# LVC Architecture study

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**ABSTRACT**: *The integration of 'Live' entities with a 'Virtual' or 'Constructive' simulation provides many new possibilities in the domain of analysis, design, acquisition and training. For example, a live training exercise can be enhanced by inserting constructive simulated forces that replace scarce operational units or equipment (this is called constructive wrapping). The LVC research programme at TNO Defence, Security and Safety investigates the possible benefits and pitfalls of integrating Live, Virtual and Constructive simulations. It investigates how the integration should take place from a technical perspective by demonstrating innovative LVC techniques using a number of case studies to develop relevant LVC applications. The programme also researches applicable LVC architectures and development processes based on the results of the case studies in this programme and based on available best practices and standards. This paper provides an overview of the case studies and describes the first results of the LVC architecture study in this programme.*

## 1. Introduction

### 1.1 Dutch LVC Programme

Modelling and Simulation is an established tool in the military domain for analysis, design, acquisition and training. Simulations are commonly categorised as Live, Virtual and Constructive (LVC). In 'Live' simulations, human operators use real hardware (e.g. a field exercise in an instrumented range). A 'Virtual' simulation is characterised by human operators that use simulated systems (e.g. a pilot in a flight simulator). In 'Constructive' simulations, we find simulated players (artificial intelligence) and simulated equipment (e.g. a wargame representing units at brigade level). Live simulations are often relatively 'unpopulated'. In Live Urban Ops training for example, there is a significant lack of supporting units, non-combatants and opposing forces. Additional (role) players and equipment (e.g. UAVs) are rarely available due to operational needs, costs, organizational problems or other limitations. In a similar way, operators of Virtual simulations often lack the broader mission context of commanding levels, joint elements or coalition partners. In constructive simulation, one often lacks realism and details.

The Royal Netherlands Armed Forces recognised the challenge to use Live, Virtual and Constructive simulations in a more integrated way and initiated a research programme at TNO Defence, Security and Safety to investigate if and how LVC integration could enrich our capabilities for training and concept development. The premise of the programme is that improved interoperability between LVC simulations uses their specific advantages, while addressing weaknesses of the separate elements.

The objective of the programme is to investigate where the benefits are in linking Live, Virtual and Constructive simulations and how this integration should be implemented. The goal is to develop techniques, methods, guidelines and standards which allow the Royal Netherlands Armed Forces and its allies to achieve LVC integration in a flexible and efficient way.

The programme will result in knowledge, guidelines, methods and tools for an effective LVC integration, such as techniques for environment and behaviour modelling, interoperability and validation. So called case studies will be the baseline for practical application of LVC and become available to project officers in the Royal Netherlands Armed Forces and its allies, project managers within TNO and partners from industry.

This paper provides an overview of the case studies performed in the programme and describes the first results related to LVC architectures.

### 1.2 Overview of this paper

The paper is structured as follows:

Chapter 2 provides a background on LVC Architectures, covering typical aspects of LVC simulation and expected integration consequences.

Chapter 3 describes the case studies that were selected for the LVC programme. Each case description includes an overview of the live actions and effects modelled, with the focus on live.

Chapter 4 provides a number of preliminary conclusions based on the case studies and the way ahead.

Chapter 5 lists the references.

## 2. Background on LVC Architectures

This chapter covers typical aspects of live, virtual and constructive simulation and elaborates on the expected consequences that concern integration.

### 2.1 About the Truth

Engineers in the M&S domain are since long familiar with the notions “ground truth” and “perceived truth” in both virtual and constructive simulation (see [1] for glossary):

***Ground truth***
*The actual facts of a situation, without errors introduced by sensors or human perception and judgment.*

For simulation the notion Ground truth is used for the simulation data that describes the true state of objects and interactions in a simulation. For example the DIS PDUs exchanged in a simulation.

***Perceived truth***
*That subset of ground truth acquired or distorted by sensors, human perception, or judgment; the situation as perceived by an observer*

Each observer can have his/her/its own perceived truth that can differ from the perceived truth of other observers.

For simulation the notion Perceived truth is used for the data that describes the sensed, observed or perceived true state of objects and interactions in a simulation. This is usually tactical data such as sensor tracks, situation reports or commands.

With the addition of “live simulation” to virtual and constructive simulation we now have a third truth notion we need to be aware of, which is called “real world” with live data:

***Real world***

1. *The set of real or hypothetical causes and effects that simulation technology attempts to replicate. When used in a military context, the term is synonymous with real battlefield to include air, land, and sea combat. Also referred to as real battlefield.*
2. *One standard against which fidelity is measured that includes both imagined and material reality in order to accommodate assessment of simulation fidelity when future concepts and systems are involved.*

With the addition of “live simulation”, real world actions and effects now need to be injected into a virtual/constructive simulation, and simulation actions and effects need to be injected in the real world.

The different notions are illustrated in the communication diagram in Figure 1.

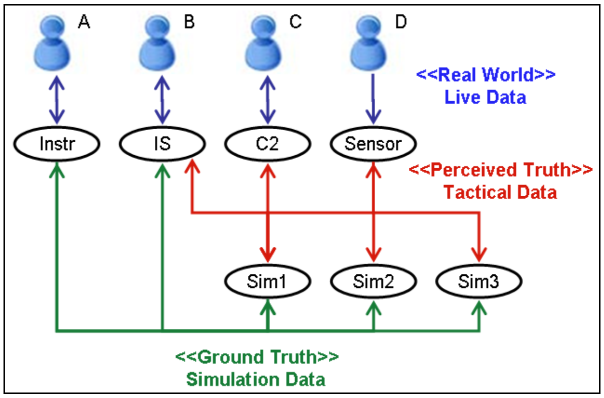


**Figure 1: LVC high level communication diagram.**

In Figure 1 we see the different kinds of data (live, tactical and simulation) that commonly exist in an LVC simulation. Each kind of data is highlighted in color and with stereotype notation “<< … >>”). Letters A through D indicate live entities (person, car, aircraft, etc.). The data is communicated between the systems illustrated by the ellipsoids, in this example Instrumentation system (Instr) to track and stimulate live entities, Instructor Station (IS) or white cell to monitor and control a simulation, Command and Control system (C2) and Sensor system. Each system has specific behavior and transforms one kind of data to another kind of data. For the communication of simulation data and tactical data different protocols / architectures are used in practise.

### 2.2 Typical Aspects of LVC Simulations

Simulations are typically categorized as live, virtual or constructive:

- Live simulation: real people operating real systems (in the real world); live actions, but simulated effects.
- Virtual simulation: real people operating simulated systems (in a synthetic environment).
- Constructive simulation: simulated people operating simulated systems (in a synthetic environment).

This section lists the typical aspects of each category. The typical aspects of each category are:

Live Simulation:

- Humans move around and interact with the environment. They can touch, smell, hear and feel it. They are immersed in it.
- Although it is the real world it often does not have a perfect fidelity because of for example the use of role players, the presence of observers and instructors and the use of training ammunition.
- Has real-time aspects in the sense that it runs in the same pace as the wall-clock time. It is however feasible to simulate historical events or even future events. In many live simulations it is possible to jump in time, in order to focus only on most relevant events.
- The same environment is shared by all.
- There can be unplanned surprises.
- Use of actual (military) equipment.
- Use of (non-computer based) mock-ups.
- Often hard to do a re-run under the exact conditions. The settings of the simulation often dependent on weather, time-of-day etc.

Virtual Simulation:

- Humans are limited in their interaction with the simulated (synthetic) environment. Some of these limitations might be overcome by having in place some agreements of how to interpret the synthetic environment.
- In virtual simulation humans can interact with a larger variety of situations and can perform actions that are not allowed in live simulation with realistic simulated effects, thus providing a safe experimental environment.
- The views from participants on the shared synthetic environment might deviate from each other depending on local hardware/software limitations.
- The participating simulation models can only reason on shared computer data, such as ground truth data, while participating humans reason on pesentations of this computer data. This may lead to inconsistencies.
- Virtual simulations often have real-time aspects in the sense that the simulation execution runs in the same pace as the wall-clock time. It is however feasible to simulate historical events or even future events. In many virtual simulations it is possible to jump in time, in order to focus only on most relevant events.. We call this aspect “soft real-time”.
- There are time constraints because there is a human in the loop. Under some circumstances it is possible to speed up or slow down the simulation. E.g. to skip boring parts or to give novice users some extra time to complete a task. This is more difficult in cooperative simulations.
- There are still good opportunities for partial deployment of operational equipment. The use is limited because of the limitations of the synthetic environment.
- Often hard to do a re-run under the exact conditions, because of the human involvement. However, participating humans can have a pretty similar experience, because a virtual simulation can control for example weather, time-of-day and other conditions.

Constructive Simulation:

- Representation of humans and their behaviour.
- Representation of systems and their behaviour.
- Fidelity usually rather low.
- Possibilities for either soft real-time, such as in virtual simulations, or logical time managed where there is no relation between simulation time and wall-clock time at all (running as-fast-as possible, aka faster, slower or other than real-time).
- When no human (or other) input is used, constructive simulations are in principle deterministic and reproducible.
- Statistical methods can be applied when constructive simulations are used in e.g. Monte Carlo approach.

## 2.3 Consequences of Integrating Live, Virtual and Constructive Simulation

Integrating Live simulation with Virtual and/or Constructive simulation brings all kinds challenges, both technical and conceptual, such as:

- how to represent live entities (humans, etc) and actions in a virtual/constructive simulation;
- how to represent virtual/constructive entities and effects in a live simulation;
- how to deal with different levels of abstraction when integrating with a virtual/constructive simulation;
- how to provide realistic and intelligent behavior of a virtual commander or constructive forces when interacting with live simulation;
- how to deal with user interfaces between live and virtual/constructivel simulation;
- how to deal with simution time (time of day/year, jump in time, go back in time, etc);
- how to deal with limits of current technology.

Different representations:
When integrating live, virtual and constructive simulations, one of the most difficult issues to overcome, is not the sharing of data, but allowing this data to have a meaningful representation in each simulation category. Each category has its own representation and abstraction level, which necessitates considerations on how to transform concepts from one category to the next. How do they correlate? Note also that such transformations are often only valid in one direction, for example units can be aggregated by leaving out information not needed on the more abstract level, but with disaggregation the additionally required information may not be present.

Abstractions:
The different abstractions in their representations of the real world (i.e. their fidelity) occur in different ways. One is the resolution. E.g. an environment can have a high resolution in location, say 1 meter, compared to another environment that has a resolution of 1 kilometre. It is often valid to transform the 1 meter mesh to a 1 kilometre mesh, but the other way around will miss detail.
Another difference is found in capability coverage. A simulation model usually considers only partial functionality of its referent. In a constructive simulation typically only high level functionalities are relevant. When integrating live and constructive simulations, it is not unthinkable that this capability difference can cause unexpected behaviour.

Intelligent Behaviour:
Human intelligence is hard to simulate. Replacing humans with AI can result in behaviour that is rather predictable and dumb. Integrating the behaviour of a real human in a Live or Virtual simulation with simulated human behaviour in a constructive simulation may e.g. result in unfair and unrealistic strategies in training scenarios where students display different reactions to actual and simulated humans.

Impact of Human Machine Interface (HMI):
A human machine interface is an important aspect of how humans experience the environment and interact with it. In an LVC setting, it is likely that various human interface designs with various implementations are deployed. This can lead to different perceptions of the same shared environment between various participants and different possibilities of interacting with it.

Dealing with Time:
Each category of simulation has its own way of dealing with time. Live and virtual simulations have a real human in the loop that imposes its “human” time constraints on the simulation progress. This in contrast to constructive simulation, that deals with simulated humans that impose no time constraints on its computational effort. Various aspects of time, such as the ability to simulate faster or slower than real-time, the ability to jump in time, to pause or even go back in time are not always possible or meaningful when integrating live, virtual and constructive simulation. Live simulation has the most limitations with respect to time and will enforce these constraints on an LVC simulation.

Technology Dependency:
When integrating live, virtual and constructive in a mixed reality, it is important to consider that technology has an important impact. For virtual and constructive the cost and usefulness are determined by computer power and software and to a lesser extent visualisation equipment. For the integration with live simulation elements such as sensors, projectors and actuators become limiting factors on the usefulness of the integration.

## 2.4 Relations with standards on architecture, development and validation

In this section we give a brief summary of some of the existing standards or developments related to architectures, simulation environment development and validation that are relevant for considering inclusion in the proposed guidelines mentioned earlier in chapter 1.

**IEEE 1471**
This IEEE standard provides a recommended practice for the architectural description of software intensive systems. The standard establishes amongst others a conceptual framework and defines the notions of views and viewpoints for describing an architecture. See reference [2].

**DoDAF**
The Department of Defense Architecture Framework (DoDAF) provides a framework for developing and representing architecture descriptions. It enables the comparison and integration of architectures across organizational boundaries by defining a set of data element, rules, and relationships, and a baseline set of products. As in IEEE 1471 it also uses the notions of views and viewpoints for describing an architecture. See reference [3].

**IEEE 1730 (DSEEP)**
This IEEE standard (DSEEP, Distributed Simulation Engineering and Execution Process) describes the recommended practice for the engineering and execution of a distributed simulation environment. The standard defines amongst others activities and associated tasks to 'prepare' the simulation environment architecture and establish data exchange agreements between the applications in the simulation environment. See reference [4].

**NATO MSG-068 (NETN)**
The objective of NATO MSG-068 NETN (NATO Education and Training Network) is to assess the distributed simulation and learning capabilities that NATO, Partner and Contact Nations, Schools, and Agencies have that could contribute to the development of a NETN capability. The MSG-068 will also recommend and demonstrate a way forward for interoperability, technical standards and architectures to link these training and education centres to provide a persistent capability. See reference [5].

**GM-VV**
From the discussions in section 2.3 it is clear that the usefulness of a constructed LVC simulation could be diminished by a host of problems concerning correctness and fidelity. What is needed is a thorough Verification and Validation (V&V) of the resulting simulation. GM-VV (Generic Methodology for Verification and Validation) is a draft standard to support the acceptance of Models, Simulations and Data [6], which is handed over to SISO for standardization [7,8,9].

GM-VV is a generic methodology which means that it is defined independently from any specific M&S application, domain or technology. This makes the methodology generally applicable and compatible to any class of VV&A problems inside the M&S domain. However, this also makes GM-VV an abstractly defined methodology that has to be instantiated and tailored for a particular M&S application or technology.

## 3. Case studies

The Dutch LVC programme includes a number of case studies with the aim to study and evaluate LVC techniques and methods, and to demonstrate the added value of LVC. The focus of each study is on the integration with live simulation.

In the initial phase of the LVC programme three cases were selected based on input from stakeholders:

- Unmanned Arial Vehicle (UAV): the integration of a simulated UAV in a live exercise.
- C2-Sim: the integration of an operational C2 system with simulation using the Coalition Battle Management Language (C-BML).
- Urban Short Range Interactions (USRI): the integration of a live player in a virtual environment with simulated role player (opposing or non-combatant).

The following paragraphs describe the three case studies in more detail. In each of the case descriptions we also describe the live objects and interactions that are modelled, using the notions "Real world", "Ground truth" and "Perceived truth", as described earlier.

### 3.1 Unmanned Arial Vehicle (UAV) Case

**Background**
The Netherlands Armed Forces use a number of UAV systems in their current operations, both long-endurance high-altitude systems as well as smaller, man-portable devices. These UAV systems improve the situational awareness of the platoon commander on the ground and can be controlled in different ways. For example by direct control from the ground (for man-portable devices such as the Raven) or indirectly through a higher echelon where UAV images are received on the ground through an operational (portable) Remotely Operated Video Enhanced Receiver (ROVER IV) system, for example for long-endurance high-altitude systems (see [10]).

However, these UAVs are scarce resources and availability is limited due to operational needs, resulting in reduced training opportunities. The availability problem of these assets for live training exercises is even further increased by legal restrictions regarding the use of UAVs in Dutch airspace and the weather conditions that often prevent UAVs from being used over our national training grounds.

**Study**

The UAV case study uses a phased approach of demonstrations, using existing simulation assets and live training facilities such as the army MOUT (Military Operations on Urban Terrain) training facility in Marnehuizen, The Netherlands.

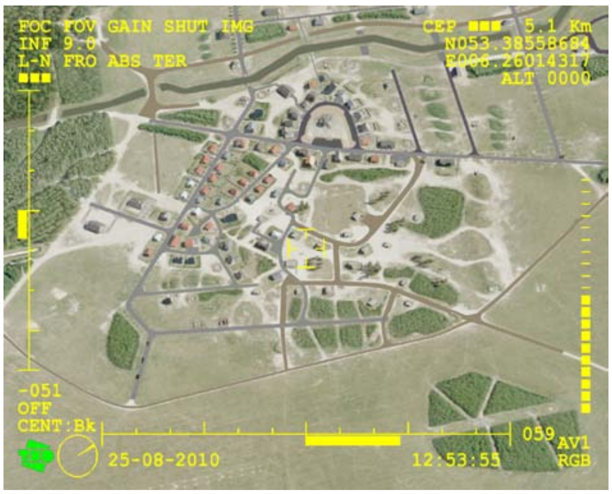


**Figure 2: UAV Simulator: UAV sensor view.**

One of the demonstrations took place in September 2010 with a demonstration of a simulated UAV in a live exercise. In this demonstration a simulated UAV "flew" above the Marnehuizen training facility, where at that time the NATO MSG-063 UCATT (Urban Combat Advanced Training Technology) team gave a demonstration with their MOUT training systems. See also reference [11].

A simplified UAV high level communication diagram is provided in Figure 3. The UCATT side of the figure takes care of the instrumentation and tracking of live entities (people, vehicles). Although greatly simplified in the figure, the tracking of live entities and provision of stimuli to live entities is in reality a complex system by itself. It is one of the goals of MSG-063 UCATT to develop a SISO supported standardized interface between MOUT training systems that includes these tracking systems. See reference [12] for more information.

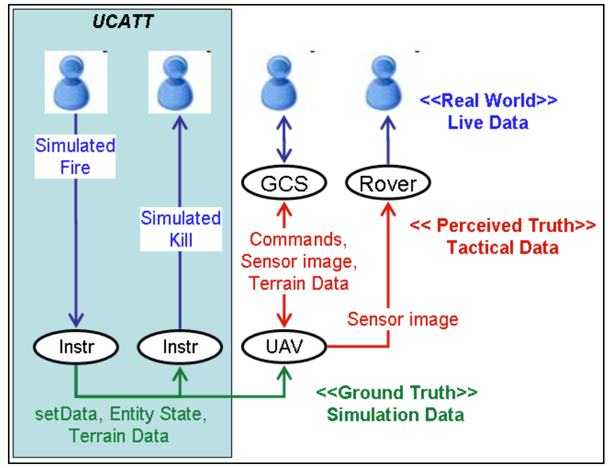


**Figure 3: UAV high level communication diagram.**

In Figure 3 the sensor images of the simulated UAV show the live entities (people and vehicles) in a virtual environment. The virtual environment contains an accurate model of Marnehuizen, constructed from previously acquired aerial imagery, elevation data, etc, of buildings, roads and vegetation. With the Ground Control Station (GCS) UAV missions can be prepared and the UAV can be controlled. The Rover is an operational ROVER IV system capable to receive and display (simulated) UAV sensor images based on STANAG 4609. The integration of the TNO UAV simulator with the equipment of the UCATT participants was achieved through the use of HLA (RPR FOM) and DIS.

The following live actions and effects were modelled from a UAV point of view:

- Person and vehicle movement, resulting in entity state PDUs.
- Fire – kill action, resulting in setData PDUs to indicate who was killed.

**Suggested Future Improvements**

- **Level of detail**. Position measuring systems are all individually tuned to fit their local terrain model. The UAV had the most accurate (ground truth) terrain model, but due to the local tuning the position of simulated entities had an offset with the live entities observed in the field.

- **Level of fidelity**. Only minimal entity state data is communicated. No information about gun fire and detonations was communicated. Also the stance of humans was not available (StanceCode of LifeForm object class in RPR FOM, e.g. is somebody running, walking or kneeling). The stance is relevant in case of close surveillance.

### 3.2 C2-Simulation Case

**Background**

When military are using simulations for training, mission rehearsal or planning for operations they prefer the use of their operational C2 systems as an interface to these simulations. The corresponding paradigm is called “train as you fight”.

Currently however simulators do not posses this quality and usually have their own dedicated interface. This has been recognized as a problem and the idea for a Coalition Battle Management Language (C-BML) has been formed. This language can serve as an communication language between C2 systems and (usually constructive) simulators. In the Simulation Interoperability Standards Organization (SISO) this language is being designed and in the NATO Modelling and Simulation group NATO MSG-048 and its successor NATO MSG-085 the language is being evaluated and recommendations to SISO are fed back. See reference [13].

**Study**

In MSG-048 several experiments were performed culminating in an experiment with Live players. Several nations provided C2 systems (GBR: ICC, NOR: NORTaC, FRA: SICF, CAN: Battleview, USA: ABCS, NLD: ISIS) and simulators (USA: OneSaf, ESP: SIMBAD, GBR: JSAF, CAN: UAVSIM). A mission rehearsal event was played using the architecture below.

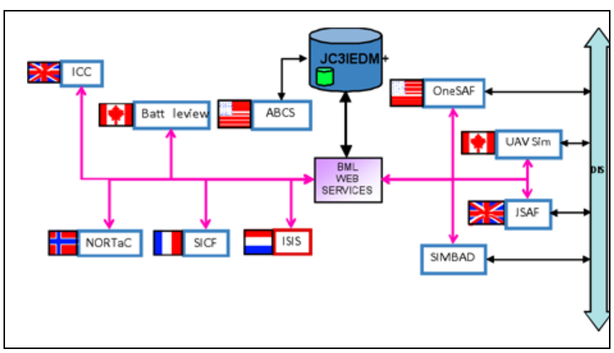


**Figure 4: MSG-048 experiment architecture.**

In Figure 5 the high level communications architecture is displayed.

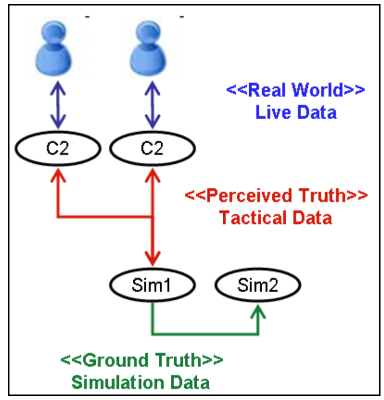


**Figure 5: C2-SIM case high level communication diagram.**

A scenario was played where the live players were in one room issuing commands to the (simulated) troops and the simulations were in another room.

The following live actions and effects were modeled:

- Commands were issued by the players on the C2 system.
- The reports from the simulation were fed back to the C2 systems using C-BML as a communication language.

The experiment showed that the used approach is very promising and one of the aims in NATO MSG-085 is to further experiment with more kinds of situations. The future vision is that manufacturers of C2 systems and simulators will enable their future systems to speak and read C-BML in order to facilitate the seamless use of C2 systems and simulators.

### 3.3 Urban Short Range Interactions (USRI) Case

**Background**

An important part of current military reality are Military Operations in Urban Terrain (MOUT). The presence of locals is an important factor in the practice of MOUT, because it is not at all clear whether persons are friendly or hostile. Additionally, winning the hearts and minds of the population is one of the key success factors of current operations. The required skills go beyond the traditional military training, and involve negotiation skills and cultural awareness. Particularly cultural awareness is crucial as subtle differences in behaviour can result in opposition instead of support.

Current training programs for urban operations include exercises in live training ranges, such as the Dutch MOUT facilities Marnehuizen and Oostdorp. Since the interaction with local population is an important issue in military operations, these facilities need to be populated with ‘locals’. However, these exercises often lack sufficient role players to simulate a populated urban environment, because adequate live role players are costly and hard to find. Additionally, the amount of time available for cultural awareness training is quite limited, because of scarce role players.

**Study**

The required number of live role players can be reduced using advanced simulation techniques. This case study aims to achieve such enhancements using advanced interaction and Mixed Reality techniques.

This poses several new requirements on the capabilities of the behaviour models of the virtual players. They need, for example, to be able to perform effective dialogs. This implies communicating using natural language, and demonstrating and interpreting non-verbal communication, including posture, facial expressions, and gestures.

Techniques for enhancing user immersion of training systems are improving quickly. In particular low-cost interaction techniques, such as the Nintendo Wii, can be deployed effectively.

**Figure 6: USRI Simulator.**

The approach of this case study is to perform a number of demonstrations in collaboration with problem owners in the training area. In these demonstrations, we use virtual characters as role players in a MOUT exercise, and address key aspects of interaction and immersion. In this way we improve training value while reducing cost.

One of the first demonstrations concerns a live person searching a (virtual) house for hidden weapons, while coming across different situations with virtual role players. This simulator demonstrates [14]:

- the possibility to simulate kinetic and non-kinetic interactions with virtual players;
- a more natural interaction with virtual players, by using the low-cost Nintendo Wii Remote as weapon and the Nintendo Wii Nunchuck for motion/gesture detection;
- the possibility to add more realistic behavior for Computer Generated Forces, using VBS2 add-on modules.

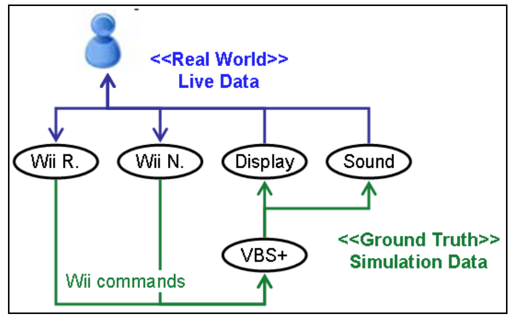


**Figure 7: USRI Simulator high level communication diagram.**

The following live actions and effects were modelled:

- Live player gestures and weapon fire, resulting in commands to VBS.
- Display and sound effects from the virtual environment.

**Suggested Future Improvements**

Movement of the live player through the virtual environment was currently scripted, following a pre-defined path. The use of a tracking system, such as the Microsoft Kinect system, will allow the spatial integration of the virtual and live environment. Such a system may also allow recognition of the live player's posture and direction, information that can be used by the virtual role player to decide on which action to take.

Besides gestures, the use of a speech recognition will enhance interaction with the virtual role player. Finally, the use of an artificial intelligence module should improve and enrich the behaviour of the virtual role players.

## 4. Preliminary conclusions and way ahead

### 4.1 Preliminary conclusions

**Is there a single or preferred architecture for LVC?**

The short answer is No. Each case study in the LVC programme has shown to bring its own unique architecture for LVC integration:

- UAV Case: UCATT equipments, DIS, HLA RPR-FOM;
- C2-Sim Case: Operational systems, BML, Webservices;

- USRI Case: Nintendo Wii components and VBS DIS/HLA RPR-FOM.

The current picture is really about the "architecture of architectures" or so called "federated architecture"; how to combine or integrate different existing architectures in an overarching architecture. The focus should therefore not be on striving for a single architecture but enabling architectures to inter-operate. Thus agreeing on concepts and mapping between concepts that exist in different architectures. This is in line with the recommendations of the US DoD LVCAR study [15]. That is, eliminate interoperability barriers between architectures, create and provide standard resources, provide free gateways, and focus on semantics of LVC systems.

**How to describe in a uniform way the architecture of a simulation environment?**

IEEE 1471-2007 defines "Architecture" as the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

A central idea of the standard is that the description of an architecture should be expressed by describing multiple views each governed by a defined viewpoint to deal with various concerns of stakeholders. The standard does not provide the viewpoints; they should be selected based on the needs of the system. An example is the Department of Defense Architecture Framework (DoDAF).

Of course the DODAF views may be used for describing architectures (see also [16]), but these may still be quite high level for simulation engineers, and need to be tailored to cover specifics of a simulation environment. With the different case studies it was recognised that a recommended set of (minimal) viewpoints and views specifically for describing the architecture of an LVC simulation environment would be helpful and would guide the developers in each case study. For example a functional viewpoint with a view that describes the interactions between components and/or live players, a view that describes the progress of time and a view that describes the execution control of components. Guidance on recommended viewpoints and views and the kind of simulation environment agreements associated with these viewpoints and views is currently lacking.

### 4.2 Way ahead

The way ahead includes the following activities:

- Continue with the case studies and **involve stakeholders in discussions and evaluations**. But also study and analyse existing LVC exercises, such as JPOW.

- Based on lessons learned from the case studies and based on related activities, **develop recommendations for standards and general principles** for the integration of LVC simulations, where possible referring to already developed standards or ongoing activities, such as SISO PDG's or NATO MSG activities. This includes the development of **LVC architectural viewpoints and views**.

- **Develop patterns for goals and subgoals for VV&A purposes**. Validation of an LVC simulation has not been a top priority in the case studies so far. As was mentioned in section 2.4 the usefulness of a constructed LVC simulation could be diminished by a host of problems concerning correctness and fidelity. The GM-VV methodology must be specialized in order to effectively and efficiently perform verification and validation of LVC simulations. One of the main areas for specialization is the argumentation network. There one recognises patterns of goals and sub-goals that are specific for the construction of LVC simulations. The case studies are going to be used to derive a set of patterns with Acceptability Criteria and tests that can be re-used for every new LVC simulation and its application.

- **Provide recommendations to NATO MSG-068 (NETN)** on the topic of integrating live simulation with virtual/constructive simulation.

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