SPECIAL REPORT

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ASPI
AUSTRALIAN STRATEGIC POLICY INSTITUTE

# The enemy below:
## Anti-submarine warfare in the ADF

by Andrew Davies

## Executive summary

### Introduction

In an arc extending from Pakistan and India through Southeast Asia and up to Japan, there is a striking modernisation and expansion of military capabilities underway. As well as indigenous development projects, off the shelf purchases of military hardware and expertise are seeing a range of countries make great strides in enhancing their ability to defend themselves and project power beyond their boundaries.

There are a number of reasons for this to be occurring, including the economic growth over the last decade. With affluence, there is a general tendency towards the acquisition of high-end military capability. But there are also geopolitical factors at work.

China and India are positioning themselves to be future great powers, fuelled by the economic boom that both have been experiencing. As such, they are expanding their military capabilities in several areas. Building predominantly on Russian expertise and hardware, both countries are now developing sophisticated platforms, missiles and command and control structures. Other countries are also taking steps to expand and upgrade their capabilities, usually by acquiring high-performance equipment off the shelf from Russian or Western European suppliers. Some are doing so in response to the growing capability of India and China, while others are being motivated by local security concerns, often based on historical enmities—arms competitions are occurring in a number of places.

The proliferation of high-end capability can be seen in a number of areas, including combat aircraft, cruise missiles, surface fleets and submarines. In the future, ASPI will report on each of these areas to provide perspectives for consideration of Australia's future force structure options. This is the first of a series of reports on regional military capabilities and their implications for Australian Defence planning.

The paper begins with submarines because there are a number of decisions to be taken later in 2007 that have the potential to impact on the Australian Defence Force's ability to operate in areas where opposition from submarines could be expected. This year decisions will be made regarding the Air Warfare Destroyer and Amphibious Ship projects. There are some recommendations for the systems that should be fitted to those vessels, and how they fit into an overall Anti-Submarine Warfare (ASW) capability.

## Submarines

Modern submarines are stealthy and heavily armed with an array of weapons, including missiles, torpedoes and mines. They are able to strike targets on the surface, on land or even—in the not too distant future—in the air. Countering their impact requires a sophisticated capability including the integration of a range of sensors, weapons and countermeasures.

## Regional fleets

The availability on the world market of sophisticated submarines ‘off the shelf’, with deals often sweetened with training packages, has dramatically shortened the time it takes for a country to develop a submarine capability.

Sophisticated Russian and western European designed submarines are proliferating into the region, with Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Singapore and South Korea all acquiring or planning to acquire modern conventional boats.

The rising major powers China and India are working to develop indigenous nuclear submarines in conjunction with acquiring sophisticated conventional submarines and weapons from abroad. China in particular has markedly increased the size and capability of its fleet over the last decade and continues to build on that progress.

The upshot is that Australia will soon face a region that has a much greater capability to conduct submarine operations. In a contingency, submarines will be able to seriously threaten the operation of surface fleets and commercial trade.

## Australia’s current ASW capability

Australian ASW capabilities have been in a state of benign neglect for a couple of decades despite a number of studies over the years that have highlighted shortfalls. Simply put, there were few submarines in our region, and those were of dubious capability. Other considerations took precedence over ASW when setting force structure priorities.

Today, faced with a region that is rapidly developing the ability to operate a range of very sophisticated submarines, Australia cannot expect to be able to conduct major naval operations in the future without a major upgrade to its ASW capabilities.

The major shortfalls include:

- Our frigates have medium frequency hull mounted sonars that are limited in their ability to detect submarines. In a wide range of oceanographic conditions, those sonar systems would not provide warning of the presence of a submarine before it was in a position to attack.
- Australian naval helicopters are currently limited in their ASW effectiveness by sonar and weapon shortcomings. The mix of different embarked helicopters makes it difficult to build a coherent helicopter ASW capability.
- The networking that is necessary for coordinated ASW operations is probably beyond our current naval communications systems.

## Recommendations for improving Australia’s ASW capability

*Surface vessels*

- The Air Warfare Destroyer will be our largest surface combatant, and is well-placed to be the primary ASW surface platform. It should be fitted with variable-depth sonar and low-medium frequency hull-mounted sonar, as well as embarking ASW-capable helicopters, with all of the necessary support systems and networking capabilities.

- Because they will be able to embark a large number of helicopters, the Amphibious Ships will provide a valuable ASW resource to a task group. They should be able to support the sonar systems and coordinate ASW operations with other surface vessels and aircraft.
- Commonality or compatibility of undersea warfare systems on the AWDs and future upgrades to the frigates should be a priority.

*Helicopters*

- Any task force operating in the presence of a submarine threat should be accompanied by at least three ASW capable helicopters. Those helicopters should have dipping sonar, surface search radar, and missile countermeasures to protect against submarine-launched surface-to-air weapons.
- Rationalisation of the Navy combat helicopter fleet to a single ASW-capable type fitted out as above should be considered in the near future. That would involve retiring the Sea Kings (already planned), forgoing the mid-life upgrade of the Seahawks and replacing the Seasprites in favour of an earlier procurement of a single new type. The MRH 90, already chosen to replace the Sea Kings, would be a sensible choice for the fleet. The net cost of such a rationalisation might be $1-1.5 billion over the next decade.

*Submarines*

- The Collins submarines will require ongoing investment, particularly in the area of sonar and weapons systems and networking capabilities.

*Networking*

- All platforms involved in ASW (fixed wing aircraft, helicopters and surface vessels) should have a networking capability that enables the sharing of sonar data.

*Other*

- Buying new equipment and platforms is only part of the development of an ASW capability. Crew training and the development of doctrine are critical to the overall capability.

## Introduction

Submarines are extraordinarily potent weapon and intelligence gathering platforms. They take advantage of the cover provided by operating in an opaque environment that confers a high degree of stealth. To combat them successfully, a wide range of sensors, weapons and countermeasures are required.

The submarine came of age as a weapon system during the two world wars. They almost defeated the allies in the Atlantic in both, and American submarines played a significant (if often underplayed) role in the defeat of Japan in the Pacific theatre in WWII. Those submarines were rudimentary compared to those of today, whose capabilities are many times greater in essentially all aspects. They are able to stay submerged for increasingly long periods and are now fitted with a formidable array of weapons that allow them to strike targets at sea or on the land.

On 26 October 2006, a Chinese submarine surfaced eight kilometres from a United States Navy aircraft carrier. At that range, the submarine was well-placed to deliver a lethal blow to the carrier had there been a state of hostility. The ability to locate submarines beneath the surface before they can position themselves for an attack is a critical one for modern armed forces.

This ASPI *Special Report* examines the capabilities of the modern submarines that are proliferating in our region and the techniques and technologies that can be brought to bear against them. It takes a critical look at the Australian Defence Force Anti-Submarine Warfare (ASW) capability and makes recommendations for future improvements.

## Submarine characteristics

Submarines fall into two broad classes, depending on their means of propulsion. Nuclear-powered submarines rely on an on-board nuclear reactor for propulsive power. Conventionally-powered boats (submarines are generally 'boats' rather than 'ships' in naval parlance) use diesel engines to generate power that is used to charge a bank of batteries that power the boat through an electric drive. The batteries provide a silent source of power for occasions when the tactical situation requires stealth. For that reason, they are also called 'diesel-electric submarines'.

The ability to run for sustained periods without access to the air allows nuclear submarines to remain submerged for long periods of time. The US and Royal Navies used that capability extensively during the Cold War for intelligence gathering missions into Russian waters. Both sides sent nuclear submarines under the polar ice cap and spent long periods shadowing each other's boats to collect potentially crucial acoustic data. Nuclear boats are also fast, due to the ability of the reactor to deliver large power loads. Nuclear attack submarines can achieve dash speeds of up to 35 knots (63 kph), making them faster than major surface vessels.

Conventional submarines are not capable of such high speeds. Typically, maximum submerged speeds are of the order of 20 knots (37 kph). However, if the tactical situation requires the submarine to be running on batteries for periods of hours, the speed will be closer to 4-6 knots (7-11 kph). The endurance on batteries at such speeds is around 3-5 days for the better diesel-electric boats. After that the batteries will need recharging. As well, conventional submarines have reduced endurance between refuellings. A large conventional submarine such as Australia's Collins class is capable of remaining at sea for about three months, while smaller boats have less endurance.

The need to run the diesel engines to recharge the batteries has historically been an Achilles heel of diesel-electric submarines. In early designs, the submarine had to surface, where it was obviously at much greater risk of detection and attack. A major breakthrough applied by the German navy during WWII was the 'snorkel'. As the name implies, that is a mast that can be raised above the water to allow the intake of air and the expulsion of exhaust. So equipped, a submarine can run its diesel engines while submerged to recharge its batteries, greatly reducing the vulnerability to detection and attack by many weapons.

However, any protrusion above the surface, be it a periscope, snorkel or antenna, can make the submarine more vulnerable to detection. Aircraft fitted with radar can search for submarines in this way. The proportion of the time that a submarine has a snorkel above the water is called the 'indiscretion rate'. Since diesel-electric submarines have to recharge their batteries at intervals ('snorting' in Royal Australian Navy parlance), they have a certain indiscretion rate forced upon them. For that reason, there has been much effort put into making the battery technology of submarines as efficient as possible and developing air-independent means of propulsion (AIP).

AIP increases the tactical flexibility of conventional submarines by reducing the indiscretion rate. One such technology is the fuel cell, in which hydrogen and oxygen are combined to produce electricity, heat and water. Now being fielded in some European submarines, modern AIP systems allow a submerged low-speed endurance of around two weeks, though future systems may allow up to a month. AIP systems do not deliver the raw horsepower required to drive a submarine at full speed, so back-up power is required for a high-speed dash if the situation demands.

Some mast exposure is voluntary, such as when the submarine commander opts to transmit or receive radio messages or to survey activity on or above the surface visually or by electronic means. Similarly, if a submarine is required to receive and/or transmit data as part of a networked force or for command and control reasons, it will generally raise a mast to do so.

## Submarine weapons

In the Falklands conflict of 1982, the British nuclear submarine HMS *Conqueror* was charged with shadowing a task group including the General Belgrano, an Argentinean cruiser of 10,000 tons. Because of the very poor Argentinean ASW capability, the *Conqueror* was able to manoeuvre to very close range. Firing from only 1,400 yards, the choice was made to fire three Mark 8 straight running torpedoes, a design dating back to the 1920s. (Some sources cite doubts about the reliability of the homing torpedoes carried by the *Conqueror* for the choice, but the heavier firepower of the older design is also a likely reason.) Two torpedoes hit the Belgrano, which sank within the hour. The third may have struck one of the other vessels in the group, but failed to explode.

This is a salutary lesson. When operating against capable submarines, surface vessels must have capable defences. The first indication the Argentineans had that there was a submarine in the area was when the first explosion occurred. This is by no means unique in the history of naval warfare and the term 'flaming datum' was coined in WWII to describe such an event.

Submarines can use a variety of means to find their target. Despite the Hollywood image of the target in the cross hairs on the periscope, they do not necessarily need to put a mast above the surface in order to gather enough data to launch an attack. In the right conditions, surface vessels can be located and tracked sufficiently accurately for targeting purposes by acoustic means. Fixed targets on land can be attacked by missiles with pre-programmed co-ordinates. Just entering the market today are surface-to-air missiles that will allow submarines to attack aircraft operating in their vicinity.

Modern submarines can carry a wide range of anti-shipping weapons. The traditional weapon of the submarine has been the torpedo, but today's submarines are armed with a range of missiles and the capability to deploy mines.

There is also a calculus for the submarine in choosing its weapon. The torpedo offers greater destructive potential than missiles but means that the submarine must approach relatively close to the target to obtain a firing solution. As well, torpedoes are relatively slow, allowing more time for deploying counter-measures against them.

Missiles are faster and longer-ranged than torpedoes, making evasion harder for the target. However, the exhaust trail from the missile provides a clear marker of the position of the submarine, offsetting the tactical advantage of longer range. Another consideration is the ability of the submarine to detect, track and target the surface vessel with sufficient accuracy to justify the risk of detection by firing the missile. Overcoming these issues normally involves using a third party targeting asset (typically a friendly aircraft), which in turn may expose the submarine to detection when it communicates with the third party. The torpedo therefore remains the submariner's weapon of choice in many circumstances and surface forces still generally regard torpedoes as more menacing than missiles.

Annex A describes the capabilities of modern submarine weapons in more detail.

## Regional submarine fleets, now and in the future

Twenty years ago, submarine capability in the Asia–Pacific was confined to a few operators. The Cold War nuclear fleets of Russia and the US continued to shadow one another in Pacific and Indian Ocean waters, while Australia and Japan operated small fleets of conventional submarines. Further afield, India operated a mixed fleet of submarines. Otherwise, submarines were operated in moribund fleets of one or two boats.

Ten years ago there were reports in the defence press of widespread intent around Southeast Asia to increase investment in submarines. However, the Asian currency crisis of 1997 put paid to many regional projects.

Today, however, Asian economies are in much better shape. In general, a country's wealth (and with it the availability of industrial capacity and trained engineers etc) is a good indicator of the capability/quality of its military hardware. Military development in East and South Asia is underpinned by a combination of economic expansion, growing industrial and technical competency and competing strategic ambitions that result in arms competitions. As the prosperity of Asian nations increases, the expectation is to see them field more and better submarines, a trend that is already well underway.

There are two identifiable thrusts. Firstly, the rising major powers , China and India are working to develop indigenous nuclear submarines in conjunction with acquiring sophisticated conventional submarines and weapons from abroad. China in particular has markedly increased the size and capability of its fleet over the last decade and continues to build on that progress. Secondly, sophisticated Russian and western European designed submarines are proliferating into the region, with Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Singapore and South Korea all acquiring or planning to acquire modern conventional boats.

Historically, building a respectable submarine capability has required patience and has taken many years, especially the design and construction phases. However, the ability to purchase the latest vessels and armaments off the shelf, often accompanied by training packages as a deal-sweetener, is shrinking that timeline rapidly.

Due to a variety of factors, China, India, Japan, Singapore and South Korea all have well-advanced programs but off the shelf purchases could also see other countries make rapid progress. (An observation pertinent to Australia is that those countries that buy 'off the shelf' generally progress faster than those that opt to modify designs to unique local specifications.)

China has taken a systematic approach to capability improvement that is beginning to pay off. Starting from a heavy reliance on Russian expertise, Chinese submarine manufacturing and design is now maturing and their already large fleet of modern conventional submarines is likely to double in size to around forty over the next ten years.

In the last couple of years, China has launched a new generation of nuclear ballistic missile submarines, no doubt to the great consternation of the US Navy. Expected to enter service in 2008 and 2010 respectively, they will be equipped with a new indigenously developed 8000km range nuclear ballistic missile. Even when operating close to China, Australia and India and large portions of the western U.S. will be within reach.

As well, the first two of a new class of nuclear attack submarines will enter service over 2006-07. Expected to be comparable in design and performance to Russian VICTOR III boats, they will be outfitted with modern electronics and communications gear. They will be able to deploy most torpedo types in the Chinese inventory as well as anti-ship cruise missiles and long range land-attack cruise missiles. As demonstrated last year, Chinese submarines already have the willingness to operate in the same water as the US fleet, which will greatly complicate US naval responses to any Chinese activity around Taiwan.

India has also been trying to develop a nuclear attack submarine for nearly thirty years, but its Advanced Technology Vessel project has been marred by political indecision, technical problems and funding shortfalls. Nevertheless, the first of class will finally be launched around 2009, with an in-service date some time after that.

Other countries are opting to buy off the shelf or build under licence conventional boats. Modern variants of the Russian Kilo and Amur classes, and French, Swedish and German designs are available. For example, Indonesia has indicated a desire to buy a dozen such boats by 2024 and may have already signed up for their first six from Russia.

In terms of acquisition of submarine-launched anti-shipping missiles, the region is divided into two distinct camps. On one side are countries with defence acquisition programs tied closely to the US (Japan, South Korea, Australia and Taiwan) who field the slower and shorter-ranged Harpoon. On the other hand, countries that aspire to superpower status (China, India and Russia) are acquiring hard-to-counter supersonic sea-skimming cruise missiles. However, as China develops its naval power projection capability, it is possible the US missile program will go down a similar path.

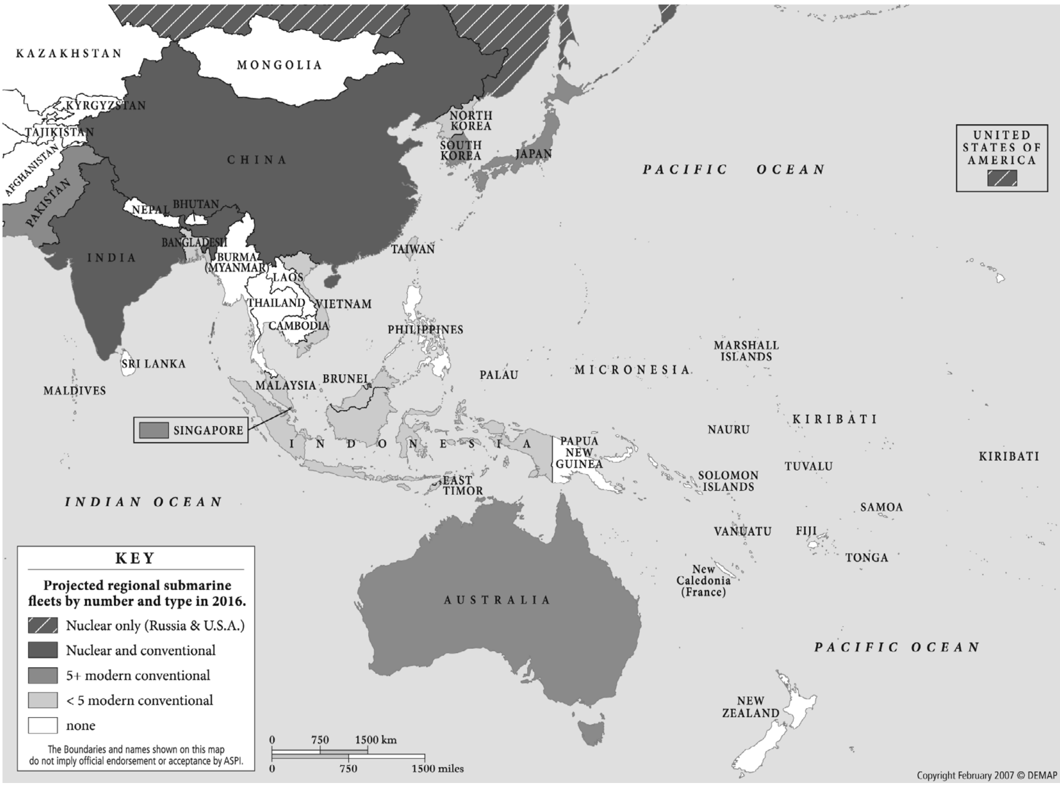
Annex B discusses the submarine plans and capabilities of the nations of South and East Asia in more detail.

## Implications of regional plans for Australia

The proliferation of submarines in our region has some widespread security implications. By their very nature, submarine operations are sensitive and have the potential to be quite provocative, especially where clandestine intelligence gathering operations are concerned. A botched operation can lead to a serious international incident. Given the tension between some of the countries discussed here, the potential for a miscalculation is significant, leading to accidents or even escalation of response. The narrow waters of East Asia only amplify the potential for trouble.

As well, the rise of regional submarine fleets is symptomatic of a wider military expansion in the region. A similar story could be told of regional air power, including the uptake of sophisticated Russian hardware. There is an element of an arms race at work here. For example, Malaysia's acquisition of submarines is likely to be strongly linked to Singapore's rapidly growing capability. Similarly, South Korea and Japan will be eyeing China's burgeoning naval capability with some concern.

The upshot is that Australia will soon face a region that has a much greater capability to conduct submarine operations. In a contingency, submarines will be able to seriously threaten the operation of surface fleets and commercial trade. (See the map below for an illustration of the submarine environment that will exist in 2016 under current planning.)




Note, however, that a low capability rating does not necessarily imply the absence of a potential threat. Events in the Falklands War of 1982 showed that even a limited submarine capability can create significant problems for a task group. During that conflict, Argentina deployed a single German-designed Type 209 conventional submarine (its other operational submarine was disabled by a missile strike by British helicopters while in port). It created considerable difficulty for the British fleet and was reportedly in a firing position on British warships on at least one occasion, only to have a misfire in the combat system. A single torpedo hit on the British carrier HMS *Invincible* may well have turned the course of the war.

Australia simply cannot expect to be able to conduct major naval operations in waters patrolled by submarines without a major upgrade to its ASW capabilities.

## First find your submarine—ASW technologies and techniques

Various ASW technologies and techniques have been developed over the decades. The basic principles are described in Annex C for the interested reader, but the key points needed in discussing the ADF's capabilities are:

- Sonar (sound location) is the primary mechanism for locating submarines. Lower frequency systems give better detection ranges than higher frequency ones, though they are generally larger and heavier. [1]
- Active sonar puts a noise ('ping') into the water and listens for an echo. Passive sonar listens for the submarine's own sounds, or for the reflection of active sonar deployed elsewhere. Those systems are complementary.

1 See Annex D for a discussion of sonar frequencies,including environmental concerns regarding their impact on sea life.

- Sonar systems can be fitted to the hull of a ship or submarine, deployed on a trailing line as a towed array, carried by helicopters ('dipping sonar') or deployed as independent buoys ('sonobuoys').
- Oceanographic conditions often limit the effectiveness of hull-mounted sonars on surface vessels because of the presence of layers of water with different temperature gradients. The ability to deploy variable depth sonar that lowers beneath the ship greatly improves the range of situations in which it can detect submarines.
- ASW-equipped helicopters are vital to extend the effective range of surface ships against submarines. A helicopter with dipping sonar can search an area well ahead of a surface vessel, which greatly complicates the submarine's tactical situation.
- Aircraft-borne radar is also a useful tool for finding submarines as it can detect a mast raised above the water. It also greatly complicates the submariner's task in compiling a picture of surface activity, as radar activity discourages the use of a periscope or other mast.

## Defence in depth

An effective ASW capability requires the coordinated effort of a range of systems and platforms. The following example shows how different platforms and technologies can be used to protect a high value surface vessel such as an amphibious ship (LHD) which might be carrying hundreds of troops and a quantity of aircraft.

Figure 1 shows how a combination of surface ships and their embarked helicopters can combine to provide defence in depth for the LHD. (This diagram represents protection from a torpedo attack, but a missile attack can be incorporated by including the air defence capabilities of the pickets—one or more of which can be an air warfare destroyer.) From the outside of the diagram, on the right-hand side, ASW helicopters are operating well ahead of the task force. Using a combination of sonobuoys and low-medium frequency active dipping sonar, they are able to 'sanitise' the water ahead of the LHD. That is, they can determine with a degree of confidence that there is no submarine present. Use of active sonar is important in that regard. A quiet diesel electric submarine (possibly even sitting silently on the bottom if the depth allows) might well avoid passive detection, but it is much more difficult to avoid an active 'ping'.

The reach of the helicopter is vital in many circumstances. The added range makes the submariner's job extremely difficult. The submarine may not be able to get into a firing position at all. As well, the use of dipping sonar makes safe counter-detection far less certain and prevents the submarine from using acoustic layer conditions to avoid detection. The submarine has no foolproof means of anticipating the location of the next dip, and it may well be in a position where detection of the submarine is likely. Balanced against that is the possibility that the submarine may decide to shoot at the helicopter with a surface-to-air missile. For that reason, the helicopter must have missile defences.

Because of limited availability, two ASW capable helicopters are much better than one. A single helicopter might operate 25% of the time, meaning that gaps might be left in the area coverage. Of course, more helicopters are better still, especially when the submarine may carry an anti-aircraft missile. Helicopters operating in pairs make it much more dangerous for the submarine to betray its position by launching a missile. In the example given here, the LHD may be able to deploy ASW helicopters directly to supplement those from the escort vessels.

Closer in to the LHD, there are a number of pickets—ships deployed in a protective cordon. Those ships, which can be frigates or air warfare destroyers, can use their on-board sensors (preferably low-medium frequency active/passive sonar deployed as a towed array or a system with variable depth capability) to maintain a watch for submarines and torpedoes. The pickets and the helicopters are networked together so that cooperative searches using multistatic techniques can be used. The pickets are also on station 24 hours per day, allowing for coverage when there is reduced helicopter availability.

Finally, the LHD itself is far from being a passive part of the ASW picture. As well as deploying ASW helicopters from its deck, the LHD is networked to all of the other elements and may even embark the control elements of the ASW effort. Finally, the LHD is fitted with torpedo defences if all else fails. It has the ability, thanks to a passive sonar system, to detect incoming torpedoes. As well, the escorting vessels can provide near-real time data from their sensors. For a last-ditch defence, the LHD is fitted with an array of torpedo countermeasures such as decoys.

Of course, ASW operations will not be confined to this diagram. Maritime patrol aircraft will be operating further afield with radar and sonobuoys in order to prevent an adversary submarine from being able to preposition itself. They will also make life more difficult for a diesel-electric boat that needs to snort in order to have fully-charged batteries to conduct its operations, but that impact will be reduced markedly if the boats have AIP systems.

Intelligence services will be collecting data on submarine movements so as to ascertain where the threat is likely to emerge. In some case, adversary submarines may be attacked in or near their home ports by strike assets or by submarines on ASW patrol.

The defence in depth approach to ASW defence has evolved over decades. Modern technologies such as low-medium frequency sonar and data networking have improved

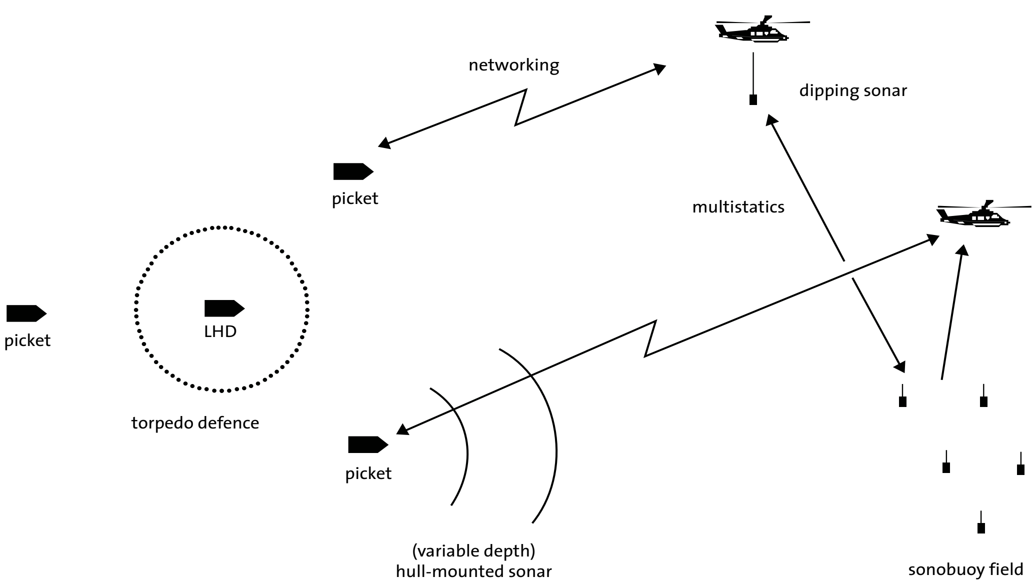



Figure 1. Near-field protection of a high-value surface ship

some components of the ASW system, but at the cost of making the information management task more complex. ASW remains complex and costly in terms of the assets that need to be employed and the information sharing that needs to occur.

The example above is not exhaustive, but it illustrates many of the main capabilities that need to be in place before surface ships can operate safely in waters patrolled by hostile submarines. Other ASW scenarios require most of the same systems, but there are be roles for additional assets. For protection of harbours or monitoring of choke points, for example, the ASW assets mentioned above can be augmented by seafloor mounted passive sonar sensors that can provide the capability to monitor activity, including submarines. As well, friendly submarines can mount standing ASW patrols in areas where geography (or politics) means that hostile traffic is likely to traverse a limited patch of ocean.

## Australian current capabilities assessed

Australian ASW capabilities have been in a state of benign neglect for a couple of decades despite a number of studies over the years that have highlighted shortfalls. Simply put, there were few submarines in our region, and those were of very dubious capability. Other considerations took precedence over ASW when setting force structure priorities. As well, some equipment choices that have been made have actually limited the potential for enhancing our ASW capability.

### *Aircraft*

ADF aircraft are currently limited in their ASW effectiveness by sonar and weapon shortcomings and, in some instances, platform deficiencies.

Airborne sonar systems are currently based on deployment of medium frequency active and passive sonobuoys used monostatically. They can be deployed from Seahawk helicopters or Orion aircraft. While they can be effective in the right conditions, they are far less efficacious than modern low-medium frequency active/passive systems. There may also be doctrinal shortcomings due to historical legacies at work. Passive buoys were effective for monitoring the position of Russian nuclear submarines during the Cold War. Against diesel-electric boats, they are much less useful, though they will pick up the sound of running diesels at a distance when the boat snorts.

The ADF has no dipping sonars capable of being deployed from helicopters. Although the Seahawk is large enough to carry one, it does so with some difficulty, reducing airframe availability. The Sea Kings originally had dipping sonar, but that was removed some years ago. The Super Seasprite helicopters as fitted out for Australia were never intended for ASW operations, being fitted with sophisticated anti-shipping missile systems. Their role in ASW would be limited to conducting search operations with their radar, and delivering ASW weapons. However, in the latter role they would usually rely on cueing from other platforms, having no organic sonar systems.

By design, the Orion aircraft are excellent ASW platforms. They are capable of low and slow flying, which can be used to look for submarines using magnetic detectors or for weapons release. Their sensor fit includes surface search radar and stocks of sonobuoys with an on-board processor for data from them. They can carry ASW torpedoes for the engagement phase of ASW operations.

The weapon shortfall appears to be in hand. The soon to be acquired MU-90 lightweight torpedo will provide the ADF with a much better anti-submarine weapon. Reports of its performance in shallow water suggest that it is a significant improvement on the previous Mk 46 torpedo.

However, the single Argentinean submarine operating in the Falklands was reportedly located by the British at one time but evaded attack by the expediency of sitting on the bottom, where British ASW torpedoes were unable to target it. Similarly, the ADF has no weapon in its inventory that is suitable for use in such a contingency.

*Ships*

The FFG and Anzac class frigates have hull mounted medium frequency sonars. (The FFG upgrade program resulted in the older FFGs being refitted with sonars of the same type as the Anzacs.) While barely adequate in some circumstances, in most ocean areas and/or environmental conditions, such systems cannot provide warning against a submarine before it is in a position to fire its weapons.

The FFGs can deploy towed-array sonar that provides better active/passive detection capability than hull mounted sonar, particularly against incoming torpedoes. The Anzacs do not have a towed sensor, but may receive them in future under project SEA 1100.

Details of the efficacy of torpedo defence on RAN warships are, understandably, closely held. But it would seem likely that similar considerations to the sonar systems might apply. That is, that modern submarine weapons have overtaken them. However, unlike sonar systems, retrofitting would be possible. In any case, future vessels must have state of the art defences.

The ability to carry multiple ASW capable helicopters is of great benefit. The FFGs can embark two helicopters and the Anzacs one. However, the embarked helicopters suffer from the ASW limitations mentioned above.

*Submarines*

Submarines make very effective ASW platforms. In fact, one of the major roles of the US Navy nuclear submarines is to conduct ASW in the waters around friendly forces, especially carrier battle groups. Conventional submarines are more limited in the open water escort role because of their slow transit speeds, particularly when maintaining a stealthy posture. However, they are very good in bottlenecks, or around ports. While it is difficult to find detailed performance data, it seems reasonable to assume that Australia's Collins class boats are very good performers in that role.

*Networks*

Finally, the networking that is necessary for coordinated ASW operations, especially multi-static detection involving multiple ships and/or aircraft, requires reliable high speed datalinks and computational capability. That is probably beyond our current naval communications systems, though current moves towards the adoption of allied standards will increase our current capability in the near-term. As well, training of all involved in ASW operations and the development of doctrine that involves the routine sharing of information would greatly assist the overall capability.

## Improving Australia's ASW capability

Recently, the Defence department has done its own review of ASW capability and has no doubt recapitulated many of the shortfalls identified in earlier studies. The difference this time is that the regional submarine picture has changed appreciably and the potential future threat has increased. This time ASW capabilities should fare better when priorities are being decided. However, there will be a number of areas in which tensions will exist and compromises may be made. This section identifies those tensions and suggest where the priority areas are for improving our ASW capability.

A number of recommendations follow immediately from our earlier discussion:

*Recommendation 1: Any task force operating in the presence of a submarine threat should be accompanied by at least three ASW capable helicopters.*

*Recommendation 2: The ASW fit of helicopters deployed in that role should include dipping sonar, preferably a low-medium frequency system, surface search radar, and missile countermeasures to protect against submarine-launched surface-to-air weapons.*

Some reflection on the current helicopter fleet leads to another recommendation. At the moment, there is no dipping sonar in the fleet, and the force mix includes three different helicopters (Sea King, Seahawk and Super Seasprite). The Sea Kings are slated for retirement in 2010, and the future of the Seasprites is under a question mark. Only the Seahawks are seemingly ensured of ongoing service.

The Sea Kings and Seasprites are not going to add much in the ASW role, leaving it to the sixteen Seahawks. A better solution would be a larger fleet of multi-role helicopters that are capable of taking on ASW duties, including at least a proportion (if not all) fitted for dipping sonar operations.

Project AIR 9000 Phase 8 is planned to replace the Navy's combat helicopter capability. A single type replacement (for the Seahawk and Seasprite) is under consideration as a rationalisation for the fleet. The year of decision is scheduled for 2015/16 or later. The expected cost is between $2.5 billion and $3.5 billion. Before then, it is planned to upgrade the Seahawks under AIR 9000 Phase 3 at a cost of $400 million.

Given the obsolescence of the Sea King systems and the limited ASW capability of the Seasprites, bringing forward the decision to standardise on a single type makes a lot of sense. Retiring the Seahawks early without the midlife upgrade and replacing the Seasprites at the same time would provide some savings to offset the acquisition cost of a single type. Nonetheless, it might still require net additional funds of around $1-1.5 billion over the lifetime of the current Defence Capability Plan.[2]

There is a similar rationalisation underway for land helicopters, with the MRH-90 (Multi-Role Helicopter) being chosen. In 2006, the Minister for Defence announced the purchase of thirty-four additional aircraft to replace the Blackhawk helicopters in service with the Army and the Navy's Sea Kings. The Sea Kings are to retire in 2010. The MRH-90 is a large and capable helicopter. It would be a strong contender as a single-type replacement for the entire embarked fleet.

*Recommendation 3: Rationalisation of the Navy combat helicopter fleet to a single ASW-capable type fitted out as per recommendation 2 should be considered in the near future.*

The effectiveness of sonar operations can be increased by allowing data to be moved between the platforms and operators involved. For example, a hull-mounted active sonar source from a surface vessel might produce echoes that can be picked up by passive sonars on other vessels, or by sonobuoys deployed by aircraft. This is called 'multistatic' sonar.

2 That figure is arrived at by estimating that operating a single type might yield a 15% benefit in terms of operating cost. Naval aviation running costs in 06/07 are estimated to be close to $600 million, giving annual savings around $90 million. It is assumed that 25 MRH-90 might cost Euro 35 million each, and that the aircraft cost would be 60% of the project cost. The Seahawk upgrade is assumed to be at the central figure of the $350-450 million DCP range—i.e. $400 million.

*Recommendation 4: Platforms involved in ASW (fixed wing aircraft, helicopters and surface vessels) should have a networking capability that enables multistatic sonar operations.*

The submarine may get through the outer levels of a layered ASW defence. In that case, vessels must be able to defend themselves against submarine-launched weapons.

*Recommendation 5: All major vessels (including submarines) should be fitted with torpedo self-defence capabilities.*

The platforms that will form the core of the future ADF ASW capability are either already delivered, or appear in projects within the Defence Capability Plan 2006-2016 (DCP). Table 1 lists the most relevant projects.

During 2007, government will make decisions on two major acquisitions of surface vessels. At a total cost of between six and eight billion dollars, the Navy will acquire three Air Warfare Destroyers (AWDs) and two Amphibious Ships (LHDs). The former will provide protection against air attack for other fleet units, while the latter will provide the capability to transport, disembark and support land forces.

There are two competing designs for the air warfare destroyer. Above the water, both vessels have the Aegis air defence combat system, a very capable system that can engage multiple simultaneous incoming aircraft and/or missiles. But, given the proliferation and improvement of regional submarines, it would make sense to ensure that the AWDs can also defend adequately below the waterline.

Whichever design is chosen, the AWD will be the largest of the navy's surface combatants. That means that the hull mounted sonar can be larger, enabling operation at lower frequencies, making it the prime candidate to be the most capable ASW platform. To maximise that capability, variable depth sonar should be fitted as well.

*Recommendation 6: The Air Warfare Destroyer should be fitted with variable-depth sonar and low-medium frequency hull-mounted sonar.*

The Gibbs and Cox evolved air warfare destroyer design is based on the US DDG51 Arleigh Burke class. It will embark two helicopters and be fitted with hull-mounted sonar with no variable depth capability. The Spanish Navanti F-100 multi-purpose frigate is a smaller design and, depending on the final configuration chosen, may only embark a single helicopter. It too has only a hull-mounted sonar.

The LHDs will be very high-value assets. As discussed earlier, as a minimum, they should be fitted with a torpedo self-defence capability. Of course, given their ability to embark a sizeable number of helicopters, they can contribute an ASW capability to a task force through the aircraft, albeit at an opportunity cost of other helicopter roles such as troop lift.

Table 1. Defence projects relevant to ASW. (Source: Defence Capability Plan 2006-16)

| Project | Name | Year of Decision |
|---|---|---|
| JP 2048 | Amphibious ships | 2006/07 |
| SEA 1100 | LRPD | 2015/16 |
| SEA 1439 | Collins progressive improvement (incl.sonar) | various |
| SEA 4000 | Air Warfare Destroyer | 2006/07 |
| AIR 7000 | Maritime Patrol Aircraft | 2011-2014 |
| AIR 9000 Ph8 | ASW/ASuW Helicopter Capability | various |

The discussion in the DCP of project SEA 1100 (Long Range Persistent Subsurface Detection Capability) correctly identifies several shortfalls in ASW capability of RAN frigates—the frequency, power and fixed depth nature of current hull mounted sonars. However, the year of decision (the year in which the project will come up for approval) is a decade away. The description in the DCP discusses the frigates and sonobuoys as being the main focus. Presumably (given the timeframe) the Anzac class is the one that is most likely to benefit from this project. Low-medium frequency systems and/or a variable depth capability would offer much better all-round performance, albeit with some extra impost of weight and space. It would be very difficult to retrofit those classes, but any future major fighting vessels should have a better sonar fit.

In any case, there will still be opportunities for compatibility between the ASW fits of the frigates and the AWDs in variable-depth or towed sonars and processing systems and datalinks. That would make multistatic operations between surface combatants easier to network.

*Recommendation 7: Commonality or compatibility of undersea warfare systems on the AWDs and future upgrades to the frigates should be a priority.*

The future manned maritime patrol aircraft to be acquired under AIR 7000 phase 2B may, ironically, be less suitable for ASW than the P-3 Orion aircraft it is to replace. A strong contender will be the Boeing P-8, based on the 737 airliner airframe. It will fly higher and faster than the Orion, making it more capable for wide area surveillance and response tasks. But those same attributes make it less suitable for ASW work, where the ability to work at low level and deliver torpedoes at relatively low speeds is highly desirable. (With the caveat that submarines with the ability to launch capable surface-to-air missiles might make future low-level ASW prohibitively dangerous.)

*Recommendation 8: The future manned maritime patrol aircraft should have a multistatic sonobuoy capability. It should also be able to deliver an ASW weapon.*

The unmanned aerial vehicle to be acquired under AIR 7000 Phase 1B will not be able to deliver an ASW weapon or deploy sonobuoys, though it will have a search radar and datalinks. It will therefore be able to add to the ASW surveillance effort.

Finally, the Collins submarines will undergo a rolling series of upgrades under project SEA 1349. In particular, Phase 6 will replace the sonar fit. While submarines must be able to operate autonomously, there may be scope for some commonality with other platforms.

A note of caution here: the DCP states that ‘although some sonar equipment may be sourced from overseas, the intention is to establish significant levels of in-country capability in terms of niche products, project management, software development, equipment assembly, system integration, training development and support’. Some in-country work is inevitable given that the Collins is an Australian-unique design. However, the history of systems integration and software development projects suggests that careful management will be required to avoid mistakes that have been made in other Defence projects (such as the ill-fated radar warning receivers for the F/A-18 fleet).

*Recommendation 9: The Collins ASW capability will require ongoing investment, particularly in the area of sonar and weapons systems and networking capabilities.*

Looking ahead even further, the replacement for the Collins class submarines will arrive sometime around 2025-2030, but the project to replace them is likely to first appear in the next DCP (2008-18). There are a number of 'big picture' options for the future submarines:

- Nuclear submarines
- Another small fleet of large conventional submarines in the 3 - 4,000 ton range
- (a) A larger fleet of smaller conventional submarines, built in Australia, or
  (b) A larger fleet of smaller conventional submarines purchased 'off the shelf'.

Nuclear submarines are extremely expensive to build and operate, and require a sophisticated nuclear industry capability to support them. So it is unlikely that Australia will opt to pursue the acquisition of a nuclear fleet.

The other options have pros and cons. The biggest weakness of the Collins fleet is its small size, so a greater number of smaller boats would give greater flexibility in terms of concurrent deployments. On the other hand, smaller boats cannot deploy as far away or for as long as larger ones. The 'submarine after Collins decision' is worthy of a study in its own right, and ASPI will be producing a report in due course.

## Acknowledgements

The assessment of regional submarine capabilities and planned future fleets is based largely on excellent work performed by Douglas Drake during an internship at ASPI in late 2006.

The author would like to thank current and former members of the Royal Australian and Indian Navies who commented on earlier drafts of this paper and have added considerably to its accuracy.

## Further reading

A classic review of the history of the submarine as a weapon of war is *The Submarine and Sea Power* by Vice Admiral Sir Arthur Hezlet. It is now out of print but is not too hard to find.

*The Third Battle* is a US Navy War College paper that describes the efforts of the USN to counter the threat of Soviet submarines during the Cold War. It is available at http://www.nwc.navy.mil/press/npapers/np16/NewportPaper16.pdf

*Blind Man's Bluff* by Sherry Sontag and Christopher Drew is a best-selling 'ripping yarn' about Cold War submarine operations.

Also out of print, mathematically-inclined readers will find a technical description of operations research techniques for locating and protecting against submarines in *Search and Screening* by Bernard Koopman. This book describes in detail the techniques developed by researchers during World War II.

The websites of the Federation of American Scientists (www.fas.org) and Global Security (www.globalsecurity.org) are rich sources of information on sonar and submarines and their capabilities. The internet encyclopedia *Wikipedia* has a worthwhile history of submarines and their capabilities.

## Annex A

### Submarine weapons

*Torpedoes*

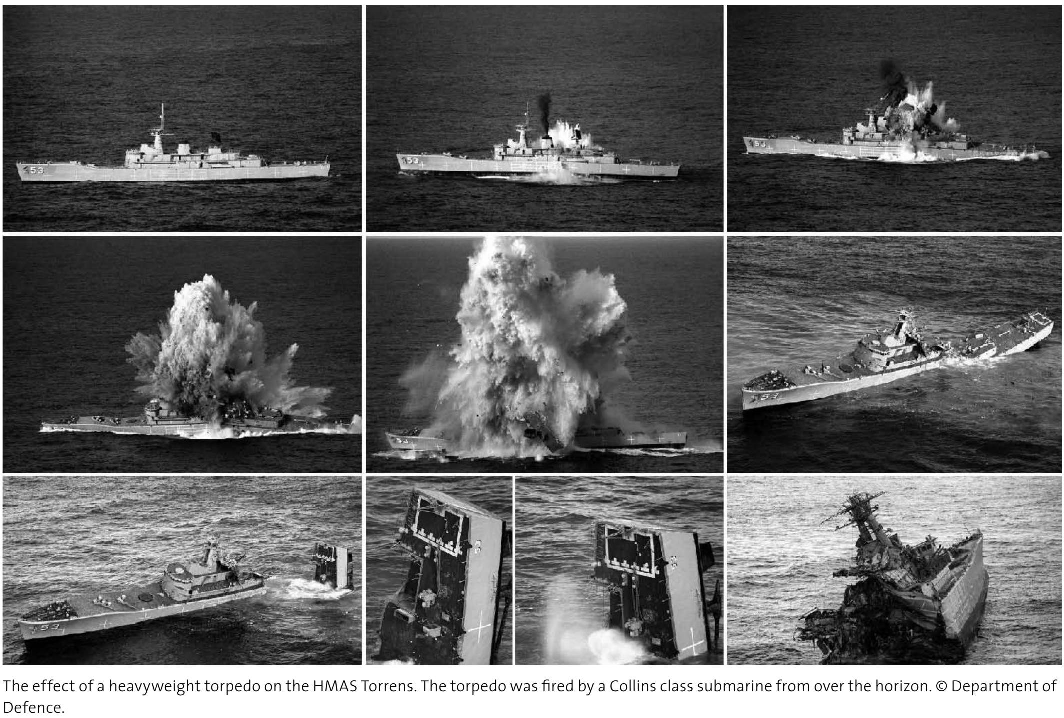
The basic design of the modern torpedo dates back to the 1800s, though the range, speed and destructive power of contemporary models far exceeds those of earlier designs.

A modern heavyweight torpedo will sink a major vessel. The torpedo is actually detonated below the ship, rather than physically hitting it. The destructive effect is through a two-step process. The detonation results in a bubble which lifts the ship, breaking its backbone. Then a powerful jet of water is formed when the bubble collapses, punching up through the ship. The deliberate sinking of the destroyer escort HMAS *Torrens* by a Mark 48 torpedo fired from a Collins submarine demonstrated just how devastating the effect can be. The 2,700 ton *Torrens* was literally torn in half by a single torpedo. (The video of the event is available on a number of internet sites.)

Originally, torpedoes were 'straight runners'. That is, once they left the submarine, they would travel in a straight line until hitting a target or running out of fuel. The submarine would fire a salvo of torpedoes at slightly different angles to give it a spread across the predicted position of the target vessel. Such an attack requires the submarine to manoeuvre to close range before firing in order to achieve a high probability of scoring a hit. Of course, that also increases the danger of the submarine being detected and counter-attacked.

In order to increase the range at which the submarine could target vessels, modern torpedoes have guidance systems via a wire connecting the torpedo back to the firing submarine and/or integrated autonomous sensors to detect and home on the target. Homing mechanisms include passive and active sonar (of which much more later). Magnetic sensors can be used to detonate the torpedo in the vicinity of a ship's hull.

Another form homing torpedo is the wake-homing variety. Primarily used in Russian and German torpedo designs, they are specifically designed to attack surface ships (as opposed to submarines). They operate at approximately 20 metres depth and have a sensor that points upwards to detect the disturbance caused by the ship's wake. Once detected, the torpedo then reverses course until it detects the wake again, repeating the process until it homes onto the vessel. (See Figure A1.) Such torpedoes present challenges for defences. By definition, they approach from the rear of the ship, where the physical and acoustic disturbances of the ship's own propeller(s) are greatest, making detection of the torpedo difficult.



The effect of a heavyweight torpedo on the HMAS Torrens. The torpedo was fired by a Collins class submarine from over the horizon. © Department of Defence.

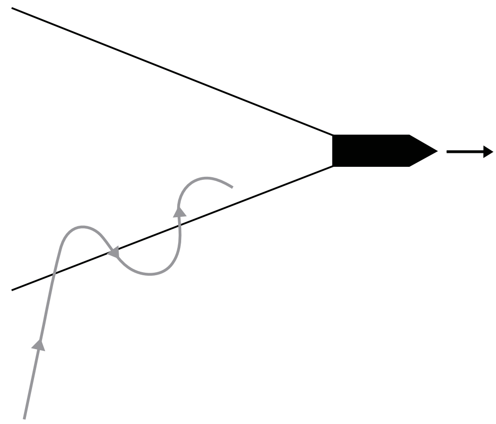



Figure A1. The principle of operation of wake-homing torpedoes

*Missiles*

As well as torpedoes, modern submarines are increasingly armed with sophisticated missiles that allow them to attack targets on the surface, on land or even other submarines. German submarines are about to field an ability to attack aircraft via the Polyphem surface-to-air missile. However, such an attack will reveal the position of the submarine to the aircraft, making it vulnerable to counter-attack if the missile is not successful, or if other aircraft are in the area. Notwithstanding that, Russian doctrine includes the targeting of ASW aircraft by surface-to-air missiles.

Anti-shipping missiles for submarine launch include the well-known French Exocet and the US-built Harpoon. The missiles are podded within a launch capsule which has its own propulsion system to enable the missile to clear the surface of the water. After broaching, the capsule is opened and the missile launched. After launch, the missile acts in essentially the same way as one launched by other means. Both are subsonic, and have ranges in excess of one hundred kilometres. Once they arrive in the predicted target area, they use active radar seekers to enable them to find hit and the target.

Another important class of submarine-launched anti-shipping missile is the Russian 'Klub' supersonic sea-skimming missile and its later derivatives. It was specifically designed to defeat US destroyers fitted with the Aegis anti-missile system. With a range of up to 180 km, the missile gives the submarine a formidable stand-off capability, though targeting information would have to come from a third-party source. Figure A2 shows

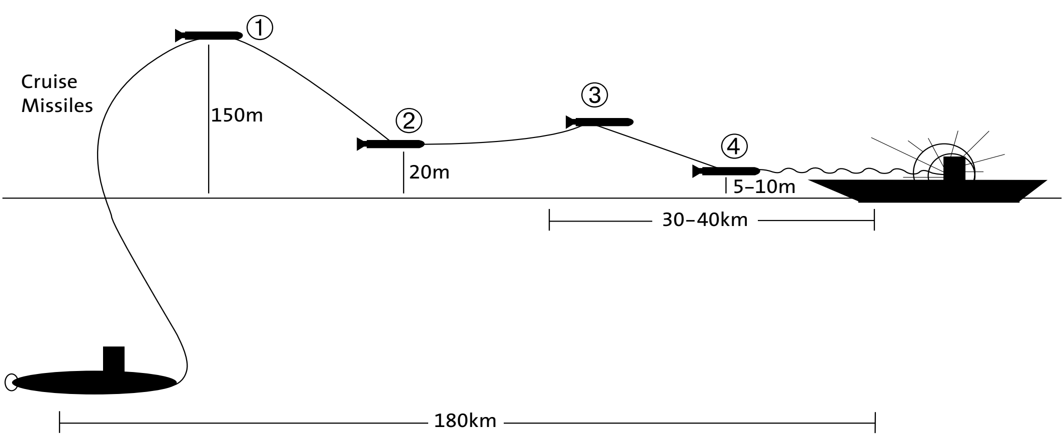



Figure A2. The Russian 'Klub' supersonic sea-skimming missile.
1) Separation phase: first stage solid rocket motor separates upon reaching an altitude of 150m. 2) Cruise phase: the air intake for the second-stage turbojet sustainer motor is deployed and two rectangular wings and 4 tail control surfaces are extended. The missile reaches a speed of 0.6 to 0.8 Mach (750-950 kph) and descends to an altitude of 20m. 3) Acquisition phase: 30-40km out from target the missile does a 'pop-up' manoeuvre and its active radar homing seeker is activated. 4) Terminal phase: once the seeker has acquired the target, the third stage solid rocket motor ignites boosting missile to Mach 3 (3,500 kph). At the same time it descends to an altitude of 5-10m and performs zigzag manoeuvres to thwart missile defence systems.

how this sophisticated weapon system works. It uses cruise missile technology to achieve a long range, and a rocket motor for the final supersonic engagement phase.

The Klub missile is integrated with several Russian submarine types, including the increasingly popular export Kilo class. Indian and Chinese Kilo class submarines will carry this missile, and other export customers may also opt for them.

*Mines*

The laying of mines in areas where an adversary wishes to be able to move ships or submarines can have a crippling effect on their ability to manoeuvre or conduct trade. Submarines are well placed to deliver mines, having the ability to do so without the probable detection that would accompany aerial delivery. Mines can be carried external to the submarine and released in situ, or can be deployed from torpedo tubes, in some instances allowing a stand-off delivery, as the mines can be 'swum' into position.

*Ballistic Missiles*

Finally, there is a special class of submarines that carries ballistic missiles. They were originally conceived during the Cold War as being able to provide a 'second strike' nuclear-armed capability consistent with the doctrine of mutually assured destruction. Given the difficulty of reliably locating submarines, a fleet of boats carrying intercontinental ballistic missiles gave each side a credible ability to retaliate after a pre-emptive nuclear strike by the other.

Today the Russian ballistic missile submarines are largely confined to port, while four of the US ballistic missile submarines are being converted to carry conventionally-armed missiles for strike missions. However, China is now developing a nuclear ballistic missile submarine capability.

## Annex B

**Regional submarine plans and capabilities**

*Australia*

After some early troubles, Australia's Collins class boats are proving highly capable. They have the size to allow extended blue water deployments and their crews are well-trained and have accumulated a wealth of practical experience, though recent crew retention issues are rapidly diluting this advantage. The fleet's main drawback is its small size, limiting the possible number of concurrent deployments. Australia's low Anti-Submarine Warfare capability also works against the maintenance of crew proficiency.

*China*

While China currently fields a small nuclear fleet and a large number of older conventional submarines, currently its most potent asset is the modern conventional submarines in its fleet. It is those that would prove the greatest headache for the US in any confrontation in the Taiwan Straits in the near future.

But by 2016, China will possess a comprehensive nuclear and conventional submarine capability covering the seas surrounding Taiwan. It will have replaced its 1960s and 1970s designs with capable modern ones—to a greater extent than the US Navy will have achieved. China will also have a credible underwater nuclear second-strike capability in their ballistic missile submarine fleet.

Chinese naval power is on the upswing, and in the foreseeable future will present a real challenge to the current US regional supremacy. It will also cause India and Japan, as strategic competitors, to upgrade their capabilities to protect their own interests.

*India*

India's submarine fleet is undergoing an overhaul. It includes ten modern Russian Kilo boats which have been upgraded with the latest Russian cruise missiles, wire-guided and wake-homing torpedoes. While a focus on the laboured development of a nuclear submarine may have been a distraction, they have managed to build a good basis for future growth in capability. They have also leased a Russian nuclear submarine, which should have provided experience in the use of such vessels.

It is expected that India will have up to three nuclear submarines by 2016. They will be armed with indigenously developed nuclear-capable cruise missiles (building on Russian designs) with an expected range of 1000km. As much of their existing conventional fleet will soon need to be retired, they have signed up to purchase six French Scorpene boats, with an option for nine more. The first is expected to enter service in 2012, followed by one per year thereafter.

*Indonesia*

Indonesia's current capability is limited. They operate two ageing German Type 209 boats, and it is common for one or both to be tied up for extended periods. (However, that didn't stop them from being available to shadow the ships deploying INTERFET to East Timor in 1999, causing operations planners some anxious moments.)

Indonesia has announced plans to acquire four KILO class submarines from Russia. But a critical factor in how capable their fleets become will be the rigour that is applied to the development of training and doctrine, and the amount of operational experience that is gathered. They are starting from a very low base and, based on observation of other TNI acquisition programs, the capability may not match the sophistication of the acquired technology for some time.

*Japan*

Japan's fleet of sixteen boats is technologically sophisticated in terms of stealth and capability. While they are restrained to some extent by Japan's constitution, they are strong performers in exercises. They are able to remain on station away from base facilities for long periods, giving them a strong blue water capability.

Japan's future military capabilities ultimately hinge on political factors. However, it is reasonable to assume that, as China's economic and military strength grows, there will be an increase in domestic support for a revision of the constitutional limits imposed on the Japanese military. As well, the US will not be uncomfortable with Japan taking on a larger role in balancing increasing Chinese power.

*Malaysia*

Malaysia will be a new regional submarine operator later this decade, with two French boats on order. This development is probably a response to Singapore's growing capability. The Malaysians will need some time to acquire the experience to get the best from their small fleet, but as South Korea has demonstrated, that can be done in relatively short timeframes.

*Russia*

Even more than that of the US, the Russian fleet has declined in quality since the end of the Cold War but remains formidable. While estimates vary, they have about ten to fifteen ballistic missile submarines, up to twenty-six nuclear attack submarines and roughly twenty conventional KILOs (though these may be sold off in coming years). After the bulk of the Russian Navy's Cold War fleet is decommissioned, the remainder will form a small but capable nuclear fleet fitted with a new generation of armaments. The major influence that Russia will have on the region is through the export of their sophisticated hardware and operational expertise.

*Singapore*

Singapore is well on the way to acquiring a very sophisticated submarine capability. As is typical for Singaporean acquisition programs, they have bought very capable hardware (Swedish Sjöormen class boats) while methodically working up the expertise and doctrine to utilise it effectively. Their fleet will expand from the current four to six by 2010.

*South Korea*

South Korea is also a very competent operator of submarines. They have embarked upon an aggressive acquisition program of nine advanced German-designed submarines, complete with a training package in order to achieve high operational effectiveness in a short time. Building on their industrial might, plans are also underway to develop a submarine comparable in size to the Collins class. By 2016 they will be in the top echelon of conventional submarine operators.

*Taiwan*

Taiwan would dearly like to upgrade and expand its submarine capability. But while the US has passed legislation allowing the sale of boats to Taiwan, it no longer builds the required conventional submarines and shows no signs of preparing to do so. Other countries will be reluctant to oblige through fear of incurring China's ire.

*United States*

The American fleet remains an important player in the Pacific region, notwithstanding

Table B1. Regional submarine plans

| **Country** | **Current Fleet - 2006** | **Planned acquisitions to 2016** |
|---|---|---|
| Australia | 6 Collins class conventional boats | No new boats in this time frame, but will improve existing ones |
| Bangladesh | | Plans to have a boat in service by 2012 |
| China | 6 nuclear boats + dozens of conventional boats of varied quality | New ballistic missile, nuclear and conventional boats |
| India | 10 Russian Kilos plus 6 other boats | 1 or more nuclear + 6 new French boats |
| Indonesia | 2 1970s vintage German boats | Plans to buy 4 Kilo class boats from Russia, with more to follow later |
| Japan | 16 indigenously designed and built boats | Will maintain the fleet through rolling production |
| Malaysia | | Two French boats on order for service in 2009 |
| North Korea | 23 very dated Russian boats + 32 midget boats | None known. Capability will not improve in this time frame |
| Pakistan | 5 French boats of 1970s and 1990s design | More of the same, but with AIP and Exocet capability |
| Russia* | 10+ ballistic missile boats, over 20 nuclear boats and 20 Kilo class | By 2016 probably an all-nuclear fleet of 20-30 boats |
| Singapore | 4 Swedish (Sjöormen) Class | 2 additional Swedish subs with AIP |
| South Korea | 9 German boats of two different 1990s designs | Will add 6-9 new boats with AIP and missile fits |
| Taiwan | 2 1980s Dutch boats + 2 very old US boats | Wishes to acquire newer boats but will struggle due to geopolitics |
| USA* | 72 nuclear boats, 18 of which are ballistic missile carriers | New boats will replace older ones progressively |
| Vietnam | Several small coastal boats | May acquire 2-3 Kilo class boats from Russia |

*Russian and American submarine fleets operate much more broadly than the East Asian/Indian Ocean regions. Only a proportion of their fleet will be in our region at any given time.

what appears to be a decline in operational expertise in recent years as the experience gained during the Cold War fades. (For example, at the time of writing, the fleet is on a safety stand down following two recent incidents, including a collision with a surface vessel.) Their fleet of over sixty nuclear submarines (of which a proportion is deployed to the Pacific region) means that they field a significant number of fast and heavily-armed boats.

*Others*

Vietnam and North Korea operate fleets of small coastal submarines that are capable of limited incursions into other nation's waters, but offer little in the way of 'serious' naval capability. Vietnam has indicated a desire to acquire a couple of KILO class boats from Russia, but North Korea will lack the resources to improve its fleet in the foreseeable future. Pakistan, no doubt spurred on by Indian developments, is also working towards a sophisticated conventional submarine capability, with half a dozen French-designed boats on the way. Bangladesh wants to obtain two conventional submarines next decade.

## Annex C

### Fundamentals of ASW

*Sonar*

Because of the difficulty posed in locating submerged submarines, there is a limited range of techniques that can be brought to bear. The most important is the use of underwater sound to locate submarines. This can be done in two ways. 'Passive' sonar is the use of hydrophones to listen for the noises a submarine makes. 'Active' sonar involves producing a sound—the 'ping' so loved by movie producers—and listening for echoes of that sound when it is reflected from the hull of a submarine.

Sonar systems can be mounted on the hull of a ship or submarine, winched up and down on cables below a ship or helicopter, or towed behind a vessel to keep it away from engine noises and other sources of interference. Buoys fitted with sound transmitters and receivers can be deployed from ships or aircraft and monitored remotely. Such 'sonobuoys' can be either active or passive.

The ability to hear a sound, whether generated by the submarine or an active ping return, above the background ocean noise will depend on the ambient noise levels and on the frequency of the sound. Ambient noise effects can depend on weather effects, such as wind strength and the resultant wave activity. The higher the sea state, the less ability there will be to distinguish the sounds that could indicate the presence of a submarine. Marine animals can also make significant contributions to background noises. In some places around Australia snapping shrimp produce so much noise at some times of the year that sonar systems are very limited in their ability to operate.

Environmental properties are also critical. The acoustic properties of the water column vary widely with location, depending on variables such as the temperature gradient of the water column, salinity and bottom type (sandy, muddy, rocky etc.). In much the same way that light 'bends' when passing through materials of different density, the direction of sound propagation varies as it moves through the water column. That means that, unlike radar detection of aircraft for example, there is no simple means of calculating the range at which sonar will detect a given target. The performance of sonar is very much dependent on a range of transient conditions. For that reason, sophisticated numerical models have been developed over decades to provide estimations of the 'range of the day'.

The propagation of sound underwater is a very complex subject, so here are some of the factors that will be important for later consideration. (See http://www.fas.org/man/dod-101/navy/docs/es310/SNR_PROP/snr_prop.htm for a much more detailed description.)

**Shallow water** often offers a difficult environment for acoustic detection. The so-called 'littoral ASW problem' comes about because the shallow-water environment is typically far more variable than the open ocean. Temperature and salinity gradients, the outflow of fresh water from rivers, high levels of biological noise and often high levels of maritime traffic all make for a challenge. As well, any sound that is present will undergo multiple reflections from the surface and the bottom, causing 'reverberation' that can mask the sounds of submarines and/or sonar pings. Unfortunately, that characterises much of the archipelagic regions to the north of Australia.

The one mitigating factor is that the problematic environment works both ways. Shallow water is also a difficult place for submarines to operate. However, a well-trained submarine crew can still operate in shallow water and pose a significant risk to coastal traffic or off-shore assets.

A **surface layer** can form on the ocean under some seasonal conditions in which a layer of water with a positive temperature gradient sits on top of water with a negative gradient. That results in a 'shadow zone' where a surface vessel fitted only with hull-mounted sonar cannot detect a submarine. (See Figure C1.)

If a surface vessel has its sonar mounted on the hull, it has limited ability to detect a submarine that opts to remain below the layer. Cross-layer detection is usually limited in range, but the tactical advantage lies with the submarine because it can go deep beneath the layer, where detection of radiated sound from the surface ship is often possible. The counter to this tactic is to provide the surface vessel with a variable depth sonar system (VDS), which allows the ship to physically lower the sonar below the layer.

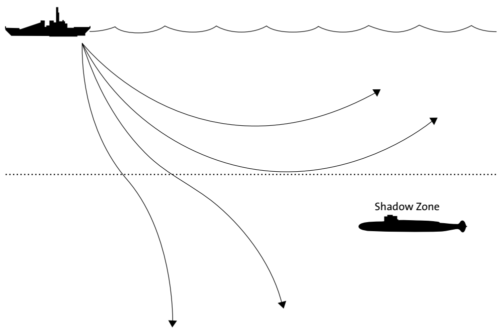



Figure C1. The effect of a surface layer on the progagation of sound in the ocean. By sitting below the boundary, the submarine greatly reduces its vulnerability to detection

## *The effect of frequency*

Generally speaking, low frequency sounds will propagate further than high frequency ones. That is why, for example, whale songs can be heard for hundreds or thousands of kilometres in the right conditions. Similarly, low frequency sounds made by ships or submarines can propagate long distances in the right conditions, allowing for passive detection.

Early ASW active sonar systems could not utilise the lower frequency effect because it was difficult to produce powerful sounds at low frequencies. As a result, high frequencies were used, with the operational limitation of short effective ranges. Typically, high frequency sonar was deployed when it was already known that there was a submarine nearby—often in response to the detonation of a torpedo.

Later systems moved to medium frequencies which had the benefit of better range. However, depending on the environmental conditions, it was likely that using active sonar meant that the submarine would hear the ping from the vessel deploying the sonar long before the relatively weak echo could be heard back at the ship. The submarine would know where the ship was without necessarily being located itself. That observation, coupled with the difficulty of obtaining reliable detection results from medium systems, led to a dislike of active sonar systems as a proactive ASW measure that has not completely disappeared from naval circles today.

Lower frequency active sonars reduce the counter-detection problem by greatly extending the range at which a return echo can be heard above the background noise. It is true that the submarine will still generally hear the sonar before the sonar operator can detect the submarine. However, the submariner cannot be certain of the range at which he can be detected and it will complicate his tactical choices. And if the detection range is large enough, it will keep the submarine at such a distance that it cannot employ its weapons. In the next section how airborne lower frequency active sonars can create real problems for the submarine is discussed.

### *Multistatic sonar*

Sonar systems can operate cooperatively. Sounds, either from an active sonar or another source, can be picked up by several different receivers after refection from a target submarine. The receivers can be buoys or on ASW platforms. This is termed 'mulistatic sonar'. For example, a shipboard helicopter might drop a small explosive charge or a purpose-built sound source into the water. A field of sonobuoys may register several detections. Using combined timing and bearing data, the underwater picture can be mapped out.

Multistatic sonar can be very effective. It offers longer-range propagation, because the explosive noise includes low-frequency components. As well, the submarine does not know where the next sound transmission will come from. Reportedly, an Australian trial of multistatics detected not only the Australian submarine sent along as the 'tethered goat', but also another boat that was in the area unannounced. To make the most of the technique, much depends on shipboard computer and communications (data link) capacity.

### *Other submarine detection technologies*

**Radar** is the most important of the non-acoustic techniques for detecting submarines. Basically, radar works against submarines only when they are on the surface or have raised a mast. While increasingly lower indiscretion rates work to reduce its effectiveness against snorkels, an increased reliance by submarines on satellite-based communications is leading to increased exposure of communications masts. If a submarine suspects that a radar-equipped aircraft is operating in the area, it will adjust its mast exposure accordingly. (Of course, depending on the circumstance, that may constitute a partial win for the aircraft, by limiting the submarine's ability to recharge its batteries or gather information.)

The **counter-detection** range of radar is greater than the detection range. In other words, if a radar emitter approaches a submarine while continuously operating, the submarine will detect the radar and lower its mast before the radar can detect the submarine. For that reason, search radars have an intermittent mode, blinking on and off at intervals, allowing the aircraft to move over a body of water that has not been illuminated previously before emitting a radar pulse. In that way, the submarine can be caught unawares.

If a submarine radiates **electromagnetic energy** in order to communicate or to look for surface contacts with its radar, then it may be detected by the systems designed to detect and geolocate radio or radar signals. Today any such submarine communications are usually via very short 'burst' transmissions that make interception and exact location very difficult. In a high-risk environment, a submarine will probably opt not to communicate at all.

Because a submarine is a large metallic object, it has **magnetic** properties that are susceptible to detection in some circumstances. ASW aircraft are sometimes fitted with magnetic anomaly detection devices. In the case of fixed wing aircraft, it is not a broad area search tool, because it requires flight at very low altitudes in order for the effect to be detectable. It was sometimes used to fix the exact position of a submarine already discovered by other means for an attack with air-dropped weapons.

Good **intelligence** can make the detection of submarines very much easier. As a very good example, the rate of sinking of German submarines in the Atlantic during World War II was highest when the German naval codes were being routinely broken by British cryptanalysts. In a broad area search, knowing where to start looking greatly reduces the wasted effort.

Finally, **visual detection** of a submarine mast or periscope or, in clear water, of the submarine itself remains a valuable ASW tool. The 'Mark 1 eyeball' remains a valuable sensor.

## Operations research

The battles of the Atlantic in both world wars gave great impetus to the development of optimal techniques for protecting surface vessels from submarines. Teams of mathematical researches discovered some simple principles that greatly assisted the allies in defending their ships from German U-boats and in taking the fight to the submarines. Two of the important principles are the benefits of convoying and the limitations of attack direction on a submerged submarine.

Convoying of merchant shipping allows for concentration of effort by the defending forces. It does not significantly assist the submarine to find its targets in the open ocean, though it does increase the number of targets available to be attacked in a single engagement if the submarine does find the convoy. The model that was eventually developed was the use of fast destroyers as picket ships around the convoys with radar-equipped aircraft operating ahead. In that way, the submarine was denied the luxury of being able to snorkel at will in anticipation of running quietly during an attack on the approaching convoy. The destroyer pickets provided a second line of defence as well as response capability if the submarine managed to instigate an attack.

Submarines are limited in the underwater speeds they can achieve while maintaining a low acoustic signature. The noise from machinery, the propeller and of water flowing around the hull all increase significantly with speed, and also have the effect of reducing the ability of the submarine to monitor external sounds. To move stealthily, the submarine may be limited to speeds of a few knots. That means that the submarine is effectively slower than most surface targets it may want to engage. When that is true, the concept of 'limiting lines of approach' applies.

When slower than its intended target, there are regions of ocean where the submarine is simply unable to work its way into firing range because of speed limitations. From the point of view of the surface vessel, the most dangerous area is a segment directly ahead. There a submarine can be very quiet—possibly even lying silently on the bottom if it is shallow enough—and still be able to manoeuvre into a firing position. Figure C2 illustrates the principle. The radius of the circle is the submarine's weapon range. The angle of the lines projecting forward is determined by the relative speed of the ship and submarine. The slower the latter is, the tighter the forward angle.

The concept of limiting lines is an idealisation that really applies in the open ocean. In littoral waters other constraints will apply. However, the basic principle remains sound—the submarine has more space to manoeuvre ahead of the intended target than behind.

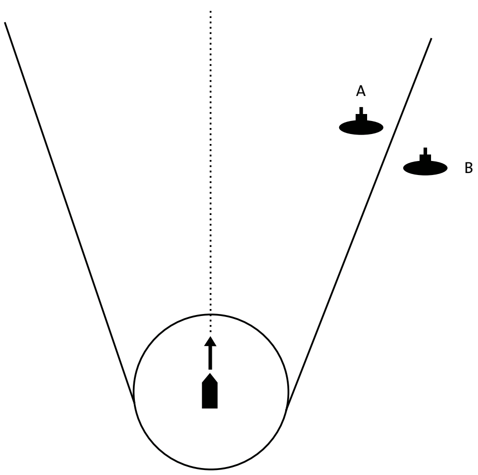



Figure C2. The limiting lines of approach. If the surface vessel at the centre of the circle continues on its present bearing and speed, the submarine at A can get into a position to attack, while the one at B cannot.

## Annex D

### Sonar frequencies and the environment

There have been reported correlations between the conduct of ASW exercises involving the use of active sonar and mass strandings of whales and dolphins. That has led to concern about the possible impact of sonar on sea life. Most concern has been focused on low frequency and high-power medium frequency active systems.

In 2004 then Defence Minister Robert Hill told the Australian Parliament that Defence was already taking steps to minimise the risk to marine mammals from active sonars. The Royal Australian Navy does not deploy any of the systems that have been linked to cetacean beachings.

The following definitions, consistent with those used by the Department of Environment and Heritage are adopted here:

**Low-frequency (LF)**. Low frequency sonars are those that emit sound below 1000 Hz. These sonars are designed to provide theatre level protection, such as for an Aircraft Carrier Task Group, up to 200 miles from the ships. They are not used by the Royal Australian Navy, and have not been operated in Australian waters by other navies.

**Medium frequency (MF)**. Medium frequency active sonars emit sounds at frequencies between 1,000 and 10,000 Hz. These sonars represent a sliding scale of compromise between possible detection range and size of the transmission array. At the lower end of the frequency range (1000- 3000 Hz) the systems are capable of extended detection ranges using high output power, but the size of the transducer limits applications to large warships. The Royal Australian Navy does not operate these systems. At the upper end of this frequency range (3,000 – 10,000 Hz), sonar arrays are smaller and output powers are less, but the systems can be fitted to smaller vessels. These systems are designed for ship self protection out to a few miles. Examples include the SQS-56 and Spherion systems fitted to Australian warships.

A further distinction between high-power and lower-power medium frequency systems is made. The high-power medium frequency system of most concern is the SQS-53C, use of which by the US Navy (USN) has been correlated to several mass deaths of cetaceans, including mass beachings in the Bahamas and Canary Islands between 2000 and 2003. The SQS-53C has an extremely powerful transmitter.

The power and frequency settings recommended here are well below those for which there are well-founded concerns and no doubt the Department of Defence will continue to set the standard for international best practice in the protection of sea life.

## About the Author

**Dr Andrew Davies** is a theoretical physicist by training, and published research papers in the area of high-energy particle physics while at the University of Melbourne and the Australian National University. Andrew joined the Analytic Studies Group in the Department of Defence in 1994. He worked on a range of scientific studies in support of Defence decision making, including submarine detection for the RAN, Army firepower options and RAAF stand-off weapons effectiveness. He led the Capability Analysis Branch within Defence Headquarters for a time, before moving into the world of signals intelligence and information security with the Defence Signals Directorate, where he held a number of positions. Andrew joined the Australian Strategic Policy Institute as director of the Operations and Capability Program in 2006.



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