C4ISR/Sim Technical Reference Model Applicability to NATO Interoperability

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ABSTRACT

The 1998 Computer Generated Forces (CGF) Conference included a paper [1] which proposed a Technical Reference Model (TRM) for interoperability between U.S. Command, Control, Communication, Computers, Intelligence, Reconnaissance, and Surveillance systems (C4ISR)[1] and Computer Generated Force simulations (Sim). This TRM characterized the "type of information that is necessary to pass between C4ISR and CGF systems". Since then, changes have occurred in technology for interfaces; the uses for interfaces; and the Architecture(s) upon which they are based. In addition, significant changes have occurred in the respective source and target systems that these interfaces connect, namely C4ISR systems and simulations. Finally, substantial interest has been expressed in the availability of C4ISR hosted simulation components, as well as the integration and exchange of components between the two domains. A recent Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshop (SIW) paper [2] has proposed substantial changes to reflect the evolution of technology, supported systems, current interface practices, and near term future uses for C4ISR – M&S interfaces.

This paper briefly describes the revised version of the TRM. It suggests when and how to use the TRM in reference to NATO Command, Control, Communication, and Intelligence (C3I) system to modeling and simulation (M&S) interoperability or integration efforts. It shows the TRM's relationship to current NATO models and standards in the C3I domain, as an aid to those concerned with interoperability, integration, or standardization efforts between the two types of systems. The paper explores the use of the TRM in light of NATO interoperability efforts, and reflects on the relationship between the C4ISR/Sim TRM and NATO guidance documents/standards such as the NATO C3 Technical Architecture (NC3TA), the NATO Common Operating Environment (NCOE) Model (NCOM), and others.

1.0 INTRODUCTION

In 1998, a TRM for interoperability between C4I systems and simulations was developed and proposed to the 1998 Computer Generated Forces Conference [1]. Since first proposed, the TRM has generated a substantial amount of interest within the US C4I – M&S interface community, particularly within the Simulation Interoperability Standards Organization (SISO) Simulation Interoperability Workshop (SIW) conferences. It has been the focus of several SIW study groups intended to "formulate a broad-based technical model to describe and categorize interoperability of systems or classes of systems" [3,4,5]. The work and discussion of these groups continues, as well as their desire to "leverag[e] existing work and foster development of that TRM into a formal SISO product."

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[1] C4ISR systems are the US DoD functional equivalent to NATO Command, Control, Communication, and Intelligence (C3I) systems

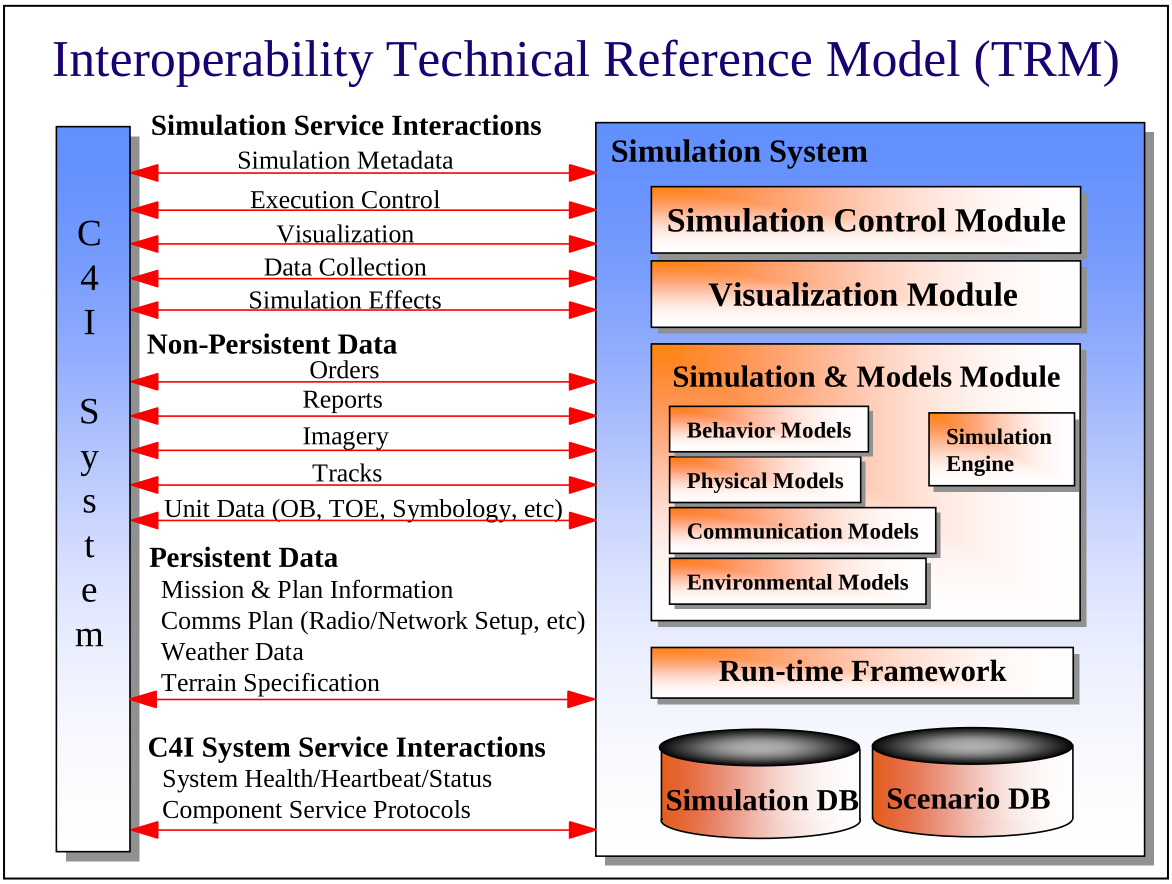

Figure 1 - C4I - M&S Interoperability Technical Reference Model

At the Spring 2003 SIW, the author proposed substantial changes to the TRM [2], as reflected in Figure 1 (Following page). These changes are being considered by the current SISO C4I – Simulation TRM Study Group, and are expected to become part of the formal C4I – Simulation TRM (C4I/Sim TRM). Section 2 of this paper provides an overview of the proposed C4I/Sim TRM, with additional detail in the source paper [2] and study group sourcebook [6].

The remainder of this paper is organized as follows: Section 2-4 provide an overview of the C4ISR/Sim TRM, Section 5 provides an introduction to various analysis sections which follow (Sections 6-9), Section 10 summarizes the result, with specific recommendations to the NATO Modelling and Simulation Group (NMSG).

2.0 C4I – M&S INTEROPERABILITY TRM OVERVIEW.

The C4I/Sim TRM is intended to be a generalized model of the components and interactions that are considered significant to efforts to establish interoperability between C3I and simulation systems/components, regardless of application for the interface effort. It is NOT intended to represent any specific simulation system, or current/future interface. Any level of detail within the C3I system has been intentionally omitted, as these systems are generously described in other documentation, such as the US DOD TRM [10,11] or NATO TRM[16 - 20]. The detail within the simulation system is kept at a high level of components that might be candidates for distribution in an architectural design. Another purpose for the high level Sim components is to suggest those that might be interchanged with C3I components as found in the NATO Common Operating Environment (COE) "basket of products". Finally, the level can be used to suggest possible candidates for component level integration, both using simulation components on board the C3I system and also using C3I components to facilitate interoperability during interface efforts. The scope of the C4I/Sim TRM is intended to allow for the consideration of component level interoperability, as well as systems level interoperability between simulation(s) and C3I system(s). The C4I/Sim TRM is intended to be appropriate whether the application for the interface is training/computer aided exercises (CAX), C3I system evaluation/test, acquisition, or simulation based decision support tools residing on (or remote from) the C3I system.

Changes in the way that C3I systems have been developed, in particular through the use of a Common Operating Environment (COE), have made them more modular or "component" based. Taking advantage of these changes, the interface community has more frequently re-used core components from C4I systems (e.g. message processors, database management systems, comms modules) in interfaces to reduce costs and improve interoperability.

The goal of the TRM is to assist programs in achieving more effective levels of portability and interoperability in the following ways:

By providing a consistent and common lexicon for description of interoperability requirements between diverse systems

- By providing a means for consistent specification and comparison of system/service architecture
- By providing support for commonality across systems
- By promoting the consistent use of standards
- By aiding in the comprehensive identification of information exchange and interface requirements

Although the TRM is based on current and past project experiences, it is intended to be evolutionary and flexible enough to support future needs, regardless of range of requirements or architecture configuration. Users are encouraged to use the TRM for guidance, and extract only those elements that support their specific project needs.

3.0 TRM INTERACTION CATEGORIES

Connecting the separate systems (or components) are *Interactions,* which are collected together into 4 categories. These categories of information exchange include service-oriented groupings for each domain's systems (C4I, Simulation) and the core data that would be of interest to both systems (Persistent and Non-Persistent data) during interface and/or integration activities. In two cases (Simulation Service and Non-Persistent Data) individual lines are detailed to represent individual classes, while in the others a single line reflects the entire class, with examples of information exchanges provided for consideration. The reason for the distinction between generalized categories and specific interactions is that in the 2 detailed categories cases sufficient work has been done to identify the specific classes, and it is expected that these classes are complete. An additional reason for the distinction is that in the two well-defined categories, the information exchanged is generally referred to in a similar way within the M&S and C3I communities.

To contrast this against the remaining two general categories (Persistent Data, C4I System Service), the lists presented are considered representative, and subject to variability depending on the C3I system. Further, it is felt that to completely enumerate all possible classes of information within these categories for all possible C3I systems would be of little use. Instead, an examination of requirements for each C3I system (or component) interface is needed, and consideration of the actual classes within each category (as well as its relevance to the interface design) is suggested.

Finally, the use of bi-directional arrows suggests the possibility that information flows within each class may go from C3I to simulation, or reverse. Clearly the existence of a particular class as well as whether it flows in a single direction, or both directions, is up to the requirements and design of the interface. What follows is a general description of the 4 categories. Additional information on Categories and Interaction details can be found in the source paper [2] and C4ISR/Sim TRM study group sourcebook [6].

3.1 Simulation Service Interactions

To facilitate the distribution of simulations, yet allow them to be accessible to C3I systems, interactions such as those defined within this category are necessary. These include not only information “about” the simulation (reflecting the potential that a variety of simulations are available), but also the ability to control or coordinate its execution with C3I resident activities, the transmission of possible visualization data (although not necessarily images), mechanisms for data collection from one to another, and the net results (or “simulation effects”) of a simulation execution.

3.2 Non-Persistent Data

Non-Persistent Data identifies very frequent information exchange interactions (typically messages, reports, or data replication) that may occur between C3I and simulation systems (or components). It represents the major focal point for interfaces used for training and CAX. In these applications most effort for interfaces goes into generating products from simulated entities, or evaluating products from operational C3I systems. In considering the potential use of these interactions within a simulation enhanced C3I system, it is possible that data from operational sources may be duplicated in forms such as these. This would allow the use of up-to-date situation awareness data in Course of Action Analysis (COAA) or Mission Rehearsal while additional data is received by operational components. Subsequently, revised data might flow through these classes to provide last minute checks against plan for feasibility. During actual mission execution, these classes might provide valuable conduits through which data used for automated execution monitoring might occur.

3.3 Persistent Data

This category represents operational data stores native to the C3I system, and having the characteristic of infrequent changes through the course of a simulation execution. Its presence within an interface, however, is important. The ability to provide direct transfer of C3I data from suggested sources to simulation equivalents for scenario initialization purposes can provide substantial cost savings, set-up time reductions, and increased flexibility for simulation use. Significant results from this type of work are reported in papers such as Furness et al, “Realtime Initialization of Planning and Analysis Simulations Based on C4ISR System Data” [12].

3.4 C4I System Service Interactions

These are interactions that may be mandated by use of particular C3I components, or merely by virtue of being connected to a C3I system. They may not contain “data” that is exchanged between the two domains, but may be required in order to connect to the C3I system, sustain the connection, or to use a particular C3I component. In the absence of these interactions, the C3I system may fail, the interface may not be recognized as a valid C3I system (versus a commercial hardware/software platform), or be unable to communicate with a particular component. These types of interactions tend to be very C3I system/component specific, based on particular component selections, hardware/software architecture implementation, or C3I system version. Therefore, no attempt is made to enumerate them exhaustively.

Rather, two general types are identified for illustrative purposes.

4.0 Simulation System Components

The concept behind simulation component modules is that they should represent the smallest reasonable piece that might be a candidate for distribution in an architectural design. In fact, they could potentially represent individual "services" distributed and tied together with the Run Time Framework. Further, they need not be a single instance, but could be multiplied across an implementation network. This would be true if used to design client/server configurations. This serves to recognize the simulation community's work on developing "federations" of simulations. In addition, it also extends the possibility to consider that such "federations" may be available to C3I systems, which might control selection of federates used to produce simulated results via guidance provided through Simulation Metadata interactions.

The simulation system components represented in Figure 1 are generalizations that would be considered most useful for, or relevant to C3I to simulation interfaces, or potentially useful for integration between systems. It is not intended that the components identified here represents a complete set required for any simulation system. Further refinement of the C4ISR/Sim TRM may expand this area, or ultimately there may be an effort to define and establish a reference model for simulations or synthetic natural environments. To date, beyond the work done on the C4ISR/Sim TRM described as part of this (and earlier) paper and the SISO study group, there has been no effort to put forth an M&S reference model, although the author believes there may be some value in doing so. There has also been little effort to establish a common M&S implementation (e.g. M&S COE). It may be possible that such efforts will be undertaken in the future, and as a result (as described in [8]) interoperability and reuse of simulation components will be improved.

In the absence of an accepted M&S Technical Reference Model, components are included in the C4ISR/Sim TRM for the purposes of architectural design consideration. Further efforts for C4ISR/Sim TRM refinements in the simulation system components area include an examination of its completeness against the work of the European Co-operation for the Long-term In Defence (EUCLID) project [21]. A comparison against the EUCLID synthetic environment architecture, as well as components contained within the EUCLID repository may confirm the accuracy of this area of the TRM, or provide clues how it could be appropriately refined. As an alternative, additional abstractions for the simulation components may come from examination of the component architectures of such systems as OneSAF [13].

5.0 NATO MODELS & STANDARDS RELEVANCE INTRODUCTION

Part of the work of the first SIW TRM Study Group [3] was to identify 5 guiding principles for the development of a C4ISR/Sim TRM. This work concluded that the C4ISR/Sim TRM must be: Comprehensive, Traceable, Easy to Interpret, Usable, and Independent. It also presented a cursory look at several M&S and other reference models, although it did not establish or reflect the relationship (traceability) between the C4ISR/Sim TRM and these other reference models. This paper seeks to establish the relevance of the C4ISR/Sim TRM to the international NATO community by examining several NATO reference models and standards, and illustrating their relationship to the C4ISR/Sim TRM in greater detail.

The Software Engineering Institute (SEI), in their Software Technology Review [9] states: "Much confusion exists regarding the definition, applicability, and scope of the terms *reference model*, *architecture*, and implementation." They go on to provide definitions for these terms (Table 1) and illustrative examples of the relationship between these concepts. In keeping with the SEI definition for reference model, the C4ISR/Sim TRM is intended to be a description of all possible software components or component services and the relationships between them.

Although repeatedly considered, no effort has been made to identify specific (or abstract) components for the C3I system portion of the diagram. The rationale for this is that C3I systems are subject to their own reference models (e.g. DoD TRM, NATO TRM), architectures (e.g. JTA, NATO C3 Technical Architecture), and implementations (e.g. DoD COE, NATO COE). Underlying each of these are sustainment efforts to continually evaluate and maintain reference and usage documentation. With all of these instances, the goal (among others) is to establish, guide, measure, or improve interoperability between systems or components. As with these efforts from the C3I domain, that is a primary goal of the C4ISR/Sim TRM.

In the following analysis sections the discussion starts with showing the traceability from the C4ISR/Sim TRM to the NATO TRM (NTRM).

As an architecture is considered a subset description of a reference model for a particular domain, the NATO C3 Technical Architecture (NC3TA) is considered to be relevant in the domain of NATO C3I systems. The NC3TA provides the principal source of procedures, architectural concepts, data (standards and products), and their relationships, from which the Technical View of C3I systems or "system of systems" can be developed. From such a defined architecture individual C3I systems are composed.

Reference Model: A reference model is a description of all of the possible software components or component services (functions), and the relationships between them (how these components are put together and how they will interact). **Architecture**: An architecture is a description of a subset of the reference model's component services that have been selected to meet a specific system's requirements. In other words, not all of the reference model's component services need to be included in a specific architecture. There can be many architectures derived from the same reference model. The associated standards and guidelines for each service included in the architecture form the open systems architecture and become the criteria for implementing the system. **Implementation**: The implementation is a product that results from selecting, reusing, building, and integrating software components and component services according to the specified architecture. The selected, reused, and/or built components and component services must comply 100% with the associated standards and guidelines for the implementation to be considered compliant.

Table 1 - SEI Definitions

This paper seeks to argue the relevance and validity of the C4ISR/Sim TRM to the NATO community, and its potential relationship to the NC3TA. To do so, an examination of the traceability of the C4ISR/Sim TRM to various portions of the NC3TA is considered. In particular, Section 7 looks at the NATO COE (NCOE) and NCOE Component Model (NCM). Section 8 proposes a simulation server functional configuration, and Section 9 relates the C4ISR/Sim TRM to the NC3TA Interoperability Model.

6.0 NATO TECHNICAL REFERENCE MODEL (NTRM)

The NTRM [17] provides guidance to NATO developers, system architects, and individuals in using and developing systems and technical architectures. The model promotes open system design, as well as the decoupling of application and external environment from the operating platform. It is based on national defense (US DoD TRM), aerospace (NASA Space Generic Open Avionics Architecture Model), and automotive (SAE GOA model) industry efforts. The NTRM contains basic elements of the POSIX OSE Reference model, which includes three classes of entities (Application Software, Application Platform, External Environment) and two types of interfaces (Application Program, External Environment). The main purpose of the NATO TRM (NTRM) is to structure the standards listed in the NATO Common

Standards Profile (NCSP) [19].

Within the NTRM, there are 12 service areas defined, which are later used organize standards within the NCSP. In addition, there are 7 application types (Mission Area Applications and 6 Support types). In order to assess the relationship between the NTRM and C4ISR/Sim TRM, an attempt was made to map the simulation modules into the various services and applications described in the DoD TRM. The results are presented in Figure 2 and discussion of the results follows.

C4ISR/M&S TRM Module	NATO TRM relevant Application and System Service Areas
Simulation Control	User Interface Services System Management Services
Visualization	User Interface Services Graphics Services
Simulation & Models Module	Mission Area Application Engineering Support Applications Common C2 Applications Services
Simulation Engine	Mission Area Application Engineering Support Applications Common C2 Applications Services
Models	Mission Area Application Engineering Support Applications Common C2 Applications Services
Run-Time Framework	Distributed Computing Services Data Interchange Services
Databases	Database Utilities Applications Data Management Services

Figure 2 - C4ISR/Sim Mapping to NTRM

In general, each module was able to map to several NTRM services and/or applications. This reflects the fact that as a reference model, it represents a potentially unlimited number of architectural definitions and/or implementations. In several cases, the modules were successfully mapped to items in both the service and application categories. This would credit the fact that simulations, due to their power and flexibility, can be seen to provide both application capabilities to the end-user, as well as perform service level functions to the system and/or other applications.

For the C4ISR/Sim TRM Simulation Control module, the limited descriptions provided for NTRM service areas suggest that a relationship would exist between Simulation Control module and NTRM User Interface Services, or NTRM System Management Services, or both. Clearly, the simulation control module might represent the user interface to the simulation "service" and provide management capabilities for it. But depending upon the specific architecture, it may (or may not) provide a user interface, style sheets, direct access to simulation capabilities, etc. If the user interface services class was intended to represent only those on-board capabilities to construct and control user interfaces (e.g. browser, Xwindows) then the simulation control module would be squarely within the system management services area.

Similarly, the Visualization module could map to one of two different NTRM service areas, either User Interface services or Graphics services. In this case, the visualization may represent intermediate results of simulation activities. Often this would be displayed on some form of two dimensional planned view display (PVD) or possibly overlaid onto a map. The potential mapping to User Interface Services might assume the development and acceptance of a simulation domain standard PVD or Graphic Information System (GIS) as a User Interface Service. In contrast to a similar evaluation of the C4ISR/Sim TRM against the US DoD TRM [15], the Visualization module was mapped easily to the Multimedia Services category not present in the NTRM. In the US DoD TRM, the Multimedia Services category contains a descriptive reference to GIS services, while the Graphics Services (within NTRM) simply refers to "functions required for creating and manipulating pictures."

The simulation and models aggregate component might be instantiated as a Common C2 Application, or a stand-alone Mission Area Application. Further, it is also identified as a potential Engineering Support application. Unfortunately, there is an absence of descriptions for applications (including Engineering Support) within NTRM documents available, however the US DoD TRM Engineering support description refers to “decision support services”, “modeling and simulation services”, and “expert system services”, all of which are potential applications for modeling and simulation interfaces or integration.

Although simulation engine(s) or model(s) are highly unlikely to be embedded (or interfaced to) by themselves, the possibility exists. As an example, it might be desirable to embed a simulation engine, which dynamically loads models (as data parameters, executable components, etc) from some central repository. Therefore, these would have the same potential mapping as the simulation and models aggregate component. Other then this possibility, more obscure mappings could be made (e.g. Simulation Engine – Mission Area Application / Models – Data Management Services).

Finally, both Run-Time Framework and Databases could map into two categories, depending principally on the intended implementation architecture. In the case of the Run-Time Framework, perhaps the more acceptable mapping would be into Distributed Computing Services. This is due to the fact that the Distributed Interactive Simulation (DIS) protocol is already an accepted standard within the NCSP for simulation use.

It was consideration of the module mappings that reinforced that the NTRM is a very generalized model and as such cannot (or has not yet) identified all possible domain services that could be provided. Also, there is presently limited documentation to describe various entities, applications, and service areas, which makes a specific direct mapping difficult. However, in several cases (specifically Run-Time Framework and Databases) descriptions provided within NTRM documents provides a somewhat clearer definition as to the potential implementation method or purpose for the modules. Therefore, although there is value in considering a mapping to NTRM areas for the purposes of communication with systems designed and built using this model, there is still relevance to a domain specific model such as the C4I/Sim TRM, which contains descriptions that should be more clear to simulation domain practitioners. However, the most ideal solution might be the use of both reference models for a more complete description of architectural components, modules, and implementation possibilities.

7.0 NATO COMMON OPERATING ENVIRONMENT (NCOE)

The goal of the NCOE is to support the development of a distributed information system infrastructure, which promotes interoperability. The NCOE provides the minimum set of services, common standards profiles, management procedures, implementation rules, interfaces, and guidelines for product selection, as well as products to implement NATO Information Systems (NIS). The objective is to ensure their interoperability within NATO and with national systems.

The NCOE Component Model (NCM) [20] capitalizes on the NATO Technical Reference Model (NTRM), utilizing its top-down layered architecture. Individual components can be described as the individual capabilities that are transparent to the end-user. Components are in essence the distributed computing capabilities, data interchange services, management services, communications services, data management services, presentation services, security services, etc. that are inherent to the NCOE as depicted in the NCM in accordance with the NTRM. The NCM depicts the high-level functional taxonomy and overall composition of the NCOE. Within the NCM, each individual component is categorized according to the type of service provided. However, the NCM only provides a view of individual component relationships by service area only. The actual products necessary to populate each service area are selected from the NCOE 'basket of products'.

C4ISR/M&S TRM Module	NCM Service Areas	NCM Service Sub-Categories
Simulation Control	Infrastructure Services	Management Services
	Common Support Services	Enterprise Management Services
Visualization	Common Support Services	Graphical Services (or) Undefined
Simulation & Models Module	Common Support Services	Common C2 Application (or) Undefined
Simulation Engine	Common Support Services	Common C2 Applications (or) Undefined
Models		Data / Objects (or) Undefined
Run-Time Framework	Infrastructure Service	Communications Services Distributed Object Services
Databases	Infrastructure Service	Data Management Services

Figure 3 - C4ISR/Sim TRM to NCM Mapping

An analysis was done to reflect the mapping between the C4ISR/Sim TRM and the NCM. The results are provided in Figure 3. However, as described in the details below, a number of simulation specific services (or components within the C4ISR/Sim TRM) remain difficult to classify.

Visualization would seem to be implementation dependent, but could be subject to some confusion based on the underlying technology chosen for implementation. For example, simulation displays that were based on GIS packages would clearly be able to fit within the Geospatial Services category. However this category seems to be identifying those components that are end point GIS systems, rather then simulation adaptation of these products that provide “added value” (e.g. displaying simulation progress on map products). Further, several existing simulations considered during the development of the C4ISR/Sim TRM utilize “home grown” PVDs, based on X Window, OpenGL, or VRML technologies (for example). These technologies/components are suggested within the presentation/multimedia services area, and therefore it may be appropriate for these Visualization components to reside there. Yet instances exist where simulation visualization tools may be distributed independent of the simulation portion itself, so correct placement within the NCOE may be important.

Similarly, Models do not easily fit into a single component category, because of the “value added” that they provide. Potentially instantiated as a model repository, they may consist of data files or objects, with their own repository infrastructure. However, this does not necessarily qualify them for data management, or distributed object services if these categories refer to domain independent tools. Clearly at some level they represent “data” or “objects”, but specific to the M&S domain and in conjunction with (or without) the Simulation Engine they represent a potentially powerful “service” that can be invoked by other applications, or as mission applications themselves.

The Simulation & Models module and Simulation Engine component doesn’t fit easily within Common Support Services or Infrastructure Services Categories. As a default, they were associated with the Common C2 Application service, although they did not seem to be consistent with the service description

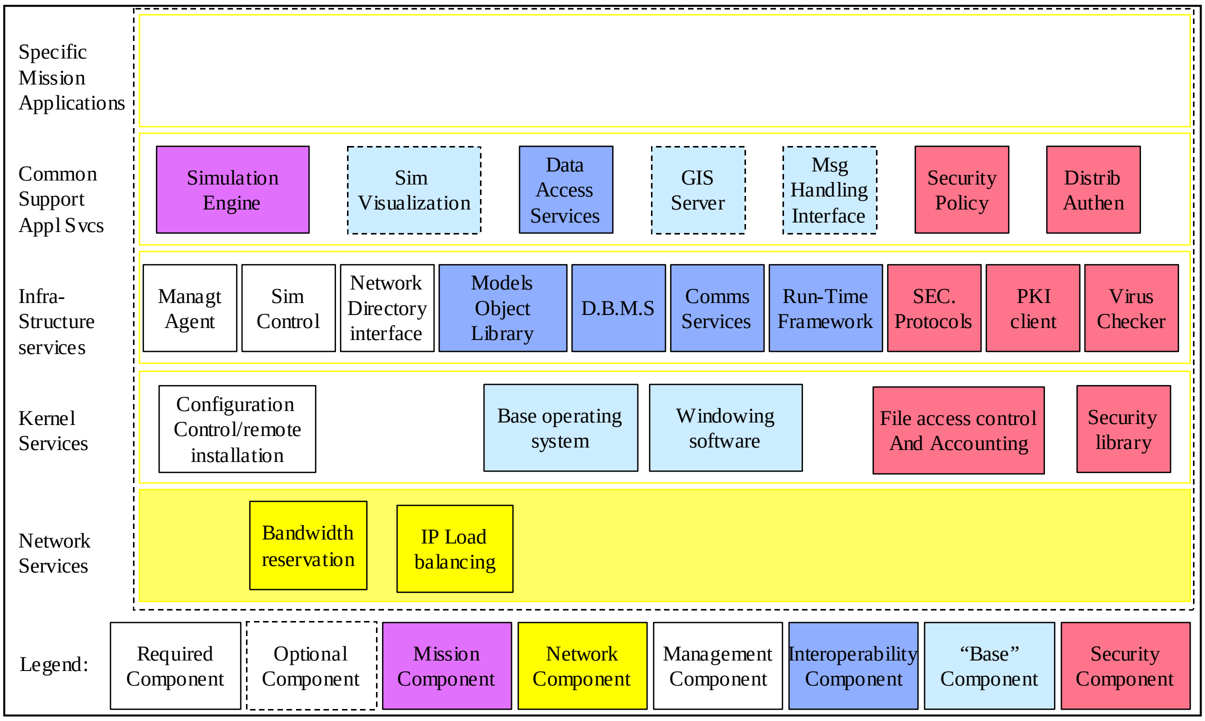

Figure 4 - Proposed Functional Components for Simulation Server

provided. Simulations, models, and simulation engine products exist in a variety of forms, not only from commercial vendors but also as by-products of nationally sponsored simulation efforts. As stated in [20] "The primary intent of the Common Support Applications is to provide the architectural framework necessary for the management, distribution and sharing of information among applications throughout a system." Further, "Infrastructure services provide a set of integrated capabilities that the applications will access to evoke NCOE services, and are necessary to move data through the network." Based on the examination of these definitions and other documentation of existing services categories, it was considered that a clear direct mapping of these simulation components was difficult.

As a result, it may be of value for the NMSG to consider development and proposal of an additional Common Support Service category. This category might be specifically oriented toward simulation-based applications or more generalized decision support services. These might not be mission applications themselves, but could provide powerful simulation based information processing or analysis capabilities to a wide audience of Mission Application developers. They could also represent the domain specific versions of various other services/applications (e.g. visualization, model repositories) that could be shared among simulation developers, or instantiated onto C3I systems.

As an example category, "Decision Support Services" might apply to a category of service level applications that provide intermediate processing of data/information from lower level (Infrastructure Service) components or data sources. Yet these "Decision Support Service" components may be general enough that they can be reused based on a common input format/standard and appropriate APIs. To extend the recommendation, it could be considered a "base" component, similar to "Document Management", "Message Handling", "Office Automation", or "Geospatial Services".

8.0 REFERENCE MODELS FOR FUNCTIONAL CONFIGURATIONS

Volume 2 of the NC3TA [17] introduces Functional Configurations (FC), which are composed of application and foundation services and interface functionally with one another. A full overview of FCs is provided in Annex B, and shows 9 FC examples that constitute an initial, although not all-inclusive list of FCs that will be validated and/or updated in future versions of the NC3TA. An examination of the existing FCs resulted in none that appeared fully appropriate for a simulation server configuration. As a further evaluation of the utility of the C4ISR/Sim TRM, a proposed FC configuration was developed and appears as Figure 4.

The motivation of a simulation server FC is the same as other FCs. It can be used to reduce architectural complexity, promote and encourage the judicious use of NCOE components, and improve interoperability. These and other reasons are consistent with recommendations made to SISO for the establishment of an M&S COE in a recent paper entitled: “Interoperability and Reuse through a Modeling and Simulation Common Operating Environment” [14]. Further motivation can be seen through the existence of other “server system” FCs, including Database Server, Web Portal/Application Server, Documentation Management Server, Messaging and Communications Server.

9.0 NC3TA INTEROPERABILITY MODELS

In order to classify NC3I Interoperability, the ISC has included in their NATO Policy for C3 Interoperability (PO(2000)39), 4 degrees of interoperability. These degrees are broken down into sub-degrees and are intended to classify how structuring and interpretation of data can enhance operational effectiveness. The sub-degrees are then be mapped to groups of standards to be referred to during the selection process.

To show the relationship between the C4ISR/Sim TRM and the applicable standards within the NC3TA, a mapping was done from the various interaction classes within the model to the interoperability sub-degrees within the NC3TA. This mapping is represented below, with specific point discussions to follow. The utility of such a mapping is that it provides a guide to interface efforts as to which categories of standards need to be considered during their efforts. It can also serve as a roadmap for NMSG standards consideration/development effort to focus on those categories where relevant standards are missing.

TRM Major Category	Interaction Class	NATO ID	Sub-Degree Name	Notes:
Simulation Service Interactions	Simulation Metadata	2.B	Enhanced Document Exchange	Assume hypertext
	Execution Control	1.C	Basic Informal Message Exchange	DIS, ALSP, RTI
	Visualization	2.B	Enhanced Document Exchange	Moving Image/Graphical Image
		2.D	Map Overlays / Graphics Exchange	GIS Geographic maps, overlays, military symbology
	Data Collection			Various forms: Potential from set of any/all Non-Persistent & Persistent Items
	Simulation Effects			Various forms: hypertext, graphical, data file
Non-Persistent Data	Orders	3.A	Formal Message Exchange	

TRM Major Category	Interaction Class	NATO ID	Sub-Degree Name	Notes:
	Reports	3.A	Formal Message Exchange	
	Imagery	2.B	Enhanced Document Exchange	Graphical/still image data, moving image, audio/visual data exchange
	Tracks	3.B	Common Data Exchange	Services for DBMS
		3.F	Real Time Data Exchange	Tactical data links
	Unit Data	3.B	Common Data Exchange	Database Replication
Persistent Data		2.A	Enhanced Informal Message Exchange	Message Logs
		2.D	Map/Overlay Graphics Exchange	Terrain Specification
		2.H	Data Object Exchange	Message Logs
		3.B	Common Data Exchange	Database
C4ISR Service Interactions		2.C	Network Management	
		3.C	System Management	
		3.D	Secure System Management	
		3.E	Security Management	

Figure 5 - C4ISR/Sim TRM Mapping to NATO Interoperability Degrees

The Non-Persistent data interactions mapped easily to the categories that would be expected for components and/or interactions among C3I systems. In cases where mappings indicated above were incorrect, users of the C4ISR/Sim TRM would be expected to utilize the interoperability profile for the specific machine (or type of machine) that was subject to interface or integration.

As indicated in the C4ISR/Sim TRM source paper [2], the items within the Persistent Data and C4ISR System Service categories are considered representative and subject to variability depending on the C4I system or proponent service. Therefore, the mappings in these two categories are also generally suggestive rather then attempting to make a single correspondence. In these two cases, no specific details for interactions are made, but general selections for sub-degrees represent common categories for items contained within the Notes column.

Identifying and categorizing the various simulation service interactions into sub-degrees was somewhat easier, yet subject to the same level of variability. The most likely form for simulation meta-data would seem to hypertext or XML formatted messages. For the purposes of simulation execution control, the example of legacy system usage of specific protocols, such as Distributed Interactive Protocol (DIS), Aggregate Level Simulation Protocol (ALSP), as well as current use of the High Level Architecture (HLA) Run Time Infrastructure (RTI) were considered. Of these, only DIS is referred to in the NC3TA standards document [18], although NATO acceptance of the HLA has occurred.

Data collection can take the form of discovery (and transfer) of numerous items from the C4ISR system, and potentially from the simulation. As a result, the sub-degrees that would be applicable would be as wide as the set of items for each system individually. Research in the area of simulation effects is still relatively new, and therefore difficult to classify the form that it might take. It could be a representation of a hypertext document (2.B), or perhaps a rendering on a Graphical/GIS image (2.D). Ultimately it may represent the influence of a particular datafile or operational database that is returned to the C3I system.

10.0 SUMMARY

This paper has provided an overview of the evolving C4ISR/Sim TRM, and examined the traceability of it to the various component reference models and standards of the NC3TA. The importance of the traceability to aid on-going efforts to establish C3I to simulation interfaces, the use of COE components within those interfaces, and the desire to migrate simulation based components and applications onto C3I systems. In the absence of an accepted (or mandated) simulation TRM, the simulation community has been free to model, architect, and implement what they choose. However, if those components are placed directly onto a C3I system, they would be subject to the models, architecture, COE, and standards as defined within the NC3TA.

As the analysis has shown in many cases, obvious relationships exist between components (and interactions) of the C4ISR/Sim TRM (and by extension the simulation domain) and the NC3TA. In other cases, the relationship is more obscure, principally due to the “generic” nature of the NC3TA. However, it has been pointed out where simulation domain specific contributions can be made within the framework of the NC3TA, that would help to make it more relevant to the simulation community. Through efforts such as this, it is suggested that the task to establish interfaces, and integrate components would be made easier, and the results more interoperable.

The following are the summary of the specific recommendations to the NMSG for this effort:

- Development and recommendation of simulation based Common Support Service category, for inclusion within the NCM.
- Development and formalization of Simulation based Functional Configurations, Technical Configurations, and Internal Interoperability Profiles.
- Identification of additional simulation based standards (e.g. HLA, SEDRIS) for inclusion in NCSP.
- Examination of C4ISR/Sim TRM to ensure that lexicon and representations are sufficiently generalized and consistent with NATO standards.
- Further examination of validity of C4ISR/Sim TRM, and consideration of Annexed inclusion within the NC3TA.

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viewpoints expressed in the paper.

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