Virtual Ships: NATO Standards Development and Implementation

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ABSTRACT

The NATO Naval Armaments Group Sub-group 61 on Virtual Ships is developing standards for modelling and simulation applied to ship and maritime systems acquisition. Its objective is to enable multi-national simulation re-use and interoperability, employing modular simulation components and standardised interfaces. Technical activity encompasses product data modelling, runtime simulation, and practical demonstration of virtual ship applications.

A standard agreement (STANAG) has been drafted which will codify SG61 results. A companion 'User Guide' will be published as an Allied Naval Engineering Publication (ANEP). The Virtual Ships STANAG (STANAG 4684) is based on the High Level Architecture (HLA) for simulation; it is oriented toward HLA federations performing physics-based calculations where fidelity is generally of higher priority than runtime performance. The STANAG provides specific Federation Object Model (FOM) extensions to the standard Real-time Platform Reference FOM (RPR FOM). They include constructs for highly coupled ship systems, hydrodynamic forces, and propulsion. These extensions together form the Virtual Ship Reference FOM. It is envisaged that the Virtual Ship Reference FOM will ultimately be used to improve the next generation RPR FOM open international standard, thus achieving maximum dissemination and use.

Member nations' experience with development of HLA federations is providing valuable input to the Virtual Ships STANAG. Example federations have been applied to: landing of aircraft on moving ships, launch and recovery of smaller ocean vessels from a mother ship, and replenishment at sea with coupled ship motions. A multi-nation Memorandum of Understanding has been established to facilitate practical application of the STANAG. Draft Project Arrangements will further international cooperation in systems design and testing for replenishment at sea operations, and for quiescent period prediction in seakeeping. This paper provides a progress report on the work of Sub-group 61 and highlights selected practical applications.

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1.0 INTRODUCTION

The requirements driving the designs of modern ships are becoming increasingly complex and demanding as new technologies are introduced and as ships take on increasingly diverse tasks. To reduce risks, simulation methods have been successful in discovering design, interface and safety flaws for such systems. Unfortunately, the production of simulations is often omitted because traditional simulation methods often incur long lead times and high costs. The NATO Study Group SG/61 on Virtual Ships has been given the task of creating an international standard (Standard Agreement, or STANAG) that will allow the rapid construction of simulations at significantly lower cost to support the ship and equipment design process. The STANAG is initially aimed at a class of simulations which feature closely coupled hydrodynamic, aerodynamic and mechanical interactions that typically arise when testing the interfaces between different equipment. Examples of such systems are given below.

1.1 The NATO Submarine Rescue System

The NATO Submarine Rescue System (NSRS) is a jointly funded project by France, Norway and the United Kingdom and managed by the UK Defence Equipment & Support organisation. In the event of a serious submarine incident, a submersible (the Submarine Rescue Vessel, or SRV) would be launched to rescue and transport submariners from a distressed submarine to a surface vessel. The SRV is launched and recovered from the surface vessel using a complex A-frame system known as the Portable Launch And Recovery System (PLARS). Figure 1 shows the live system in action. The surface vessel is not a dedicated NSRS ship, but a 'ship of opportunity', chosen from ships that happen to be near to the distressed submarine at the time. The ability to safely recover the SRV in high sea states is strongly influenced by the surface vessel sea keeping performance, helm control and its generated stern-wake. Recovery of the SRV requires attaching a lift cable to the lift point on the SRV while it is being towed by the surface vessel. A key user requirement is to be able to recover the SRV in high sea states, when it is not safe to use swimmers to attach the lift cable. To meet this requirement, a 'catcher' mechanism has been designed which can be attached to the lift cable and lowered down a guide wire to automatically latch onto the SRV lift point.

Figure 1: Deploying the SRV on NSRS trials in Norway (left) and using the catcher to recover the SRV off the Scottish coast (right)

Illustrated at Figure 2 are some of the physical couplings between the NSRS systems. The interactions shown are limited to the physical interactions between the major systems - the mechanical handling system (PLARS), the submersible (SRV), the ship and the seaway. Clearly, there are more complex interactions present inside the mechanical handling system. For a full picture, the interactions of the control systems (e.g. ship helm) would need to be added.

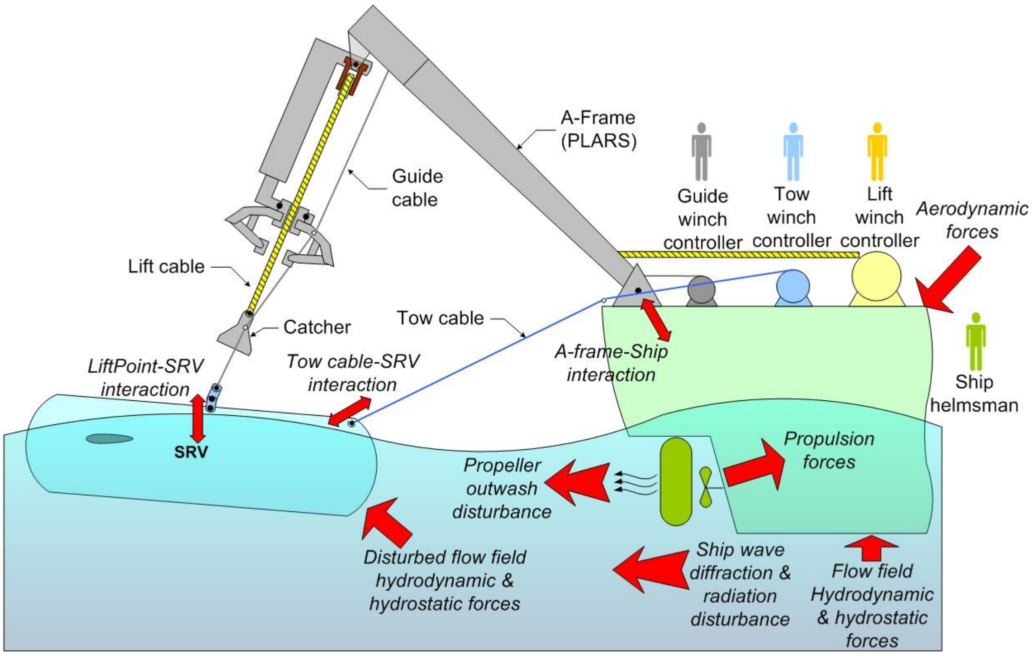


Figure 2: Physical interactions for the SRV recovery system

1.2 Replenishment At Sea

Replenishment At Sea (RAS) is an important naval operation where two ships come alongside to transfer supplies between them. Two different mechanical systems are used to transfer solids and liquids supplies. The physical interactions for the transfer of solids are illustrated at Figure 3. Mechanical coupling between the ships occurs through the RAS transfer system, while hydrodynamic coupling occurs through the common seaway between the ships.

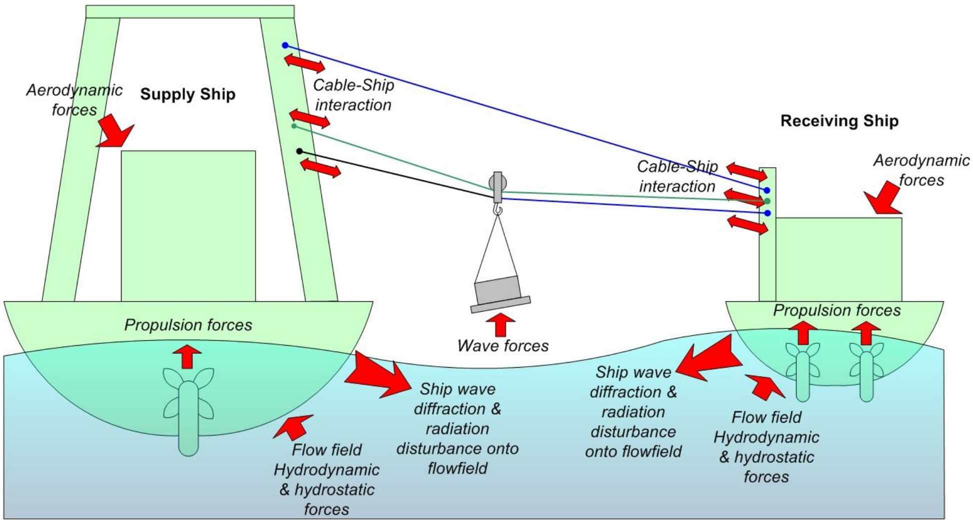


Figure 3: Physical interactions for solids RAS

1.3 Aircraft Recovery

The recovery of aircraft to ships is another important naval operation that features aerodynamic and hydrodynamic coupling. In Figure 4 the air flow is disturbed as it flows over the moving ship's superstructure, creating a turbulent airwake for the incoming aircraft.

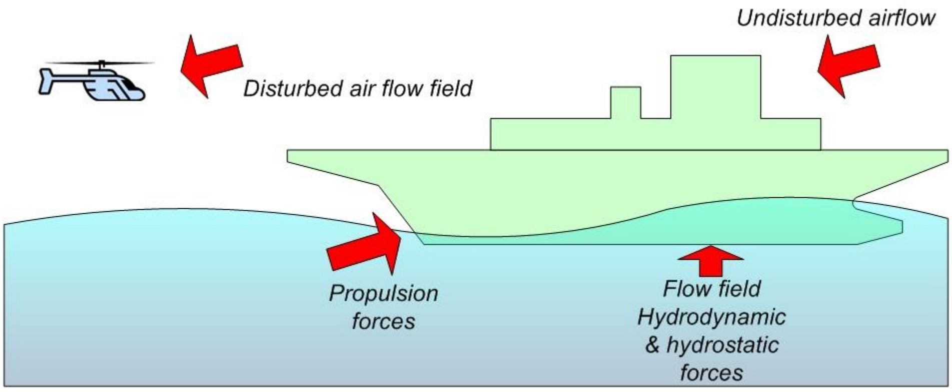


Figure 4: Physical interactions for aircraft recovery

1.4 A Variety of Interfaces

The forgoing scenarios illustrate that the ship system designer needs to cater for a wide variety of interfaces. In the case of NSRS, external interfaces include the surface vessels the PLARS is fitted to, and the large variety of submarines the SRV needs to mate with. NSRS internal interfaces include mechanical interfaces between the SRV and the catcher and the SRV and the surface vessel decompression chambers, all of which have been designed and built by different manufacturers.

In the case of RAS, ships from different navies need to come together in close proximity and maintain safe relative positions. The different hull forms will produce widely varying hydrodynamic interaction forces that are unique to that pair of ships. Furthermore, ships will need to interface with different designs of RAS rigs, which will have different performance characteristics and which will be influenced by the seakeeping performances of both ships.

It is clearly no longer sufficient to design a ship or equipment in isolation. A ship or equipment design needs to support interfaces with other equipment and platforms, which can be from other navies and different manufacturers.

2.0 THE CASE FOR SIMULATION

The design of these interfaces needs to be assessed as early as possible to discover design and safety flaws. At the design stage the ship or equipment does not exist in physical form, so the best means of testing the interfaces is often through simulation. In the case of testing the interoperability between existing ships and their equipment that are to meet for the first time, it is clearly preferable to try this out in the simulated world in order to anticipate possible safety and operational issues.

2.1 Simulation Road Blocks

The testing of such interfaces requires the simulation of systems that are closely coupled mechanically, hydrodynamically and aerodynamically. Traditionally, such simulations were constructed from the ground up, which resulted in a large, monolithic simulation built using custom interfaces. Such simulations were unable to be re-used for other applications because they were too application specific and too highly customised. Considerable time and money was invested in the creation of such simulations. When faced with trying to solve another similar problem, it was often easier to start the simulation development all over again rather than attempt to adapt the original simulation. This was a major obstacle to the use of simulation in the early design phases. The costs to create the simulations were too high and the time to realise them was simply too long.

2.2 The Solution – A Repository

Clearly another method of creating simulations is needed that is quicker and less costly. It was noticed that the large simulations built in the past often contained within them re-usable components. If these components could somehow be given standard interfaces, this would allow the rapid construction of new simulations from the re-usable components. From this, the idea of a repository of re-usable simulation components was born. Such a repository could ultimately be populated by contributions from many different nations and companies.

3.0 REALISING A REPOSITORY

The creation of a repository, however, does introduce additional challenges:

- How can we ensure that the contributions to the repository will inter-operate?
- How can we protect the Intellectual Property Rights (IPR) of the repository contributors?
- How can we protect sensitive simulation components?
- How do we ensure the contributions are fit for purpose and have been sufficiently validated?

The NATO Study Group SG/61 on Virtual Ships has been tasked to meet these challenges by developing a standard known as the Virtual Ship Standard Agreement (STANAG) [1], supported by an on-line repository. We discuss each challenge in turn.

3.1 Simulation Interoperability

To enable simulations to interoperate and exchange data requires simulations to share a common understanding of the data content, format and data exchange protocol. This common understanding needs to be expressed in the form of a simulation standard.

Fortunately, such standards already exist and in this case SG/61 has adopted the IEEE 1516 High Level Architecture (HLA) [2]. This is a well proven standard used for assembling a large simulation (federation) from a number of smaller simulations (federates). While this looks as if this has solved our simulation interoperability problems, unfortunately it hasn't quite. The problem is that the HLA gives the user complete freedom to design their own federation data exchange content and format. This data content and format is known as the Federation Object Model (FOM). So while the HLA allows wide classes of simulations to be connected, they will still need to agree upon a common FOM.

Now it is impractical to design a FOM that can be used by every possible kind of simulation - the simulation world is just too diverse. What can be done, however, is to design a FOM for a particular class of simulations - in our case, ship and equipment simulations for the purpose of ship and equipment design and naval operations. This FOM forms a key part of the Virtual Ship STANAG, and is known as the Virtual Ship Reference FOM (VSR FOM). The Virtual Ship STANAG is therefore defined by the combination of the HLA IEEE 1516 standard and the VSR FOM.

3.1.1 The Virtual Ship Reference Federation Object Model

The Virtual Ship Reference FOM is an extension of the Real-time Platform Reference FOM (RPR FOM) [3] which is frequently used for HLA federations. It is an orthogonal extension, in that if one were to delete the classes introduced by the VSR FOM, one would be left with an unaltered RPR FOM. The VSR FOM specifically addresses the needs of naval simulations featuring coupled, multi-physics interactions.

Table 1 shows the Object classes of the VSR FOM in the shaded cells. Some of the RPR FOM classes are shown in the un-shaded cells. The VSR FOM is currently under review, so its final form may differ from that presented here. To give an idea of how the VSR FOM has been structured, some of the classes have some of their attributes listed as bullets in the table. The VSR FOM classes fall into two groups. The first group, ***VS_Body***, represents physical objects within the simulation, such as rudders and cables. The second group, ***VS_Env***, represents environmental effects, such as aerodynamic and hydrodynamic effects.

Class 1	Class 2	Class 3	Class 4	Class 5
BaseEntity	PhysicalEntity	Platform	Aircraft SurfaceVessel SubmersibleVessel	
VS_Body • *EntityType* • *ForceAndMoment*	***VS_RigidBody*** • *Spatial* • *VSRelativeSpatial* • *Dimensions*	***VS_FittedObject***	***VS_Propulsor***	***VS_BladedPropulsor***
			VS_ControlSurface	***VS_Rudder***
			VS_Winch	
			VS_VisualLandingAid	
			VS_BallastTank	
			VS_Mount	
		VS_FreeObject		
	VS_SoftBody • *Vertices*	***VS_SoftBody2D*** • *Diameter*	***VS_Cable***	
		VS_SoftBody3D • *Indices*	***VS_Net*** • *Diameter*	
VS_Env • *IsPartOf*	***VS_FluidDynamicsRequest*** • *ForceAndMomentRequest* • *DensityRequest* • *VelocityRequest* • *PressureRequest* • *AddedMassRequest*	***VS_AerodynamicsRequest***		
		VS_HydrodynamicsRequest • *WaveElevationRequest*		
	VS_EnvironmentResponse • *WaveSpectrum* • *Current* • *WaterDensity* • *Wind* • *AirDensity*			

Table 1: The Virtual Ship Reference FOM object classes.

Object classes are used when the entity being represented has some persistence in the simulation world. Physical objects and requests for aerodynamics and hydrodynamics data are usually persistent. These requests apply on a per object basis and usually do not have to be sent more than once. Another kind of class exists in HLA known as interaction classes. These are used for transmitting data that is viewed as transient in nature (lacking persistence). Interaction classes are often used to represent communications messages, for example. It is sometimes not clear whether one should use object classes or interaction classes. In fact either can be used in practice. However, object classes have the distinction that an HLA object must be created in order to transmit the object's attributes. Table 2 shows the interaction classes introduced by the VSR FOM.

Class 1	Class 2	Class 3
VS_InteractionBase • *IspartOf*	***VS_FluidDynamicsResponse*** • *NameOfRequestingObject* • *ForceAndMoment* • *Density* • *Velocity* • *Pressure* • *AddedMass*	***VS_AerodynamicsResponse***
		VS_HydrodynamicsResponse • *WaveElevation*
	VS_EnvironmentRequest • *WaveSpectrumRequest* • *CurrentRequest* • *WaterDensityRequest* • *WindRequest* • *AirDensityRequest*	
	VS_Controller • *Demand*	

Table 2: The Virtual Ship FOM interaction classes

For representing the environmental effects, we distinguish between the large scale, slowly changing environmental data (such as the wave spectrum, wind and current) and the more rapidly changing data as a result of an object disturbing the environment (such as a ship wake). The slowly changing data is handled by the ***VS_EnvironmentRequest*** interaction class and the ***VS_EnvironmentResponse*** object class. The the rapidly changing data is handled by the ***VS_FluidDynamicsRequest*** object class and the ***VS_FluidDynamicsResponse*** interaction class. These classes of data have to be attached to a ***VS_Body*** or ***Platform*** object, as environmental effects are spatially dependent. Object classes have been used for the ***VS_EnvironmentResponse*** because the response data is rarely changing data that many federates need access to, and so could be obtaining simply by discovering the environment response object, or by raising an interaction to request creation of the response object. Object classes have been used for the ***VS_FluidDynamicsRequest*** because requests are typically issued only once, while the responses will be frequently updated.

The *ForceAndMoment* attribute of the ***VS_Body*** class is used to communicate forces and moments. This attribute is updated for each of the objects in other federates the body is applying forces to.

The ***VS_Body*** class divides into ***VS_RigidBody*** and ***VS_SoftBody*** classes. The ***VS_RigidBody*** class represents rigid objects whose position and orientation can be defined using a single spatial attribute. Rigid bodies have a constant shape and so their bounding box (given by the *Dimensions* attribute) is well defined. The *Spatial* attribute defines the world location and orientation (and their rates of change) of the rigid body. A mechanically attached rigid body is described by the *VSRelativeSpatial* attribute. This is a compound data structure which identifies the parent object and the relative location and orientation (and rates of change) of the object with respect to the parent, expressed in the coordinate frame of the parent.

The ***VS_SoftBody*** class represents objects such as cables, nets and other deformable objects that require a different representation of their shape and location. This is done using a vertex array (*Vertices*) for cables and an additional indexed array (*Indices*) for volumetric shapes.

Finally, in the interaction classes, the ***VS_Controller*** class allows controller federates to send demand values for various types of actuators.

It is important to realise that the FOM classes are only used to define information that is passed between federates. For example, it is not the intention for a federate to completely describe to all other federates the insides of a mechanical system that it is simulating. As an illustration, a ship may have many federates simulating mechanical systems attached to the ship. These federates will publish the forces and moments acting on the ship, but have no need to publish the internal forces acting within each mechanism. Furthermore, there is usually no need for the ship federate to publish information saying that it is part of the mechanical systems.

3.2 Sensitivity Issues and IPR

A key method to overcoming obstacles in protecting Intellectual Property Rights (IPR) and other sensitivity issues is to make use of data driven models. A data driven model is a generic model of a system that requires an external data file to be able to model a specific instance of a system. The generic model is free of IPR and other sensitive issues as it does not, on its own, simulate any particular system. It can only do so when provided with a data file that enables the generic model to simulate a specific system. The means by which the data file is created is typically where the IPR is held. Companies will use their own private methods to generate the data file content. From the point of view of sensitivity, only the data file needs to be protected. Clearly, the format and structure of the data file needs to be open source.

For hydrodynamics applications, a data-driven approach may take output from off-line Computational Fluid Dynamics (CFD) models in the form of computed hydrodynamic coefficients, which can then be used as source data for a model that calculates the hydrodynamics forces and moments acting on a ship as it moves through the seaway. This is an example of a data driven dynamics. An example of data-driven kinematics is in the use of conventional Response Amplitude Operators (RAOs) for generating ship motion.

3.3 Quality Assurance

The VS STANAG ensures that simulations that are VS STANAG-compliant, in the sense that they are HLA federates that use the VSR FOM, will be interoperable and can be found within a VS Repository. However there is a large amount of information to be absorbed by the engineer that uses the VS STANAG, VSR FOM and repository for the first time.

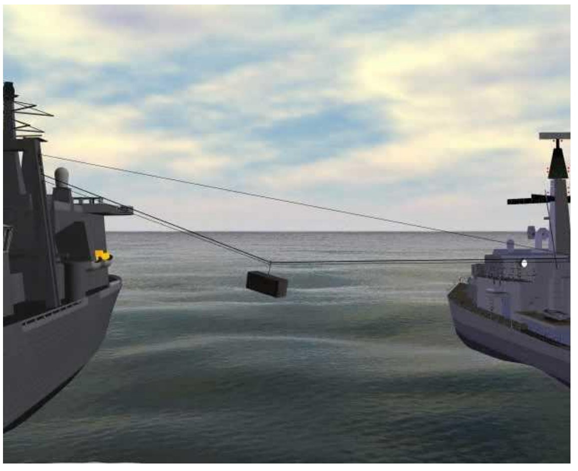
To assist the engineer, a user guide is being created in the form of an Allied Naval Engineering Publication (ANEP). The user guide describes the details of the VSR FOM and recommends a process by which the new federation can be constructed and verified. The repository will be managed by a small team that will ensure the required verification and validation documentation is provided for VS STANAG-compliant federates.

4.0 RECENT PROJECTS

The UK has contributed to the development of the VS STANAG as a result of lessons learned from three major simulation projects. These are summarised below, including screen shots from the actual simulations:

Ship Air Interface Framework (SAIF), predicting Ship/Helicopter Operating Limits for new ship designs. A pre-computed ship air wake is fed at real time rates to a manned flight simulator, which is used to assess the operational limits for recovering the aircraft onto the ship.

Replenishment At Sea (RAS) federation, predicting the behaviour of ships alongside when mechanically coupled by a solids transfer system.



NATO Submarine Rescue System (NSRS) federation, predicting the recovery system behaviour in high sea states.

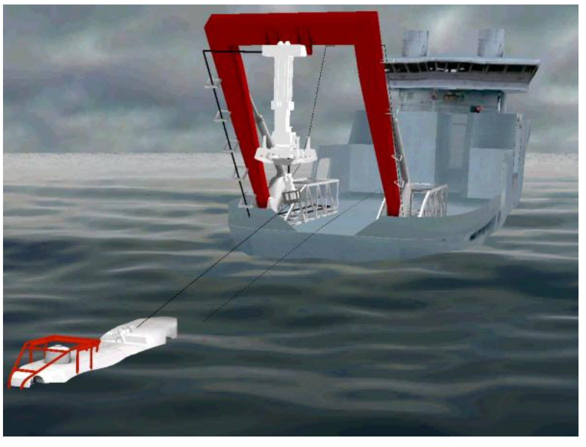


Table 3 summarises how each simulation (HLA Federation) was broken down into interoperable federates (we omit the visualisation federate that is common to all of these federations).

	SAIF	RAS	NSRS
Environment federates	*Environment*	*Environment*	*Environment*
Aerodynamic federates	*Airwake*	-	*Aerodynamics*
Hydrodynamic federates	-	-	*Hydrodynamics*
Platform federates	*Ship*	*Supply Ship*	*Mother Ship*
	Air vehicle	*Receive Ship*	*SRV*
Mechanism federates	*Landing Aids*	*RAS gear*	*PLARS*

Table 3: Breakdown of the SAIF, RAS and NSRS federations into federates.

The RAS federation was a little inconsistent with the other federates in that it included the hydrodynamics and aerodynamics within the Environment federate. The most mature of these federations is the NSRS federation, which utilises the following seven federates:

- *Environment federate:* Responsible for providing the basic environmental data to all other federates that request it. This includes the wave spectrum, water density, ocean current, air density and wind velocity.
- *Aerodynamics federate:* Calculates the air flow field and provides air flow field data (including air flow induced forces and moments) to other federates that request it.
- *Hydrodynamics federate:* Calculates the water flow field and provides water flow field data (including water flow induced forces and moments and added masses) to other federates that request it.
- *Ship motion federate:* Responsible for collecting together all the forces and moments that act on the ship and integrating them to evolve the ship motion. The NSRS federation also included the ship propulsion forces and helm control within the same federate.
- *Submersible federate:* Responsible for collecting together all the forces and moments that act on the submersible and integrating them to evolve the SRV motion.
- *PLARS federate:* Responsible for simulating the behaviour of the PLARS mechanical handling system and providing the forces and moments it exerts on the SRV and ship.
- *Visualisation federate:* Responsible for providing one or more interactive displays of the simulation using three-dimensional graphics.

4.1 Quiescent Period Prediction Project Arrangement

One of the current activities of SG/61 is setting up a Project Arrangement (PA) for a Quiescent Period Prediction (QPP) simulation capability. This QPP PA aims at better prediction of quiescent periods for wave induced ship motions. Such motions, particularly in bad weather, limit the operational capability of the ship, for example they may hinder tasks like launch and recovery of Rigid Hulled Inflatable Boats (RHIBs), RAS, and Landing Platform Dock (LPD) – Landing Craft Utility (LCU) interactions. The use of QPP allows for better timing of these tasks to reduce operational limitations.

Classical prediction approaches use statistical data to assess whether a task can be executed or not. However, this may result in the outcome that an operation is never executed, whereas quiescent periods do exist. The basic principles QPP are illustrated in Figure 5. It shows an example where current methods indicate high wave induced motion (red rectangle) while short quiescent periods actually are present (green rectangles).

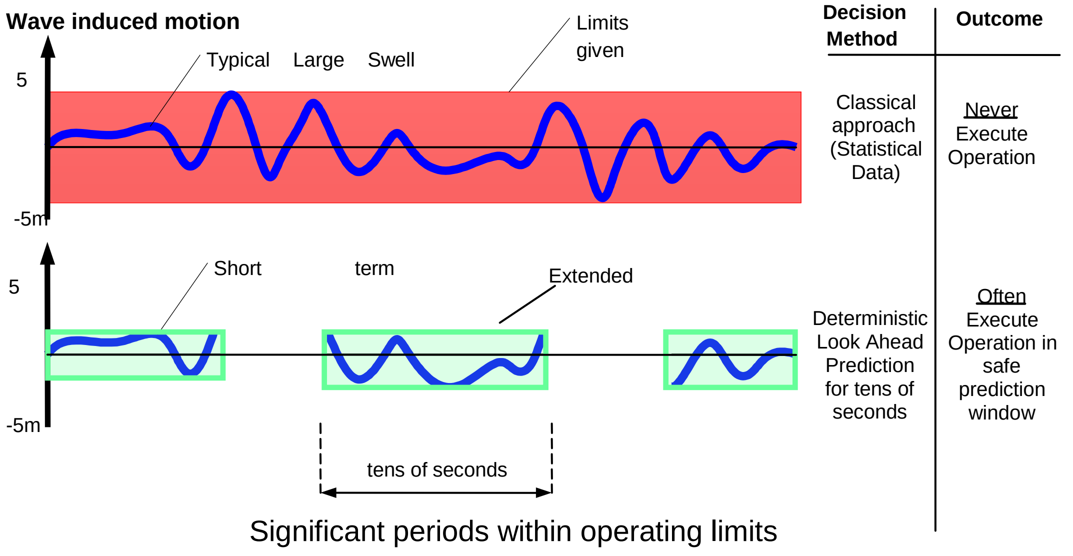


Figure 5: Basic principles of Quiescent Period Prediction

One important aspect to consider for a task is the required length of the quiescent period. The available prediction horizon must be larger than this required time. A short prediction horizon, i.e. up to about five seconds, is sufficient for tasks like, for example, unassisted landing of Unmanned Air Vehicles (UAVs). Other tasks, including the tasks mentioned previously, require extended prediction horizons. It is recognised that for many wave limited tasks the length of the prediction horizons are about one minute [4].

The aim of the QPP PA is to develop a high fidelity simulation of a new QPP system that is capable of delivering such extended prediction horizons. This simulation is intended as a technology demonstrator utilising the VS STANAG, which can be further developed into an actual on-board prediction system.

It is envisioned that such predictions can be achieved by remotely measuring waves, using a ship-mounted radar or lidar system, combined with advanced signal processing and wave prediction. The draft conceptual model for this system is shown in Figure 6. The components in light blue represent the true wave environment and ship motions. These are required to provide an environment in which the measurements and predictions can be made. The green components represent the different sensors, which simulate measuring the waves and the ship motions. The dark blue components constitute the advanced motion prediction system. This comprises of the signal processor, wave predictor and the vessel motion predictor, which are controlled by a process manager that optimizes the prediction quality by tuning various simulation parameters. Further background and discussion on the feasibility of a QPP simulation can be found in Crossland et.al. [5].

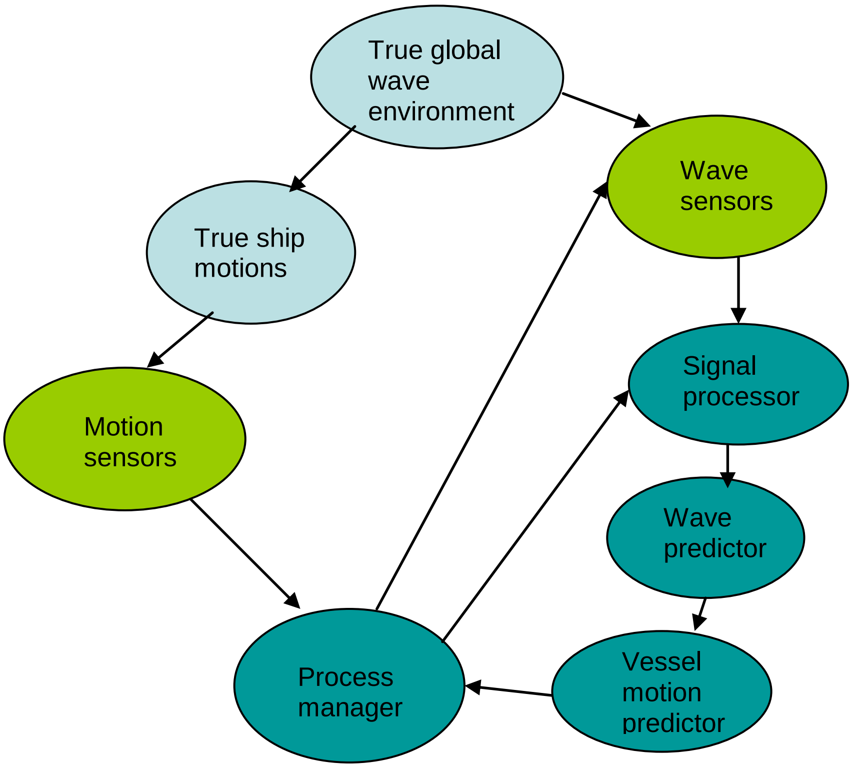


Figure 6: Draft QPP Conceptual Model

The status of the QPP PA is that an agreement is currently being drafted, which includes descriptions of the contributions from the participating nations, milestones and deliverables. It is expected that the actual QPP simulation development will commence in 2010.

5.0 FUTURE VISION

Here we describe our future vision of what it will be like to construct simulations when the VS STANAG and supporting tools have been well established. As an example, we assume there is a requirement to determine the highest sea state for which the replenishment of a large ship can be safely undertaken. The replenishment involves the following processes:

- Fuel transfer from a tanker supply ship.
- Solids transfer from a fleet supply ship.
- Solids transfer from a fleet supply ship via helicopter.

It is clear that federates from the RAS, NSRS and SAIF federations can be re-used to construct the large ship replenishment federation. Although a federation using QPP has not yet been designed, we shall assume for the purpose of this exercise that a Ship Motion Sensor federate is available along with a QPP federate that predicts the quiescent periods. Federates from other nations may also be required. We will therefore assume the following VS STANAG compliant federates are available from the repository, this list of federates being sufficient to build the large ship replenishment simulation:

- Environment federate
- Aerodynamics federate

- Hydrodynamics federate
- Ship motion federate
- Lead ship helm control federate
- Following ship helm control federate
- Rudder federate
- Propeller federate
- Roll stabilisation federate
- Air vehicle federate
- Landing aids federate
- Liquids RAS federate
- Solids RAS federate
- Ship motion sensor federate
- QPP federate
- Visualisation federate

Most of the preparation work to create the large ship replenishment federation will be in the creation of the data files to drive the hydrodynamics and aerodynamics federates for the chosen classes of ships. Once that work has been completed, the federation experiment can begin.

We will assume that a tool is available to help the user construct and execute the federation. We will call the tool the *Virtual Ship Federation Configuration Manager*. This tool will guide the user through the following steps:

- Choosing the federates from the list of available federates in the repository.
- Downloading of federate executables.
- Allocation of federates to each computer in the network.
- Configuration of each federate, in terms of what data files they will access.
- Copying the federate executables and their data files to each computer.
- Initiating the federation execution, ensuring that all required federates join the federation execution.
- Controlling the rate of execution of the federation and allowing pause and continue.
- Closing down the federation execution.
- Collecting the data files generated by the federation execution for results analysis.

This example clearly shows the power of the framework, in being able to rapidly assemble a completely new simulation from existing modules, with time being spent only on where it is needed most - on the aerodynamic and hydrodynamic analyses.

6.0 CONCLUSIONS

The goal of rapidly creating simulations of complex ship systems from re-usable components can be achieved by mandating a standard data exchange mechanism and creating and maintaining a repository of components that respect that standard. The Virtual Ship STANAG and associated repository will be able to realise this goal. As part of the modularisation effort, data driven methods have evolved which help to protect Intellectual Property Rights and deal with other sensitivity issues. Multi-national simulation projects can be realised with greater efficiency by taking full advantage of the VS STANAG and repository.

7.0 ACKNOWLEDGEMENTS

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8.0 REFERENCES

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9.0 ACRONYMS AND ABBREVIATIONS

ANEP	Allied Naval Engineering Publication
CFD	Computational Fluid Dynamics
FOM	Federation Object Model
HLA	High Level Architecture
IEEE	Institute of Electrical and Electronics Engineers
IPR	Intellectual Property Rights
LPD	Landing Platform Dock
LCU	Landing Craft Utility
MOU	Memorandum Of Understanding
NATO	North Atlantic Treaty Organisation
NSRS	NATO Submarine Rescue System
PA	Project Arrangement
PLARS	Portable Launch And Recovery System
QPP	Quiescent Period Prediction
RAS	Replenishment At Sea
RAO	Response Amplitude Operator
RHIB	Rigid Hulled Inflatable Boat
RPR	Real-time Platform Reference
SAIF	Ship Air Interface Framework
SG	Study Group
SRV	Submarine Rescue Vessel
STANAG	Standard Agreement
UAV	Unmanned Air Vehicle
VS	Virtual Ship
VSR	VS Reference
XML	eXtensible Mark-up Language