The globally deployable minor warship -
A conceptualisation of future solutions

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SYNOPSIS

Minor warships are a category of naval vessel covering a range of roles, including mine
countermeasures, offshore patrol and survey. These vessels may be deployed in a war role, within
threat environments, but are often small and of a specialized nature. To date, the roles have generally
been achieved through the design of specialized vessels for each role with little commonality. This is
particularly true of the MCM vessel, a highly optimized platform due to the demanding nature of its
role. Previous attempts at a common platform to meet these varying roles have met with mixed results.
The emergence of new technologies, particularly the expected widespread use of off-board, unmanned
systems offers new potential for a single common platform to be reconfigurable across these roles. It is
also necessary to consider the requirements for global deployability as the small size of legacy vessels
is a restriction to true deployability, whilst adoption of much larger frigate sized vessels may limit the
potential number of affordable hulls.

This paper discusses the work conducted into concepts for a small surface combatant capable of being
configured to perform the roles of MCM, maritime security, hydrographic and environmental
assessment and patrol. The objectives of this work were to identify how much commonality can be
achieved in a relatively small hull and how to optimise a small hull for global deployment. The latter
was facilitated through a consideration of key requirements, parametric hull analysis of seakeeping,
powering and stability performance and comparison of monohull and SWATH hull forms and the
conduct of a design exercise for the most beneficial vessel concept. Key aspects investigated include:
the type of hullform adopted, comparing monohull and multi-hull performances to achieve global
deployment requirements, issues of modularity, arrangement of multi-mission spaces, and deployment
of unmanned vehicles to perform some missions.

Author’s Biography

Andy Kimber is a Senior Manager at BMT Defence Services. He has undertaken a variety of auxiliary ship and
warship design studies including the joint BMT - Skipskonsulent AEGIR family of replenishment ships. He recently
participated as a team member of the joint industry / MOD Sustained Surface Combatant Capability Pathfinder project.
Previous to his current role, he held the position of Platform Architecture Manager for the CVF for three years. Andy
joined BMT Defence Services after completing a degree in Naval Architecture and Ocean Engineering at University
College, London.

Will Giles is a Naval Architect in the Surface Ship Team within the Naval Architecture Department of BMT Defence
Services. Prior to this role he was Naval Architect of the Research and Development Department of a Small Craft
Production Facility in South East Asia. He has completed a BEng in Mechanical Engineering from Herior-Watt
University Edinburgh and an MSc in Maritime Engineering from Southampton University.

Tom Dinham-Peren is a Director and Senior Hydrodynamicist at BMT SeaTech. He has over 25 years experience of
ship hydrodynamics with particular expertise in the fields of hydrodynamic hull design, resistance, powering and
seakeeping. He has been responsible for the initial Type 45 Hull form studies carried out by BMT SeaTech for VT
Shipbuilding Thornycroft Ltd and for the large model test programme for the Type 45 AAW Destroyer which was
carried out by BMT. More recently, he has been responsible for the hull design of the CVF for the Aircraft Carrier
Alliance and has conducted an extensive model test programme including resistance, propulsion, cavitation,
manoeuvring and seakeeping tests backed up by a large range of desk studies and additional analysis. Previous to his
current role he worked as a Hydrodynamicist for BMT. Tom has a Bsc in Naval Architecture from the University of Newcastle upon Tyne.

**INTRODUCTION**

BMT believes that along with a versatile multi-role capability, military planners have high expectations from future minor warships. They expect these ships to maintain pace with the Naval Task Group, operating in all oceans and all seasons and also to have the capability to operate independently for an extended period when required. As navies seek the best overall capability that their funds allow, the prospect of deriving a range of capabilities from a single hull design has become more attractive. Whilst some examples already exist of reconfigurable minor warships, the specialised nature of mine counter measure (MCM) operations has prevented the wide spread and successful adoption of such vessels in all but a few navies.

With the increasing use of unmanned vehicles to conduct autonomous or semi-autonomous MCM or survey, the need for highly specialised platforms decreases, in particular the removal of the manned MCM platform from the high risk area will allow relaxation of the stringent signature requirements. This will simplify the MCM platform design and offers the potential for reconfigurability through changes in the off-board vehicles carried. As the technology and operating procedures associated with the new generation of remote MCM equipment matures over the next 5 to 10 years, it is timely to consider how these may impact the platform designs and where the opportunities exist to offer more utility from the minor warship classes. This paper describes a concept study for this type of platform conducted by BMT under the name Project VENATOR.

**ROLE RECONFIGURATION**

The design of a baseline concept began with the definition of the required payload; both deadweight items and military fit equipment. For the purposes of this study BMT considered the following roles and developed payload estimates for each:

- Mine Countermeasures (reconnaissance, classification and neutralisation);
- Mine Countermeasures Support (operational tasking, logistic support and limited maintenance support);
- Hydrographic Survey and Rapid Environmental Assessment;
- Maritime Security Operations (MSO), including interdiction, stop / search and persistence presence / observation;
- Offshore Patrol;
- Training.

This investigation established that a baseline payload of between 620 to 700 tonnes (including approximately 500 tonnes of fuel) would be required and that the volumes of the mission specific equipment were conducive to a modular approach. Similarly, investigation of the complement suggested a variation in accommodation from 60 to 80 personnel (based on a core complement of approximately 40) across the roles.

A rapid re-role requirement is not envisioned and hence modularity will primarily be concerned with bounding mission systems and interfaces, configuration control of both mission packages and platforms but as separate entities and in providing suitable routes for exchange but within a controlled environment, e.g. an up-keep period in a home base or similar facility (Reference 1).

A key aspect to the role reconfiguration is the increasing trend towards the use of off-board vehicles, specifically unmanned vehicles, for the conduct of the above roles. Hence, a significant part to the reconfiguration is the ability to exchange vehicle types. For the baseline design, Table I indicates the assumptions for payloads:
<table>
<thead>
<tr>
<th>Role</th>
<th>Off-Board Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCM</td>
<td>Reconnaissance UUV’s</td>
</tr>
<tr>
<td></td>
<td>Sweep equipped USV’s</td>
</tr>
<tr>
<td></td>
<td>Shallow water / Very Shallow Water UUV’s</td>
</tr>
<tr>
<td></td>
<td>Disposal Systems</td>
</tr>
<tr>
<td>Hydrographic</td>
<td>Survey UUV’s</td>
</tr>
<tr>
<td></td>
<td>Survey launch</td>
</tr>
<tr>
<td>Maritime Security</td>
<td>RHB’s</td>
</tr>
<tr>
<td></td>
<td>Surveillance USV’s</td>
</tr>
<tr>
<td></td>
<td>Surveillance UAV’s</td>
</tr>
<tr>
<td></td>
<td>Helicopter</td>
</tr>
<tr>
<td>Patrol</td>
<td>RHB’s</td>
</tr>
<tr>
<td>MCM Support</td>
<td>None specific</td>
</tr>
<tr>
<td>Training</td>
<td>None specific</td>
</tr>
</tbody>
</table>

In order to provide both the numbers of vehicles required and the flexibility to exchange vehicles, the design requires a relatively large payload “garage” area. With suitable material handling provided, this allows tailored mission equipment to be embarked according to the role for which the vessel is required.

In addition, reconfigurable operational mission space is required to control the unmanned systems and provide mission control facilities. Ideally, this is best achieved through reconfigurable and common workstations allowing role and vehicle change to occur without embarkation of new control stations; this may however prove difficult in all cases and therefore a flexible and easily reconfigured control space will be required which has ready access for the embarkation / disembarkation of mission specific equipments.

For the embarkation of static mission equipment, equipment support facilities and spares, the use of standardised bulk storage units is a sensible and obvious choice. However, the widely assumed use of twenty foot equivalent (TEU) ISO units presents a number of issues:

- The TEU container is heavy and bulky and therefore difficult to move within the confines of a small vessel. Embarkation of TEU’s is relatively easy when located externally but is more difficult when they require embarkation within an enclosed space (e.g. a garage area); this is particularly difficult when flight decks are also required and vertical cranking is difficult to arrange;
- The TEU can be too large for some applications and can be inefficient to pack if the items are not a uniform shape or size, particularly important when space is at a premium on a small vessel.
- Access in / out of the TEU may be required for some items which will require additional material handling equipment.

For naval vessels and particularly small warships it is potentially wiser to consider the “sub inter-modal” range of units; those which are smaller than the TEU but are compatible with packing within the larger units. Such a system is illustrated in Fig 1, utilised in recent trials for the UK MERLIN helicopter Deployable Support Packs. These offer the following advantages:

- The size is more compatible with material handling systems that may be fitted internally within the garage area;
- The units can be efficiently packed and customised for specific uses;
The units are air transport and compatible with replenishment limits for both at sea RAS and VERTREP;

- The units are stackable.

**Fig 1 Storage and Transport Frame developed by MSS (images courtesy of and © Mobile shelter Systems)**

Fig 2 shows the garage concept developed as an illustration of a typical approach and identifies the key aspects.

**Fig 2 VENATOR Mission Garage**

**CONCEPTUAL DESIGN - VENATOR**

The baseline VENATOR concept design is a conventional displacement monohull of 90m length. The choice of this length was based on initial estimates of the minimum likely size to meet the payload requirements together with potential changes to standards that occur for vessels of a greater length. An example is the UK Naval stability standard (Reference 2) which stipulates a change in damage stability standard for vessels above 92 metres length.

The principal characteristics are illustrated in Table II.

**Table II VENATOR Baseline Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length, metres</td>
<td>93.25</td>
</tr>
<tr>
<td>Waterline Length, metres</td>
<td>90</td>
</tr>
<tr>
<td>Moulded Breath, metres</td>
<td>15.12</td>
</tr>
<tr>
<td>Design Moulded Draught, metres</td>
<td>3.95</td>
</tr>
<tr>
<td>Design Displacement, tonnes</td>
<td>2680</td>
</tr>
<tr>
<td>Scantling Displacement, tonnes</td>
<td>3039</td>
</tr>
</tbody>
</table>
Arrangement

The arrangement is illustrated in Fig 3. The large mission equipment garage is conspicuous aft of the superstructure. Whilst the chosen configuration shows an enclosed garage, this is to provide weather tight protection to the equipment and it is not an integral part of the superstructure and has not been included within the watertight structure.

Fig 3 VENATOR Baseline Arrangement

Immediately forward of the garage is the reconfigurable mission space; this is within the superstructure and is located to allow ready access through rear access doors into the garage area. This allows embarkation of mission specific equipment through the garage into the reconfigurable space.

Given the length of the vessel and the provision of a large garage space, the only suitable solution for a flight deck is to locate this over the garage. The flight deck provided is of sufficient length for the embarkation of a helicopter of Lynx size whilst also providing a telescopic style hangar. That latter will provide protection to a helicopter embarked for MSO type operations although it is not envisaged that the helicopter would be embarked for long periods and therefore facilities are limited to stowage, refuelling, basic maintenance and crew accommodation.

Propulsion

The requirement for long range and an emphasis on affordability led to the choice of a straight forward mechanical / diesel drive propulsion system. Two medium speed diesels have been provided, one per shaft and driving via a gearbox to a 3 metre CPP propeller. The propulsion engines are located within a single main machinery compartment.

Fixed Mission Systems

A number of fixed systems are assumed. These offer a capability similar to many OPV / patrol ship style vessels and include:

- A medium calibre gun such as a 57mm or 76mm calibre gun capable of engaging surface targets together with a degree of air engagement capability. There is a potential argument to make this weapon modular in nature as this may reduce the number of guns to be procured (i.e. only fit to vessels requiring the capability) and it may also allow higher payload missions to sacrifice the gun in favour of other equipments.
- An air / surface search radar in addition to a navigation radar;
- An electro-optical surveillance and tracking system;
- Suitable commercial and military communications systems;
- A core command system;
- Obstacle avoidance sonar.
GLOBAL DEPLOYABILITY

Development of Criteria

The development of seakeeping criteria for the study is based upon the NATO standard guidance for seakeeping assessments (STANAG 4154, Reference 3). The criteria can broadly be split into those associated with mission performance and those associated with vessel transit. As the primary role of the vessels is to conduct missions in the littoral and offshore environments, the mission criteria are generally applied to Sea State 4 and 5 environments, reflecting a similar performance to existing offshore vessels and smaller warships. However, the global transit requirement imposes transit and survival requirements in higher sea states. For the purposes of this study it is suggested that transit in Sea State 6 would be a key requirement for world wide operations whilst survival in Sea State 8 may be required in extremis. Table III indicates the criteria applied.

Table III Seakeeping Performance Criteria

<table>
<thead>
<tr>
<th>Specific Operations</th>
<th>Speed</th>
<th>Sea-state</th>
<th>Heading</th>
<th>Roll</th>
<th>Pitch</th>
<th>Motion Induced</th>
<th>Vertical displacement</th>
<th>Vertical velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survive</td>
<td>10</td>
<td>8</td>
<td>All</td>
<td>4</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intercept, Limited Capability</td>
<td>25</td>
<td>5</td>
<td>All</td>
<td>3.8</td>
<td>1.5</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Intercept, Full Capability</td>
<td>25</td>
<td>4</td>
<td>All</td>
<td>1.6</td>
<td>1.5</td>
<td>1</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Transit, Limited defence</td>
<td>18</td>
<td>6</td>
<td>All</td>
<td>3.8</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Air Operations</td>
<td>18</td>
<td>5</td>
<td>+/-40</td>
<td>1.8</td>
<td>1.5</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Vertrep</td>
<td>18</td>
<td>4</td>
<td>0 +/-20</td>
<td>1.6</td>
<td>1.5</td>
<td>0.5</td>
<td>0.7</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Requirements for all conditions:
Monohull
- Wetness Index: 30/hr @ bow
- Slamming index: 20/hr @ keel

SWATH
- Wetness Index: 5/hr @ lower leading edge of cross-structure if it has a corner
- Slamming Index: 20/hr @ worst location under cross-structure

Monohull + SWATH
- Motion Sickness Index: 20% crew @ 4 hrs throughout
- Vertical Acceleration: 0.2g RMS @ bridge
- Lateral Acceleration: 0.1g RMS @ bridge
- Propeller Emergence: 90/hr @ 1/4 prop diameter

Performance of Baseline

The performance of the hull form was assessed against the following:

- Stability - UK naval ship stability standard (DEF STAN) 02-109 (Reference 2);
- Powering - capability to maintain 18kn in SS6 (as part of a task group);
- Seakeeping - NATO Seakeeping guidance criteria as defined by STANAG 4154 (Reference 3).

Analysis of the intact stability in beam winds against the naval standard indicates more than adequate performance. DEFSTAN 02-109 states that vessels between 30 and 92m must conform to prescribed two-compartment damage criterion. VENATOR was designed and optimised to conform to this requirement by subdividing the ship with watertight bulkheads such that DEFSTAN 02-109 damaged stability was achieved.

The baseline hull form is a variant of successful parent designs and has been designed to optimise resistance in calm seas. From theoretical resistance curves a shaft power was determined and appropriate engines sized. However a far more onerous requirement is for the ship to transit as part of a convoy. Therefore to assess powering characteristics the VENATOR power requirement was assessed to maintain
18 knots in heavy weather to identify if the vessel can achieve this requirement (without an involuntary speed loss).

Fig 4 illustrates power estimates based on a Holtrop and Mennen series estimates in various sea states, assessed using the Paramarine package. An assessment of propeller emergence was also undertaken which indicated that the STANAG criteria (20 emergences per hour) would be exceeded above approximately 16 knots in following seas, but would be acceptable in other headings at such speeds. This indicates that the installed power to achieve the 25 knots maximum speed (up to 20 MW) is sufficient to achieve 18 knots in heavy weather in most headings and that involuntary speed loss is not likely to be the limiting factor.

![Fig 4 Power Predications in Waves](image)

The above graph is based on twin 5-blade propellers, 3m diameter, BAR 1.0, 18kn design speed. Appendages, fouling and roughness have all been incorporated.

Overall, in Sea State 6 transit conditions the vessel showed, as expected, a poor seakeeping performance. Fig 5 indicates the roll and pitch results for both the design displacement and the scantling draught (maximum displacement conditions). The assessment included bilge keels but not stabilisation measures.

![Fig 5 Roll and Pitch Predications, Sea State 6, 20knots](image)

The worst case roll approaches a predicated 9 degrees compared to the set criteria of 3.8 degrees, requiring an approximate 60% reduction in roll to be achieved. At higher speeds (circa 15 knots) this is achievable.
with active fin stabilisers and at lower speeds a passive tank system may significantly improve the performance. However, the driving criterion is where a pitch maximum pitch angle of 2.5 degrees is predicted and the STANAG criterion is exceeded for quartering through to head seas. Related to this, very high slamming occurrences are also predicted, 90 slams occurrence per hour in head seas at station 3 (approximately in line with the bridge). This implies that voluntary speed loss is highly likely to occur in Sea State 6 conditions and hence achievement of an 18 knots transit is unlikely due to potential damage and crew discomfort. The results suggest that a reduction of speed to circa 10 knots would reduce slamming at station 3 to the criterion.

Parametric Analysis of Monohull Solution

To investigate the impact of the hull parameters on the performance, a further eight derivative forms were considered based on variations to the baseline in length and length-to-beam ratio. The parameters considered are illustrated in Table IV. The forms studied consisted of three groups, based on 90m, 100m and 110m lengths with one group assuming narrower hulls and one wider hulls than the baseline. The lightship weights associated with each hull were scaled to reflect the changing parameters, but all the forms considered the same payload. This is an important point as the larger hulls imply more internal volume but this is not utilised in the designs - size is only being used to improve hydrodynamic performance and not payload capability.

<table>
<thead>
<tr>
<th>Hull No.</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Draft (m)</th>
<th>L/B</th>
<th>W/L</th>
<th>Ch</th>
<th>Displacement (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>15</td>
<td>4.02</td>
<td>6</td>
<td>4.7</td>
<td>0.479</td>
<td>2860</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>15.30</td>
<td>3.75</td>
<td>6.5</td>
<td>4.7</td>
<td>0.479</td>
<td>2830</td>
</tr>
<tr>
<td>3</td>
<td>110</td>
<td>14.67</td>
<td>3.66</td>
<td>7</td>
<td>4.7</td>
<td>0.479</td>
<td>2810</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>15</td>
<td>4.02</td>
<td>6</td>
<td>4.7</td>
<td>0.479</td>
<td>2860</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>15.30</td>
<td>3.75</td>
<td>6.5</td>
<td>4.7</td>
<td>0.479</td>
<td>2830</td>
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<tr>
<td>6</td>
<td>110</td>
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<td>7</td>
<td>4.7</td>
<td>0.479</td>
<td>2810</td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>6.5</td>
<td>7.5</td>
<td>3</td>
<td>6.5</td>
<td>0.479</td>
<td>2760</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>6.5</td>
<td>7.5</td>
<td>3</td>
<td>6.5</td>
<td>0.479</td>
<td>2760</td>
</tr>
<tr>
<td>9</td>
<td>110</td>
<td>6.5</td>
<td>7.5</td>
<td>3</td>
<td>6.5</td>
<td>0.479</td>
<td>2760</td>
</tr>
</tbody>
</table>

The nine hulls were considered against an abridged set of seakeeping criteria (transit requirements in Sea State 6), required power for maximum speed and intact stability.

Damage stability was not considered as the bulkhead spacing and arrangement would be adjusted to suit. However, it should be noted that the UK MOD stability standard (Reference 2) requirements become more stringent for hulls greater than 92m, which could impact the choice of hull length. This in part reflects the perceived difference in coastal to ocean going vessels and suggests that further thought is required into appropriate damage stability requirements for this type of vessel.

An extract of the results, for roll and pitch are illustrated in Fig 6. The graphs illustrate that none of the hulls achieve the criteria without active stabilisation and also illustrate the difficulty in optimising the form against conflicting requirements. The results suggest that the use of active fins stabilisers is, as expected, a necessity and the roll criteria are within achievable reductions for modern systems. Hence, it is the pitch and slamming criteria that represent the potential limitations to global deployment.
An interesting feature of the pitch results is that whilst there is a noticeable difference in the absolute maximum pitch for the hulls, the percentage of headings on which the criteria is achieved is similar for the designs for the given value of the pitch criteria. This suggests that it becomes important whether the requirement is to minimise the worst case pitch angle or maximise operational headings against a given criteria. In simple terms, the longer hulls do reduce pitch motion, but do they actually result in a larger range of headings in high sea states given a specific criteria and what range of headings may confer “global deployability”? However, as a counterpoint it should be noted that were the value of the pitch criteria higher, there would be greater differences in the percentage of headings on which the criteria is achieved, thus suggesting there are actually real benefits in having a longer vessel which are not reflected in the somewhat simple motions criteria used.

As a simplistic comparison, the parametric forms have been ranked against the percentage of acceptable headings. Table V indicates the results for unstabilised forms and also indicates the effect if roll is ignored on the assumption that active fin stabilisers are able to reduce it to an acceptable level for all forms. This indicates that the best performing hull when unstabilised is Hull 4, a relatively short and thin hull due to the influence of the roll results. If roll is mitigated then the better form becomes hull 9, a longer wider form, now reflecting pitch as the driving criteria. However, in either case the range of available headings remains limited.
Table V Heading Availability (as %) for Sea Sate 6, 18 knots

<table>
<thead>
<tr>
<th>Hull</th>
<th>% Of Course Operability</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td></td>
<td>33</td>
<td>45</td>
<td>64</td>
<td>57</td>
<td>45</td>
<td>64</td>
<td>38</td>
<td>45</td>
<td>64</td>
</tr>
<tr>
<td>Roll</td>
<td></td>
<td>24</td>
<td>19</td>
<td>26</td>
<td>100</td>
<td>67</td>
<td>50</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Foredock Wetness</td>
<td></td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>69</td>
<td>75</td>
<td>75</td>
<td>81</td>
<td>81</td>
<td>81</td>
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<tr>
<td>Bridge Vertical Acceleration</td>
<td></td>
<td>69</td>
<td>75</td>
<td>86</td>
<td>64</td>
<td>69</td>
<td>75</td>
<td>75</td>
<td>81</td>
<td>100</td>
</tr>
<tr>
<td>For all above criteria</td>
<td></td>
<td>3</td>
<td>3</td>
<td>19</td>
<td>44</td>
<td>28</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>

The assessment of powering considered the achievement of the defined maximum speed of 25 knots, in Fig 4 expressed as shaft power. These results, as expected, indicate that the longer hulls reduce the required power against a defined speed.

![Fig 7 Power Prediction Estimates for Parametric Hulls](image)

Finally, an assessment of the intact stability performance, considered against Reference 2 was conducted and the results are illustrated in Fig 8. This indicates that the thinner group of hulls (4, 5 and 6) considered were assessed as failing the criteria. Notwithstanding the possibility to adjust the design KG, this indicates that the preference will be for a wider beam than in this particular group.

![Fig 8 Intact Stability Comparison for Parametric Hull](image)

**Performance Comparison**

In order to consider the balance between these results, the seakeeping, resistance and stability assessments have been ranked relative to each other and Figs 9 and 10 indicate this relative assessment (100 = best; 0 = worst). From this, it is suggested that the best starting point would appear to be hull 3; this offers as good
seakeeping results as hull 6 or 9, has adequate stability and offers good resistance results. In fact this hull is not optimal for any specific characteristics but represents a potentially good balance.

As a principal driver in the design is the hydrodynamic performance, it is worth considering alternative hullforms to the monohull. In order to most improve the seakeeping performance in larger waves, the SWATH form represents an obvious choice to consider for this vessel type.

A SWATH form was developed by BMT Nigel Gee utilising the same payload requirements as the baseline design. The characteristics of this form are presented in Table VI.
Table VI SWATH Variant Principal Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length, metres</td>
<td>75</td>
</tr>
<tr>
<td>Waterline Length, metres</td>
<td>51.2</td>
</tr>
<tr>
<td>Extreme Breath, metres</td>
<td>37.6</td>
</tr>
<tr>
<td>Waterline Breath, metres</td>
<td>34.7</td>
</tr>
<tr>
<td>Design Draught, metres</td>
<td>8.6</td>
</tr>
<tr>
<td>Design Displacement, tonnes</td>
<td>4076</td>
</tr>
</tbody>
</table>

For this size of SWATH the critical pitch motion is reduced to circa 1.1 degrees in Sea State 6 at speeds of up to 20knots. This is a significant reduction compared to the monohulls, typically 2 - 2.5 degrees in comparison. Hence, from a sea keeping perspective the SWATH form is a much more stable and will provide a significantly enhanced ride.

However, the power prediction for the SWATH form indicates that a much higher installed power will be required to achieve the maximum speed. In fact, at the maximum speed the resistance curve for the SWATH becomes steep in comparison to a monohull and hence it is not just the increase in estimate but the increase in the tolerance that must be applied to the estimate that becomes a problem.

Overall, it is concluded that a SWATH design shows much promise for this vessel type if the speed requirement is significantly reduced (below 20 knots). However, as speed is considered an essential requirement in order to allow MCM operations ahead of the task group and to keep pace with faster commercial bulk carriers, the SWATH is unlikely to present the best overall performance compromise when compared to a conventional monohull.

CONCLUDING REMARKS

The aims of the VENATOR project were to assess the practicality of a small reconfigurable surface combatant for MCM, MCM support, hydrographic and maritime security operations and to investigate the issues of a global deployment capability. In developing a concept, a 90m monohull design has been shown to be a practical proposition and the design incorporates material handling, vehicle deployment and modular storage solutions that are consistent with the concept of reconfigurability between roles.

Investigations into the seakeeping, powering and stability of scaled monohull variants illustrate the difficulty in achieving unrestricted global operations. In particular, achieving pitch and slamming predictions that are within acceptable limits for transiting in up to sea state 6 conditions will require an increase in hull length from the baseline design which was sized against consideration of the payload requirements alone. A SWATH solution would mitigate the seakeeping performance issues but will not meet the maximum speed requirements set for the study. This demonstrates overall that the setting of requirements against a global deployment capability will be a difficult but important aspect for the success of such vessels. Issues such as the setting of absolute criteria (i.e. STANAG 4154) and the extent of heading limitations that are acceptable will require consideration together with investigation of the trade space of ship size (and cost) and performance in heavy weather.

REFERENCES