# STUDY OF HIGH LEVEL ARCHITECTURE APLICABILITY IN AIR DEFENSE

**Marius ALEXA*, Cătălin CIOACĂ****

*Air Forces Simulation Training Center, Boboc, Romania (alexamarius@yahoo.com)
**"Henri Coandă" Air Force Academy, Braşov, Romania (catalin.cioaca@afahc.ro)

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***Abstract:*** *Today we live in a complex world, in a complex environment; we are used to having a complex life, supported by a lot of technology, automatic tools, which is supposed to be sustained by more and more resources. In all domains of activities modeling and simulation are designated to resolve the problem of time spending and resources. In high technical domains, which involve well prepared operators, like air defense artillery and aviation, the main skills are formed and improved through many hours of theory and practice on a specific simulator. Virtual and constructive simulators had begun to play a main role and the users can't operate in real until they practice some hours on specific simulator. Serious games and multilevel simulator represent the key for the epistemic learning and in the present project we established another program simulation for Air Defense Artillery. This program is trying to connect two type of simulation (constructive and virtual simulation) and is designated to train command-control staff and Fire Control Unit users.*

***Keywords:*** *high level architecture, simulation program, air defense, fire control system, serious games*

## 1. INTRODUCTION

Multilevel simulation is not a new concept, but it has new implications and applications in simulation training and is designated to train individual operators and Command and Control (C2) staff. In air defense artillery C2 staff and Fire Control Unit (FCU)/ gun operators work together like an individual entity and time is the main adversary for both. Working together they are supposed to respect the procedures and to do hours of rehearsals. The rehearsals have to be made on simulators and after that the staff and operators can operate in real [1].

For training, both staff and operators should connect constructive, virtual and real simulators in one physical model – multilevel simulation. Now the Romanian army has some individual simulators (aviation, naval, land and air defense), but that model works independently and trains the operator individually, in individual scenarios.

Multilevel simulation is a federation model, a connection between constructive, virtual and real simulations and that connection is done with High Level Architecture (HLA). HLA is a standard essential part of a multilevel simulation and is the key for models like that. Technically it is a procedure, a common language between different types of simulations [2,3].

Another essential part of training is represented by software and models designated to train real people, not only theoretically but also in practice and epistemic learning too. That kind of model is called serious games and is the future key for learning and training skills [4].

A serious game is a model which is almost similar with real model and is necessary to follow the same pattern, operation control and procedures like the original. The beneficiary has the opportunity to train in real-like conditions and the differences have to be almost zero, with some exception (eg. can't simulate the gravitational force).

Finally, the purpose of the multilevel simulator is to give a feedback to C2 staff representing the results of plans and planning, generating reports and training the staff in making decisions in the military process. The staff has the opportunity to restart one or more procedures if something is wrong with the execution of the plan.

After hundreds of hours of training on the multilevel simulator, the mission itself will not be anything other than training „somewhat serious". This explains the success of NATO fighter-bomber aviation which plays out the tasks and missions with a very low rate of failure [5].

## 2. THE DESIGN OF HLA

The High Level Architecture (HLA) is a standard that enables all types of simulation systems to work together. The simulations systems need to work together in such a way that they can achieve an overarching goal by exchanging services.

According with the "Practical guide for developing distributed simulations", there are five important concepts regarding HLA [6]:

1. The Runtime Infrastructure (RTI) is a part of software that provides the HLA services. The main service is to send and receive the right data to the right receiver.
2. The Federate is a system that connects a simulator to the RTI. Each federate can model any number of objects in a simulation; it can connect one aircraft simulator with one air defense simulator and both can be connected with a constructive simulator.
3. The Federation is all federates together with the RTI that they connect to and the FOM that they use. That is the group of system that interoperates.
4. The Federation Object Model (FOM) is a file that contains a description of the data exchange in the federation. This can be seen as the language of the federation.
5. The Federation Execution is a session when the federation runs. If you run the federation several times you will have several federation executions.

Runtime Infrastructure (RTI) is a basic topology formed by a number of simulations that have one single connection to a service bus (Fig. 1).

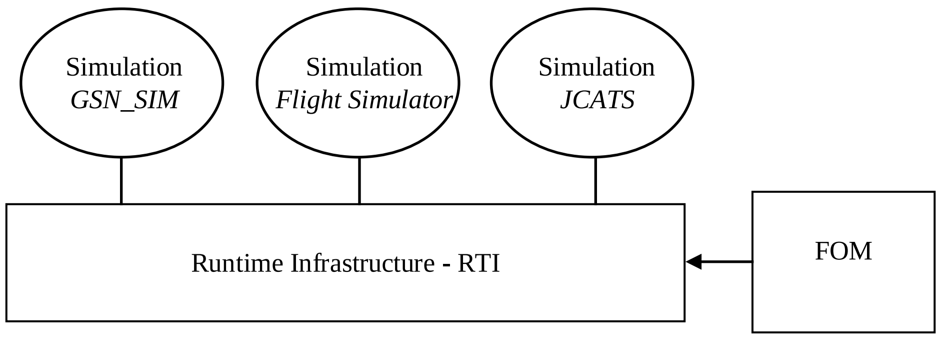


**FIG. 1.** The RTI architecture

Support Services are a number of utilities and here is the full list, in the order that the HLA standard describes them:

1. Federation Management (keep track of federation executions and federates, synchronization points, save/store);
2. Declaration Management (publish and subscribe of object and interaction classes);

3. Object Management (registering and discovering object instances, updating and reflecting attribute);
4. Ownership Management (transfer or modeling responsibilities);
5. Time Management (handling of logical time including delivery of time stamped data and advancing federate time);
6. Data Distribution Management (filtering based on data values);
7. Support Services (utility function);
8. Management Object Model (inspection and management of the federation).

For example, Simulation Generator (SimGe) is a fully-dressed HLA object model editor, simulation design and development environment, and a code generator that is intended to generate code automatically for HLA based distributed simulations [7]. The target platform for code generation is an HLA Runtime infrastructure abstraction layer called RTI abstraction component for .NET (RACoN). The architecture of the generated code by SimGe conforms to the layered architectural style.

## 3. SPECIFIC REQUIREMENTS

Oerlikon Contraves 35 mm caliber air defense system is an automated system designated to protect different objectives (eg. HQs, air bases). If the radar (SHORAR-TCP), Gun*Star Night and 35 mm Gun Air Defense System is engaged in a permanent position, according with the Drill Book a complete reconnaissance needs to be made only once [8].

Usually the position of Search Radar, FCUs, Guns and PSUs is fortified or protected in some way. Also the ammunition dump, first aid post and quarters can be constructed and perhaps coordinated with the installation of the defended critical asset or vital point.

The communication systems can be permanently installed. A typical critical asset of this type is an air-base or a land forces-base. In this case the defense system should be coordinated with the activities of the Air Force or Land Force. A lot of infrastructure can be used by air defense, too.

The Oerlikon Contraves 35 mm caliber air defense system is a complex one which works in a centralized mode and is mainly composed of [9]:

1. SHORAR TCP is designated for search, detection, identification and automatic target accompany. The SHORAR has the main role of managing the air space security and optimizing the air targets data to the fire control system Gun*Star Night.

2. Gun*Star Night is an automated subsystem designated to control two sets cannons. It is based on electro-optical tracking system and equipped with a computer to calculate ballistic trajectory and the timing of the fire release.

Fire control system Gun*Star Night provides the following main operations:

a) receives data on air targets at SHORAR TCP or its digital optical viewfinder (DOS);

b) evaluates the potential air attack in the area of responsibility (in decentralized mode);

c) searches, finds and identifies the target;

d) accompanying three-dimensional target (finders using laser and electron-optical system);

e) calculates angles of sight for guns;

f) forwards angles in gun sights.

3. Digital Optical Sight (DOS) is operated by a single operator and is designated to search air targets and send data to GSN. DOS is the main Intel sensor when GSN works in decentralized mode and receives data only from this subsystem.

4. Anti-aircraft automatic guns (AOKs) comprises two 35 mm caliber and are designated to fire directly against air targets or field targets, coordinated by GSN or by an individual.

A usual scenario looks like this: SHORAR-TCP radar is searching the air space and detects a target at 28 km; it identifies the target as friend/ non-friend and sends data to the GSN which has the best position in AOR or is ready to combat.

Sending data to one or more GSN is made according to the best course of action and according to the value of the target. This is a procedure that is one of the most important part of the military decision making process and is a quick and short one.

GSN is requiring the target and it follows it with infrared camera. The target's data are continuously updated by computer and laser telemeter and when the target is in the fire area, AOK can open fire against it conducted by FCU.

The output laser device wavelength is 1.54µm. In normal conditions of utilization, this laser device is considered eye safe as defined under class 3A in accordance with the EN 60825-1 classification. To prevent permanent injury to the human eye is strongly recommended never to view at the laser directly or with optical instruments (lenses, binoculars).

The whole system (two sets cannons and fire control system) is powered by electricity, with voltages of 220V AC and 110V DC. In order to work independently of the national electricity network in any place and time conditions, voltages are provided by two sets, running on leaded petrol, with a consumption of 24 l\h, and a generating set of low power, functional unleaded petrol, with a consumption of 1.5 l\h. Thus we can realize the costs involved in preparing a one-man operator, since the basic and advanced skills needed require at least three training phases, each phase taking place over a period of 2-3 weeks.

## 4. FIRE CONTROL SYSTEM GUN*STAR NIGHT SIMULATOR

*GSN SIM* is a simulation program for fire control Gun*Star Night system destined for learning and involvement of the operators and staff, for training and improving their skills in order to shorten the preparation time and training costs.

The model is a multilevel simulator. The FCU simulator (for individual operator) and the console (for staff or instructor) are connected and are working together, sending and receiving data and generating reports to staff about how the operator works.

Simulation software can be a way to train even when, for some reason, the technique is unable to be efficient. It also represents a necessary learning tool for the main menus and submenus and the presentation of the art verification algorithms. In current conditions, modern combat no longer leads through direct contact with the enemy, but it is based on information received from higher echelons or the discovery and tracking of its equipment.

Respecting the laws of modern conflict, fire control Gun*Star Night system flies over the target and gathers information from the research station (radar) to senior and displays them on the video display. Target data are displayed while the operator has selected the option of designating the target by radar and has been aligning with the radar.

If these operations are not performed the display will show data on the flight parameters of the target. Besides fire control interface device, the frame main menu, we created a help menu designed to facilitate the understanding of the operation of the simulator. Everything here may be introduced by the instructor or operator of the target flight and the parameters can evolve.

The success of operations depends not only by the operator, but the staff too; a good planning and a good management of forces will lead to success. If staff doesn't respect the procedures or if plans have some weaknesses, then it is possible to fail mission, even if the operators do everything in according with procedures. Failing a mission can be possible because the system counts all plan's details (location, points of view, no-go or slow-go zone) and too many weaknesses of planning affect the military operation.

The simulator respects the rules and principals of serious games, the rules of real systems simulation [10, 11]. For example, the background of FCU screen is represented by pictures tacked from Capu Midia, the camera can be moved from mouse, the fire trigger has two positions - FIRE/SAVE (Fig. 2).

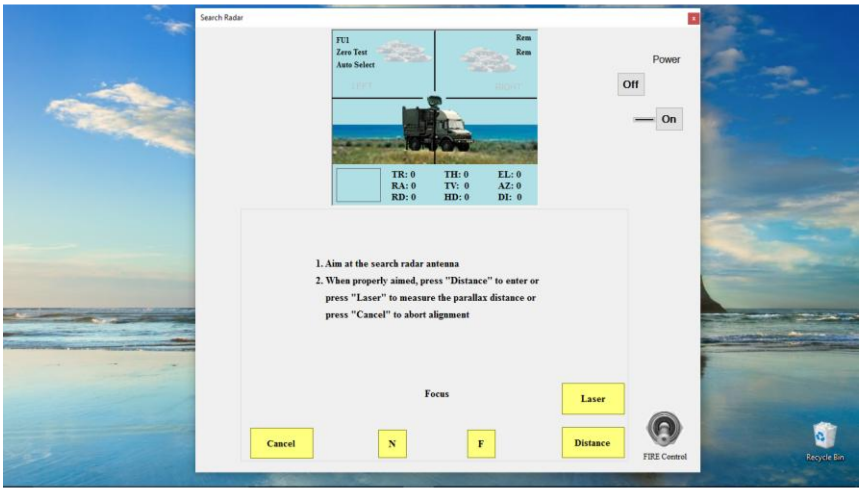


**FIG. 2.** Capture from GSN SIM

The operator or staff/instructor can operate in some different predefined scenarios, each scenario having a different location, weather and targets. Also the weather can be selected by operator or staff (instructor) and can affect the possibility of target combating.

The locations are the same with real locations. They respect the distances, the predefined point of view and the orientation points too, the Nord, no-go or slow-go zone.

Also, in the same idea of respecting principles of serious games, all procedures and activities have their roll in accomplishing the mission successfully.

For example, if the operator doesn't proceed to do the mount adjustment in according with procedures that will seriously affect the fire probability and it is possible to fail the mission.

Another essential point in respecting rules of a serious game is represented by left and right limits of the polygon, materialized on the field. Operators and the staff have to pay attention to the left and right limits of the polygon and these values must be operated from the *Firing menu*. Both – servo and fire sectors – have their roles in working in safety and in air security management. For staff is important to designate the right target to the right GSN and for operator is important not to fire in non-secure area.

It is important to know that the left and right limits have different values, in according with FCUs and AOKs position. The limits value depends of the point of view and the operators have to pay attention to that, because the computer automatically calculates the angles between FCUs, AOKs and limits.

In according with Romanian Army disposal about simulation training, to create a connection between virtual, real and constructive simulation in a multilevel simulation with HLA, in this model we constructed a set of values (data) that are necessary for RTI function, and here are only some examples:

*SearchRadarAzimuthValoare, SearchRadarElevationValoare, FunctionalCheck, SearchRadarDistanceValoare, SearchRadarTiltValoare, GunStarEastValoare, GunStarNorthValoare, GunStarAltitudeValoare, CRPEastValoare, CRPNorthValoare, CRPAltitudeValoare, SearchRadarEastValoare, SearchRadarNorthValoare, GunStarEastTemp, SearchRadarAltitudeValoare, CRPNorthTemp, GunStarNorthTemp, GunStarAltitudeTemp, CRPEastTemp, CRPAltitudeTemp, NrSalve, SearchRadarEastTemp, SearchRadarNorthTemp, SearchRadarAltitudeTemp, ReferencesAzimuth, SearchRadarUnitValoare, ReferencesOrientation, MountElevation, ReferencesElevation, MountAzimuth.*

On the video display device of fire control Gun*Star Night system there are displayed information about the target (Fig. 3).

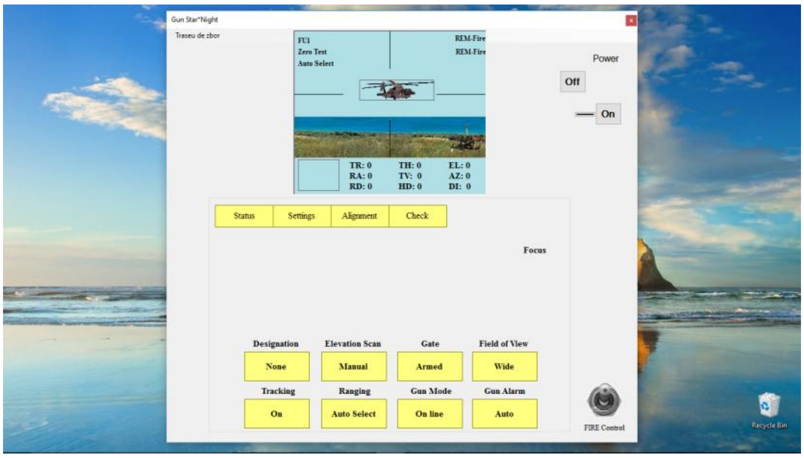


**FIG. 3.** Information about target

This information is vital in engaging the fight, so the operator needs to know and know how to interpret them very well. Next we will present information and their interpretation:

- TR / Track Number: number of targets designated by unit fire;
- AR / Radar Azimuth: angular position value SHORAR-TCP research station to the fire control system;
- RD / Radar Distance: parallax offset distance in feet from the research station;
- TH / Target Height: once target height in meters;
- TV / Target Velocity: target speed in m/s.

Information designated by the discovery and identification of its equipment:

- HD / HIT Distance: distance measured to the point of impact between the target and the projectile beam, calculated in meters;
- EL / Line of Sight Elevation: elevation angle of the target to fire control system;
- AZ / Line of Azimuth: azimuth angle of the target to fire control system;
- DI / Target Distance: distance inclined to direct fire control system to the target;
- T / Distance Tracing Mode: how to determine the distance to the target.

On the other side the simulator respects the number of fire, the probability on hit a target; if a target is in the fire area and the operator, with a well prepared system, succeeds to open fire against target with 6 to 8 shots, then there is a big probability to hit and accomplish the mission.

If the FCU's operator doesn't succeed to open fire or the number of shots is insufficient, then the target will fly away or can hit the system, and that means the mission is failed. We will exemplify that with some codes realized in VisualStudio focused on opened fire:

```
private void FireButton_MouseDown(object sender, MouseEventArgs e)
{
if((NorthDirection == true)&&(OpticalSight == true)&&(AOKsGuns1 ==
true)&&(AOKsGuns2 ==true)&&(SearchRadar == true) &&(MountAdjustment == true))
```

```
{
 if ((NrSalve >= 6)||( (NrSalve =< 8)))
  {
   Explosion.Visible = true;
   field.Location = new Point(flagX, flagY);
   nori.Location = new Point(70, 16);
   nori1.Location = new Point(204, 27);
   Target.Visible = false;
   difference = 0;
  }
  else
 {
 FireButton.Image = Image.FromFile(@"\\ON.gif");
 if((NorthDirection == true)&&(OpticalSight ==
 true)&&(AOKsGuns1 == true)&&(AOKsGuns2
 ==true)&&(SearchRadar ==
 true)&&(MountAdjustment == true))
 if (countpozitie < 700)
 {
 legaturatun1.Text = "REM-Fire";
 legaturatun2.Text = "REM-Fire";
 NrSalve = NrSalve + 1;
 System.Media.SoundPlayer player = new
 System.Media.SoundPlayer(@"\\fire.wav");
 player.Play();
 difference = -1;
 }
 else
 {
 field.Location = new Point(flagX, flagY);
 nori.Location = new Point(70, 16);
 nori1.Location = new Point(204, 27);
 LeftButton.Visible = true;
 RightButton.Visible = true;
 Target.Visible = false;
 difference = 0;
}}}}
```

In that new *GSN SIM* we implemented the rules of engagement: the target with the highest value is the most important target; more than that, the operator has the opportunity to combat a target and on command or by himself he can combat another target, according with the operation plans.

In order to test the way that an operator respects the rules of engagements, in *GSN SIM* there are present some air and field targets, in a check list. The operator or instructor has the possibility to choose one or more targets to be combated. Also one can select the order and time for action and these targets will respect the list.

This *GSN SIM* will be connected with another simulator model, like *Microsoft Flight Simulator* or *JCATS (Joint Conflict and Tactical Simulation)* in a multilevel simulator, via HLA standard.

This multilevel simulation model will train aviation, air defense artillery and radar, working together, and staff will be able to plan a joint operation, and more than that, will be able to see if these plans are available or not. The rehearsals, with minimum resources spending, will play the central role: what better.

## CONCLUSIONS

Simulation can save financial resources, materials, time and, last but not least, human. Also, the diversity decision algorithms can be tested using the simulator, just respecting the initial conditions. In this way you can obtain optimal peak performance without spending any additional resources or alternative optimal algorithm.

Regardless of the number of hours the operators spend practicing in front of a simulator, regardless of their level of preparation (simple or advanced students) technique will not suffer as a result of “experiments” that could be taxed.

When the operator and staff are well prepared, when discovered, through experience, which is the best algorithm to follow and the best decision to be taken at a given time, then they can shift the actual equipment in the best conditions. Military educational institutions in the field do not have at the moment a simulation program of fire control Gun*Star Night system, so the present program could be a useful tool for training students or trainee officers.

Currently, in the Romanian army antiaircraft artillery gun there is a program for simulation equipment operator’s anti-aircraft artillery, but the only occasions for training in real conditions are those of the polygon of drawdown conducted missions. This is an expensive method. Therefore, simulation software is intended as a first step in the field.

In the future, according with new simulation training doctrine in Ro. army, we intend to connect all individual simulators in a multilevel simulator and this is a first step in that direction. If we will be able to train a structure of the air defense battalion level (3 Air Defense Battery and C2 structure) with this simulator, definitely we will succeed to connect all simulators in one multilevel simulator.

The key for complex simulation training is represented by serious games, connected via HLA standard in multilevel simulators. Finally we will be able to say that the passion for air defense weapon, for the aviation, radar and air defense artillery has regained the place it deserves: a weapon of first-class, among weapons that can decide, in just the first two hours armed conflict, whether the fight is won or not.

## REFERENCES

[1] *** North Atlantic Treaty Organization. *NATO Modeling and Simulation Master Plan*, Draft v 0.2.2. NATO Working Paper AC/323-WP02, 1998;

[2] R. M. Fujimoto, *The Management in The High Level Architecture*, Computational Science and Engineering Division, College of Computing, Georgia Institute of Technology, Atlanta, 1998;

[3] *** IEEE New Standards Committee (NESCOM). *Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Object Model Template (OMT) Specification*, IEEE Project Authorization Request (PAR) 1516.2, 1997;

[4] B. P. Zeigler, H. Praehofer, and T. G. Kim, *Theory of modeling and simulation: integrating discrete event and continuous complex dynamic systems*, 2000;

[5] *** NATO Modeling and Simulation (M&S) Orientation Course, ADL Course, Marshall PfP Consortium;

[6] *** Pitch Technologies AB, *The HLA tutorial a practical guide for developing distributed simulations*, Sweden, 2012;

[7] O. Topcu, *Simulation Generator (SimGe) – 0.2.6 user manual*, 2014. Available on: http://user.ceng.metu.edu.tr/~otopcu/simge/docs/SimGeUserManual_026.pdf;

[8] *** Oerlikon Contraves, *GDF – 103 AA Drill book Oerlikon*, Oerlikon Contraves Publishing House, 2002;

[9] *** *Air defence artillery operator’s training manual – Land Forces*, 35 mm Oerlikon System, MOD Publishing House, 2008;

[10] Gh. Barbu and M. Miroiu, *Simulation Techniques*, Technical Publishing House, Bucureşti, 2012;

[11] K. Velten, *Mathematical Modeling and Simulation*, John Wiley and Sons, New York, 2009.