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ADDSIM: A NEW KOREAN ENGAGEMENT SIMULATION ENVIRONMENT USING HIGH RESOLUTION MODELS

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ABSTRACT

AddSIM is a simulation environment for integrating models such as platforms, sensors, command and control systems, and shooters into the same synthetic battle field. AddSIM aimed to integrate the models which were developed and used during each weapon system development phase. AddSIM consists of four components; user interface including resource repositories, simulation engine (kernel), external interface, and support services. The user interface is a set of tools to make models, set-up scenarios, check execution options, run the kernel, and analyze the simulation results. The kernel can manage discrete-event and discrete-time hybrid simulations and run the simulation in stand-alone or distributed modes. It can also support parallel simulations. AddSIM can interoperate with legacy models in various forms, C/C++, MATLAB, HLA/RTI, and DIS, through the AddSIM external interface functions. The support services are environmental services (terrain, atmosphere, and maritime), spatial service, journaling/logging service, and utility service.

1 INTRODUCTION

Defense M&S (modeling and simulation) takes big and essential part in the defense domain from element drawings to operational researches of system of systems.(Piplan, Mercer and Roop 1994) The defense M&S is classified by their resolutions into theater, mission, engagement, and engineering levels. In Korea, the lower resolution models, theater and mission level, have been used for war games and battle experiment by JCS, Joint Chiefs of Staff, and the forces of Korea. The higher resolution models, engineering and engagement level, have been used by ADD, Agency for Defense Development, and defense industries for the weapon systems R&D. (JCS 2011; JCS 2012)

Thanks to U.S., Korea could obtain many of them and also JCS, forces and related industries have made many efforts for these models. The models do their roles on each position. These applications have some elements such as model, data, simulation logics and simulation environment. We think about the current status of each elements of Korea defense M&S models. About simulation logics and simulation environment we have no problem, because we know well about the Korean tactics and obtain the simulation engines for each application. But Model and Data have problems. The models have different resolutions.

That means there are many difficulties to find relations between models. Some major models and data were from U.S. So there is no data for Korean weapons. We have to generate them by ourselves. But unfortunately the know-how about them is very limited. Because of that, the results of the models have some difference from that of real systems.

In addition, let's think about the battle field in the future. The future weapon systems have complex dynamics because they are fast, precise, multi-functional, and so on. And future warfare is Network Centric Operational Environment integrating sensors, networks, commands/controls, and shooters. So, currently there are many studies to analyze multi weapon systems engagement. (Jeon 2006; Kim 2011) Jeon et. al studied guidance law of coordinating multiple anti-ship missiles to enhance those weapon effect. They needed to simulation of multi missile model. On the other hands, Kim et. al introduced defense strategies from the multi attacks using multiple anti-air missiles. They also needed to multi engagement simulation. There are many options to achieve the goal. First primitive way is duplicating the source code directly might be Jeon and Kim do. That is easy to implement but hard to maintain and expend to larger number of missiles or other various scenarios. The other way is using the legacy mission or engagement tools. They have some limits because of bellows:

1. When we use the tools, we must simplify the model in applicable form. But sometimes that is very difficult especially for complex systems.
2. The Data loss due to the aggregation is unaffordable
3. The needs of users such as decision makers, analysis operators and war-fighters of forces to know more about the battle field are increased.

To overcome these limits, many M&S experts suggested ideas for engagement/mission level M&S using high resolution engineering models. (McQuay 2000; Lauzon, et. al 2001; Urban and Hawlay 2004) McQuary suggested JMASS, Joint Modeling and Simulation System, for integrate US air force models. Lauzon et al made a library of C++ legacy weapon system models wrapped with MATLAB and interoperating them via HLA/RTI. Urban et al just introduced to make models as C++ classes in proposed standard structure and direct link them. ADD also try to obtain a new Korean simulation environment named AddSIM. The characteristics of AddSIM is presented in follow-on chapters. Comparing to legacy mission/engagement simulations, in the engagement simulation with high resolution models, it is more important issue that how to standardize weapon system models to be components which can be plug-in and play on the same simulation engine.

2 HIGH RESOLUTION MODELS

2.1 Definition of High Resolution Models

Before starting introduction to AddSIM, it is needed to define high resolution model. We define them the models used in R&D phase. They used for system design, performance estimation, and T&E. Among them, we focused on system level M&S such as trajectory simulation with dynamic model including position, velocity, acceleration and so on. Also they include embedded SW. The system level M&S can simulate almost behaviors of the real systems with high fidelity.

The reason why we focused on the high resolution models is that ADD is the unique institute of Korea for weapon system R&D. That means ADD has almost high resolution models of Korean weapon systems. Also, because of our very short R&D history for modern weapon systems. M&S legacies of ADD are very recent and normalized. Therefore, standardizing and integrating the high resolution models of ADD using AddSIM is easier than that of other counties.

2.2 AddSIM Vision

Basically AddSIM can be used by developers of ADD for analyzing weapon effectiveness considering operational environment. After some further studies, high resolution defense analysis models for each battle-field such as ground, naval, air and space will be developed. The analysis models will support more accurate defense analyses of JSC and forces of Korea.

To achieve this vision, we made a Korean M&S technology roadmap as Figure 1.

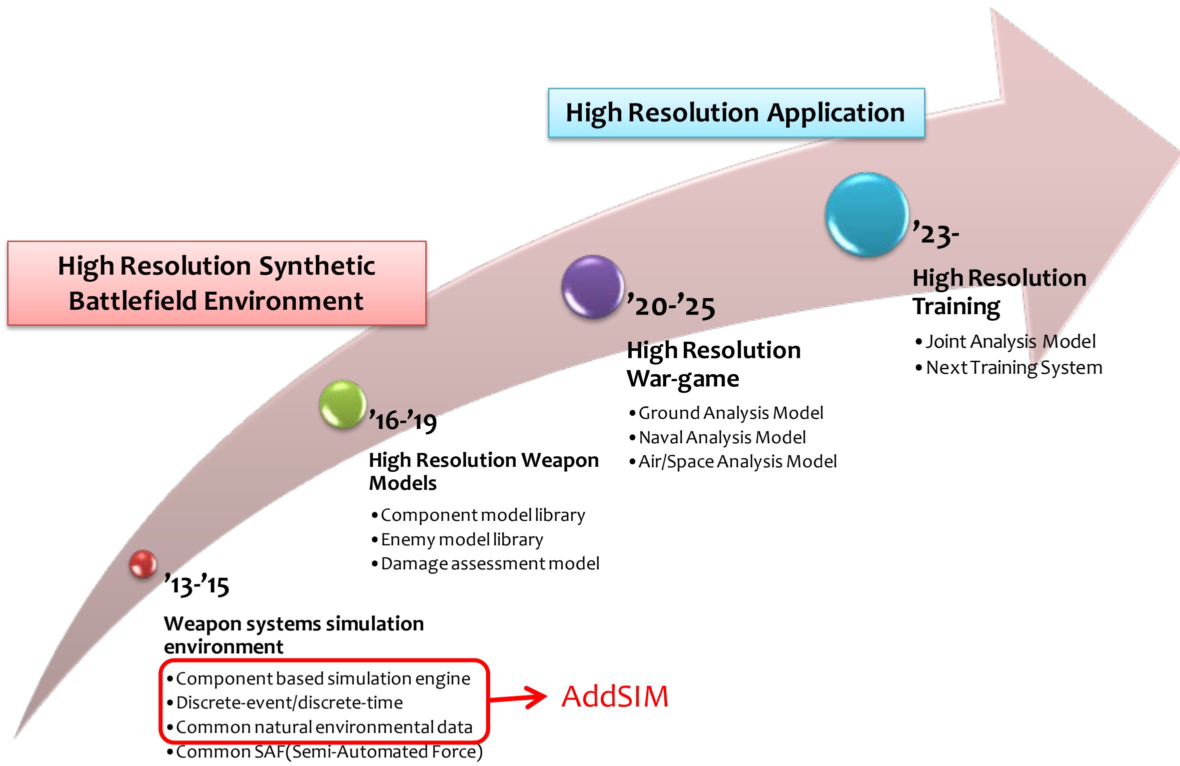

Figure 1: Korean Technology Roadmap for High Resolution M&S.

Left side of the roadmap is key technology development phase to build 'High Resolution Synthetic Battlefield Environment' and right side is application system development phase to build 'High Resolution War-game and training.'

In the first step we start with weapon systems simulation environment including Component based simulation engine, Discrete-event/discrete-time, Common natural environmental data, and Common SAF (Semi-Automated Force). In the second step High Resolution Weapon Models will be obtained in form of libraries. After that we can make these applications. The project of the red highlight area is AddSIM project.

The final goal of High Resolution War-game model consists of GUI, AddSIM as the simulation engine, models of weapon systems and humans, and high resolution natural environmental data.

3 ADDSIM PROJECT

AddSIM is a component-based simulation environment for integrated M&S systems. AddSIM is Common M&S infrastructure for composing and reconfiguring M&S models, especially high resolution weapon system models, in plug-and-play way. AddSIM project is a key technology development of ADD. We finished the advanced research in the end of 2011(Lee, Lee, Kim, and Baik 2012; Oh and Kim 2011; Oh, Kim, and Kim 2012) and we are in applied research phase from Oct. 2012 to Sep. 2015. The main contractor for developing prototype is SIMNET in Korea. Department of industrial engineering in UCF (Univ. of Central Florida) is conducting a project for LVC interoperability of AddSIM.

AddSIM is a simulation environment for integrating M&S models of sensor, shooter and information systems. AddSIM aimed to integrate the models which were developed and used during each weapon system development phase. AddSIM users can make their own models according to minimum AddSIM coding rules, simulate them in synthetic battle-fields, and analyze their weapon system effectiveness by interoperating with other weapon models.

Figure 2 shows the operational concept of AddSIM. AddSIM is installed on a local computer. Users can develop models, setup simulation scenarios, execute, and get the results with GUI. Developed models are saved in the repository. The instances of the participant models are configured on the background map. AddSIM can accommodate models on remote computer's repositories and legacies in various form through external interface module. After the simulation, the users can check the results as text files or 3D visual.

AddSIM consists of five components; simulation engine (kernel), user interface, resource repositories, support service, and external interface. The kernel can manage discrete-event and discrete-time hybrid simulations and run both of stand-alone and distributed modes. It can also support parallel simulations. The user interface is a tool to make models, set-up scenarios, check execution options, run the kernel, and analyze the simulation results. The resource repositories are rooms for the models of weapon systems. AddSIM users can publish their models for being reused by others and search the published models for reuse. The support services are environmental services (terrain, atmosphere, and maritime), spatial service, journaling/logging service, and utility service. AddSIM can interoperate with legacy models in various forms, C/C++, MATLAB, HLA/RTI, and DIS through the AddSIM external interface functions.

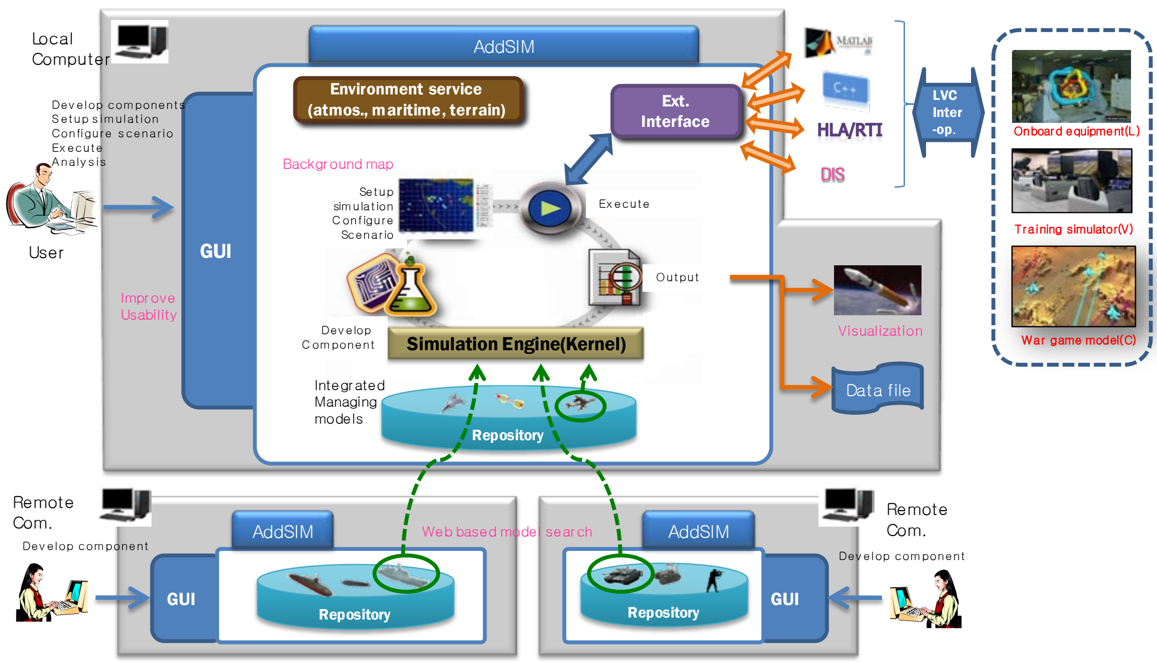

Figure 2: Operational concept of AddSIM.

The software architecture of AddSIM is shown in Figure 3.

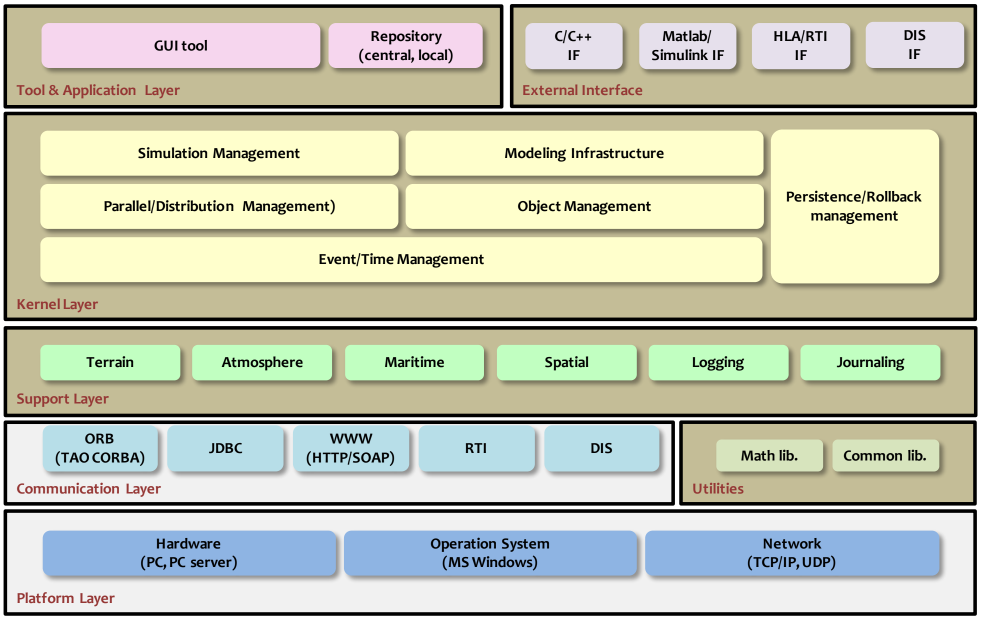

Figure 3: SW architecture of AddSIM.

To perform the AddSIM project, we selected a development procedure based on build concept shown in Figure 6. At the end of 2013, a prototype of AddSIM build #1 was developed and tested and in 2014 we develop AddSIM build #2 with revised requirements. After developmental test we can finalize AddSIM ver. 2.0 in 2015.

4 ENGAGEMENT ANALYSIS PROCESS USING ADDSIM

To analyze an engagement simulation using AddSIM, users have to follow the operational process in Figure 4.

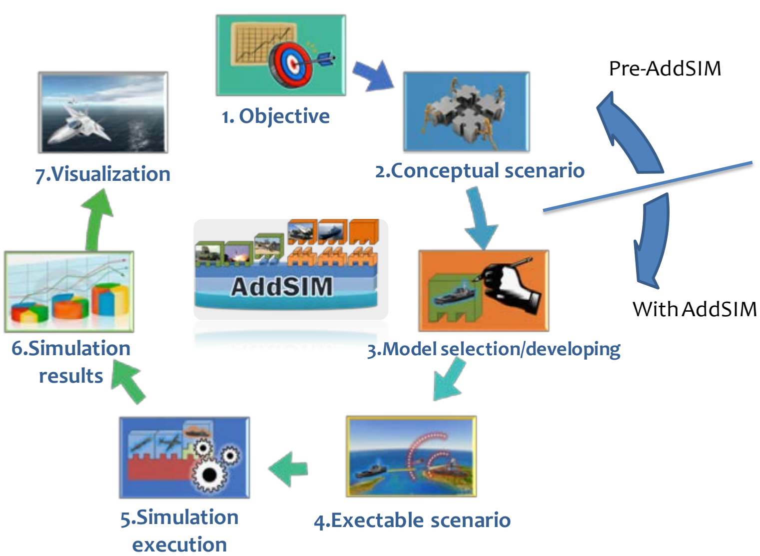

Figure 4: Operational process of AddSIM.

The process consists of 7 steps. The First 2 steps, objective and conceptual scenario, have to be done by user without AddSIM and the least are with AddSIM as follows: 3. Model selection/developing, 4. Executable scenario, 5. Simulation execution, 6. Simulation results, and 7. Visualization.

Following these processes, weapon system developers can make engagement simulations of their own system model with high fidelity models of other enemy and/or friend weapons. Once the simulation is built, they can easily check the weapon system effectiveness in various scenarios such as not only 1:1 but also N:M cases. Additionally they can use various natural environmental data and utility functions which help them to build their models. At the end of every simulation run, AddSIM can generate outputs in forms of text files and visualization such as SIMDIS(GOTS Software of US Navy) and Vega(a commercial visualization product of Presagis Inc.).

5 ADDSIM: GUI TOOLS

AddSIM GUI, Graphic User Interface, tools provide functions such as model development, simulation execution, result analysis, and using repository for the purpose of engagement simulation of weapon systems. The first appearance of AddSIM is shown in Figure 5.

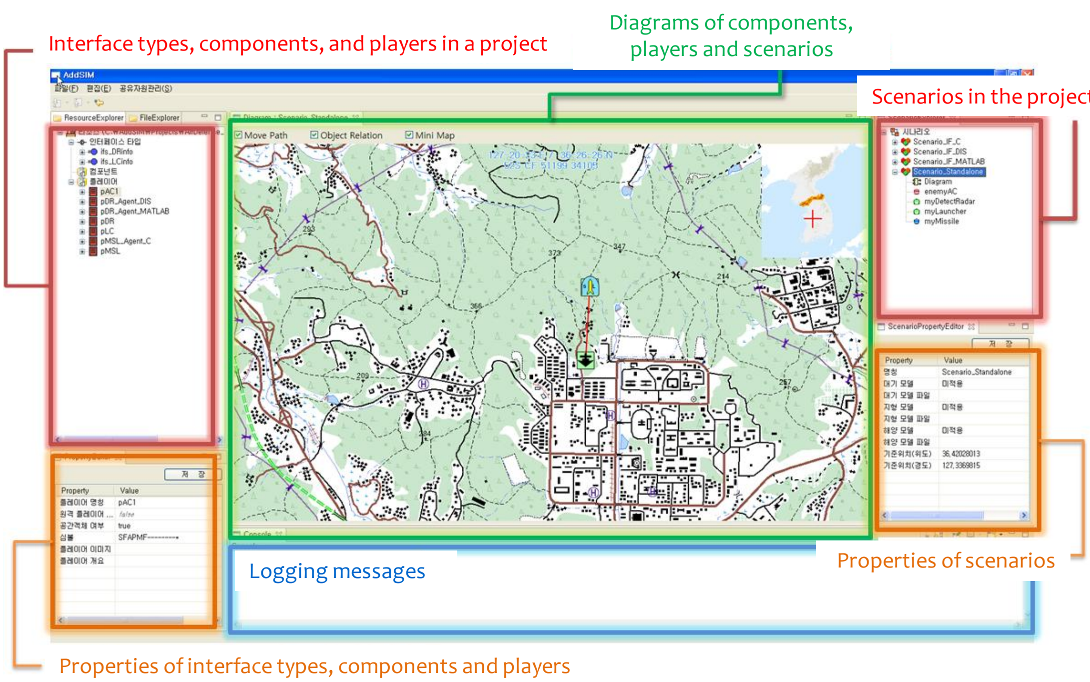

Figure 5: AddSIM GUI tools.

The first function of AddSIM GUI tools is model development. The users can handle each engagement analysis simulation as an AddSIM project. Using the GUI, users can develop skeleton codes of the models in intuitive way. After the code generation, users can add user logics via Mircosoft Visual Studio 2008 which is pop-up by double clicking inside the GUI. We define 'player' as a system model representing its own behaviors and functions separated from other systems. Inside the player we can make multi-components for the dynamics or functions of sub-systems. The basic functions to handle the weapon system player are developed in Build #1. The assessment player which independently generates the engagement result between 2 players and interface player which is a ghost player of other legacy models such as C/C++, MATLAB, HLA/RTI, and DIS legacies are developing in Build #2. The developed models are saved in AddSIM model repository. The other or same user can find and reuse them in various ways, referencing it in remote computer or downloading it to the local computer. For the convenient finding models, AddSIM will provide searching web pages.

The second function is scenario development. GUI provide tool for making scenario, instancing players and setting scenario properties – initial data of each player instance, reference position of the scenario, and natural environment model. AddSIM GUI provides 2 views to developing scenarios, scenario diagram showing players position on background map and relationship diagram displaying the interfaces between instances of players.

After setting a scenario, simulation execution tool allows user to select some options for executing the simulation such as simulation type, repeat time, execution speed, end time of simulation, time synchronization period, restore option, log option, and parallel simulation option and execute it. During executing the GUI display the running logs for the user.

The last one is analysis tool. Users can generate the results as text files in CSV (Comma Separated Value) and visualize in 3D linking with SIMDIS and Vega.

6 ADDSIM: SIMULATION ENGINE (KERNEL)

For the purpose of achieving the roles of AddSIM, the simulation engine has to do many functions such as Time/event management, Simulation/object management, Parallel/distribute management, Persistence management, Batch/Monte Carlo simulation and Stand-alone execution mode as shown in Figure 6.

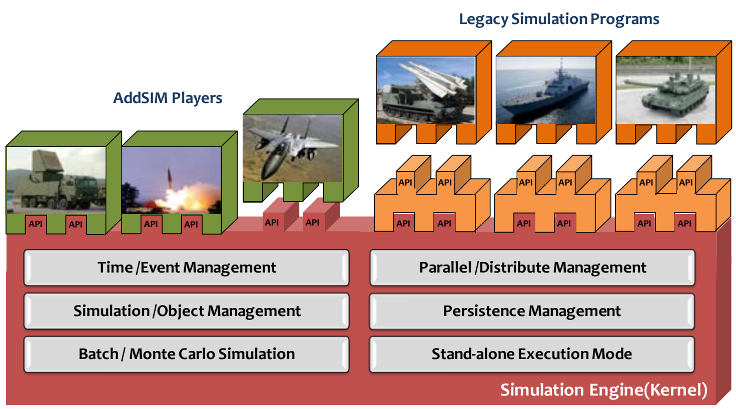

Figure 6: AddSIM simulation engine.

Time/event management provides functions to manage simulation time and process sequences of events. It gives a function of (soft) real time synchronization, discrete event simulation that models are executed as a discrete sequence of events in time, and management based on global event list.

Simulation/object management provides functions to control creation/execution of a simulation and to manage running objects on memory. It activate the background service for creating simulation instances, controls execution of a simulation (start, suspend, resume, stop), manages loading/instantiation/execution of DLLs for plug & play, and automatically switches between stand-alone and network distributed mode.

Batch / Monte Carlo simulation provides functions to run a batch simulation or a Monte Carlo simulation. Batch simulation allows automation of repetitive executions according to the scenario batch option. Monte Carlo simulation can concurrently run on multi-computers and/or multi-cores environment with multiple seeds.

Parallel/distribute management provides functions to run parallel and distributed objects simulation based on multi-processors and multi-cores. We implemented BTB, Breathing Time Bucket, and LA, look ahead, algorithm for parallel and distributing simulation mechanism using TAO, the ACE ORB (Object Request Broker).

Persistence Management Provides functions to recover from failures power failures, deliberate/accidental reboots, and hardware failures.

7 ADDSIM: EXTERNAL INTERFACE

AddSIM also provides external interfaces to accommodate legacy models which are already made in C/C++, MATLAB, HLA/RTI and DIS.

For interfacing C/C++ and MATLAB legacy models, AddSIM provides time and data synchronizing libraries based on the socket communication with client-server architecture. (Kim, Oh and Hwang 2013)

The HLA/RTI external interface (MAK RTI) helps model developers use RTI services and implement callbacks easily. The DIS external interface (Open-DIS) support DIS interoperability using formatted PDU and multicast over TCP.

8 ADDSIM: SUPPORT SERVICES

AddSIM equips some support services to improve user's convenience. Support service consists of natural environmental service, spatial service, journal/logging service, and utility service.

The natural environmental service can be divided into 3 parts which are atmosphere, maritime, and terrain. Atmosphere service provides 1 dimensional standard atmospheric model, user defined data or 3 dimensional high resolution analyzed data which are supplied from NIMR, National Institute of Meteorological Research. The 3-D atmos. data are 5 km and 1 hour gridded data in Korea peninsula. Model developer makes his/her own code for using AddSIM atmosphere service with atmosphere service API (Application Programming Interface). On scenario phase, users can select what data which will be applied to the simulation.

Maritime service also provides its API to use 1-D model or 3-D data. The 3-D data are obtained from the naval weapon system development institute of ADD.

Basically, AddSIM runs based on WGS84 ellipsoid earth model and DTED data. And AddSIM is designed to handle FDB(Feature Data Base) of the Korean peninsula from KDGIA, Korea Defense Geospatial-Intelligence Agency.

Terrain service provides some terrain function API's as follows: LOS(Line-Of-Sight) analysis, converting between Lat, Lon Coordinates ↔ ENU Coordinates, and FDB(Feature Data Base) handling.

Spatial service manages the spatial data of all weapon players in the simulation such as position, attitude, velocity and so on. Users can query the spatial information from the spatial DB. Because of spatial service, there is no need to interface directly between a weapon model and its enemy model. It is also needed to manage parent/child relation among them and dead reckoning function for improving simulation performance.

Journaling service journal all attributes of players and events along with time for after simulation review and roll back of parallel simulation. Logging service displays log messages during simulation running. The log messages have been defined in AddSIM simulation engine or user codes.

Utility Service provides math and common engineering utility API listed in Table 1.

Table 1: Utility list of AddSIM.

Cat.	**API**
Matrix	AB, A×B, A+B, A-B, A', A-1
Coordinate transform	DCM↔EULER, Quat LL↔Az, Range LLA↔ENU
Interpolation	Interpol
Random	Uniform, Gauss

9 EXAMPLE: AIR DEFENSE SIMULATION

As an example to application of AddSIM, We select an air defense scenario in Figure 7 (Oh 2011).

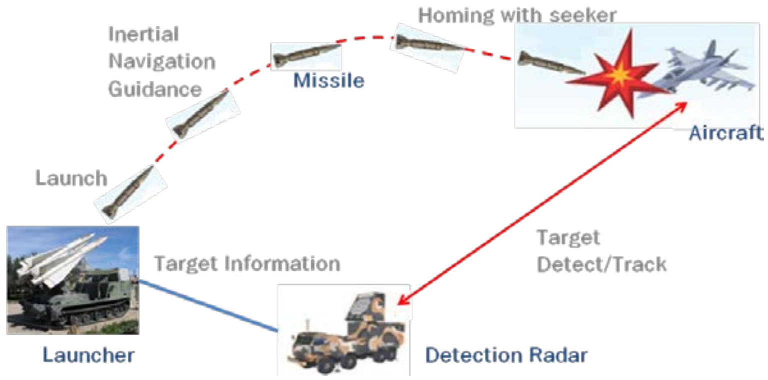

Figure 7: Air Defense Engagement Scenario.

When an aircraft is coming into the engagement area, a detect radar detects it and sends the target information to a launcher. Receiving the information, the launcher calculates the launch direction and the mid-course way-point of inertial navigation guidance, injects the way-point to a missile, and gives launch command to the missile. After taking off, the missile flies to the way-point with inertial navigation system. Reaching the way point, the missile starts homing guidance with its own seeker. If the aircraft detect the missile coming with its own radar, it does an evasive flight within its maximum maneuverability.

We integrated 4 weapon system models: aircraft, detect radar, launcher and missile from the reference(Oh 2011). Each model pretends to be an high resolution model of the specific system which is used to analyze the MOP, Measure-Of-Performance, of each system during the system development phase. It has the similar program structure and interface for inter-operation to those of the real system's simulation.

Figure 8 shows a batch simulation result of air defense simulation in case that a detect radar, a launcher and a missile in the position (0, 0, 0) and a aircraft is initially in various positions identified from 1 to 25 in the figure.

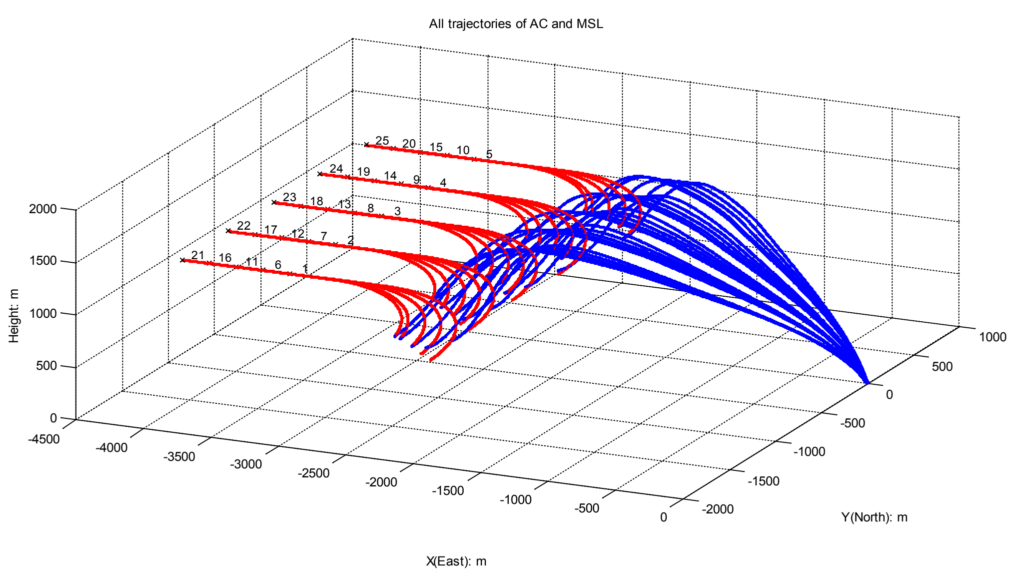

Figure 8: Batch Simulation Result of Air Defense Simulation.

Figure 9 shows contour plots of final miss distance in meter between the missile and the aircraft with respect to the initial positions of the target aircraft. If we assume that the effective range of missile's warhead is 10 m, the aircrafts started in the area of higher miss distance right side of 10m contour line can be alive but the lower killed.

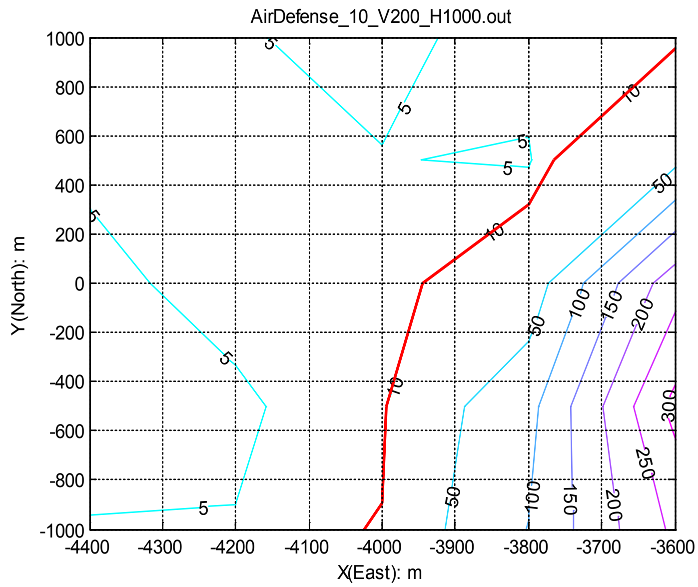

Figure 9: Contour plot in case the aircraft flies 200m/s in speed and 1km altitude.

A single engagement simulation is 3D visualized with SIMDIS and Vega in figure 10.

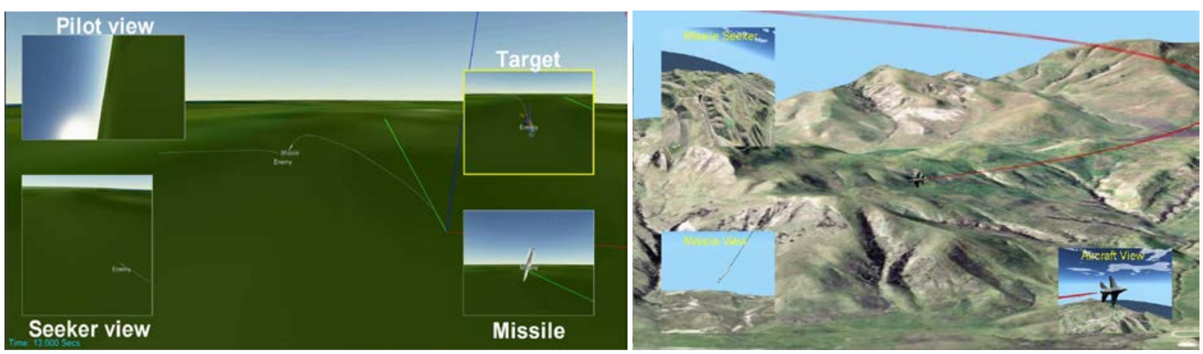

Figure 10: Visualization with SIMDIS(left) and Vega(right).

10 CONCLUSIONS

Considering current status of Korea defense M&S and future battle field, high resolution war-games are highly needed. To develop the high resolution war-game models, we set up a technology roadmap. As the basis of the roadmap, we proposed AddSIM which is component based weapon system engagement simulation environment.

AddSIM consists of five components; simulation engine (kernel), user interface, resource repositories, support service, and external interface. The kernel can manage discrete-event and discrete-time hybrid simulations and run both of stand-alone and distributed modes. It can also support parallel simulations. The user interface is a tool to make models, set-up scenarios, check execution options, run the kernel, and analyze the simulation results. The resource repositories are rooms for the models of weapon systems. AddSIM users can publish their models for being reused by others and search the published models for reuse. The support services are environmental services (terrain, atmosphere, and maritime), spatial service, journaling/logging service, and utility service. AddSIM can interoperate with legacy models in various forms, C/C++, MATLAB, HLA/RTI, and DIS through the AddSIM external interface functions.

AddSIM build #1 was developed successfully at the end of 2013. We will upgrade it and finalize AddSIM build #2 until 2015.9.

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