Developing and Deploying the Thai Army Tactical Trainer using HLA 1516

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ABSTRACT: *The Army Tactical Level Advanced Simulation (ATLAS) is a three-year research and development project spanning the period of 2002-2005. It will be deployed during 2005-2006. The purpose of the ATLAS project is to develop a tactical-level simulation for use at the Command and General Staff College of the Royal Thai Army to train staff-level officer students during annual command post exercises and to transfer world-class software development skills to the military. The federation consists of both locally developed federates and imported COTS systems.*

While initially using HLA DoD 1.3 the decision was taken during 2003 to switch interoperability standard to HLA IEEE 1516 to ensure that ATLAS is compliant with emerging standards. The current ATLAS implementation uses most of the functionality of the HLA 1516 standard. It makes extensive use of HLA 1516 DDM. Some experiences from this are presented including suggested alternate designs.

A partial system has been used for exercises from August 2004 and on. The full system will go live in August 2005. The project also plans further deployment throughout the Thai Army.

1. Simulation in the Thai Defense

Combat simulations were first introduced into the Royal Thai Army (RTA) in 1967 when the Command and General Staff College (CGSC) incorporated the use of wargames into the curriculum [1].

1. 1 Background

These initial wargames conducted at the CGSC were based on battle boards, with combat outcome being determined by the roll of the dice. These games were continually refined and were in use up to the mid-Seventies.

A working group was formed within the Military Research and Development Center (MRDC) several years later, to create a computerized version of the wargame. A system was developed, and first deployed at the CGSC in 1982, which enabled simulation of attrition resulting from close combat, direct and indirect fire, and close air support.

System enhancements based on advances in hardware and network technologies continued throughout the mid-Eighties. Separate monitors for the friendly and opposing forces were introduced, while advances in software development enabled simple cell-based terrain representation, and continuous simulation of Unit location and combat effectiveness.

In the late-Eighties, further developments including experiences gained from the Cobra Gold joint military exercises were incorporated into a second version of the MRDC wargame.

That version of the system had been in use at the CGSC continuously up to 2001 when it was replaced with the Joint Theater Level System (JTLS) based at the Supreme Command Headquarters (SCHQ).

1.2 Current Plans and Policy

The CGSC requires, as part of the curriculum, tactical-level simulation capabilities. Plans are now in place to test a newly developed system in March and August 2005, with deployment to follow.

One aspect of the CGSC mission is to facilitate the use of combat simulations in military exercises conducted throughout the RTA. There currently exists an opportunity to deploy the newly developed system in several regions throughout Thailand.

The new system, described in this paper, was developed in accordance with the Army [2], Ministry of Defense [3], and National research policies [4].

2. ATLAS - Army Tactical Level Advanced Simulation

2.1 Purpose

The primary purpose of the ATLAS project was to develop, over the period 2002 to 2005, a tactical-level simulation prototype to support Command Post Exercises (CPX) conducted by the CGSC to train staff-level officer students.

The secondary objective was to transfer world-class software development processes and technology to the military, enabling them to develop more sophisticated and advanced applications within their specialized domain.

2.2 Command Post Exercises

A CPX consists of both live and constructive simulations [5], [6]. The staff-level officer students (participants) assume the roles of Division commanders and their staff. These participants, situated in a Command Post (CP) use actual military command and control equipment such as field telephones, radios, and composite 1:50,000 scale maps with a multitude of overlays – products of the Intelligence Preparation of the Battlefield (IPB) process [7].

Communication equipment connects numerous CPs within their chain of command down to the Unit commanders whom translate policy, doctrine and mission parameters into specific maneuvers for input into the simulation.

The actual forces that they command (infantry, cavalry, artillery, etc.) are simulated entities within the computer and appear as icons on a map of the battlefield. Unit movement over terrain, consumption of supplies, and outcome of engagements are among the responsibilities of the constructive simulation. Status reports are fed back to the participants, to the "live" part of the exercise, and up the chain of command, for further tactical decisions.

The CGSC exercises are scheduled to run from 0900 - 1500 each day, and continue for four consecutive days. The battlefield clock is set to run at twice real time, simulating a time period from 0600 - 1800. This places some time pressure on the students, and instructors alike.

At the conclusion of the exercise, an After-Action Review (AAR) takes place. This is a formal process where performance is assessed against training objectives, and doctrine [8], [9].

Within the CPX, ATLAS fulfills the constructive simulation requirements.

2.3 Development History and Plans

Infowave (Thailand) Co., Ltd. was contacted in 1999 to discuss the possibility of providing expertise in the area of Object-Oriented (OO) technology and the Unified Modeling Language (UML) to the CGSC.

Those early discussions led to preliminary research on the current state of simulation technology and a decision was made very early on to adopt the High Level Architecture (HLA) standard for interoperability.

Our technology induction program for the CGSC started in 2001 when ten officers were put through an intensive 5-day course in Object-Oriented Analysis and Design with UML. The formal project kickoff occurred in 2002 when we developed the project's Vision and Operational Concept documents, following the completion of a course in Requirements Management with Use Cases.

A research lab was established at the CGSC providing us with full access to the domain experts. We were able to interview instructors, brief students, and observe the exercise planning process.

We adopted the iterative Unified Process as our software development process and supplemented it with practices for operational concepts [10], project management [11], federation execution [12], and verification, validation, and accreditation [13].

During the elaboration phase, the team received formal training in the Java Programming Language and the Capability Maturity Model for Software [14].

2.4 Overview and Participating Systems

Our software architecture includes commercial-off-the-shelf-software (COTS) such as digital map rendering software, HLA IEEE 1516 runtime infrastructure (RTI) software, and distributed Object-Oriented databases.

Several applications were developed to support ATLAS, including a graphical tool for creating Unit prototypes. In collaboration with Jane's Defense, we experimented with eXtensible Markup Language (XML) files containing full specifications of weapons, vehicles, and equipment.

This concept of a Unit prototype enabled ATLAS to be more responsive to the RTA's training needs by fulfilling an ambitious goal of reducing the Unit preparation time of several months [15] down to several days.

One of our many design goals was to eliminate the discrepancy between the 1:50,000 scale maps that the students use and the digital representation of the same terrain within previous simulations. This goal was realized by replacing cell-based terrain representations with digital maps (raster and vector files) from the Royal Thai Survey Department (RTSD).

The raster images provided graphics consistent with the standard paper maps used by students, while the vector files provided a continuous terrain model consisting of lines and polygons with respective properties such as vegetation type and density, road width and surface composition, populated areas, and irrigation – factors which dictate the maneuverability of Units.

Logistics processes modeled include the consumption and re-supply of Class I (subsistence), Class III (fuels lubricants, greases, and other petroleum products), and Class V (explosives and other munitions or pyrotechnics) supplies.

Statistical distributions that influence the "fog of war" and "friction of war" are also being incorporated into ATLAS.

Finally, in order to fully support the Army's training needs, ATLAS is being built with an AAR mechanism, where significant events can be replayed, and lessons learnt documented.

3. Choosing a Standard for Simulation Interoperability

3.1 Overview of Interoperability Standards

HLA was developed in the mid 90's as a general simulation interoperability standard to replace two earlier standards: Distributed Interactive Simulation (DIS) and Aggregate Level Simulation Protocol (ALSP). DIS mainly applied to real-time, platform level simulation and provided no time management. ASLP mainly applied to discrete-event, logical-time simulations. After some experimental version the first complete version of HLA was called HLA 1.3. It was released as a US Department of Defense (DoD) standard. A free RTI for HLA 1.3 was also provided and maintained by the US Defense Modeling and Simulation Office (DMSO).

Since the intent was to address a broader market and promote COTS the HLA 1.3 standard was transferred to IEEE after some improvements. The first IEEE version of HLA was released in 2000 and is called IEEE 1516-2000. The development of the previous HLA 1.3 standard has ceased. The free RTI implementation from DMSO is no longer available. Several companies now provide HLA software such as RTIs on a commercial basis.

The US DoD now mandates the use of HLA IEEE 1516 and transition is underway. Several countries in Europe and Asia who do not have a large investment in HLA 1.3 systems have migrated faster than the US. Examples of countries with extensive HLA 1516 use are Sweden and Japan. Since the HLA 1516 standard is an open, transparent and international standard it has also started to attract civilian industry. Examples of this include medicine, offshore oil production, space industry and car manufacturing.

The next version of HLA, "HLA Evolved", is now under development. This standard is expected to be available late 2005 or early 2006. The standard is improved and new functionality requested by users is added, for example fault-tolerance support.

3.2 Selecting a Standard

We experimented with the RTI NG product from the DMSO's Software Distribution Center (SDC), as well as several commercial RTI products during 2000 and 2001. All these products were based on the HLA 1.3 specification.

By the middle of 2003, we started the development of our Federation Gateway subsystem based on several HLA 1.3 RTI products. At around the same time, we obtained an evaluation RTI based on IEEE 1516.

We experienced some problems with the tick mechanism in the Federation Gateway while simultaneously registering a large number of instances and processing callbacks. These problems included a number of non-recoverable runtime errors.

During the August 2003 exercises, we discovered additional issues concerning inconsistent callback implementations that would affect our distribution design. We consulted with the ATLAS team and decided to switch interoperability standards to HLA IEEE 1516.

We developed a new Federation Gateway subsystem based on the IEEE 1516 specification [16] and were able to complete preliminary testing by January 2004. The Defense Research and Development Office (DRDO) approved funding for the RTI software.

The IEEE 1516 standard also incorporates the use of XML and Unicode, an important factor for localization into the Thai language.

4. Federation Design and General Experiences

4.1 Federation Design

Our approach to architecture required a good understanding of the simulation requirements as well as the operational concept of managing a military exercise involving several hundred people. Scenario planning, unit composition, site visits, map acquisition, and exercise logistics all play a part in the success of the exercise – with many of these planning activities taking place some eight months prior to the CPX itself.

Detailed analysis of the operational concepts of a CPX by our team revealed that the most natural partition of responsibilities within the exercise would be along the lines of a Military Division. This same partition would be deployed within our federation.

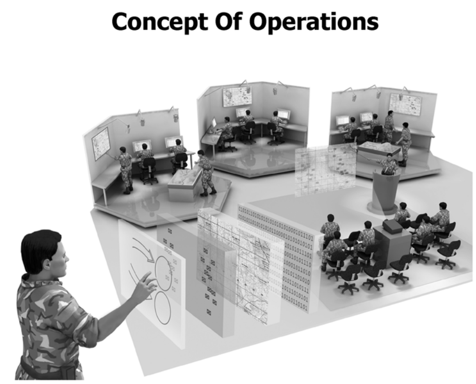

Figure 1: Concept of Operations

We determined that this would provide for the most scalable architecture in development as well as deployment. Army units wishing to utilize ATLAS for exercises simply have to decide, during the exercise-planning phase, the number of Military Divisions to be involved and then simply deploy the equivalent number of systems. This would satisfy small-scale exercises of two Divisions, through to the larger CPXs of 12-15 Divisions.

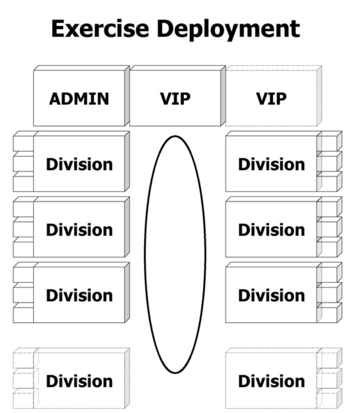

Figure 2: Exercise Deployment

4.2 Federate Components

The ATLAS Federate is a self-contained simulation representing one Military Division. Each Division may consist of a tactical, main, and rear CP [17]; 3-5 Regiments, which in turn consists of 3-5 Battalions. The tactical Division may also contain fire support, and other Combat Support and Combat Service Support Units. All together, the Federate may contain around 100-150 Units.

The software architecture for the Federate contains a number of subsystems – Digital Maps for terrain effects, Simulation Executive for processing events, Federation Gateway that encapsulates the RTI, and Persistent Mechanism containing a distributed Object-Oriented database.

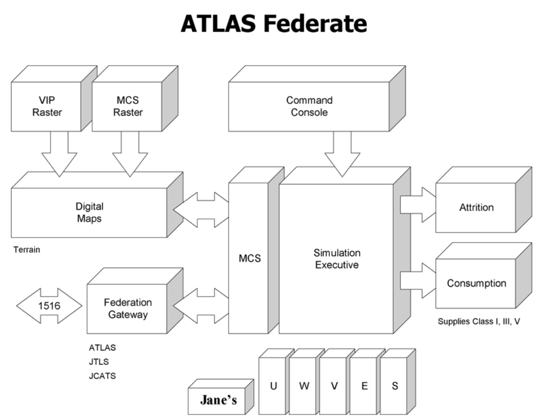

Figure 3: ATLAS Federate

Our simulated entities are Units, which contain Warfighters, Weapons, Vehicles, Equipment, and Supplies.

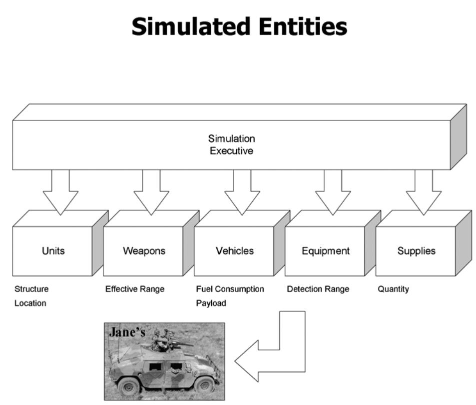

Figure 4: Simulated Entities

4.3 FOM

The information exchanged by ATLAS Federates via the RTI is documented in the Federate Object Model (FOM) [18]. These include the object class Unit, interaction classes representing fire support, as well as dimensions and regions used for multicasting purposes.

5. Experiences of HLA 1516 DDM

5.1 Overview of 1516 DDM

HLA provides services for simulation interoperability covering data exchange, services for managing logical time, synchronization and coordination of responsibilities. HLA acts as an intelligent data bus for the exchange of data. A producing system will "publish" information and a consuming system will "subscribe" to information. The HLA RTI then provides the information that a certain system is interested in without requiring it to have any direct interaction with the producing federate.

The first level of interest management, "Declaration Management" is based on the object class of the information. A system may choose to subscribe to the classes "Ship" and "Aircraft" but not to "Tank". This will reduce the amount of information that is provided to the subscribing system.

The second level of interest management, "Data Distribution Management" (DDM), is more advanced. It allows the developer to specify a number of dimensions that the filtering will be based on. These dimensions may be qualitative, like "color" or quantitative, like "altitude".

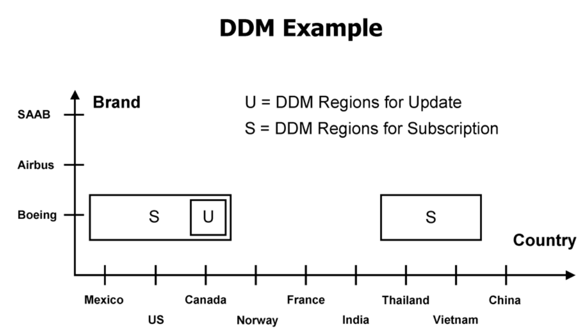

Figure 5: DDM Example

If we want to exchange information about airplanes in different countries we may want to define country as one dimension and airplane brand as another. A subscriber may subscribe to information about Boeing, but not Airbus airplanes in Canada, US and Mexico as well as in Thailand and Vietnam. This makes two DDM regions. A publisher can publish information denoting that it applies to an airplane in Canada. Since there is an overlap between the regions of the publishing and subscribing federate this information will reach the subscriber.

When an update is sent or a subscription is made federates provide DDM information separate from the data. The RTI will not look at data values of the update, only the DDM regions that are provided by publishers and subscribers and how they overlap.

In HLA 1.3 dimensions were always grouped in advance into "Routing Spaces" in the FOM. Only one Routing Space could be specified for a specific attribute so it was only possible to specify either the dimensions "x, y" or "x, y, z" for the data exchange of an attribute. This limitation was removed in HLA 1516-2000. It is now possible to specify a number of potential dimensions for an attribute in the FOM and then use only the necessary ones at run-time. One benefit of this is that it is easier to extend the DDM functionality in a federation since existing federates do not have to be modified when a new dimension is added.

The benefits of DDM are that a subscribing federate will only receive a smaller amount of data. It may also be used to limit the amount of data that needs to be transmitted over the network to a specific federate since the RTI has insight in the filtering parameters. Today it is generally perceived that large, distributed simulations require DDM to achieve scalability.

5.2 Use of DDM in ATLAS

ATLAS currently defines two DDM Dimensions in the Federation Object Model Document Data (FDD), Northing and Easting, to represent any specific location on the battlefield. Each DDM Region made up of these two dimensions represents an area on the battlefield.

Military Units are modeled as an aggregation of warfighters, weapons, vehicles, equipment, and supplies – that require a physical presence, or a "footprint" on the battlefield. Our HLA strategy has each Unit publish a DDM Region, which corresponds to this footprint.

Military Units also have engagement and detection areas. Each Unit subscribes to a partial list of the Unit object class attributes in the detection DDM Region, and the full list in the engagement DDM Region.

The size of the engagement region may change depending on the current threat, concealment, weapon composition, rule of engagement, and many other factors.

Similarly, the detection capability may also change dynamically based on available detection equipment, terrain, visibility and weather conditions, size and action of hostile forces, etc.

As a Unit moves across the terrain, the Simulation Executive subsystem computes the new location based on Unit speed, Unit posture, terrain type, and a number of other parameters. The new footprint, engagement, and detection DDM Regions are recalculated and these values updated to our Federation Gateway subsystem. This may result in a detection, engagement, or attrition event (in the case of a Unit approaching a minefield).

The Federate can differentiate between a detection event and an engagement event by means of the Object Management Service callback ATTRIBUTES IN SCOPE †. This requires that each Federate invoke the ENABLE ATTRIBUTE SCOPE ADVISORY SWITCH service.

Units may also become disengaged, or revert to being undetected as a result of movement while in a specific state.

Detection and Engagement Ranges

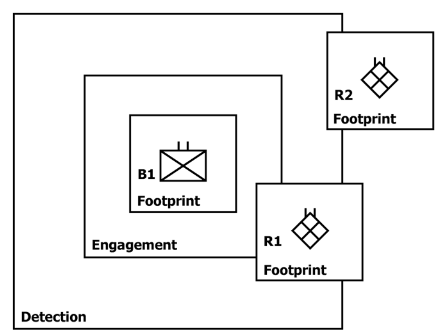

Figure 6: Detection and Engagement Ranges

Indirect Fire from artillery companies are represented as HLA Interactions, with the ground detonation modeled as another DDM Region, where dimensions correspond to the blast radius.

When an indirect fire shell detonates in an area that overlaps with a Unit's footprint, attrition may take place within that unit.

A third DDM Dimension in the z-axis, representing altitude, is being considered. This will enable us to approximate the flight of aircraft, model air corridors, and create air defense domes.

5.3 Optimizing DDM performance in federates and RTI

The intersection between publishing and subscribing regions can be statically computed by the RTI for increased performance. Whenever a region or a set of regions changes the interchanges will have to be recomputed. This means that sending updates using DDM may not be computationally costly but modification of the regions may well be.

As a result federates may want to prioritize the use of static regions and base the use of DDM primarily on static domain information. When dynamic domain information is used it the easiest approach for better performance is to reduce the region modification rate by increasing the region sizes.

There are other optimizations than can be made for example to reduce network, RTI or federate load. One example is that the RTI may use different multicast groups for different regions. The implementation and tuning of multicast based DDM in a federation may be a challenge. Finding the optimal mapping between multicast groups and DDM regions is a complex task. Multicast may also cause systems that have not requested the information to receive it requiring extensive receiver-side filtering which may increase instead of decrease the workload.

5.4 DDM analysis and optimizations

The design of the ATLAS Federation requires advisories to be enabled.

The first tests showed insufficient performance when federates were doing their initial registration of instances. There were no DDM performance problems once all instances were registered.

The performance issue was reported to the RTI vendor, Pitch Technologies who did an analysis. Part of each instance registration was the creation of three regions. The total number of regions created can be calculated by taking 10 federates times 100 units times 3 regions per unit, giving a total of 3000 regions. The analysis showed that the creation of each region triggered recalculation of discoveries and advisories. A small change was made to the RTI. The change involved postponing the recalculation for a short time. During this timeout, more regions were created. At the end of the timeout, the recalculation was made once for all regions that were created during the wait period. The change resulted in a very significant performance increase, on the order of 50 times faster. This means that the startup time went from a few minutes to a few seconds in one of the test cases.
Another way around the issue would have been to use DDM but to disable advisories in the RTI and do the overlap calculations in federates themselves. This solution would have required a significant redesign of all federates.

6. Future Plans

ATLAS shall undergo live testing during the exercises scheduled for August 2005. We expect to deploy the initial version of ATLAS at several sites in Thailand following these exercises.

In 2004, we were able to demonstrate the benefits of a scalable and component-based architecture by creating extensions to our ATLAS framework to enable the development of Maneuver Control Systems (MCS), and an application for tracking Operations Other Than War (OOTW) activities.

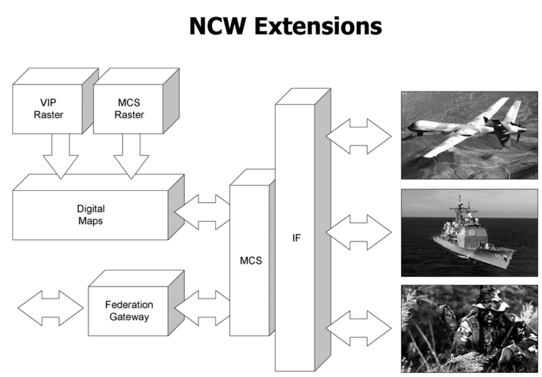

Figure 7: NCW Extensions

In light of the tsunami that recently hit the South East Asian nations, the capability to create simulations of OOTW activities that model humanitarian assistance and disaster relief take on a new significance.

7. Conclusions

The RTA conducts many joint training exercises with the Royal Thai Navy and Royal Thai Air Force, as well as armed forces from other nations. The ability to interoperate using internationally recognized standards are regarded as essential. The adoption of the HLA

IEEE 1516 standard has provided the RTA with this capability.

The ATLAS project has benefited greatly from the DDM services within the HLA specification. DDM provides a multicast mechanism that enabled us to define a clear separation of the Federate, therefore fulfilling the scalability requirements of the CPX.

The DDM services have also enabled fine grain control, through the use of advisories, of other HLA services that form the core of our detection and engagements mechanisms.

Finally, at the implementation level, the Java Application Programmer's Interface (API) of the HLA IEEE 1516 utilizes the rich features of the Java 2 Collections Framework, unlike that of the HLA 1.3. This allows for more elegant program structures and higher performance [19].

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