THE NEXT GENERATION MCM PLATFORM – NOT YET FULL AUTONOMY

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SUMMARY

Unmanned systems offer a revolutionary change to the concept of operations for naval minewarfare. Extensive research led BMT to conclude, that given the current rate of development of autonomous systems, a need shall remain for the foreseeable future for a specialist mine counter-measures (MCM) platform from which the autonomous systems can be hosted and operated. These ships shall form an integral element of a nation's maritime MCM capability and the new operating concept requires a very different platform to the existing ships. The paper summarises BMT's research into near-future autonomous minewarfare and examines the requirements of the next generation of MCM ships and how that is balanced against the need to provide an affordable, capable and safe national asset that can be adapted through life to continue to support the ever-developing autonomous MCM systems.

GLOSSARY

ASW	Anti-Submarine Warfare
ASuW	Anti-Surface Warfare
AUV	Autonomous Underwater Vehicle
CBRN	Chemical, Biological, Radiological & Nuclear
CFD	Computational Fluid Dynamics
CIC	Command Information Centre
CONOPS	Concept of Operations
LARS	Launch And Recovery System
LIDAR	Light Detection And Ranging
MCM	Mine Counter-Measures
MCMV	MCM Vessel
MIDS	Mine Identification & Disposal System
MLO	Mine-Like Object
nm	nautical mile
OA	Operational Analysis
OEM	Original Equipment Manufacturer
OPV	Offshore Patrol Vessel
RHIB	Rigid Hulled Inflatable Boat
ROV	Remote Operated Vehicle
UAV	Unmanned Aerial Vehicle
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle (either remotely operated or autonomous
URN	Underwater radiated Noise
UxV	Unmanned vehicle (of any type)
VERTREP	Vertical Replenishment

1. INTRODUCTION

Sea mines continue to be a weapon of maritime warfare and an enduring threat to both military and commercial shipping but the means to detect and destroy the weapons is evolving rapidly. The desire to remove mine-warfare personnel from the mine threat has been long recognised and since the advent of remote vehicles, systems have been developed to provide that distance. Initially, offboard systems were used only for the mines' classification and destruction following detection by the mine-hunting ship's hull-mounted sonar. Fully autonomous systems now offer navies the opportunity to remove their personnel from the mine threat and to automate the dull and repetitive work of mine-hunting.

The design of mine-countermeasures (MCM) ships has not changed significantly over the last 100 years (Figure 1) but MCM technology is on the cusp of a revolution. Additionally, a large proportion of the word's legacy MCMV fleet is reaching the end of its operational life and requires replacement over the next decade. BMT began studies in 2015 to explore whether future mine-warfare would need a host platform and, if so, what the requirements for the platform would be.

Figure 1 – Examples of MCMV Designs Spanning the Last Century

This paper summarises the work done by BMT and presents the necessary characteristics of the next generation of MCM platform.

2. ESTABLISHING THE REQUIREMENT

2.1 THE FUTURE MCM TOOLBOX

Tethered unmanned underwater vehicles (UUVs) or remote operated vehicles (ROVs), as they are known, have been used by navies to identify and neutralise mines for several decades to distance the most risky MCM operations from the ship and personnel. Some navies are already using autonomous unmanned vehicles (UxVs) for domestic, coastal MCM operations and this trend is set to continue and their roles grow as the technologies develop. Exercise Unmanned Warrior conducted by the UK Royal Navy and managed by QinetiQ in 2016 demonstrated that a number of different autonomous technologies could be deployed and linked to conduct a joint operation.

The research team engaged with minewarfare experts, UxV manufacturers and combat systems suppliers to gain a thorough understanding of the latest MCM methods and technologies and the expected technological developments of MCM systems both in the short and long term. A synopsis of the different autonomous systems and their capabilities follows:

Larger, long range Autonomous Underwater Vehicles (AUVs) using a mix of side-scan and synthetic aperture sonars are being used to conduct wide area surveys of the minefield to detect mine-like objects (MLOs).

Smaller, shorter range AUVs are then deployed to identify, classify and, potentially, neutralise the objects identified in the initial search.

Unmanned Surface Vehicles (USVs) are anticipated to become the multi-role workhorses of the fleet fulfilling the roles of:

- Pulling a towed side scan sonar system. In shallower water, this is potentially a higher speed alternative to the large AUVs;
- Mine-hunting using an integral hull-mounted sonar;
- Taxiing smaller AUVs into the minefield/swept channel;
- ROV mothership used to deploy tethered inspection / mine disposal vehicles (potentially a manned role);
- Diver taxi – In a manual operating mode, the vehicle will carry clearance divers to an area of operation;
- Conducting acoustic and influence sweeps. Depending upon the threat, a sweep may be conducted in place of hunting. However, a sweep is expected to be conducted post the hunting operation to activate any undetected mines.

USVs for MCM are still developing but consensus amongst the OEMs is that they will be larger than the current generation to enable them to embark and power the envisaged payloads. A USV with a length of 13m, beam of 4m and displacement of 20 tonnes was selected as appropriate dimensions for a future-proof solution.

Unmanned Air Vehicles (UAVs) operating as part of the toolbox offers the ability to vastly increase its effectiveness. An UAV at height provides greater situational awareness. When equipped with LIDAR sensors, the UAV can make a rapid optical search ahead of the ship/USVs for floating/near-surface mines. It is hoped that the UAV will also act as a communications bridge between the ships and the USVs or AUVs on the surface, thus increasing their range and ensuring a communications link is maintained. Communications generally rely upon line of sight and there is a risk that a small vessel operating in large waves will lose visibility of the ship's antennae even at a short distance.

Data transfer from the AUVs to the ship is anticipated to happen either via the USV and UAV using a short range Wi-Fi link or directly between the AUV and ship via Wi-Fi/acoustic link (through-water) or on board the ship by direct connection. It is an aspiration that the AUV will surface and transmit directly to the UAV.

The paper "Generational Shift: How technology is shaping a step change in the future of mine counter-measures" [1] provides greater detail of the integration and control of the toolbox during MCM operations.

2.2 THE FUTURE MCM CONCEPT OF OPERATIONS

Legacy MCM practices require the ships to operate within the minefield but the desired Concept of Operations (CONOPS) envisages the MCM operation being controlled from a position outside the minefield and over the horizon; either from within the deployed Task Group or from shore (if host nation support is available). BMT identified four distinct CONOPS spanning the spectrum from the legacy approach to the fully autonomous concept (Figure 2):

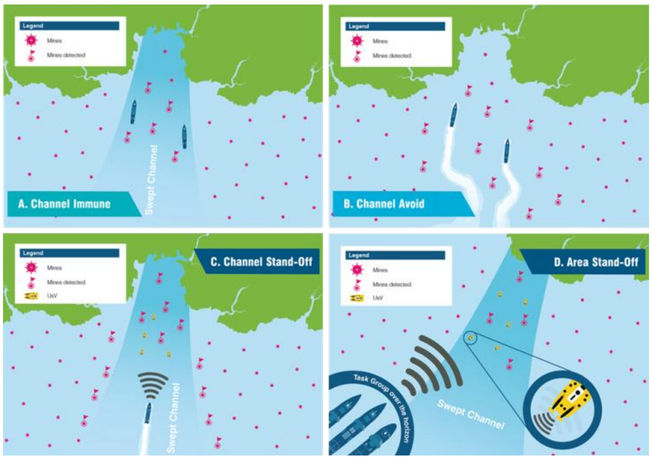

Figure 2 – The Four MCM Concepts of Operation

1. Channel Immune – A legacy practice that relies upon a highly capable ship which is effectively immune to the mine threat. The ships traditionally conducted towed minesweeping but most now have a hull-mounted mine-hunting sonar and tethered submersibles for mine-hunting.

2. Channel Avoid – The ship is still very capable but conducts mine-hunting operations only using a hull-mounted sonar and tethered submersibles. It is highly manoeuvrable and maintains a greater stand-off distance from the threat than the Channel Immune platform needs to.

3. Channel Stand-off – Autonomous systems are used to hunt and clear a swept channel but the limited maturity of autonomous systems technology requires the ship to follow the vehicles into the swept channel.

4. Area Stand-off – The MCM UxVs are deployed a considerable distance from the minefield and work autonomously to clear a channel through the minefield enabling shipping to pass through the channel upon completion. Tasking of the UxVs is conducted from a point over the horizon either on land or from a low capability ship.

Whilst the Area Stand-off CONOPS is the panacea most navies aspire to; several hurdles must be overcome before the adoption of long range, fully autonomous systems becomes a viable solution:

- Current AUV battery life limits their range and speed or operational time if there is a long transit to the minefield (particularly in bad weather);
- Legal limits on the use of autonomous systems and the need to keep a man in the loop. The IMO COLREGS [2] still require a maritime platform to maintain a visual lookout. Rules of engagement and the respect of international human rights laws mean armed forces still need a human with the most complete situational awareness available to make the decision to "pull the trigger" [3]. To achieve each of these requirements, effectively requires a live CCTV feed to be in place.
- It is desirable if the data being passed from the UxVs to the operators remains unprocessed. This has the advantages that the data is unclassified and the data and equipment on board the UxVs is of less value if the vehicle falls into opposition hands.

The disadvantage of the latter two requirements is that they vastly increase the quantity of data which needs to be passed back to the operator. Passing more data demands more battery life and also means that a high bandwidth, reliable and covert communications bridge is essential.

- Assurance must be provided that the area swept by the unmanned vehicles is clear of mines before a high-value military assets or commercial shipping transits the channel. A low signature, resilient MCM platform fitted with a hull mounted mine/obstacle avoidance sonar can conduct a low speed search of the channel as it follows the toolbox.
- Unmanned systems deployed far ahead of friendly units could be captured or suffer damage from hostile forces, and could become lost. The larger the UxVs (which scales with range), the higher value and less covert they become, thus increasing the protection, they themselves need.

Advances in mine technology means that the features of modern minefields are changing. Mine clearance operations are expected to become more onerous due to the need to hunt for more sophisticated mines, in deeper water and over large areas and clear long and wide safe channels. AUV and helicopter-based systems are unlikely to be able to provide sufficient time on station to give the necessary assurance to amphibious forces unless they are closely supported by a dedicated asset able to remain on task for extended periods (to maintain clear channels against mobile mines).

It is, therefore, Channel Stand-Off which appears to be the most likely CONOPS for the next couple of generations of UxV and hence the scenario upon which BMT focussed its research.

2.3 IDENTIFYING THE MCM TOOLBOX COMPOSITION

Discussions with unmanned systems suppliers and MCM equipment manufacturers established their products' capabilities and the probable make-up of a MCM toolbox comprising a mix of USVs, AUVs, UAVs and tethered UUV–based hunting/disposal systems. Using agent-based modelling as a simple Operational Analysis (OA) technique, the team simulated a range of mine clearance operations to identify the most appropriate toolbox composition to clear an example minefield within an acceptable timeframe. The different vehicles' ranges, speeds and survey windows were input and the following parameters were varied: number of each vehicle type; water depth; the size of the minefield being cleared; sensor range and overlap; neutralisation time; number of mines and mine-like objects.

The OA results showed that two survey units and two classification units provided an acceptable rate of clearance and detection and on a par with the clearance rates of legacy systems. The impact of additional systems was investigated but did not offer significant reduction in the operation's duration (Figures 3 & 4). Accordingly, it was decided the platform should embark the capability to deploy two medium AUVs simultaneously and two USVs with their range of payloads.

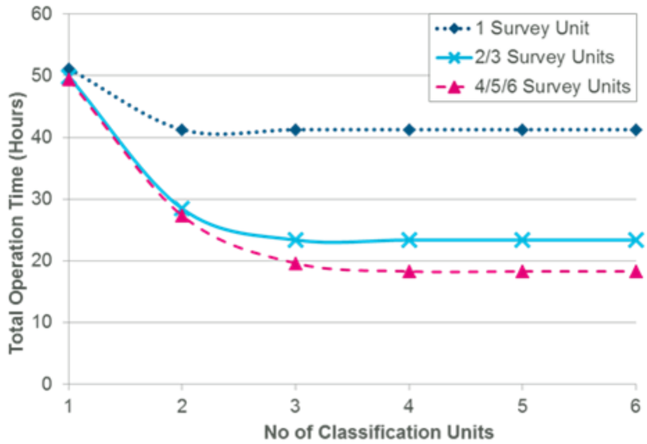

Figure 3 – OA Results Running A Range of Survey AUVs

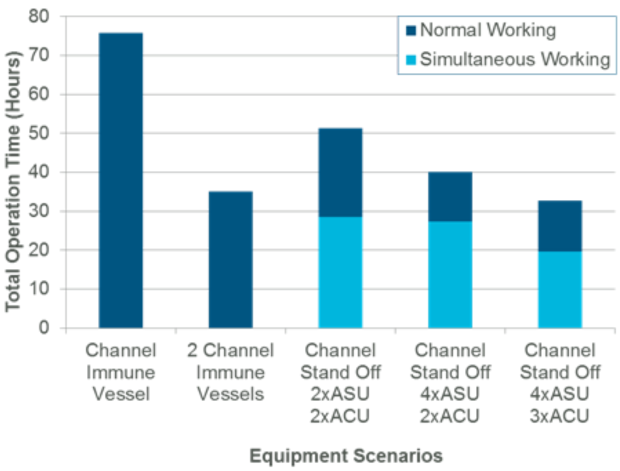

Figure 4 – OA Results Comparing Legacy Channel Immune Capability Clearance Time With Alternative Channel Stand Off Toolbox Permutations

2.4 DEFINING THE PLATFORM CAPABILITY

The agent based modelling also allowed the team to explore and identify where the MCMV needed to be in relation to the UxVs and the minefield. In turn this enabled the threat to the platform and its survivability requirement to be defined.

The model simulated realistic minefield geography and assumed that an 800m wide channel was cleared through a 50 nm deep field.[4] The toolbox was assumed to clear a 5-10 nm section ahead of the ship. This range matches UxV suppliers' and MCM experts' expectations of near-future MCM systems' capabilities. The distance provides a reasonable balance of transit time versus survey time for the vehicles' batteries. The ship is expected to remain within the channel during clearance operations and follow the toolbox at a safe distance.

The ship's anticipated location during MCM operations means that its acoustic, magnetic and electrical signatures should be no worse than a front line surface combatant.

The ship may operate within the confines of the swept channel for several days so must be highly manoeuvrable and capable of holding its position and heading to a high degree of accuracy.

The MCM platform will be the first platform to transit the swept field. Therefore, if there is an undetected mine, it is likely to be the asset which triggers it. With the risk that further undetected mines may be present, the platform needs to have sufficient damaged stability to survive such an incident and the shock capacity for its systems to function sufficiently for it to self-extract itself from the channel and not require another vessel to be placed in danger to effect a tow.

The OA made clear that this ship would need to have the capabilities of a warship; accordingly it should be designed and constructed to a classification society's naval rules set. The ship is designed to satisfy ANEP-77 [5] with munitions safety designed to Def Stan 00-101 [6] standards and underwater signatures satisfying AMP-14 [7]. This rationale aligns with the duty of care Ministries of Defence have to protect their personnel and provide them with equipment appropriate to the threat they are exposed to. Satisfying the Combat Safety Case is particularly pertinent to the UK [8] but other nations are adopting the approach.

The OA showed that while conducting MCM, the platform would often be operating alone and up-threat and probably outside the task group's protective umbrella so will need to have sufficient self-protection against the anticipated threats of low, slow flyers and fast inshore attack craft (FIAC), both manned and drone, in particular. In the littoral environment, the ship may be within range of land-based artillery.

MCM is a key element of an amphibious operation so the ship is expected to deploy as part of a task group and must be able to maintain passage speed. Additionally, navies may find a platform of this type useful for patrol duties so a cruising speed of 15 knots and a top speed of at least 17 knots were deemed the minimum necessary. A minimum range of 3500nm and an endurance of 30 days were specified. These values are typical of a warship this size and enable the platform to sail as part of the task group or deploy unsupported to transit to expeditionary operating locations.

A total complement of at least 60 persons was set initially to enable ship sizing. Subsequent studies were conducted (and continue) to establish both the ship's complement and the MCM component. The MCM crew needs to be sufficient to plan operations, support and sustain the toolbox, and compile and maintain the MCM picture.

2.5 THE NEED FOR A DEDICATED MCM PLATFORM

The Channel Stand-off CONOPS is envisaged to be the maximum realistic level of capability possible for the next few generations of UxV so a mothership for the unmanned systems will be necessary to provide a persistent, offensive MCM capability.

Many are questioning why this needs to be a dedicated MCM platform when MCM systems are becoming more modular? A dedicated platform does not detract from the function of the rest of the fleet.

If the MCM capability is embarked on a frigate or destroyer, platforms which have the necessary survivability, then the ASW/ASuW protection of the task group would be diminished and a high value asset is placed in harm's way. Also, many combatant platforms lack the manoeuvrability and the space to accommodate the systems.

Offshore Patrol Vessels (OPVs) lack the survivability features and hull shape to be a safe and suitable platform for MCM operations and handling large UxVs.

Naval auxiliaries are often too large to be covert and tasking them on MCM would detract from the support role they provide to the wider task group. Naval auxiliaries (and commercial platforms of opportunity, should they be considered) are usually built to commercial standards so lack the inherent capability and the signature controls to be safe for the Channel Standoff CONOPS.

3. THE SOLUTION - THE FUTURE MCM PLATFORM

3.1 PRINCIPAL PLATFORM PARTICULARS

To accommodate the MCM toolbox, the 60 person complement, the ship's systems, stores and tanks, a ship with a waterline length of 85m and a beam of 16.8m is required. The ship's maximum draught was limited to 5.5m to enable it to operate in shallow waters around the entrances of smaller ports and harbours. The ship is arranged with its accommodation and operational spaces forward, leaving the aft half of the ship as a semi-enclosed working area for stowage and support of the MCM toolbox.

The ship will be constructed of mild steel built to naval ship standards, giving an all up displacement of ~3,500 tonnes. Steel was selected as it enables the ship to be built in any indigenous shipyard and does not necessitate the specialist skills and facilities required for composite construction. A steel hull is also significantly cheaper than a similar sized composite platform. It may be possible to construct the superstructure of composite to reduce top-weight, if necessary.

The beam is driven by the breadth of the USVs and the need to be able to service and support them. Achieving naval damage stability requirements also influences the beam.

3.2 HULLFORM

The hull's form was developed to provide a solution which best delivers the numerous requirements placed upon the platform:

- It must provide a stable and low motion platform during MCM operations when station-keeping behind the toolbox and launching and recovering the large USVs. This requirement favours a deeper, heavier, fuller hull.
- The military speed requirement drives toward a finer hull with LCB aft of amidships. However, accommodating the open working deck and AUV garage aft drives the LCG forward.
- Many navies may consider using the platform for a hydrographic role so producing a hullform that generates low self-noise at survey speeds was a primary requirement. Consideration of the bow shape, thruster positions and identifying locations for sensors were key to achieving this.
- The ship must meet naval stability standards.

The ship's open aft end is also a challenge to obtaining sufficient buoyancy to meet the naval damaged stability requirement and is a driver of the main deck height.

The hull was derived from a previous similar design which had been model tested and analysed for seakeeping and manoeuvring performance. The baseline hull was compared with BMT's database of ships with similar parameters to identify improvements to the hull to minimise resistance. A number of options were analysed using FineMarine CFD and changes showing most promise were incorporated into the final hullform. The CFD analysis was also used to examine the streamlines in way of the sensor positions to reduce risk of interference.

3.3 MACHINERY ARCHITECTURE & MECHANICAL SYSTEMS

The ship is provided with a diesel-electric 690V power generation and propulsion architecture which is split equally between two main engine rooms. Each machinery space contains two acoustically mounted and enclosed diesel generators which are connected via the switchboards to acoustically quiet motor/gearboxes. The multiple prime mover solution offers the flexibility required for the variable power demand and the redundancy necessary to meet the survivability requirement.

Depending upon the installed power required, the signature requirement and, potentially, customer preference, the generators may be either high speed or medium speed.

The ancillary and auxiliary pipe systems and their pumps/motors will be sized, specified and arranged to minimise the creation of noise.

The ship shall comply with MARPOL requirements [9]. For emissions and pollution control, this is achieved via the size and distribution of the fuel tanks. A water-ballast treatment plant will be provided to prevent the transfer of invasive waterborne species. For a shock rated vessel, a challenge is identifying an exhaust gas scrubber which is capable of withstanding shock. Most scrubbers use ceramic filters which risk shattering and falling into the engines when shocked. Military spec scrubbers with a bypass or alternative solution must be identified.

3.4 POSITION KEEPING & MOTION CONTROL

A conventional twin shaft and rudder arrangement with lateral tunnel thrusters was selected as the only viable solution for a MCM platform as the system must be shock certified and have low acoustic and electric signatures. Azimuthing thrusters are not typically shock capable and azipods place the electric motors/gearboxes outside the hull which compromise their signatures. The system will probably include controllable pitch propellers to enable rapid direction changes but their shock capacity and noise levels compared to a fixed pitch propeller will be evaluated prior to selection.

A dynamic positioning system equivalent to the DP2 standard would offer the system redundancy necessary for MCM operations of this nature. The ship is likely to be operating in areas with strong tidal currents and must be able to hold against cross winds/wave so is fitted with large tunnel thrusters fore and aft.

A flume-type roll reduction tank is provided beneath the Bridge to reduce the ship's motions whilst stationary and at low speed. Providing a stable, comfortable platform is necessary not just to make launch and recovery of the offboard assets (UxVs, boats and other equipment) easier but also to create an effective environment for the ship's staff to analyse the gathered data, compile the situational picture and plan the mission.

The ballast system will include anti-heel and trim-control tanks to maintain the ship upright and level during launch/recovery of the MCM payload, particularly the laden USVs.

3.5 SURVIVABILITY FEATURES

Mines can be triggered by a number of means; these are typically changes in the water pressure, electrical or anomalies in the earth's magnetic field, by recognising an acoustic profile or by direct contact (e.g. the conventional horned mine). An acoustic signature may activate a mine but, due to sound's ability to propagate through water, it is difficult for the mine to establish the target's location and direction of travel unless there are multiple microphones/hydrophones (which is becoming more common in complex minefields). Magnetic, electrical and pressure signatures provide an easier means to locate the target. Mines normally use more than one type of detection sensor. Typically they are primed by URN signal, and then actuated by the magnetic signature.

A well configured multi-coil 3D degaussing system can reduce a ship's magnetic signature by up to 90% [10] and is considered essential for a MCM platform which will be operating within the cleared channel for extended periods (and depending upon wind, current and interaction with the USVs may be operating up to the channel's edges).

As discussed above, main machinery will be acoustically mounted and ancillaries specified and mounted to minimise noise creation. Systems and connections will be designed and installed to minimise noise creation and avoid noise shorts (e.g. by using flexible couplings and connections).

The ship is expected to operate at a very low speed or be station-keeping when it is in the swept channel which will mean pressure changes caused by the hull will remain low.

Despite the underwater signature reduction measures provided, there remains a possibility that a MCMV will encounter an underwater shock load in its lifetime. The likelihood and load experienced by a Channel Stand-Off MCM should be lower than the legacy systems. The ship structure will be designed to withstand the load specified and the ship's propulsion system is designed with sufficient shock capacity to enable it to self-extract from the threat area following a shock event. Other equipment and systems will be designed to remain captive at least up to the hull lethal shock load. It is anticipated that the ship will have a shock capability equivalent to a frontline surface combatant warship.

The ship's above water signatures will be minimised by a number of means. The ship has a low profile which will reduce its visual signature; its superstructure and mast shall be inclined and dihedral corners avoided wherever possible to reduce its radar cross-section; 'cheese-graters' will be fitted to the main engines' exhausts to reduce the infra-red signature.

In common with most military platforms, the ship is designed with a citadel and HVAC system to offer protection to the personnel in the event it needs to transit a CBRN environment.

Fire protection, fire-fighting and damage control systems and arrangements are designed in accordance with ANEP-77's requirements to provide naval standard protection with which crews shall be familiar and offers protection against the perceived threat to the ship whether it is operating alone up-threat or within the task group. The following assumptions underpin the philosophy adopted for the design of the ship's damage control and protection systems:

- The ship will be operated by a core sailing crew which will be supplemented by different sized mission crews as required for the ship's particular deployment, whether MCM or an alternative role.
- All personnel embarking the ship are assumed to be damage control trained and shall support a damage response as required.
- The level of response to a particular incident shall be a command decision and depend upon the number of personnel available to support the effort.

3.6 EMBARKING THE MCM TOOLBOX

Unmanned technologies are evolving fast so the ship (which is designed for a life of at least 25 years) is expected to embark several generations of the MCM toolbox over its lifetime. Hence, it is fundamental that the ship's design is able to readily accommodate these different solutions without incurring significant cost or impact to its availability.

To achieve this flexibility, an approach was adopted similar to that used by the offshore sector where the ships are adapted frequently to embark and deploy different project payloads. This approach was helped by most navies' assumption that MCM is moving towards a modular solution that enables the capability to be transported by air and road and deployed from shore as well as the MCMVs. The solution is ensuring that sufficient space with ready over-side access and the means to embark, support, deploy and recover the different toolbox components is provided.

A large open working deck would provide the best solution for the surface and underwater vehicles in terms of space, flexibility, crane access and water access. However, enclosing the deck to form a garage is highly desirable for operational reasons: it provides a protected, illuminated and discrete environment to maintain, support and re-role the vehicles. The space is served with overhead cranes to enable movement of the AUVs, USV payloads and vehicle spares. The space is adjacent to the MIDS magazine to facilitate easy movement of the armed MIDS vehicles to the USVs or point of launch (in the event the system can be deployed from the ship). Several other features which must be adjacent to the garage include: workshops, battery charging facilities, spares and consumables storage, and storage for the USVs' payload modules. The MCM capability will continue to include clearance divers for the foreseeable future to support the identification and recovery or disposal of unfamiliar munitions or munitions which the UUVs are unable to reach. Therefore, the mission space needs to include or embark the divers' facilities. A crane is provided to support deployment/recovery of the sweep system components towed by the USVs and can also be used to embark the mission containers when alongside.

The larger, long range AUVs may be deployed directly from the ship and it is intended that a dedicated, gantry-type launch and recovery system (LARS) is provided adjacent to their stowed positions. Alternatively, the AUVs may be deployed and recovered via the ship's crane.

Determining whether the solution for the USV LARS should be davits or a stern ramp was the subject of much debate. A davit solution was selected for the following reasons:

- A stern ramp removes significant buoyancy from a critical position in the ship;
- A stern ramp requires the ship to be on a specific heading relative to the wind/waves/current and is easier if the ship is making way. This may be hard to achieve within the confines of the swept channel [11].
- Keeping the USVs at the stern of the ship reduces crane access for re-roling and servicing the craft. Also, a hoist system would be required to bring the USVs level to make re-roling and servicing easier;
- A single stern ramp is a single point of failure preventing deployment/recovery of the USVs and potentially, jeopardising the mission. Accommodating two adjacent ramps in the MCMV's transom is difficult – an off-centre ramp will have a reduced operating window in large waves; integrating the ship's steering gear is difficult; more buoyancy is lost from the ship's stern;
- If the ramp is shared by numerous USVs then the USVs must be moved forward of the ramp to enable others to use it, having the effect that greater ship length is required for the same capability as davits;
- The need to immerse a ship's transom to accommodate a stern ramp results in a much less efficient hull form resulting in higher fuel usage and associated operating cost.

A davit based solution is not without its challenges. The USVs are large and heavy and sufficient structure must be provided to support them. In order that there is redundancy in the davit solution, a boat handling system is needed to move the USVs between the davits.

A challenge to both systems is recovery of the unmanned vehicles. It is undesirable, from a safety perspective to put a man in the loop (i.e. on board the USV) to effect its recovery. Capture systems for USVs are becoming more common but connection of the davit hooks to the USV lifting points needs development and is an area both davit and USV OEMs are investing effort. The USV's aft davit point may interfere with its aft working deck and the payload modules must accommodate this. A major challenge facing stern ramp solutions is hitting the quiescent period of both vessels' relative motions to recover the USV at the right attitude and without causing damage.

The UAVs are provided with a hangar with direct access to the flight deck. Up to 3 UAVs may need to be embarked to support 24 hour working depending upon how they are used and what alternative solutions for communications between the ship and USVs are achieved. The flight deck may also serve as a VERTREP position for manned aircraft.

3.7 OPERATIONAL SPACES

The MCMV will be "fought from the Bridge". As is increasingly common on lean manned, minor warships, the Bridge is the centre for situational awareness. Greater automation of warships' engineering and combat systems and their links to ship's IPMS and CMS allows fewer people to be concentrated on the Bridge and still provided with the full situational picture.

Central to ensuring command effectiveness for the MCM mission is the link between the Bridge and the MCM mission planning and direction. Therefore, a Command Information Centre (CIC) is provided immediately aft of the Bridge. The CIC will contain a number of consoles for MCM mission planning, control of the unmanned vehicles, operation of the ship's guns, control of the ship's machinery and systems, external communications.

Near to the CIC will be a separate, quieter space where the data returned from the UxVs shall be analysed and the MCM picture is compiled.

The intention is that the mission consoles/systems in the CIC and analysis/compilation spaces and the various associated servers shall be modular enabling them to be reconfigured or replaced if the ship is required to fulfil alternative, non-MCM roles. The modular approach also makes them readily upgradeable as technology advances.

3.8 ACCOMMODATON SPACES

A flexible accommodation solution shall be necessary to accommodate the variable crew numbers and compositions which will be embarked for different missions. Some MCM missions shall be more personnel-heavy than others and non-MCM duties will require a different composition again. Also, the unknown ratio of male/female staff must be accommodated efficiently.

The accommodation comprises a mix of single, twin and four berth cabins to a high, modern, naval standard. The standard can be relaxed if higher occupancy cabins are desired by a particular client. As is necessary on a MCMV, all the accommodation is located above the waterline.

To meet the flexibility need, the berthing accommodation is designed for regions to be shut down if they are not required. A single galley and dining hall is the easiest to support with a small catering staff and allows a small crew to come together socially. Separate recreation rooms are provided for each rank/rate as experience has shown that crew and officers do prefer some separation even on a lightly manned ship [12].

3.9 COMBAT SYSTEMS & COMMUNICATIONS

The weapons, sensors and combat management system fitted to the platform will depend upon the customer's requirement based upon the threat he foresees the ship being exposed to and how it shall be operated. The design can therefore accept a range of defence systems from small local, point-defence weapons up to a 57mm gun integrated with an all-weather fire control director.

The ship is expected to need a surveillance radar capable of maintaining an operational picture of the unmanned assets and this would also allow detection of incoming threats.

The communications fit would also be subject to customer preference and space is made available on the bridge top and mast for a variety of antennae. Space within the ship and margins in the systems are provided to accommodate the necessary equipment.

Key to the platform's success as a next generation MCMV is a system which links the unmanned systems and the ship's combat management system. For this reason, the platform is assumed to be equipped with an intelligent infrastructure technology which would allow a small number of personnel to plan and execute a mission in a dynamic operational environment, employing a large number of unmanned vehicles and deployed sensors from any equipment supplier. Such a system would enable co-ordination of concurrent operations spread over a wide area. A system of this type would allow control of different vehicle types from different manufacturers through a single, common interface and compilation and presentation of the MCM situation in concert with the wider operational, combat picture. The system should be able to integrate fully with the rest of the task group to assist creation of a comprehensive situational picture.

An equipment agnostic, open architecture system simplifies integration activities when new applications are added to the mission system and reduces the maintenance burden and logistics chain by reducing the variety of mission system hardware components on board the platform. A system incorporating international military standards for all information exchanges would ease international interoperability too.

4. ALTERNATIVE NON-MCM ROLES

A small, capable, low signature and highly manoeuvrable platform with good situational awareness facilities and adaptable mission spaces and systems is likely to be highly attractive to navies for a variety of roles.

The platform's inherent survivability features allows it to be deployed safely into a higher threat environment than an OPV can be.

4.1 HYDROGRAPHIC SURVEY

Many of the ship's inherent features and the MCM tools embarked enable it to support up-threat rapid environmental assessments (REA) ahead of other vessels' passage. For this reason the platform can be fitted with a multi-beam echo-sounder in addition to the mine/obstacle avoidance sonar.

The open aft working deck lends itself to fitting an A-frame on the transom and stowing towed systems.

The USVs may be replaced or reconfigured to fulfil the role of manned or autonomous survey motor boats.

4.2 MARITIME SECURITY & INTERNATIONAL ENGAGEMENT

The ship suits the requirements of a patrol and constabulary role. The UAVs and USVs can enhance the platform's situational awareness. The ship is provided with two 7.5m RHIBs to support low threat interdiction operations. The USVs may be replaced with specialist interdiction craft to enhance the capability.

The mission space may be used to embark Humanitarian Assistance and Disaster Relief (HADR) modules or provide shelter to rescued/evacuated civilians.

4.3 ANTI-SUBMARINE WARFARE (ASW) SUPPORT

The ship's controlled signatures and space to embark a variable depth towed array sonar suite enables it to deploy as an effective ASW surveillance capability. The platform would not have the full capability of an ASW frigate but can bolster monitoring and deterrence in a nation's home waters allowing the high-value specialist frigates to deploy on more demanding operations. Deployment of thin-line towed array sensors from the USVs could augment the surveillance picture.

5. CONCLUSIONS

The adoption of autonomous systems for mine countermeasures is causing a revolution in the approach to mine warfare. While autonomous systems offer the opportunity to remove the man from the minefield during MCM operations; the systems are not yet capable of delivering a persistent, offensive MCM capability.

BMT's research showed that for the next few generations of UxV, a dedicated, capable MCMV shall be required to act as a mothership to the unmanned systems. This new platform shall be very different to the legacy MCM fleet to allow it to embark and safely deploy the UxV-based toolkit of underwater, surface and air vehicles.

The expected Channel Stand-Off CONOPS will require a highly manoeuvrable, signature-controlled platform to follow the deployed UxVs of the MCM toolbox into the swept channel. OA conducted by BMT showed that the platform and its assets shall have the capability of two legacy MCMVs. However, the lower mine threat which the platform will be exposed to will enable it to be constructed of steel. A steel hull is significantly cheaper than a composite platform of similar size and does not require the rare and specialised facilities of composite construction. Hence, the platform may be built indigenously by prospective nations.

To remain useful over its lifetime, the platform must be readily adaptable to accept each new generation of the MCM toolbox, whether this is a change of the vehicles or the systems and sensors which will control them. The platform's size, capability and adaptability will make it a versatile asset in a navy's fleet able to fulfil numerous alternative military roles.

Several challenges still exist to delivering the Channel Stand-Off CONOPS successfully, including data transfer between the UxVs and the ship and recovery of the USVs, but the vehicle and equipment suppliers are working to deliver solutions. These are not envisaged to be major challengers to the need for a platform or to its design.

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7. DISCLAIMER

The opinions expressed in this paper are those of the author and do not necessarily represent BMT.

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