Pathfinder Integration Environment – Knowledge and Resources Documentation Enabling Efficient Reuse

NATO MSG-27

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ABSTRACT: *The NATO Modeling and Simulation Group (NMSG) under the Research and Technology Organization (RTO) has the mission to provide readily available, flexible and cost-effective means to enhance NATO operations and the vision to promote co-operation among Alliance bodies, NATO Member Nations and Partnership-for-Peace (PfP) Nations to maximize the effective utilization of M&S. NMSG is responsible for the Pathfinder program, which guides various technical activities conducted by NMSG expert groups. The Pathfinder Integration Environment (PIE) is currently defined and implemented under leadership of Technical Activity MSG-027. Part of this activity is the prototypical implementation of the Pathfinder Web Portal.*

This paper presents the Web Portal in the context of MSG-027 and the Pathfinder program. The potential standards for describing M&S Resources and Knowledge for efficient reuse are the main focus of the paper.

1 Introduction

Modeling and Simulation (M&S) has been a cornerstone of NATO Research and Development (R&D) for analysis, education, and procurement since its beginning. While initially the focus was on Operational Research and analysis of stable strategy and doctrine, this focus shifted to computer-assisted exercises (CAX) in the following years. New initiatives target Defense Capability Initiative as well as Concept Development, Experimentation and the Support of Operations.

The fall of the former Soviet Union and the Warsaw Pact and the integration of new members let NATO grow to 26 nations and requested new processes and procedures, but also a new NATO doctrine. The restructuring of NATO's organization resulting in the Allied Command Operations (ACO) in Brussels, BE, and the Allied Command Transformation (ACT) in Norfolk, VA, USA, are examples for the continuing process of reorientation and adaptation to the new requirements.

The use of M&S became pivotal to NATO. The symposia on "C3I and M&S Interoperability" (2003, Antalya, Turkey) [1], "M&S to address NATO's new and existing Military Requirements" (2004, Koblenz, Germany) [2] and "Effectiveness of Modeling and Simulation – From Anecdotal to Substantive Evidence" (2005, Warsaw, Poland) [3] proved the growing importance of M&S in the alliance. The proceedings of these workshops are available and can be downloaded by every interested researcher.[1]

A closer collaboration of NATO's M&S bodies with SISO is not only reflected in mutually presented papers, but also in supportive activities, such as the NATO MSG-048 group and SISO's Study/Product Development Group on "Coalition Battle Management Language" (C-BML). However, the most successful step is that SISO only recently was accepted by NATO as a standardization organization eligible to contribute to NATO Standard Agreements (STANAG), which means that SISO standards can become NATO standards.

This paper will focus on the work currently conducted targeting the Pathfinder Integration Environment; in particular a web portal for knowledge and resources documentation enabling efficient reuse.

[1] See http://www.rta.nato.int/Main.asp?topic=msg.htm for downloadable versions of all reports.

We will give a short overview of M&S relevant NATO organizations and the NATO M&S Master Plan, describe the NATO M&S Group and the Pathfinder Program, and finally enumerate some relevant activities. In the main part of the paper, we will focus on the web portal and the standardizable elements, which are based on open standards and NATO solutions already implemented.

Figure 1: Objectives of NATO's M&S Master Plan

2 Organizations, Programs, and Technical Activities

NATO Research & Technology Organization (RTO) consists of the Research and Technology Board (RTB) leading the activities via regular meetings, and the Research and Technology Agency (RTA), a permanent staff to support the activities. The RTO reports to the Military Committee of NATO as well as to the Conference of National Armament Directors (CNAD), which means that the RTO is one of the highest organizations within NATO. RTO's mission is to conduct and promote co-operative research and information exchange within NATO and with its partners.

To conduct technical activities, RTO uses its panels and groups. The following permanent panels/groups are established under RTO:

AVT	Applied Vehicle Technology
IST	Information Systems Technology
SET	Sensors & Electronics Technology
HFM	Human Factors and Medicine
SCI	Systems Concepts & Integration
SAS	Studies, Analysis & Systems[2]
MSG	Modeling and Simulation Group

These panels/groups conduct technical activities by bringing experts of NATO and its nations – and increasingly partner nations, such as Sweden – together to evaluate solutions for NATO's various challenges. For the Pathfinder program, the MSG is responsible.

2.1 NATO Modeling & Simulation Group

NATO's MSG was established with the NATO Modeling and Simulation Master Plan (NMSMP). In 1996, CNAD established a Steering Group on Modeling and Simulation (SGMS), consisting of a Governmental Policy Subgroup (GPSG), a Military Policy Subgroup (MPSG), and an Industrial Policy Subgroup (IPSG), and tasked them with writing a Master Plan for M&S to align and coordinate the M&S related activities better. The SGMS agreed on the Master Plan (Version 1.0) in July 1998, which was approved by the North Atlantic Council (NAC) in December 1998. This plan is still valid and the basis for NATO's M&S activities.

The NMSMP formulates five objectives for M&S agreed to by all nations after mutual consensus and various sub-objectives to be reached within NATO, shown in the Figure 1.

The experts agreed that a common technical framework is the cornerstone for efficient use of M&S. This means that the coherent and rigorous application of common standard is a necessary, but not sufficient requirement. Technology without the application of common processes is useless. Distribution of information, education on how to work with M&S, and the use of common repositories were therefore summarized as the second objective group. Developing and Employing Simulations for practical use are objectives four and five. This means that NATO

[2] The panel's name was "Studies, Analyses, and Simulation" before, however, to distinguish better between SAS and MSG (Applying M&S as one tool within studies versus technical questions of M&S to enable their applications), a name change was proposed in the end of 2005.

is interested in setting up its own means, like currently manifested in the efforts to establish

- a Joint Warfighter Center (JWC) in Stavanger, Norway,
- a Joint Force Training Center (JFTC) in Bydgoszcz, Poland, and
- a Joint Analyses and Lessons Learned Center (JALLC) in Monsanto, Portugal[3]

Finally, technology never stands still. Therefore, observation and active participation in future technologies is a mandate for a viable organization and is summarized in objective five.

The NATO Pathfinder Program addresses all five objectives and is the flagship of the NMSG.

2.2 The Pathfinder Program

The Pathfinder Program can be considered as being the yardstick for all technical activities, defined by the following principles:

- NATO established the High Level Architecture as the common M&S standard as defined in IEEE1516 [4]. Currently, a STANAG is being worked on to achieve this. However, as you remember objective five, this does not exclude future oriented solutions.
- The technical activities support the Defense Capability Initiative as well as Concept Development and Experimentation.
- Training, Education, Analysis, Experimentation, Transformation, and Support of real Operations are in the scope of the program.

The vision of Pathfinder can be summarized by the following enumeration.

- Instead of using one system, every nation brings their own systems that are then federated into the common solution. The idea is that national ideas are nowhere better modeled than in the national simulation systems.
- M&S is only relevant when being applied to the benefit of the NATO user. To enable this, the convergence of Command and Control and M&S is mandatory.
- Setting up a scenario should be done in days or hours, not in weeks or months. Rapid scenario development is therefore another necessity.
- Effective and efficient reuse of existing solution is the last principle. Pathfinder shall support components being reusable beyond the borders of systems and nations, enabling synergistic reuse across the nations.

Pathfinder supports all parties in the long term, from developing better concepts via improved procurement to better education. It is obvious that such a program must comprise more than one expert group and more than one technical activity.

It is also clear that the concept required a solid foundation of standards for processes and technical solutions.

2.3 Technical Activities

The Figure 2 shows a selection of past, current, and recently initiated technical activities conducted under the aegis of the NMSG, contributing to Pathfinder. The selection is based on contributions to the technical activity MSG-027 and is therefore neither complete nor exclusive. The interested reader is referred to the proceedings of the annual NATO M&S Conferences published and distributed by the RTA.

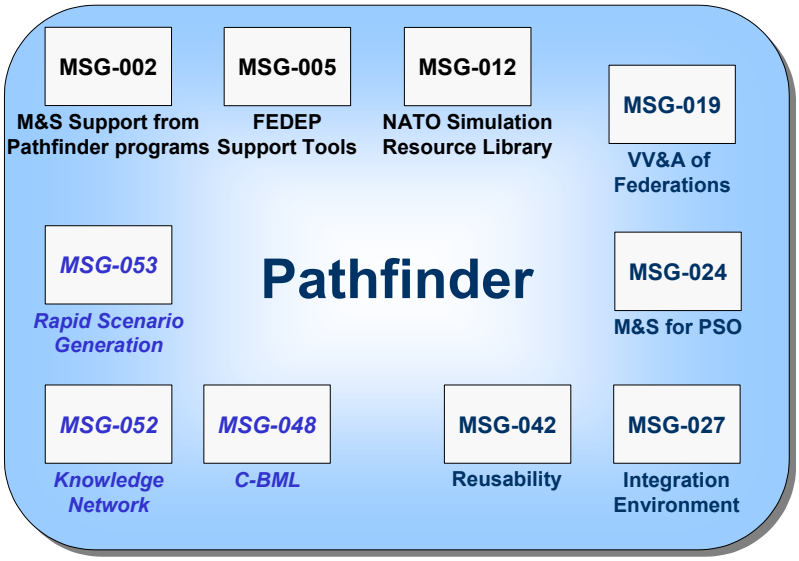

Figure 2: Technical Activities of Pathfinder

Earlier studies evaluated the possibility to support the program with current M&S functionality, how the Federation Development and Execution Process (FEDEP) is supported by tools, and how NATO's M&S resources can be described in a common Simulation Resource Library (SRL). Verification, Valida-

[3] See http://www.act.nato.int/organization/hqsact.htm for more information on these and related organizations.

tion, and Accreditation (VV&A) of federations is a topic supported by SISO as well. This topic is studied by a NATO expert group aligned with SISO activities in this domain. Reusability and M&S for Peace Support Operations are other current topics of interest. The only recently initiated activities on Coalition Battle Management and Rapid Scenario Generation are also overlapping with SISO activities in these domains.

This paper will focus on the current work to implement and evaluate a NATO Web Portal for knowledge required for the NATO Pathfinder Integration Environment. Emphasis lies on the structure of the knowledge descriptions, which has the potential to become a standard for knowledge representation for M&S reuse of M&S tools and other resources.

3 The NATO Technical Activity MSG-027

Technical Activity MSG-027 copes with the challenge of developing a common Pathfinder Integration Environment enabling the timely access, configuration, and federation of simulation-based tools in support of NATO activities. This Integration Environment envisioned for the Pathfinder program will be a web-based facility that will leverage NATO and national M&S integration expertise.

NATO and national organizations responsible for the development and provision of simulation support to the allied forces are the targeted user group. It will be usable in a distributed environment and capable of supporting collaborative High Level Architecture (HLA) federation development. It will provide an Integration Framework, which is described below, and other software systems and documentation that can aid HLA federation development. The systems referred to may include specific national models and simulations used for CAX/training support and other application modes, or web links to sources of these systems. It should be pointed out that national contributions in form of experiments have been essential to identify and derive the knowledge captured in the web portal. While additional papers focus on these experiment, this paper focus on the structure to capture the knowledge derived from such experiments.

3.1 Phased Approach

Based on the result of the early study on "M&S Support from Pathfinder Programs" a technical team started to evaluate the possibility of designing a web portal capturing knowledge and resource documentation, enabling efficient reuse in support of the Pathfinder idea. In the first phase, the concept was developed and several use cases of interest were identified.

In order to keep the scope of the technical activity on an achievable level, the team decided to limit the integration framework examples to the fourth and fifth step of the FEDEP: Developing a Federation and Planning, Integrating, and Testing a Federation. By doing so, developers can assume that a federation design is chosen and simulation software and tools are selected. The knowledge should be described in a way that software, tools, and other resources could be reused and the FEDEP can be supported. To this end, the applied processes have to be captured and documented as well. Processes as well as applied resources must be captured as elements. While principally all steps will be supported on the long run, MSG-027 targeted the solution providers with the technical aspects of the solution first. In section 4.1, we will cope with the potential in more detail.

A technical review of HLA federation integration issues and the availability of appropriate processes, tools, and standards identified 39 application categories or use cases in nine categories [5]. An MSG-027 report summarizes them in detail and gives more information. In addition, a survey of the MSG-027 nations conducted in November 2004 showed that 21 tools are available to satisfy the IFE tool requirements. However, this categorization and enumeration of available solutions showed additional gaps in current capabilities and identified additionally needed tools, standards, and processes.

A web portal provides access to this knowledge in the form of description of processes and applied resources. For the demonstration, a prototype with limited functionality was developed by VMASC and populated with some high-level examples. This will be described in the next section.

3.2 The Pathfinder Integration Environment

Principally, we have to distinguish between the structure and the content of the PIE. We recognize three domains:

- The knowledge section copes with how to apply resources to support the use case identified.
- The resource description section describes available M&S resources, such as tools, federates, and other software. However, this section also describes lessons learned, codes of best practice, etc.
- The resource section is only logically part of the integration portal. While the resource section comprises the description of resources, the resources themselves must be stored somewhere as well. In many cases, such resources are commercial solutions, such as Runtime Infrastructure (RTI) implementations or FEDEP support tools as identified in MSG-005. In these cases,

only a link to the provider will be provided. However, if free software is available, it may be accessed from this storage section.

In order to build a federation, all three components are necessary: the knowledge about the resources, the knowledge to apply them, and the resources themselves.

We shall focus in the rest of the description on the knowledge representation accessible via the web portal.

4 Components of the Pathfinder Integration Environment Knowledge Web Portal

Although the group decided to focus on steps four and five of the FEDEP, some studies were conducted regarding the categories of products to be supported for all steps. After we presented this overview, we will look into the components of the current prototypical implementation.

4.1 NATO M&S Resources and the FEDEP

In order to categorize the M&S resources, two SISO related ideas were used:

- Federation Development and Execution Process (FEDEP) [4],
- Levels of Conceptual Interoperability Model (LCIM) [6].

Figure 3 is based on a couple of ideas developed and shared within the MSG-027 technical expert team and summarized in [7] and [8]. The FEDEP has been designed to support all levels of interoperability:

- the technical level (network- and communication protocols);
- the syntactic level (common data format),
- the semantic level (common interpretation of data, reference information exchange data models);
- the pragmatic level (common use of information, common business objects for applications);

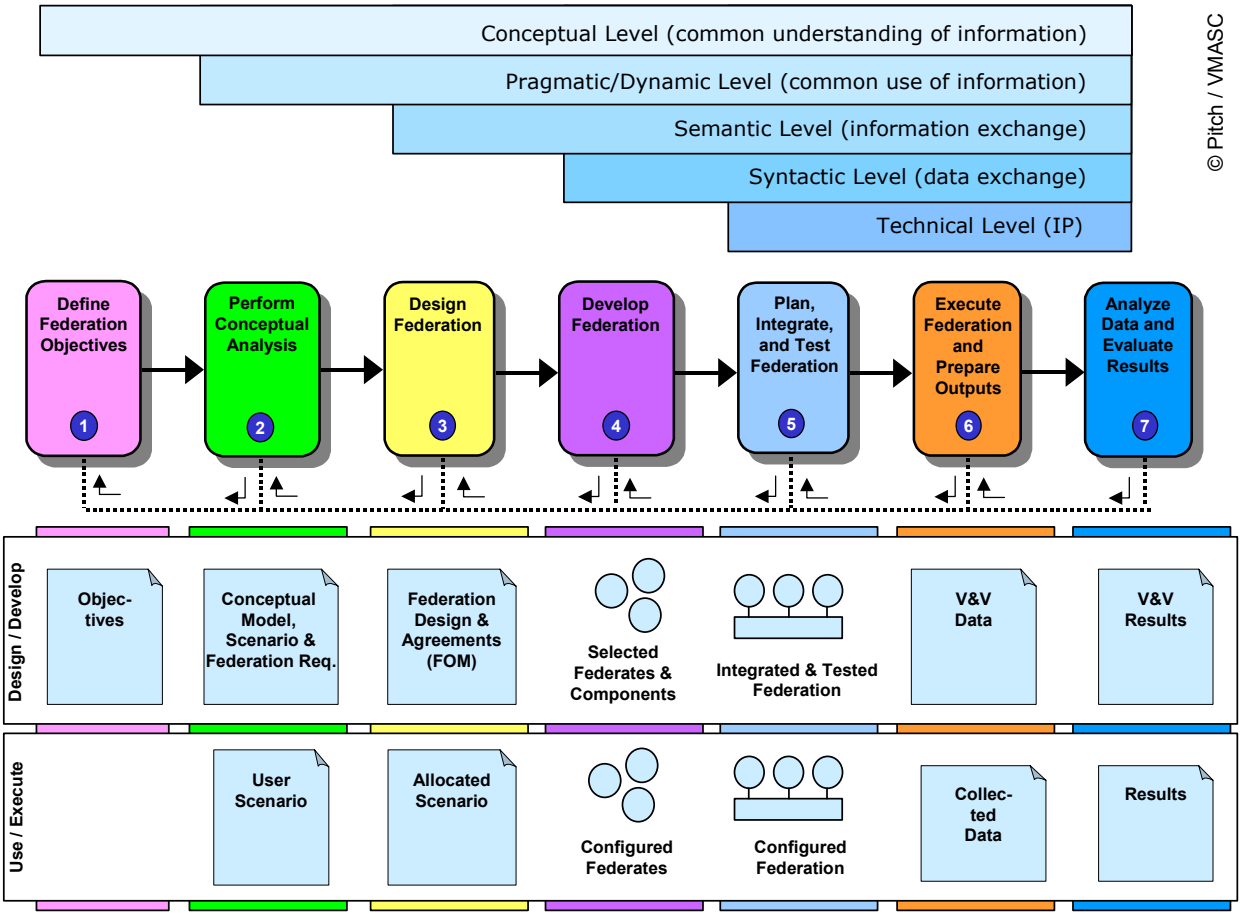

Figure 3: M&S Resources and the FEDEP and LCIM

- the dynamic level (orchestrated execution based on information exchange); and
- the conceptual level (common understanding of information on the conceptual level, common abstraction of reality).

Each step produces artifacts supporting these goals, such as objectives, the conceptual model, requirements and agreements, etc. These artifacts have assigned products on the users site when he executes the steps of the FEDEP, such as real user scenarios based on the scenario requirements, real configured federates based on selection criteria, etc.

Figure 3 is a principle scheme of the association between the LCIM, the FEDEP steps, the design and development artifacts, and the concrete resources.

4.2 Describing NATO M&S Resources

As mentioned earlier, we need the resources in order to apply them in a federation process. However, many resources are commercial products supported by vendors, so that it is not possible to make them directly available via a web portal. Even some academic solutions claim intellectual property rights and refuse to make solutions publicly available without protection. Therefore, we decided to distinguish between the resource section and the resource description section (see 3.2), where the first one is a logical connection to the place where a resource can be obtained (which can be a file server for open software or the vendor website for commercial solutions) and the second one is a description of this resource.

The web portal was designed under the assumption that NATO wants to be able to cope with all forms of descriptions for such resources, giving maximum flexibility to the web portal user. At the same time, we wanted to be able to share and use information of other resource description sources already used within NATO and its nations and supporting partners to maximize reuse. While these requirements seem to be mutually exclusive on the first look, the application of metamodels in connection with translation layers as suggested in [9] allows implementing a solution:

- The web portal supports the currently identified standards and solutions for the description of reusable M&S resources in form of identifying XML schema definitions (XSDs).
- The data elements supported by the identified XSDs are mapped to each other using the principles of data engineering [9] and resulting in a Mega-Resource-Schema comprising all possible data elements.

This allows the support of different and similarly structured resources descriptions in one web portal and furthermore the management of mutual exchange of data. To prove the feasibility, we are prepared to support the

- Standards, Tools, and Federate Container (STFC) as used in the prototype of the web portal demonstrated during the I/ITSEC 2006 and rooted in the structures identified in [5],
- NATO Simulation Resource Library (SRL) structure as defined in [10],
- Modeling and Simulation Resource Repository (MSRR) used within the US to share descriptions of M&S resource [11], and
- Industry Standard IEEE1420 for reusable components descriptions [12].

The use of metamodels to store the structure and the content independently from each other, allows regrouping the information from one to another interpretation. It furthermore allows merging additional resource descriptions to populate the resource description of the web portal as well as to retrieve information in the native format of the request – if the information is available in another already supported format.

The web portal doesn't mandate any standard. If a user decides to use a proprietary form to tag his description of a resource, or if he decides to use simply a single, huge free text field, he is able to do so. However, this allows only the display of his information on the web portal, not the exchange of data with other applications. To make the user aware of potential benefits of standardized structures, he can choose which resource description standards he wants to support when he enters new descriptions. The web portal evaluates the underlying XSDs and asks for all information required to support all XSDs in a dialog with the user. Information used in several supported formats must only be given once.

Figure 4 gives an example on how two contributing resource descriptions contribute to the Mega-Resource-Schema. It also shows how they can be displayed and how overlapping information can be exchanged using the metamodels captured in the Mega-Resource-Schema. To what degree the prototype implemented these ideas will be captured in section 4.4.

4.3 Describing M&S Resource Applications

While NATO and its nations have experience in describing the resources that have to be reused, the idea to separate the description of sources, the resources themselves, and the processes and use cases on how to reuse these components is new. The original idea of the expert team was to combine processes, standards, and tools as a unit into use cases [5]. Evaluations led to the recommendation to separate re-

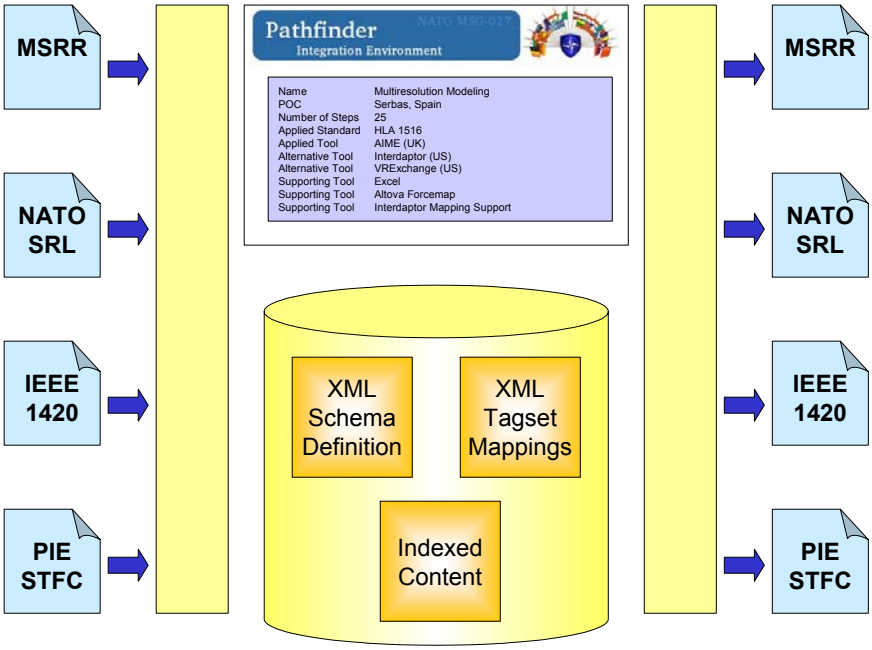

Figure 4: Use of Alternative Resource Standards

sources (standards, tools, federates, lessons learned documentation, etc.) and their use (processes), as the same tools have been used in different contexts, leading to redundant information, which normally is hard to manage in a consistent manner. This led to the decision to have a reuse knowledge section dealing with the use cases on the one side, and a reuse component section – split into the resource section and the resource description section – on the other side.

Again, the design chosen for the prototype is driven by the objective to include as many alternatives as possible to capture the knowledge of NATO concerning the reuse of components. The literature on knowledge management shows many domain-specific approaches, such as published in [13]. We decided to follow the most general recommendation suggested in [14]: capture the use case in form of a process comprising a sequence of steps. Of these steps, each step itself can be a sequence (sub-process), an iteration, or an atomic step, which is not further divided. To reflect the original idea of [5], we introduced the possibility that each step can be associated with resources (no resource, one resource, or multiple resources) that are used in this step. In addition to the process, the user can also specify who generated the use case and other relevant metadata.

Finally, it must be assured that all resources being used in the knowledge section are described in the resource section. This is not a requirement in the opposite direction, as some resources may be described without an applying use case, but if a resource is used in a process, it must be described.

It should be pointed out that the decision to model a process as a series of steps with each step being itself a series of steps, an iteration of a series of steps, or an atomic step limits the possibility to model parallel activities: only processes that are truly parallel can be modeled using this approach. If a process bifurcates into a main process and a side process A, and then the main process again bifurcates into another side process B before the side process A is finished, the web portal cannot model this behavior. However, the evaluations within MSG-027 led to the conclusion that this behavior seems not to be relevant to reuse (at least, no participant was able to come up with a relevant example in which this would be the case).

4.4 Implementing the PIE Web Portal

The implementation of the PIE Web Portal was conducted at the Virginia Modeling Analysis and Simulation Center sponsored by NATO's Allied Command Transformation (ACT) between September 2005 and April 2006. A first prototype was presented during I/ITSEC 2005 in Orlando, FL. The prototypical implementation as handed over to NATO was presented at ITEC 2006 in London, UK.

The implementation distinguishes between the server side and the client side. The server software has been developed under Linux and has been tested on Unix-like kernels and Windows. To ensure consistent and easy to administer handling of the information, the content is stored in a MySQL database. The developing language is Java (versions earlier to 1.5), using JSP version 2.0. The web services are using the runtime server Apache Jakarta Tomcat 5.x. All components are freely available for download from the Internet; nonetheless, they are professional concerning their performance as well as support by the using communities.

The client side is very thin. It is actually just a web browser with the right settings. We tested and ran the system on Firefox version 1.0.7 or above. We also tested it on Microsoft Internet Explorer version

5.0 or above, but the interpretation of XML and JSP differs between the Internet Explorer and other Internet browsers. In any case, the execution of JavaScript must be enabled, the use of cookies must be enabled, and the browser must accept certificates, as we use secure HTTP for the transfer of knowledge and resource description data.

In order to use the web portal, a password is required. We currently support three user group types:

- **Standard users** are only allowed to browse the web portal to find information. If they have additional questions or recommendations, they can send emails to the point-of-contacts listed with the entries or to the Webmaster of the web portal, but they are only passive consumers.
- **Contributing users** can browse the information and download the entries for editing. Once they edited a data set or produced a new one, they can send this data set via a SEND button to the Webmaster of the web portal. This is done in form of an XML formatted document, which can be parsed and inserted into the database (or used for updates). However, the information does not go directly into the web portal but undergoes a quality check by the web portal providers first.
- **Administrators** can use the web portal to access the database immediately. They have the ability to delete, update, and insert datasets via the web portal. This role will be used extremely seldom, as normally the Webmaster takes care of this issues at the server site.

The Webmaster has furthermore a set of database tools supporting him technically in his work. However, the lion's share of the administration work has to be done by a steering committee, which decides, which of the recommended changes, updates, inserts, and deletions make sense and will be supported and implemented.

5 Potential for Standards

The web portal is of interest to SISO for two reasons:

- The web portal supports several (de facto) standards for the description of M&S resources, currently shown for MSRR [10], NATO SRL [11], and IEEE1420 [12].
- The web portal implements (meta) schemas to store and map these different standards as recommended in [9] and furthermore a schema to capture procedural knowledge for the reuse of M&S resources.

Figure 5 shows the way the web portal captures the different standard descriptions in a meta schema. This schema is capable of capturing various XML schemas and allows tagging the same content with various standardized tags, as envisioned in Figure 4. The schema is one of the three guiding principles of the internal structure of information, derived from the ideas described in [9]: the structure of the XML schemas (structure of used name set), the mapping of equivalent tag sets with an tag index, and the content tagged with the tag index, and an instance index is shown in Table 1. It allows that the content can be exported in every name set that schema is completely satisfied, no matter if the information was originally imported in this XML schema or not.

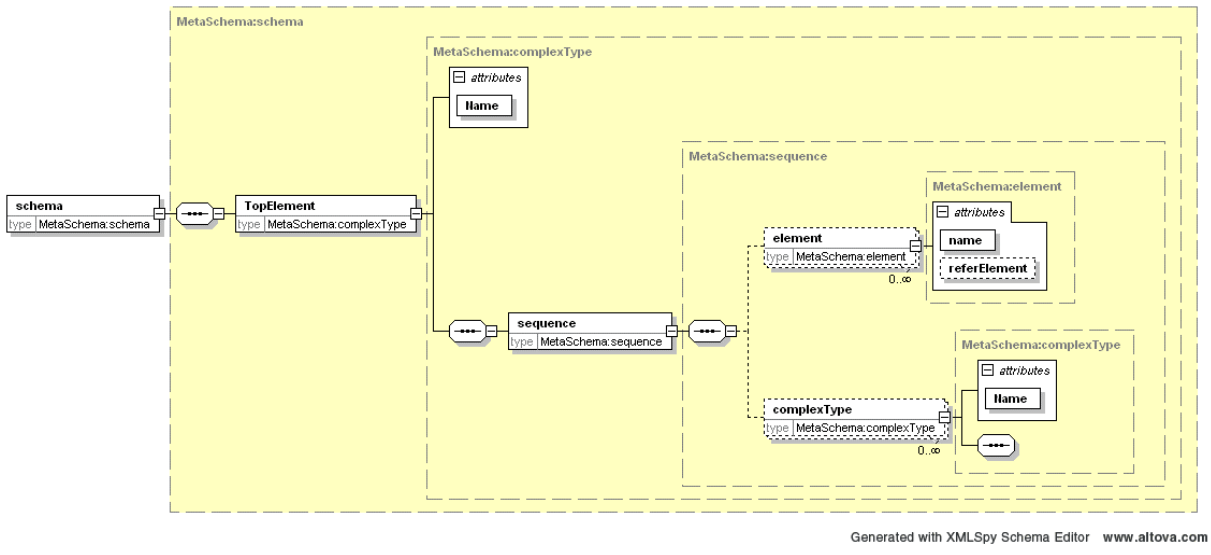

Figure 5: PIE Meta Schema for M&S Resource Descriptions

The example in Table 1 shows two entries for a name and an address for a point of contact, and an entry for the nation for one of them. The entrance in the meta schema shows that the first entry can be exported to the all three XML schemas, the second one is missing information on the nation and therefore can only be exported if this information is optional. The web portal allows entering this additional information, if desired by the user.

Table 1: Example for Meta Schema Use

Tag Index	XML Schema A	XML Schema B	XML Schema C
1	Name	POC Name	Contact
2	Street	POC Address	Address
3	Nationality		Nation

Instance Index	Tag Index	Content
1	1	Andreas Tolk
1	2	VMASC
1	3	US/GE
2	1	Paul Newman
2	2	NATO MSCO

This approach is also interesting for SISO, as it allows us to capture alternative XML representation of the same content, as long as the resolution is similar enough to support mapping without extensive aggregation and disaggregation requirements. The same approach was prototypically used in the effort described in [15], where the XML tags of the Coalition Battle Management Language (C-BML), the Military Scenario Definition Language (MSDL) and the Command and Control Information Exchange Data Model (C2IEDM) were aligned and the result was used to exchange information between systems supporting the different interpretations.

6 Summary

The Pathfinder Integration Environment Knowledge Web Portal contributes to the NATO Pathfinder program, which is the flagship of NATO MSG. It supports several standards for M&S resource description, helps to map them to each other, and implements a recommendation to capture procedural knowledge regarding the reuse of M&S resource.

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