Future Ship Concepts for Repair and Maintenance at Sea

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SYNOPSIS

The repair and maintenance of naval vessels deployed away from their primary support infrastructure is an often overlooked area, with existing repair and maintenance ships either being of old design or vessels converted from commercial ships. Increasingly the nature of the Royal Navy and other navy operations will see an emphasis on deployments away from home waters for extended periods as global presence is demanded from a decreasing pool of warships. Hence the maintenance and repair of deployed naval vessels will become a significant issue. Additionally, future changes in the operating nature of the fleet with an increased focus in support of expeditionary warfare and humanitarian relief operations will require more utilitarian vessels.

The impact of these evolving operations on potential concepts for future maintenance vessels has been explored and notional requirements developed. These have been considered against a variety of vessel options and an innovative heavy lift ship solution has been developed as one potential concept for an expeditionary repair and maintenance platform.

This paper explores some of the potential future requirements for the next generation of repair and maintenance vessels, within a historical context of current and past vessels. Two case studies are presented and discussed for a cable ship conversion and an innovative heavy lift concept as potential solutions.

Author’s Biography

Andy Kimber is a Managing Naval Architect at BMT Defence Services Limited, where he leads the Naval Architecture Future Platforms Team. He has undertaken a variety of future ship and options studies over the past three years. Previous to this role, he held the position of Platform Architecture Manager for the Thales CVF team for three years. Andy has a wide experience of design, in service support and disposal activities since joining BMT Defence Services in 1990, after completing a degree in Naval Architecture and Ocean Engineering at University College, London between 1986 and 1989.

HISTORISICAL PERSPECTIVE

The repair ship, depot ship or maintenance ship is somewhat of a Cinderella capability; for much of the time the vessels quietly support their navies in overseas deployments and are often overlooked. However, occasionally these vessels are seen in the public eye when their capability proves invaluable to an operation.

This was seen in the recent comments following Operation Telic in which RFA DILIGENCE was singled out by Admiral Sir Alan West; “The basic repair ship was invaluable during Telic”, Reference [1]. The same vessel again proved her worth in 2005 when she provided support to civilian authorities in the aftermath of the Tsunami.

For the purposes of this paper, the three types relevant to the discussions are:

Repair vessels - extensive workshops and facilities to repair damaged ships;
Depot vessels - provide administrative, recreational, provision and maintenance support, notably to submarines, destroyers and smaller strike craft which require significant external support. Maintenance Ships - provide more limited workshops and smaller staff for the less demanding support of vessels other than damage repair.

An early example is the Torpedo Boat Depot ship HMS VULCAN. This purpose built vessel, launched 13th June 1889, was designed to operate as a “mothership” to the smaller torpedo boat craft, which she carried and deployed by large cranes. Extensive workshops and repair facilities allowed her to support not only the torpedo boats but to perform a wider repair ship role to the fleet. Later used as a submarine depot ship, she survived until she was scrapped in 1955.

![Fig 1 - Torpedo boat Depot and Mothership HMS VULCAN](image1)

![Fig 2 - Workshops aboard HMS VULCAN](image2)

To demonstrate the width of activities being conducted, by the end of the second world war the Royal Navy operated a significant number of vessels offering support to ships at sea, often optimised for a specific role and not always fully able to meet the demands.

<table>
<thead>
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<th>Table 1 Wartime Depot and Repair Ships</th>
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<td><strong>Conversions</strong></td>
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<tr>
<td>Submarine Depot Ships</td>
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<td>Destroyer / Escort Depot Ships</td>
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<td>Costal Forces, Landing Craft and Auxiliary Vessel Depot Ships</td>
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<td>Maintenance and Repair Ships</td>
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† Vessels transfer from USN under lend / lease arrangements
‡ Vessels completed as merchant hulls post war

By the 1970’s, the number of vessels in UK service had reduced to small number of depot ships (submarine and destroyers) and one heavy repair vessel. These included the dedicated submarine depot vessels HM Ships FORTH, MAIDSTONE and TYNE and the heavy repair ship HMS TRIUMPH.

The depot vessels were purpose built, dating from the 1930’s, and were latterly used to provide support to the UK nuclear submarine fleet whilst dedicated shore facilities were constructed. On their completion, the submarine depot ships were no longer required and the move to an all nuclear fleet only operating out of the dedicated naval bases negated their need in the fleet.

The heavy repair vessel HMS TRIUMPH was converted from an aircraft carrier in 1958 to 1965 with extensive workshops in the former hangar and deckhouses constructed on the former flight deck. A notable feature was that the repair facilities were kept in mothballs in peacetime and the vessel primarily used for maintenance of vessels deployed to the Far East.
These vessels steadily paid-off as global deployments reduced and newer shore facilities were developed to support the warships; the final repair ship HMS TRIUMPH also paid off in 1975 without replacement, finally being broken up in 1981.

By the time of the Falklands Conflict, no dedicated repair vessel remained in service. Given the extreme distance of the operations from the UK and the lack of host nation support close to the theatre of operations, very quickly the need to covert a commercial vessel for service as a repair ship was identified. The offshore support vessel M/V STENA INSPECTOR was taken up for service and quickly modified. The vessel was such a success that she was purchased and formally converted to a Forward Repair ship, entering service in 1984 as RFA DILIGENCE. Built in 1981, before being taken up from trade in 1982 and purchased outright by the MoD 1983, the vessel was converted at a cost of £25M to dedicated forward repair ship. This vessel is expected to remain in service beyond the end of this decade, Reference [2].

Today, RFA DILIGENCE acts not only as a forward repair vessel, but as a maintenance vessel and occasionally as an MCM support vessel. She has been supplemented by deployment of temporary modules for MCM vessel support, notably on survey vessels and more recently LSL’s vessels.

Overall, it can be seen that even in the most recent operations, the repair and maintenance ship remains an important element of the globally deployable navy, although the number of hulls has dramatically reduced to today when only one dedicated platform is in use by the UK.

**PAST AND CURRENT CAPABILITIES**

A paper presented to the Royal Institute of Naval Architects in 1947, Reference [3], provides a detailed account of the modifications and success of the wartime repair and depot ships and compares the conversion of mercantile vessels to the dedicated builds.

The key characteristics and lessons learnt for the immediate post war vessels were:
Extensive workshops were required including a pattern shop, foundry; coppersmiths and plumbers shop; smithery and plate shop; electric welding shop, engine shop.

A significant issue was the fitting of smithery and foundry workshop, requiring the removal of strength deck material to provide sufficient working height.

The large work force could not be accommodated onboard requiring accommodation ships to support the repair ships and the ineffectiveness caused by having to transfer staff between repair ship and accommodation ship.

Table II provides a comparison of a number of depot and repair vessels characteristics, representing differing dedicated roles and service dates over 50 years.

| Table II  Typical Repair and Maintenance Ship Characteristics |
|---------------------------------|-----------------|-----------------|--------------|--------------|
| Ship Type                        | Resource        | Assistance      | Maidstone    | Triumph      |
| In-service Date                  | 1930            | 1945            | 1938         | 1965         |
| Length, metres                  | 134.6           | 134.6           | 151.5        | 192          |
| Breadth, metres                 | 22.3            | 22.3            | 24.4         | 20.5         |
| Deep Displacement, tonnes       | 11685           | 11685           | 17,000       | 10765        |
| Workshop Area, metres sq.       | 3700            | 1500            | 1600         | Approx. 2000 |
| Lifting Capacity                | One 25ton crane; Two 3 ton cranes; One 20 ton derrick | Four 10 ton derricks | One 10ton crane; One 6 ton crane; Other 1 and 2 ton cranes and derricks | Extensive cranage installed on former Flight Deck | One 25 te, one 20 te, two 5 te |
| Maintenance / Repair Staff      | Up to 700       | 200             | 285          | Circa 150    |

1 - As converted to repair ship.
2 - Based on dimensions of former Hangar.

The key characteristics that can be drawn from these platforms and define the basic requirements for a maintenance or repair ship are:

Cranage for the transfer of materials from ship to ship and shore to ship, including the removal of equipments for maintenance onboard the repair ship. Typical a range of capacities should be available with a maximum lift capacity in the region of 25 tonnes.

Space for a significant array of workshops, including plate metal, welding, machinery, heavy electrical as well as clean workshops such as hydraulic and electronics. The area is dependent on the level of support provided and will range from several hundred to several thousand square metres.

Extensive storerooms for the required tools, spares and consumables.

Accommodation for the repair and maintenance staff in addition to the ships complement. To day this typically amounts to approximately 100, much reduced from the 500 to 700 staff in earlier ships.

Supplies of fuel, fresh water, high pressure sea water, air and power for vessel alongside.

It is also noted that RFA DILIGENCE is equipped with a dynamic positioning system by virtue of her previous role as an offshore support vessel, which has advantages when manoeuvring alongside stricken and damaged vessels.
DISCUSSION ON FUTURE REQUIREMENTS

With many of the in-service vessels nearing the end of their useful lives, the issue of replacement needs to be considered. However, in budget constrained times these ships are increasingly “unaffordable” but ever more necessary.

The Future Navy paper, Reference [4] reinforces concepts of global reach with sustainability and, importantly, decreasing the Joint Force dependence on Host Nation Support (HNS). This leads to the need for vessels to provide a wide range of support to both the fleet and expeditionary forces ashore.

The primary role of the vessel is likely to remain as today, i.e. the need to provide equipment support and repair. Specifically:

To provide a maintenance capability to allow ships to remain in theatre for extended periods with less reliance on HNS;
To provide an unplanned maintenance capability to vessels and equipment to allow them to remain on station;
To repair damaged asset (from get-home capability to salvage).

Whilst this implies that many of the facilities seen in today’s maintenance and repairs ships will remain in the next generation, there are some changes that are likely to occur. These include the increased use of composite materials requiring large composite workshop and the increased use of modular replacement rather than repair of components. The latter will reduce the need for repair onboard but will increase the stores required and will also require enhanced communications and transport facilities to allow asset ordering, tracking and transport.

Increased submarine support may also emerge as a new requirement in the next generation vessels for the UK. As discussed earlier, the Submarine Depot ship was a valuable asset in the time of the short range conventional submarine, but has disappeared as nuclear powered submarines became common for the major navies. However, the renewed emphasis on global reach, sustained operations in support of ground forces and power projection combined with a smaller submarine fleet suggest the ability to rearm and to provide respite for the crews in theatre may become an important factor. Notable factors that may influence a future repair ship are:

Need to assist submarines in mooring due to poor low speed manoeuvring;
Primary consumables support is munitions supply, which differs from surface ship resupply;
Nuclear plant imposes range of constraints.

As well as providing direct support to navy vessels (maintenance and required repair), the future repair and maintenance vessel will increasingly be used to support non-naval elements. The maintenance of helicopters may be achieved more efficiently on board vessels than ashore, due to the presence of dedicated facilities and a more controlled atmosphere. Whilst a number of support ships offer expanded aviation maintenance facilities, the repair ship could offer much deeper levels of maintenance and repair due to the greater available workshop area and heavier machinery.

Also humanitarian and disaster relief will be seen as an important future role, emphasising the non-military utility of such vessels. This is unlikely to be affordable if expectations are high, but the incorporation of facilities at small cost should be considered.

A vessel incorporating all the above capabilities and flexibility will clearly become an important part of the emerging global sustainability requirement and emerging sea-basing requirements. However, the potential for dedicated and specialised vessels is unlikely and a single vessel with all these attributes may be difficult to design and ultimately unaffordable.
POTENTIAL SOLUTIONS

There are a variety of options open to provide the future repair vessel and the principal options would include:

- A modular facility that may be temporarily hosted on an existing vessel;
- A conversion of an existing vessel (probably commercial vessel);
- A barge facility that may be moved by a heavy lift vessel;
- A purpose designed vessel.

This paper addresses some of the issues and potential concepts that emerge from the first three options.

The Modular Facility

The modular approach to maintenance facilities offers the advantages of flexibility in the capability to be deployed and may be hosted on various non-specialised vessels.

Modular support facilities have been in use for a long time in roles such as the RN MCM Support Unit. Using standard ISO containers, the support workshops and stores have been embarked in a number of vessels, such as RFA SIR GALAHAD. These facilities allow forward deployment of MCM vessels which are too small to deploy overseas without external support.

It is easy to consider the expansion of this capability to provide support to a wider fleet. The use of containers would allow selective deployment of facilities according to the vessels to be supported and the mission being supported. A dedicated platform is not required and the containers are even land deployable if necessary.

However, a purely modular approach has some significant drawbacks:

- Cranage has to be available on the host vessel;
- Large area workshops cannot be provided;
- To provide the range of systems/workshops for deeper maintenance, a large number of containers are required;
- Sufficient accommodation has to be available on the host vessel for the maintenance / repair staff.

These factors suggest that the modular approach is well suited to a maintenance role and supporting specific vessel types. It is however difficult to provide the required facilities only in this way for very deep maintenance and ship repair.

The Commercial Conversion

Commercial conversions have always been used to provide repair and maintenance vessels. Historically vessels were mostly adapted from liners and passenger ships. More recently, offshore vessels have been used, notably RFA DILIGENCE and for a short period her “sister” M/V STENA SEASPREAD. Warship conversions also have featured in the past, notably HMS TRUIMPH as already discussed, but also the former Italian frigate ALPINO converted to an MCM command and support ship and the former Swedish minelayer HMS ALVSBORG now in service with the Chilean navy as a submarine and fast attack craft depot vessel.
Table III presents a comparison of current commercial vessel types against the repair and maintenance ship role.

### Table III Comparison of Commercial Ship Advantages / Disadvantages

<table>
<thead>
<tr>
<th>Space for Workshops</th>
<th>Offshore Support Vessel</th>
<th>Cruise ship, liner</th>
<th>Containership</th>
<th>RO-RO</th>
<th>Cable ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation</td>
<td>Limited</td>
<td>Good</td>
<td>Very Limited</td>
<td>Good</td>
<td>Limited</td>
</tr>
<tr>
<td>Dynamic positioning</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Possibly</td>
<td>Limited</td>
</tr>
<tr>
<td>Speed</td>
<td>Adequate</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Adequate</td>
</tr>
<tr>
<td>Craneage</td>
<td>Yes</td>
<td>No</td>
<td>Possibly</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Space for Auxiliary Systems</td>
<td>Limited</td>
<td>Limited</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

The cable ship offers an interesting proposition for conversion due to its basic configuration. Key features include a large working deck, often covered with rear access and large cable holds which may be utilised for holds and additional machinery and accommodation. A principal disadvantage is the lack of berths for the naval repair party.

Fig 6 indicates the concept of conversion for the (former) James Fisher vessel C/S OCEANIC PEARL.

The extensive workshop facilities would be arranged within the cable deck, which is already served by an overhead gantry for movement of heavy items and plate. Existing electronics support spaces and test equipment spaces would serve as clean workshops. The cable deck accesses the stern working area through a large, hydraulically operated door, which would provide the primary transit route for equipments being shipped from the vessel(s) alongside.

The current working deck includes a large A frame for the deployment of the cable plough. This would be removed and the area cleared of obstructions to provide a working space for large items such as diesel generators to be shipped and maintained. The working deck and the upper weather deck would provide container stowages for specialised modular workshops and additional stores.

![Fig 6 C/S OCEANIC PEARL Proposed Conversion as Repair Ship](image)

The vessel’s hull is dominated by the large cable holds, extending over one-third of the length of the vessel. During the conversion, the holds would be removed and the space subdivided by additional transverse watertight bulkheads to improve stability and provide additional compartmentation. The forward parts of the former hold would provide additional accommodation for the naval party; the existing accommodation is suitable for the RFA complement plus senior embarked repair staff, with an approximately 100 berths added in the conversion.
One space below the cable deck would be utilised as an additional auxiliary machinery compartment. The new auxiliaries would be required to support the additional hotel loads associated with the new accommodation complex and the workshop equipments. In addition, overboard supplies of power, water, air and fuel are proposed. The current vessel is diesel electric with three diesel generators providing the propulsive and power loads. This offers a high degree of flexibility in power management, as the vessel would not be underway when conducting repairs or maintenance and hence an excess of power would be available. However, all the diesel generator sets are currently located aft in one space, therefore to improve redundancy of supply, additional diesel generator sets (two at 1MW) are proposed as the primary overboard supply sets. These would be cross connected to the current power systems, but would also be able to operate independently if required.

The remaining hold space would provide large cargo holds for the spares and tools, with expanded deep double bottom tankage provided for additional fuel and fresh water.

The vessel is already equipped with a single container handling crane; this would be supplemented by additional cranage serving the aft working area and small cranes serving the flight deck which had been located aft of the bridge. This vessel is also is also provided with a dynamic positioning and joystick control for manoeuvring.

The Float On / Float Off Vessel

A heavy lift float on-float off (Flo-Flo) concept is illustrated in Fig 7 and has the following advantages in delivering a repair and maintenance capability:

- Large open deck for flexibility in embarking different options.
- Low freeboard for ship and submarine access.
- Ability to lift a vessel out of the water for underwater engineering.
- Ability to recover damaged vessels.

It is anticipated that the vessels could operate in three modes according to operational tasking:

- Retain facilities onboard, operating as a “conventional” repair vessel.
- Deliver the facilities to a sheltered area or port and then leave.
- Offload the facilities in sheltered area or port and remain alongside as a “float dock”.

It may not be necessary to purchase the FLO-FLO, possibly using assured charter or PFI arrangements to provide a guarantee of a vessel being available at short notice to embark the repair facility when required.

The concept for the barge design illustrated in Fig 8 is based on maximum dimensions 120 metres by 32 metres, consistent with a range of existing FLO/FLO vessels, and has a light displacement of approximately 3,500 tonnes. The basic layout is driven by the principle of separating the workshops at one end and the accommodation at the other. This provides separation of workplace from quarters and should minimise the transmission of noise and vibration from the workshop area to the accommodation block. The space between the workshop and accommodation blocks, over 60 metres in length, is then available as a flexible working and storage area.
A large dedicated workshop area of 960m² is provided on a single level at one end of the barge. This is accessed via large doors from the working deck and is subdivided into a range of workshop types as shown in Fig 9. The principle used to develop this arrangement is to provide easy access and movement for heavy items; all the workshops are arranged on one level and the Mechanical and Composite workshops are provided with large openings on to the working deck to allow the movement of heavy items of equipment and structural assemblies (or indeed airframes) into the workshops. The smaller and clean workshops are provided to the rear of the block, and if necessary can be safely accessed without access through the other workshops.

Fig 7 FLO-FLO Workshop / Accommodation Barge

Fig 8 Illustrative Layout of Repair Barge

Fig 9 - Layout of Workshops
The roof area of the workshops has been reserved for a helicopter deck. A further landing spot may also be provided on top of the accommodation block, however, to reduce noise the main operating area is considered best placed away from accommodation. This operating area is of sufficient size to land any helicopter up to Chinook size, and there is area which may also be utilised as a vertical replenishment stores dump or even as an aviation repair complex. In Fig 8 it can be seen that a series of containerised workshops is illustrated for by-type maintenance of helicopters.

The accommodation block assumed is a two story, modular arrangement capable of providing accommodation for up to 200; this is sufficient for a very large support party and also accommodation for ship / submarine crews alongside if required. In this concept, the accommodation is not required to cater for the ship complement as they are embarked in the heavy lift vessel.

The area between the workshop and accommodation block would act as the main working deck. Extensive carnage, shown in Fig 10, may be provided along each side for supporting vessels, removal and replacement of equipments as well as provided a self loading capability. To aid rapid storing and re-role of the facility, it is assumed that much of the stores would be provided using standard sized ISO containers. It is also possible that additional workshops, generators and other facilities may be provided as containers stored on this deck. It would be possible, for example, to provide power using containerised diesel generators (for example 1 M per unit), hence allowing flexibility in the number carried and allow maintenance by replacement. Indeed, the units may even be hired in as required by the vessel’s role and deployment pattern.

Finally, the barge offers an extensive volume that may be used for:

- Auxiliary machinery as a permanent fit;
- Bulk Stores;
- Fluid Stores;
- Ballast tanks to affect trim / draught when not embarked on the FLO-FLO.

This would be further supplemented by the FLO-FLO vessel itself, which is capable of carrying both cargo solids and fluids to supplement its heavy lift cargos.
CONCLUSION

There is likely to be an increasing gap between the funding available and the need for this Cinderella capability; indeed future operational needs are likely to imply a much expanded roles for this type of vessel due to its flexibility and utility within a globally deployable force. This is recognised in references such as the Royal Navy Future Navy paper, Reference [3].

New ideas explored using cable ship conversions or heavy lifting vessels demonstrate that there are new concepts to consider in the future to replace and expand the current capabilities and on which to base future vessels. The collapse in the dot.com market and the subsequent over capacity in the cable ship market offers the potential for vessels that this paper shows as being a sound base ship for conversion. Alternatively, the use of heavy lift FLO-FLO style vessels offers a number of significant features that could make the next generation of repair and maintenance platforms more flexible and capable.

ACKNOWLEDGEMENT

The work conducted jointly with James Fisher Defence in the concept for the C/S OCEANIC PEARL and their willingness to allow this to be summarised in this paper is acknowledged.

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1 Select Committee on Defence; WEDNESDAY 24 November 2004, comments by Admiral Sir Alan West GCB DSC ADC.

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4 The RN Future Navy Process; Strategic Concept.

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