NATO Industrial Advisory Group (NIAG) Mission Modularity Studies.

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Author Biographies:

Rod Pudduck is a member of the Royal Corps of Naval Constructors who has held many appointments in surface warship and submarine design in the United Kingdom Ministry of Defence (UK MoD). He served at sea as the Fleet Naval Constructor Officer which included the oversight and management of conflict action damage (South Atlantic 1982) and wrote the first UK MoD Ship Safety Management handbook JSP430 in 1996. After retiring from the MoD in 2000, he was Chief Engineer with Atkins Defence for eight years, then a Director at Houlder Ltd. He is now a self-employed consultant. Rod has participated in every NIAG Modularity study since 2010. He chaired NIAG SG-213 Mission Modularity Integrated Logistics Support (Reference 13) and most recently delivered the report for SG-236 Scenario Development for Mission Modularity Force Architecture (Reference 15).

Jon Goodwin trained in the MoD as a naval architect and spent the earlier part of his career in a variety of naval related posts including ship and submarine design, submarine refitting as a line manager, R&D, project and programme management of ships, submarines, equipments and infrastructure projects, weapons/ship integration, concept and feasibility studies (including the NATO Submarine Rescue System), safety management and CAT A bid evaluation. During a period of secondment to industry he was the bid manager for the NATO Submarine Rescue System contract. Before leaving the MoD, Jon worked in the UK Defence Equipment and Support Materiel Strategy Team communicating key features of this major change programme to key stakeholders. He is now an independent consultant and has been the Rapporteur for four of the most recent NIAG Mission Modularity studies.

Commander Dickie Burston commanded several Royal Navy submarines including HMS *Sceptre* before joining the MoD Procurement Executive in 2000. His expert knowledge of naval missions and operational requirements as defined by NATO and the Royal Navy is comprehensive and up to date. He was UK Project Director NATO Submarine Rescue System NSRS with full responsibility for delivering multi-national new design and build submarine rescue system throughout the acquisition programme from concept through to acceptance and gave expert input to the NIAG pre-feasibility study. Dickie has been a member of all the NATO industry Modularity studies to date. He was the Chairman of NIAG SG-168 (Reference 9) and also NIAG SG-186 (Reference 11).

Synopsis

This paper outlines the range and depth of the series of NATO Industry Advisory Group (NIAG) modularity studies conducted by industry over the past ten years that examined the operational benefits, capabilities and costs of modular fleets for naval forces and makes comparisons with traditionally designed organic vessels.

Commencing in May 2010 NATO has commissioned five Mission Modularity studies. This work drew together over 50 defence contractors from 14 countries in the Alliance. In total 78 representatives attended working meetings to contribute expertise in all branches of engineering and science for the design, procurement, operation and support of naval ships and systems. The main sponsor for these studies was the NATO Ship Design Capability Group SDCG (formerly Maritime Capability Group MCG-6) with guidance of members of the United States Department of Defence (DoD NAVSEA), United Kingdom Ministry of Defence (D Ships) and the Netherlands Ministry of Defence (DMO).

The ubiquity and cheapness of the ISO (International Standards Organisation) container suggested wide application for transportation and pre-outfitting to form a Mission Module and for the first NIAG study SG-150 (Reference 1) the standard ISO Twenty foot Equivalent Unit container (TEU) was considered for Civil-Military Co-Operation (CIMIC) operations, specifically Humanitarian Aid and Disaster Relief (HADR),

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Harbour Protection (HP) and Counter Piracy (CP). The base vessel types considered were Landing Platform Dock/ Joint Support Ship (LPD/JSS) which provided necessary space and loading/unloading facilities without major design modifications.

Subsequently it was realised that a prepared package of equipment (a module), designed to be self-contained with suitable ship-to-module interfaces (space, power, communication links etc.) that could be quickly installed in a host ship, could provide an alternative means of enhancing the organic (i.e. built-in) capability of naval vessels for other types of missions. Where a threat exists, ISO TEUs need protection and issues of security may be involved that need careful management. Applications of mission modularity include combat systems, both self-contained e.g. Unmanned Vehicle (UXV) or Close In Weapons System (CIWS) as well as primary weapons that depend on the ship's organic resources such as the command system.

The studies have evolved to consider the interfaces between module and host vessel and this work made an important contribution to a NATO Standardization Recommendation (STANREC) and its supporting document Allied Naval Engineering Publication ANEP 91 (Reference 7) and STANAG 4834 supported by ANEP-99 (Reference 16). These documents identify the many interfaces between module and host ship that should be standardised in order to facilitate the sharing of modular capabilities between NATO naval ships.

NIAG studies have focused in large measure on what can be considered a module and the necessary ship design features and arrangements for fitting them. The type of modules appropriate to both CIMIC and warfighting missions were evaluated, including embarkation, layout and ship fitting requirements, interfaces, ballistic and shock protection, logistics and costs. Many options were considered for the most advantageous means of owning and managing module deployment to conduct NATO missions.

The most recent NIAG study SG-236 (Reference 9) assessed available computer tools suitable for evaluating the operational and cost effectiveness of mission modular ships compared to traditionally designed ships. The objective being to inform fleet owners and operational planners of the benefits and costs of mission modularity taking into account all variables including the numbers and sizes of host ships, availability and time to deploy assets to the tasking area, module and ship preparation and fitting time etc.

The challenges for most NATO Nation to commit to building a modular fleet are considerable. However, some new ship designs are emerging with designated 'mission bays' for augmented capabilities to meet emerging tasks and this may be a sign that the potential value of mission modularity is beginning to be recognised. This paper traces the history and progress that NIAG studies have made in contributing to NATO's knowledge of the engineering and operational issues and benefits of mission modularity.

Key Words:

Modularity, Mission Module, Mission Package, Interoperability, Interface Control Document.

1. Introduction

It is useful to evaluate experience since the 1980s when the Danish StanFlex ships first demonstrated how a variety of modular systems could be installed or replaced to change the role of the ship. The ingenuity of this design solution to the Danish government's cost reduction requirement which was achieved by building 16 multi-role vessels to replace 22 previous minor warships, has been much admired but not closely copied by other navies.

The Danes developed the concept in the *Absalon* flexible support ships which includes five StanFlex modules (typically three x 12 RIM-7 Sea Sparrow missiles SAM Surface to Air Missile and two x eight Harpoon Block II SSM Surface to Surface Missiles) that can be shared across several ship classes in service with the Royal Danish Navy. These ships also have a 900m^2 deck to carry ISO containers or vehicles with a roll-on/roll off stern ramp. They were followed by the *Iver Huitfeldt* frigates, (commissioned from 2012) based on the *Absalon* hull, with six StanFlex weapon module slots but no dedicated container space.

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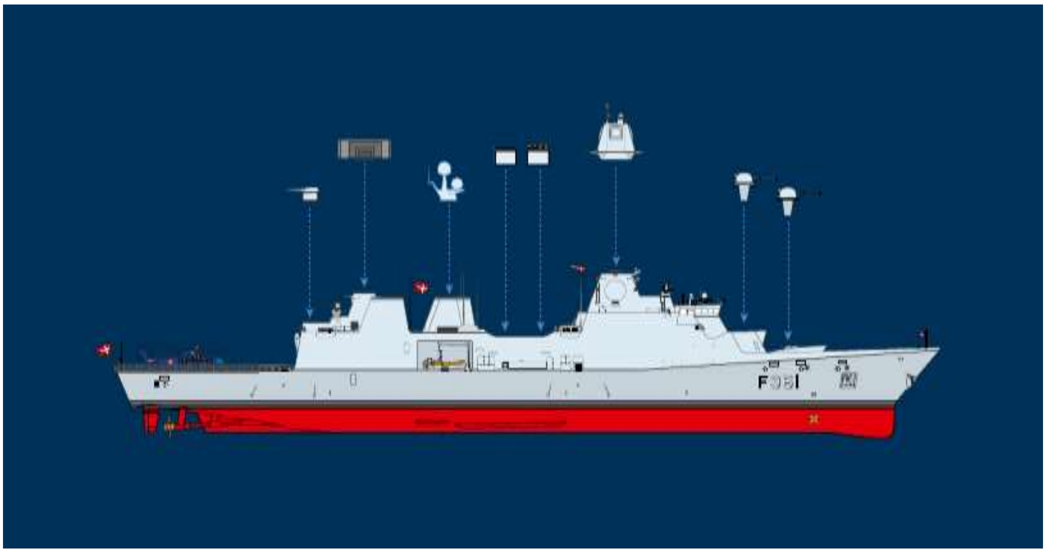

Figure 1: *Iver Huitfeldt* showing plug-and-play modules (SG-186)

The StanFlex system is a cost-effective solution because it is based on modularised legacy combat systems utilising a limited range of equipment built to the first chosen set of dimensions. Upgrading is constrained by the geometry of the module slots and modules must be integrated with the ship's installed command and control systems.

The United States Navy Littoral Combat Ship (LCS) was designed to be primarily modular, with dedicated spaces to fit a choice of different mission modules in bespoke ruggedised containers. In May 2012, a study by Northrop Grumman Aerospace Systems suggested that seven LCSs could more efficiently perform counter-piracy patrols in the Western Indian Ocean than a fleet of 20 conventional ships, for a quarter of the cost.

Figure 2: LCS Mission Package definition (US Navy)

Despite the novelty of design, the LSC has been plagued by criticism of complexity, lack of fire-power and engine breakdowns which have caused major cost overruns. All three major mission modules, surface warfare, anti-submarine warfare and minesweeping have been slow to achieve acceptance testing and although this is not the main reason, it seems likely that the original intention to procure up to 55 vessels will not take place and existing LCS ships will be re-configured without the capability to swap roles.

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Several other European navies however, are building or designing vessels with a 'mission bay' or area dedicated to fitting mission packages which may not necessarily be embarked in an ISO container.

The UK Type 26 frigate can carry up to ten ISO TEUs in a midships mission bay, with the capability to load and unload with a built-in handling system. It has no major modularised combat systems but could embark a mix of resources e.g. additional aircraft and boats for litterol strike and maritime security and unmanned vehicles (UXVs) to carry out ASW and mine countermeasures missions. This is a good example of using mission modularity to augment the capabilities of a primarily organic front-line combatant.

Figure 3: Type 26 Mission Bay handling system (Rolls Royce)

Babcock's Type 31 frigate, recently selected for the Royal Navy, is based on the Danish *Iver Huitfeldt* design. It has a 119m^2 mission space under the flight deck for up to six TEUs.

Damen's Omega FFI (Future Frigate Indonesia) concept features two dedicated multi-mission bays, one amidships and one at the stern. The midships mission bay can load and move four TEUs or can launch and recover RHIBs (Rigid Hull Inflatable Boat) or USVs/UUVs (Unmanned Surface/Underwater Vehicle) with an overhead handling system similar to Type 26. The stern mission bay has space for two TEUs and a further two containers can be positioned in an additional space on the upper deck.

Figure 4: Omega FFI concept ship (Damen)

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There are other good examples. The Italian Navy's PPA class multi-role offshore patrol vessel OPV, first ship delivery due in 2021, will have dedicated mission space for logistic, residential, healthcare and operating modules. The Spanish Navy has commenced building the F-110 frigate which will also have the capability to carry a range of mission modules such as unmanned vehicles, medical support, special forces equipment and a brig.

2. Experience and Aspirations

With the notable exception of new frigate designs mentioned with multi-mission bays, few navies have yet to demonstrate the ability to rapidly change roles by swapping out mission modules. Only the Danish navy has ships with dedicated slots for modular weapon systems.

A mission bay takes up valuable volume and it is clear that if a role change is required, readiness, logistics, speed of change-out, time to deploy to the task area and operational effectiveness are all key. Before these factors are even considered, naval decision-makers need to know whether modularity is cost-effective.

NATO supports standardisation of naval assets to strengthen collaborative operations using the potential of mission modularity to enable the sharing of equipment between its partners. Combined tasking/operations with units of different nations should ideally work as an integrated force, able to communicate, share information and perhaps share equipment. Interoperability is the watch-word. If an NH90 variant NFH (NATO Variant Helicopter) can land on several different navy frigates and all NATO warships can be refueled from any NATO supply ship whilst underway, why shouldn't a modular mission package from one nation be loaned to another (assuming the receiving ship is better placed for the task)? It is clear there are differing national issues and when NATO requests a contribution for a mission (whether for CIMIC or to counter a threat situation) that may include sharing equipment, questions of ownership, management and control will be central to the response.

Experience gained from using mission bays will be keenly watched. The rapid development of unmanned systems is an obvious application and if they are put to good use, other navies may be encouraged to extend the possibilities of modularity and maybe the sharing of modules in future.

3. Maritime Mission Modularity Philosophy

NIAG studies derived the following basic assumptions:

- NATO vessels should provide dedicated space, securing arrangements and interface connections for modules in accordance with ANEP-91 and ANEP-99.
- Modules should be designed and built to provide additional resources to augment the capabilities of naval vessels to meet NATO missions.
- The installation and/or exchange of modules at ship, should be achieved more rapidly than traditional system upgrading that requires extended time in a naval base/shipyard.
- Modules should be maintained and stored in suitable locations around the world to enable rapid transportation and deployment.
- Mission packages comprise all equipment necessary to provide a resource. This may be a single or multiple set of modules and should be maintained at suitable levels of readiness to enable preparation and departure from the base to meet mission demands.
- All modules should be air portable and dormant deployment plans must include provision of suitable road, rail and air transport vehicles. Air and sea port combinations must be developed to coordinate the timed arrival of modules with host vessels and dockside facilities should be appropriate for embarkation.
- Suitably Qualified and Experienced Personnel (SQEP) must be available to support preparation of ships and modules, installation, commissioning, training and operation.

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4. Interfaces

To prepare a ship to receive a modular package requires information on all the physical features of the module(s). Earlier NIAG studies listed inventories of existing products, designed specifically or potentially suitable for naval tasks, that are either able to be containerised or transportable in other forms. The means of embarkation and removal were assessed for suitable host ships together with requirements for handling and securing on board. A cardinal requirement is to ensure that module units do not adversely affect the core capabilities and safety of the host ship. Consideration was given to protecting sensitive equipment, including a live shock trial of an ISO container, which resulted in the development of a special deck mounting system.

Figure 5: Patented TEU deck mounting system (Weidlinger Associates Ltd.)

A major part of this work was to gain knowledge of all the necessary module to ship interfaces, resulting in the development of Interface Control Documents (ICD) for principal mission modules. This work underpinned the publication of ANEP-91 and ANEP-99.

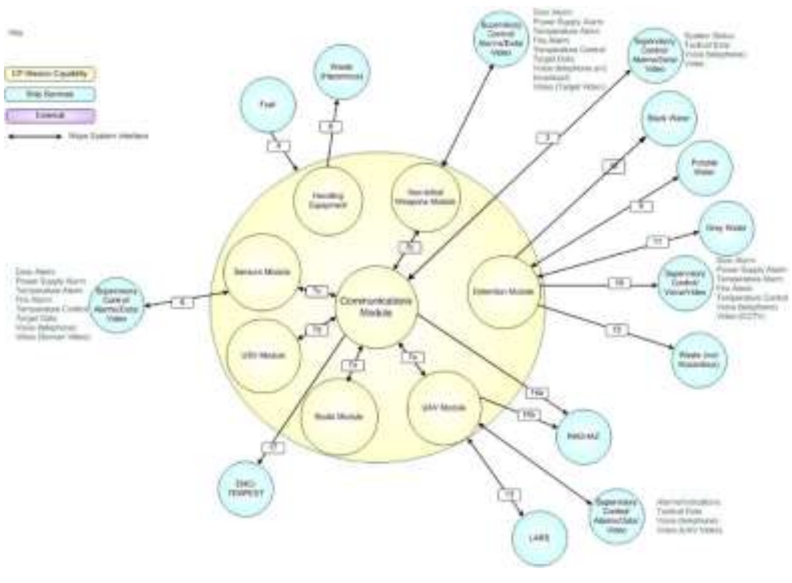

Figure 6: Interface Control Diagram for a Communications module (SG168 Reference 9)

The blue circles show the many interfaces between the module and the ship such as power and in this case to other modules which may be part of a modular package such as a USV or UAV.

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5. Logistics

The 2010 Haiti earthquake starkly demonstrated the difficulties of disembarking heavy equipment from ships when the port facilities are disabled, so the first study considered LPD/JSS vessels since these offered the most suitable space and handling capabilities with landing craft and causeways for delivery to a beach.

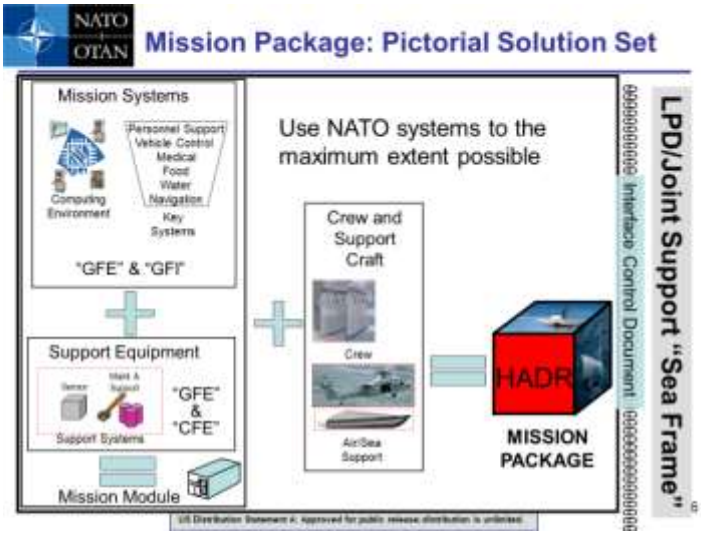

Figure 7: Components of a HADR Mission Module Package (SG-150)

HADR may require many types of modules, for example, temporary accommodation, food and drinking water, medical treatment/field hospital, sanitation, power generating plant etc. If port facilities are unavailable, unloading TEUs may require specialised handling equipment and rough terrain vehicles to transport modules across beaches and hinterland. Early and accurate intelligence must be communicated to mission controllers to procure the appropriate resources from module depots.

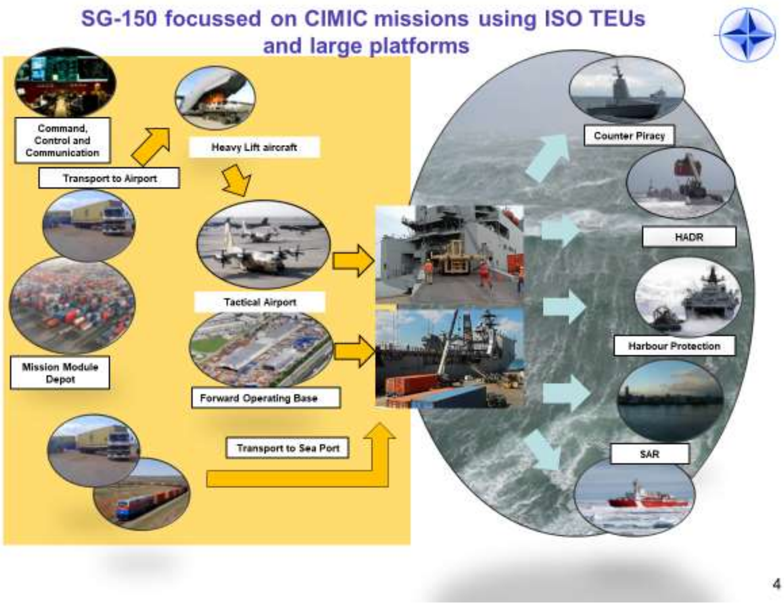

Figure 8: Logistics routing of modules to host ships (SG-150).

NIAG SG-213 concentrated on logistics and developed a concept and strategy for managing the sharing of mission packages between NATO navies. The study focused only on the utilisation and support stages and assumed that equipment has been fully designed and manufactured. The study found that the current NATO logistics framework and procedures (References 1-3 and 5) are applicable to mission modules and there is no need to develop a bespoke ILS management system. A Generic Mission Module Logistics Process (GMMLP) was derived and tested during the study.

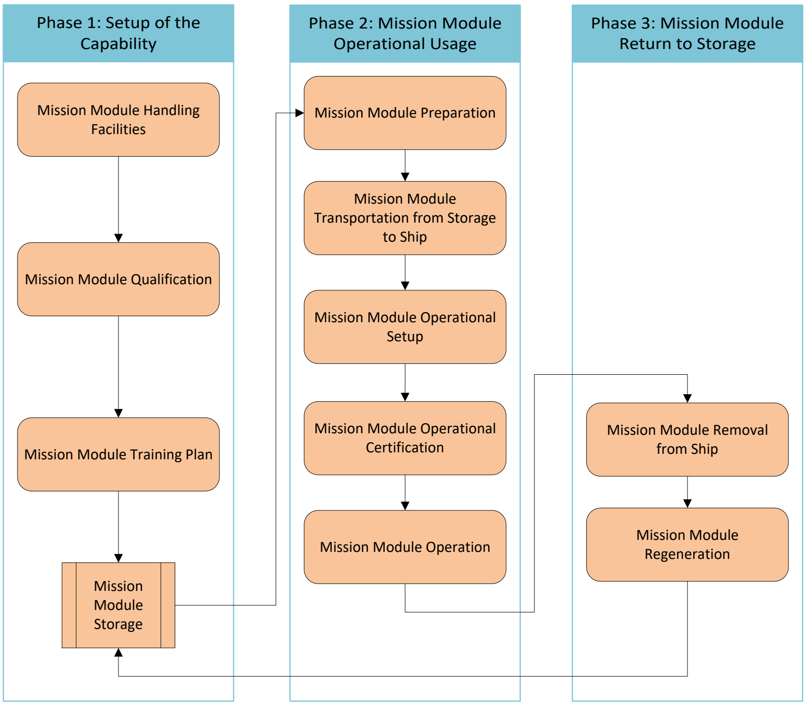

Figure 9: The logistics chain may be considered in three phases (SG-213)

Each stage is considered in detail from Authorisation, through Preparation of modules for Deployment, Transportation, Installation and Commissioning, Operation, De-commissioning, Checking and Regeneration to final return to the depot for Storage and Preservation. Figure 7 shows elements of the Authorisation process.

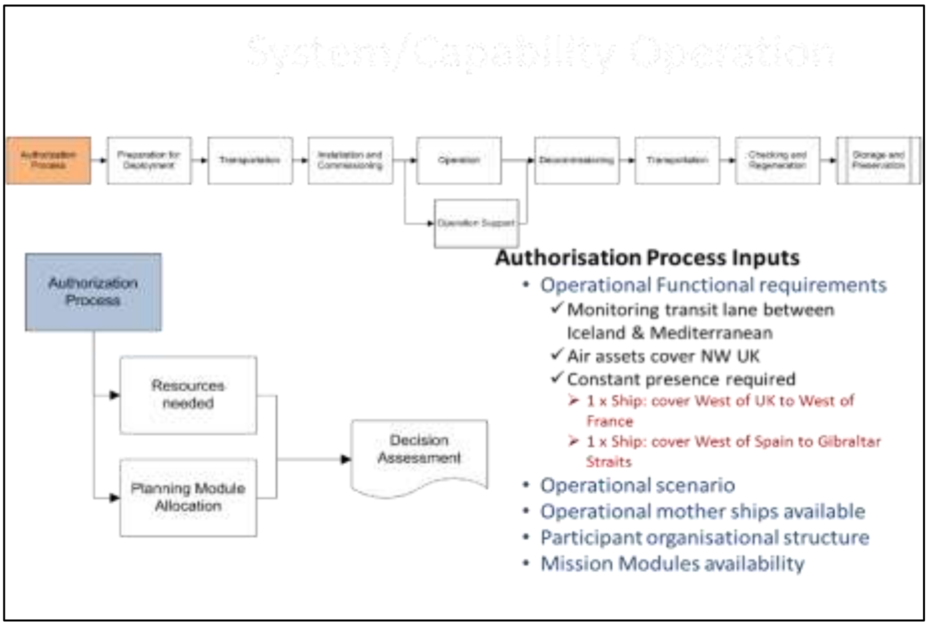

Figure 10: First Step - the Authorisation Process (SG-213)

6. Testing the Logistics Model

Two illustrative operational scenarios, CIMIC and warfighting, were constructed to test the logistics model as a desk-top exercise. Basic elements of the scenario are shown below:

ASW Anti-Submarine Warfare Exercise

The following mission assumptions were made:

- Pre-planned ASW deployment (i.e. not an emergency)
- Monitoring transit lane between Iceland & Mediterranean
- Air assets cover NW UK
- Continuous presence required
- One ship covers West of UK to West of France
- Second ship covers West of Spain to Gibraltar Straits
- Duration: 6 weeks on-station + transit and training
- Mission: Detect, Classify, Localize and Track (threat submarines)

The required resources were assumed to comprise:

- Organic Resources:
    - Bow mounted sonar
    - ASROC (Anti-Submarine Rocket) in VLS (Vertical Launch System)
    - UAV (Unmanned Air Vehicle) drone
    - Command space and vehicle command & control
    - RHIB (up to 11m) with LAR
    - Helicopter hangar and maintenance facilities
- Modular Resources: One ASW Package to be installed per ship. Each Package contains:
    - MH-60R (Seahawk helicopter) with 3 x TEUs Pack-up Kits
    - Air-launched weapon in a TEU (munitions stowed in ship's magazine)
    - Unmanned Surface Vessel with 3 x TEUs equipment
    - Towed Array Sonar in one TEU.

Figure 11: ASW Scenario - Example of routing modules from base to host ship (SG-213)

Although this was a fictitious scenario using arbitrary inputs, the process was considered useful. A more rigorous test was however recommended, conducted as a table-top exercise with SQEP operators and logisticians and possibly in due course a live exercise by a combined NATO force.

7. Computer modelling

Computer modelling is essential to determine for example how many module logistics bases would be necessary for any or all scenarios. Modelling is appropriate for both the requirements derivation phase of a project and for design validation and verification.

The influence of the location and the number of support facilities on the overall mission success of a modular fleet, amongst many questions, was investigated during the SG-236 study. Consideration was given to the suitability of three different model types:

1. Graphical analysis. Used to determine the time a ship takes to transit to a support facility, to install the modules and to reach the final destination. Because the initial location and the final location are unknown a Monte Carlo simulation is used to calculate the time distribution.
2. The second model is a high-level interactive model which takes into account things like ship maintenance periods, different capabilities of ships and module combinations.
3. Simple Excel-based models offer benefit when determining specific requirements for mission modularity and their logistics. These types of models don't provide the full answer that fleet modelling provides but can be executed quickly and simply.

The following example of an Excel model assesses the impact of mission module demand, procurement quantities and deployment times on overall operational availability.

Inputs to the model:

- Number of modules available (0 to 4)
- Number of events requiring mission modules deployment (0 to 10)
- Deployment time (2 days)
- Usage time (21 days)
- Demobilization time (14 days)
- Regeneration time i.e refurbishment and/or capability upgrade (21 days)

The model includes a Monte Carlo process that randomly assigns each event to a day of the year. It then 'deploys' the next available mission package. If a mission package is not available for any reason, operational availability is degraded. The Monte Carlo is run at least 1,000 times to give an overall probability of mission package availability. The results (Figure 12) shows how availability quickly degrades when only one mission package is available but is required several times per year.

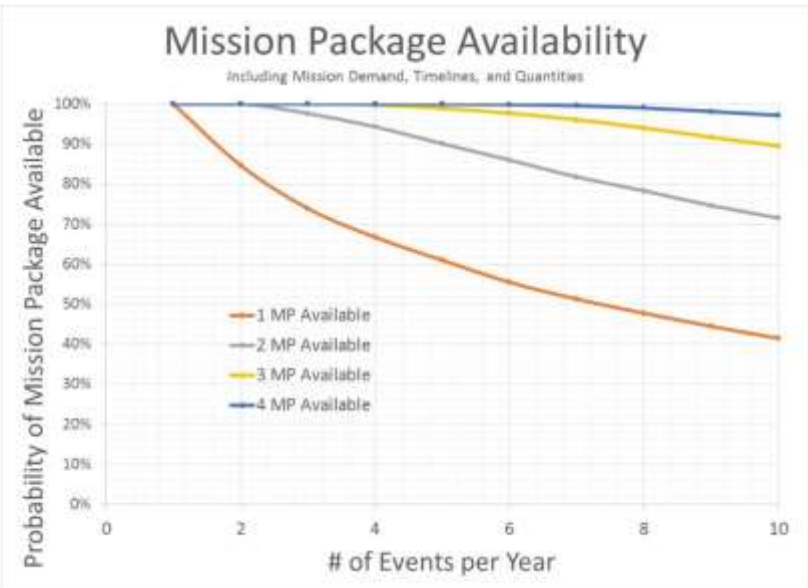

Figure 12: Results of Operational Availability Model (SG-213)

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The details of the figure are less important than the type of analysis. The tool provides a simple way to translate operational requirements (availability) and combine them with fiscal measures (quantities procured) and derive or understand the impact of logistics requirements (base quantities, locations, distance from use, complexity of maintenance, etc.).

8. Ownership

NIAG studies have considered many options for owning and sharing the use of mission modules. It may take many years before fully designed modular capable ships become more common. In the near-term nations should work individually or in federations to identify and procure suitable modules, with the ambition of contributing towards a NATO-wide solution. For navies that cannot commit to building modular capable ships, they should be encouraged to consider providing modular capabilities in modules or units that may be shared with others in a NATO force. Some ownership options are:

a) **All modular assets are provided by partner nations and managed by NATO at one or a small number of locations**. This is perhaps unlikely in the short term but might be conceivable in the future, if sufficient owner nations agree. A variation would be total or partial NATO ownership and management of modules, similar to NAEW&CF (NATO Airborne Early Warning and Control Force) but ship ownership is a variable.
b) **A geographical spread of module depots and assume ownership by each host nation.** All costs, i.e. running the depot, procurement, maintenance and preparation of the modules is borne by the owner. The nation requesting the use of modules for a NATO mission, provides the host ship(s) and informs the owner of the delivery point for embarkation.
c) **Mission packages come from different locations.** This would add complexity, including possible difficulties with documentation when crossing borders and maybe requiring teams of different nationalities required to install, test and operate the systems. It could however be appropriate for CIMIC missions such as HADR, e.g. with medical units from one nation; rough terrain vehicles from another; food, water purification plant and tented accommodation from a third.

Any of the above ownership options (and others) could be used to evaluate the effectiveness of a modular task force or fleet and compare the results with traditionally designed vessels responding to a given operational mission. The most likely situation in the short term, when only a small number of nations own modular capable ships, is to consider one navy’s solution (assuming it owns all the necessary resources) when tasked to undertake or contribute to a NATO mission. This could be a straightforward modelling task because the ship and module resources and initial module locations are known. The variables are simply the availability of assets, time to prepare and load the modules and distance to the mission zone.

Until such time as agreements between nations on the sharing of assets have been established, operational effectiveness and costing models must assume arbitrary ownership arrangements and use standard times for obtaining permission for use and the logistics of preparation and deployment. With feedback from experience, more realistic data can improve verification of results and predictions of any advantages that might be achieved by extending the application of modular interoperability in the future.

9. Cost Effectiveness

NIAG has collaborated with the NATO specialist team on ship costing who lead on the cost benefit comparison between conventional and modular ships. This work is on-going. Obtaining reliable cost data relevant to new and emerging technologies will always be difficult. Predicting future costs for ‘yet to be developed’ types of ship, modular systems, fitting/exchanging modules and associated new strategies for ownership, basing and overall management (either by individual nations or by

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Alliance partners) requires large data inputs and high-level computer processing to handle the many variables. The metrics for evaluating cost-benefit of must include the uncertainty that is being addressed. An assessment tool will generate these metrics on a Monte Carlo or similar type simulation where the uncertainty is modelled as a probability density function. This type of modelling needs to include a dynamic model of the management action (or choice model) which would determine how potential cost-benefits of modularity could be exploited over the fleet or ship service life.

10. Operational Effectiveness

The most important question that operators ask about a modular capable vessel is how effective might it be? NIAG SG-236 has assessed available computer tools suitable for evaluating the operational effectiveness of mission modular ships compared to traditionally designed ships with organic capabilities. The objective is to inform fleet owners and operational planners of the benefits and costs of mission modularity taking into account all variables including the numbers and sizes of vessels, availability and time to deploy assets to the tasking area, module and ship preparation and fitting time etc. Although model details differ, each has a similar basic architecture as shown in Figure 10 and most have the ability to input data similar to that used for naval fleet operational analysis.

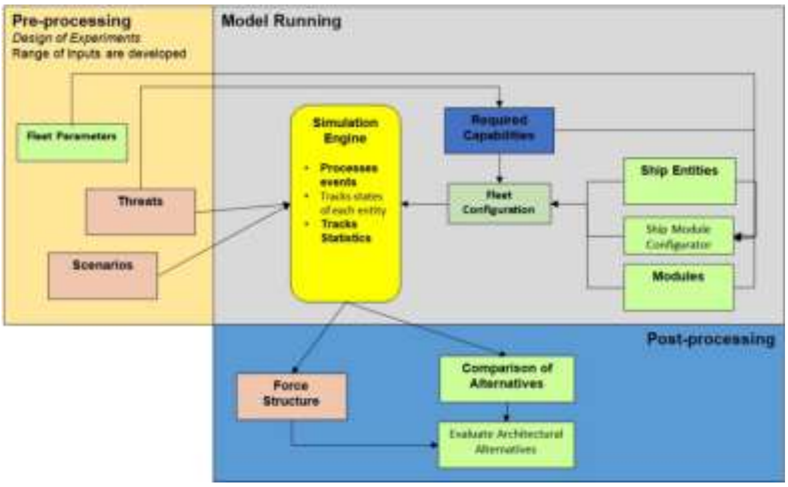

Figure 13: Generic model architecture (SG-236)

Users will need answers to questions at fleet, task force and ship level. For example, at fleet level:

- What is the optimum future fleet configuration? - continued traditional ship design, wholly modular or a mix of types including some modular capable ships?
- What will be the impact of a transitional phase with a mix of traditional and modular assets?
- Would more mission modular ships allow a reduction in the total number of ships in a fleet?
- Under what future conditions do modular ships offer the most / least benefit?
- How should a fleet/module set be employed for optimal effect?
- What might be the optimal fleet construct to respond to emerging threats?
- When a new threat emerges, how are additional capabilities introduced to counter the new threat?
- What are the margins of error in the computation that may arise from uncertainty and unreliable data sources?
- What are the relative cost benefits of different fleet configurations?

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Different questions will test effectiveness at ship level. For example, comparisons could be made on the performance of individual or a mix of modularised and traditional ships. Questions to ask might include:

- What should be the principal roles and most suitable capabilities of modular ships?
- What is the improvement in operational by reducing the time to install and set to work the modules on the host vessel?
- What is the gain from using the ship's crew rather than deploying specialist staff with the modules?
- Is there any advantage in dividing modules between two smaller, slower vessels, rather than using a single faster ship?
- What is the effect on time to deploy by introducing automation or other ways of speeding the process of installing the modules and setting to work?
- What might be the advantages of having a module support ship with an array of modules available for transfer at sea to other ships in a task group?

It is likely that a mix of analyses at the fleet (top down), task force and ship (bottom up) levels answering question such as described above will be required to assess the benefits (or otherwise) of modular versus traditional options. Probabilistic analysis of many missions over extended periods of time is mathematically the proper way of making decisions at fleet and task force level.

Some caution is necessary when evaluating assessment model results. A graphical presentation can be very convincing but the granularity, that is the margin of error associated with an output, can be misleading. For example, a five percent difference between a modular fleet and a conventional fleet may well be within the margin of error in the modelling. Therefore, when assessing options, the margin of error in any output from these types of models should be absolutely clear. If not, fundamental decisions like deciding whether to continue with a traditional fleet rather than a modular fleet could be based on a false premise.

Other NIAG studies allied to modularity are SG-171 (Reference 10) and SG-187 Launch and Recovery (LAR) of manned and unmanned systems (Reference 12) and SG-232 Utility of Unmanned Vehicles in NATO ASW Operations (Reference 14). Rapidly advancing technology is producing a wide variety of options to exploit the potential of unmanned systems that can enhance the capability and extend the range of organic maritime systems. Most unmanned systems can be packaged and easily transported for installation as a module, giving for example, an augmented Mine Counter Measures (MCM) or ASW role to a traditional warship. Embarkation at a port is easy but LAR when the ship is underway or in even moderate sea states and disembarkation of TEUs requires special handling equipment that is often overlooked by UXV and module providers.

11. Conclusions

Industry has contributed 10 years of study into the merits and future potential of modular warships. The combined expertise of many major defence providers working closely with Alliance defence organisations in Europe and the United States of America, has made a significant contribution to understanding the merits and problems of maritime mission modularity. The overall conclusion is that mission modularity makes sense for CIMIC and certain wartime scenarios.

Although several navies have provided mission bays in new ship designs, there is little national experience of rapid module swapping for role-change, except for adding equipment for CIMIC scenarios. To date, NATO's interoperability goal of sharing modules between the nations has not been achieved to any significant degree.

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The question of whether it is worth building mission modular ships is continually being asked. Intuitively the answer is yes, for flexibility within a national fleet and if NATO partners invest in the principle, the benefit to the Alliance for improved response time and interoperability is clear - but there are challenges that to be resolved before fleet owners will agree. A real event, such as HADR or HP where NATO forces have worked well together in the past, could help gain support of governments if modular capable ships were deployed to good effect.

The work of the NIAG has exhaustively analysed most aspects of mission modularity. The benefits and costs of a modular fleet cannot be determined only by consideration of ship design but the continuing development of assessment tools will help naval planners realize the best options for using mission modularity. At any point in time the uncertainty of changed/emerging threats and the required response will drive decisions and will provide answers to the success or otherwise of the modular warship.

The extensive work sponsored by NATO provides a strong database of knowledge ready for nations to use to develop the characteristics and capabilities of their future fleets.

12. **What next?**

Industry’s role in promoting the concept of mission modularity has been comprehensive and far reaching. There are still areas worth exploring in more detail – for example the development of unmanned vehicles in modular packages for various missions. It remains a key task for defence force leaders to decide whether or not to progress the modular concept more widely.

Presenting the case for modularisation of ships is challenging. Therefore, the most recent NIAG study (reference 15) reviewed the efficacy of fleet effectiveness and costing models that are now being developed. These models can compare the merits of future fleets comprising modular designed vessels compared to traditionally designed vessels as at present (or a mix). Navies and their senior procurement managers need to be made aware of these tools that aim to provide unambiguous answers to complex questions of efficiency and effectiveness for various combinations of ships in given scenarios.

Figure 14 suggests the route to development of future fleets which may contain mission modular vessels. The green boxes indicate where progress is already underway or where it is recommended it should start.

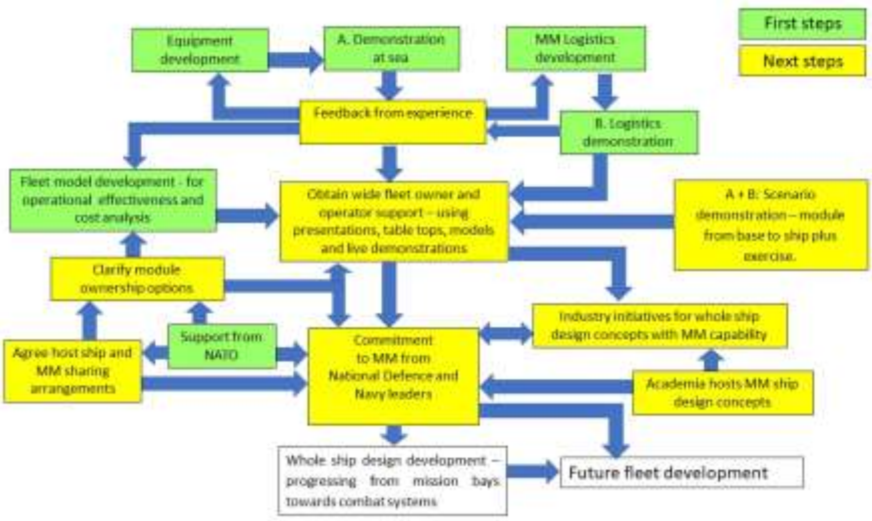

Figure 14: Inputs and decision making for Mission Modularity

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