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From the Sea and Beyond

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Multi-Domain Operations

- Australia's Submarine Surprise
- USS CONSTELLATION (FFG-62)
- Interview with Chief of Royal Swedish Navy

MITTLER REPORT

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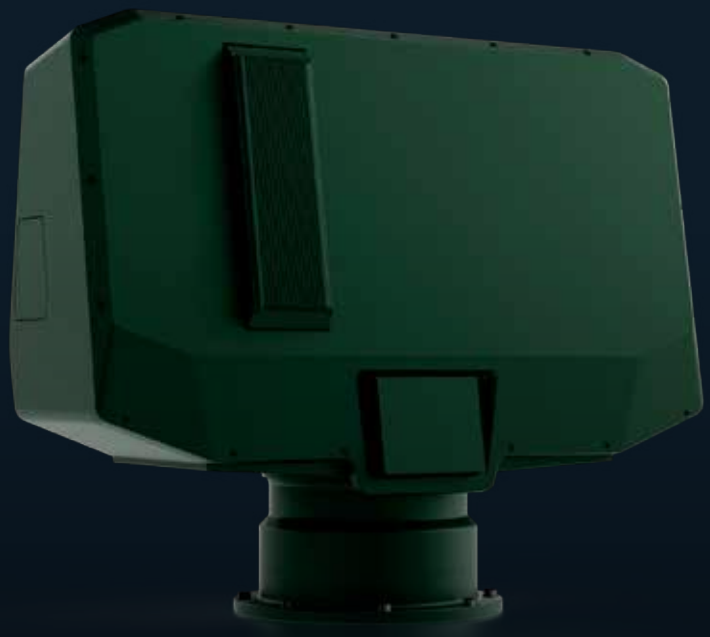

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Holding a Steady Course

Remember World Maritime Day? I would not be surprised if you do not recall 30 September. You might have been distracted by Mark Zuckerberg's announcement that Facebook was going to change its name to Meta. It had far more impact on the public consciousness than the IMO`s initiative to promote the core role of seafarers in shipping and its future.

As Maritime Security and Defence enters its second year of existence, we, the crew on the bridge, are more convinced than ever that we must give maritime security and defence a voice. Shipping's critical role in keeping our global supply chains running has never been more evident as the world struggles to emerge from the depths of the COVID-19 pandemic. The blockage of the Suez Canal – one of the planet's most important trade arteries – earlier this year certainly demonstrated the consequences when things go wrong.

Turning to the sharp edge of maritime defence, great power competition is on everybody's lips. The pressure increases, for example in the Pacific and across the Baltic out into the Atlantic.

Meanwhile, climate change has stealthily established itself as the greatest threat to the world's overall security. The maritime response needs to be complex and multi-faceted. From a technological perspective, the boundaries of know-how are being steadily pushed forward to enhance ship efficiency and environmental performance.

These are just three important examples of often intertwined factors and trends that illustrate the ongoing importance of the maritime dimension to the future of mankind. Your command team is convinced that greater situational awareness of the nautical environment is essential. We remain dedicated to promoting a 'maritime mindedness', with the objective of providing the information and analysis required to secure a better understanding of the maritime and naval environment.

Furthermore, I would like to inform you that we will change the magazine's name. We had launched it as part of the European Security & Defence family. We later got an argument with an institution and have now decided to change the name. Anyhow, nothing will be changed apart from the name. I trust that with this move we keep everybody happy.

Last but not least, I would like to thank all of our readers, advertising clients and partners for their great support in 2021.

Wishing you and your families a merry Christmas and a happy and healthy year 2022,

Yours,

Peter Tamm

Peter Tamm, Owner,
President & CEO Tamm Media

Photo: author

Hans Uwe Mergener
Editor-in-Chief

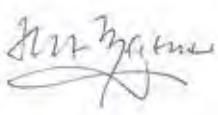

Photo: author

Conrad Waters
Editor-in-Chief

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Cover photo: ATLAS ELEKTRONIK GmbH

EUROPE

GREECE: Naval Group Selected for Surface Fleet Renewal

(cw) On 28 September 2021, Nikólaos Panayotópoulos, the Greek Minister of Defence, and Naval Group CEO Pierre Éric Pommellet signed a memorandum of understanding to commence negotiations on the supply of three "BELH@RRA" Frégates de Défense et d'Intervention (FDI) for the Hellenic Navy. The agreement, which encompasses an option for a fourth vessel, was won against stiff competition from other European and US-based companies, providing timely good news for the French shipbuilding group following Australia's decision to terminate the ATTACK class submarine programme earlier in the month (see Peter Layton's article in this edition of MSD). The Hellenic Navy's frigates will all be built at Naval Group's shipyard in Lorient, which is already allocated construction of five of the class for the French Navy. The second of these – AMIRAL LOUZEAU – has just entered production.

Photo: Naval Group

The Naval Group BELH@RRA design has been selected for the Hellenic Navy's new frigate requirement.

MSD Editorial Commentary: The selection of the FDI for the Hellenic Navy forms a central plank in a programme of Greek naval modernisation announced in September 2020 that was also expected to encompass modernisation of the fleet's four MEKO 200HN HYDRA class frigates and the acquisition of an interim (second-hand) surface combatant capability pending arrival of the new frigates. It was initially anticipated that the revitalisation of Greece's shipbuilding capabilities would form a key criteria in the selection of the winning bid and it is therefore somewhat surprising that all the new FDIs will be built in France. Moreover, no interim capability of HYDRA class modernisation has been mentioned in the recent agreement.

France has, however, become an increasingly important defence partner for Greece in recent years – a letter of intent to acquire the "BELH@RRA" design was previously signed in 2019 – and it seems that this political aspect has had an important role in the new agreement. This was reflected by the announcement of a new strategic defence partnership between the two countries by the two countries' leaders at the time the FDI's selection was revealed. It may well be that this partnership will eventually extend to meeting Greece's industrial modernisation requirements, possibly under the auspices of the European Patrol Corvette (EPC) initiative. Meanwhile, it has subsequently emerged that Greece has signed a letter of intent to acquire second-hand Dutch 'M' class frigates (along with TRIPARTITE minehunters), thereby meeting the interim need.

ESTONIA: BLUE SPEAR Missiles for Coastal Defence

(jh) The Estonian Centre for Defence Investment (ECDI) has announced that it has reached an agreement to develop Estonian coastal defence capabilities by arming its defence forces with the BLUE SPEAR (5G SSM) land-to-sea missile system. Following a tender process, Proteus Advanced Systems Pte. Ltd. – a joint venture between Israel Aerospace Industries Ltd (IAI) and Singapore Technologies Engineering - has been selected to provide the Estonian Defence Forces with the system. The project, with tight timescales and encompassing a complex set of requirements, is one of the biggest projects in Estonian defence procurement according to ECDI.

Photo: Israel Aerospace Industries

The BLUE SPEAR surface-to-surface missile will enhance Estonia's coastal defence capabilities.

The BLUE SPEAR missile system is a precision weapon which can operate in all weather conditions, day and night, enabling strike capabilities beyond the line of sight and against mobile and stationary targets at sea. The missile's maximum range is 290km. BLUE SPEAR missiles share a heritage with IAI's GABRIEL missile family system which was developed over many years.

FRANCE: Progress with FLOTLOG Programme

(cw) Tangible progress is now being seen with the French Navy's FLOTLOG (Flotte Logistique) programme, which encompasses the construction of four JACQUES CHEVALLIER class logistic support ships to Fincantri-

Photo: Fincantieri

The bow of JACQUES CHEVALLIER waiting departure from between Fincantieri's Castellamare di Stabia shipyard.

eri's VULCANO class design. Fabrication of the vessels is being split between Fincantieri's Castellamare di Stabia shipyard in the Bay of Naples and the Chantiers de l'Atlantique at Saint Nazaire; the latter being responsible for integration of the constituent parts in conjunction with France's Naval Group. On 6 November 2021, Fincantieri announced that it had delivered the bow selection of the lead ship, which will now be transported to France to be joined to the rest of the vessel. It was initially envisaged that the four ships would be delivered between 2022 and 2029 but arrival of the lead unit may be adjusted due to the impact of the pandemic.

GERMANY: NVL (Naval Vessels Lürssen) Launched

(lh) Bremen-based Lürssen has implemented a major reorganisation of its business, consolidating all its naval shipbuilding activities under the umbrella of the independent NVL Group with effect from 1 October 2021. NVL (Naval Vessels Lürssen) will henceforth be responsible for all Lürssen's naval operations, with Fr. Lürssen Werft remaining as the umbrella company of the yacht division. Both divisions and all associated companies will remain part of the Lürssen Group, which will continue to be family-run.

The new holding company of the NVL Group – based in Bremen-Vegesack – is managed jointly by Klaus Borgschulte and Tim Wagner as spokespersons, alongside Dirk Malgowski and Lena Ströbele as managing directors. The group includes newbuilding sites at Peene-Werft in Wolgast and Blohm & Voss in Hamburg; repair yards Neue Jadewerft in Wilhelmshaven and Norderwerft in Hamburg; the service activities of Lürssen Logistics; as well as international operations in Australia, Bulgaria and Brunei. The split reflects the growing complexity and increasingly heterogeneous nature of the group's defence and yacht markets and a consequent desire to optimise the group's competencies and infrastructure.

UNITED KINGDOM: Fabrication Starts on Type 31 Frigates

(cw) On 23 September 2021, an event was held at Babcock's Rosyth facility near Edinburgh to mark the first steel cutting for VENTURER, the first of the Royal Navy's new Type 31 or INSPIRATION frigate class. The symbolic event was conducted at Babcock's new advanced manufacturing facility, a cornerstone of the company's digital transformation at Rosyth, which includes panel lines with robotic welding capability, as well as other semi-automated manufacturing machines. Assembly will take place in a new 147m x 62m x 42m shipbuilding hall – named "The Venturer Building" – that is capable of housing two Type 31 frigates for parallel build and assembly. The new infrastructure forms part of a GBP60M investment programme on the site, on top of a further GBP100M that has already been invested over the last decade

Photo: Babcock International

Dignitaries attend the first steel cutting ceremony for the lead Type 31 frigate VENTURER. The new ship hall where assembly will take place can be seen in the background.

The start of work on VENTURER came just a week after Babcock announced that it had secured the first export contract for its ARROWHEAD 140 frigate design (the export variant of the Type 31) through a design licence agreement with PT PAL of Indonesia encompassing the local construction of two frigates. Babcock is also one of three companies shortlisted to provide a design solution for Poland's MIECZNIK (SWORDFISH) frigate programme.

THE AMERICAS

UNITED STATES: Submarine CONNECTICUT (SSN-22) Damaged in Underwater Collision

(cw) On 2 October 2021 the US Navy's SEAWOLF (SSN-21) class submarine CONNECTICUT (SSN-22) suffered an underwater collision with an unchartered sea mount in the course of operations in the South China Sea. Eleven sailors were injured in the accident but the submarine's nuclear powered-propulsion plant was reported as being undamaged, with the boat subsequently making the US Navy facility at Guam under her own steam. A subsequent assessment saw CONNECTICUT's Commanding Officer, Executive Officer and Chief of the Boat relieved of their positions due to "loss of confidence". The US Navy has been tight lipped over the precise extent and nature of the damage that has been caused by the incident.

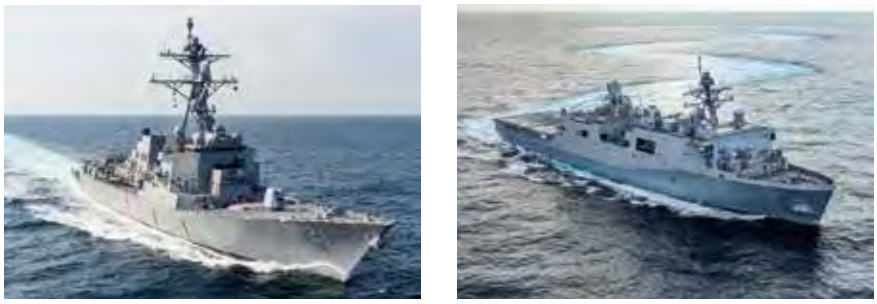
MSD Editorial Commentary: The mishap suffered by CONNECTICUT (SSN-22) is the latest of a series of incidents to afflict the US Navy and could prove particularly problematic for a number of reasons. In addition to providing bespoke capabilities unmatched by the later VIRGINIA (SSN-774) class, the three complex and expensive SEAWOLF class boats form a unique design that could make CONNECTICUT's repair a difficult and costly exercise at a time when overall submarine numbers are under pressure. Moreover, the collision has inevitably resulted in renewed scrutiny of operating practices after previous incidents impacting US Navy destroyers and the destruction of the amphibious assault ship BONHOMME RICHARD (LHD-6) by what is now believed to be arson. Finally, the accident has been seen as something of a propaganda coup by China, which has – perhaps unsurprisingly – being pressing for further details of the nature of an incident that might well have taken place in waters that it calls its own.

Photos: IUS Navy

CONNECTICUT (SSN-22) – pictured here in July 2021 at the Yokosuka naval facility – has been damaged in an underwater collision.

UNITED STATES: Busy Months at Huntington Ingalls Industries

(cw) The autumn has proved to be a busy period for Huntington Ingalls Industries' Ingalls Shipbuilding Division. Completion of acceptance trials of the ARLEIGH BURKE (DDG-51) class destroyer FRANK E. PETERSEN JR. (DDG-121) in September was swiftly followed by the start of a first round of (builder's) trials for the SAN ANTONIO (LPD-17) class amphibious transport dock FORT LAUDERDALE (LPD-28) the following month. Along with her sister RICHARD M. McCOOL JR. (LPD-29), the new amphibious assault ship is a transitional design incorporating a number of cost-saving modifications (including a revised bow design and replacement of composite masts with more traditional steel structures). These are intended to pave the way for the new Flight II variant of the class that will ultimately replace the US Navy's legacy dock landing ships.



PhotosHuntington Ingalls Industries

Huntington Ingalls Industries' Ingalls Shipbuilding Division has recently completed acceptance trials of the destroyer FRANK E. PETERSEN JR. (DDG-121) and builder's trials of the amphibious transport dock FORT LAUDERDALE (LPD-28).

Meanwhile, Huntington Ingalls Industries' main US rival in major surface warship construction – General Dynamics Bath Iron Works – has also been fully occupied, conducting builder's trials of the third and final ZUMWALT (DDG-1000) class destroyer LYNDON B, JOHNSON (DDG-1002) over the course of the summer.

ASIA-PACIFIC

INDIA: Lead Project 15B Class Destroyer Completed

(cw) The commencement of sea trials for the Indian Navy's first indigenous aircraft carrier VIKRANT in August 2021 has now been followed by the delivery of the lead Project 15B destroyer, VISAKHAPATNAM, marking an apparent acceleration of the country's often ponderous naval modernisation plans. The c. 8,000 tonne ship was handed over by builders Mazagon Dock Limited (MDL) on 28 October 2021 and is expected to be formally inducted into the fleet before the end of the year. Three other members of the class are at various stages of construction by MDL under a project first approved in 2011, with deliveries currently expected to be completed around the middle of the current decade.

Photo: Indian Navy

The lead Indian Navy Project 15B class destroyer VISAKHAPATNAM in the course of sea trials.

MSD Editorial Commentary: The quartet of Project 15B VISAKHAPATMAN class destroyers are derived from the earlier trio of Project 15A KOLKOTA class destroyers that were delivered by MDL between 2014 and 2016. This new batch utilises the same hull and much of the armament and sensor suite of the earlier ships whilst incorporating a significant number of incremental improvements. The lead ship was laid down in October 2013, with her construction period of eight years a material improvement over the eleven years required to complete the first Project 15A and the ten to ten and a half years taken by subsequent members of the KOLKOTA class. Whilst this suggests investments made in modernising MDL's shipyard facilities have brought some positive benefits, completion times remain far in excess of those required for the Indian ships' nearest Chinese rival, the c. 7,500 tonne Type 052D LUYANG III destroyer.

AFRICA & THE MIDDLE EAST

QATAR: Corvette AL ZUBARAH Delivered by Fincantieri

(cw) Another milestone in Qatar's ambitious naval modernisation programme has been passed with Fincantieri's delivery of the lead AL ZUBARAH class air defence "corvette" from their Muggiano shipyard near La Spezia at the end of October 2021. The first of four ships, AL ZUBARAH has been designed in accordance with the RINAMIL regulations and is intended to be capable of multi-role frontline and constabulary operations in addition to her primary air defence role. Effectively a frigate-sized vessel with a length of 107 metres and a beam of 14.7 metres, she is equipped with a Combined Diesel and Diesel (CODAD) propulsion system capable of achieving a maximum speed of 28 knots.

MSD Editorial Commentary: The four c. 3,250 tonne AL ZUBARAH class corvettes form the centrepiece of a huge naval acquisition contract for the Qatari Emiri Navy that was agreed with Fincantieri in June 2016. In addition to the corvettes, the seven ship deal also encompasses an amphibious transport dock and two small but heavily armed "offshore patrol vessels". Owing much to tensions within the Arab world, the procurement represents a massive step for Qatar's military that might prove difficult to sustain in practice in spite of substantial investment in supporting infrastructure and training. The latter has included the purchase of two specialised training ships from Turkey's Anadolu (ADIK) shipyard, the lead of which was delivered in August 2021.

Photo: Fincantieri

The lead AL ZUBARAH class corvette was delivered at Fincantieri's Muggiano facility on 28 October 2021.

EGYPT: "New" Logistic Support Ships

(cw) Another piece in the jigsaw of Egypt's remarkable scheme of naval expansion fell into place in late October 2021 when it was announced the Egyptian Navy had acquired two former Royal Fleet Auxiliary solid support vessels in what was said to be the first sale of British naval ships to the country in over thirty years. The vessels concerned – FORT AUSTIN and FORT ROSALIE – can hardly be said to be in the first flush of youth, having been first delivered as long ago as 1978 and 1979. Withdrawn from the British inventory as a result of the recent Integrated Review, it was originally intended to sell them for scrap before negotiations with Egypt commenced. A significant amount of work will be required to bring them into operational condition, with Merseyside-based Cammell Laird reported to be negotiating the necessary contract. Whilst elderly units with no refuelling capabilities, the two units should allow the Egyptian fleet to gain useful experience performing replenishment at sea capabilities as it attempts to expand its operational reach.

Photo: Crown Copyright

The veteran British solid support ship FORT AUSTIN – as well as her sister FORT ROSALIE – has been sold for further service with the Egyptian Navy.

FRANCE (Naval Group): Anne Quillon Appointed Procurement Director

Photo: Naval Group

Anne Quillon

(jh) Naval Group has announced the appointment of Anne Quillon as Director of Procurement, Sourcing and Supplier Management within the Operations and Performance Department of company. She will manage all of Naval Group's resources in the area of purchasing and will define the group's "responsible purchasing" policy and manage its performance. She will also support the group's subsidiaries. Anne Quillon is 45 years old and joined Naval Group on 8 October 2021. She holds a degree in political science and a master's degree in purchasing and supply chain management. She has previously held several purchasing and supply chain positions at Safran, Alstom Power and GE Renewable Energy.

Vice Chairman of United Kingdom (Royal Navy): First Sea Lord to Become Chief of the Defence Staff

(cw) On 7 October 2021, Her Majesty the Queen approved the appointment of Admiral Sir Tony Radakin KCB ADC to take over from General Sir Nicholas Carter GCB CBE DSO ADC Gen as the next British Chief of the Defence Staff. Admiral Radakin will assume his new role on 30 November, becoming the first Royal Navy officer to hold the top position since Admiral Sir Michael Boyce retired from the role in 2003. First commissioned in 1990 and currently First Sea Lord and Chief of Naval Staff, Admiral Radakin has earned positive publicity for improving the Royal Navy's operational ability whilst cutting a "top heavy" naval establishment. He will himself be replaced by Vice Admiral Sir Ben Key KCB CBE, the present Commander of Joint Operations, in the Chief of Naval Staff role.

Photo: Crown Copyright 2021

The First Sea Lord and Chief of Naval Staff, Admiral Sir Tony Radakin CB ADC will be Britain's next Chief of the Defence Staff

Australia's Nuclear Submarine Surprise

Dr. Peter Layton

In September 2021, Australia's Prime Minster startled almost everyone by declaring the replacement submarine for the nation's COLLINS class boats would now be nuclear powered. The United States and United Kingdom had just agreed to share nuclear propulsion technology with Australia to allow eight nuclear-powered submarines to be acquired. Moreover, these would be built in Australia with the first boat delivered by 2040.

This decision had immediate consequences. Contracts with France's Naval Group and the United States' Lockheed Martin for developing a large new conventional submarine, the ATTACK class, would now not proceed. Instead, a contract break point would be exercised even though overall sunk costs would be considerable. A new technology sharing arrangement dubbed AUKUS (Australia, the UK and US) was to be established, with its first task an 18 month feasibility study to examine Australia "becoming a responsible and reliable steward" of nuclear technology. Moreover, given all this, the COLLINS class boats would now be life-of-type extended by more than ten years; well past their design life.

These latest developments in the long-running saga of replacing Australia's COLLINS fleet appeared extraordinary. However, in many ways they were also simply a product of a combination of long-standing strategic decisions made a decade ago interacting with emerging technologies. The implications of all this though are significant, with both positive and negative aspects for the Royal Australian Navy and for defence industry.

The Long Tail of Strategic Decisions

A key decision taken over a decade ago has shaped Australia's new submarine ambitions. This determined the new submarines should be able to operate into the South China Sea from their home port near Perth, a distance of some 6,500 km. For a conventional submarine this is a long way and has significant design implications. A related issue is weapon loadouts, as submarines have to return to home port to rearm if their weapons are fired while on patrol. A submarine with a long transit to its patrol area must carry a sizeable weapons load to be operationally useful. Meeting both these factors requires a large submarine. Unsurprisingly, the cancelled French ATTACK class boat was to be amongst the world's largest conventionally-powered submarine at some 4,500 tonnes (surfaced). In contrast, the COLLINS displaces some 3,000 tonnes.

The smaller 2,000 ton OBERON class submarines in-service before the COLLINS class had a much shorter range and endurance. To operate in the South China Sea, they needed to replenish at a closer port such as Darwin, Singapore or Guam. Once the decision was taken

Photo: Australian Department of Defence

Australian COLLINS class submarines on manoeuvres. The Australian government has exercised a radical change of course on its replacement for the class.

Photo: Naval Group

A graphic of the SHORTFIN BARRACUDA design that formed the basis for the now cancelled ATTACK class. The submarines would have been amongst the largest conventionally-powered submarines in the world.

Author

Dr. Peter Layton is a Visiting Fellow, Griffith Asia Institute, and a RUSI Associate fellow. He has extensive defence experience and writes frequently on geostrategic matters, force structure issues and emerging technologies.

Photo: Australian Department of Defence

Chinese PLAN submarines at sea. Developments in Chinese submarine production have exercised a significant influence on Australia's decision to build its own nuclear-powered force.

on the patrol area location and, crucially, that an intermediate replenishment stop was not acceptable, the size of the submarine and, thus, its cost was effectively decided. Given this, the costs of the ATTACK boat fleet came to appear comparable to that of a small nuclear-powered submarine (SSN) fleet.

These decisions also meant that, when comparing a conventional boat doing such missions, a nuclear-powered, general purpose attack submarine looked much more effective. SSNs have much faster transit speeds, especially when sailing in uncontested waters. For example, in the South China Sea case a large conventional boat like an ATTACK class may take some 25 days to transit there and then 25 days to return, allowing some 30 days on patrol. However, for an SSN, total transit times might reduce to 20 days from 50, allowing 60-80 days on patrol. The SSN's patrol time is essentially limited by the crew's endurance rather than by fuel usage.

SSNs are also more survivable in contested waters as they do not have batteries that need regularly recharging from onboard diesel engines. An SSN does not snort like a conventional boat, that is raise a mast to the surface to gain fresh air for the diesels to run and so possibly reveal itself to hostile anti-submarine forces. In addition, SSNs also cruise deeper as the propulsion plant and propellor combination is more efficient when in denser, deeper waters.

In choosing the distant South China Sea scenario, it seems most likely that patrol operations would be contested by People Liberation Army Navy (PLAN) units rather than by any ASEAN or other East Asian navy. Accordingly, a new submarine would be competing against modern Chinese boats and be benchmarked against those.

Today, the PLAN operates mainly conventional submarines. However, after a slow start, the PLAN is now rapidly building up its SSN force and has in the last few years expanded its SSN construction facility to be the world's largest. The Bohai shipyard tasked with building these boats appears potentially able to build up to five nuclear boats simultaneously. The PLAN is currently believed to have around six JIN class strategic submarines (SSBNs) and six SHANG class SSNs in operational service. By 2030, US Government sources expect another two SSBNs and six SSNs to enter service, while the conventional submarine fleet will plateau at its current circa 55 boats.

In South China Sea operations, the PLAN's conventional boats might stay close to shore in shallow water with the SSNs operating further out. In this, the South China Sea is almost an inland sea being bounded by several ASEAN nations and China. To the west and north, it covers a continental shelf and is shallow, while to the south and east it is very deep, with the China Sea Basin averaging 4,000 m depth. In comparison to the Mediterranean Sea, the South China Sea has a similar overall average depth (1,500 metres versus 1,200 metres respectively) but is about 30 percent larger (by a million km²).

For the majority of the Cold War, anti-submarine warfare involved passive acoustic detection technology but this was changing as it ended. The last Soviet-built SSNs were as quiet as the best Western SSNs, making passive sound detection systems ineffective. Each side's SSNs could not find the others. Today's Chinese SSNs are still noisy but it is estimated that they will be nearing Soviet sound levels over the next decade. Finding them passively will become hard.

Photo: Australian Department of Defence

An Australian P-8A maritime patrol aircraft. Improved ASW technology has made the acquisition of SSNs more attractive for the Royal Australian Navy.

The Pull of the Future

The cancelled ATTACK class and the proposed Australian SSNs both have the same problem in needing long lead-times to construct. Both are also long-life ves-

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Photo: Australian Department of Defence

Existing COLLINS class submarines will have to stay in service much longer than previously planned as a result of Australia's decision to acquire nuclear-powered submarines. HMAS RANKIN is likely to stay in service until the late 2040s under these plans.

sels. In broad terms, the ATTACK Class was envisaged being in service from around 2040 to beyond 2080. The new SSNs fleet's operational life seems likely to be from 2045 to almost 2090. These boats are not for today, or even tomorrow, but much later.

In Australian eyes, the ATTACK was an evolutionary improvement on the COLLINS class, being mainly larger and with longer range and endurance. By comparison, SSNs appear revolutionary. That leap might be a necessity as many of today's cutting-edge technologies will be commonplace in two decades time, with worrying new ones on the horizon.

Today's anti-submarine technology has moved from passive sensors to wide-area active detection systems. For example, anti-submarine warfare aircraft like the P-8 POSEIDON drop a field of Multi-static Active Coherent (MAC) sonobuoys in the general area a submarine might be. The field features distributed transmitters and receivers; the former send out active sound pulses that bounce off the hulls of nearby submarines to be detected by the remote receivers. These advances are starting to favour the anti-submarine warfare forces, placing conventional boats at increasing risk. Active detection might accurately locate a submarine within a sonobuoy field, making quickly getting out of this field crucial to survival. SSNs would be much better at such defensive manoeuvres, and could better exploit the water column's vertical dimension to assist breaking active tracking.

More exotically, Unmanned Underwater Vessels (UUVs) are emerging and being adopted by several navies. These combine commercially developed artificial intelligence with robotics. In time, submarines are expected to begin launching and controlling large and small UUVs. This is important for anti-submarine warfare for, as already noted, passive sensors are less useful when adversaries have very quiet boats. In the future, widely-distributed UUVs may act as transmitters and crewed submarines as receivers, allowing the use of multi-static active detection techniques when hunting hostile boats. In earlier times, the use by a submarine of an active sonar was unthinkable, as it simply acted as a beacon. However, if remotely deployed UUVs are used as a noise sources, this worry goes away.

Moreover, the role of crewed submarines in close-to-shore reconnaissance or surveillance missions to monitor the movement of adversary warships and submarines may be taken over by UUVs. Such semi-expendable craft could be hazarded as needed, getting much closer into sensitive areas and staying there longer than by comparison with a large crewed vessel. Such ideas again favour SSNs as they have the size to carry, deploy and use multiple – perhaps numerous – UUVs when on patrol.

The end result is that submarine operational concepts are evolving. Tomorrow's submarines are likely to abandon littoral waters to the UUVs and head to deeper water. Submarines will become 'motherships' managing their own and other friendly-force UUVs but will also need to defend themselves against the multiplying UUV threat. Although this may sound to be in the realms of science fiction, it reflects current official thinking on the new SSN(X) that will start replacing the US Navy's VIRGINIA (SSN-774) class boats around the mid-2030s.

Moreover, at the strategic level and with great power competition intensifying, the role of submarines is shifting to refocus on their traditional tasks of sinking hostile ships and submarines in contested waters. As John Keegan observed decades ago, submarines are the capital ships of the modern era, vessels of the first rank that are the great warship killers of our time. The time of using them to deliver Special Forces to hunt terrorists, directly collect intelligence in denied areas or even fire the odd cruise missile against distant land targets appears to be ending.

Given this, the ATTACK class boats – with their marginal improvements – do seem best-suited for an era that is already passing, not the 2040s and well beyond. There is a logic in seeing SSNs as the wave of the future in a technological sense. However, timing is everything in military affairs. Australia's SSNs are far away, and the devil may be in the details.

Operational Implications

The AUKUS statement's first major outcome was having no programme to replace the COLLINS class submarines. Instead, a Life-Of-Type-Extension (LOTE) costing some US$4.4Bn will commence with the first boat entering this in 2026. Each boat will then undergo the two-year LOTE, allowing the first boat (HMAS FARNCOMB) to remain in service until 2038 and last boat (HMAS RANKIN) until 2048. The COLLINS submarines have a notional planned life of 30 years; with LOTE the fleet average age will be extended by 13 years. Obvious risks include doubts over whether the six submarines' aging structures will last this long; the deep ocean is a harsh operating environment. Moreover, will the boats still be operationally capable in 20 years' time? The PLAN is making great strides, several ASEAN nations are planning on new submarines and UUVs may one day be armed and become submarine killers.

Timing concerns also arise with the new SSNs. Taking an optimistic view, the first will enter service in early 2039, with the others being regularly delivered after that every three years. Australia now has six submarines in service, dropping to five as each cycles through LOTE. Australia will not get back to six submarines in service until the mid-2050s, with the eighth and last SSN entering service in 2059. For comparison sake, the first ATTACK boat was due to enter service in 2034 with the 12th and final boat in 2052. Going nuclear has costs greater than simply money.

Such considerations have led to commentators calling for the US or the UK to lease nuclear submarines to Australia in the interim before Australia's own fleet enters service. India offers a precedent. The Soviet Union initially leased a CHARLIE class SSN to India during 1988-92. An AKULA was then leased from Russia between 2012 and 2021, with a new contract recently signed for another leased AKULA to enter service in 2026 and talk of a possible second. However, neither the US nor UK have surplus SSNs suitable for leasing and have publicly push backed. The Australian Government, while noting the forthcoming 18 month study could research such matters, has begun scaling back leasing expectations. In a similar vein, there is discussion about a small number of Australians in the 2030s being included in the crews of US and UK SSNs to gain nuclear propulsion experience. This is unlikely with the US, but a possibility with the UK and would have value.

Photo: Huntington Ingalls Industries

Construction of VIRGINIA (SSN-774) class submarines such as USS DELAWARE (SSN-791) is one option for Australia to pursue under the AUKUS agreement.

An Industrial Calamity

There is also significant impact on Australia's defence industry. The ATTACK submarine programme was carefully structured to be a central part of the Government's continuous shipbuilding plan. This aimed to keep the construction of naval vessels to a carefully determined 'drumbeat' that kept industry continuously employed, rather than experiencing a 'boom and bust' business cycle as ships started being built and were then completed. The tempo aimed to keep all the various skills required at different stages of shipbuilding to be constantly engaged. Compounding the tempo problems induced by cancelling the ATTACK class, the parallel new frigate programme is now being delayed due to technical issues. The project to build nine HUNTER class frigates, a version of the UK's Type 26, has already slipped 18 months since contract signature three years ago. The continuous shipbuilding plan laid out in the government's 2017 Naval Shipbuilding Plan, and expanded in its 2020 Force Structure Plan, is now in considerable doubt and may be quietly abandoned. At the least, it needs a major rethink.

The change to the SSNs also has more direct defence industry impacts. As part of the ATTACK boat buy, France's Naval Group had committed to spending a

Photo: BAE Systems

Use of the British ASTUTE class design – this is HMS ANSON – is another possibility open to the Australian government.

Photo: Australian Department of Defence

The US Navy's nuclear powered attack submarine USS SANTA FE (SSN-763) is seen here operating with Australian COLLINS class boats. The transition to nuclear-powered technology will be a major challenge for Australia's naval service and industry.

minimum 60% by value of its contracts in Australia. Over the life of type, the total value of Naval Group's contracts was expected to be around US$65Bn. Accordingly, many local companies were expanding to win the expected work, including training a new workforce. Much of this will now be lost, as it is expected to be some five years before the new SSN project reaches the stage where the ATTACK project was when it was cancelled.

The cancellation of the ATTACK programme also reflected a legacy of unease in some quarters about Naval Group's handling of the programme. Critics argued that the company seemed to consider that Australia was trapped and unable to abandon the contract, even while it had agreed several possible break points. In this early stage, the contacts were more like costly project definition studies, than necessarily locking Australia into full-scale manufacture. The company was regarded as being rather insouciant and this casual approach did not go unnoticed by the public.

Over the last two years, the Australian media has been casting severe doubts on Naval Group's ability to meet the costs and schedule contracted. Those used to the workings of democracies might suggest that the intensive media campaign itself reflected serious internal Australian government and naval concerns. Remarkably, Naval Group proved unable to build confidence or enthusiasm for the programme amongst Australia's local defence industry, who should have been the programme's greatest supporters. For the broader Australian public, the ATTACK boat contract cancellation was not surprising.

Moving On

The 18-month study by the new Nuclear-Powered Submarine Task Force headed by Vice Admiral Jonathan Mead has commenced. This will determine the basic design and key technologies. The broad construction concept is that the US or the UK will provide the back-end nuclear propulsion modules to be married up with a front-end built in Australia at the Osborne shipyard in Adelaide. Some argue however, that given Australian shipyards lack of nuclear experience, the first few new SSNs might be built offshore.

As Australia does not have a civilian nuclear power industry, the programme relies on using a sealed propulsion system fuelled by highly enriched uranium and so not needing refuelling during its life, some 30 years. In contrast, French and Chinese SSNs use low-enriched uranium and require refuelling every 10 years or so. Importantly, the sealed propulsion system meets nuclear non-proliferation treaties in word, although less so in spirit. In the US, concerns over this are already being raised by former government officials.

The study will also decide on adopting a US or a UK design. The public assumes Australia will go with the US given the strong alliance connections and that such a buy will reinforce links at a time when worries over China are growing. On the other hand, the UK's deep involvement in creating the AUKUS agreement and worries emerging in the US submarine community about releasing nationally significant technology, hints the UK might be the hidden favourite.

The UK's latest SSN design, the ASTUTE class, was, however, designed for North Atlantic operations where the home port, and thus rearming, is reasonably close. These boats would need to be heavily modified to fit Australian requirements, including with a US combat system and weapons. On the other hand, the US Navy's VIRGINIA class, while having a larger crew, are optimised for Indo-Pacific Operations.

The Australian Government's nuclear submarine decision has, as the saying goes, upset many boats. The situation remains fluid so the final outcomes can today only be imagined. More may come out in the next several months in the leadup to the Australian Federal election; the government may yet have some vote-winning surprises in store.

In that regard, history records a Canadian conservative government the year before their 1988 election announcing Canada would buy 10 SSNs. That plan vanished. Australia's SSN plan may also ultimately fail. However, worryingly in Australia's case there is no fallback, no Plan B. There are interesting times ahead. ■

"We need to be aware of the huge amount of issues and challenges linked to climate change"

Photo: Swedish Navy

The increase in the importance of NATO's Northern Flank has clear implications for neutral Sweden andthe Royal Swedish Navy. Threat perceptions based on the capabilities of the Russian Navy and the Russian Armed Forces, particular with regard to the Baltic Sea, have also changed over recent years, whilst the Arctic region is also gaining greater and greater attention. Against this backdrop, MSD spoke with Rear Admiral Ewa Skoog Haslum, Sweden's Chief of Navy.

MSD: Rear Admiral, what is your perspective of the most significant recent developments impacting Sweden's waters and the broader Scandinavian and Arctic region? What would your advice be to your country's political leaders if you were required to provide it?

Skoog Haslum: Allow me to start with an opening remark. Many of these questions have a broad strategic relevance which can only be answered fully at a higher level within Sweden's defence organisation. However, from the navy's perspective, the increased risks of malignant actions in the name of climate change, as well as the potential impact of climate refugees, are well known factors to weigh in our future planning. And, as often stated and discussed, most recently at the International Seapower Symposium in Newport, US, our success, or failure, lies in our ability to cooperate and work together to create safe and secure seas.

Taking the Arctic as an example, in order to achieve a complete geopolitical understanding, one must be aware of the multitude of complex challenges in the area. Therefore, a whole of government approach, also embracing emerging geopolitical tensions, is necessary. Last autumn, the Swedish Government issued a communication about the Arctic, which included reference to these geopolitical challenges. Before we can identify specific issues related to the operational capabilities required by this environment, we need to develop a deeper situational awareness. This kind of awareness will probably need to be based upon more traditional (military) means, such as INTEL/OSINT and technological R&D. However, it could also encompass a broader approach, such as seminars to improve understanding of culture, the economy, education and, of course, the impact of climate change. The possibility of the European Union and its member states playing a more prominent role in developing the capabilities required for this enhanced situational awareness – for example, through both military and civilian R&D programmes, should not be excluded.

From the perspective of the Swedish Armed Forces, the Arctic is just one part of a geo-strategic continuum that extends across the Arctic and the Baltic as far as the Black Sea. Hence the geopolitical challenges in the Arctic cannot be isolated from the broader geopolitical picture, including the transatlantic link. With this in mind, Sweden is building a web of mainly bilateral – but also trilateral and multilateral – cooperation agreements in which its armed forces are actively participating. For example, with respect to military-related issues in the Arctic, the Swedish Armed Forces participate in the Arctic Security Forces Roundtable (ASFR).

Taking a broader perspective, we must also be aware of the actions taken by countries that aggressively challenge both other na-

Photo: Forsvarsmakten

The VISBY class corvettes – depicted is KARLSTAD – are a revolutionary design and provided the Swedish Navy with valuable knowledge in the field of signature management.

Map: ESA

From the perspective of the Swedish Armed Forces, the Arctic is just one part of a geo-strategic continuum that extends across the Arctic and the Baltic as far as the Black Sea.

tions and international laws. In this context, we need to be mindful of their capacity to use a broad toolbox to achieve their objectives, for example through trade, information and disinformation, culture and legal action as well through military capabilities. This means that we must develop our own to tools to meet and counter their actions, whilst also keeping in mind the need to avoid escalation when this is not necessary. At the same time, we also have to keep in view that we also have many common interests, such as avoiding accidents that could result in environmental damage, reducing the effects of climate change and participating in regional Search and Rescue (SAR)

Looking at specific examples, the Swedish Armed Forces can contribute to a non-escalatory approach by respecting and promoting international law in the course of their operations, such as supporting freedom of navigation. Similarly, by participating in different exercises related to the Northern Areas – both in Sweden and in our geographical vicinity – we signal our readiness to contribute to a safe and stable security environment. Clearly, we also need to obtain and develop the competence and capabilities required to achieve our objectives, such as the capacity to operate effectively in a Sub-Arctic environment. In this regard we need to keep in mind the importance of 'Total Defence' to our overall defence strategy. For example, it is worth noting that the vast and sparsely populated Northern Areas contain important infrastructure, such as mines, hydro-electric facilities and the Esrange Space Centre.

As already mentioned, an emerging factor influencing our geographical areas is climate change. Beyond the visible consequences such as the melting ice cap, a warmer climate will undoubtedly impact operational conditions in the Northern Areas. One consequence will be the more extensive thawing of the ground frost in these regions, with an increased need for tracked vehicles. Another aspect will be an increased number of refugees fleeing their home countries due to drought, flooding or heat waves. There will be fewer areas of land available where more people must coexist. This will cause tension and destabilisation in areas not originally affected by the climate change itself.

Looking at another aspect of the impact of climate change, the Swedish Armed Forces in general are striving for more sustainable capabilities. This shift towards a greener military will also give rise to new R&D opportunities; both in Sweden and in an EU-context.

MSD: Considering this backdrop, what is the main conclusion for the Swedish Navy?

Skoog Haslum: We need to be aware of the huge amount of issues and challenges linked to climate change and the associated risk of large geographical areas being destabilised when large number of humans are forced together. This destabilisation is something that malignant nations might take advantage of in order to gain benefits for themselves. Taking the situation in the Arctic as just one example of the global situation, my conclusion is the importance of cooperation between countries to create a safe and secure world, together.

MSD: Turning to specific naval capabilities, it appears that the VISBY class corvettes will be upgraded and that a new class of corvette will also sail the seas. Could you provide some further details?

Skoog Haslum: Our five VISBY class corvettes will go through a Mid-Life Update (MLU) programme, starting in 2024. This will enable them to stay relevant for their remaining service lives. It will encompass a comprehensive modernisation of the ships, under which existing systems will be upgraded or replaced. We will also introduce new electronic warfare capabilities and, most notably, a surface-to-air missile system.

In parallel to the VISBY class MLU we are in the planning phase of procuring four new surface combatants. This programme has been in a preparatory phase for a long time, with the earliest plans for a follow on class of corvettes to VISBY dating back more than 15 years. However, last year's defence bill, which included several important procurement projects for the Swedish Navy, funded the delivery of four new corvettes. Of these, the first two will be delivered before 2030.

In many ways, the defence bill has been a game changer for us. We now have a ten-year plan that has been politically approved, which will in result in the armed forces receiving increased funding to a level of approximately 1.5% of our GDP in 2025. This will bring a much needed increase in operational capability. It also means that we are able to complete the procurement of the new corvettes in a relatively short time frame. For that reason, we are seeking synergies with the ongoing VISBY MLU. VISBY was a revolutionary design, which has given us valuable knowledge in the field of signature management and its integration with sensors and weapon systems in order to maximise overall effectiveness. This knowledge will, of course, be utilised for the new corvettes.

With the new corvettes, we aim to supplement our existing vessels in order to create an effective surface combatant force for the 2030s. Increased air defence capability, longer endurance, and margins for future growth are some of our main focus areas. And given the goal of having operational units at sea prior to 2030, we do not intend to embark on another lengthy project, as we did with the VISBY class.

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Photo: Forsvarsmakten

Sweden has opened all parts of the military service to women.

MSD: According to MSD's understanding, Sweden intends to strengthen its amphibious capabilities. Could you share some insights with our readers?
Skoog Haslum: Our Marine units will also undergo a modernisation program. The first step, which is already underway, is the transformation and strengthening of the present single Marine battalion into a two-battalion force. This is going hand-in-hand with the re-establishment of the Marine regiment in Gothenburg. From 2025, we will be also start to bring new equipment into service. The first notable reinforcement will be a new combat boat, larger than today's CB90. This is being driven by a requirement to carry heavier armament, initially in a version deploying a 120mm mortar.

MSD: Staying with the theme of amphibious capabilities, Germany and the Netherlands are focusing on a collaborative approach. As integration is currently one of the buzzwords in European defence endeavours, could you see Sweden participating in a similar initiative?
Skoog Haslum: We already have a special relationship with Finland that has developed further in recent years. Indeed, Finnish-Swedish cooperation in the amphibious sphere was a pioneering effort that has now been ongoing for more than 15 years. Our Marines also regularly interact and train with our regional partners, primarily the United Kingdom, the Netherlands and Germany as well as with the US Marine Corps. This brings us valuable knowledge and supports our interoperability.
So it is with Finland that we are developing the most comprehensive force integration. This is valid both for amphibious forces and for the navy as a whole. And when you also operate the same equipment, there are possibilities for cooperation throughout that equipment's lifecycle. One recent project is our cooperation related to the light-weight torpedo procurement (the TP 47). This brings opportunities, not only in the area of logistics but also in terms of operational aspects.
MSD: Can you envisage the Swedish Navy expanding this sort of collaboration to other partner navies? For example, could integration between Belgian and Dutch efforts in the field of mine countermeasures serve as an example?
Skoog Haslum: We are constantly open to new areas of cooperation with our Nordic, European Union and NATO partners. In the field of mine countermeasures, we are closely following what is being done by others and we are participating in various collaborative efforts. Right now we are assessing participation in the PESCO project for autonomous systems for mine countermeasures (MAS MCM).

MSD: Although Sweden has rather distinct submarine requirements, are there opportunities for cooperation in this area?[1)]
Skoog Haslum: Cooperation and coordination activities related to submarine operations are well established in our region. One of the most visible areas is in the field of submarine rescue. Subject to the outcome of ongoing and future procurement programmes, this cooperation could be expanded to logistic support and life cycle management.

MSD: Are there other areas of collaboration that Sweden and the Swedish Navy would like to strengthen?
Skoog Haslum: Given that the Swedish Armed Forces are currently in an expansive phase in accordance with our latest defence bill, cooperation will undoubtedly remain an important area of focus. Developing and deploying new technology whilst simultaneously meeting our operational requirements will demand high standards of innovation and efficiency, particularly given what we wish to achieve within a ten-year period. Co-operation will also have a significant operational benefit, for example, when it comes to enhancing situational awareness.

MSD: Recently, during a conference held in Kiel, you stressed that the society as a whole has to be involved in security issues. Could you elaborate?
Skoog Haslum: The concept of 'Total Defence' is being rebuilt in Sweden. This means that the civil, as well as the military, parts of our society need to be fully involved in creating the prerequisites for resilience and resistance under a wide range of circumstances. This applies equally to times of peace, crisis and of war.

MSD: Covid-19 has had a major effect on our way of life. How did the Swedish Navy navigate through the troubled waters of the pandemic?
Skoog Haslum: The Swedish Armed Forces managed the pandemic well to that extent that our day to day operations where largely undisturbed. We were not able to continue with as much international participation as we might have hoped but, fortunately, there have been no outbreaks of Covid in our navy's units.

MSD: What is your perspective on the Swedish Navy's participation in European-led missions relating to maritime security?
Skoog Haslum: The Swedish Navy has previously participated in international missions such as UNIFIL's maritime operations and EUNAVFOR off the coast of Somalia. We are ready to contribute to similar operations if the need arises in future.

MSD: Finally, please allow us to ask about your role as a woman who leads a component of the Swedish Armed Forces. While female leaders are nowadays no longer alien to command positions in the military, a female Service Chief is still uncommon. Would you share your perspective?
Skoog Haslum: Well, it is rather unusual, even in Sweden. But we have had female conscripts since the 1980s and, in 1989, we opened all parts of our Service to women. The ratio of females in the military increases year-by-year and, even if things move slowly, we can see a positive trend in the number of women at higher levels. We select the best in our society to serve in our armed forces, and now we can choose these from among the whole of our citizens and not from just half. It's pretty simple actually.

The interview was conducted by Hans Uwe Mergener

[1)] Background

Through cooperation in submarine design and construction, Germany and Italy have been able to reduce costs by using many identical (or, at least, similar) systems and facilities, procuring spare parts more effectively and thus ensuing economic underwater operations. This lengthy collaboration in the area of in-service submarine support has been seen as a success story and was joined by Portugal in 2019.

South America – A Unique Naval Market: An Overview

Guy Toremans

MSD takes a look at the South American navies' current procurement plans and how they are gradually starting to acquire the technology and know-how to decrease their dependence on foreign suppliers.

Maritime security is a critical concern in South America. The region's expansive maritime economic zones, its natural resources, and the biodiversity of South American waters are being subjected to an increase in the unauthorised presence of ships that can bring problems including the depredation of marine fauna by large fishing fleets, drug-trafficking, smuggling, marine pollution and even insurgency and terrorism. Given that this growth in maritime security challenges requires an enhanced and more comprehensive maritime presence, the modernisation of South American fleets is becoming an imperative. This is quite a challenge as the region's complex and diverse operating environment – ranging from the expanse of the Pacific through the relevant EEZs and territorial waters through to the extensive river network of the Amazon – generates very specific requirements for new platforms. One particular factor is the proximity of some countries to Antarctica, spurring the need for some of these new platforms to be capable of sustained operations in the icy and stormy waters. In general terms, the need to safeguard maritime assets has tended to focus procurement on constabulary and logistic support vessels, with combatants accorded a secondary priority.

Argentina *(Armada de la República Argentina)*

The Argentine Navy comprises fewer than 50 ships with an average age of over 30 years. Many are of doubtful serviceability. Since the loss of the submarine ARA SAN JUAN in 2017, the naval service's ability to maintain its fleet's operational effectiveness has gained increased attention.

Author

Guy Toremans is a freelance naval journalist based in Belgium.

Photo: Naval Group

ARA BOUCHARD is one of four GOWIND type OPVs being supplied by Naval Group to Argentina.

The most important recent procurement has been that for four GOWIND OPV 87 patrol vessels from France's Naval Group. ARA BOUCHARD (the former L'ADROIT) entered service in February 2020 and was followed by ARA PIEDRABUENA and ARA STORNI in April 2021 and October 2021 respectively. They will be followed by BARTOLOME CORDERO in April 2022. The contract with Naval Group is understood to include the option for the transfer of technology and technical support to build additional ships domestically.

The navy has reportedly been examining more significant acquisitions, largely through the purchase of second-hand vessels. These have included the potential transfer of two of the Brazilian Navy's TUPI (Type 209/1400) class submarines to rebuild the submarine arm, as well as a South Korean ULSAN class frigate. The latter may be associated with the potential offer of new build of a MAKASSAR type amphibious transport dock, a design which has proved popular with many regional navies and seems a better option than the transfer of a used AUSTIN (LPD-4) class vessel from the US Navy that was previously reported. The Argentine Navy also has a requirement for a replacement icebreaker but negotiations for the possible acquisition of the former Australian RSV AURORA AUSTRALIS did not reach a satisfactory conclusion.

Brazil *(Marinha do Brasil)*

The Brazilian Navy's order of battle comprises well over 100 vessels, many with coastal and brown water roles. Encompassing a range of overseas and locally constructed new builds supplemented by second-hand acquisitions, many of these ships are nearing the end of their service lives. The navy has been relying on two pillars to modernise its fleet: the Programa de Desenvolvimento de Submarinos (PROSUB) for the renewal of the submarine fleet, and the Programa de Obtenção de Meios de Superfície (PROSUPER) covering the acquisition of major surface vessels.

The navy has been prioritising its PROSUB programme under a partnership with France's Naval Group. The programme

Photo: Naval Group

Naval Group has supported Brazil in delivering its large and costly PROSUB programme. Here the lead RIACHUELO (SCORPÈNE) class submarine is seen departing the new Itaguai submarine base to commence sea trials.

Photo: TKMS

A graphic of the new TAMANDARÉ being produced by the Aguas Azuis consortium for the Brazilian Navy based on TKMS's MEKO technology.

Photo: Guy Toremans

OPVs have established themselves as one of the most sought after platforms by the South American navies. This is the Chilean PILOTO PARDO class ARC COMANDANTE TORO, based on the Fassmer OPV80 design.

aims at assisting Brazil in the design and construction of both conventional and nuclear powered submarines through the transfer of technology and capacity building (although the nuclear reactor technology for the proposed nuclear-powered boats will be of Brazilian origin). The first of these domestically produced submarines, a variant of Naval Group's SCORPÈNE design, is the diesel-electric RIACHUELO. She is expected to enter the fleet in December 2021 after a protracted period of trials and testing. Three additional boats – named HUMAITÁ, TONELERO and ANGOSTURA will follow. Work is then expected to transition to ALVARO BAZARO, the prototype for the new nuclear attack submarine programme. Physical construction is expected to begin as early as 2023 but it will be far into the next decade before the submarine is expected to enter service.

The focus on the expensive PROSUB programme has meant that tangible progress on PROSUPER has lagged far behind. Original acquisition plans have been revised over time and the current emphasis on fleet renewal is the TAMANDARÉ frigate project. This is being led by the Aguas Azuis consortium, comprised of ThyssenKrupp Marine Systems (TKMS), Embraer SA and Atech, and will see the local assembly of an initial class of four ships based on TKMS' MEKO technology. The construction phase is expected to begin in 2022, with deliveries commencing towards the end of the decade. Meanwhile, the Arsenal de Marinha at Rio de Janeiro is completing a pair of MACAE (NPa 500 type) patrol vessels after taking over the project following collapse of the local builder. It was originally hoped to acquire up to 15 of the NPa 500-BR (based on based on CMN's VIGILANTE 400 CL54 design) but only two have entered service to date. The navy would like to complete further acquisitions by the end of the decade if budgetary conditions allow. A high priority is a requirement for up to six mine countermeasures vessels, which could either be newly built (potential suppliers would include South Korea's Kangnam or Italy's Intermarine) or second hand. Former British HUNT, Swedish LANDSORT or even TRIPARTITE class minehunters might meet the latter requirement. Other vessels on the shopping list include amphibious vessels and a Polar support ship. The Brazilian Navy also has long term aspirations for a new carrier under the Programa de Obtenção de Navios-Aerodromos (PRONAE) to replace the decommissioned SÃO PAULO but progress seems unlikely in the short term.

The Amazon Basin

In addition to their role on the open seas, the Brazilian, Colombian and Peruvian navies are also heavily involved in policing the immense river network of the Amazon Basin, where they face multiple challenges. These range from traditional surveillance missions to the dangerous "war" against criminal elements, such as narcotics-traffickers, criminal/quasi-terrorist organisations, illegal loggers and even goldminers. They maintain large fleets of patrol boats, floating river stations, assault craft and – in the case of Colombia and Peru – hovercraft (typically the Griffon 2000TD type) and have more procurements planned. For example, Peru anticipates new Metal Shark Defiant class fast assault craft and Swedish Combat Boat 90-based assault craft joining its Amazon Command in coming years. Colombia's COTECMAR is regarded as having particular expertise in building river patrol boats and its PAF design seems likely to form the basis for the joint construction by Brazil, Colombia and Peru of a new class of Patrullera Fluvial Posa-Helicoptero (PF-PH) river gunboats. If the project proceeds, it seems likely that COTECMAR will takes responsibility for the design, SIMA will work on the ship's structures and Brazil's EMGEPRON will be responsible for the propulsion system.

Photo: COTECMAR

Ecuador's COTECMAR has become an acknowledged expert in the construction of riverine patrol vessels.

Chile *(Armada de Chile)*

The Chilean Navy operates a fleet of around 40 sea-going vessels supplemented by numerous inshore patrol craft. It operates both second-hand and newly-built vessels, many of the latter being constructed by the local Astilleros y Maestranza de la Armada (ASMAR) shipbuilding group. The shipbuilder has already completed four PILOTO PARDO class (Fassmer OPV-80 type) offshore patrol vessels under licence and a new Antarctic support vessel the ARC ALMIRANTE ÓSCAR VIEL TORO – based on the Vard Marine 9-302 design – is currently under construction and expected to enter service in 2024. In 2021, a further contract with Vard Marine saw the selection of its VARD 7 series to meet the requirements of its Escotillón IV programme. This could ultimately see the construction by ASMAR of four vessels to replace existing amphibious support and landing ships.

The navy has longer term requirements to replace its second-hand former British and Dutch frigates of the ALMIRANTE WILLIAMS (Type 22) and LATORRE ('L') classes and its two THOMSON (Type 209/1400) class submarines. An interim solution has seen Chile take delivery of two former RAN ADELAIDE class frigates to replace the 'L' class but new construction, most likely by ASMAR, is expected within the next decade. The new ships will, however, almost certainly be of a foreign design, with Babcock, BAE Systems, Damen, DSME, Fincantieri, Navantia and Naval Group all likely to be in the running. The replacement of the THOMSON class will most likely involve overseas construction and is probably further into the future, with competition expected to be equally wide-ranging.

Colombia *(Armada Nacional de la República de Colombia)*

The Colombian Navy's force structure is similar to many of its South American contemporaries with a relative small force of seagoing assets supported by many brown water vessels for coastal and riverine patrol. Force renewal is currently being carried out under the Plan de Desarrollo Naval 2042 (Naval Development Plan 2042) that calls for acquisition of up to five frigates, four offshore patrol vessels and two amphibious transport docks supplemented by logistic support and patrol vessels.

Like Chile, Colombia is keen to expand construction by its local shipbuilding enterprise, in its case the Cartagena-based COTECMAR. The group has already delivered a wide range of constabulary and logistic support vessels ranging from the three 20 DE JULIO (Fassmer OPV-80) class offshore patrol vessels through to the locally-designed BAL-C logistic support landing craft; the latter even having gained export success. However, the most emblematic project for future local construction is the Plataforma Estratégica de Superficie (PES) programme encompassing the procurement of new surface combatants to replace the ALMIRANTE PADILLA class frigates. Again as for Chile, these will rely on an international competition to procure the design, which will then be built indigenously by COTECMAR. A

Graphic: Vard Marine

Chile's new amphibious logistics support vessels will be based on Fincantieri's Vard Marine subsidiary's VARD 7 series concept.

number of European shipbuilders have already floated design proposals for the programme (including BMT's VENATOR 110, Navantia's AVANTE F538 and Naval Group's BELH@RRA) whilst South Korea is another likely contender. Colombia will also need to replace its 1970s-vintage PIJAO (Type 209/1200) class submarines in the foreseeable future, likely sparking another fierce procurement competition.

Ecuador *(Armada del Ecuador)*

The Ecuadoran Navy currently operates an aging force of around 30 vessels, of which ten are frontline combatants. The local Astilleros Navales Ecuatorianos (ASTINAVE) shipyard is likely to play a major role in any replacement programme and is currently building its first MPV70 MKII multi-purpose patrol ship under a design, material and support package under a contract with Germany's Fassmer. Delivery of this lead ship is expected in 2022 and is expected to be followed by a second vessel. The shipyard has previously worked with Dutch Damen to complete smaller licence-built patrol vessels and further contracts may be concluded as Ecuador continues to focus on strengthening its ability to police its EEZ.

The Ecuadorian Navy's major assets – including two British-built LEANDER class frigates transferred second-hand from Chile in 2008 and two 1970s era SHYVRI (Type 209/1300) class submarines – are all elderly and in need of replacement over the course of the decade. It is believed that talks have been held with several European navies over the purchase of used frigates but local construction – either of the Damen SIGMA or an indigenous ASTINAVE design – is another possibility.

Peru *(Marina de Guerra del Perú)*

With approximately 80 ships and craft, around a quarter of which are major combatants, the Peruvian Navy has been largely successful in rejuvenating its capabilities through the upgrade of units currently in service and the procurement of new platforms. As elsewhere in South America, the latter has focused largely on the indigenous construction of licence-built designs, in Peru's case by the local SIMA shipbuilding group. Important current programmes include the second PISCO (MAKASSAR) class amphibious transport dock BAP PAITA, which is scheduled for launch in the first part of 2022 and the RÍO PATIVILCA class coastal patrol vessels. Like the MAKASSAR class, these are of South Korean design, with six delivered to date out of a total planned procurement of ten units. Future plans also include three offshore patrol vessels of indigenous design and the licensed construction of COTECMAR's BAL-C landing craft.

In common with trends elsewhere in South America, aspirations for replacement frigates and submarines are further into the future. Like Argentina, Peru is eyeing the possibility of acquiring second-hand Brazilian Type 209 class submarines – to replace BAP ISLAY and BAP ARICA

European and Asian Shipbuilders' Ambitions in South America

Recent years have seen some of Europe's leading naval shipbuilding groups expand their presence in the Latin American naval market to support both new build and refurbishment programmes. Important examples include Naval Group's involvement in Brazil's giant PROSUB programme and its more recent sale of GOWIND family designs to Argentina. Germany's Fassmer has enjoyed ongoing success selling its OPV designs to Chile, Colombia and Ecuador whilst its national counterpart and rival, TKMS, is leading Brazil's TAMANDARÉ frigate project and working alongside Elbit Systems in Chile in supporting SIMA's midlife modernisation of the Peruvian Navy's ANGAMOS (Type 209/1200) class submarines. Another, different example of the opportunities available is represented by Fincantieri-owned Vard Marine group's involvement in the development of designs for production by Chile's ASMAR. Spain's Navantia is also believed to have an agreement with COTECMAR to support naval construction opportunities in the region.

Photo: Guy Toremans

TKMS is working with Elbit Systems to assist Peru's SIMA with the mid-life update of the navy's four ANGAMOS class submarines.

A particularly noteworthy development has been the entry of South Korea into the South American market, supported by the donation of former Republic of Korea Navy ships as a means of facilitating future sales. Colombia, Ecuador and Peru have all benefitted from this approach, which might be expanded to other countries. This sales pitch has been further assisted by a willingness to forge partnerships with local companies for the design and construction of vessels locally, including generous "transfer of technology" clauses to assist the development of local shipbuilding infrastructure, sometimes extending to rights to offer the resultant designs for export. Peru's SIMA has developed particularly extensive ties to South Korean shipbuilding industry and Colombia's COTECMAR has been another to benefit from these industrial ties.

Graphic: Fassmer

Fassmer has been awarded a contract for the design, material package and support for the construction of MPV 70 Mk II multi-purpose patrol ships for the Ecuadorian Navy.

– pending a more comprehensive replacement programme in the 2030s. New frigate procurement is also likely to be delayed into a similar timescale, with licensed production of a European or South Korean design the most likely outcome.

Uruguay (*Armada Nacional de la República Oriental de Uruguay)*

Uruguay's small navy comprises vessels that are largely past their operational lives, with the ROU VANGUARDIA (the former East German PIAST class salvage ship OTTO VON GUERICKE) possibly the only unit capable of deployment to ensure the country's EEZ. The navy urgently needs to replace its constabulary assets and, in 2016, Germany's NVL (formerly Lürssen) was reportedly selected to provide three of its OPV80 type patrol vessels. However, lack of funding has prevented tangible progress being made. The French GOWIND or even the Chinese P-18 design would also be potential contenders should the competition be reopened.

Venezuela *(Armada Bolivariana de Venezuela)*

The current Venezuelan Navy has only a marginal effective fleet, with many of its ships laid up or in semi-derelict status. Any major acquisition procurements seem unlikely given the country's current political and economic situation.

Conclusion

Over the next twenty years, around 40 major procurement programmes are likely to be launched by South American navies. Although frontline submarines and frigates appear prominently in these lists, such expensive projects are heavily dependent on financial factors and it is a matter of doubt whether governments will have the motivation to see through such "high end" projects. By contrast, patrol vessels and, increasingly, amphibious support shipping appear to enjoy more support, particularly given such programme's relevance to shipbuilding and broader economic activity. As such, these projects are more likely to be realised in the foreseeable future. ■

Evolving the FREMM

The US Navy's CONSTELLATION (FFG-62) Class

Sidney E. Dean

In 2020, the US Navy began procurement of the new CONSTELLATION (FFG-62) class frigates. The contract was awarded to Fincantieri Marinette Marine (FMM), the Wisconsin-based US subsidiary of Italian shipbuilder Fincantieri. The Italian variant of the FREMM (FRegata Europea Multi-Missione or European Multi-Mission Frigate) was selected as the basis for the new American warship. Some design changes are currently being made to accommodate the particular requirements of the US Navy.

The US Navy decommissioned the last unit of the OLIVER HAZARD PERRY (FFG-7) class in 2015, and has been without frigates ever since. Tasks traditionally performed by frigates, including Anti-Submarine Warfare (ASW) and Surface Warfare (SuW) against lighter targets, were to be passed to the Littoral Combat Ship (LCS); Anti-Air Warfare (AAW) and most SuW tasks were handed to the ARLEIGH BURKE (DDG-51) class destroyers (and in the long term, these destroyers' large surface combatant replacements).

Photo: Fincantieri

A graphic of the lead CONSTELLATION (FFG-62) class frigate, which is derived from the Italian FREMM variant.

Filling a Gap

The LCS was also expected to demonstrate presence and conduct independent operations in less challenging environments not requiring heavier warships. Delays in maturing LCS operational capability, limits to its offensive and defensive capabilities, and concerns that LCS would have inadequate survivability in combat convinced the US Navy that re-introducing frigates was necessary. In July 2017, the Pentagon issued a formal Request for Information (RFI), launching the "Future Frigate" or "FFG(X)" development and acquisition programme.

Chief of Naval Operations Admiral Mike Gilday has referred to the future frigate as a "workhorse" of the fleet, equally capable of littoral and blue-water operations. The new ships will perform the standard array of missions normally associated with frigates. These include such peacetime missions as engaging with allied and partner navies, "showing the flag" and maritime security operations. Wartime missions would encompass the full operational spectrum, including Intelligence, Surveillance and Reconnaissance (ISR) as well as AAW, ASW, SuW and Electromagnetic Manoeuvre Warfare/Information Operations (EMW/IO), either operating independently or embedded in a larger naval formation.

Choosing FREMM

Ultimately, four different vendor teams submitted proposals for the frigate contract.[1] On 30 April 2020, the US Navy announced that Fincantieri/Marinette Marine had been awarded the fixed-price incentive Detail Design & Construction (DD&C) contract for up to ten ships. Fincantieri had entered the competition partnered with the Virginia-based firms Gibbs and Cox (design and engineering) and Trident Maritime Systems (electric and propulsion systems integration and shipboard habitability).

From the beginning, the USN had decided to pursue a frigate based on an existing ship design. This approach had several advantages, including shortening development time and reducing the associated costs. Even more importantly, this approach promised to reduce technical risk and minimise the likelihood of delays and cost overruns during the initial production stage. For the same reason, the Navy determined that only technologies and systems already in existence or already being developed for other platforms should be incorporated into the new frigate.

The US Navy's decision to choose FMM as prime contractor reflects a number of factors. The FREMM proposal represented a highly modern but fully matured design already in service with allied fleets. Since delivery of the first French and Italian units in 2012 and 2013 respectively, the FREMM has performed well, including on global deployments. Moreover, FMM was already a contractor of record for the US Navy, building the FREEDOM (LCS-1) class Littoral Combat Ship at Marinette. Both of FMM's primary partners also have long track records designing and outfitting US Navy vessels.

FMM had also made a significant marketing effort, even enlisting the aid of the Italian Navy, which despatched the FREMM frigate ALPINO to Norfolk in 2018 to give the US Navy (and the US defence press) a first-hand look at its capabilities. Upon announcing the contract award in 2020, Rear Admiral Casey Moton, director of the Program Executive Office for Small and Unmanned Combat-

Photo: US Navy

The Italian multi-mission frigate ALPINO – seen here operating with the US Navy destroyer GONZALEZ (DDG-66) – was sent on a marketing mission to the United States to demonstrate the FREMM's suitability for the FFG(X) programme requirement.

ants, acknowledged that Fincantieri had made considerable effort to present the ship's capabilities.

Selling Points

A major advantage of the FREMM is the modularity of the basic or "parent" design. As the Fregata Europea designation implies, the ship was intended from the beginning to serve the needs of more than one nation. The FREMM variants serving in the Italian and the French navy respectively have been customised to meet the priorities of each fleet. This modular aspect demonstrated from the beginning that FMM would be able to adjust the parent design to the US Navy's particular requirements.

One of the particular features which FMM presented as a selling point is the ship's Combined Diesel-Electric and Gas (CODLAG) propulsion system. This will consist of two 3MW electric propulsion motors supplied by power from the ship's electrical distribution system provided by four Rolls Royce MTU 20V 4000 M53B generator sets rated at 2.865MW each, and one General Electric LM2500+G4 Gas Turbine rated at 30.4MW. The Italian FREMM variant is one of a small number of warship classes already utilising CODLAG. The new system promises greater fuel economy than previous US Navy propulsion suites, extending operational range without compromising performance. The FFG-62 class is expected to attain top speeds exceeding 26 knots and achieve a cruising range of 6.000 nautical miles at 16 knots average speed. Operationally, CODLAG's reduced acoustic profile enhances ASW capabilities. Finally, the FFG-62's propulsion suite provides excess electrical production capacity which will facilitate future ship systems upgrades, potentially including directed energy weapons.

Another asset the CONSTELLATION class inherits from FREMM is its conditions-based maintenance regime. According to FMM's FFG-62 Programme Manager, Chuck Goddard, this feature encompasses automated surveillance of shipboard systems in order to detect maintenance requirements early, giving the crew ample opportunity to either take preventive measures at sea or schedule maintenance during the next port phase. Speaking at the 2020 Surface Navy Association symposium in Washington, DC, Goddard stated that this predictive capability would provide improved availability rates over currently deployed US Navy vessels, reduce operating costs, and preclude equipment failure by allowing proactive maintenance.

Photo: Fincantieri

The Italian ASW configured FREMM VIGINIO FASAN (foreground) in company with her general-purpose counterpart CARLO BERGAMINI. The FREMM's modularity was one of its major attractions to the US Navy

Upgraded Combat Capability

Despite the well-developed capabilities of the original FREMM, a fairly extensive redesign process has been required to meet the particular operational requirements of the US Navy. Modifications involve adapting the ship to specific mission profiles, as well as accommodating standard US Navy weapons, sensors and electronics. Overall, the American frigate will be more densely equipped than the original FREMM, and have somewhat more complex weapon systems. Chuck Goddard equated the FFG-62's combat performance to "virtually" that of the DDG-51 Flight IIA variant. "The only real difference between what this ship brings to the fight and what a DDG-51 brings to the fight is the number of VLS cells," Goddard said.

Naval Combatant Design Standards have also been implemented to ensure that the CONSTELLATION class's survivability performance meets USN requirements for combatant vessels. These survivability standards include shock resistance against underwater explosions, armour and ballistic protection around selected areas, blast and fire-resistant structure in designated areas, and vulnerability reduction – through redundancy and isolation – of key systems. To enhance survivability, 300 tons of steel were added to the parent hullform. This improves both the ability to withstand weapons effects, and seakeeping capability. The CONSTELLATION class can continue to operate at Sea State 8 (Douglas scale) in near-Hurricane conditions, Goddard emphasised.

Design Adjustments

Detailed structural differences between the FREMM parent design and the US Navy's FFG-62 class were revealed in a Congressional Research Service (CRS) study published in September 2021. The underlying data was taken from an internal US Navy information paper dated 18 August 2021. This document was provided to both the

CRS and the Congressional Budget Office (CBO) by the US Navy on 27 August 2021. According to this information paper, the changes had been independently conceived by Fincantieri and incorporated into the company's design proposal prior to contract award. The latter fact is significant, as it promises a smoother redesign process when compared to changes demanded by the Navy following contract award.

Major design adjustments revealed by the CRS report include:

- The hull has been lengthened by 7.25 metres overall to accommodate larger generators and future growth (the length between perpendiculars was increased by 8.5 metres). The overall length of the FFG-62 class is 152.6 metres.
- Waterline beam has been increased by 1.1 metres to 18.3 metres. Overall beam remains unchanged at 19.9 metres.
- Displacement has been increased by more than 500 tons to allow for margins and future growth, as well as to enhance survivability. Light ship displacement is now 6,112 metric tonnes, with full load displacement at 7,408 tonnes (approximately 25 percent less than an ARLEIGH BURKE class destroyer).
- The topside has been modified to accommodate US Navy warfare systems, as well as its standard raked sensor mast rather than the larger European sensor tower. This simultaneously acts to lower the ship's overall profile and radar signature.

Photo: Fincantieri

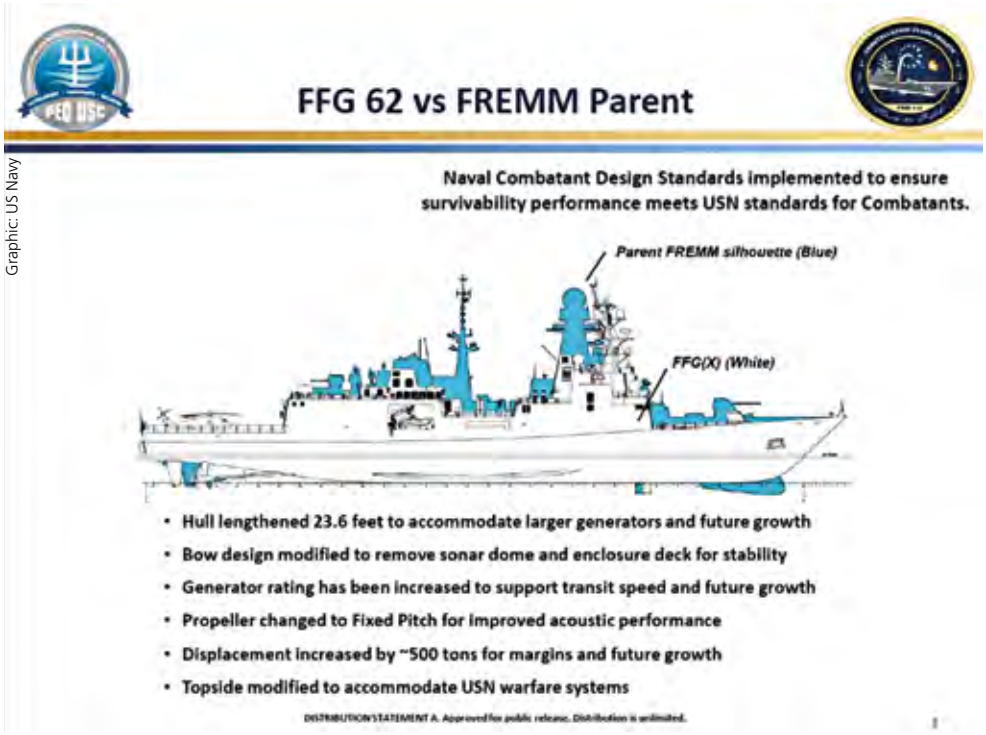
Despite the well-developed capabilities of the original FREMM, a fairly extensive redesign process has been required for the CONSTELLATION (FFG-62) class to meet the particular operational requirements of the US Navy.

- The bow design has been revised to remove the sonar dome and the enclosure deck to enhance stability (eliminating the sonar dome became possible as the US Navy decided against the originally planned low-band hull array in favour of the AN/SQS-62 variable depth towed sonar array for ASW operations).
- The generator rating has been increased to support enhanced transit speed and allow for future growth.
- The two propellers were changed from controllable pitch to fixed pitch to improve acoustic performance

The US Navy Program Officer for the FFG-62 programme, Captain Kevin Smith, told attendees of the US Navy League's 2021 Sea Air Space Symposium in Maryland that, despite the hull expansion, the inner layout of the American frigate will remain largely unchanged from the parent design. "The Italians did a very good job in the design of the internal spaces, and the flow of a lot of these spaces," Captain Smith said on 2 August 2021. Smith specifically named the bridge and the propulsion plant as areas where no significant layout changes were planned. Minimising layout changes is expected to reduce the risk of cost overruns, technical complications or changes to ship-handling characteristics.

The US Navy has factored in a five percent growth margin to accommodate additional or larger equipment and systems over the course of the class's service life. Critics consider this margin to be quite narrow. The Navy's required growth margin on newly built destroyers is ten percent. Some observers are concerned that the five percent margin could potentially restrict options for mid-life design changes requiring more Space, Weight, and Power or Cooling (SWAP-C) capacity. In addition to the overall five percent growth margin for general category equipment, the Navy has factored in specific additional growth margins for the later addition of directed energy weapons (laser or microwave) or an active electronic attack system.

Graphic: US Navy



This graphic shows the major differences between the original FREMM parent design and the FFG-62 variant.

Major Weapons, Sensors and Components

The CONSTELLATION class will be equipped with the AEGIS combat system (Baseline 10). It will have a scaled-down version of the three-faced AN/SPY-6(V)3 E\NTERPRISE AIR SURVEILLANCE RADAR (EASR) originally developed for later Ford (CVN-78) class aircraft carriers on its forward superstructure. The forward superstructure will also house the AN/SLQ(V)6 electronic warfare suite.

Major weapon systems for the FFG-62 will include a Mk 110 57mm deck gun; 32 Mk-

Photo: Fincantieri

A concept image of the FFG-62 design's starboard profile. Weapon systems and sensors are clearly visible.

Photo: Fincantieri

A concept image of the aft starboard view of the FFG-62 design. The hangar will accommodate one manned and one unmanned helicopter.

Photo: Fincantieri

Ground breaking for the new Fincantieri Marinette Marine construction facility at the FMM shipyard in Marinette, Wisconsin, where the CONSTELLATION (FFG-62) class will be produced

41 Vertical Launch System (VLS) tubes integrated into the foredeck; midships-deck-mounted box launchers for 16 over-the-horizon anti-ship missiles; and a 21-cell ROLLING AIRFRAME MISSILE (RAM) launcher. The VLS launchers will initially be capable of carrying a mix of STANDARD MISSILE 2 (SM-2) and EVOLVED SEA SPARROW MISSILES (ESSM); there has been no official change to early US Navy statements that ESSM (packed four missiles per VLS tube) would constitute the primary load for the Mk-41 system. The Anti-Ship Cruise Missile (ASCM) arsenal is likely to consist of the Kongsberg NAVAL STRIKE MISSILE (NSM). In coming decades additional weapons may be added to the arsenal. The self-defence capabilities will include the NULKA active missile decoy system and the AN/SLQ-25 NIXIE towed torpedo decoy system. Two 7 metre RIBs will be carried in covered bays in the aft superstructure.

The aviation section will encompass a manned MH-60R helicopter as well as the MQ-8C Unmanned Aerial System (UAS).

Regarding other shipboard components, the US Congress has mandated exclusive use of US-sourced components for certain equipment categories, including air circuit breakers; gyrocompasses; electronic navigation chart systems; steering controls; pumps; propulsion and machinery control systems; totally enclosed lifeboats; auxiliary equipment pumps; shipboard cranes; auxiliary chill water systems; and propulsion propellers. As of the eleventh ship, the mandate will extend to US-sourced propulsion engines and propulsion gears. As a percentage of cost, ultimately 96 percent of the vessels components will be US-sourced.

A December 2020 Congressional conference report voiced concern that this shift from the original (mainly European) component suppliers could entail "significant" technical risk. The conferees made the same determination regarding the "complex Combined Diesel Electric and Gas Hull, Mechanical and Electrical (HM&E) drive train that has not previously been used on U.S. Navy ships." For this reason Congress has mandated land-based testing of the FFG-62's entire engineering plant prior to sea-testing the first operational units.

Infrastructure Investments

Construction of the requisite government-owned test site began in the summer of 2021 in Pennsylvania. Captain Smith stated in August 2021 that the facility should be operational by the time the lead ship is delivered to the Navy. Integration testing of C4I systems and combat systems, as well as software specifically developed for the FFG-62, will also be conducted on land prior to at-sea testing.

For its part, FMM is making significant infrastructure investments as well, expanding production facilities at the Marinette Marine shipyard and at the Bay Shipbuilding facility, both in Wisconsin. The 8,360 square metre Bay Shipyard is FMM's site for naval steel processing, and includes module construction and hull erection facilities. The main shipyard at Marinette is twice as large and includes module and grand module construction facilities, as well as the final hull erection and outfitting facility. To support construction of the frigate – which is notably larger than the LCS constructed at Marinette – FMM is

installing a new shiplift capable of moving vessels of up to 10,000 tons displacement. This controlled and gentle launch method will allow the frigates to be outfitted to near completion and tested inside climate-controlled facilities before being launched into the adjacent Menominee River. Installation is being conducted by Pearlson Shiplift, and will be completed in 2020. Captain Smith confirmed in August 2021 that these capital improvements are proceeding on schedule.

Acquisition and Delivery

Formal FFG-62 procurement began with funding of the first-in-class vessel in the Fiscal Year 2020 (FY2020) defence budget. The cost of this unit comes in at US$1.28Bn. The second unit was funded in the FY2021 budget at US$1.05Bn and formally ordered in May 2021. The USN's FY2022 budget proposal includes procurement of one additional vessel plus advanced funding for two more units to be procured in subsequent years. The FY2021 budget submission had envisaged procuring two vessels per year from FY2023, and three ships in FY2025; however, it remains unclear whether this procurement tempo will be realised in light of budget constraints.

Increasing production beyond two ships per year would likely require contracting with a second shipyard. On 18 October 2021, the Senate Appropriations Committee included a provision in the draft 2022 defence authorisation budget that would require the Navy to eliminate "unneeded risk" in the design before expanding to a second contractor. The draft appropriations bill would require the Navy to prioritise "technology maturation and risk reduction for critical shipboard components; major systems integration; full ship technical data package creation; and successful operationally realistic testing for the first ship" and report achievement of these objectives to Congress before contracting with a second shipyard.

The US Navy is currently expressing confidence in the programme. Speaking in August 2021, Captain Smith stated that design maturity work was proceeding on schedule, and that the critical design review and production readiness review would be conducted in early 2022. This joint Navy-industry review will cover the basic and functional design for the ship's 34 design zones prior to the start of construction. Additionally, for each major construction module, FMM plans to complete the detail design and construction drawings before starting module construction in order to minimise risk during the construction phase.

Construction of the lead ship in the class is expected to begin in spring 2022. Barring delays in design or construction, it should be join the fleet in 2026 or 2027, Smith said. This should enable initial operational capability by 2029 or 2030. FFG Squadron One will be homeported in Washington State at Naval Station Everett. The first operational deployment is scheduled for 2030.

Construction of the first ten ships is expected to be completed in 2035, according to the April 2020 contract award announcement. The US Navy currently plans to acquire a total of 20 Constellation class frigates. However, the US Navy's impending shift to more distributed concept of operations may ultimately result in a larger frigate procurement. ■

Note:

1. Five teams – headed by Austal USA, Fincantieri, General Dynamics Bath Iron Works, Huntington Ingalls Industries and Lockheed Martin – were initially awarded contracts to develop conceptual designs for the FFG(X) programme. Of these, Lockheed Martin subsequently withdrew from the competition.

Developments in the Global Sonar Market

Bob Nugent

This article reviews current and future developments in the field of naval sonar, with specific focus on sonar markets, drawing on proprietary data from naval market experts AMI International. It begins by looking at the current state of sonar fit in the world's naval forces, presenting information on the four main types of naval sonar: hull-mounted, towed array, variable depth, and flank array.

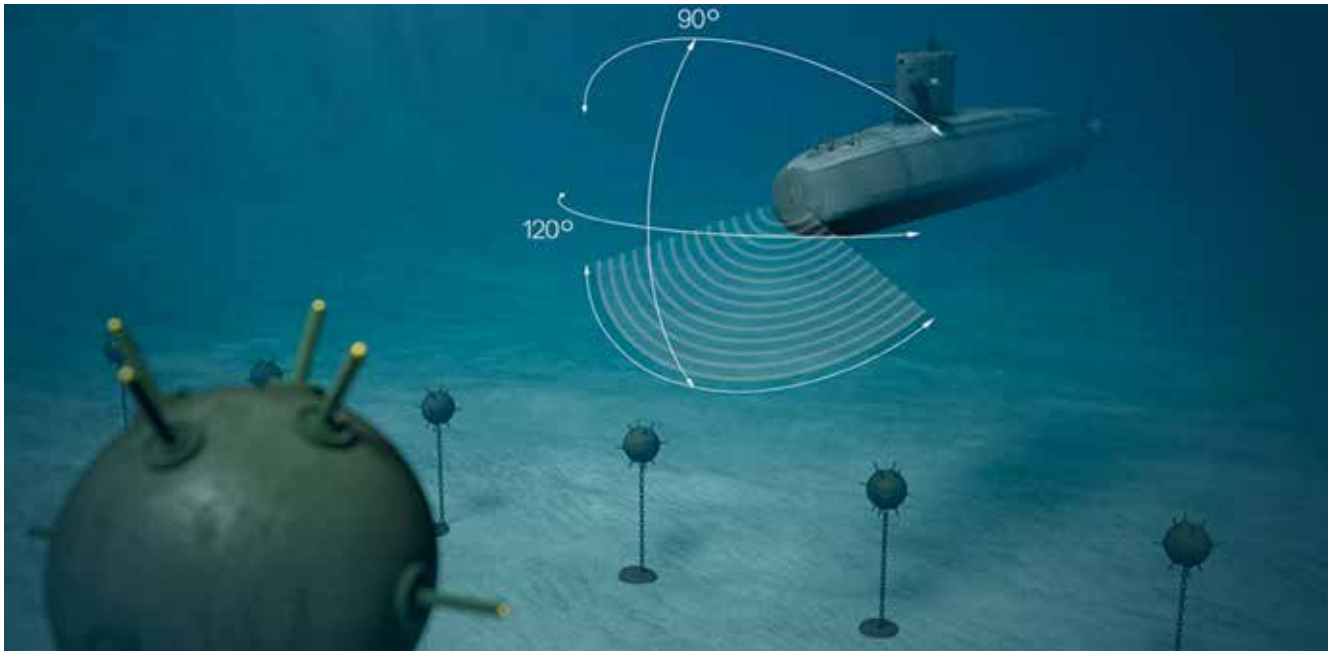


Photo: Kongsberg

Kongsberg`s hull-mounted active mine detection and avoidance sonar for submarines. The sonar is capable of detecting bottom mines, moored mines and floating mines, as well as other objects.

Next, the article examines prospects for the naval sonar market in the coming two decades, using AMI's detailed forecast of future markets for ship and submarine-mounted sonars. Finally, it reviews recent technological, operational and acquisition developments in naval sonar that suggest how this key naval capability will further evolve in its second century of service.

Author

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Introduction

It has been just over 100 years since the sonar became practical as a remote sensing device for naval operations. Sonar remains a primary means to detect and localise underwater objects of tactical interest—most prominently submarines. The state of the sonar art has accelerated in the last two decades with technological advances in two main areas—information technology for signal processing, and materials science affecting most components of sonar systems. Taken together, these technology drivers have

Ships with	Ships Commissioned		Ships Commissioned	
	All Years	%	2000-2021	%
Hull	2348	58.85%	824	35.10%
Towed	819	20.53%	363	44.30%
VDS	592	14.84%	157	26.50%
Flank	231	5.79%	118	51.10%
Total	**3990**		**1462**	**36.6%**

	Region-All	Commissioned 2000-2021							
	Asia-Aus	NATO	Non NATO Eur	US	Russia	MENA	Carib/Lat Am	Sub Sah Africa	Total
Hull	416	167	7	80	59	65	15	15	824
%	50.5%	20.3%	0.8%	9.7%	7.2%	7.9%	1.8%	1.8%	100.0%
Towed	176	71	3	74	25	11	3	0	363
%	48.5%	19.6%	0.8%	20.4%	6.9%	3.0%	0.8%		100.0%

Name	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Sonar Hull	75	81	73	88	94	89	89	77	76	67	52	42	45	38	36	29	28	16	17	12
VDS Sonar	19	25	20	32	26	34	35	30	25	14	9	13	8	12	7	5	3	5	3	3
Sonar Towed Array	32	34	31	37	39	34	43	35	39	37	30	24	24	21	23	21	21	15	15	11

increased the effectiveness and reduced the size, weight, power and cost of sonar systems. These technological advances in sonar systems come at time when the options for platforms to deploy sonars are expanding. Notably, unmanned maritime systems (surface and underwater vessels) are emerging as more effective and longer range platforms with sufficient space and power to mount some sonar sets. Equipped with better sonars, USVs and UUVs promise to further complicate the already challenging business of operating submarines at sea undetected.

Current Market Scope – Ships in Service

The AMI Existing Ships Data Base (ESDB) identifies almost 4,000 sonars now in service in all navies around the world. The four different sonar types installed on ships or submarines now in service are hull, towed, varable depth, and flank (submarine).

Breaking down the percentages for all sonar shows that the hull type is most numerous, representing almost 60% of all types of sonars (2,348 of 3,990 sets) on ships and submarines now in service (all ages). Towed array types are next most common, making up over 20% (819 of 3,990 sets).

A look at the current fit for the most modern ships and submarines, those commissioned since 2000, shows 1,462 sonars in service, or 36% of total world naval inventory. This suggests that,with over 2/3s of current sonar on ships and submarines over 20 years old, modernisation will only grow in importance when looking at market activity for sonar systems.

Another observation is that towed sonars are more numerous than hull sonars on more modern ships as a percentage (44% compared to 35%). This highights the development of towed arrays as especially suited for detecting modern submarines at extended ranges. As noted above, the growth in towed array systems has been aided by reductions in their size and weight, and improvements in signal processing.

The chart above provides a regional assessment of the existing sonar market on ships commissioned since 2000. The Asia Pacific region has the largest share of the current hull and towed array segments, reflecting the more general increase in naval spending on new ships in the area over the past two decades. About 50% of all hull and towed sonars globally are equipping Asia-Pacific navies.

NATO navies (excluding the US) and the US Navy remain heavily invested in sonar capability, with the two areas accounting for between 30-40% of hull and towed sonar worldwide. The other regions of the world make up the difference, with Russia and the MENA region leading the rest of the table. The paucity of sonar equipment in navies of the Caribbean/Latin America and Sub-Saharan Africa regions is explained both by the more limited numbers of submarine targets found in those regions, and constraints on overall naval ship-building budgets.

Future Market Scope

AMI's World Naval Projections Report (WNPR) forecasts new naval ship and submarine contruction worldwide through 2041. This two-decade forecast segments the sonar market into the same three types of systems: hull, variable depth and towed array. Hull-mounted sonar on both surface ships and submarines are the most numerous in the forecast, with over 1,100 systems of that type projected to be acquired. This represents just over half of the future market for the 20 years period, with variable depth and towed array sonars combined

Sonar Type	2021	2022	2023	2024	2025	20 yr Total	20 year %
Sonar Hull	75	81	73	88	94	**1124**	**55.7%**
VDS Sonar	19	25	20	32	26	**328**	**16.3%**
Sonar Towed Array	32	34	31	37	39	**566**	**28.0%**
Total	**126**	**140**	**124**	**157**	**159**	**2018**	
Annual %	**6.24%**	**6.94%**	**6.14%**	**7.78%**	**7.88%**		
5 year % of 20 years					**34.99%**		

making up the other 45% of the market. Since more than one sonar can be fitted to a ship or submarine, the 1,100 sonars in the table above represent installation on a fewer number of ships.

Ship construction contracts, and their system fits, are concentrated in the nearest five years period out to 2026. This pattern helps explain why future sonar acquisitions in the data are "front-loaded," with about 35% of forecasted sonar acquisitions found in the 2021-2026 period. The chart below examines estimated future sonar buys for this period, and compares the percentages and trends for each of the three types to numbers for the 20-year period.

The near term market forecast for sonars is representative of the longer term projections. Breakdowns by market subsegment in that five year period shows patterns similar to the 20-year forecast: just over 50% of the near-term market is for hull-mounted sonars, just under 30% for towed arrays, and close to 20% for variable depth sonar.

Hull Sonar	For Ships Commissioned 2000-2021		
Supplier	**Number of Sonar Sets**	**% of 576**	**% of 824**
Thales	144	25.00%	17.50%
ATLAS	105	18.23%	12.70%
Raytheon	98	17.01%	11.90%
SIMRAD (now Kongsberg)	65	11.28%	7.90%
Lockheed Martin	52	9.03%	6.30%
Kongsberg	33	5.73%	4.00%
BEL (India)	27	4.69%	3.30%
NEC/Mitsubishi (Japan)	20	3.47%	2.40%
BAE	14	2.43%	1.70%
L-3/Nautik (now Wärtsilä ELAC Nautik)	9	1.56%	1.10%
Ultra	9	1.56%	1.10%

Supplier Positions

The sonar market features a number of highly effective and competitive offerors. The chart on the next page shows the relative market position of US, European, Japanese and Indian manufacturers of hull sonars equipping ships now in service (the 824 sets equipping platforms commissioned since 2000-highlighted in yellow). Taken together, the companies indicated make up about 70% of all hull sonar types now operating. Additionally, Chinese and Russian sonar producers remain the primary source for new hull sonar in those navies, which also represent sizable numbers of sonars going to sea.

Germany's Atlas Elektronik and French-Dutch Thales are the leading manufacturers of sonar on the European side of the market, representing 18% and 25% (respectively) of the market represented by 576 sonar sets equipping navies outside Russia, China and other non-addressable markets such as Iran and North Korea. Norway's Kongsberg (including ex-Simrad) British companies BAE and Ultra also make up a notable part of this market segment.

On the US side, Lockheed Martin and Raytheon Technologies have the strongest position in the US market. Both European and US companies also compete effectively in the sonar export market.

Recent Developments

As noted above, the joining of sonar and unmanned maritime platforms offers budget-constrained navies some promising alternatives in fielding more effective anti-submarine warfare systems. As mentioned in a recent US Naval Institute article, NATO's Centre for Maritime Research and Experimentation continues to organise exercises and tests of this approach. Exercises such as the DYNAMIC MANTA event continue to offer a venue for novel combinations of new sonar and unmanned host platform capabilities. While the unmanned platform is not likely to replace manned multi-mission surface combatants or submarines as the leading choice for new sonar deployments, they promise to contribute to the ASW mission (and anti-mine or other barrier defense applications of sonar).

Deployment of sonar in fixed acoustic arrays linked to the shore is another proven operational configuration being tested for new sonars. The US Navy's Office of Naval Research is seeking solutions for the Affordable Mobile Anti-Submarine Warfare Surveillance System (AMASS). The goal of the programme is to field a persistent, deep water, active Anti-Submarine Warfare system (ASW) that can detect new emerging threat submarines at extended ranges."

The Naval Research Lab is also exploring Low Frequency Broadband (LFBB), an active sonar using advanced synthetic aperture processing drawing on advances in Artificial Intelligence (AI). The ability to extract even more tactically and operationally significant information from low frequency returns using advanced information technologies will prove critical for detection and classification of submarine targets.

Existing sonars are also seeing investments to upgrade their performance. Pennsylvania State University's Applied Research Laboratory is working with the US Navy's Surface Warfare Centers in Crane, Indiana and Newport, R.I. in areas that include sonar development. Tests include the work on the TR-343 transducer, a core component of the AN/SQQ-89(V) undersea warfare combat platform now equipping US Navy DDG-51 destroyers. This work is taking place under a 10-year US$2.1Bn contract awarded in 2018.

Major Surface Combatant Procurement: Status Report

Conrad Waters

Acquisition of major surface combatants – destroyers, frigates and corvettes – continues to see healthy growth. The pressing need to replace life-expired vessels, often deferred during the post-Cold War period, has been supplemented by the need to bolster maritime capabilities given the re-emergence of international tensions and great power competition. Asian economic growth, the current pandemic notwithstanding, remains another important market driver. This review provides a brief status report of the major programmes currently underway.

Europe

The procurement of major surface combatants in Europe is currently being driven by two competing factors. Having spent much of the post-Cold War period reconfiguring their surface forces away from traditional high intensity operations, many of Europe's navies are now embarking on another period of change as they seek to counter the threat of Russian "expansionism". This is placing an increased emphasis on the procurement of "high end" surface combatants that are capable of sustaining operations in the face of a full spectrum of threats. The other key consideration driving procurement relates to the desire to maintain industrial infrastructure and associated employment, a factor that continues to place an emphasis on securing overseas sales. As affordability tends to be a key success factor in export markets, this is driving ongoing demand for less capable vessels.

Photo: DAMEN Schelde Naval Shipbuilding B.V.

Damen's MKS-180 (F126) frigate design for the German Navy.

Germany's current procurement is a good example of the former trend. With completion of deliveries of the quartet of F125 BADEN-WÜRTTENBERG class "stabilisation" frigates now imminent, attention is now focused on the successor F126 (MKS180) design. In contrast to their predecessors, these c. 10,000 tonne leviathans will be highly capable multi-mission combatants supported by a significant amount of built-in modularity. Four members of the class are scheduled for delivery between 2028 and 2031 and there are options for a further two ships. A notable feature of the F126's acquisition is the appointment of Dutch Damen as lead contractor, albeit that construction will still take place in Germany. Whilst preparation for the start of physical work is completed, shipyard capacity is being kept busy by the assembly of the second batch of five K130 BRAUNSCHWEIG class corvettes by the ARGE K130 consortium.

France's surface warship construction is also in a transitionary phase as the completion of FREMM multi-mission frigates is giving way to the ramp up of work on the FDI (Frégate de Défense et d'Intervention) type vessels of the AMIRAL RONARC'H class. Fabrication work on the first of five vessels commenced at Naval Group's yard at Lorient in October 2019. Formal keel-laying is expected before the end of 2021 prior to the commencement of deliveries in 2024. Intended to be a relatively sophisticated but smaller and cheaper alternative to the FREMM, the c. 4,500 tonne FDI is focused on driving export sales. This ambition has already gained initial success with the signature of a memorandum of understanding with **Greece** in September 2021 to sell the Hellenic Navy three of the type (plus one option).

The **United Kingdom's** Royal Navy has ongoing programmes for both "high end" and "low end" frigates. The former requirement is being met by BAE Systems' c. 7,000 tonne Type 26 Global Combat Ship (GSC), a multi-mission design optimised for Anti-Submarine Warfare (ASW). Three of a planned total of eight ships have been ordered to date, with launch of the lead ship, GLASGOW, scheduled within the next 12-months. The basic design has also been adopted by Australia and Canada as the basis for their own frigate programmes. Meanwhile, fabrication of five of the less complex Type 31 frigates commenced at Babcock International's Rosyth facility in September 2021, when first steel was cut on the class's lead ship, VENTURER. De-

rived from the Danish IVER HUITFELDT, the Type 31's modular design allows it to be configured to meet a wide range of customer specifications. The type's export variant – marketed as ARROWHEAD 140 – has already achieved its first success with the signature of an agreement with **Indonesia's** PT PAL for licensed construction of two of the frigates.

Spain's surface warship construction over the coming decade will be dominated by the five F110 frigates of the BONIFAZ class, which will be built at the Navantia facilities in Ferrol. Authorised in 2019, the programme will replace the Spanish Navy's existing FFG-7 type frigates. The design is broadly similar in concept to the British Type 26 in being a multi-mission ship with a primary ASW emphasis.

As is the case for France, **Italy's** FREMM programme is starting to reach the end of production for domestic naval requirements. However, an additional pair of ships is required to replace the two transferred to **Egypt** when close to completion and six additional ships were ordered by **Indonesia** in June 2021; two to be assembled locally. Fincantieri are also heavily occupied building the seven frigate-like PPA patrol vessels of the PAOLO THAON DI REVEL class ordered in different configurations under the 2014 Naval Law. It can also anticipate the start of construction on two new DDX destroyers by the middle of the decade. These ships are needed to replace the existing pair of DURAND DE LA PENNE class destroyers. Preliminary concepts suggest they will be large ships with a displacement in the region of 10,000 tonnes and significant air defence capabilities.

Elsewhere in Europe, **Belgium** and the **Netherlands** are likely to sign contracts for the two pairs of 'ASWF' anti-submarine warfare optimised frigates being jointly procured for their navies within the next few months so as to allow deliveries to commence around the end of the decade. Construction will be in the hands of Damen, although it is not yet certain to what extent construction will be split between their Dutch and Romanian facilities. **Romania's** own naval modernisation plans appear to be on hold after reports that a deal for four Naval Group GOWIND corvettes – to be assembled locally by SNC – has been suspended. The situation in neighbouring **Bulgaria** is more positive following conclusion of contract negotiations with NVL (formerly Lürssen) for two corvette-like multi-purpose modular patrol vessels towards the end of 2020. The ships will be built by the Bulgarian MGT Dolphin shipyard in Varna and delivered in the 2025 and 2026 timeframe. Meanwhile **Turkey** continues to make progress with building the first of its four planned ISTANBUL class frigates following launch of the lead ship in January 2021. Commencement of the more ambitious and much delayed TF-2000 destroyer programme will probably await completion of modernisation of the navy's MEKO 200TN Batch 2 BARBAROS class frigates by an Aselsan-Havelsan consortium, which will test many of the systems intended for the new ships.

Turning to the Baltic, **Finland's** "Squadron 2020" fleet renewal programme should see tangible progress in 2022 with commencement of physical construction of the first of four new POHJANMAA class cor-

Photo: Fincantieri

Fincantieri are heavily occupied building the seven frigate-like PPA patrol vessels of the PAOLO THAON DI REVEL class ordered in different configurations under Italy's 2014 Naval Law.

Photo: Conrad Waters

Russia's STEREGUSHCHIY class corvettes – this is BOIKIY – continue to form the basis of the modernisation of its force of green water surface combatants.

Graphic: Dutch Ministry of Defence

A graphic of the ASWF frigate that will be built by Damen for the fleets of Belgium and the Netherlands.

Photo: Navantia

AL-JUBAIL, the lead ship of Saudi Arabia's five Navantia-built AVANTE 2200 corvettes – in the course of preliminary sea trials.

vettes. In spite of some delays, it is hoped that all the ships will be in service by the end of 2028. Elsewhere in the region, Poland will soon make a decision on its preferred design partner for three new frigates being acquired under the MIECZNIK (SWORDFISH) programme. The frigates are to be built by the PGZ-Miecznik consortium, with designs from Babcock International (ARROWHEAD-140), Navantia (F-100 derivative) and TKMS (MEKO A300) shortlisted for licensed construction.

Russia

Although the re-emergence of **Russia** as a potential military threat has had a significant impact on recent "Western" naval procurement, its own construction of major warships has been restricted by the need to overcome the period of fragmentation and neglect that followed the Soviet Union's collapse. The prioritisation attached to modernising strategic underwater assets and an institutional preference for smaller surface combatants has also served to limit investment in larger surface ships.

Current construction of major surface combatants has two main strands. The largest, more complex vessels are the Project 22350 ADMIRAL GORSHKOV class frigates. Intended for blue water operations, these are now being built in considerable numbers following orders for the ninth and tenth units from United Shipbuilding Corporation's Saint Petersburg's Severnaya Verf facility in the summer of 2020. Russian press reports indicate that the design of a larger and improved Project 22350M frigate is close to completion, suggesting any further orders will be for the new type. The second strand of procurement is focused on the Project 20380/85/86 series of STEREGUSHCHIY class green water corvettes. Built both by Severnaya Verf and the Amur Shipbuilding Plant in Russia's Far East, a total of twelve Project 20380 and six Project 20385 corvettes have been ordered to date. Work also continues on the new Project 20386 class vessel MERKURIY, a stealthier development of the corvette line that might well form the basis for future acquisitions.

Photo: Japan Ministry of Defence

Japan's new MOGAMI class frigates – this is KUMANO – are seen as being crucial to increase its number of major surface combatants.

Middle East & Africa

Military spending in the Middle East and Africa is inevitably dominated by the former region. Here several significant naval capitalisation programmes involving major surface combatants are underway against a backdrop of ongoing regional tensions. Prominent amongst these is **Saudi Arabia's** recapitalisation of its Persian Gulf-based Eastern Fleet with ships supplied by the United States and Spain. America's Lockheed Martin has been contracted to provide four SAUD class multi-mission surface combatants; more heavily-armed derivatives of the FREEDOM (LCS-1) littoral combat ship design. Fincantieri's Marinette Marine is sub-contracted to undertake the actual construction, with two of the quartet now under fabrication. These will be supplemented by five corvettes based on Navantia's AVANTE 2200 design. The lead ship, AL-JUBAIL, commenced sea trials in September 2021.

Other Gulf nations investing in their surface fleets include **Qatar** and the **United Arab Emirates (UAE)**. The former is close to seeing the first tangible fruits of its massive 2016 contract with Fincantieri that encompassed four c. 3,250 tonne air-defence "corvettes" as well as two smaller but heavily armed "offshore patrol vessels" and an amphibious transport dock. Three of the corvettes have now undergone sea trials and the first was delivered at the end of October 2021. Meanwhile, the UAE is making further investment in its indigenous shipbuilding capacity with the announcement of a contract with local Abu Dhabi Shipbuilding (ADSB) to acquire four corvette-like FALAJ 3 offshore patrol vessels in what was stated to be the company's largest ever order. The ships will be designed with the assistance of Singapore's ST Engineering, which has previous regional experience through supplying vessels to Oman. The UAE also has outstanding contracts for two Naval Group GOWIND type corvettes that are currently in the course of construction at Lorient.

The NAVY 18 WP military combat boat is a valuable asset for any navy

The NAVY 18 WP is Baltic Workboats' latest addition to its naval vessels portfolio and is designed to meet the most challenging operational conditions and missions. Specifically designed with naval forces and coastguards in mind, the NAVY 18 WP fulfils an extensive range of missions, such as anti-piracy, anti-terrorism, maritime traffic interception, and surveillance of territorial waters. The NAVY 18 WP is capable of carrying out missions alone, but is also ideal as a support vessel for larger naval ships. Its shallow draft and excellent handling characteristics make this vessel ideal for operations in coastal areas with varying depth and weather conditions. The NAVY 18 WP is designed to be operated by a crew of two to six persons. The vessel has an overall length of 17.5 metres and its maximum speed is in excess of 30 knots. As with most of Baltic Workboats fast vessels, the hull is designed with a patented wave piercing bow design which enables it to reduce the vertical accelerations of the vessel in heavy seas by up to 40 per cent, reduces fuel consumption at high speeds up to 20 per cent and significantly improves sea-keeping and handling characteristics in rough conditions. The NAVY 18 WP is also designed as a self-righting vessel which has become standard for Baltic Workboats for all patrol and pilot boats of a similar size. Baltic Workboats has delivered two NAVY 18 WP vessels to the Estonian Navy in 2021 and is currently fulfilling an order of 14 vessels on the same platform to a Middle Eastern customer. The first vessel of this order was delivered and accepted in September.

The NAVY 18 WP is designed with numerous features to best suit navy needs. The vessel is equipped with a Remote Weapon Station (RWS) Herstal SEA DEFENDER at the bow deck which is operated from a control station in the wheelhouse. The Herstal SEA DEFENDER RWS features gyroscopic stabilisation, a day and night camera, target tracking and image stabilisation. It can integrate all FN Herstal machine guns up to .50 calibre, including the unique FN® M3R with its high firing rate of 1,100 RPM. In addition, the vessel can be fitted with two light machine guns such as the MG3 on the aft deck engine room vent boxes. Areas of the vessel such as the wheelhouse, engine room and accommodation area can also be fitted with ballistic protection panels to guarantee crew and vessel safety during hostile encounters. Furthermore, the aft deck railing and engine room ventilation boxes can be built as an integrated ballistically protected bulwark to offer protection to the light machine gun operators on the aft deck. The vessel is also equipped with the gyrostabiliser SEAKEEPER 7HD to guarantee best sea-keeping characteristics and an ergonomic work environment for the crew in all weather conditions.

The NAVY 18 WP has an aft platform, close to the waterline which allowing it to be used for diving operations. The vessel's perimeter at main deck level has heavy duty fender protection enabling it to board other vessels at high speeds in challenging conditions.

The ship's propulsion system includes two Volvo PENTA D13 1,000 marine diesel engines with a combined total power of 1,470 kW and ZF 665V gear boxes which drive two fixed pitch propellers. The sailing range of the vessel at a speed of 25 knots is over 225 nautical miles. The vessel can be fitted with a bow thruster as an option to increase manoeuvrability in tight areas such as ports and rivers.

The control and monitoring of all vessel systems such as propulsion, steering, navigation lights, ventilation and heating, tank levels, status of watertight doors, operation of pumps, etc. is carried out from the captain's position from a single touchscreen thanks to Baltic Workboats in-house developed IAMCS (integrated alarm, monitoring and control system). This helps Baltic Workboats to adjust IAMCS according to each specific vessel and customer so that the operation of the vessel is optimised and programmed taking account specific needs of each customer.

The NAVY 18 WP has an accommodation area below deck, which features six bunk beds, toilet, kitchenette, and seating area with table, enabling multi-day missions without the necessity of logistical support from shore. Special attention is paid to storage solutions with the vessel equipped with numerous lockers on the aft and fore decks, in the wheelhouse and in the accommodation area in order to facilitate the storing of deck equipment, as well as special equipment and weapons for the crew.

All in all, the NAVY 18 WP is designed and built in close cooperation with navy units taking account their specific needs and requirements. Features such as RWS, ballistic protection, gyrostabiliser and its wave piercing hull design make the NAVY 18 WP a valuable asset which would complement any navy.

Photos: Baltic Workboats

Israel's most significant surface ship procurement programme is now drawing to a close with the arrival in country of the last of the four SA'AR 6 (MAGEN class) corvettes that were ordered from TKMS with German financial assistance in 2015. Actually built by German Naval Yards Kiel, the ships are being outfitted with sensors and weapons systems by Israel Shipyards prior to entering operational service. Israel Shipyards are also in the course of undertaking the detailed design of the SA'AR 72 (RESHEF class) corvettes that will ultimately supplement the larger MAGEN class and replace older fast attack craft.

Egypt's remarkable programme of regional naval expansion- involving acquisitions from a diverse range of sources – has already seen renewal of much of its surface fleet. Assembly continues in Alexandria of the final pair of the quartet of GOWIND type corvettes being acquired from Naval Group whilst TKMS' MEKO A-200 frigates are being fabricated under sub-contract by the Rönner Group. It is believed that three of the class will be completed in Germany and the fourth at Alexandria. There has been less tangible news of further acquisitions from North Africa's other major naval power, **Algeria**, although it is believed a class of at least three new corvettes based on China's Type 056 design are close to delivery.

Photo: US Navy

The Indian Project 15B destroyers are a modified variant of the early Project 15A KOLKATA class design, pictured here.

Photo: Huntington Ingalls Industries

The failure of the US Navy's ZUMWALT (DDG-1000) class programme has meant that it has continued to rely on iterations of the veteran ARLEIGH BURKE (DDG-51) class design – this is DELBERT D. BLACK (DDG-119) – for major surface combatant construction.

Asia-Pacific

The expansion of **China's** People's Liberation Army Navy (PLAN) continues to drive warship procurement in the Asia-Pacific region. The PLAN's own recent acquisition of surface combatants has followed three main strands encompassing (1) Type 052D destroyers, (2) Type 054A frigates and (3) Type 056/56A corvettes. The first-mentioned class – encompassing 25 units launched to date – has recently been supplemented by eight new Type 055 'RENHAI' class vessels, cruiser-sized ships displacing in the region of 12,000 tonnes. Both types are built by Dalian Shipbuilding and the Jiangnan shipyard close to Shanghai. However, neither yard has launched any of either class since the summer of 2020, possibly suggesting that the PLAN wishes to assess the operational performance of these classes before incorporating lessons learned in a new design.

The Type 054A frigates are the workhorses of China's fleet. Production paused with the completion of 30 ships in 2019 but further units are now in the course of assembly, possibly of a revised design. In additional, four Type 054A/P variants are being built for **Pakistan's** navy. Construction of the Type 056 series for the PLAN ended after the delivery of 72 ships early in 2021. However, the diminutive corvette design continues to be promoted for export.

Japan's naval programmes are inevitably heavily influenced by the PLAN build-up, with current policy based on expanding the surface fleet to 54 units (including four "helicopter carrying destroyers"). This objective is reflected in construction of the new 30FMM MOGAMI class frigates, eight of which have been authorised to date. Displacing around 5,500 tons at full load, these are smaller than recent JMSDF surface combatants and extensive automation allows operation by a smaller crew. Japan also has a requirement for two additional AEGIS-equipped ships following its decision to abandon AEGIS-Ashore installations but it is not yet certain that these will be surface combatants in the traditional sense.

South Korea has one of the region's largest naval procurement programmes. This includes both blue water and green water surface combatants. Construction of the former is being focused on three AEGIS-equipped KDX-III Batch 2 destroyers, on which Hyundai Heavy Industries (HHI) commenced fabrication of the first in February 2021. The lead ship is expected to complete late in 2024 and will be joined by her sisters in 2026 and 2028. Current plans then envisage production progressing to a smaller KDX-IV destroyer, which will utilise an entirely indigenous combat management system. Meanwhile, HHI and DSME are continuing construction work on the eight FFX Batch II DAEGU class frigates, of which two have been delivered to date. These will be followed by six FFX Batch III variants for which HII is currently completing detailed design work and, ultimately, a FFX Batch IV type. The FFX design has also formed the basis of exports to the **Philippines** and **Thailand**.

Australia's ambitious shipbuilding programme encompasses the construction of nine HUNTER class frigates by BAE Systems' local subsidiary to a variant of the company's Type 26 GCS. Fabrication of prototype blocks has already commenced at the building yard in Osborne, South Australia but the need to undertake significant redesign work to accommodate Australian requirements has pushed the start of actual construction back and deliveries will not now commence until the early 2030s.

Elsewhere in the Asia-Pacific region, acquisitions by Indonesia, the Philippines and Thailand have already been touched upon. Modernisation of **Malaysia's** surface fleet

continues to be delayed by Boustead Heavy Industries' troubled implementation of the contract to build Naval Group designed GOWIND type frigates. Neighbouring **Singapore** is looking to replace its current VICTORY class corvettes with its new Multi-Role Combat Vessel (MRCV) concept, which is expected to rely heavily on off-board, autonomous systems to extend its operational reach.

Like China, **India's** surface combatant procurement is based on several types. The largest and most sophisticated ships are the c. 8,000 tonne Project 15B VISAKHAPATNAM class destroyers. A quartet of these ships, modified from the three preceding Project 15A KOLKATA class design, has been under construction by Mazagon Dock Shipbuilders Ltd (MDSL) since 2013 and the lead ship was delivered at the end of October. MDSL is also sharing work with Garden Reach Shipbuilders & Engineers (GRSE) on seven slightly smaller Project 17A stealth frigates, which are all expected to be delivered by the middle of the decade. Whilst India has made progress with modernising its shipbuilding infrastructure, past experience suggests that his might prove optimistic. This may well account for the contract for four modified Project 11356 TALWAR class frigates signed with Russia at the end of 2018 in spite of the current government's "Made in India" mantra. Two of these ships will be completed by the Yantar yard in Kaliningrad using hulls previously designated for the Russian Navy. The other pair are being completed under licence by Goa Shipyard in India, which commenced work on its own lead ship in January 2021.

The Americas

Procurement of major surface combatants in the Americas is inevitably driven by the **United States'** requirements. US Navy acquisition programmes have continued to be impacted by the design dead-ends that were the ZUMWALT (DDG-1000) class destroyers and littoral combat ships. Termination of the former project has seen continued production of the latest iterations of the veteran ARLEIGH BURKE (DG-51) class, a design that has now been in service for more than 30 years. These ships continue to be acquired under multi-year procurement contracts with Bath Iron Works and Huntington Ingalls Industries, with a further multi-year buy anticipated for FY2022-2027. Production will then transition to the new DDG(X), for which a program office (PMS 460) was established in June 2021. Meanwhile, as construction of the littoral combat ships draws towards a conclusion, smaller major surface combatant production is increasingly focused on the CONSTELLATION (FFG-62) class frigates. Derived from Italy's FREMM variant, the initial units of a planned 20 ship class will be constructed by Fincantieri's American Marinette Marine subsidiary. This programme is described in more detail elsewhere in this issue.

Canada has also selected a foreign design for its new Canadian Surface Combatant programme in the form of BAE Systems' GCS. The design effort for the new ship is being led by Lockheed Martin Canada and construction will take place at Irving Shipbuilding's Halifax yard. Recent reports suggest fabrication of an initial batch of three of the frigates will commence in 2023, with as many as 15 ships ultimately expected.

With naval requirements in Latin America dominated by constabulary and logistics support vessels, most regional naval aspirations for replacement frigates are on the back burner. A major exception is **Brazil's** programme for four TAMANDARÉ class frigates. Scheduled for local assembly by the TKMS/Embraer Águas Azuis consortium utilising the former's MEKO technology, an initial batch of four ships should be in service before the end of the decade. ■

Masthead

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Warship Habitability Today

Bruno Huriet

Imagine you are boarding a recently built European frigate. After exploring its sensors, weapons and propulsion system, you should take the opportunity to examine how the crew's living quarters are arranged. Most probably, you will find that the ratings and petty officers have "cabins" instead of large berthing areas. These will be equipped with two-tiered bunks for between two and four people, large lockers and wardrobes, and each cabin will also have its own attached sanitary unit. When sailing, noise levels and vibrations will be at an acceptable level. Obvious care will have been taken with the decorative scheme. Meals will be prepared in an easy to clean, stainless steel-clad galley; after eating in a spacious dining room, the crew will be able to relax in a dedicated recreation space.

The Importance of Habitability

Habitability, the "quality of being fit to live in" covers all these points. Resting, washing, eating and even receiving proper medical care are all essential functions for life on board a modern warship. Inevitably, therefore, habitability is a point of focus for most navies. The US Navy document *Opnavinst 9640.1C* published by the Chief of Naval Operations (CNO) and updated in June 2019 provides an insight into current naval thinking: "Habitability is that military characteristic of US Navy ships directed toward satisfying personnel needs which are dependent upon physical environment…A warship cannot be designed around habitability factors alone, but conversely, habitability factors cannot be progressively sacrificed to other readiness elements without eventual degradation of mission readiness. Maintaining the appropriate shipboard quality of life within established habitability criteria supports positive moral and peak mission readiness".

Some serious, occasionally tragic recent events highlight the importance of habitability. To give just two examples:

- During the recent COVID-19 pandemic, at least two aircraft carriers, the US Navy's THEODORE ROOSEVELT (CVN-71) and the French Navy's CHARLES DE GAULLE had to shorten their missions due to COVID outbreaks affecting large proportions of their crews. Reports published after these events mention the density of berths – up to 30-40 per berth – in crew quarters as a contributory factor to the rapid spread of the virus.
- Investigations carried out after two separate collisions involving US Navy destroyers – FITZGERALD (DDG-62) and JOHN S. McCAIN (DDG-56) – noted that crew fatigue was part of the causes of these accidents; both resulted in the deaths of US Navy sailors.

The changes one can see in recent ships, as well as the improvements made to existing units, show that serious efforts are being made to improve warship accommodation. The factors driving these improvements are varied in their nature but are also often linked by common themes.

Author

Bruno Huriet is a qualified merchant naval officer who has worked for more than 20 years in the interior outfitting segment of the international shipbuilding industry.

Photo: US Navy

US Navy crew members relax in a mess deck on board the destroyer NITZE (DDG-94). Providing acceptable standards of habitability is crucial to effective mission readiness.

Recent Changes & Their Impact: Crew

Crew sizes are reducing; studies suggest that, perhaps between 30 and 40 percent of a ship's operating costs relate to personnel expenses. Navies, living within shrinking budgets, have had to take action in this regard. To take the example of German frigates:

- The Type 123 frigates of the BRANDENBURG class, delivered from 1994 onwards and displacing circa 4,900 tonnes, have a crew of circa 215 men.
- The Type 125 frigates of the BADEN-WÜRTTEMBERG class, delivered from 2019 onwards and displacing circa 7,200 tonnes, have a core crew of circa 125, of whom a portion are women.

Photo: German Armed Forces

The German F125 class frigate the BADEN-WÜRTTEMBERG operates alongside of two earlier F123 BRANDENBURG class ships. The new frigate is larger than its predecessors but requires far fewer crew members to operate.

The same evolution is found in the ships of other European fleets. This downsizing of crews has been made possible by extensive automation eliminating basic, repetitive, and non-essential tasks. A focus on ergonomics – the "human factor" – is now a fundamental part of a ship's design phase in order to optimise onboard workflows.

At the same time, the sophistication and increasing complexity of modern systems are driving a requirement for better qualified and more versatile crews: the non-specialist, often conscript sailor of the past has been replaced by the professional petty officer. Most navies have also opened up to female crewing, with women comprising an increasing proportion of the onboard workforce.

These various factors have been a significant driver of changes to habitability. Notably, the end of conscription and the transition to a professional force of volunteers has emphasised the competition with the civilian world to recruit and retain young, qualified specialists. If these sailors are to be persuaded to cut themselves off from their families and social life ashore, an appropriate living environment must be provided. It is becoming increasingly difficult to cram them into a 40-person berthing compartment with large, noisy communal washrooms.

Some of the major changes that have resulted include:

- More space per individual: The space per person ratios for cabins and communal areas has increased. A recent Italian Navy presentation by Admiral Claudio Boccalatte – *Progetto delle Navi Militari di Superficie* – suggested that, for ratings, the requirement has expanded by a third from 2.9m² to 3.9 m² per person. Within this uplift, the ratios for catering and entertainment areas had doubled.
- A switch from large berthing compartments to cabins with a limited number of berths: This is particularly noticeable in the main European navies, where cabins are provided from two to, at the most, eight berths on modern ships. Even in the more Spartan US Navy, berthing areas have come down from the 180 "racks" found in, for example, previous generation aircraft carriers to a much lower number today.
- Facilities are more comfortable: Beds on a maximum of two levels allow adoption of a sitting position. There is also often provision of an individual reading light, a socket for electrical equipment, a data connection and more spacious lockers.
- Layout changes to accommodate mixed crews: This has been one of the drivers of locating washrooms as close as possible to – or even within – cabins, avoiding the necessity of sailors having to move along passageways in order to reach them.

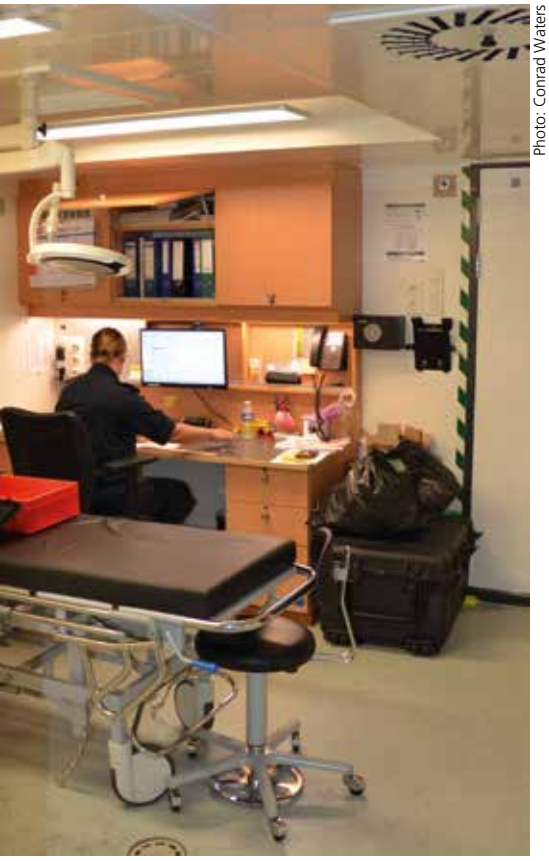


Photo: Conrad Waters

The medical facility onboard a Dutch HOLAND class OPV. Resting, washing, eating and even receiving proper medical care are all essential functions for life on board a modern warship.

Another objective has been to reduce chores, which are even more resented than usual when being performed by a lean and well-qualified crew. For example, providing smaller sanitary facilities close to cabins makes their maintenance more "acceptable" than having to clean large, collective facilities, particularly when constructed from "easy to clean" materials. The traditional provisioning detail – involving the whole crew passing boxes from the dockside to lower deck storage rooms – has been simplified by making stores and galleys more accessible to automated handling means.

Finally on this subject, recent analysis confirms – if this was ever needed – that sleep plays an essential role in a crew's ability to fight at high intensity. The US Naval Postgraduate School has published extensive studies and recommendations on this subject. In addition to optimising the watch system, their research demonstrates the design and construction of berthing quarters are fundamental to receiving good rest. The provision of darkness and silence – with no noisy recreation areas in the vicinity and an avoidance of frequent walk-throughs – are all critical to achieving this aim.

Recent Changes & Their Impact: Regulations

The rules and standards used to design naval ships have changed for two main reasons: the greater attention being paid to international conventions and the increasing adoption of classification society rules.

In recent decades there has been pressure on navies to become more aligned with the requirements of the major conventions applicable to civilian ships by adapting these to the peculiarities of naval operation. The International Maritime Organization (IMO),

Photo: ©Frédéric Lucas/Marine Nationale/Défense

A fire drill being performed in galley of the French amphibious assault ship MISTRAL. Fire safety standards onboard modern warships are being increasingly influenced by international standards.

a UN body, has responsibility for most conventions applicable to maritime activities. The IMO's conventions are transformed into laws by the signatory countries, which represent nearly all the world's merchant fleets. The most important of these are:

- The Safety Of Life At Sea (SOLAS) convention, which encompasses rules for ship stability, life-saving equipment, radio communication and fire safety. Inevitably combat ships do not follow all the requirements as they can be incompatible with their combat missions but they are a major design influence. Moreover, internationally-defined test procedures such as the Fire Test Procedure (FTP) Code for the classification of materials are increasingly being specified in naval construction.
- The International Convention for the Prevention of Pollution from Ships or MARPOL convention, first adopted in 1973 and since regularly updated. This has impacted warship habitability in areas such as the sorting of garbage and its stowage – extending to the provision of a dedicated cold room – and the treatment of waste water, including stowage to avoid discharges near the coast.

In addition to these international regimes, national rules in areas such as food hygiene, electrical and broader workplace safety are also taken into account. For example, US Navy ships typically refer to US Public Health rules relating to the storage of food and meal preparation.

In parallel with the growing influence of international conventions, classification societies have also taken on an increasing role in the preparation of standards and regulations governing warship construction. Private bodies, they publish detailed standards regulating construction (e.g. hull design and materials, machinery, electrical systems and fire protection); provide on-site inspectors to monitor assembly; and ensure vessels are maintained in good condition throughout their lives. Traditionally focused on surveying on commercial ships to provide assurance to ship owners, insurers and national authorities, they have become increasingly involved in setting standards for naval construction. Shifting this responsibility from bespoke standards provided by naval engineering departments has provided a means of independent quality control from external technical experts – particularly important when acquiring a warship from overseas – whilst allowing access to the latest technologies based on the international standards used in the much larger civilian market. A related advantage is increased access to Commercial Off The Shelf (COTS) equipment; it is – for example – much easier to acquire a mattress that has been tested with reference to a widely used FTP Code-defined requirement than one which needs to comply with a navy's own specification.

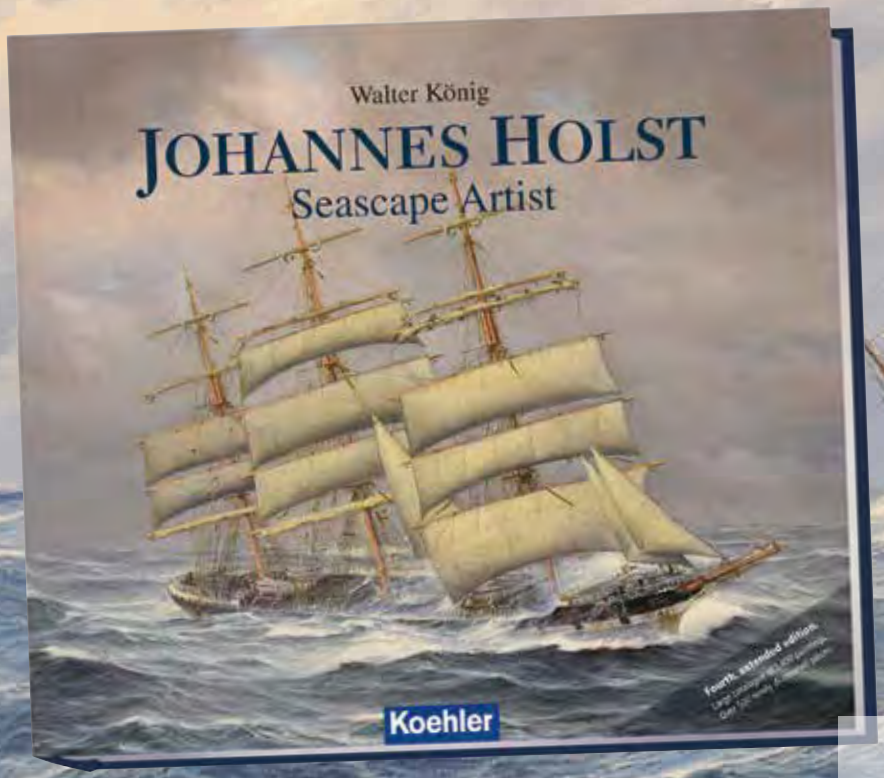
Amongst the more prominent classification societies are the American Bureau of Shipping (publisher of the International Naval Ship Guide), France's Bureau Veritas (Naval Rules), Italy's RINA (RINAMIL), the Norwegian DNV (Rules for Classification: Naval Vessels) and the UK's Lloyd's Register (Rules and regulations for the classification of naval vessels). All these companies are part of INSA: the International Naval Safety Association that comprises a broader group of seven societies and 13 navies aimed at providing cost effective goal-based standards for naval ships that are accepted by the global naval community and intergovernmental bodies. Originally developed as a NATO initiative, the association's jointly drafted Naval Ship Code (NSC) is published by NATO as Allied Naval Engineering Publication (ANEP) 77. A Naval Submarine Code and Naval Boat Code have also been produced. It is important to note that combat operations are not covered by the NSC; these fall within the ambit of the relevant national navy.

It should also be noted that classification societies do not cover the layout of living areas or the space assigned to each function. Again, it is navies that provide these requirements.

Photo: Crown Copyright 2017

This six-berth cabin onboard the British aircraft carrier QUEEN ELIZABETH is typical of the high standards of accommodation offered to modern sailors.

THE GERMAN SEASCAPE ARTIST



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Habitability Today: Design Factors & Constraints

To achieve a satisfactory result, habitability must form part of the ship's preliminary design; living areas shouldn't just be placed in whatever space remains when warfighting functions have been taken care of.

General Arrangement: The layout of living areas is a complex job, which must take into account many factors, notably traffic flow and comfort. It is necessary to plan crew movements in port, at combat readiness, during damage control operations, and even when eating meals. Many and varied questions that need answers include how wounded crew can be transported to the sick bay, which handling means will be used to load food, spare parts and ammunition, and which emergency routes are available. For example, how can the engine room's lower level be evacuated if the main exit is blocked?

To ensure comfort, rooms intended for sleeping must be far from the engine rooms to limit noise and vibrations but close enough to the centre of the ship to limit sea induced movements. Berths should be oriented with their length in a fore to aft direction. Recreation areas must also be well separated from sleeping areas. The location of cabins, for officers, petty officers and ratings will be based on a hierarchical grouping but there will often be two well-separated accommodation zones in order to provide dispersion of key personnel in the event of damage. The layout should allow for gender neutral accommodation, with a possibility to adapt the male / female ratio to allow for changes in crew balance.

The minimum space required for each type of berthing compartment/cabin has to fit within the ship's overall plans in accordance with the following typical values. For ratings and junior petty officers, a four berth cabin will encompass around 14m²; prefabricated sanitary facilities will either be included within each cabin or in the immediate vicinity of a cabin group. For senior petty officers, a two berth cabin will be around 12m²; commissioned officers will be allocated a similar amount of space but for single occupancy. A day cabin of 16m² and a sleeping cabin of 8m² are required for the commanding officer.

Having enough space for sleeping areas is not sufficient: a ship's interior layout also has to plan for communal areas. Keeping a good level of social interaction is important to build up a team spirit and allow relaxation; with more comfortable cabins and the ready availability of electronic appliances there is a risk that crew members will retire to their bunk to play with a console or watch a movie rather than to integrate with their crew mates. Meals are a particularly important moment; a reason why dining rooms offer more space per individual with better furniture and good sound attenuation. There is usually self-service for all, with meals being eaten in rooms separated by rank to allow each element of the hierarchy to unwind. Additional recreational facilities – increasingly including a fitness room or gym – have also to be accommodated.

The location of food storage and preparation rooms is also important and must be decided upon early in the design process, To reduce the work associated with loading provisions, cold rooms and storerooms are placed on a deck with easy access from loading areas, possibly near the galleys. Cold rooms are sized to maximize the quantity of fresh food. The same goes for waste storage; food flow should be planned in a logical sequence to minimize cross contamination from dirty to clean.

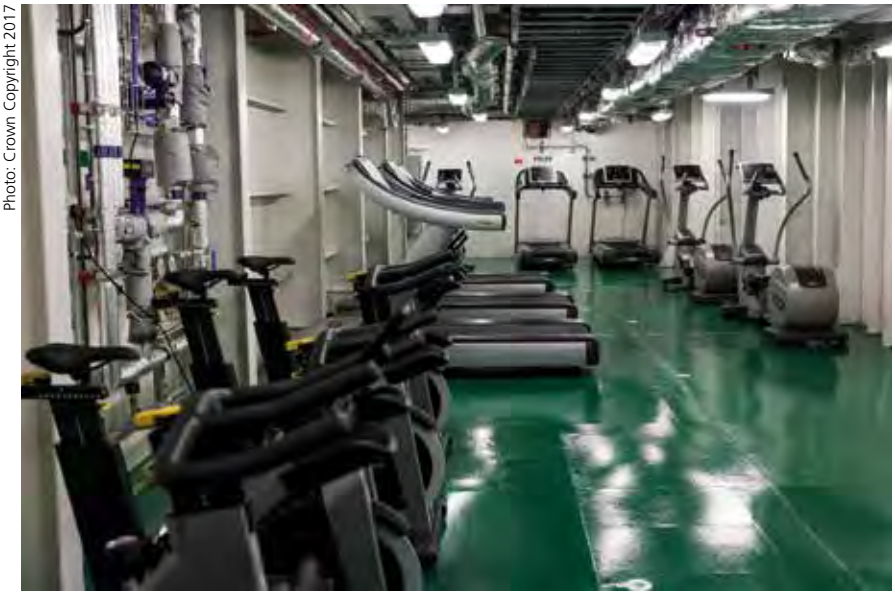
Photo: US Navy

An inspection of the berthing in the US Navy Destroyer PAUL IGNATIUS (DDG-117). US Navy crew berthing tends to be more austere than in recent European warships but standards are improving.

Fire Resistance: Fire is the number one enemy at sea: consequently rules from SOLAS, from classification societies, and national agencies all have strong requirements in this regard. Fundamental principles are prevention, detection and containment of fire in the space of origin.

Prevention has a major impact on accommodation. Furniture, insulation and floors should all hinder the development of fire. This translates into metallic furniture in-

Photo: Crown Copyright 2017



A gym compartment housing fitness equipment is a typical recreational facility in many modern warships.

stead of wood; as well as non-combustible partitions, ceilings, and insulation that have been tested according to SOLAS procedures and that must not give off toxic fumes. Floors must also reduce the spread of flames in accordance with recognised tests.
To contain a fire, different compartments must be separated from each other by partitions and ceilings that meet specific requirements such as fire resistance and limitation of temperature rise. For areas of high fire risk such as the engine room and galleys, resistant separation – typically a steel structure from deck to deck and insulation – is required. For spaces where the fire risk is lower, for example between two cabins, lighter prefabricated panels can be used with a sandwich of rockwool-lined by sheet metal. Regulations provide very detailed tables specifying which type of separation is to be used between different types of compartments.

Noise and Vibration: These factors will often form a core consideration of a warship project for operational reasons, viz. to reduce a ship's acoustic signature and its likelihood of detection by a submarine. However, as already mentioned, their absence is also important for the efficiency of a crew working in a high intensity environment.
Equipment will often be located on special mounts and some noisy rooms – such as engine rooms – will have bulkheads and overhead decks isolated with complex damping material. Partition panels separating living areas have specific noise reduction characteristics. In terms of vibration, living quarters placed above engine room or shaft lines can be protected by a noise and vibration damping floor structure, typically comprising a rock wool and sheet metal laminate with a visco-elastic layer.
Each navy defines acceptable sound levels in different areas. For example, the US Navy limits sound levels in cabins, messes and recreation areas to 65dB A; some other navies base acceptable levels on IMO or International Labor Organization (ILO) requirements. It is noteworthy that classification societies may assign an additional rating when higher requirements regarding noise and vibrations are met.

Shock Resistance: A criterion very specific to combat ships relates to shock resistance in case of underwater explosion. Each navy has its requirements, which are classified. To meet the specified resistance, partitions and ceilings systems will be designed and mounted to remain in place during these significant accelerations: passageways must not be blocked by panels falling into them. Systems are tested with devices reproducing the specified values and sometimes also during spectacular sea trials.

Photo: US Navy

GERALD R. FORD (CVN-78) undergoing shock trials. The need to provide resistance against underwater shock has an important influence on warship habitability, impacting how cabins and passageways are designed.

Weight: Designing a naval ship is a constant struggle to limit weight: any unnecessary weight increases fuel consumption and has an impact on hull performance. Consequently, habitability-related items need to be as light as possible; furniture is frequently made of aluminium or of a honeycombed material.

Ship Machinery: Increased comfort impacts some less obvious areas, such as Heating Ventilation and Air Conditioning (HVAC) and water. Working and living in a metal hull, without openings, full of heat generating machinery and electrical equipment, requires a HVAC system with good capabilities. The trend is to have individually adjustable systems for cabins, in some cases with an individual diffusor near each berth. Maximum and minimum temperatures, humidity, and the number of air changes are specified. More recently, the COVID-19 pandemic has focused attention on the efficiency of filters and the need to limit air recirculation.
Demand for water has strongly increased. Wärtsilä, which supplies fresh water production systems amongst its range of businesses, indicates that daily water consumption has now reached 130 litres per person per day. This is quite similar to values for households ashore, perhaps reflecting the fact that many navies specify that systems should provide for two showers each day. Reverse Osmosis fresh water plants are mainly used: their compactness is a benefit for ships where space is always an issue. As already indicated, "dirty" water must now be treated before being discharged overboard to fulfil MARPOL requirements. Biological wastewater treatment plants are the most common type found in frigates whilst ectrolytic or physical-chemical wastewater treatment plants are often designed for smaller ships. Biological plants have the lowest operational costs as no chemicals are needed and there are no electrodes to replace regularly.

Conclusion

All these developments should not make us forget that going on a mission for several months, in permanent proximity to one's crewmates and with little free time, is always difficult. To maximise the use of expensive vessels, while giving sailors the opportunity to rest ashore and have a more predictable life, several navies are adopting rotational crewing systems. Under these arrangements, once the preserve of strategic submarines, two crews share duties at sea. Along with all the physical improvements mentioned above, along with those yet to come, this flexibility will contribute to increasing the attraction of life at sea. ■

Note:
European navies do not typically publish habitability specifications but some typical details can be found in studies and reports. The US Navy publishes a detailed document: *Shipboard Habitability Design Criteria and Practices Manual (Surface ships),* reference T9640-AC-DSP-010/HAB, which is available on the internet.

Cruise Lines after the Pandemic: Rising from the Shutdown

Franz Neumeier

After a complete and worldwide shutdown in March 2020, the cruise industry is coming back. Little noticed by the general public, some cruise ships even started sailing again as early as June 2020. While the challenges and obstacles for a full recovery seem terrifying from an outside point of view, the cruise industry can use its unique strengths and flexibility to reinvent itself for a new, post-pandemic world.

The DIAMOND PRINCESS is an unfavourable symbol of the early days of the pandemic. In February 2020, Japanese authorities put the 2,670-passenger cruise ship under strict quarantine in Yokohama for more than two weeks while the whole world was watching live on TV. To this day, media refer to this situation as supposed proof of how risky cruising is.

In early March 2020, Covid case numbers were rapidly growing on cruise ships worldwide. Hardly any ports allowed ships to dock; tens of thousands of passengers were temporarily stranded on cruise ships. What followed was a complete, worldwide shutdown of the cruise industry by 13 March 2020. Never in modern times has an industry been grounded so instantaneously and, as it turned out, for such a long time.

For some cruise lines the shutdown lasted for more than 15 months. Instead of sailing with passengers, for many months they were desperately busy transferring tens of thousands of crew members to their home countries while international air traffic did not provide sufficient connections. Travel bans around the world prevented crews from getting home. Cruise lines even employed their own cruise ships to transfer crew members.

Photo: Franz Neumeier

An important port for cruise ships laid up during the pandemic was – and is – Civitavecchia. Amongst others, especially Norwegian Cruise Line and Costa Cruises did lay up some of their ships here.

Author

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All this happened to an industry that, prior to the pandemic, achieved double-digit growth rates each year, breaking their own records on a regular basis. It seemed that the sky was the only limit. 2019 was the most successful year for the cruise industry ever, though it didn't dare communicate these numbers during the early months of the pandemic. It would have been too much of a contrast to the grim reality at that time.

Can an industry recover from a hit like this? Or does the complete disruption of business in the moment of its biggest success bring new opportunities?

The answer has come quickly: The first cruise ships were already sailing again at the end of July 2020. TUI Cruises' MEIN SCHIFF 2 was the first big cruise ship sailing again, departing Germany on 24 July 2020. Dream Cruises' EXPLORER DREAM started out from Taiwan on 26 July 2020. However, this was only in Europe and Asia.

In the United States, the Center for Disease Control and Prevention (CDC) continued to block all cruises until late June 2021. The only exceptions were very small ships, which are out of the CDC's area of responsibility. The Center showed a consistent negative attitude, despite robust hygiene protocols that had already proven to be sufficient in Europe. Eventually, in the late summer and autumn of 2021, all the cruise lines did have at least a part of their fleet back in operation. This included such important destinations for the United States as the Bahamas and the Caribbean.

Cruising has some important strengths. Two of these are: (i) Ships can be deployed flexibly worldwide and are thus less affected by regional crises. Their area of operations can be relocated, at least in principle. And (ii) cruising is used to dealing with challenging situations – its high overall complexity and global network are capable of excellent operation as long as all the usually well-organised parts of the system are able to mesh smoothly together. Of course, these strengths can also become a major issue in pandemic conditions.

In order to assess the challenges with which cruise lines are confronted, a short analysis of the current situation is provided below:

Tourism Infrastructure: The tourism infrastructure on shore has been partly disrupted, and needs new arrangements, for example to meet hygiene requirements. One result is

smaller group sizes on shore excursions. This means, among other things: more buses, more tour guides and higher costs.

Changed Attitudes towards Cruise Tourism: Some destinations have changed their attitude towards cruises as a result of the experience of the shutdown and have become more restrictive with regard to tourism and associated environmental aspects. For example, residents in Key West tried to ban most big cruise ships (although they eventually failed, as they were overruled by a Florida state law). Anti-cruise activists are also becoming more interconnected in support of each other on a global basis.

Disrupted Supply Chains: Supply chains that were previously optimised for cruises have been disrupted. The food chains supplying ships have had to be rebuilt step by step. Some of the previous contractual partners no longer exist. At the same time, demand is enormous: A medium-sized cruise ship with 3,500 passengers, for example, requires a quarter of a million eggs, almost five tons of flour, and 75 tons of fresh fruit and vegetables per week.

At the end of August 2021, a supply bottleneck led to Carnival Cruise Line having to ration bacon at their buffets: at times, it was only available every second day. The story is more comical than serious, but it shows how many details interact in the cruise industry to make a product work successfully.

Crew Shortages: Crew shortages were a challenge even before the pandemic. During the shutdown, many former crew members changed jobs of necessity. A lot of expertise and experience was lost. Continued travel restrictions and persistently low vaccination rates in typical countries of crew supply, such as Indonesia, the Philippines, India and South and Central America makes, recruiting a major challenge. Norwegian Cruise Line even used their own cruise ships at the end of 2020 to pick up crew members from Asia – unfortunately to no avail. The line had to postpone the re-start of their operations and transfer the crews back to their home countries, again by cruise ship.

However, it is in the nature of cruising to solve complex tasks, as this industry has always been very innovative and adaptable. It is this ability that those in charge can now play on so as to emerge stronger from the pandemic. The real challenge is posed by factors over which the cruise industry has no or only limited influence: inconsistent and contradictory rules and regulations in various countries and an inconsistent public approach in dealing with the virus during transition to a "new normality".

Photo: Franz Neumeier

To achieve the highest level of safety in protecting against Covid-19, cabins on board of cruise ships are fogged with special disinfectant on the turnover day before new passengers move in.

Lack of Planning Certainty

The lack of planning certainty for destinations and routes is a critical issue. Approval processes have become very complicated, inconsistent and unreliable. Longer-term planning is currently based more on hope than on solid agreements with authorities in the countries to be visited. Whereas cruise lines ideally need planning certainty two to three years in advance, conditions currently tend to change on a weekly or monthly basis.

Particularly problematic are routes in areas where vaccination of the population will still take a very long time. Another complication arises with countries that continue to close themselves off completely to the outside world, such as Australia and New Zealand. This particularly affects those cruise lines typically traveling in such regions or offering world cruises, such as Holland America Line, Princess Cruises and Oceania Cruises, to name but a few.

New concepts will have to be found here, temporarily or even permanently, especially since the ports in more reliable cruising regions such as the Mediterranean, the Baltic Sea, the Caribbean, or Alaska are reaching their capacity limits and will hardly be able to accommodate additional ships.

Cruises are flexible and sail wherever they can. As such – in the current phase – cruise lines are planning their voyages with port calls only in a single or very few countries, for example the Bahamas, Alaska, Norway, Iceland, Italy or Greece, in order to keep risk and bureaucratic hurdles within acceptable limits. However, if the industry wants to return to full-scale operations, such a limited offering will not be good enough.

Photo: Franz Neumeier

The ship's crew regularly disinfects contact surfaces in public areas, such as the sun beds on the MSC GRANDIOSA, as well as hand rails and elevator buttons, just to name a few items.

Inconsistent Covid Strategies

Another challenge that can only be influenced to a limited extent by the cruise lines themselves is the different political and

social development of strategies that are being adopted for normalising social life. A global consensus on a common, long-term strategy on how to deal with the virus in the long term is presumably still a long way off. Vaccination requirements, mask rules and the acceptance of a certain level of Covid cases as part of the general risk of life all vary widely. International cruise lines must reconcile very different stages of development of these considerations among their internationally diverse passengers on board, and at the same time aim to offer a fun and carefree vacation experience.

A key factor in the success of cruises is certainty and consistency with respect to relevant operating conditions. However, this is precisely what cannot be guaranteed at present with regard to hygiene regulations. For example, the policy of the US Center for Disease Control is too erratic, and the "Freedom Day" approach of the British government is too contrary to the cautious approach of other European countries, to name just two examples.

Cruise lines with narrowly defined source markets are initially at an advantage in these conditions. These include companies that serve the North American source market almost exclusively, such as Carnival Cruise Line, or the German market, like AIDA or TUI Cruises, for example.

The PR Challenge

However, the pandemic also holds some excellent opportunities for the future of cruising. Largely hidden from the public eye, cruising has proven that it can quickly find very robust responses, even to such an all-encompassing global crisis. Indeed, cruising is a very reliable form of vacation that can provide safety and security in difficult times.

It is important that industry manages to communicate these capabilities – to its customers, to the general public and also as best practice and orientation for tourism businesses on land. This means first and foremost overcoming a damaged public image and persuading people to forget about the quarantined DIAMOND PRINCESS from the early days of the pandemic.

At times, cruising in Europe during the summer of 2020 was almost the only way to take a vacation outside your own country. This was possible because long before Sars-Cov-2, cruise lines had extensive hygiene protocols in place, particularly as required by U.S. Public Health Service (USPH) rules in the US, for example to prevent Noro virus infections. These protocols could be adapted very quickly to Sars-Cov-2, whereas many other areas of public life had to deal with hygiene protocols for the first time ever, starting from scratch.

With reduced passenger capacity, flexible Covid testing, physical distancing, consistently enforced masks requirements indoors, constant disinfection efforts, modified air conditioning (with 100 percent fresh air supply, UV and HEPA filtration),cruise ships provide an environment that is significantly safer than comparable spaces on land. Shore excursions can be conducted "in the bubble" whereby passengers are not free to roam on their own but have to stay within their tour group and have little to no contact with locals, thereby preventing a transfer of the virus in either direction.

With fine-mesh contact tracing, even during shore excursions, testing labs and sealed-off isolation sections on board, cruise lines are responding very efficiently to positive cases. All of this was already in place in July 2020, long before there was even a vaccine. There have been very few Covid cases since then relative to the total number of passengers carried, let alone infections directly on board, as evidenced by the statistics below:

Positive Covid cases onboard cruise ships in active passenger service from August 2020 to July 2021:	
Crew members tested positive	69
Passengers tested positive	102
Passengers carried during this period	approx. 800,000

One single incident on the ROALD AMUNDSEN at the beginning of August 2020 accounted for 41 percent of all these cases. Due to serious mistakes by the cruise line, 42 crew and 29 passengers contracted the virus.

These statistics only take into account all cases publicly known, so the actual number probably is higher. From August 2021, numbers were rising along with the re-start of many cruise ships from US ports. In the beginning there, hygiene protocols had been much weaker than in Europe and Asia. Due of the high number of ships sailing again from August 2021, it has been impossible to gather reliable and comprehensive data from that time on.

So that summarises the situation related to the pandemic. What follows is a short description of future trends.

Digitalisation

The complete standstill of their operational business has given the cruise lines' headquarters time to take a fundamental look at the nature of their activities. This has opened doors for innovation, as well as an acceleration of processes that had already been started prior to the pandemic.

One example is the digitalisation of on-board processes. Hygiene protocols made contact tracing technology essential and created a fundamental demand for contactless procedures. To give one relatively simple but obvious example, digital restaurant and bar menus largely replace paper menus now.

Photo: Franz Neumeier with kind permission of MEYER WERFT

The bow section of the IONA in one of the two building halls of the Meyer Werft shipyard in Papenburg, Germany (archive picture). The IONA was delivered to P&O Cruises during the pandemic in October 2020.

Photo: Franz Neumeier

As part of the ship's hospital, there is also an isolation emergency bed available on the MSC GRANDIOSA which enables proper treatment until the patient can be transferred to a hospital on land.

Another example that might sound just like a side note but makes a big difference to the vacation experience whilst smoothing logistics on embarkation day has been a redesign of the muster drill that for decades has caused unpleasant 30 to 60 minutes of downtime for hotel operations. This drill is now mostly individualised by video clips on the cabin TV or a smartphone, sometimes even before arrival at the port. This is followed by just a few minutes of briefing at any given time during the embarkation day at the muster station, either individually or in small groups.

For contact tracing, cruise lines use tracking technology already available, depending on the age of the ship, based on Near Field Communication (NFC), Bluetooth and WiFi in conjunction with tracking wristbands or tokens. These can be combined with the ubiquitous video surveillance, as well as with transactional data from bars, restaurants and stores. On the newest cruise ships, such technology as "MSC for Me" (MSC Cruises), "Ocean Medallion" (Princess Cruises) or "Tracelets" (Royal Caribbean) is already designed for a wide range of other applications. These can encompass individual offers for shopping, specialty restaurants, spa treatments and other additional sales; individualised service based on personal preferences, for example at the bar; as well as such convenient services as delivery of a pizza or a drink exactly to the actual position of the passenger, anywhere on the ship.

Cruise lines had previously been hesitant with using the full potential of this technology. But now that no questions are asked regarding privacy due to the widely accepted contact tracing technology, the pandemic will open the door for a rapid introduction of more of these features.

Another important side effect of this technology is that the improved ability to analyse passenger flows and undertake the behavioural analysis of different passenger cohorts will allow a more even distribution of passengers on the ship. Hence, higher passenger loads will also be possible during the pandemic by better maintaining physical distancing at any given place. For future cruise ships, this also creates the opportunity to accommodate more passengers in the same space without a perceived loss of comfort.

Fleet Renewal

At least 20 relatively old cruise ships, or about five percent of the total fleet, have been sent for scrapping during the pandemic. Several more are likely to follow. These ships had been very profitable on short voyages in the pre-pandemic boom despite outdated technology and poor energy efficiency. Their passenger capacity had been hard to replace, as ship yards were fully booked for years in advance.

However, high maintenance costs made these ships a burden during the pandemic. Hence, the pandemic is leading to fleet rejuvenation. The process started early, as cruise lines took delivery of about 30 new ships during the pandemic which had been ordered long before the crisis began. The scarce capital available after the pandemic standstill can now be invested more sensibly. Instead of investing in the renovation of old tonnage with a relatively short remaining lifetime, more investment will be focused on the long-term, and thus in new construction.

But even though the cruise industry is expecting a strong comeback, orders have been cancelled at the shipyards as much as possible and ship deliveries have been postponed. This has plunged those shipyards specialised in cruise ships into a crisis. Of course, this opens up new opportunities for cruise lines: shipyards are more willing to negotiate on price and, unlike prior to the pandemic, construction slots can be obtained on fairly short notice.

At the same time shipping companies have undoubtedly been faced with heavy debts. A few shipping companies, such as the British Cruise & Maritime Voyages (CMV) and the Spanish Pullmantur Cruises, did not survive the pandemic. However, the large, publicly traded shipping companies, such as Carnival Corp, Royal Caribbean Group and Norwegian Cruise Line Holdings, managed to significantly reduce their costs and raise several billion dollars each on the open capital market on relatively good terms to cover ongoing costs during the shutdown. Stock prices that plummeted to between 15 and 20 percent of their pre-pandemic values have already recovered to between 45 and 60 percent of their previous value. Still, the financial situation of the cruise lines somewhat limits the scope for investment in new ships for now.

Cruise Line	Ships sold for scrap	Sold for other purposes	Delivery of New builds (up to October 2021)
Carnival Corp	4	15	7
Royal Caribbean Group	3	2	5
Norwegian Cruise Line Holdings	0	0	1
MSC Cruises	0	0	1
Others	13	5	about 25

Optimistic Growth Estimates

The annual report of the quarterly magazine Cruise Industry News reported a record-breaking year 2019 with 27.8 million cruise passengers worldwide. And while this number was down to only 7.1 million in 2020, mostly from the pre-pandemic months, and an estimated 13.9 million in 2021, the report expects as many as 31.7 million passengers for 2022, increasing to 38.7 million over the next five years. This forecast is based on the passenger capacity of the existing fleet plus the over 100 new ships which are on firm order from the shipyards until 2027. More than 20 of these orders are due for delivery in 2022.

Based on record booking numbers, even compared to pre-pandemic, most cruise lines expect to be back on their previous track by mid-2022. So these estimates might not be as unrealistic as they initially sound. ■

Opinion: Three Global Flashpoints of Area Denial

Tim Guest

Western navies and maritime forces face a future where the traditional maritime, rules-based order has been usurped by an intensifying set of destabilising, aggressive actions and strategies in the maritime domain, primarily pursued by China, Iran and Russia. Aggressive actions in three regional hotspots are already, in peacetime, putting the West's notions of Anti-Access/Area Denial (A2/AD) operations at sea to the test and act as a warning of what to expect should actual hostilities arise.

Between China's activities in the South China Sea, Iran's in the Strait of Hormuz and Russia's in and around Crimea and the Black Sea, these three regional hotpots have the fateful potential to deny Western naval powers the ability to project themselves in critical regions. This is something that will become even more acute in a wartime scenario, when current, "sub-war" behaviour is replaced by full military A2/AD actions. This could be disastrous should allied nations be in urgent need of military help but could not be reached by naval forces subdued by A2/AD weaponry. This article looks at some of the regional hotspots mentioned, any of which could initiate a major conflict; how Western allies are partnering to address denial in these regions; as well as A2/AD in relation to certain current scenarios.

Facing Geopolitical Hot Spots Together

The world faces some testing years ahead. Should a major global conflict occur anytime soon, maritime A2/AD in the regions mentioned above and below will, absolutely, play a massive part in how hostilities unfold and early advantages are seized by nations involved. And exactly who will be involved? We all will. In the Pacific, for instance, QUEEN ELIZABETH led its Carrier Strike Group (CSG) – including its American and Dutch components – back through the South China Sea with ships and aircraft

Author

Tim Guest is a freelance journalist, UK Correspondent for MSD's sister journal ESD, and a former officer in the British Forces.

F-35B Jets from 617 Squadron return to QUEEN ELIZABETH after a sortie during Exercise FALCON STRIKE 21, a multi-national exercise to apply the advanced capabilities of latest generation aircraft to increasingly complex and contested battle spaces, including areas like the South China Sea.

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Photos: US Navy

The ARLEIGH BURKE (DDG-51) class guided-missile destroyer ROOSEVELT (DDG-80) conducts joint operations with RAF Typhoon FGR4 fighters in the increasingly "contested" waters of the Black Sea in September 2020.

from Australia, Canada, Japan and New Zealand as well as further vessels from the United States; a clear indicator that whatever happens in the Indo-Pacific will involve us all. Late October, too, the US Navy's CARL VINSON (CVN-70) CSG made a scheduled deployment in the US Navy's 7th Fleet area of operations to enhance interoperability through alliances and partnerships while serving as a ready-response force in support of a free and open Indo-Pacific region.

Other indicators of Pacific support include the United Kingdom's commitment of two patrol ships, TAMAR and SPEY, permanently to the region; Britain becoming the first new Dialogue Partner to ASEAN in 25 years; the United States reinvigorating its ASEAN commitment in late October with a US$102M funding injection; the United Kingdom's bilateral defence negotiations with Japan; and notably the Australia/UK/US AUKUS partnership "to protect and defend shared interests in the Indo-Pacific".

In Europe's Black Sea maritime hot-spot, 30 ships from 14 NATO allies and partners – Albania, Belgium, Bulgaria, Georgia, Greece, Italy, Latvia, Poland, Romania, Spain, Turkey, Ukraine, the United Kingdom and the United States (along with the constituents of Standing NATO Maritime Group Two and Standing NATO Mine Countermeasures Group Two) – took part in the Bulgarian-led maritime Exercise Breeze 2021 in July. Since Russia's illegal and illegitimate annexation of Crimea, NATO has increased its presence in the Black Sea with its ships routinely operating there, consistent with international law, and patrolling the waters for around two-thirds of the year. This latest exercise followed the June passage, by the Royal Navy destroyer DEFENDER, through waters off the coast of Crimea, when it was shadowed by the Russian coastguard and aircraft causing a degree of diplomatic tension. And the 2018 illegal capture by the Russian Navy of three Ukrainian patrol vessels, operating legitimately in their own waters off the coast of Crimea near the Kerch Strait, must not be forgotten; such actions all indicate these waters will be the focus of aggressive A2/AD should "real" hostilities ever arise.

Last but not least, just one of many examples of Iranian moves to harass shipping in the Strait of Hormuz is the early May 2021 example of 13 Islamic Revolutionary Guard Corps Navy fast boats, which approached six US Navy and Coast Guard ves-

An F/A-18E Super Hornet, assigned to the "Stingers" of Strike Fighter Squadron (VFA) 113, launches off the flight deck of the NIMITZ (CVN-68) class aircraft carrier CARL VINSON (CVN-70) in the South China Sea.

sels escorting the guided missile submarine GEORGIA (SSGN-729) through the strait. The fast craft ignored warnings to move away and the US Navy ships fired warning shots. Other examples of similar Iranian actions against shipping are too numerous to cite here, but suffice to say, the Strait of Hormuz would see an extension of this harassment to comprehensive A2/AD activity should full-scale war arise.

Beware of the Dog – But Don't Run Away

Just as a postman might ignore a beware-of-the-dog sign on a gate, reach the front porch, post a letter through the door and make it back out the gate again before an angry Rottweiler has a chance to bite him, so, too, the A2/AD abbreviation doesn't mean an area is impenetrable to a maritime force, that it cannot be entered, but, rather, that operating in such an area unfortunately comes with greater risk from the air, land and sea. Resultingly, prior to any offensive excursion into such a region, all known threats must be addressed, engaged and, where possible, neutralised, either actively, or passively, using physical attacks with aircraft and missiles, or passively with the likes of electronic counter measures and jamming. But if the owner of the house, (back to the analogy), then buys a second, bigger, faster Rottweiler, well, the postman has to adapt and find new ways of dealing with the dogs so he can still reach the door and make his delivery. Allied maritime forces will similarly need to adapt, like the postman, to constantly developing adversarial A2/AD threats...yet still make their delivery. Regions like the Black Sea around Crimea and the Kerch Strait, for example, where layers of potential A2/AD weaponry will face any allied force approaching and entering within range, and the disputed South China Sea around newly created and militarised artificial 'islands', will have allied naval commanders marking their charts with the maximum engagement ranges any known A2/AD weaponry in these regions can achieve. In the Crimea, for example, medium and long-range surface-to-air missile batteries and coastal-defence anti-ship missile batteries join the increasing number of advanced combat aircraft that raise the A2/AD stakes for any opposing naval force. Add to that a modernised and expanded Black Sea Fleet in which the Soviet-era guided-missile cruiser MOSKVA and two KRIVAK class frigates have now been joined by three new ADMIRAL GRIGOROVICH class guided-missile frigates, (as well as a KILO class submarine force that now boasts seven modernised vessels compared with its previous one) and the Russian arsenal that could be brought to bear on any approaching, opposing naval forces is considerable. Its smaller craft and patrol vessels, too, have increased in number and, as far as is known, include three BUYAN-M-class missile craft, each of which is equipped with as many as eight KALIBR cruise missiles. Shorter-range KALIBR variants typically carry conventional warheads, though a long-range, 2,500 km variant can potentially carry a thermonuclear warhead.

An MV-22B Osprey attached to Marine Medium Tiltrotor Squadron (VMM) 165 (Reinforced), 11th Marine Expeditionary Unit (MEU), on the flight deck of the amphibious assault ship ESSEX (LHD-2) during flight operations in the Arabian Gulf in support of regional maritime stability and security.

If there is any doubt of the potential A2/AD that would take place here in a full war footing, Russia has already shown its colours. It has impeded or, in some cases, totally prevented naval vessels from entering the Sea of Azov via the Kerch Strait from the Black Sea in order to reach Ukrainian ports, particularly that of Mariupol – enacting a kind of 'peacetime' A2/AD. Ukrainian fishing boats have been denied fishing access to the Azov and even been detained; no foreign vessels are able to approach the Kerch Strait without potential aggressive confrontation, and since March, the Sea of Azov has remained completely cut off to all but Russian naval vessels and shipping, with access and movement having been denied on the grounds of manoeuvres, even to economically crucial Ukrainian grain exports.

Sadly, fundamental principles of maritime law are being trashed by Russia's behaviour, even though no one is officially at war. Ukraine has even challenged Russia's anti-access to the Sea of Azov in the International Court of Arbitration, in a case set to last into 2022, though unlikely to resolve things. For even if a verdict goes Ukraine's way Moscow will probably ignore the ruling. For the wider world, such a precedent would be a dangerous thing, particularly in the context of the South China Sea, where China's claims exclusive control. This includes its new maritime law, which came into effect – as far as it is concerned – on 1 September. That "law" decrees certain foreign vessels provide information, including: vessel name, call sign, current position, cargo, port of call and ETA, to Chinese authorities prior to transiting Chinese-claimed waters. Any international maritime legal challenge to China is, like the Russian-Ukrainian situation, likely to fall on deaf, though in this case, Chinese ears.

Legal Footnote

Despite the existence of the non-binding San Remo Manual, which is today the main reference document for the law of naval warfare, the already belligerent behaviour of three aggressive nations in three critical regions where control of the sea through anti-access and area denial could prove strategically decisive in a conflict, suggests few legal constraints will be respected by them if a true conflict does ensue. Allied nations, just like the postman, beware. ■

NATO's Maritime Centres of Excellence

Edward Lundquist

For NATO, accredited Centres of Excellence constitute a hub of knowledge and expertise. Centres of Excellence are a vital element in transformation and contribute to improved interoperability.

NATO Centres of Excellence: An Overview

Centres of Excellence (COEs) contribute to the NATO Alliance by bringing together subject matter experts in a providing functional area to deliver their in-depth knowledge through training, conferences, seminars, concepts, doctrine, lessons-learned reports and papers. Each of the 26 NATO accredited COEs (plus two in the course of accreditation) focus on four main pillars: (1) education, training, exercise and evaluation; (2) analysis and lessons learned; (3) doctrine development and standardisation; and (4) concept development and experimentation in their area of specialisation. According to Italian Army General Paolo Ruggiero, the Deputy Supreme Allied Commander Transformation, "The Alliance has been successful because it has constantly adapted and transformed into what has been needed to be relevant. The COEs have helped us do that." The COEs contribute knowledgeable specialists who can enhance NATO capabilities to that relevance. "They can cover similar areas of interest in terms of domain – for instance, maritime, land, air – but they're specific in one specific military area and expertise," Ruggiero said.

The COEs are nationally or multi-nationally funded institutions, and not part of the NATO command structure. As such, they do not cost NATO any money, but as go-to knowledge hubs, they deliver incredible value. Each COE has a "Framework Nation" that serves as host, develops and implements the concept, provides the physical space and the cadre of experts and staff to run the COE. They are joined by "Sponsoring Nations" and "Contributing Nations" that provide staff experts, funding, or some other service that is of use to the functioning of the COE

Photo: Crown Copyright 2020

NATO warships on exercise. NATO's Maritime Centres of Excellence contribute to the interoperability of the Alliance's operational naval forces.

Photos: NATO

Italian Army General Paolo Ruggiero, the Deputy Supreme Allied Commander Transformation, based at ACT headquarters in Norfolk Virginia, believes the COEs are vital in allowing NATO to be aware of and understand the new ways of thinking and new capabilities needed to maintain its edge

According to a NATO statement, the COEs "train and educate leaders and specialists from NATO member and partner countries, assist in doctrine development, identify lessons learned, improve interoperability and capabilities, and test and validate concepts through experimentation. They offer recognised expertise and experience that is of benefit to the Alliance and support the transformation of NATO, while avoiding the duplication of assets, resources and capabilities already present within the NATO command structure."

Author

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"Each COE must act as a catalyst for NATO transformation and open activities to all Alliance members," the statement said.
The COEs are a vital element in transformation, and contribute to interoperability among NATO and partner nations. Their experts are well connected in their respective networks, where they are able to they receive new ideas, exchange views and information, and learn about new technologies. "Because technology today is available everywhere, and is spreading at such a high speed, NATO needs to be linked to these networks to be aware of and understand the new ways of thinking and new capabilities to maintain its edge," Ruggiero said.
COEs do not duplicate or compete with current NATO capabilities, but instead offer an area of expertise not already found within the organisation.
According to Ruggiero, the COEs belong to the participating nations, not NATO per se, but are accredited by NATO Allied Command Transformation (ACT). There are a set of prerequisites and a rigorous process for a centre to be accredited, and there are periodic assessments that are required for a COE to maintain its status. More specifically, upon ACT's recommendation, the Military Committee and the North Atlantic Council approve the initial accreditation of individual COEs. ACT then periodically reassesses the Centres of Excellence in order to ensure that they continue to meet those criteria and assure continued NATO accreditation status.
The COEs may not involve every NATO nation, but most represent more than one country, and in some cases, they are joined by partner nations such as Sweden, Finland, Switzerland and Austria. "Our partners benefit from this sharing of information, and we benefit from them," Ruggiero said. While they all support NATO's transformational pillars, the COEs take different approaches to their training, education, conferences, research and experimentation. Each COE is closely aligned with their respective communities of interest, including research organizations, academia, think tanks, and other centres of excellence that may or may not be affiliated to NATO. Each of the COEs has an annual programme of work and receives inputs, requests of for information or support, and – potentially – funding from a variety of customers.
Since the end of the Cold War, as the threat situation has continuously evolved, the NATO Alliance has grown. The newer nations can take advantage of participation in the COEs, and even host one as the framework nation. With that comes increased visibility for their militaries and acknowledgement for their areas of leadership and expertise. "Not only are they making a valuable contribution to the Alliance, but they are able to raise the NATO flag in their nation, which is a powerful statement in and of itself," Ruggiero said.

Photo. NATO

The expertise of NATO MCM formations such as Standing NATO Mine Countermeasures Group 1 is bolstered by the Naval Mine Warfare (NMW) COE is headquartered at Ostend, Belgium.

Maritime-focused Centres of Excellence

The NATO accredited COEs cover a wide range of warfighting disciplines and domains. Some are defined by domain, such as NATO Centre of Excellence Cold Weather Operations (COE CWO) and the Joint Air Power Competence Centre (JAPCC). Others transcend all of the domains, such as military medicine, modelling and simulation, strategic communications or energy security. Others, like cyber and space, constitute domains in themselves. Some, like the NATO Mountain Warfare Centre of Excellence, are most important to countries that operate in mountainous regions.
Four of the 26 COES are focused on the maritime domain and dedicated to expanding Alliance maritime warfare capability. These are:

CJS COE: The Combined Joint Operations from the Sea (CJOS) Centre of Excellence is based in Norfolk, Virginia, and is the only COE in North America. CJOS COE provides rapid development of concepts across all areas that influence the maritime domain. Although the CJOS COE is independent of the NATO command structure, it is directly aligned NATO Joint Forces Command (JFC) Norfolk and the US Second Fleet under one commander. The centre draws on knowledge and capabilities of sponsoring nations, ACT, United States Fleet Forces Command (USFFC), and


Photo: German Navy

The Centre of Excellence for Operations in Confined and Shallow Waters is focused on improving NATO's competence to perform in the littoral. Here the German Navy's Type 212A submarine U-33 is seen passing the mine-countermeasures vessel HAMELN.

2021 Maritime Security Regimes Roundtable

The Combined Joint Operations from the Sea Centre of Excellence (CJOS COE) conducted a virtual Maritime Security Regimes Roundtable (MSR RT) between 3 and 4 November 2021, with the rather broad theme of "Challenges and Threats in Global Maritime Security."

CJOS COE is led by Vice Admiral Daniel Dwyer--who is also Commander, US Second Fleet and Commander, Joint Forces Command Norfolk, and has an international staff representing 13 nations.

"We started the MSR roundtable in 2012 as a forum for sharing best practices and mutual education," said Royal Navy Commodore Thomas Guy, the deputy director of CJOS COE. "The round table will bring maritime security stakeholders – military experts, academics, and representatives of the industry—together to exchange experiences, knowledge, and concerns in the field of Maritime Security. "As the host, CJOS COE aims to enhance knowledge and raise awareness on important issues in maritime security and, by doing so, support and preserve the interests of NATO Allies and partner nations."

Guy said, "Their participation and that of the greater community of interest will serve as an enriching forum to advance the achievement of a safer maritime domain within which everyone will be better prepared to face future challenges."

According to Guy, NATO's military focus has evolved since the end of the Cold War. At first, it appeared that the threat from the Soviet Union had dissipated. "At that time, NATO was more focused on maritime security instead of warfighting. Since then, NATO has focused much more on high-end warfare, but there still is a demand signal for addressing global maritime security issues, and we've got a good pedigree in facilitating that."

The round table was intended to bring about a better understanding of some of NATO's most pressing geographical hot spots in terms of maritime security, the issues found there, and the challenges they pose. That included understanding the most influential actors within those hot spots, their motivations, and how they are affected by the interests and actions of external global actors, as well as the international legal aspects of maritime activity, the intersection of naval activity and commercial shipping, and new more complex threats faced by the international community.

"We want to share awareness across the community of some current at-sea operations; discuss technical and operational challenges, breakthrough technologies, and knowledge gaps to facilitate future research and collaboration across the community; and inform the maritime security community of the spectrum of work accomplished through the MSR RT working groups," said U.S. Navy Cmdr. Nathaniel Hathaway, the MSR RT project officer.

In his keynote remarks, Vice Adm. Keith Blount, RN, who commands NATO's Allied Maritime Command, discussed the importance of the physical presence of NATO navies at sea, and that demonstrable credibility is a fundamental part of deterrence.

While the presenters covered a wide range of maritime threats and challenges, Russia and China rose to the top. Russia is of special concern to NATO because of the spectrum of threats it represents, from nuclear submarines and hypersonic missiles to seizing and occupying territory. "After having been in the doldrums for many years following the Cold War, we see a different Russia emerging," Blount said. Meanwhile, although China does not border any NATO nation, what it does in the South China Sea and its expanding influence around the world does affect the West and NATO.

other neighbouring US commands, to drive maritime warfare development. CJOS COE enjoys particularly close cooperation with Allied Maritime Command (MARCOM), other NATO commands and COEs.

COE CSW: The Centre of Excellence for Operations in Confined and Shallow Waters (CSW) is based in Kiel, Germany. The COE CSW recognises that blue water and littoral operations can be dramatically different, and frequently require different platforms, sensors, weapons and tactics. Coastal, confined and shallow waters have significant relevance to transportation, trade and food sources, and directly impact the majority of the world's population. CSW supports development of warfare capabilities and examines issues such as operational maritime law and strategic decision making.

MARSEC COE: The Maritime Security (MARSEC) Centre of Excellence is located in Istanbul, Turkey. The MARSEC COE provides expertise and promotes cooperation in the protection of critical infrastructure, maritime counter terrorism, counter proliferation of WMD, Maritime Security Capacity Building (MSCB), Maritime Situational Awareness (MSA), Freedom of Navigation (FoN), Maritime Interdiction Operations (MIO), and crisis management/ whole-of-government coordination. It encompasses maritime security issues such as piracy, drug trafficking, and illegal fishing, as well as undersea cable protection, cyber threats, pandemic responses, terrorist threats, and pandemic challenges.

NMW COE: The Naval Mine Warfare (NMW) COE is headquartered at Ostend, Belgium. Naval mines have always been a threat, and today's mines can cause a great deal of damage while being extremely hard to find. Evolving mine warfare and mine countermeasures technologies require updated doctrine and tactics, planning and evaluation algorithms, tools, education and training of personnel. The NMW COE's focus is on concept development and experimentation, doctrine and standardisation, lessons learned and analysis, and education and training

In addition, two COEs currently completing the accreditation process are multi-domain focused, but with a strong connection to the maritime. These are Integrated Air & Missile Defence (IAMD) and the Maritime Geospatial, Meteorological & Oceanographic (MGEOMETOC) COEs.

The IAMD COE is located in Chania, Greece. It will support the development of NATO IAMD capabilities with coherent up to date expertise, keeping up with technological advancements in the IAMD are – to include hypersonic missiles, surveillance system integration and counter-unmanned aerial systems, as well as overcoming the interoperability deficiencies of existing air defence systems. Subject Matter Experts (SMEs) will come from land, maritime and air commands of the respective NATO Nations.

The Maritime Geospatial, Meteorological & Oceanographic (MGEOMETOC) COE, located at Lisbon, Portugal, will focus on the maritime domain. However, environmental data, analysis and forecasting is vital to the success of operations under the sea, on the surface of the ocean, on land and in the air. The MGEOMETOC COE will support the Alliance by improving the creation and sharing of geospatial, weather-related and ocean-related information, helping to build an enhanced Common Operational Picture (COP) and preparing and delivering situational awareness to enable better decision support for commanders.

600 Blue Dots

Why NATO should adopt Multi-Domain Operations

Andreas Uhl

When the NATO Maritime Commander - COM MARCOM – in Northwood/UK looks at the screen in his operation centre, he can recognise the ships and boats in the four maritime task groups under his command[1] – about 15 to 20 labelled dots on the screen. However, he can also see about 600 dots in the North Atlantic region between the Arctic and the Equator, and between the Caribbean and the Black Sea. Unfortunately, these 600 maritime platforms of the 30 NATO nations do not, at least not directly, contribute to COM MARCOM's situational awareness and understanding in the area he is responsible for. They operate under national responsibility or under the command and control of multinational organisations such as the UN, the European Union, or others.

His Land and Air focused colleagues in the NATO HQs in Izmir and Ramstein face similar challenges to build up and maintain the required level of situational awareness and understanding in their individual domains[2].

Even at a brief glance, it would seem to be beneficial to have all the 600 dots contributing to a better, more comprehensive maritime picture for COM MARCOM. Hence, all maritime, air and land, cyber and space assets could weigh in an overall "seabed-to-space situational awareness and understanding" within the Alliance.

Photo: U.S. Army / Sgt. Aven Santiago

U.S. Naval Special Warfare Operators assigned to Naval Special Warfare climb aboard a simulated enemy ship during a visit, board, search, and seizure exercise during a multi-domain training mission at the NATO Maritime Interdiction Operational Training Center, Greece on July 31, 2020.

NATO Warfighting Capstone Concept (NWCC)

During the Brussels NATO Summit in June 2021, the Heads of State and Governments endorsed the new NATO Warfighting Capstone Concept (NWCC) and called for its quick and complete implementation.

NWCC is the so-called "North Star" of the Alliance's transformation to handle the simultaneous, persistent, boundless challenges of today's security environment. The concept looks from today towards the future with a 20-year scope. It questions the effectiveness of NATO's linear Peace – Conflict – Crisis thinking in a security environment where Western democracies might be co-operating and trading with a particular nation, while at the same time competing in space, being challenged in certain areas, and even being attacked by the same nation, e.g., in cyber. Our relationships with Russia and China may serve as examples for the challenging environments such as these that NATO is encountering today. Consequently, NWCC requires a new approach from the Alliance in its transformation to this new environment.

Implementing the requirements of the NWCC, a new "Alliance Warfare Development Agenda" will extend the military options in NATO from a sole focus on warfighting towards a new trifecta of "Shaping, Contesting and Fighting". This includes the idea of the co-ordination and synchronisation of military actions with actions from other instruments-of-power (governmental and non-governmental). In doing so, the shaping and contesting elements of the approach could avoid the necessity of warfighting – or at least could ensure the necessary advantage to win the fight.

Multi-Domain Operations

The new mind set and culture being introduced with the NWCC, and the subsequent Alliance Warfare Development Agenda, leads towards an Alliance Multi-Domain Operations Approach. The capability for Multi-Domain Operations is the pre-requisite to prevail in the current contested security environment. It encompasses a deeper understanding of the competitor, his and our own strengths and weaknesses, and increases situational awareness, as well as interrelations and linkages within the operating environment.

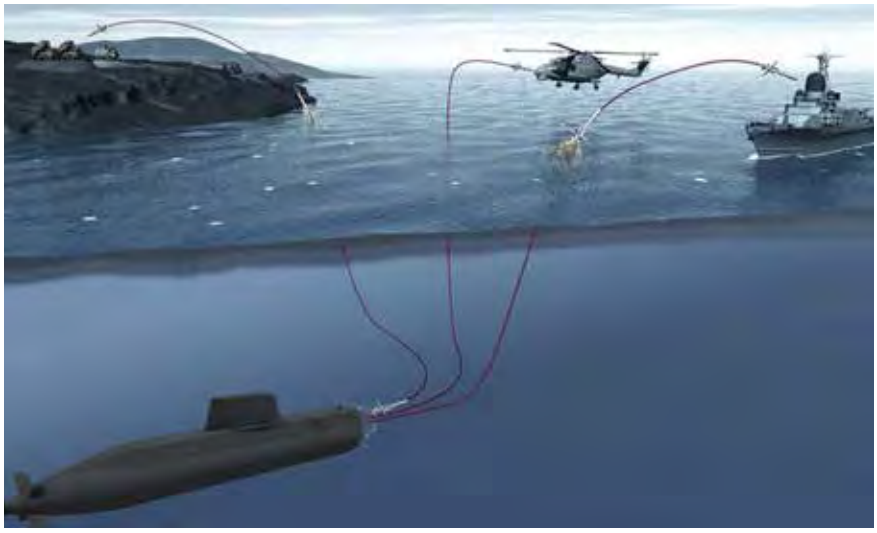
Author

Andreas Uhl is a German Navy Commander and has published numerous articles on Joint Interoperability and on Integrated Air & Missile Defence within the last 20 years. Currently he works at NATO Allied Command Transformation. The views expressed represent those of the author and not neces-sarily of NATO ACT.

1 Standing NATO Maritime Groups 1 and 2 and Standing NATO Mine Counter Measure Groups 1 and 2

2 NATO acknowledges Air, Maritime, Land, Space and Cyber as 'domains'

Photo: IDAS



Lookout to future multi-domain operations: A submarine receives target data generated by INTEL, provided via Cyber and Space ressources attacking a land target while being engaged in a self defence battle against air- and surface assets.

This requirement for understanding takes us back to the 600 blue dots and their counterparts in the air, land, space, and cyber domains. How can NATO make best use of all the capabilities within the Alliance, not only the ones under NATO command and control, but also the ones under its member nations command and control?

Technically, two different areas must be better aligned and integrated to achieve Multi-Domain Operations within the Alliance. These are, first, the NATO command structure – including the headquarters and forces under NATO operational control – and, second, the forces operating under national control for better situational awareness. In addition, the strategic, the operational and the tactical level in NATO all require better synchronisation to ensure speed of relevance to achieve effective kinetic and/ or non-kinetic effects in the cognitive, the virtual and the physical dimensions.

Already, there are some NATO nations using national Multi-Domain Operations concepts and ideas. Most of them strive for better integration of the "classic" national services with the new domains of space and cyber. Some national concepts also mention the increasing demand to integrate military options with the actions of the other instruments-of-power. NATO will not be able to integrate more than 100 military services of 30 nations with their thousands of different systems; the technological heritage would be way too complex. Leaving the platform centric approach, NATO will have to deliver top-down options for better agility and alignment of its command structure. At the same time, the Alliance must provide guidance and interfaces for better bottom-up connectivity and integration with national capabilities.

NATO's Digital Backbone

To put it plainly: if NATO fails to enable Multi-Domain Operations via an effective digital backbone, it will not be able to provide improved connectivity and interoperability in the future. How, exactly, this digital backbone will appear is subject to current studies and research. Clearly, we do not have 20 years for its realisation; thus NATO will realistically be able to adopt some of the national concepts for total, global integration of all military capabilities. Given the time pressure, NATO could start with sensor & communication integration (i.e., receiving data from the 600 blue dots) and simultaneously integrate those warfare areas which seem to be highly time critical (among them: integrated air and missile defence, and joint fire support).

Fortuitously, NATO's digital backbone would not start at zero. Although "plug-and-fight" and "network centric" are still niche-capabilities after 20 years of combined-joint operations, there are capable systems and networks already existing or under development. These would only require some retrofitting and acceleration. And, most importantly, require connectivity with each other and across the board, where it is deemed necessary. NATO does not need to integrate everything. The idea of a 'Single Combat Cloud' might work for some services of some specific nations; but it might not be the most desirable concept for NATO as a whole. On the contrary, NATO has done well in improving interoperability and connectivity within the last years with its different Federated Mission Networking projects.

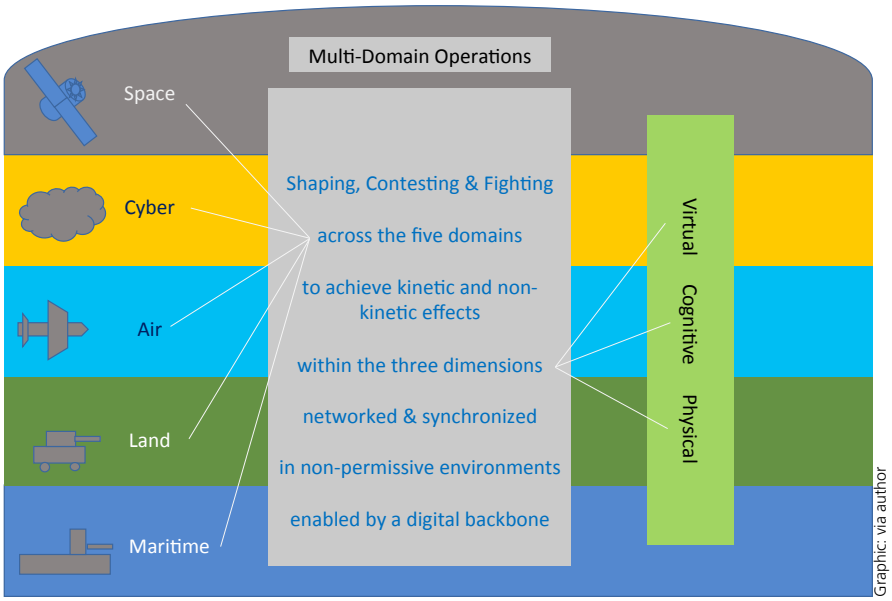
In contrast to the "illusion of total integration", a federated environment would provide more resilience and less vulnerability against hostile interference. Such a NATO approach could benefit from distributed command structures and some sort of "digital autarchy", utilising aligned data protocols in todays and tomorrow's systems and networks.

More digitalisation is the best chance for NATO to multiply existing capabilities and to better synchronise operations. The NATO Warfighting Capstone Concept does not call for increased quantities of tanks, bombers, or frigates. It only demands the improved level of connectivity, interoperability, and synchronisation, which a NATO digital backbone would be able to provide. Thereby, its own strengths would be allowed to achieve their full potential, and its own weaknesses limited.

The top-down process towards a future digital backbone on the operational level has already started within the NATO Com-

Photo: U.S. Navy / Ryre Arciaga

Sailors on board USS SHILOH (CG-67), one of the 600 blue dots, contributing to the Maritime Commanders' understanding of the overall Common Operational Picture.



Graphic: via author

Elements of Multi-Domain Operations which are common in most of the present concepts

mand Structure. One example is the creation and expansion of the OpNet. A bigger endeavour will be the required bottom-up approach on the tactical level, particularly when it comes to "sensor-shooter integration. Sensor-shooter integration ensures coordinated task group reactions in time-critical situations. This is key to avoiding blue-on-blue engagements, as well as ensuring mutual support under attack and the survival of one's own assets, for example in a force air defence situation. Such a coordination of force threat evaluation and engagement will have to be supported by artificial intelligence in order to generate decision processes with sufficient speed to be relevant. Some nations already have achieved sensor-shooter integration at different levels of complexity; unfortunately only a few of these systems provide multinational interoperability by design. NATO's big success in peacetime, the deterrence by multinational resolve and solidarity, would turn into an interoperability challenge if it came to the fight. A NATO digital backbone will therefore have to guide and facilitate the connectivity of such national systems.

Russia and China dominate the Electromagnetic Spectrum

Connectivity and interoperability at the tactical level do not only face the challenges of harmonising multinational capabilities and C2 nodes/systems. As an imperative, they must also function in "non-permissive" environments. Especially for Russia and China, dominance over the Electromagnetic Spectrum (EMS) is an important part of their military strategy. Relevant capabilities are in use in both countries and their forces are solidified and hardened against enemy EMS attacks. In particular, for the new domains space and cyber, control over the EMS is essential: cyber-attacks utilise the EMS via space-based infrastructures, or attack opponent's space-based infrastructure using the EMS.

Furthermore, systems and forces in the classic domains of air, maritime and land are prone to attacks via the EMS and increasing digitalisation enhances their vulnerability. While one measure will be the hardening of one's own systems, another must be to provide the famous "battle short" button – to avoid the push on the "restart" button during the battle. NATO nations will have to develop their own capabilities further to achieve solid effects in the EMS.

Another Achilles heel for NATO is the reliance on the World Wide Web. Conversely, China and Russia have created own nationally controlled web systems.

Cross-Domain Leaders and Mission Command

The future culture of command will most likely follow the principle of Centralised Intent, Distributed Command and De-centralised Execution. More than ever before, the next war will be a war against each other's command & control lines. This requires a much higher degree of "Mission Command" – a principle that becomes key to success when connection to the higher echelons start blurring.

Proven, tested and established military principles will not relent in a more and more digitalised world. Military leadership and command come with responsibilities, no matter if lethality is achieved manually or digitally. The final decision for a kill is taken by human beings – at least in the rules-based world of NATO. Multi-Domain Operations require a new kind of cross-domain leadership, able to command and synchronise kinetic and non-kinetic effects in shaping, contesting, and fighting. Such leaders must be able to understand their own and opponents' digital capabilities and limitations across all domains in their mission area, as well as being able to continue operations on "days without space". It is a big misinterpretation of the digital age to think that traditional communication skills such as semaphore, flashing light or voice are no longer required. Unlimited global 365/24/7 broadband connectivity does not exist in peacetime. How much less can we count on it during a war? To take care of the loss of connection to supporting networks, specific capabilities have to be maintained within battle formations (e.g., reconnaissance, threat assessment, target illumination, etc.) and should not be exclusively provided via a combat cloud. If required, a mission commander must be able to generate and process essential data within his task group – preferably supported by artificial intelligence. He should be up to generate a tactical picture and communicate his intent in situations, where IP and satellite-based services are not available.

The NATO Warfighting Capstone Concept is striving for this new kind of military leader, the so-called "Cross Domain Commander".

Summary

The concept of Multi Domain Operations per se is not revolutionary. It is the consequent evolution of Combined-Joint Operations, applying a much higher degree of integration and synchronisation. Beyond the technical/technological components that enable its implementation, military leadership is required for its realisation. Through this combination military advantage can also be achieved in the challenging electromagnetic environments to be expected in future armed conflicts. The Maritime Commander who is able to make best use of all sensor data ashore, at sea, over sea or under sea – and thus understands the situation across all domains in his area – will take the right decisions.

However, despite all technological development and smart digital solutions, the art-of-war still includes a lot of military craftsmanship. In the event of lost connectivity or a power outage on board, the sailors on board of the 600 blue dots have to be able to survive and navigate their ship home safely. ■

Lessons Learned – Collision Avoidance

Guy Toremans

With sea lanes becoming busier, collision avoidance detection techniques and associated tracking systems are gaining increased interest. Despite advances in marine navigation systems, the number of incidents is still high. The last few years have seen a spate of collisions between warships and civilian vessels from which valuable lessons have been learned. In the longer term, technological developments offer the prospect of further advances in navigational safety. However, the human factor will likely always remain important.

Recent Collisions involving Warships

Starting from 2017, there have been a number of well publicised collisions in which warships have been involved. These events have included the following incidents:

- **27 April 2017:** The Russian Navy intelligence gathering vessel RSS LIMAN sank in the Bosphorus Strait, after colliding with the 2282-ton Togo-flagged livestock freighter M/V YOUZARSI H.
- **9 May 2017:** The TICONDEROGA class cruiser USS LAKE CHAMPLAIN (CG-57) collided with the South Korean fishing boat NAM YANG 502 in the Sea of Japan.
- **17 June 2017:** The ARLEIGH BURKE class destroyer USS FITZGERALD (DDG-62) smashed into the Philippine-flagged container ship M/V ACX CRYSTAL, about 80 nautical miles southwest of Tokyo.
- **21 August 2017:** Another ARLEIGH BURKE class destroyer – USS JOHN S. McCAIN (DDG-56) – collided with the 30,040-ton Liberian-flagged tanker M/V ALNIC MC off the coast of Singapore near the eastern entrance of the Strait of Malacca.
- **18 November 2017:** Yet another ARLEIGH BURKE class destroyer – USS BENFOLD (DDG-65) – was involved in a minor collision with a Japanese tugboat during a towing exercise in the Sagami Bay.
- **8 November 2018:** The Royal Norwegian Navy FRIDTJOF NANSEN class frigate HELGE INGSTAD collided with the 113,000 ton Maltese-flagged tanker SOLA TS in the Hjeltefjord while on transit to Haakonsvern Naval Base.

Photo: US Navy

The US Navy destroyer FITZGERALD (DDG-62) being towed into port after her collision with the merchant vessel ACX CRYSTAL in June 2017.

- 30 March 2020: The Japanese Maritime Self-Defence Force HATAKAZE class destroyer SHIMIKAZE came into collision with a Chinese fishing vessel in the East China Sea, approximately 400 nautical miles west of Yakushima Island.
- 23 September 2020: The Russian Navy's PARCHIM class corvette KAZANETS collided with the 14,567-ton Swiss reefer container ship M/V ICE ROSE in the entrance to the Baltic, south of the Øresund Bridge that spans the sea strait between Denmark and Sweden.
- 27 October 2020: The 50,736-ton Portuguese-flagged container ship M/V MAERSK LAUNCESTON hit the Greek minehunter HS KALLISTO (ex-HMS BERKELEY) outside the port of Piraeus, opposite the Salamis naval base, cutting off the minehunter's stern.

Causes & Consequences

These incidents inevitably raised concerns about navies' policies towards navigation safety, training and seamanship. Comprehensive investigations launched by Norwegian and US authorities have provided useful information about their causes. In all cases, multiple operational, technical and organisational factors had contributed to accidents but the most important factor that gave rise to collisions came down to human error. Common issues influencing these errors included:

- The combination of complex systems and system functionality
- The introduction of new technologies that were not always fully understood
- Inadequate bridge operating procedures
- Deficient training of bridge watch teams
- Insufficient crew preparation for handling complex damage control scenarios

Looking more specifically at some of the accidents involving US Navy ships, it is interesting to note that problems and conflicts in communications between the bridge team and the combat information centre coupled with poor ergonomics of bridge systems and crew fatigue were important issues. For example, sailors from the cruiser ANTIETAM who were assigned to JOHN S. McCAIN

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were reportedly not familiar with the latter's Integrated Bridge and Navigation System (IBNS). To them, the touchscreen-based control equipment was overly complex and, as such, challenging to interpret. And although impossible to draw a direct line to the cause of the accidents, it is noteworthy the incidents involving US Navy ships were focused on 7th Fleet-based units where a culture of allowing overly-stressed crews to take on too many burdens to meet operational demands had taken hold. A navy Risk Assessment and Mitigation Plans (RAMP) concept allowed units to operate with gaps in functioning equipment, training and appropriate certifications, even in critical areas such as damage control and navigation. The 'normalisation-of-deviation' and "can-do" approach arguably created significant additional risk.

It is also worth noting that another important factor that had a hand in the incidents was that, as far as can be ascertained, in at least five out of the nine above mentioned cases the naval units were not transmitting signals on their Automatic Identification System (AIS).

As a result of the investigations, both the Royal Norwegian Navy and the US Navy instituted measures to address the deficiencies that had been identified, including the introduction of new measures to reform relevant training. The steps implanted have included:

- Putting greater emphasis on basic seamanship, navigation and maritime situational awareness for future surface warfare officers.
- Placing increased emphasis on visually judging the behaviour of other ships rather than placing exclusive reliance in electronic aids. This was particularly intended to address the tendency of less experienced personnel to be "captured" by the data provided by electronic displays at the expense of actually physically observing the maritime environment through the bridge windows, thereby degrading their situational awareness.
- In the Royal Norwegian Navy, implementation of more systematic Bridge Resource Management (BRM) and Crew Resource Management (CRM) training from March 2019 onwards.
- In the US Navy, attempting to resolve the potential confusion caused by differences in bridge equipment across its various ship classes by accelerating the standardisation of the systems used in in its surface combatants along common lines. This will reportedly favour the use of wheels and throttles in lieu of touchscreen technology. In addition, the navy is reconsidering the generalist culture among its surface warfare officers – the so-called "unrestricted line officer" concept – under which officers are expected to gain experience both as platform and as combat system engineers, thereby becoming so overloaded with tasks that there is little room to gain soli watch keeping experience. Moreover, the US Navy has also discontinued the RAMP concept.
- Both navies have also made it mandatory for their units to transmit actively on their AIS systems when operating in restricted waters or transiting busy shipping lane areas, unless there is a high risk of a terrorist attack. In addition, when using AIS in passive or encrypted modes, these units must ensure that adequate compensatory measures are put in place in order to ensure safe navigation.

Photo: US Navy

A patched-up JOHN S. McCAIN (DDG-56) seen in transit for long term repair. Her collision with the ALNIC MC – the second fatal incident of the kind within two months impacting US Navy destroyers – produced fundamental changes in navy procedures and training.

Photo: Maria Gran/Norwegian Armed Forces

The Norwegian frigate HELGE INGSTAD under tow to the scrapyard after being declared a total constructive loss after her 2018 collision. The costs of such incidents can be high in both human and materiel terms.

Preventing Collisions: Current Technology

Today, most ships are outfitted with onboard collision avoidance systems that compute ship tracks, target the closest point of approach (CPA) and the time to CPA, providing watch keepers with automated alerts on the risk of collision. Technologies used to support these systems include:

The Automatic Identification System (AIS): This is used to transmit the position and velocity of a ship to other vessels. This system automatically acquires and constantly monitors a tracked object's course, plots its speed and course, and calculates its closest point of approach and the time when that will occur. AIS depends on satellite navigation and is reliant on factors such as the frequency with which traffic data is uploaded/downloaded, which may vary from region-to-region and on the basis of traffic density. It may therefore not be entirely accurate. Moreover, the availability of information is restricted to vessels equipped with AIS transponders. Many vessels, such as lei-

Photo: Royal New Zealand Navy

The spacious bridge of the Royal New Zealand Navy's replenishment vessel AOTEAROA. Although bridge management and navigation systems have improved significantly, collisions still happen.

sure craft, and other objects in water, such as navigational aids or debris, will therefore not be captured by the information AIS provides.

Automatic Radar Plotting Aids (ARPA): This system process positional data and displays the navigational situation on the radar screen, allows a navigator to make reasonable decisions on what manoeuvres to take. In some situations, the number of moving obstacles – as well as static obstructions – might make it difficult to designate waypoints in advance and also increase the overall risk of collision.

The NAVigational DECision (NAVDEC) support system: This observes and assesses the navigational situation in real time, presenting a consolidated "picture" encompassing bathymetric data from an Electronic Chart Display and Information System (ECDIS), images of surface situation from the ARPA tracking radar and positional information from both the AIS and the Global Navigational Satellite System (GNSS). These systems provide enhanced situation-specific data but the algorithms they incorporate are based largely on fixed, static values with little ability for the use of selected information. They do not consider the problems of delayed data update, equipment operator errors, nor other problems leading to inaccurate ship trajectory information. The issue of inadequate situational awareness on the part of watch keepers referenced above remains a problem. The current situation is therefore not fully satisfactory, particularly in terms of providing a collision avoidance alarm. As a result, future electronic navigation systems are looking to provide enhanced capacity – incorporating increased autonomy and human-centred design – to improve overall performance.

The Way Ahead

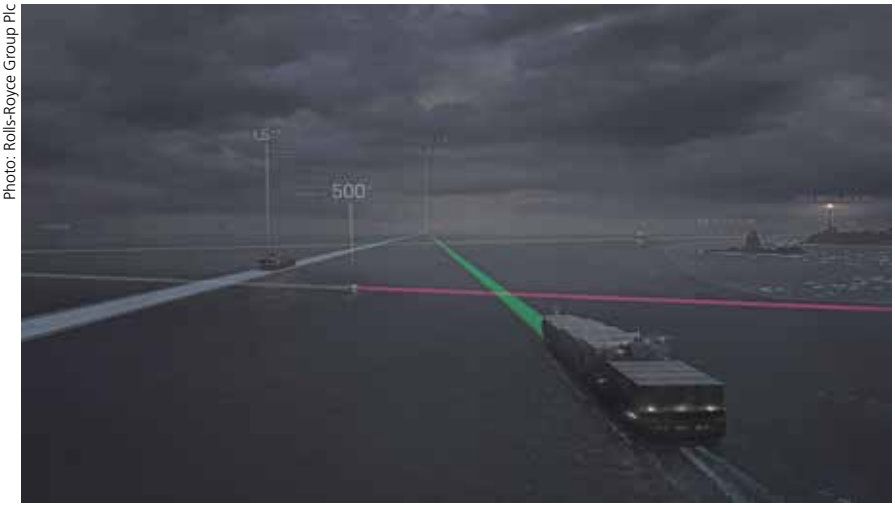
Autonomous – or at least semi-autonomous operation – is gaining increasing attention as a means of solving the ongoing risk of collision alongside growing interest in applying artificial intelligence as a means of enhancing the control of shipping manoeuvres. Rapid advances in computerised technology are paving the way for the introduction of new navigation control and decision making equipment. In particular, intelligent guidance systems incorporating enhanced collision avoidance algorithms that can predict likely vessel movements offer the prospect of generating collision-free paths that avoid both static and dynamic obstacles under a wide range of operational conditions, providing optimal and timely information for the performance of avoidance manoeuvres. Researchers and technical experts are involved in a range of studies looking at developing and implementing this technology.

One of these studies covers a quantitative real-time multi-ship collision risk analysis and collision avoidance decision-making model that combines data provided by AIS and the Vessel Traffic Service (VTS) system with artificial intelligence to gather and analyse maritime traffic patterns. The model is reportedly capable of making correct decisions under a range of different scenarios.

Another study is looking at multi-ship collision avoidance and route generating algorithms based on the general requirements of the International Regulations for Preventing Collisions at Sea (COLREGs) and Artificial Potential Field (APF) methodology. The algorithm consists of two modes: one relating to course-changing and one relating to track-keeping. The course-changing mode guides the ship to turn away from the obstacles. The track-keeping mode steers the ship back to and along a pre-designed track. The algorithm works on data based on the Distance to the Closest Point of Approach (DCPA), the Time to the Closest Point of Approach (TCPA) and bearing angle. It is reportedly very simple to implement and would have obvious application to a working collision avoidance system.

The most challenging issue is how to determine optimal path planning. Route finding in congested waterways is a complex task because of the many limitations and constraints generated by ship manoeuvrability, hydrodynamics and the operating environment. One concept under development encompasses an intelligent route planning

Photo: Rolls-Royce Group Plc



A Rolls-Royce graphic showing some of the data that needs to be considered when devising navigation and collision avoidance systems.

EUROPE AND THE SEA

A CONTINUING STORY

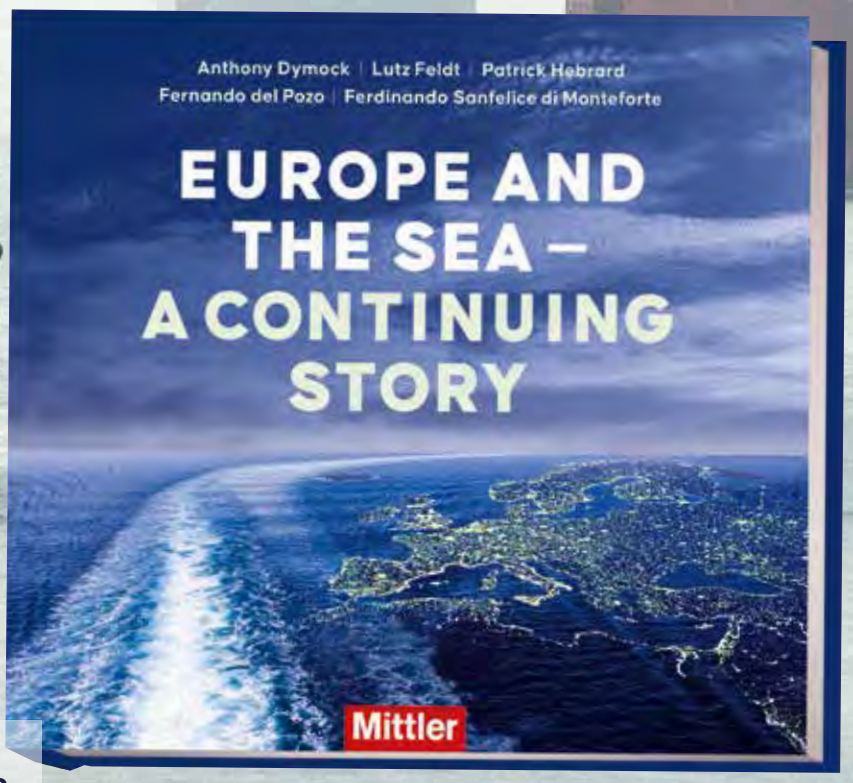


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Photo: Republic of Singapore Navy

Singapore's MARSEC USV – a variant of the VENUS unmanned surface vehicle – is equipped with the autonomous Collision Detection' and Collision Avoidance (CDCA) system.

system that can both to predict the future locations of vessels and compute the consequences of different actions that they might take. A trajectory-planning component provides optimised trajectories in sufficient time to avoid a collision and is able to suggest a track automatically. The concept is based on a modified version of a Rapidly-exploring Random Tree (RRT) algorithm that utilises a randomised data structure. The algorithm is able to manage multiple moving obstacles with variable speed and course and able to detect static as well as moving obstacles

Autonomous Vessels

A wide range of automatic collision avoidance systems and dynamic route-planning systems are being tested or already operational onboard unmanned surface vehicles (USVs).

One fleet that has been an early embracer of this technology is the Republic of Singapore Navy. In partnership with Singapore's Defence Science & Technology Agency (DSTA), it has developed an advanced autonomous Collision Detection' and Collision Avoidance (CDCA) system that is installed in the VENUS 16 USVs that will be used to conduct maritime security operations and mine countermeasure missions. Featuring an algorithm designed specifically for operations in the busy waters around Singapore, the CDCA integrates data from a wide range of sensors and collision avoidance equipment to generate automated commands that are in full compliance with the COLREGs regime.

Another system – currently being tested by the US Navy on its unmanned surface vehicles NOMAD and RANGER of the "Ghost Fleet Overlord" programme – is the L3Harris ASView Bridge Aid. This system provides advanced situational awareness, path planning and navigation in complex contact situations. The ASView Bridge Aid is claimed to incorporate a highly intuitive user interface to monitor the ship's environment through active and passive perception sensors and to display "own ship" performance information. Interfaces are available for GPS receivers, gyro-stabilised and satellite compasses, inertial navigation systems, marine radar systems, AIS, electro-optical and thermal cameras, depth sounders and environmental sensing.

Some autonomous systems are also being developed commercially. For example, Hyundai Heavy Industries (HHI) developed its Hyundai Intelligent Collision Avoidance Support System (HiCASS) to aid mercantile navigation of merchant shipping a decade or so ago. Equipped with a collision notification system that signals "Caution", "Urgent" and "Danger", HiCASS searches for optimum sea routes and prevents collisions by automatically detecting vessels and analysing the locations of other potential obstacles within a range of up to 50 km. HiCASS has subsequently been used as the basis for the Hyundai Intelligent Navigation Assistant System (HiNAS). This uses autonomous navigation technologies which automatically recognise objects surrounding the vessel and its future route to provide alerts on the risk of collision based on augmented reality and remote sensing technology such as special cameras and LiDAR (Light Detection And Ranging). The HiNAS system can cope with various unexpected situations, such as adverse weather conditions, strong currents, and the appearance of fishing boats or other small craft. In June 2021, the autonomous, unmanned operation of a small ferry equipped with HiNAS in Pohang-si, a10 km long, 10m wide canal known for its complex and challenging navigating environment, was successfully concluded. It is more than likely that this system could be adapted to be installed aboard an autonomous surface warship after being tailored to suit specific naval requirements.

Conclusion

It can be seen that ongoing developments in computing and the associated area of artificial intelligence are opening up a wide range of practical technologies that will equip the collision avoidance systems of the future with much greater capacity than the equipment in use today. These technologies – that will effectively allow systems to "think for themselves" will be crucial for the development of the new generation of unmanned and autonomous vessels that are an important trend in future naval operations. At the same time, the lessons from recent collisions would seem to suggest that technology alone cannot fully replace the experience of sailors that currently crew a ship, particularly the in depth naval mastery and knowledge of navigators tasked with handling potentially dangerous situations. Although tomorrow's ships may well be controlled by technology and monitored by "sailors" at distance on the shore, effective training in navigation and bridge-management, even if performed remotely, will remain a valuable investment. It is difficult to avoid the conclusion that the human element will always be important in ensuring safety at sea. ■

Photo: Crown Copyright 2021

The Royal Navy's MADFOX USV is one of a number of vessels around the world trialling similar autonomous technologies.

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