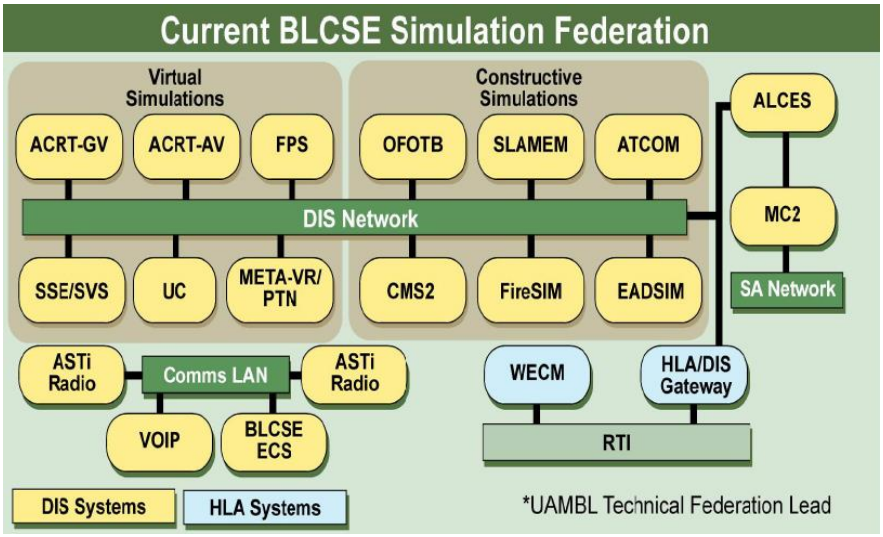

Figure 3: BLCSE simulation federation (2006)

- Joint Land Component Constructive Training Capability (JLCCTC) [16**].** JLCCTC has a mixed approach: "The federate models are connected by a combination of the standard high-level architecture run-time infrastructure, distributed interactive simulation, custom interfaces, the master interface and point-to-point."

HLA and DIS

One of the pretended objectives of HLA creation was taking the place as "main standard" and effectively substituting DIS. In this direction, NATO adopted DIS as reference architecture in the STANAG 4482, *Standardised Information Technology Protocols for Distributed Interactive Simulation (DIS)* in the year 1995 and retired it in 1998, officially cancelling it in 2010 [17]. We can see this transition in NATO MSG-033 SG [18] that ran from 2003 to 2006: "NATO is transitioning from STANAG 4482 on Distributed Interactive Simulation (DIS) to STANAG 4603 on HLA".

But simply, this substitution hasn´t happened yet. For example in LVCAR study (2009) there was a statistic about use of different standards (valid for sure up to 2009, but, arguably, still valid), this statistic showed a use of DIS of almost 35%. This figure is from 2009, that is, 11 years after the adoption of HLA, created with the idea of substituting DIS.

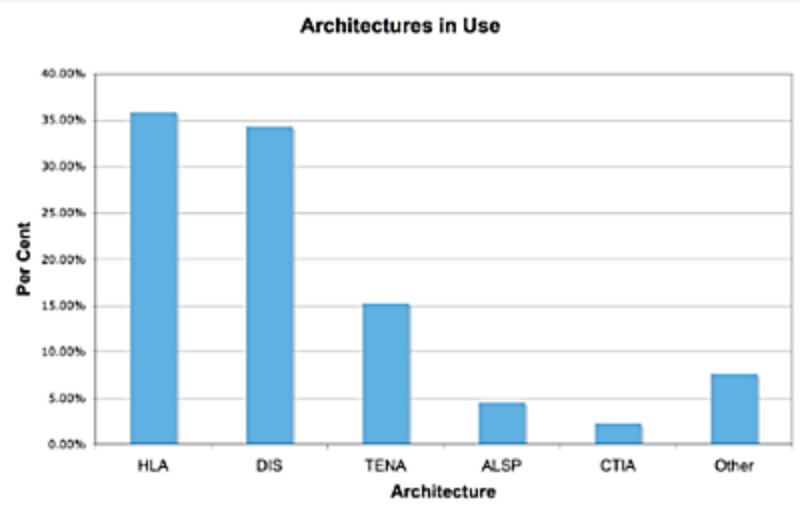

Figure 4: Use of standards (2009)

Also, DIS as a standard that is still evolving, deploying new versions and being still active in Simulation Interoperability Standards Organization (SISO) [19]. Latest version of DIS is from 2012 (version 7).

Repeating scenario in new simulation projects is a discussion between the use of DIS or HLA as base standard. Operational people tend to prefer DIS use for its simplicity and readiness; on the other hand, technical people usually support the use of HLA (lately HLA-evolved). This same debate has repeated as recently as during the latest MSG-128 meetings. We can see a typical example in an Australian army document of the year 2000 ("The DIS vs HLA Debate: What's in it for Australia?" [20])

To summarize this repeating debate, DIS is preferred by operational people because is very simple and easy to implement and is used for creating simple and fast scenarios of simulation typically involving local clusters of simulators. From this perspective, HLA is seen as very complex (for example in terms of the API needed to be implemented), taking to many time to create a federation (typically by an agreement or even following some standardized way like Federation Development and Execution Process (FEDEP) [21] or more recently Distributed Simulation Engineering and Execution Process (DSEEP) [22]) and having to many services that, in most situations, are not needed. Also, proprietary situation of the software (having different and incompatible versions of HLA of different versions for example) is sometimes a key argument. This discussion leads to the creation of new simulators with only DIS capabilities, for example in 2014 the JFACTSU Immersive Simulator [23], or with HLA and DIS capabilities together.

HLA and TENA

HLA was developed by Executive Council for Modeling and Simulation (EXCIMS) of US DoD in the period 1995-1996. From the beginning it has the support of US DoD and as early as 1998 (see NATO M&S Master Plan, December 1998) of the entire NATO.

But in 2001, the Foundation Initiative 2010 of the same DoD started the creation of a new standard called TENA. Initially the idea was evolving TENA from HLA and the requirement was being complaint with HLA [Test Capabilities Requirements Document for Foundation Initiative 2010 (FI 2010), 12 Sep 99 (see Sections 1.2.1, 3.2.1, and 7.3)][24] and even complementary with it, but soon TENA become something different not compatible with HLA.

This created a situation, that continues to this day, of coexistence and somehow competition, of both standards in the USA. TENA has a great support and use in the USA, but almost no use or influence in the rest of NATO.

The idea of the creation of TENA was to have a simple approach to foster interoperability. Key objective in the creation of TENA was to improve perceived HLA failures [25].
To this day, there are no known plans for standardizing TENA in the same way as DIS and HLA have been standardized.

The last straw: HLA and MSaaS

NATO started the MSaaS initiative circa 2010. The vision of MSaaS is to offer simulation solutions wherever and whenever they are needed, under user demand [26]. Given a problem specification a user would search and discover what services are available. Next step would be composing these services so that the resulting composition would provide a solution to the problem.

Key requirements to MSaaS, in whatever approach it will take, are:

- Plug and play capabilities: final user will compose the different services, not caring about setting a costly federation agreement. Take into account that the current implementation of a HLA distributed federation (in non-local connections) when connecting different simulators that hasn´t been connected before, can typically take more than one working day: "much time and effort has to be spent on the problem of the semantic inconsistencies that might occur during interoperation" (Boer, De Bruin and Verbraeck, Distributed simulation in industry, 2008) [27].
- Distributed simulation in any kind of device and network: the idea is to liberate the user to have the simulation available only in specific places; thus having the needed simulation built under demand anywhere and in any device (tablet, laptop, etc).
- Full flexibility in the number of participants; allowing even incorporations or abandons during run-time. Imagine, for example, a temporal loss of connection for any device using MSaaS.

HLA current capabilities are not well suited for this kind of requirements. It is difficult to have real plug&play and to use HLA in any kind of network or with a flexible approach in the number of participants (with participants entering and leaving any moment) is almost impossible [28].

Possible HLA evolutions

HLA is a mature standard that is still in evolution; the direction of this evolution is still speculative, but we can have some insights from the HLA vendors. In "SISO days" during ITEC 2014 (Cologne) there were some presentations about some possible evolutions of the standard (for example, see: *SISO day 2014 – Pitch HLA vision* [29]). Referring to these presentations, HLA is currently under a new revision that started in 2013. This new version is pretended to be a minor version and has no defined name. It is intended to be published in 2016 with a potential new major version in the period 2020-2026. Some of the pretended scenarios covered by this new version are the use of HLA in the cloud or with different devices.

Some of the (tentative) ideas exposed for this future version (HLA presentation V3 –Mak; *HLA present and future* [30]) were:

- Changes of the Federation Object Model (FOM) to avoid problems with multiple interpretations.
- Addition of new Quality of Services (QoS) and, for example, heartbeat signals like DIS and Reliable UDP. The objective will be improving communication features. Some of this QoS are copied from other standards like Data Distribution Service (DDS)
- Improvements in security.

The simulation deadlock

What is the situation that all these considerations draw? During the last two decades, we have been in a situation were four standards and architectures compete for the building of distributed simulations. There is a standard, HLA, which has been created with the objective and the support (technical and political) to become the "only" standard, but has failed to prevail so far. Real permanent infrastructures for long-distance distributed simulation (especially in Europe and NATO-wide) are the exception and are mainly made using the most simple and old standard, DIS. The struggle between DIS and HLA is still present in new simulators and in the creation of distributed simulation networks.

From a pure user point of view, M&S is today in a weird situation. The technology and standards have more than 30 years of development. HLA, the main standard is a mature standard after almost 20 years of development and use, but still user expectations have to be very low when planning and running a new simulator (isolated or joined in a federation).

One of the most anomalous things is the lack of isolation with the low-level technologies involved. Final user needs to know and manage very low level details. For example, user needs to know details about the standards that is using (if any) and has to be specialist in dealing with the communications problems in terms of connection and reconnection. E.g, in HLA the user typically has to check if the federates are connected to the federation and from time to time if the federates are still connected to the federation, and has to know how to fix the federation problems. Time-outs and loses of connection of some elements are not uncommon.

It is not uncommon to find the situation that in a running simulator, the operator knows how to run the simulator in a "safe path" and is not able to have freedom in the exercises. Any "movement" out of the safe path leads to unexpected behaviors or instabilities that can tear down the entire simulation. Flexibility, scalability and interoperability are the exception, and not the norm. In a mature technology, the user don´t need to know about the details of the low level layers. Technology, communications and standards-under-use are transparent to the user in a mature technological environment.

This situation is part of what we call "the simulation deadlock". User "ideal" expectations for a 30 years-old technology are not fulfilled and HLA the mainstream standards is not covering the new and current requirements.

Ideal requirements of integration	**Real situation**
Joint simulation	Limited to some vendors and versions (same HLA implementation for example)
Permanent infrastructure	Only CAF-DMO and some others in the USA
Every possible kind of network	Difficult to guarantee. Some approaches in some vendors using non-standard approaches and tools
Use of every possible standard related with M&S	Using gateways
Reusability of COTS	Only compatible COTS following standards, almost never seamless and usually never plug&play.
Legacy simulators	Only possible with some simulators following standards. Sometimes using gateways built "ad hoc"
Legacy simulation models	Difficult to reuse. There is no standardized way for reusing simulation models

Ideal requirements for operation	**Real situation**
Seamless operation	Real operation is rarely uneventful. Usually operator knows the "safe path" of warm-up of the simulator, operation, simulation scenarios and simulation cycles.
Faultless operation	Usually simulators don´t recover from failures (of any component) easily
Transparent operation	Operator need to know details about connection, technologies, gateways, etc.

Ideal requirements for MSaaS	Real situation
Services running anywhere	Usually M&S technologies are optimized for local networks. Each vendor uses own system for local or remote connection; there is no standard approach.
Services integrating "plug&play"	Difficult to achieve. Almost impossible during run-time operation
Services running in any platform	Some advances in multi-platform
Services integrating seamless	User has to be aware of the integration process; it usually takes more than a day.
Services entering and leaving in any moment	Almost impossible with current standards

4. LSA: FINDING A WAY OUT

M&S world needs urgently to find a way out of this bleak situation. What can industry do to find a way out? Following LVCAR final report, we have five alternatives to consider.

1. "Do Nothing": Keep current situation

This is the easiest approach. Leave the standards and the industry evolve at their own pace. Eventually, a standard will be the "de facto" winner or a new standard will overcame all of them. "*Each existing architecture will evolve based on its own users' needs…"* (LVCAR final report)

CRITICISM
This solution only perpetuates current situation. Standards evolve very slowly and the changes in matures standards are never revolutionary (since there is an installed base to consider and a base architecture that hampers the change). This approach can perpetuate current situation for decades.

2. Convergence of main standards

In this approach, simulation authorities have to encourage architectures to converge into a common vision in a certain period of time. One possible first step could be obtaining standards compatible between them; second stage could be merging all the standards in one.

CRITICISM:
There is no defined M&S authority to lead the process although NATO, the DoD or even SISO can potentially lead it. There is no clear vision about the requisites of this "final" standard. A lot of national/transnational bodies and companies need to agree on this procedure to be really useful. Also, the time to achieve this objective can be from 5 to 10 years at a bare minimum.

3. Select one existing standard/architecture to make it hegemonic

The objective here would be to pick the most promising standard or architecture and make it dominant in the medium and long term.

CRITICISM:
This is what NATO and SISO has been doing the last decade with HLA without much success. Strongest objection to this approach is that it leaves "out" the rest of simulators built with the other standards and architectures.

4. Create a new architecture/standard

This new standard would have all the good ideas of the current standards and all the new requisites.

CRITISIM:
This approach needs a strong financial support and leadership during a minimum period of 5 to 10 years. Will take a few years to be finished, but at the end will compete with the rest of standards being "one more" standard". Also, this approach doesn´t solve the problem of already existing simulators and standards.

5. Create a new inter-architecture standard

The idea is to create a standard able to integrate all the existing standards, that is, an "architecture of architectures" standard. This new standard should be able to integrate existing standards without having to change them: "*Keep the current multiple architectures but invest in improving the construction / performance / integration of various gateways, translators, object models*, and create processes and procedures to make inter-architecture integration "faster, easier, cheaper."" (LVCAR final report)

This last approach is the only one that we think can solve the simulation deadlock in the short term. The same approach can be found in LVCAR 1, that follows LVCAR study conclusions (see: *Live, Virtual, Constructive, Architecture Roadmap Implementation and Net-Centric Environment Implications* [31]). This proposal calls for the creation of a new standard which sole mission is to integrate current simulation standards and architectures in a new one. The requisites for this standard should be:

- Integrate all possible standards and technologies related with M&S without changing them. This integration has to include also standards "used" in simulation like LINK16 or even C-BML, and can be also extended to others (e.g. in simulation for robotics can include Robotic Operating System (ROS))
- Integrate simulation models (new and existing) in a common architecture without modification. The integration must be done using a normalized interface approach.
- Normalize the data gateways between different standards. This could (if there is any defined) include any standard for gateways [32]
- Add a common standard communication layer specialized in the communication problems
- Important requisite is that the aim of this standard should be to complement, not to compete with the other standards.

There is already an initiative going on in SISO for such standard. The Layered Simulation Architecture (LSA) [33] is a proposed standard (now starting product nomination phase in SISO) for creating a common architecture to build and interoperate simulators based on current simulation standards [34].

LSA: breaking the Gordian knot

From the beginning, LSA was born based on the idea of complement existing gaps in current simulation standards.

The mains concepts of LSA are:

- The incorporation of simulation standards (HLA, DIS and TENA) as they are now without changing them via; either the use of gateways (standardized if possible), or by direct codification of specific layers of code into the standards.
- As a common communication layer, the proposal is the use of Data Distribution Service (DDS/DDSI) [35] that it is a real-time communication standard of the Object Management Group (OMG).
- Finally, one of the objectives of LSA is the creation of a standardized interface for simulation models.

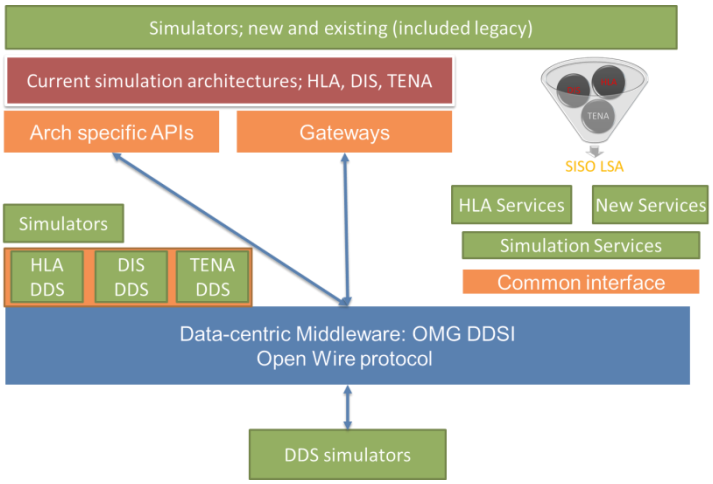

Figure 5: LSA proposed architecture

Note that LSA is not a standard in the same sense as HLA or DIS, but a meta-standard or framework for complementing current standard without modification.

The requisites that LSA proposal covers are:

- Use of current standards (in any version or evolution) without modification. This mean leaving current simulators and tools using these standards like they are now and incorporating them to a joint simulation with the same capabilities, data models and services that they have now.
- Use of "normalized" gateways: LSA model admits the use of any gateway to connect with the standards. It is strongly desirable to use a standardized way for creating and maintaining these gateways. There isn't any standard in gateways yet, but there are some initiatives like Gateway Description and Configuration Languages (GDACL PDG) in SISO.
- Creation of a standardized minimum interface for simulation models. This is the least developed area in LSA concept. There are a plethora of simulation models and services that are very difficult to reuse and to share in a joint simulation. This problem is not only related with the creation of a minimum interface for services, but has also many other facets to explore like Fidelity and fair fight.
- Use of a real time communication standard for the communication layer. LSA proposes the use of DDS as the common communication layer. DDS is a real time communication standard with a long history of use in different industries. Current simulation standards can take advantage of this real time communication layer. This layer can act as an autonomous layer, taking care about the communication, and can be used for:
    - Distributed simulation between simulators based on standards connected in a Wide Area Network (WAN).
    - Adding quality of services capabilities to the communication. That way communication is guaranteed in any kind of network, even with heterogeneous networking.
    - Multi-platform approach (including for example Android [36].
    - Security characteristics over the communication layer [37].
    - Dynamic discovery allowing real "plug&play" for simulators. For example, this allows a certain simulator to loss connection and recovers it later or allows the incorporation of new simulators during an exercise without having to stop it.
- Use of standards in every layer: LSA aims to incorporate HLA, DIS and TENA for simulation, DDS for communication and "yet to exist" future standards in gateways and services interfacing. LSA will thus be a "metaframe" for simulation standards. This approach will allow LSA to follow the evolution of these

standards. This also will allow LSA not to compete with the rest of standards and architectures avoiding thus to become "just one more standard".

State of the art of LSA initiative

LSA is now starting Product Nomination phase in SISO. The plan is to have a first version of the standard for the period 2016-2017.

The requisites for LSA are in different "state of the art":

Incorporation of M&S standards:

- Extensive test and real projects has been made for the integration of HLA and DIS standards. HLA integration has been proven feasible in every version from HLA13 to HLA1516-2010 [38].
- TENA integration has been studied and is theoretically possible, although there is not known plan to use DDS in TENA [39].
- Integration of HLA has been made by using gateways and by direct coding of DDS inside the HLA implementation (in this case using DDS as the HLA runtime infrastructure or RTI)
- About DIS; both approaches have also been taken. For example see "*Addressing the Challenge of Distributed Interactive Simulation With Data Distribution Service*" [40].

Use of normalized gateways:
There is no finished standard for gateways. Different tests and real projects have used gateways build over multilayer libraries trying to solve the problems of reusability, scalability and maintenance common to gateways.

Incorporation of simulation models:
There has been little advance in the creation of the pretended minimum interface for simulation models.

Use of standard communication layer for interoperability:
There have been a lot of experiences and experiments about the use of DDS for a real distributed interoperability. For example, the NOGESI project for the Spanish Mod or the experience of connection between Rome and Madrid (see "*M&S Interoperability experiments between SimWare and M&S COE laboratories*" [41]).

Extension to other simulation standards:
LSA architecture can be expanded to incorporate other standards close to M&S. For example, an implementation of LSA architecture with C-BML has been built and probed; with that the original concept of MSaaS can be also expanded to C2 systems. Particularly interesting are the extensions of LSA concept with robotic standards like Robotic Operating System (ROS) [42] or Joint Architecture for Unmanned Systems (JAUS) [43].

Use of security in simulation:
Security can be implemented by using DDS security standard that is now in beta state pending final approval. Proposal can be found in DDS website.

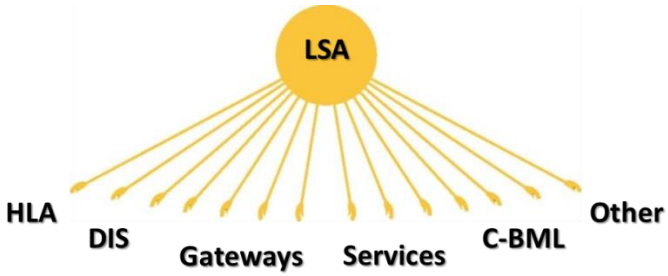

Figure 6: Some LSA standards and architectures

5. CONCLUSION

M&S and more specifically distributed simulation are stuck in a strange and not comfortable situation. User demands are not satisfactory met. Long time demands for distributed simulation using permanent infrastructures have not been fully covered, and new demands like MSaaS are also difficult to reach using current simulation standards and architectures. Technological scenario is that are four competing standards and that the evolution of these standards doesn't show a short-term path to go out of this situation. HLA, now a mature standard, is nowadays not able to cope with these demands. DIS is able to be used in long-distance permanent-infrastructures but lacks simulation services and has limitations in the data model. Meanwhile, TENA and CTIA are evolving in a non-known way and are out of the "main standard" circuit.When creating new simulators or clusters of simulators, the use of HLA or DIS is still being discussed. Sometimes, DIS is still being used because its simplicity and faster implementation. To complete the scenario, final operator of the simulation (isolated or distributed) needs to be aware of the technologies implicated in an undesired low level. Final simulators transmit, arguably, an image of fragility. All these elements come together in what we call "simulation deadlock".

We have proposed on this paper a way out of this situation. We propose the use of a "meta-standard" like LSA to complement and reuse the best qualities of current standards. This approach is similar to LVCAR I approach and offers a short term solution to current simulation situation. As final consideration, the adoption of LSA, don't exclude other medium-term or long-term approaches like the convergence of standards, the creation of new standards or the final evolution of an existing standard to become the prevalent.

REFERENCES

[1] Hollenbach, James W. *Inconsistency, Neglect, and Confusion; A Historical Review of DoD Distributed Simulation Architecture Policies*, SISO, 2009
[2] Allen, Gary W. ; Lutz, Robert ; Richbourg, Robert, *Live, Virtual, Constructive, Architecture Roadmap Implementation and Net-Centric Environment Implications.* SEP 2010, http://www.dtic.mil/get-tr-doc/pdf?AD=ADA530587
[3] Sunders, Randy, *Live Virtual Constructive Architecture Roadmap (LVCAR) Convergence Approaches*, ITSEC 2010, Orlando Fl.
[4] Henninger et. al, *LVCAR Final Report*, 2008
[5] *NATO MODELLING AND SIMULATION Strategic Plan*, 2012, http://ftp.rta.nato.int/Public/Documents/MSG/NATO_MS_Master_Plan_Web.pdf
[6] *Modelling and Simulation as a Service (MSaaS) Rapid deployment of interoperable and credible simulation environments (MSG-136)* https://www.cso.nato.int/ACTIVITY_META.asp?ACT=5642
[7] Martinez-Salio, Jose-Ramon, et.al. *Future of LVC simulation Evolving towards the MSaaS Concept* at ITSEC 2014, Orlando, Florida 2 -5 December 2014
[8] *NATO Modelling and Simulation Group (MSG)* in https://www.cso.nato.int/panel.asp?panel=5
[9] Figure taken from http://selab.inha.ac.kr/selab2/index.html?p=research/mdwr
[10] For the Aozou exercise, see http://onboard.thalesgroup.com/2015/02/25/new-dimension-operational-training/

[11] SISO Simulation Smackdown in San Diego 2013: http://www.simul8.com/blog/simul8-support-siso-simulation-smackdown-team/
[12] Incremental Implementation of NATO Mission Training through Distributed Simulation Operations (MSG-128) https://www.cso.nato.int/ACTIVITY_META.asp?ACT=2821
[13] Aldinger , Michael, et.al. *CAF DMO Standards-Based Approach for Achieving M&S Interoperability:* http://ftp.rta.nato.int/public/PubFullText/RTO/MP/RTO-MP-MSG-056/MP-MSG-056-13.pdf
[14] Foale, Simon, *Achieving a Cost Effective Live, Virtual and Constructive Training Mix*, 2011
[15] *Battle Lab Simulation Collaboration Environment (BLSCE): Multipurpose Platform for Simulation C2* in http://www.dodccrp.org/events/2006_CCRTS/html/presentations/208.pdf
[16] Joint Land Component Constructive Training Capability (JLCCTC), in http://www.peostri.army.mil/PRODUCTS/JLCCTC/
[17] See http://en.wikipedia.org/wiki/Distributed_Interactive_Simulation
[18] High Level Architecture STANAG Development (MSG-033) in https://www.cso.nato.int/Activity_Meta.asp?ACT=817
[19] For the DIS group in SISO see: http://www.sisostds.org/StandardsActivities/SupportGroups/DISPSGDistributedInteractiveSimulation.aspx
[20] Ryan, Peter and Zalcman, Lucien, *The DIS vs HLA Debate: What's in it for Australia?* in http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.124.5042&rep=rep1&type=pdf
[21] Waite,William F,. *HLA Federation Design / Development and Federation Implementation Process Model* at http://aegistg.com/Technical_Papers/HLA%20Federation%20Design_97F-SIW-173.pdf
[22] DSEEP Product Development Group, *IEEE P1730™/Dv2.0 Draft Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)*, January 2008
[23] *JFACTSU Immersive Simulator* at http://www.closeairsolutions.com/jfactsu-immersive-simulator/
[24] Powel, Edward, *TENA Overview*, August 2012
[25] Noseworthy, Russell, *Supporting the Decentralized Development of Distributed Applications and LVC Simulations*
[26] Siegfried, Robert *M&S as a Service: Perspectives, Expectations, and Challenges*, NATO CAX Forum 2013, Rome, Italy
[27] Boer, De Bruin and Verbraeck, *DISTRIBUTED SIMULATION IN INDUSTRY – A SURVEY PART 3 – THE HLA STANDARD IN INDUSTRY*, Proceedings of the 2008 Winter Simulation Conference
[28] Martinez-Salio, Jose-Ramon, et.al. *A Comparison of Simulation and Operational Architectures*. SISO Fall 2012, Florida: 10-14 September 2012
[29] Möller, Björn, *The Future of HLA – Vision*, SISO Day, 19 May 2014, http://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=42025
[30] Rodríguez ,Félix, *HLA: Present and Future*, SISO Day, 19 May 2014, http://www.sisostds.org/DigitalLibrary.aspx?Command=Core_Download&EntryId=42022
[31] Allen, Gary, et. al., *Live, Virtual, Constructive, Architecture Roadmap Implementation and Net-Centric Environment Implications*, ITEA Journal 2010; 31: 355–364
[32] Gateways group in SISO in: http://www.sisostds.org/StandardsActivities/DevelopmentGroups/GatewayDescriptionandConfigurationLanguages.aspx
[33] LSA group in SISO: http://www.sisostds.org/StandardsActivities/StudyGroups/LayeredSimulationArchitectureLSASG.aspx
[34] Martinez-Salio Jose R, Dan Gregory. *A New Approach for Converging LVC Simulation Architectures*. *SISO Spring SIW 2013, Orlando, FL, USA*
[35] About DDS, see: http://www.omg.org/hot-topics/dds.htm
[36] Leung, Ronald. *DDS "Data Distribution Service" Android Integration*. http://blogs.rti.com/tag/dds-data-distribution-service-android-integration/ March 2011
[37] For DDS security proposal, see: http://portals.omg.org/dds/content/document/dds-security-extensions-rfp-proposal
[38] Martinez-Salio, Jose R. et al. *Spanish MoD NOGESI Battle Lab. SISO Session. ITEC 2014, Cologne, Germany*
[39] Powell, Edward, *TENA and DDS: Some Thoughts*. SISO spring 2013
[40] Hakiri, Akram, et. al., *Addressing the Challenge of Distributed Interactive Simulation With Data Distribution Service*, at http://arxiv.org/ftp/arxiv/papers/1008/1008.3759.pdf

[41] Martinez-Salio, Jose-Ramon, *M&S Interoperability experiments between SimWare and M&S COE laboratories*, Presented at CAX forum 2013. Rome 30 Set-3 Oct 2013
[42] Fernandez, Esteve, et. al. *Next-generation ROS: Building on DDS*, http://roscon.ros.org/2014/wp-content/uploads/2014/07/ROSCON-2014-Next-Generation-of-ROS-on-top-of-DDS.pdf, ROSCon Chicago, Sept 2014
[43] *JAUS Messaging over the OMG Data Distribution Service (DDS)*, at http://standards.sae.org/wip/arp6227/