NATO Standards for Virtual Ships

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ABSTRACT: *The NATO Naval Armaments Group Sub-Group 61 on Virtual Ships has been chartered to establish NATO standards for modelling and simulation applied to ship acquisition. Its objective is to enable multi-national simulation re-use and interoperability, as well as simulation composability. Technical activity encompasses data modeling, runtime simulation, and process aspects of virtual ship representation. SG61 is responsible for development of a formal NATO standards document (STANAG) to codify its results.*

Currently a draft Virtual Ships STANAG is being written and reviewed. The draft STANAG describes the architecture and rules for NATO-standard virtual ship representation and the associated Virtual Ship development process. A series of annexes provide further details on realising the Virtual Ship, including: Federation Object Model (FOM), Federation Agreements, maritime natural environment representation, scenarios, and data & data structure requirements. A central tenet of the SG61 STANAG is establishment of a Virtual Ships Repository containing STANAG compliant assets (e.g., simulation components, FOMs,). The STANAG provides information templates and process guidance for using the Virtual Ships repository.

This paper describes the SG61 technical programme of work, and discusses current progress and activities toward STANAG publication.

1. Introduction

Over the past several years, the NATO Naval Armaments Group on Ship Design – NG6 – has investigated the potential of common multi-national frameworks for modelling and simulation (M&S) for ship and ship systems acquisition. Following a successful program of work by a NATO specialist team[1,2] that included the multi-national M&S technology demonstrator known as NIREUS[3,4,5], NG6 became convinced that reuse and interoperability are key indicators of the value of M&S to naval warship acquisition. Further, NG6 became intent to harmonise investment in and development of ship virtual prototypes, to permit M&S reuse and interoperability to be realized across nations.

In 2002, NG6 chartered a formal sub-group, SG61, on Virtual Ships, to establish NATO standards for M&S in naval warship acquisition. SG61 currently consists of 16 nations[1]. SG61 is responsible for development of a formal NATO Standarisation Agreement (STANAG) to codify its results.

The scope of the NATO SG61 Virtual Ships programme of work encompasses the following high-level objectives:

[1] SG61 NATO, PfP, and invited nations are: Australia, Bulgaria, Canada, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, and United States.

- Information exchange and collaborative efforts in modeling and simulation in support of Naval ship acquisition;
- To organise this technology and promote the use of simulation modules, and to standardise the interfaces to those modules;
- Achieve cost efficient reuse and interoperability of simulation modules during ship design;
- Development the Virtual Ships STANAG to facilitate improved access to simulation technology during all phases of ship acquisition.

The Virtual Ships (VS) STANAG will describe the procedures and mechanics of how to achieve modularity in a secure, effective and expeditious manner[6]. The VS STANAG currently exists in draft form and is under review. Presentation of the final draft STANAG to NG/6 for proposed ratification is planned for December 2005. This paper discusses current progress and activities toward VS STANAG ratification.

The remainder of this paper is organized as follows. Chapter 2 introduces the context for the VS STANAG. Next, Chapter 3 presents the design considerations of the VS STANAG. Chapter 4, which is the main part of this paper, explains the purpose and content of the VS STANAG. Lastly, Chapter 5 summarizes the VS STANAG and presents its way forward.

2. STANAG Overview and Scope

The VS STANAG details procedures & specifications required to deliver virtual ship technology addressing the following key objectives:

- Allow NATO and partner Navies to use common development procedures that will maximize reuse and interoperability of virtual ship technology;
- Specify the contractual requirements for virtual ship technology to be developed by industry that will maximize reuse and interoperability of that technology;
- Leverage wherever feasible extant government and industry technology of known pedigree through the establishment of a Virtual Ship Repository to be configured and expanded over time under the control of a NATO executive body;
- Establish within the repository a number of common functions that could become available for use by NATO, partner Navies and their industry.

The goal of the VS STANAG is to define a consistent framework for simulation implementation that is robust but not too rigid. The participating governments expect to include the VS STANAG in contractual requirements for ship design projects as a de-risking mechanism. Development risks are lowered significantly due to, for example, predisposition toward simulation interoperability, known good pedigree of simulation resources, and limited required new development effort.

The intent of the VS STANAG is to be concise and explicit; results of a more advisory nature will be moved into an update to the Allied Naval Engineering Publication (ANEP) on Warship Simulation Based Design & Virtual Prototyping.

2.1 Virtual Ships

Here the notion of Virtual Ship is introduced. The implemented Virtual Ship includes the set of all simulations depicting the behaviour of a real ship for purposes of

- validating operational performance,
- testing technical integration of sub-systems,
- demonstration of critical technical capabilities,
- verification of interoperability with other systems, and
- evaluation of concept alternatives.

In the context of the VS STANAG, the Virtual Ship may be described as an architecture and a digital infrastructure where simulation models representing Naval systems and functions can work together. The requirements for Virtual Ships can only be met if existing and new simulation components can be included in many applications (re-usability). To achieve re-usability, we need interoperability of simulation components. Non-runtime interoperability can be achieved through use of shared databases, Product Data Management (PDM) systems, and data exchange standards. Runtime interoperability requires time-managed communication between simulations running on different computer hardware, with different operating systems and different compiler languages.

The basic premise of Virtual Ships standardisation is to leverage existing standards and practices where reasonable. Thus, the standardisation of a simulation architecture for virtual ships will recognize NATO's adoption of the IEEE 1516 High Level Architecture for simulation. It follows then that the ensuing simulation standards will be HLA federation standards. Here again, previous efforts will be leveraged. The IEEE 1516.3 FEDEP systems engineering process for simulation development will be recognized. The basic structure of federation standards will be built upon the standard Real-

Time Platform (RPR) Federation Object Model (FOM), and its associated federation agreements (known as GRIM).

3. Virtual Ship Architecture Design Background

This chapter provides background information for two main aspects of the Virtual Ship Architecture (VSA) that is defined in the VS STANAG. It presents general considerations that play a role when developing a standard for the complex of design supporting simulations like the VS STANAG. Also, as the VS Repository is a prominent part of the VSA, this chapter discusses the main VS Repository requirements.

3.1 General standards considerations

Simulation development is a complex area of work. It involves a lot of experts from different domains and also involves different technologies, such as simulation models and middleware. Hence there are different stakeholders that each a have different architectural viewpoint on the matter. The VSA has to accommodate these different stakeholders and provide a standard that meets their needs. Therefore a number of relevant general standardization issues have been identified, which are discussed here and which provide background to the design of the VSA.

The first issue that developers of any standard need to consider is the degree of flexibility of the standard. A standard that is completely fixed and non-flexible is very clear, which is a great advantage. A standardized file format is a typical example of such a rigid standard. The downside of a rigid standard may be that its application area is very limited. A standard that is very flexible may have a much broader application area. However, as it is very flexible, the standard may be interpreted in different ways by different people. In turn, this may make that it not regarded as a standard after all. Therefore, the degree of flexibility of the standard has to be chosen carefully.
The VSA consists of several parts, see also the next chapter, that each have a higher or lower degree of flexibility, whichever fits the use of the part best.
For example the VSR FOM is in principle a rigid model, whereas the VS Development Process is amore flexible one.

The second issue is an aspect that is an important factor in the life of a standard: time. After a standard is published it will sooner or later become out of date. The more fixed a standard is, the likelier it is that it will become out of date sooner. Standardization bodies, such as SISO, ISO and IEEE, often allow a standard to be updated, for example every few years. The time interval between updates is in principal dependent of technological advancements in the specific area.
We also consider it important that the VSA has the ability to mature over time. Therefore, the VSA has built-in facilities that enable the growth and maturing of the VSA. For example, new releases of the VSR FOM will be developed further as appropriate and the VS Development Process may be enhanced with new best practices when they become available.

The third issue concerns the acceptability of the standard. This is for a large part driven by the amount of best practices that are proven versus the amount of new technology that are present in the standard.
A standard that is fully based on known best practices may be acceptable and may be valuable in its own right. However, as it contains ‘nothing new’ such a consolidated standard does not help governments and industry to really improve their processes. On the other hand, a standard that mainly contains new technology and imposes this new -and not yet proven- technology may not be acceptable to its intended audience. An additional problem of the latter type of standard is probably the lack of possibilities to transit or upgrade to the new situation.
In order to make the VSA acceptable for the maritime simulation community, it is for a large part based on the well-known and accepted HLA and FEDEP standards. Also, it gives opportunities for the (re)use of existing simulation resources through the VS Repository. Lastly, the VSA defines –based on experiences– a reference FOM that is new.

The fourth issue concerns the aspect of technology versus process. Many existing standards only consider technology. However, for developing simulations both technology and process are important. Therefore parts of the VSA describe technology aspects, e.g. the VSR FOM and the VS Data Structures, whereas other parts describe the process aspects, e.g. the VS Development Process. They connect seamlessly together as the VS Development Process also described when and how to use the technology aspects.

All things considered, we think that the VSA has been designed in such a way that it covers these issues in an adequate way, and so accommodates the needs of all stakeholders.

3.2 VS Repository Requirements

One important part of the VSA is the VS Repository, see also chapter 4. To provide background information on the VS Repository, here its main requirements are discussed.

There is no sensible way of advocating re-use of simulation resources without having a central place where to find information on re-usable simulation resources. Without having such a central information place any proposal for enabling re-use will be fragmented and incomplete. The central place for finding maritime related simulation resources is the proposed VS Repository.

The main idea behind having a repository of re-usable resources is that the repository acts as a *marketplace*. The repository is the place to effectively *advertise* simulation resources. In this way the repository functions as a catalogue of simulation resources for potential customers and users.
For industry such advertising has the benefit of getting exposure for their simulation components, and increase their chances of generating business.

The repository is the place to go to when you need certain simulation resources. Instead of developing these resources yourself, they may already exist, and may be available for re-use. This does not mean that all repository items are available for free. The repository is a place where industry and research institutes provide high-level information of the capabilities of their simulation resources. A typical example is information on a simulation software component; the repository would contain an entry that describes the simulation component.

The VS Repository contains several types of simulation resources, including FOMs, Data Structures and Simulation Components, see also chapter 4. As the development cost of Simulation Components is high, Simulation Components in particular are very good candidates for re-use.

Which information on simulation components should be captured? We believe that the information on simulation components in the repository should give the user a good first impression which are the simulation components that might fulfill his requirements. The information in the repository should not be very detailed, but should only cover high-level information. Therefore the following information on Simulation Components should be captured:

- Description
  A short textual description of the simulation component functionality.
- Key words
  A selection -from a pre-defined list- of key words.
- Evidence of good pedigree
  A textual description of the simulation component usage history, e.g. by listing the projects that used the component, and/or VV&A information.
- Point of Contact
  Point of contact for obtaining further information on the simulation component.
- Availability & Licensing
  Indication of release conditions.

With this information the repository serves as an initial, reliable enabling mechanism for the identification of likely candidate resources.

There are two additional reasons for having only high-level descriptions in the repository.
First, for various reasons, providers of simulation components are not keen to publish all available detailed information. Providing high-level information on the other hand should not be a problem.
Second, having high-level information is much easier to check and validate and to maintain.

Whereas the VS Repository for Simulation Components is essentially a catalogue, other simulation resources may actually be downloaded. The VS Repository, see also 4.4, also contains the FOMs, Data Structures, Scenarios and a Natural Maritime Environment. As far as these simulation resources are unclassified and are releasable, it should be possible to make them available for download and hence re-use.

From the user perspective, a simulation resource repository should be easily accessible and searchable. In order to make the repository successful, good searching possibilities must be available. (This also implies that the repository only contains unclassified information.)

A different type of user functionality is the following. It should be possible for users to automatically obtain the information of their interest. It should therefore be possible subscribe to a category of simulation resources, and to be informed by e-mail automatically, when new information in this category is added or information is changed.

From a maintenance perspective, also supporting functionality can be required. For example, automatic triggers can occur at regular time intervals to verify if the information that is stored of a simulation resource is still current.

4. VSA Pillars

Developing maritime simulations is no sinecure. Ensuring that simulation models are also interoperable and re-usable requires even extra attention. Therefore the VS STANAG defines an architecture that guarantees the development of maritime simulations are interoperable and re-usable. This architecture consists of a number of parts that not only defines simulation technology but that also defines a process model with special attention for maritime aspects. Besides, the VS STANAG is based on known best practices. The VS STANAG adopts the High Level Architecture (HLA), which is a standard for distributed simulations developed by the US DoD and initiated in 1995. In the meantime HLA has proven itself as a standard that promotes re-use of simulations and their components. It specifies the general architecture of simulation capabilities and interfaces between simulations without making specific demands on the implementation of each simulation. The standard is developed in a co-operative, consensus-based forum of developers. It became an IEEE standard in September 2000.

While much of the early HLA development effort was focused on the creation of the HLA Run Time Infrastructure (HLA-RTI), the importance of the early federation design processes was recognized. The US DoD has formalized a description for the high-level process by which HLA federations should be developed and executed to meet the sponsor's requirements. This model is known as the HLA Federation Development and Execution Process, or FEDEP Model.

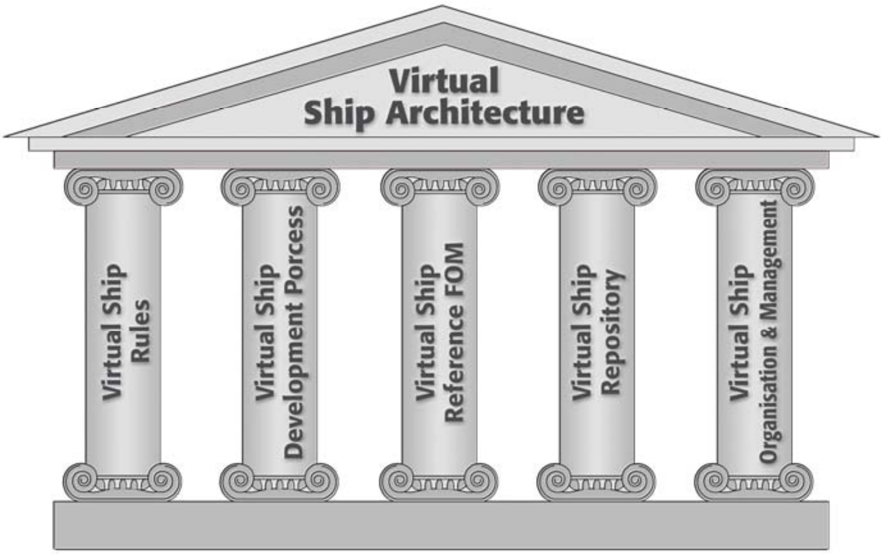

Figure 1. VS Architecture

The content of the VSA is supported by five pillars:

- VS Rules
- VS Development Process
- VS Reference Federation Object Model
- VS Repository
- VS Organisation & Management

These pillars are visualized in Figure 1 and are explained below.

4.1 VS Rules

The HLA standard specifies a number of rules to which simulations have to comply. Following this same approach, the VSA specifies an additional number of rules to which maritime simulations have to comply.

As the simulation is part of the acquisition process, the VS Rules describe at a high level the relationships between the simulation and the acquisition process. This is elaborated in the VS Development Process, see 4.2. The VS Rules describe from a process perspective how the simulation is embedded in the acquisition process and from a technical perspective how communication and data exchange between them is performed. Therefore these rules describe:

- formulating the question that needs to be answered by the simulation, i.e. the user need statement;
- the way ship design data is exchanged, i.e. how it is made accessible and how it can be used in the simulation;
- the way in which feedback from simulation results is processed in the acquisition process;
- the use of the VSR FOM, see 4.3;
- the times at which the VS Repository, see 4.4, is used and the associated activities.

Summarizing, the VS Rules describe at a high level the framework for developing maritime simulations that support the acquisition process.

4.2 VS Development Process

The FEDEP, which was introduced above, is a generic process model for developing simulations. In other words, it is applicable in different domains, both within and outside the domain of defense. However, when developing simulations for the maritime domain, a number of specific requirements are introduced. Which these are exactly depends on the question asked, but one example is the representation of the maritime environment in which various aspects from sea state to salinity levels of the sea water can play a role.

The VSA defines for three important aspects specific activities and considerations in addition to the FEDEP. These activities and considerations are coupled to the different steps of the FEDEP. They are formulated as so-called overlays. The three aspects are:

1. Product Data Management
   This overlay specifies process aspects and Product Data Management (PDM) considerations.

2. Maritime Natural Environment
   This overlay specifies recommended practices for the development of an adequate representation of the maritime natural environment.

3. Verification, Validation & Accreditation (VV&A)
   This overlay facilitates the development of evidence to prove to a predetermined level of confidence that the federation is credible and acceptable to use for its intended purpose.

The PDM overlay specifies the integration of the simulation in the ship acquisition process. In other words, it ensures that the simulations become design-supporting simulations. It embeds the simulation in the acquisition process in a more or less formal way by using the concept of workflows. Workflows can be regarded as well-defined sequences of tasks, which include the specification of input and output data and documents, schedule information, access rights, etc. Workflows are used to define the data exchange process from ship design systems to the simulation, and to define the process of feeding back simulation results. The overlay concerns the definition as well as the implementation of these workflows.

One aspect described in this overlay is the exchange of ship design data. Figure 2 shows an example of how ship design data is used in a simulation. The relevant data is exchanged from the ship design system, depicted as a Product Data Model, to the simulation, depicted as Simulation Components. The relevant Ship Design Data is extracted from the ship Product Data Model and is represented using pre-defined Data Structures from the VS Repository, see also 4.4. The Ship Design Data is used to configure the Simulation Components.

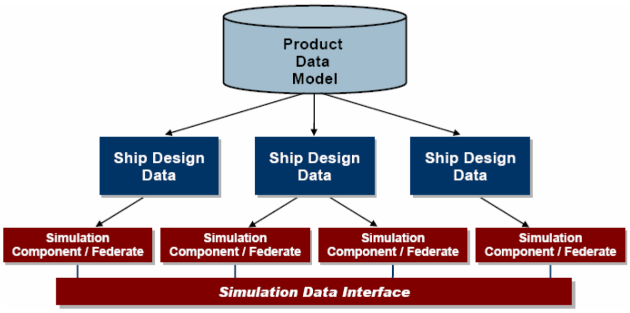

Figure 2. Design Data Access

This data exchange is performed when required, e.g. when a new version of the ship design is released that needs to be assessed using the simulation.

The VSA only prescribes that an appropriate (XML based) Data Structure is used. The actual data transport may be performed using any suitable and agreed form. For example, it may be exchanged using data files on a disk or via more advanced ways like using automated access (web services) over a network.

This overlay also provides general development considerations. These for example include the prioritization of requirements and scenarios, and best practices for creating concept diagrams.

An other important part of this overlay is the specification of when to consult and how to use the VS Repository. The role of the VS Repository is that it is the place where information on re-usable items is collected. Typical examples of such items are (see also 4.4): Simulation Components, Data Structures and Federation Object Models (FOMs).
The overlay enables the best possible degree of re-use of such items. For that purpose, for each of the items it prescribes the following VS Repository usage pattern:

1. Whenever an item is required during development of the simulation, consult the VS Repository to see if such an item is available and can be re-used.

2. After development of the simulation has been completed, newly developed or modified items are submitted to the VS Repository, making the items available for re-use by others.

So, besides having the benefit of being able to obtain information from the VS Repository, users of the VS STANAG also have the obligation to submit information to the VS Repository. Although security issues in some occasions could potentially waive this obligation, the VS STANAG is intended to be a contractual document and therefore this obligation is a legal requirement.

Figure 3 gives a graphical view of the usage of the different VS Repository items (vertical axis) in the different FEDEP steps (horizontal axis). It shows that in the early FEDEP steps simulation resources are obtained from the repository, while in later steps feedback from the simulation development experience occurs to the VS Repository occurs.

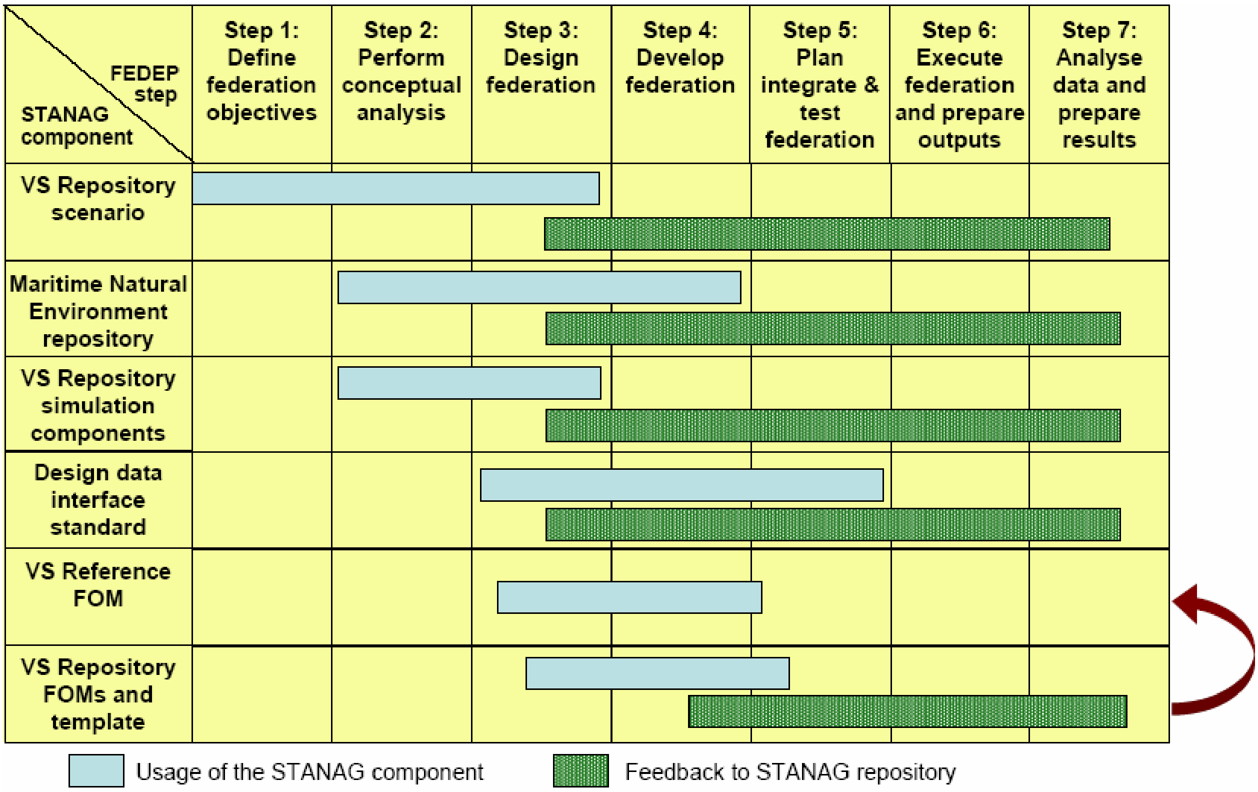

Figure 3. Usage of VS STANAG parts

The Maritime Natural Environment (MNE) overlay provides considerations for each of the FEDEP steps regarding the development of the maritime natural environment. Important features of this overlay include considerations regarding:

- the required environmental phenomena and effects;
- the level of detail of the natural environment requirements;
- the need to view the natural environment as a distinct system;
- the allocation of functionality to one or more federates;
- the possibilities to design and develop an adequate natural environment representation at reasonable runtime.

Although each of the steps in the overlay are important, the allocation of MNE functionality onto federates requires attention in particular. The creation of a singe MNE federate that handles all interactions is ideal from some perspectives. However, for various reasons (such as required runtime performance, inclusion of legacy federates) this is not always feasible. Consequently, MNE functionality is often distributed over several federates and is possibly partly duplicated. Managing and handling this during the development process requires more than average efforts, for example during integration testing.

The VV&A overlay facilitates the development of a federation, and the production of associated supporting evidence. This evidence is to prove, to a predetermined level of confidence, that the federation is credible and acceptable to use for its intended purpose.

An objective of working to the VS STANAG is to produce simulation components (and in particular federates) that can be cost effectively re-used. Therefore, determining that a component within the VS Repository is credible and valid (within a bounded set of conditions) is vital to give future users of the component the confidence that they require. The purpose of this overlay is to define the mandatory VV&A activities that developers must undertake in order to be compliant with the STANAG, and in addition to define the evidence that must be produced to demonstrate that these activities have been performed.

Also provided is the checklist for VV&A information that a user submitting or re-using VS Repository items shall provide or review respectively.

With these overlays, the VS Development Process specifies a simulation development process that is tailored for maritime simulations that support the acquisition process.

4.3 VSR FOM

In HLA simulation, the Federation Object Model (FOM) defines the interface between the different simulation components. In other words, the FOM defines the language that is spoken among the simulation components.

A well-known FOM is the Real-time Platform Reference (RPR) FOM, which is aimed at simulating land and air platforms. Because no widely accepted reference FOM is available that is suitable for maritime simulations, the Virtual Ship Reference (VSR) FOM has been developed as an extension of the RPR FOM. The VSR FOM bundles partial FOMs that have been developed by several nations. The VSR FOM comprises the RPR FOM and the VS FOM extensions. Similarly, the VS Federation Agreement (VS FA) comprises the Guidance, Rationale and Interoperability Manual, (GRIM) for the RPR FOM and the VS FA extensions.

For synchronized start up and shut down of a federation, the VS STANAG provides a set of recommended synchronization points. Besides, it recommends an associated execution life cycle when using a Federation Execution Manager (FEM).

The main part of the VS FOM extensions consists of objects and interactions that represent Replenishment at Sea (RAS) systems. Examples of such objects are TransferRig and Cable. They each have attributes that describe their physical properties.

Besides, the VS FOM extensions define a number of useful datatype extensions.

The VS FA extensions concern technical aspects of communicating timestamps, endianess, ownership management and scenario management.

The VSR FOM will be developed further in the future, see also 4.5.

4.4 VS Repository

The VS Repository is a web-based repository in which different types of simulation resources are available for re-use. The VS Repository contains resources of the following categories:

- Simulation Components
- Federation Object Models (FOMs)
- Data Structures
- Scenarios
- Maritime Natural Environment

The Simulation Components are software modules that were developed earlier by governments, research institutes and industry and that are –under certain conditions– available for re-use. The VS Repository functions as a catalogue for such software modules.

The VSR FOM is available in the VS Repository. Also extensions and new releases of the VSR FOM will become available.

The Data Structures define formats for the representation and exchange of different types of data.
Examples are:

- product data such as Computer-Aided Design (CAD) and Product Data Management (PDM) data;
- the representation of different types of signatures such as sonar, infrared and radar;
- data to represent physical aspects such as ship motion, air wake and downwash.

Lastly, (unclassified) Scenarios are available and a basic re-usable Maritime Natural Environment is developed.

The information on each of the types of simulation resources needs to be stored in the VS Repository in a structured way. Therefore, for each of the simulation resource types, a template for recording this information has been designed. For example, see
Figure 4, which shows the Scenario template. It contains the preferred fields for defining a scenario.

Family	Category
General Information	Name
	Type
	Version
	Modification date
	Purpose
	Application domain
	POC
	References
	Timeframe
	Geographical area of interest
	Countries/parties involved
Environment	Environmental aspects
	Consequences
Entities	Platforms
	Weapons
	Sensors
	C3 Structure
Threats	Platforms
	Weapons
	Enemy Counter Measures
Vignettes/Sequence of Events	Description of events

Figure 4. VS Scenario Template

4.5 VS Organisation & Management

Experiences from the past have learnt that a repository cannot be successful if it is not actively managed and maintained. Stated differently, the content of the repository needs to be kept accurate and current. For that purpose, the VS STANAG contains a so-called Future Development Programme. This programme defines the structure and responsibilities of an organization, called the Virtual Ship Executive Group (VSEG), that manages the VS STANAG. The outline of the responsibilities comprises:

- the management and administration of the VS Repository;
- managing the assessment of contributions to the VS Repository;
- Developing new releases of the VSR FOM.

Figure 5 graphically shows the process cycle of simulation resource and the role of the VSEG. When a simulation is developed for supporting the design of a ship, the VS Repository is consulted for various simulation resources. The ship design process benefits from the simulation allowing the ship design to demonstrate evolution. When the simulations have been completed, the VS Repository is consulted again to submit the simulation resources (using the available templates) which were changed or newly developed during the simulation exercise. The VSEG verifies the submissions and they become available for others to be re-used. This organization ensures that the VS STANAG will also in the future be up to date.

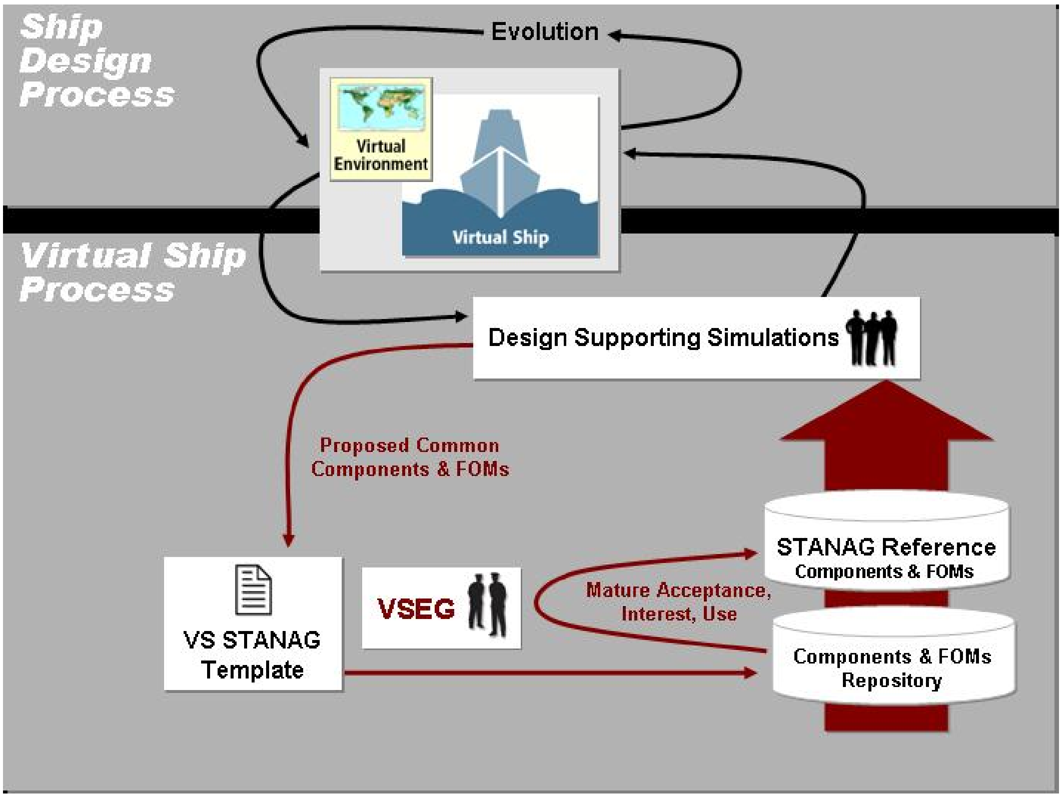

Figure 5. VS STANAG Process Governance

5. Way Forward

The Virtual Ship may be described as an architecture and a digital infrastructure where simulation models representing Naval systems and functions can work together. Use of Virtual Ships in ship and maritime systems acquisition holds the promises of cost avoidance, reduced time to field new systems, improved systems interoperability, earlier retirement of risks, and superior system performance.

NATO SG61 is responsible for development of a formal NATO Standardisation Agreement for Virtual Ships representation during acquisition. The Virtual Ships STANAG includes virtual ship data management, simulation, and process aspects. It stands on five pillars:

- VS Rules,
- VS Development Process,
- VS Reference Federation Object Model,
- VS Repository, and
- VS Organisation & Management.

The Virtual Ships Repository is a critical enabler for VS STANAG success. It is a web-based repository that connects potential users to different types of simulation resources available for re-use. Categories of VS Repository content include: simulation components, Federation Object Models (FOMs), Data Structures, Scenarios, and Maritime Natural Environment information. Each is supported by a standard template of resource information. The VS Repository will be organized under a multi-national executive group that will oversee configuration and expansion over time.

The VS STANAG has been drafted and is on target for presentation to NG/6 for proposed ratification in December 2005.

Military acquisition realities yield concurrent acquisitions at differing levels of design maturity, with systems interoperability requirements and overlapping mission needs. SG61 is demonstrating the value of common, re-usable frameworks for exercising and interoperating product designs to produce the greatest mission effectiveness for the lowest cost.

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Author Biographies

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