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Selecting a HLA Run-Time Infrastructure:

Overview of Critical Issues Affecting the Decision Process for War-in-a-Box

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Defence R&D Canada – Ottawa

TECHNICAL MEMORANDUM

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Abstract

The High Level Architecture (HLA) is a distributed simulation architecture designed to facilitate interoperability and promote software reuse within the modeling & simulation (M&S) community. In HLA, the unit of software reuse is the federate. Federates communicate via a distributed middleware called the Run-Time Infrastructure (RTI). The HLA specifies the interface between each federate and the RTI but does not specify how the RTI is implemented. As such, several RTI implementations exist. All federates must choose a single RTI implementation in order to interoperate at run-time. This paper discusses the technical, political and economic considerations one must weigh when selecting a HLA RTI implementation.

Résumé

L'architecture de haut niveau (AHN) est une architecture de simulation répartie conçue pour faciliter l'interopérabilité et promouvoir la réutilisation des logiciels au sein de la collectivité de modélisation et de simulation (M&S). Dans une AHN, l'unité de réutilisation des logiciels est le fédéré. Les fédérés communiquent au moyen d'un intergiciel réparti appelé infrastructure valorisée à l'exécution (IVA). L'AHN précise l'interface entre chaque fédéré et l'IVA, mais n'indique pas comment l'IVA est mise en application. En fait, il y a plusieurs versions d'IVA. Chaque fédéré doit en choisir une afin que l'exécution soit interopérable. Le présent document traite des facteurs techniques, politiques et économiques à considérer lorsqu'on choisit une version d'IVA pour une AHN.

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Executive summary

This paper discusses the technical, political and economic considerations one must weigh when selecting an RTI implementation for a HLA compliant distributed simulation. Research into these issues was initiated within the Future Forces Synthetic Environments (FFSE) section under the auspices of the Collaborative Capability Definition, Engineering and Management (CapDEM) Technology Demonstration Program (TDP). This paper follows in response to a subsequent request for advice on these issues from the DND SEWG, the national assembly of M&S representatives from all DND Level 1s and by the CASE Project WIB simulation community. The latter represents the first Canadian Joint Distributed Simulation and they are presently engaged in a joint HLA/RTI selection process.

The High Level Architecture (HLA) is a distributed simulation architecture designed to facilitate interoperability and promote software reuse within the modelling and simulation (M&S) community. The HLA was originally defined by the U.S. Defense Modeling and Simulation Office (DMSO) and is now an Institute for Electrical and Electronics Engineers (IEEE) standard (IEEE 1516).

There is no single RTI implementation suitable for all federations. Different RTI vendors build their RTI with different design goals. In general, one should approach the decision of which RTI to use on a per federation basis. Beyond such generalities, however, this paper also details the wide variety of technical issues needed to make an informed selection, ranging from use of existing and legacy simulation components and performance issues to data models and development tools.

As part of the RTI selection process, consideration of the political issues is also necessary. Such issues are often implicit in the various software components used within an M&S environment along with issues such as availability, timeliness, interoperability, costing and standards compliance. They are also heavily influenced by less objective matters, such as anecdotal experience and technological, personal and organizational biases. Therefore, in providing a holistic approach to RTI selection, various political aspects of technology selection and integration are also discussed.

A final issue affecting RTI selection is that of economics. Historically, RTI releases were available from DMSO free of charge. Recently, however, DMSO has terminated its provision of RTI implementations, though they still freely offer some federation development tools. Therefore, monetary and licensing issues have become increasingly relevant as the HLA/RTI marketplace begins to develop and expand.

Given the breadth and depth of the technical issues associated with distributed simulation technologies, further work in understanding and addressing the performance as well as technical flexibility and constraints associated with any specific HLA technologies, including RTIs, is warranted. In this regard, our group has undertaken the development of an RTI test suite and is in the process of performing a number of experiments to clarify and highlight where specific issues affect RTI deployment. Subsequent publications will therefore continue

to expand on these issues and serve as a concrete mechanism to assist in the technical evaluation of distributed simulation technologies, including specific RTI implementations.

In addition to these aspects, we offer a series of recommendations for members of the War-in-a-Box community to consider in their selection of simulation technologies based on their relationship to the various HLA/RTI technologies.

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Sommaire

Le présent document traite des facteurs techniques, politiques et économiques à considérer lorsqu'on choisit une version dIVA pour une simulation répartie conforme à une AHN. Des travaux de recherche à ce sujet ont été entrepris au sein de la section de l'environnements synthétiques des forces du futur (ESFF), sous les auspices du Programme de démonstration de technologies (PDT), volet Définition, ingénierie et gestion collaboratives de capacités (DIGCap). Le document répond à une demande subséquente de conseils sur ces questions de la part du GTES du MDN, de l'assemblée nationale des représentants de M&S de tous les niveaux 1 du MDN et de la collectivité de simulation WIB, dans le cadre du projet CASE. Cette dernière représente la première simulation répartie conjointe du Canada et participe actuellement à un processus de sélection conjoint AHN/IVA.

L'architecture de haut niveau (AHN) est une architecture de simulation répartie conçue pour faciliter l'interopérabilité et promouvoir la réutilisation de logiciels au sein de la collectivité de modélisation et de simulation (M&S). L'AHN a été définie, à l'origine, par le Modeling and Simulation Office (DMSO) des États-Unis et elle est maintenant une norme de l'Institute for Electrical and Electronics Engineers (IEEE) (IEEE 1516).

Il n'existe pas d'IVA unique qui convienne à toutes les fédérations. Différents fournisseurs d'IVA construisent leur IVA selon des objectifs de conception différents. En général, le choix de l'IVA à utiliser devrait revenir à chaque fédération. Au-delà de ces généralités, toutefois, le document traite de façon détaillée de la vaste gamme de questions techniques dont il faut tenir compte pour faire un choix éclairé, notamment le recours aux éléments de simulation actuels et anciens, les questions de rendement, les modèles de données et les outils de développement.

Dans le cadre du processus de sélection de l'IVA, il faut aussi prendre en considération des questions d'ordre politique, qui sont souvent implicites dans les divers composants logiciels utilisés dans un environnement de M&S, ainsi que de questions comme la disponibilité, l'opportunité, l'interopérabilité, le coût et la conformité aux normes. En outre, le processus est fortement influencé par des aspects moins objectifs comme l'expérience anecdotique et technologique, les préférences personnelles et organisationnelles. Par conséquent, une approche holistique à la sélection de l'IVA permet d'aborder divers aspects politiques de la sélection et de l'intégration des technologies.

Un dernier facteur influe sur la sélection d'IVA : l'économie. Par le passé, les versions d'IVA étaient offertes gratuitement par le DMSO. Or récemment, le DMSO a cessé de fournir des versions d'IVA, bien qu'il offre encore certains outils de développement gratuits pour les fédérations. Les questions de coût et de licence sont donc devenues de plus en plus pertinentes, alors que le marché des AHN/IVA commence à prendre de l'expansion.

Vu l'étendue et la complexité des facteurs techniques liés aux technologies de simulation répartie, il y a davantage de travail à faire pour comprendre et traiter les questions de rendement ainsi que la souplesse et les contraintes techniques associées à des technologies particulières d'AHN, y compris les IVA. À cet égard, notre groupe a entrepris l'élaboration d'une suite de test pour l'IVA et est en train de procéder à un certain nombre d'expériences

visant à cerner et à mettre en lumière les cas où des facteurs spécifiques affectent le déploiement d'une IVA. On continuera donc d'étudier plus à fond ces questions dans des publications ultérieures, qui serviront de mécanisme concret facilitant l'évaluation technique des technologies de simulation répartie, notamment les versions d'IVA particulières.

En plus de ces aspects, nous offrons une série de recommandations que les membres de la collectivité de la guerre « en boîte » (War-in-a-box) pourront étudier lorsqu'ils choisiront des technologies de simulation en fonction des rapports de celles-ci avec les diverses technologies d'AHN/IVA.

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Table of contents

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1. Introduction

This paper discusses the technical, political and economic considerations one must weigh when selecting an RTI implementation for a HLA compliant distributed simulation. Research into these issues was initiated within the Future Forces Synthetic Environments (FFSE) section under the auspices of the Collaborative Capability Definition, Engineering and Management (CapDEM) Technology Demonstration Program (TDP). This paper follows in response to a subsequent request for advice on these issues from the DND SEWG, the national assembly of M&S representatives from all DND Level 1s and by the CASE Project WIB simulation community. The latter represents the first Canadian Joint Distributed Simulation and they are presently engaged in a joint HLA/RTI selection process.

1.1 Background

The HLA is a distributed simulation architecture designed to facilitate interoperability and promote software reuse within the M&S community. The HLA was originally defined by the U.S. DMSO and is now an IEEE standard (IEEE 1516).

In the HLA, the unit of software reuse is the *federate*. A group of communicating federates at run-time is called a *federation*. Federates communicate with each other via a distributed middleware called the RTI. The RTI provides the services that allow federates to manage the federation's global state.

Contrary to popular belief, the RTI is not a centralized software entity that federates plug into. Rather, each federate communicates with it's own local copy of the RTI software library (called the Local Run-time Component, or LRC). The LRCs then communicate amongst themselves to coordinate the execution of the federation.[1] Thus, the RTI library encapsulates the complexities of inter-federate communication.

1.2 Motivation

The HLA specifies the interface between a federate's simulation logic and the RTI library. More precisely, HLA defines two interfaces: the *RTI ambassador interface* and *the federate ambassador interface*. The RTI ambassador interface is implemented by the LRC and defines the services that the federate can invoke on the RTI. The federate ambassador interface is implemented by the simulation logic and defines the events that the RTI can signal to the federate.

[1] This does not preclude the use of a centralized component. Some RTI library implementations contact a central component. However, the RTI library encapsulates its use.

The HLA does not, however, specify how the LRC is implemented. The RTI vendor is free to choose how the LRC is organized internally as well as the inter-LRC communication protocol. **Thus, all federates within a federation must agree to use the same RTI library**.[2]

To complicate matters, there are two interface specifications currently in use. The first is the DMSO specification we referred to as 1.3-NG. The second is the newer 1516 specification, defined by the IEEE 1516 standard and based on the 1.3-NG interface. Federates can conform to either or both standards, and likewise, RTI libraries can conform to either or both. In order for federates to communicate with an RTI, however, all must support the same interface specification.

Several RTI implementations exist that conform to either the 1.3-NG or 1516 interfaces (or both). It is therefore natural to wonder which RTI implementation best suites the needs of a particular community.

1.3 Scope

This paper does not provide a direct comparison of each RTI implementation in existence. Instead, it highlights the factors that one must be aware of in order to make an informed decision.

Also, the paper implicitly discusses only certified (or soon to be certified) RTI implementations.[3] In particular, we do not consider open-source RTI implementations such as [1], [4] and [5]. At the time of this writing, no open-source RTI implementation is complete (i.e. implements all services) and their use would therefore severely limit or cripple federate interoperability.

1.4 Organization

Section 2 discusses the technical factors while sections 3 and 4 discuss the political and economic factors, respectively. We conclude in section 5 and provide recommendations in section 6.

[2] This is true regardless of whether an RTI-to-RTI bridging solution is used. An RTI-to-RTI bridge is a federate that joins more than one federation and forwards/translates events between federations. Such a bridging federate would use multiple RTI libraries – each one appropriate to the federation in which it is joined. Furthermore, bridging solutions introduce new difficulties as outlined in [3].

[3] There are separate certification processes for the 1.3-NG and 1516 specifications.

2. Technological considerations

There is no single RTI implementation suitable for all federations. Different RTI vendors build their RTI with different design goals. For example, some may provide a more efficient time management implementation and are thus better suited to constructive rather than virtual simulations.[4] In general, one should approach the decision of which RTI to use on a per federation basis.

It is important to understand that, in general, the choice of RTI library used by a particular federate is a compile-time decision. That is, switching to another RTI library will require recompilation of the federate. Some RTI libraries, however, are swappable at federation load-time (i.e. when the federate executable is loaded by the operating system) and do not require recompilation. This is called *link-compatibility* and RTI libraries are said to be link compatible with one another. For example, the DMSO 1.3-NG family of implementations is link compatible. Some commercial vendors also provide link-compatibility with the DMSO implementations.

There are several factors to consider when choosing an RTI implementation for a particular simulation exercise:

- The set of existing simulation components that will be reused
- The need to develop new federates
- The required level of federation performance
- Choice of Federation Object Model (FOM)
- Choice of computing platform
- Choice of development tools

The degree to which the above factors are relevant varies considerably. In fact, some of these factors have little or no bearing on the RTI selection process but are discussed nonetheless to dispel potential misconceptions. Each such issue is discussed further in the following sections.

2.1 Use of existing simulation components

This paper distinguishes between four types of simulation components that one may wish to reuse within a federation:

[4] The RTI time management service coordinates the flow of causal events within a simulation. It guarantees that simulation events are processed at the appropriate time. A virtual simulation executes in wall-clock time and would not use the time management service. A constructive simulation may execute faster or slower than wall-clock time and so must rely on such a service for proper execution.

- Distributed Interactive Simulation (DIS) compliant simulations
- Federates that comply with the 1.3-NG interface
- Federates that comply with the IEEE 1516 interface
- Simulations that are neither DIS nor HLA compliant but do provide a programmable interface

DIS simulations require what is commonly referred to as a DIS-to-HLA bridge (or gateway). This is a software component that translates between the DIS Protocol Data Units (PDUs) and HLA objects/interactions. The use of a DIS component requires that the federation adopt the Real-Time Platform Reference (RPR) FOM (or a superset of the RPR FOM). The specific version of the RPR FOM to use is directly dependant on the revision of the DIS standard that the DIS component is based. For example, an IEEE 1278.1-1995 DIS simulation requires a 1.0 compatible RPR FOM while an IEEE 1278.1a-1998 DIS simulation requires a 2.0 compatible RPR FOM [7, 8]. Several RTI vendors provide DIS-to-HLA bridge products. It is important to understand that the gateway product should in no way be tied to the RTI implementation! The gateway should itself be a federate that simply translates all PDUs seen on the network to the appropriate RPR FOM objects/interactions (and vice versa). The gateway requires no knowledge of the internals of any specific RTI implementation. Therefore, any vendor's gateway should work with any other vendor's RTI (provided, of course, that both use the same interface).

There are two options available when required to mix both 1.3-NG and IEEE 1516 federates within the same federation:

- Port the 1.3-NG federates to the newer standard
- Use an RTI implementation that supports both interfaces

Recall that the IEEE 1516 interface is a refinement of the 1.3-NG interface and so porting 1.3-NG federates to the newer standard is a straightforward process. The prerequisite for porting any piece of software, of course, is obtaining access to its source code. And despite a potentially limited porting effort, any source code changes need to be followed by regression testing to validate that the changes did not introduce unintended behaviour in the federate. Porting an IEEE 1516 federate is also possible but there is little if any advantage in doing so – the IEEE 1516 standard is superior to 1.3-NG specification.

Perhaps a better/easier solution that requires no source code changes is to choose an RTI implementation that supports both interfaces. Some RTI vendors choose to package this as a separate product while others provide this capability as part of the RTI itself.

The final category of simulation components that may be required to participate in a HLA federation are those that may be neither DIS nor HLA compliant, but those that provide some programmable way to access and/or alter the simulation's state. This type of simulation component must be encapsulated in a federate that exposes the simulation's state as one or more HLA objects/interactions. Some of these HLA-wrappers already exist for simulation frameworks such as [9]. The choice of RTI is inconsequential since the HLA-wrapper is just another federate that needs no knowledge of the RTI's implementation.

2.2 Federate development

The choice of RTI can have a large impact on the development speed of new federates. The original DMSO RTI implementations were largely considered black boxes – the federate developer could not examine the RTI's state at runtime. Later implementations addressed this problem with various debugging/monitoring tools that report the RTI's internal activities (publications, subscriptions, object updates/reflections, interaction sends/receives, lookahead values, etc.).

Such tools can be either open or closed. Closed tools provide a user interface that presents the relevant information. Open tools provide the ability to plug custom code into the RTI to both monitor and affect the behaviour of the RTI. Open tools enable more advanced diagnostics to be performed on a federation at run-time.

2.3 Performance

As previously discussed, no two RTI implementations are equal. It is therefore natural to wonder which RTI performs best in a given scenario. For example:

- Which RTI is most efficient when executing over a wide area network?
- Which RTI most efficiently implements the Data Distribution Management (DDM) service group?[5]
- Which RTI provides the lowest latency communication?
- And so forth...

The FFSE section has defined a performance benchmark and developed associated test harness software to assess performance issues across the various RTI implementations. The benchmark identifies both the parameters that can affect a given RTI's performance as well as what values are measured. We are currently executing the benchmark on a variety of implementations.

It is important to distinguish between RTI performance and federation performance. In general, the former is a subset of the latter. That is, there are several factors that can affect a federation's performance that are not directly linked to the selected RTI. For example, a time regulating federate performing an expensive computation will slow the execution of all time constrained federates.[6] In this case, improving the performance of the federation requires

[5] The RTI's DDM service group allows filters to be defined for simulation events.
[6] When using the RTI's time management service group. A time regulating federate controls the flow of simulation time. A time constrained federate depends on the time regulating federate for the control of simulation time.

faster hardware for the computationally expensive federate or a redesign of the federate itself (perhaps replacing the expensive computation with an acceptable approximation).

2.4 FOM

The Federation Object Model (FOM) defines the vocabulary of data exchange within a federation. All federates participating within the same federation must support the same FOM.[7]

There is a misconception amongst many researchers entering the world of HLA simulations that the choice of FOM is somehow linked to the choice of RTI implementation. While its true that a federation must agree on a single FOM, all RTIs can process all FOMs. Of course, FOMs are expressed differently in the 1.3-NG baseline and IEEE 1516 standard. That is, the file format of each differs so an RTI implementation may only recognize the file format that corresponds to the interface it supports. However, the differences between the formats are largely syntactic and easily convertible.

The issue of FOM-agility is often brought up when discussing RTIs. FOM-agility is defined as the ability of a federate designed for one FOM to be reused in a federation using another semantically equivalent yet syntactically distinct FOM [6]. That is, relevant objects/interactions in the new federation must somehow be mapped to objects/interactions understood by the reused federate. FOM-agility can be supported at different levels – one of which is at the RTI itself.[8] Some RTI implementations support a plug-in architecture that allows the federate to supply a translation layer to accomplish the necessary FOM mappings. However, FOM-agility is not a direct factor in choosing an RTI (as other FOM-agile techniques are available above the RTI level).[9]

2.5 Computing platform

A computing platform refers to the mix of hardware, operating system and programming language used to implement an application. This paper distinguishes between three platform related issues:

- The implementation language of the RTI
- The RTI's supported hardware and operating systems
- The RTI's supported language bindings

[7] That is not to say that a federate cannot be designed to support multiple FOMs.
[8] Another possibility is at the compilation time via a custom solution or a third party development library such as [2].
[9] A federate can be understood as being composed of a number of layers. The RTI library is the lowest layer a federate developer must consider since it abstracts all inter-federate communication. The topmost layer is the federate's simulation logic. Between the RTI layer and the simulation logic can sit any number of layers to provide services such as FOM-agility, encryption, etc.

The implementation language of the RTI can have an effect on its performance. For example, a Java implementation of an RTI may require more computer resources than an RTI implemented in C++.

A more important factor in choosing an RTI is whether there is an implementation for your chosen hardware and operating system(s). In this case, the cross-platform nature of a Java-based RTI is advantageous since it can run without modification on any Java-enabled platform. In a heterogeneous computing environment, it is important that the chosen RTI vendor support *all* your platforms since, as previously stated, federates within the same federation must use the same RTI implementation.

The final platform related issue is one of programming language bindings. An RTI must support a binding for a programming language in order to develop new federates using that language. The dominant languages for federate development are C++ and Java. Most RTI vendors provide language binding for these two languages.

Note that there may be a small performance penalty when programming a federate in a programming language other than the one used to implement the RTI due to some translation overhead. In general, however, the benefits of freely choosing the most appropriate language independent of the RTI's implementation language far outweigh the negligible performance penalty.

2.6 Development tools

The services provided by the RTI are both complex and low-level. Third-party tools exist that both isolate and abstract the RTI's functionality and provide a simpler application programming interface (API) to the federate developer. While some RTI vendors also provide such tools, they are not (and should not) be dependent on that vendor's RTI.

3. Political considerations

As part of the RTI selection process, consideration of the political issues is also necessary. Such issues are often implicit in the various software components used within an M&S environment along with issues such as availability, timeliness, interoperability, costing and standards compliance. They are also heavily influenced by less objective matters, such as anecdotal experience and technological, personal and organizational biases. While not necessarily "scientific", it is important for decision makers to realize that they do exist and that they can colour the perception of other factors in the decision process.

The prime issue with potential political overtones is that of "what" federates to use. Often, perceptions associated with the "branding" and "source" of a federate result in it being selected (or rejected) due to "who" is the source (be it corporate or governmental, domestic or foreign) because of a sense of trust and/or "comfort" between organizations that lie outside the scientific and technical arenas. Examples include potentially selecting a Semi-Automated Forces (SAF) product because it comes from a domestic corporation or selecting another such tool because it was produced by an allied military organization. While these are considerations to be made, they are purely political. Conversely, they do become relevant when the source of the technology can affect availability and the timeliness of that availability due to corporate issues and/or inter-governmental problems (such as import/export restrictions, the current international political climate, memoranda of understanding and so forth).

Related to the choice of federate is the "branding" and "source" of the RTI on which the federate is compatible. For example, preference may be given to a federate because it requires an RTI from a particular source (as above, either geographical, organizational or other). Interoperability plays a role here in that RTIs are generally not interoperable and efforts need to be made to address this aspect. While usually addressed through uniformity, this can be addressed through use of "adapters" or "gateways"; however, the technical complexity arising from this approach is often an issue in itself.

Beyond this issue of federate and RTI "sourcing", technology selection can be affected by other miscellaneous, non-technical factors; these include:

- Ownership: Does the organization have a set of federates and/or RTIs available that could be complemented through selecting specific other tools rather than "starting from scratch"? This is often an issue of cost and interoperability, but can also be influenced by personal and organizational bias towards the "easiest" solution, rather than one based on more objective measures.

- Past experience: Often anecdotal, did the group selecting the new technology have good or bad experiences with the same vendor or organization? Has the organizational culture and "rumour mill" suggested that certain products and combinations thereof prove problematic? This is the most obvious source of non-objective bias in the selection process.

- Costing. Licensing and Ownership: While primarily an economic issue, how much a particular RTI implementation costs, how that cost is borne out in licensing with respect to deployment, scalability and distribution both within and across organizations can prove difficult both in terms of technology (networking, etc) and the political ramifications of who "owns" and is "in control" of the software and its individual components. This is particularly an issue when it comes to large simulations involving a number of distributed entities.

- Standards and Certification: For certain situations and organizations, it is important to comply (or be seen to comply) with standards. This can be for both the technical domain as well as for political reasons, in which the current climate of interoperability adds significant public credibility to organizations seen to be employing well-known standards in all their activities. This is also applicable with respect to certification, in which many organizations and decision makers are often more comfortable with the use of certified products and processes as a means of risk mitigation. The problem lies in the case where possible technical or project-specific goals (such as research efforts) may not conform to the expected standards, for whatever reasons. Typical issues in this area include FOM selection and agility, multi-standard support and support for the open source movement and custom/experimental implementations.

While the notion of political considerations is not necessarily of itself a negative aspect, care needs to be taken such that they are balanced by other more objective considerations. **The ultimate political issue of "fear of failure" by selecting the wrong RTI "for life" needs a reality check; it is crucial to realize that technological and political issues change over time, just like the players in different exercises/simulations. Consequently, the technology (i.e. RTI) selection made today will not necessarily be the relevant or correct choice in subsequent years**. Politically, we may need more than one RTI in our tool suite. While future considerations must be taken into account when making the selection, so too must present day pragmatics. An informed decision today is better than no decision made for years to come.

4. Financial considerations

The final, yet extremely important issue affecting RTI selection is that of economics. Previously, the RTI-NG releases were available from DMSO at no cost. Currently however, DMSO has terminated its provision of RTI implementations, though they still freely offer some federation development tools. As such, a few commercial providers for both HLA 1.3 and IEEE 1516 specifications have emerged. The DMSO RTI 1.3-NG V6 implementation is now available only as a free yet unsupported product from Virtual Technology Corporation (http://www.virtc.com/).

When purchasing RTIs for federation development, one needs to consider that the pricing schemes adopted by vendors show significant variation. They generally have a non-negotiable pricing scheme for a small number of licenses but for a large number of licenses, the price is usually negotiable. In one scheme, the cost of RTI licensing for Java federates is broken down into three ranges: (i) 1-5 federates at a fixed cost; (ii) 6-10 federates at a slightly higher fixed cost; and (iii) a negotiable price for 11 or more federates. Bindings for other programming languages must be purchased as an add-on. In another scheme, the first license is sold as a "developer license" and priced higher than additional licenses marketed as "run-time licenses". The price for a large number of licenses is again negotiable; however, the definition of "a large number" is not given. Additionally, vendors may also market their IEEE 1516 version at a higher price than their HLA 1.3 version.

The technical support and maintenance costs also show similar variations. Additionally support tool costs should be factored into a RTI purchasing plan. In one RTI marketing model, all support tools are purchased separately. In another scheme, the RTI is marketed in two versions, one without any bundled tools, and a second bundled with diagnostic and networking support tools. When purchasing a bundled package, a buyer needs to be aware of potentially paying for tools that have little utility for their intended users. Additional support tools may also be purchased from third parties. Ultimately, not providing for appropriate tools can lead to significant difficulties in the development and deployment of a HLA federation. Therefore, support tools must not be seen to be as an option but as a necessary component.

Thus when purchasing commercial RTIs, careful consideration should be given to a variety of factors that contribute to the cost of the package.

5. Summary

This introductory paper has outlined the three broad areas of concern that need to be considered in selection of technologies associated with the use of the High Level Architecture, or HLA. In each of these areas, different specific issues were highlighted and briefly addressed. It is again stressed that this paper is intended to serve as an initial overview and introduction to these various issues and is not a final compendium.

As obvious from the breadth and depth of the technical issues associated with distributed simulation technologies, further work in understanding and addressing the performance as well as technical flexibility and constraints associated with any specific HLA technologies, including RTIs, is warranted. In this regard, our group has undertaken the development of an RTI test suite and is in the process of performing a number of experiments to clarify and highlight where specific issues affect RTI deployment. Subsequent publications will therefore continue to expand on these issues and serve as a concrete mechanism to assist in the technical evaluation of distributed simulation technologies, including specific RTI implementations.

6. Recommendations for War-in-a-Box

As a project definition study for the Canadian Advanced Simulation Environment (CASE), the first large national joint distributed simulation of War-in-a-Box had requested specific advice from the Future Forces Synthetic Environments (FFSE) section at DRDC Ottawa on how to select an RTI.

Ultimately, selection of the RTI would involve addressing the numerous issues that have been mentioned in the body of this paper. However, as highlighted early in the document, a significant driver of technology selection is which individual federates will be employed. That is, selection of the individual simulation components needs to be addressed first. Based on our knowledge of the current status of WIB tool selection, this issue has not yet been completely addressed.

At the time of this writing, the various tools known to be under consideration were Joint Semi-Automated Forces (JSAF), Synthetic Tactical Real-Time Interactive Virtual Environment (STRIVE) and Joint Conflict and Tactical Simulation (JCATS). Based on the presumed flexibility of tool selection, this section highlights issues to consider in tool selection as it relates to interoperability relative to RTI technology.

Strictly speaking, the following bullets isolate the applicability of specific tools to a specific RTI family:

- JSAF: link compatible with the DMSO RTI 1.3NG family

- STRIVE: link compatible with the DMSO RTI 1.3 NG family

- JCATS: DIS-based

Based on these points, JCATS is the most easily isolated tool. If JCATS is to be used independently with no HLA-aware product (such as either JSAF or STRIVE), then no RTI is necessary, as the simulation would be a DIS-only environment. Furthermore, if JCATS were to be used with either of the above tools, the choice of RTI is moot as all that would be needed would be a gateway to connect JCATS to either of the selected tools. However, while the selection of the RTI would not be an issue, the selection of the federation's FOM would be limited to the RPR FOM in order to provide compatibility with DIS.

Of either JSAF or STRIVE, if all players in WIB were to be unanimous in their choice of a simulation tool, the selection of an RTI would be straightforward. While both of these products claim to support additional non-DMSO RTIs, to address the immediate need, use of a DMSO RTI would suffice. In particular, since the International release of JSAF already contains RTI 1.3NG (version 6), the use of this already provided RTI would markedly simplify the selection, procurement and technical integration process – particularly if JSAF were the sole choice amongst all players in WIB. In much the same vein, an "all-STRIVE" environment would be of similar complexity, although the RTI is not included with the STRIVE product itself.

The difficult situation would arise if there would be a mixture of JSAF and STRIVE federates within the WIB federation. While both tools are HLA-aware and are able to work with DMSO RTIs, such a configuration has yet to be tested. Therefore, such a blend of simulation components would be exploring largely “uncharted waters”. While such a configuration should work in theory, its deployment would involve more experimentation and risk at this time. In particular, the mixture of operating systems (Linux and Windows for JSAF and STRIVE respectively) compounds the difficulty with RTI interoperability due to version conflicts. A possible option would be to use the Mäk RTI, which works on both operating systems at the same version level (cross-compiled from the same source code). Again, however, this option has not been systematically tested within our local group. Therefore, should a more “risk-mitigated” environment for the WIB exercise be desired, it is recommended this particular combination of tools be avoided.

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List of symbols, abbreviations, acronyms and initialisms

AHN	L’architecture de haut niveau
CapDEM	Collaborative Capability Definition, Engineering and Management
CASE	Canadian Advanced Synthetic Environment
DDM	Data Distribution Management
DIGCap	Définition, ingénierie et gestion collaboratives de capacités
DIS	Distributed Interactive Simulation
DMSO	Defence Modeling and Simulation Office
DND	Department of National Defence
ESFF	L’environnements synthétiques des forces du futur
FFSE	Future Forces Synthetic Environments
HLA	High Level Architecture
IEEE	Institute for Electrical and Electronics Engineers
IVA	Infrastructure valorisée à l’exécution
JCATS	Joint Conflict and Tactical Simulation
JSAF	Joint Semi-Automated Forces
MOU	Memorandum of Understanding
M&S	Modelling and Simulation
NG	Next Generation
PDT	Programme de démonstration de technologies
PDU	Protocol Data Unit

RPR	Real-time Platform Reference
RTI	Run-Time Infrastructure
SAF	Semi-Automated Forces
SEWG	Synthetic Environment Working Group
STRIVE	Synthetic Tactical Real-Time Interactive Virtual Environment
TDP	Technology Demonstration Program
WIB	War-in-a-Box

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The High Level Architecture (HLA) is a distributed simulation architecture designed to facilitate interoperability and promote software reuse within the M&S community. In HLA, the unit of software reuse is the federate. Federates communicate via a distributed middleware called the Run-Time Infrastructure (RTI). The HLA specifies the interface between each federate and the RTI but does not specify how the RTI is implemented. As such, several RTI implementations exist. All federates must choose a single RTI implementation in order to interoperate at runtime. The CF/DND is currently in the process of selecting an RTI for their distributed simulation needs. This paper discusses the technical, political and economic considerations one must weigh when selecting a HLA RTI implementation.

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HLA, RTI, Distributed Simulation, Modeling and Simulation

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