Extending LSA philosophy to real world challenges

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Abstract

Requirements in interoperation between real Manned and Unmanned Vehicles (UV), Naval Command and Control systems (C2) and simulation networks present new and daring challenges. Already existing standards combined in new ways allow us to solve these challenges without the need of over-extending the standards out of their natural areas.

This paper, presents the project CITIUS "Command and Control for Interoperability of Unmanned Systems". In CITIUS, Distributed Simulation is been used as a central enabler of Network operations between C2 and robotics systems.

CITIUS combines existing standards: in simulation DDS, HLA and DIS; in C2 naval systems using C-BML and MSDL; in robotic systems using JAUS and in learning, systems using SCORM. All these standards are kept in their natural area and are seamless combined using SISO´s LSA orientation.

In this project, it is essential the development and prototyping of new capabilities for standardizing the concept of plug & play; this is achieved by using open and modular architectures, based on the use of emerging and mature standards like MSDL or C-BML for the semantic interoperability between C2, robotics and simulations systems, DDS, HLA and DIS to data exchange of simulation data and JAUS to interoperate robotics platforms with ground stations and simulation networks.

In this paper we will explore the challenges presented by these unique combinations. With projects like CITIUS we can see the real possibilities of applying LSA philosophy to real needs. As a conclusion, based on this experience, we will explore the possibilities of growth of LSA.

1 Introduction

In the last few years, the use of unmanned vehicles (UV) in different fields has grown and extended. New developments in artificial intelligence, communications, connectivity solutions and energy storage (specifically batteries) have created a revolution in UV [1][2]. These systems can be now deployed in an autonomous way with little or no assistance from the human operators.

In parallel, the number of scenarios where they can be deployed has also exploded. Due to its extreme versatility, we can find these systems already running of being planned for every possible environment, including environments hostile to human life. [3]

This explosion of uses has created new necessities and requirements that very fast have developed into new standardization efforts.

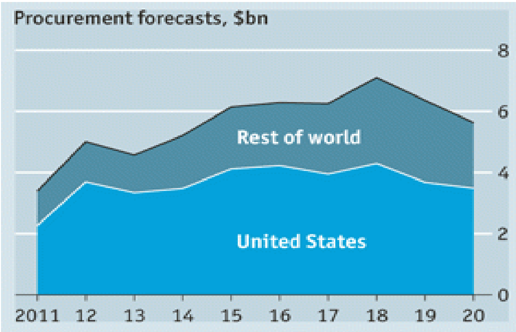


Figure 1: Forecast demand for UAS 2011-2020

In this paper, we present a novel perspective for this standardization. Based on our previous experience in SISO LSA study group[4] and in a new project we are performing called CITIUS (Command and control for InTeroperability of Unmanned Systems), we will show how the clever combination of current simulation, robotic and Command and Control (C2) standards (or standards-to-be like C-BML) can solve this requirements without the necessity of over-extending current standards.

2 Setting the requirements for UV

The requirements for UV that are relevant for us (e.g. we are not considering Energy Consumption here) can be summarized in:

- Interoperability: Demand is having seamless integration in all domains (air, ground and maritime) and between manned and unmanned systems.
- Autonomy: Human assistance is still needed in most systems. The aim is having autonomous systems capable of performing missions [5]. For example, a C2 system can give an order like „patrol the area" and the UV will run it using its own criteria for finding the path, sorting the obstacles, etc.
- Communications: Improvements in reliability and security in communications are essential. Also related is the necessity of dynamic incorporation of elements.
- Training: Training, specially using e-learning tools is mandatory due to the increasing complexity of UV and the interaction with other manned and unmanned vehicles. Training standardization is also needed to improved training efficiency and effectiveness.
- Manned and Unmanned Teaming: Joint operations between manned and unmanned create complex scenarios. The use of the same standards and tools can simplify these complexity (e.g. the use of C-BML for orders)

We can see that some of these requirements for UV are shared in some other fields like distributed simulation. Since, in projects like CITIUS, we are dealing with the combination of both fields, this leads us to try to find common solutions.

3 A closer look to Citius

CITIUS project objectives go beyond unmanned systems. The objective of the project is the development of new capabilities of Command and Control for the universal interoperability of nonmanned systems, autonomous or under remote control.

Here we have in this definition:

- Command and Control (C2): CITIUS wants to incorporate the C2 developments with standards such as C-BML and MSDL [6]
- Universal interoperability: CITIUS aims to create a complete framework were different simulation, unmanned systems, and other standards can be seamless integrated.
- Nonmanned systems: CITIUS has in mind the real use of these systems in autonomous or supervised way.

CITIUS project proposes setting an architecture for the future of complex scenarios where intervention vehicles manned and unmanned vehicles and platforms matrixes in every segment (air, land, sea surface and underwater) will coexist simultaneously. It is essential the development and prototyping of new capabilities for Command and Control Systems (C2) with the objective of standardizing the plug-and-operate concept. This will be achieved by using open, modular architectures, and by the development of a common set of interfaces and messaging standards required to implement universal interoperability. The project tries to avoid the creation of mission specific systems aiming to create systems that can exploit common components [7].

The main issues in UV systems that CITIUS is addressing are:

- Interoperability: UV has to interoperate in a seamless way with other real and simulated systems. The experience for the final user has to be pure plug&play across different architectures and standards of robotics, C2 and simulation.
- Cross world operations: Real and virtual world interacts. Real systems can be integrated and take advantage of simulated systems and technologies.
- Autonomy and Communications: UV are incorporating developments in Artificial Technology (AI) that allow them to work in an autonomous or semi-autonomous way. The incorporation of military semantic standards like C-BML (Coalition Battle Management System) open new possibilities to the control of these systems not limited to the military scenarios.
- New formation challenges: The use of simulations interacting with real systems allow the creation of formation platforms that combine real and virtual environments. The formation can thus cover all the new necessities.

We can now see these objectives and challenges in closer detail and see how CITIUS has tried to address them.

3.1 Interoperability

UV systems uses standards like JAUS (Joint Architecture for Unmanned Systems). This standard is built on five principles: mission isolation and independence in vehicle platform, computer hardware, technology and operator use [8]. The objective of CITIUS is integrating this standard with the main core of simulation technologies that uses SISO's LSA architectural model. That way, UV technologies can be seamless opened in primary instance to pure simulation standards and in secondary instance to other standards that are already connected to the simulation platform.

CITIUS approach to this issue has been generic. The connection will be as generic as possible and agnostic to the UV and data model used.

There are two possible approaches to this problem.

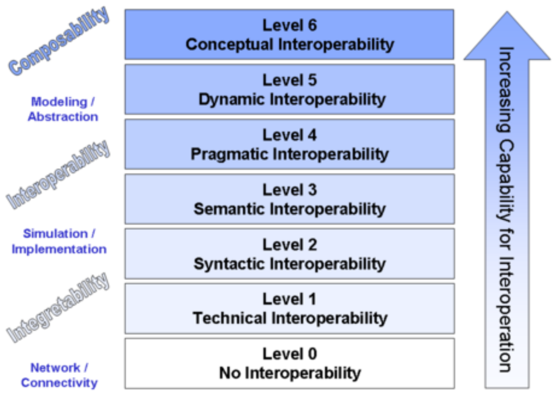
1. JAUS standard can be exchanged over multiple transports like JAUS-over-UDP (JUDP). This opens the possibility of using DDS as the communication layer of JAUS standard. In fact, there is already a working group in JAUS called "JAUS Messaging over the OMG Data Distribution Service (DDS)" that is working of it since 2013. This group defines a standard representation of JAUS AS5684A message data in DDS IDL defined by the Object Management Group (OMG) specification.

2. Simpler but faster approach is building data bridges between simulation and UV data models. This approach can use any possible simulation data model and JAUS data models.

CITIUS is implementing the second approach for two main reasons:

- The simplicity of the solution keeps problems at bay.
- Previous experience in the creation of data bridges guarantees that added latency by the data bridges can be almost nil and that the scalability and maintainability of the solution will be optima.

Connection between UV standards and simulation standards allows seamless interoperability between UV and standards like HLA, DIS and DDS. Both JAUS and DDS are open standards, thus creating an open approach.



3.2 Cross world operation

Connecting real unmanned systems and mainstream simulation standards allow the creation of two very interesting scenarios:

- UV systems in the field feeding real data to simulated systems. This can be used for adding real data to simulation or to create simulation systems able to learn from real data.
- UV systems being controlled from simulation.

This connection is being implemented through open standards as has been already commented. Semantic interoperability is also possible in those scenarios.

To have the most of cross-world operation, data models have to be chosen carefully in both sides.

3.3 Autonomy and Communications

UV nowadays can understand orders and act in an autonomous way. E.g. is possible to order a robot to patrol between different waypoints. Details about the navigation or decisions about sorting obstacles are left to the real device.

One natural extension of this scenario is the use of command and control languages like C-BML. C-BML aim is the creation of unambiguous language used for command and control forces and equipment conducting military operations and to provide for situational awareness and a shared and common operational picture. This language is also used for simulated forces. This language is now under standardization in SISO, but there are some operational experiences and real software that is ready for use and experimentation (C2 clients and services that uses C-BML)

Here, the objective is the connection of UV systems to this language. This can be done using different alternatives:

1. Connect C-BML to UV standards like JAUS. This approach can connect C-BML data model (called MIPS) with JAUS data model using data bridges.

2. Connect C-BML directly to simulation platform. The idea is again to connect simulation data models to MIP data model using data bridges.

For CITIUS we have chosen the second alternative. That way we can reuse previous experiences of connection between C-BML and simulation.

The idea, again is to be as generalist as possible. The way the data bridge between MIPS and simulation is created is actually agnostic to the real data being connected. Key aspect here is separating communication complexities in a different layer and isolate the real connection between data fields in a final layer. Thus the architecture of the data bridge is not dependent of the connecting models.

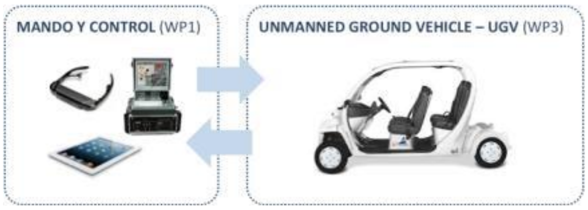


Figure 2: UGV and C2 system

3.4 New training challenges

Completing the objectives of CITIUS are the improvement in the learning of operations and systems using the web. This objective is reached by connecting SCORM standard to the same architecture.

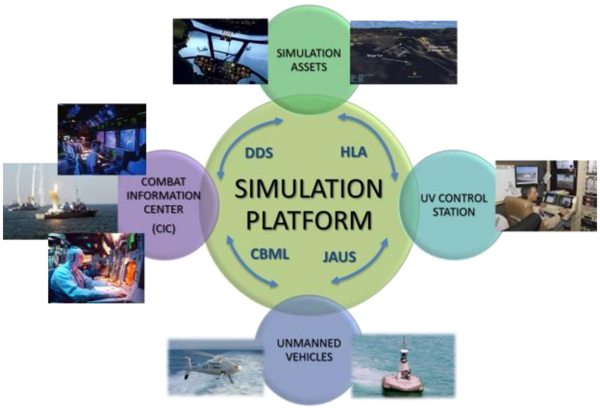
Sharable Content Object Reference Model (SCORM) [9] is a collection of standards and specifications for web-based e-learning. It defines communications between client side content and a host system (called "the run-time environment"), which is commonly supported by a learning management system.

We can connect SCORM to simulation thus allowing the simulation to become active part of e-learning. Lessons can be completed by adding simulation as part of the learning and incorporating simulation results into the learning.

Here, the connection and its details are not so straightforward as in previous challenges.

4 LSA oriented architecture for CITIUS

Citius looks for a System of Systems (SoS) architecture in which simulation can be used in a seamless way in any stage of the life cycle of the SoS, from design to training. As we have explained before, Citius demands interoperability between different standards in a very flexible way.



Therefore, CITIUS is requesting a System of Systems simulation architecture, in which heterogeneous systems can interoperate easily. Indeed this is the main purpose of SISO LSA (Layered Simulation Architecture).

Back in 2012 the seminal idea for the creation of LSA group at SISO was based on the desire to apply concepts on network centric interoperability and open systems architecture to modeling and simulation. This group was inspired by recommendations of the Live, Virtual, Constructive Architecture Roadmap (LVCAR) [10] ,and advances made by other organizations such as the Network Centric Operations Industry Consortium (NCOIC), Object Management Group (OMG) and World Wide Web Consortium (W3C) [11].

The architecture proposed in this group try to facilitate a modular, loosely coupled structure that enables more flexibility and performance than current approaches. Its layered approach enables the reuse of existing Data Centric Middlewares (DCM) such as OMG's DDS, by decoupling generic data distribution functions, leading to a simple and pragmatic solution that not only provides open-wire protocol interoperability, but also offers a richer set of functions.

CITIUS project is a perfect example of LSA solving real problems and demands.

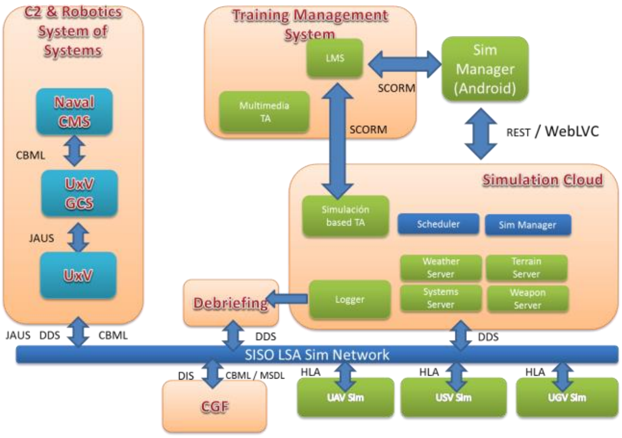


Figure 3: Converging multiple stds in a SISO LSA network

CITIUS architecture is centered around a simulation architecture based on DDS/DDSI that connects simulators based on HLA and DIS. In this project direct interfacing with standards and the use of data gateways are both explored. Finally, a standardized set of simulation services (sensor and weapons) is added.

So, following LSA guidelines we have:

- DDS/DDSI[12] as the system backbone
- Common simulation services available to everyone in the cloud
- Converging multiple standards on top of a DDSI wire protocol : HLA, DIS, CBML, JAUS.

5 Extending LSA concept

CITIUS project allows us to extend the concepts proposed in LSA. Original idea, centered in simulation was reusing current (and future evolutions) of the simulation standards „as they are now“ and connecting them to a DDS/DDSI communication layer. Added, there were simulation services connected in a standardized way.

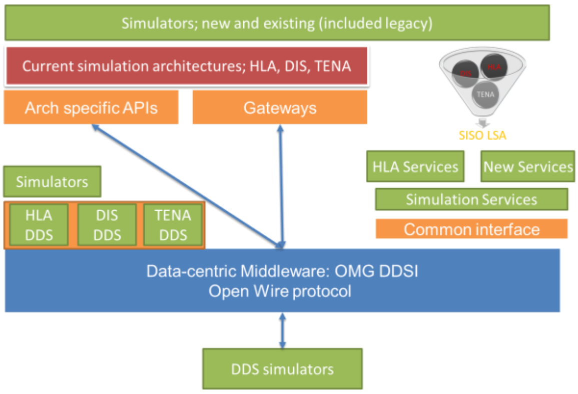


Figure 4: LSA architecture

But simulation world is not isolated, both requirements and real world projects usually go beyond pure simulation requirements. In the case of UV, as we have seen, requisites and necessities are close and similar to distributed simulation requisites and necessities.

CITIUS project demonstrates that the LSA concept can be extended to other set of standards no related to simulation keeping the same rules; keep standards and software/hardware made with them as they are now and integrate them with DDS/DDSI based communications backbone.

- JAUS: JAUS is a standard for robotics. Following LSA concept, it can be integrated using data gateways or direct connection to DDS. In the case of CITUS project, data gateway has been implemented for simplicity.
- ROS (Robotic Operating System) [13] is not included in CITIUS project, but both the architecture of ROS and the relations with DDS can be the same as in JAUS:
  - Creation of data gateways between ROS and DDS is possible in the same way we have made with JAUS in CITIUS project
  - Direct use of DDS as the communication layer for ROS has been demonstrated in projects like IMPERA for NASA [14]
- C-BML: C-BML (and MSDL) can be integrated into DDS/DDSI using data gateways. Since C-

BML is a language, no direct integration with DDS has been made.
- SCORM: SCORM can be connected to the simulation environment. In this case, connection is not so direct as in the rest of standards.

Finally, the use of LSA architecture with standards not related with simulation opens the possibility of extending the original concept of LSA group to new standards related with C2 and robotics.

6 Evolving LSA concept: Future work

LSA study group is now (June 2013) finishing its study report in order to propose a new development group to define the standard. In this phase, is still possible to extend current ideas and concepts to standards not related with simulation (arguably, this can put the standard out of current SISO scope). For example, we can consider including C-BML/MSDL (which is also SISO standard) and robotic standards like JAUS or ROS.

The concepts and ideas obtained in making CITIUS project are currently being internally discussed in the group. Some open questions are:

- Can LSA concept be safely extended to include other non-simulation standards like ROS or JAUS?
- Will this be out of the „natural" scope of SISO or can SISO reach this new areas?
- Can C-BML be implemented over DDS creating a tool using a fixed data model (maybe a subset of MIPS)?

SUMMARY

CITIUS project addresses current necessities of UV mixing them with simulation, communication and formation.

- Interoperability: In CITIUS UV interoperate in a seamless way with other real and simulated systems. The experience for the final user has to be pure plug&play across different architectures and standards of robotics, C2 and simulation.
- Communications: UV can now work in an autonomous or semi-autonomous way. The incorporation of military semantic standards like C-BML (Coalition Battle Management System) open new possibilities to the control of these systems.
- New formation challenges: The integration of learning standards like SCORM open new possibilities in complementing e-learning and simulation.

CITIUS project has made extended use of LSA proposed architecture. In this sense, it is a new proof of concept of LSA applied to real projects

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