

**Royal Australian Navy**  
**Maritime Studies Program**

Working Paper No. 1

New Technology  
and  
Medium Navies

*Norman Friedman*

August 1999

© Copyright Commonwealth of Australia 1999

This work is copyright. Apart from any use as permitted under the *Copyright Act 1968*, no part may be reproduced by any process without written permission from the Department of Defence

**Announcement statement**—may be announced to the public.

**Secondary release**—may be released to the public.

All Defence information, whether classified or not, is protected from unauthorised disclosure under the *Crimes Act 1914*. Defence Information may only be released in accordance with *the Defence Protective Security Manual (SECMAN 4)* and/or Defence Instruction (General) OPS 13-4—*Release of Classified Defence Information to Other Countries*, as appropriate.

Requests and inquiries should be addressed to the Director General, Maritime Studies Program, HMAS CRESWELL, JERVIS BAY NSW 2540.

#### **National Library of Australia Cataloguing-in-Publication entry**

Friedman, Norman, 1946-.  
New technology and medium navies.

ISBN 0 642 29527 1

1. Navies. 2. Naval art and science. 3. Naval strategy. 4. Sea-power. 5. Navies – History. I. Australia. Royal Australian Navy. Maritime Studies Program. II. Title. (Series : Working paper (Australia. Royal Australian Navy. Maritime Studies Program; no. 1).

**Disclaimer**

The views expressed are the author's and not necessarily those of the Department of Defence. The Commonwealth of Australia will not be legally responsible in contract, tort or otherwise for any statement made in this publication.

**Royal Australian Navy Maritime Studies Program**

In 1990 the Royal Australian Navy established the Maritime Studies Program (MSP) to undertake activities which would promote the study, discussion and awareness of maritime issues and strategy within the RAN and the defence and civil communities at large. The aims of the MSP are: to promote the awareness among members of the RAN and wider Defence community of maritime strategy, maritime issues and the role maritime forces play in the security of national interests; and to contribute to the development of public awareness of the need for sea power in the defence of Australia and her sovereign interests.

Comment on this Working Paper or any inquiry related to the activities of the Maritime Studies Program should be directed to:

Director General Maritime Studies Program  
HMAS CRESWELL  
JERVIS BAY 2540  
Australia

Telephone: +61 2 4429 7948  
Facsimile: +61 2 4429 7969  
E-Mail: [hmas.creswell-msp@navy.gov.au](mailto:hmas.creswell-msp@navy.gov.au)

**Maritime Studies Program Working Papers**

The Maritime Studies Program Working Paper series is designed as a vehicle to foster debate and discussion on maritime issues of relevance to the Royal Australian Navy, the Australian Defence Force and to Australia and the region more generally.

**About the Author**

**Norman Friedman** is a naval historian and a consultant on defence affairs. He holds a Ph.D in theoretical solid-state physics from Columbia University, New York. Previously, he was a staff member (and, ultimately, Deputy Director for National Security Affairs) of the Hudson Institute and was a consultant to the Secretary of the United States Navy from 1985 to 1994. His many books include: *The Naval Institute Guide to World Naval Weapons Systems* (biannually); *British Carrier Aviation* (1987); *The US Maritime Strategy* (1989); and *The Post-War Naval Revolution* (1986). He has also been widely published in the defence press, including a monthly column in the US Naval Institute's *Proceedings*.

## Abbreviations and Acronyms

AAW	anti-air warfare
AEW	Airborne Early Warning
AWACS	Airborne Early Warning and Control System
ASW	anti-submarine warfare
ASUW	anti-surface warfare
ATACMS	Army Tactical Missile System
CEC	co-operative engagement capability
CIC	combat information centre
CO	Commanding Officer
DARPA	Defence Advanced Research Projects Agency
DF	direction finding
ECM	electronic countermeasures
EORSAT	ELINT (Electronic Intelligence) Ocean Surveillance Satellite
ESM	electronic support measures
FCC	Fleet Command Centre
FOSIC	Fleet Ocean Surveillance Information Centre
FOSIF	Fleet Ocean Surveillance Information Facility
GPS	Global Positioning System
HF	high frequency
HMS	Her Majesty's Ship
JMCIS	Joint Maritime Command Information System
JORN	Jindalee Over-the-Horizon Radar Network
JOTS	Joint Operational Tactical System
LASM	Land Attack Standard missile
MPA	maritime patrol aircraft
NACCIS	NATO Command and Control Information System
NATO	North Atlantic Treaty Organisation
NSA	National Security Agency
NUWC	Naval Underwater Warfare Centre
OIC	Operational Intelligence Centre
OPV	Offshore Patrol Vessel
OTH	over-the-horizon
OTH-T	over-the-horizon targeting
R&D	research and development
RAAF	Royal Australian Air Force
RAM	radar absorbing material
RAN	Royal Australian Navy
ROE	rules of engagement
RORSAT	Radar Ocean Reconnaissance Satellite

vi

SSIXS	Submarine Information Exchange System
TFCC	Tactical Flag Command Centre
UAV	unmanned aerial vehicle
US	United States
USS	United States Ship
UUV	unmanned underwater vehicle
VSTOL	vertical/short take-off and landing

# NEW TECHNOLOGY AND MEDIUM NAVIES

Norman Friedman\*

## Introduction

Prediction of any kind is tricky. Any concept for the design of a navy must take into account both the likely long lifetime of its ships and the excellent odds that those ships will experience a very wide variety of international environments. Say, for example, that ships are to last forty years—and remember that, the longer the unit lifetime, the easier it is to maintain a fleet large enough to meet a wide geographic range of commitments. Remember, too, that modern ships take at least a decade from concept to completion of first of class, so that the appropriate time scale may be closer to fifty years. For a complete class, it may be sixty years from concept to retirement. Past history is not a perfect guide, because before 1945 the time scale from concept to completion was considerably shorter (the difference is due partly to the rise of modern electronics, but surely partly also to the rise of modern defence bureaucracy). Furthermore, in the past few ships lasted as long as they now do.

Given these caveats, imagine a ship conceived in 1938, just before World War II, at a time when it seemed that battle fleets would dominate future Pacific warfare. With the time scale now in place, she would be completed in 1948, when enemy fleets were gone, and naval warfare seemed to be intended mainly for strikes against land targets (i.e. carrier operations) and for shipping protection (ASW). The political environment would have been transformed altogether by the course of World War II and by the onset of the Cold War. Even the viability of navies would be in question, due to the rise of nuclear weapons. It seemed, for example, that major amphibious operations would no longer be possible (this was two years before Inchon). Thus it might have been difficult to justify a serious fire support capability. At mid-life (1968), the naval air threat (imposed by missile-carrying bombers) would be quite prominent. Anti-air warfare might well be the dominant theme. However, there was also a strong belief in limited war, which was then occurring in Vietnam, so naval gun fire support was very much back in style. By the time the second ship in the class was retiring, in the 1990s, the Cold War was over, and the international scene seemed much more fluid. That development was

---

\* All opinions expressed in this paper are the author's, and should not be construed as necessarily reflecting those of the U.S. Navy or of any other organization with which he has been associated.

symbolized by the Gulf War—which demonstrated a real need for the ability to support an embargo.

The lesson in all of this is that the one great virtue navies offer is flexibility. It is the virtue most difficult to quantify, and least apparent in the usual studies of optimum solutions to stated problems. Yet it is very real, even crucial. Within NATO, at the end of the Cold War the U.S. Navy was the strongest exponent of naval power projection. That made it by far the most adaptable to the new international environment. The main European NATO navies had all committed themselves to a fairly narrow sea control mission. At a stroke their fleets became obsolescent. This was not a matter of technology. They were mission-obsolescent. A Type 23 frigate, for example, is a very poor power projection platform. It is still an excellent deep-water ASW ship, but without much of a Soviet submarine force to fight it lacks justification. The Royal Navy retains some inherent projection capability mainly because it has inherently flexible light carriers. This is not to say that carriers equal flexibility, but rather that they are the only open-architecture combatants in the Royal Navy. They are open in the sense that alternative mixes of aircraft can be placed on board. In the U.S. Navy, vertical launchers capable of carrying either anti-aircraft (Standard) or strike (Tomahawk) missiles offer a flexibility which surface combatants in other fleets currently lack.

No one has a magic way of projecting ahead ten years, let alone twenty or fifty. We can, however, distinguish between a business-as-usual projection and some important alternatives. The great question must be whether some type of Cold War (say, a rivalry between the West and China) arises, or whether the world will simply be generally unruly, as now, without any single hostile power or bloc emerging. Prediction is dangerous. For example, it now seems impossible for the Russians to return to their Cold War peak of power and threat. Yet one can see the Cold War as a sort of World War I fought in very slow motion. In 1920 it must have seemed that the Germans were finished. Their country was in chaos, with private armies fighting it out in the streets. Revolution, both from the right and from the left, was very much in the air. The situation must seem familiar, with the important difference that in 1920 revolution was inspired partly by an ongoing Russian Revolution (to which there is no current analog). Perhaps 1999 is not too bad a parallel to 1920 in Germany, however. Or perhaps it is 1929, when the postwar German recovery had been sapped, and people were really desperate. If so, when will 1939 come back? Will it?



On the other hand, one might analogize Russia now to post-revolutionary France, again stretching out the time scale. About 1815 France was in ruins; Napoleon's ambitions had exhausted the country. Most Britons believed that the French would seek revenge for their defeat, and for nearly a century France was considered the most likely future enemy. Yet the next occasion French and British soldiers were in battle at the same time, they were allies, in the Crimea, thirty years after Waterloo. Moreover, in 1815 the Royal Navy planned a force structure fit to fight a second set of Napoleonic Wars. It was well aware that no big war was on the immediate horizon, so it laid up the battle fleet it would need once war broke out again. Meanwhile it operated on a much smaller scale. The RN was caught by two surprises. First, when the big war did come (in the Crimea), it required very different resources. Second, a technological revolution (steam and armor) made the carefully preserved fleet obsolete.

### **A Medium Navy**

First, what is a medium navy? It is medium in resources—which divide into capital and operating budgets. Obviously different navies can buy different amounts with what they have, but it is probably fair to say that all Western navies find themselves increasingly squeezed for personnel, and perhaps somewhat less so for hardware. Indeed, a major current and future trend is to buy hardware to minimize personnel numbers. Almost inevitably cuts in personnel fall on the less qualified branches of the service, so that personnel costs will not fall nearly as quickly as numbers. A ship manned mainly by officers and senior enlisted personnel will not be inexpensive to run.

Note that while the number of personnel required to operate surface combatants is falling, the number on board aircraft carriers is still quite high. If the main constraint on a medium navy is manpower, then it can be argued that manpower-intensive ships such as carriers are simply unaffordable. In navies which do have carriers, these ships are the primary means of attacking land targets. A carrier-less navy needs its own means of doing the same job, preferably from similar ranges (to limit vulnerability to counter-attack). Otherwise it may be unable to act entirely independently of larger fleets, a situation which its government may find unacceptable.

Medium means medium numbers of ships, whatever types of ships are bought. It means that annual shipbuilding numbers are likely to be quite limited. Say ships last an average of thirty years (perhaps necessarily more, given adverse economics). A twenty-ship fleet builds an average of two-thirds of a ship each year. This implies that overall national naval building capacity is

quite limited. The further implication is that it will be difficult very quickly to replace any ship which is lost due to enemy action. The larger the fleet, the more easily it can deal with both enemy attack and the normal hazards of the sea. The smaller the fleet, one would suggest, the more important survivability becomes.

Medium probably also means medium material resources, at least in terms of what the navy itself can obtain or develop for its exclusive use.

Medium does NOT necessarily mean medium capabilities. A medium navy is limited in the number of commitments it can fulfill at any one time. It is likely to operate much or most of the time on a regional basis. However, the government which funds it may well find that one important virtue of a navy is that it can operate very far from home. For example, by taking part in a coalition operation the navy gives its government a say in that operation. In the Australian case, this important role is exemplified by operations during the Gulf War.

The navy will likely have a spectrum of missions. In a major war, in which it is linked with other navies, it may be responsible for protection of shipping and it may combine with other navies for offensive operations. That was, for example, the experience of the Royal Australian Navy during World War II. Given such requirements, the navy should be capable of operating in high-threat areas, or at least it should be suitable for upgrade to meet such requirements.

In its local area, the medium navy may be far more powerful than other local navies, so that to them it is the large high-tech navy. It offers those navies important advantages; in return, those navies' governments may want an alliance with the owner of the medium fleet. Alliance demands a degree of tactical interoperability. It may also demand capabilities, on the part of the medium fleet, that are more obviously valuable for the alliance than for, say, home defence.

The medium navy's mission clearly includes insuring sea communication with its homeland. In many areas lines of communication run through narrow straits. It is by no means impossible that local wars, which do not directly involve the medium navy, may endanger those lines of communication. In that case the medium navy will probably find itself escorting shipping through war zones.

In case this seems too abstract, think of the Iran-Iraq War, in which both sides tried to stop tankers passing through the Gulf. The tankers were vital to the West, so the British and U.S. navies found themselves escorting them. This escort mission was particularly difficult because the rules of the situation precluded any attacks against the anti-ship forces arrayed on either side; the British and the U.S. were neutrals (albeit tilting towards the Iraqis). This seems likely to be a prototype for future operations in many places. Note that, as in the case of USS STARK, it makes for surprise attacks on escort ships, under conditions in which rules of engagement prohibit pro-active defence.

The issue is complicated further by a dramatic change in the character of a navy. Since the beginning of this century, portions of the navy external to the fleet have had a larger and larger OPERATIONAL significance. That is, what amounts to sensors located far from the ships themselves have more and more often provided near-real-time information. The most striking current examples are OTH radar (e.g., JORN) and various satellite systems. For the U.S. Navy, the use of such external systems is enshrined in the current concept of Net-Centric Warfare.

In effect, the use of external sensors can reduce the burden on the deployed fleet. There seems to be a trade-off between investment in ships and in ship-based systems and investment in external sensors (including the communications system which brings their data out to the deployed ships). It would be foolish to imagine that the sensors and long-range strike systems can somehow replace the ships; but no designer of a next-century medium fleet can ignore the potential the sensors offer. Nor, of course, can that designer ignore their cost—if the medium navy has to shoulder that cost by itself.

Alternatively, it might be said that the use of external sensors in combination with shipboard assets can leverage the considerable investment the ships represent. For example, during the latter part of the Cold War the U.S. Navy planned to fight an Outer Air Battle to destroy the Soviet naval bombers (mainly ‘Backfires’) which would otherwise have destroyed NATO shipping. It was quite clear that existing NATO frigates, which were optimized for anti-submarine warfare, could not deal with the ‘Backfire’ threat. At best they might have fended off some of the missiles the bombers launched, without dealing with the bombers at all. The bombers would simply have come back, and destroyed the surface units whose weapons had been depleted.

This thinking is very different from that usually associated with sea control. It is, however, very consistent with classical naval strategy. The question is, how can sea communications be protected against a very powerful enemy force? Naval assets did not (and do not) suffice to provide effective cover for enough convoys. In the case of the ‘Backfires’ and also of nuclear submarines, it could be argued that nothing short of main fleet assets could really deal with the threat; indeed, that any convoy escort which could *not* deal with the threat would merely provide the attackers with a good target. The solution the U.S. Navy preferred was to seek a decisive battle in which the enemy fleet (in this case, its bombers) could be destroyed. Once the decisive battle had been won, sea control would be ensured, at least against the air threat.

Clearly the Soviets would have preferred to use their bomber force against NATO shipping, rather than to risk it against F-14s and high-grade missile ships. The U.S. Navy therefore emphasized the threat the carriers would present to the one naval asset the Soviets really valued, their ballistic missile submarines. The U.S. Maritime Strategy proclaimed an intent to use carrier-based bombers and Tomahawk missiles to attack the Soviet bases in the Kola, and it was from these bases that the Soviet ballistic missile submarines operated—and were covered, against U.S. and allied submarine attacks. Thus, the U.S. Navy deliberately set up the carriers as a combination of threat and irresistible target. In its view, the ‘Backfires’ would have to concentrate first on the carriers. The U.S. Navy’s tactical problem, then, was not merely to keep the carriers alive, but rather to use them to destroy the ‘Backfires’.

Any enemy with a land-based anti-ship strike air force presents a threat similar to that of the ‘Backfire’ force, because its aircraft can attack from beyond the effective range of surface ships protecting high-value targets. The question for the medium navy, then, is how to use its surface assets and whatever air assets it may share, to destroy the enemy’s anti-ship squadrons. Once they are gone, the overall threat to shipping decreases dramatically. Ships incapable of supporting serious anti-air operations may well be effective against the remaining naval threats, such as submarines and surface fast attack craft. However, until the air threat has been neutralized, these ships are very much at risk. The U.S. Outer Air Battle example may, therefore, be worth pursuing.

It was soon appreciated that any effective counter to the ‘Backfires’ would have to combine air and surface assets in some new way. At first it seemed that carrier fighters were the only means of dealing with ‘Backfires’ before they could launch their weapons; but the fighters had very limited

endurance. It would not be enough to maintain a classical Combat Air Patrol. Instead, a considerable defence in depth would be needed, using all or most of the fighters on board a carrier. This defence could have only a limited endurance, about four to six hours. There was a real possibility that the bombers would appear either before the fighter defence had been erected, or after it had run out of endurance. Surface ships offered two important possibilities. First, given a very effective anti-aircraft system (Aegis), they could back-stop the fighters, to the extent that even if the fighters were not present they could probably save the fleet from destruction. Second, given airborne early warning, selected surface ships could be stationed closer to the approaching bombers. They could be cued to fire their missiles long before the bombers approached the main body of the fleet.

That is, there was a synergy between ships and aircraft in this anti-aircraft role. Although it is unlikely that any navy will soon face an air threat on the scale of the Soviet naval air arm, the idea of synergy remains very interesting. At present, surface ships are armed with anti-aircraft weapons mainly for self-preservation, or to protect the ships they are escorting. They face the same problem the U.S. Navy faced. Aircraft will generally attack using stand-off missiles. The ships may well be able to deal with the missiles, but that will not do much to the attacking aircraft—which can return later with more missiles. Short-range airborne early warning, like the radar on board the British Sea Kings, will detect incoming missiles approaching at low altitude, but it will not detect bombers at very great distances. On the other hand, an AWACS-type radar, such as that aboard the U.S. E-2C or that planned for the RAAF under Project Wedgetail, ought to provide really early warning. This will be particularly the case if it is combined with OTH warning of the type offered by JORN.

In this case, something like U.S. Outer Air Battle tactics becomes possible. The surface fleet is at once a protector of high-value shipping and a lightning rod for the enemy's anti-ship air arm. In the latter role, the fleet is intended to attract and destroy enemy air attacks, on the theory that *only* the fleet, with its high-capacity anti-aircraft systems, can do the job. In this model, there are two counters to the enemy's anti-ship bombers. One is a force of land-based fighters, which can be vectored out to the fleet; the other is the fleet's own high-capacity anti-aircraft system.

The argument against depending on land-based fighters has always been that, due to communications and control problems (and to operational ones), the fighters are never in place when needed. In that sense the fighters are not too different from the carrier-based fighters envisaged in the U.S.

Outer Air Battle: they are extremely effective, but at times they will not be in place. If they are not in place, then it is crucial that the ships are effective backstops. In the U.S. case, the key issue was the availability and capacity of the Aegis system, which was considered an effective backstop.

If the anti-aircraft system works, some ships can be detached to lie in the direction of the threat, beyond air-launched missile range of the main body, on the theory that they can defend themselves effectively, and that the bombers will have to pass over them en route to their targets. Naturally this is something of a bet, and naturally much depends on how well the bombers can be tracked from take-off. That in turn requires more than the usual AEW support for the fleet. In the U.S. case, early tracking was provided by long-range OTH (over-the-horizon) radar and by other sources of information, such as satellites.

In this sort of battle, the ships defending the main body must control all available AAW resources. It is vital that both OTH resources and AWACS data go directly to them, and that they be able to communicate effectively beyond the horizon to those units sent out along the threat axis. That is, the key tactical decisions will probably be made on board the flagship, where the overall tactical picture will be assembled. Since some key information may be obtained by intelligence systems, they, too, must connect to the surface force. Since information may become available only fairly close to the likely time of attack, it may be very important that the outlying anti-aircraft ships be capable of fairly high speed in the open ocean, to reach their stations in time. It will also be essential that the ships be able to control those fighters which do become available to deal with the incoming bombers.

Clearly, the tactics outlined would work more effectively if the surface force had organic fighters available, but that is unlikely to be the case. There is an intermediate possibility. The U.S. Navy is currently developing CEC, the Cooperative Engagement Capability. To some extent CEC is the latest form of an older idea, Forward Pass, in which a ship would launch an anti-aircraft missile which would be controlled by an aircraft. The idea of Forward Pass was that the airplane could see much further, but could not carry many missiles. The ship could carry many more missiles (with greater range), but her onboard radar had only limited range. Forward Pass seemed particularly attractive to the U.S. Navy circa 1979, when it seemed that big carriers were unaffordable. The very small carriers then envisaged could have supported the necessary radar platforms, but not fighters like F-14s.

The problem was handover: how to coordinate the ship with the airborne radar platform. CEC seems to have overcome this problem. Radar pictures from different platforms can, it seems, be used interchangeably. Development has slowed, but probably mainly because of attempts to integrate CEC with theater ballistic missile defence. The air-ship connection was demonstrated several years ago. This connection carries with it the possibility of Forward Pass. One can, then, imagine providing the necessary radar either on board a powered airship (following a surface force), or a VSTOL, or a land-based AWACS. In fact, one might imagine a sequence. The enemy strike might be detected initially by intelligence or by JORN or a similar asset. That would cue a land-based AWACS. The AWACS in turn might cue a radar aircraft operated from a ship.

In any case, the point of the operation would not be merely to protect the surface force, but to eliminate a powerful anti-shipping weapon—a specialized air arm—operated by the enemy. This would be quite different from the current goal of ship-based air defence. It would justify (indeed, necessitate) the most powerful and the longest-range shipboard anti-aircraft weaponry.

### **The Surface Fleet**

The special capabilities of surface ships are:

- **PERSISTENCE**, which means sustained presence, both before and during combat. Because the water supports a surface ship she does not have to expend energy merely to remain in place—as an airplane must. Thus she has inherently long endurance, limited only by the need to feed her crew and to fuel her engines for movement. Nearly as importantly, the ship normally operates in international waters, and thus does not need permission for its presence. No other military force can operate near another country on a sustained basis without the consent of that country or of a neighbor; therefore no other kind of force can offer the sort of coercion which governments inevitably sometimes have to exercise. In particular, no long-range strike force, however well directed, can provide presence on a sustained basis; its effectiveness, if any, in this role depends on the imagination of the other government involved. Recent experience suggests that such imagination is often lacking.
- **MOBILE CAPACITY**: a surface ship is by far the least expensive way to transport material over long distances. That makes it much more

economical, for example, to load a ship with cruise missiles than to fire similar weapons thousands of miles. On the other hand, ship mobility is limited. A small number of major warships cannot be in many places at once.

- **FIREPOWER:** due both to capacity and to the fact that, since she is on the surface, a surface ship's weapons are always available for use.
- **CONNECTIVITY:** a surface ship can easily exploit space-based communications on a continuous basis. A submarine cannot, without destroying her stealth. The ship, moreover, can accommodate personnel and computers needed to make sense of the information flowing in from external sensors and command information systems. On a tactical level, connectivity means that one ship can exploit data collected by others in a group, as is now widely done using digital links (e.g., Link 11). At a higher level, connectivity is likely to make it possible for a group of surface ships to detect even stealthy aircraft and missiles. At least as currently designed, they cannot be stealthy at all bearings; inevitably any one radar will pick up a few reflected pulses. At other bearings it will see only a very weak signal which is generally lost in noise. However, if several radars are netted together, pooling all the signals they receive, then the pooled set of signals will reveal a consistent track rather than a few random detections. That is one benefit of the current U.S. CEC program. Too, connectivity can help cut manning. For example, until very recently, from an administrative point of view, a U.S. ship operated as an independent entity. That required it to have, for example, its own personnel office and its own ship's office handling questions like when and where the ship would get its food. Given reliable computer links, these non-combat jobs can be done on shore, far from the ship. That is now being done in the U.S. Navy, partly by putting ships on a navy-wide Intranet, under an IT-21 initiative (IT-21 has many other functions).
- **ECONOMY:** because the ship's strike weapons are not manned, a surface combatant has a relatively small crew.

### **Weapons for Power Projection**

If the surface fleet is ultimately valuable for its ability to project national power, what sort of weapons can it deploy? Ideally, the fleet should be able to strike from as far offshore as possible, to eliminate threats such as mines and



coast-defence missiles, and to avoid detection by coastal radars. In many cases ships more than a hundred miles offshore will be effectively invisible.

There are three quite separate projection requirements. One is to be able to make deep strikes broadly equivalent to air strikes, comparable to the Tomahawk attacks U.S. warships have been making in places like the Gulf, Afghanistan, Kosovo and Bosnia. Long range demands a big missile, which cannot be carried in massive numbers. For example, DD 21 as currently imagined has 240 vertical cells, some of which must be devoted to defensive weapons.

A second requirement is to be able to support a ground force by attacking approaching enemy forces before they can get very close. By trading off warhead for range, it is possible to place a powerful missile in a standard vertical launcher. Current examples are the projected U.S. Land Attack Standard Missile (LASM) and the naval version of ATACMS. As in the case of Tomahawk, numbers are inherently limited.

Moreover, it is apparently difficult or impossible to replenish the contents of a vertical launcher at sea. The one guided weapon which can easily be replenished at sea is a guided shell, fired by a gun. Probably it is best to think of the gun as the reusable first stage of a missile; shells can be transferred relatively easily at sea because (thanks to the gun) they are much smaller than missiles, for a given payload and range. There are, of course, limits; no 5-inch or 155mm shell carries much of a punch. However, they can be fired relatively rapidly—and their magazines can be replenished as they are emptied. These characteristics make guided shells the only logical choice for the direct support of troops. If, as the U.S. services suggest, it is vital to limit what troops take ashore, then providing them with artillery support mainly from the sea becomes the solution.

There is a rub. Guns are mechanical launchers; like missile rail launchers, they are subject to malfunction (vertical launchers are far simpler and virtually unjammable). The ideal large surface combatant, then, needs multiple gun mounts, each capable of firing guided shells. Guidance itself is not too complicated; the new generation of shells are fitted with GPS receivers, and they generally go to preset aim points.

The missiles and guns are clearly only part of a larger system. Since the operator is a medium-sized navy, it is unlikely to have access to a dedicated satellite reconnaissance or communications system. The likely local solution is UAVs (both for observation and, as a 'poor man's satellite,' for data relay

beyond the horizon), so the ideal surface combatant ought to be able to support several medium-endurance UAVs, presumably vertical take-off types.

Of course this brings up the question of using gun-launched projectiles for other roles, such as anti-ship (guided) and anti-aircraft. Current surface warships carry far too few anti-ship missiles to deal with large ship targets. A gun magazine certainly holds enough projectiles to do real damage, if a large fraction of them hit. In recent years there has been considerable interest in course-corrected (in effect, command-guided) shells, although none has apparently reached the operational stage. The same is true of seagoing laser-guided shells. However, some guided tank and howitzer projectiles have entered service, in NATO countries, Israel, and in Russia. It may be time to explore an extension of such technology to naval warfare.

### **Other Fleet Elements**

Typically a fleet includes a shore establishment, underway support ships, amphibious ships, submarines, and a naval air arm. The question of fleet design is how to balance off these elements against surface combatants. In peacetime or in many kinds of war, the surface combatants are the main visible elements of the fleet. They are also likely to be its main striking elements, at least against land targets. Against sea targets, aircraft offer large numbers of repeat strikes, as long as they can survive terminal defences, and as long as the targets are within range of their bases—and, as a matter of survivability and endurance, as long as they need not spend much time searching for those targets. Maritime patrol aircraft offer long-range search capability, but it should be borne in mind that such searches are generally cued. The longer the range at which a search must be mounted, the greater the importance of cueing. The smaller the number of operational MPAs, the greater the chance that a potential target will be undetected, unless the search is cued. Thus an MPA may more often operate as the intermediate step in a search-strike operation than as the initial target detector. Submarines offer the ability to attack such targets at very long ranges, in areas nominally dominated by an enemy fleet. However, they are probably more important as a means of gathering intelligence in enemy-dominated areas.

From an operational point of view, the important part of the shore establishment is that which connects to external sensors (including sources of intelligence which cannot normally be characterized as sensors) and which produces a tactical or strategic picture on the basis of which the fleet can

operate. Since many of the sensors (in the broad sense) are either joint-service or are held at a governmental level above that of the services, the shore establishment as understood here may not be a naval entity at all; it is more likely a joint-service centre. The important issue is how intelligence data are handled and how an intelligence product is disseminated to the fleet. U.S. practice, for example, is to provide ships with a dual stream of information, all of it sent by covered satellite link: both a tactical picture, assembled ashore, and semi-raw intelligence data, which the ship can collate with local data to feed back to the shore centre. Note that this practice is impossible *without* a dedicated covered satellite link, because no other form of communication offers the necessary capacity. This is quite aside from the need for imagery to support aircraft and missile strikes.

Clearly, to some extent the shore establishment can trade its capacity off against the need for reconnaissance aircraft and even against the need for numbers of ships. Conversely, if the fleet is very small, its impact may depend on the quality of data produced by the shore establishment.

The fleet's reach is a trade-off between underway support and the inherent endurance of its ships. Given the downward pressure on personnel numbers, and the fact that manning is by no means proportional to the size of a ship, it would seem that there will be intense pressure to minimize the number of afloat support ships by increasing the unit size (hence endurance) of the major fleet combatants. Here endurance applies not only to fuel but also to ordnance; current underway replenishment ships carry weapons. Most surface combatants have very small missile load-outs: only forty weapons, for example, in a missile destroyer or a frigate. Even these missiles are difficult to transfer at sea. There are, it would seem, considerable advantages in adopting vertical launchers, which carry more weapons in the same volume as current rail launchers, even though they cannot be replenished at sea. Again, larger is better, because a larger ship carrying more weapons can probably avoid weapons replenishment altogether.

There is also the issue of mobile support—tenders. Typically tenders are used to turn a sheltered bay into a usable fleet base with maintenance facilities. The alternative is to build permanent bases. The issue is just how flexible fleet operation must be. If the fleet normally operates in concentrated fashion, then a concentrated base is worthwhile. It can be argued that if the fleet must shift frequently from (say) coast to coast, then it is worthwhile to maintain a fleet train which can move the base as needed. However, that is expensive. Again, a larger ship may be better able to maintain itself. For example, in U.S. practice destroyers needed tenders; cruisers did not (this no longer holds true, as both

types are now more or less equivalent). The larger ships did still sometimes need outside assistance, in the form of repair ships or floating drydocks, but on a much smaller and less expensive scale than the small ones. One might argue, then, that there is a trade-off between unit ship size and support cost.

There is, to be sure, a rub. In order to be truly self-supporting, a ship must accommodate fair numbers of technicians. If the ship is not really self-supporting at all, then she can make do with a much smaller complement; the technicians can be concentrated ashore. This argument was the rationale for the British practice of using mobile maintenance teams for Type 23 frigates (the team can be flown out to wherever the ship makes port, every so many weeks). Another approach would be to enlarge the ship to the point where most important equipment was redundant. The ship could, therefore, operate for a protracted period with neither technicians nor base support. This concept may become more attractive as electronics continue to become more reliable, and in view of the high reliability of standard gas turbine powerplants.

### **Insuring Against Obsolescence**

Looking ahead, what vulnerabilities must a fleet plan overcome? The main possibilities, given past history, seem to be:

- technological obsolescence
- mission obsolescence
- economic obsolescence (systems become unaffordable, e.g. because they are too manpower-intensive; this is what happened to steam plants in the Western navies)
- obsolescence due to the emergence of overwhelming new threats (e.g., the obsolescence of generations of armor plating during the nineteenth century)

Since the end of World War II, the usual response to the emergence of new naval technology has been to rebuild existing ships to embody it. That is, the weapons and sensors changed much more quickly than the underlying fabric of ships or their powerplants. One can speculate that the major powerplant revolution, to gas turbines, was possible because it coincided with the end of the natural lifetimes of the mass of World War II-built ships which filled the world's navies (and whose existence made reconstruction much more attractive than massive new construction). The main lesson of reconstruction after World War II was that larger ships were far more adaptable than smaller

ones. For example, during World War II the Royal Navy built ships, category for category, which were much smaller than their American counterparts. British naval constructors argued that their designs were much more efficient. After the war, the British found that many of their ships were simply too small to accommodate new weapons. For example, plans to modify existing cruisers to accommodate surface-to-air missiles had to be abandoned as unfeasible.

Mission obsolescence is trickier, but no less real. NATO navies carefully built for deep-water escort ASW have little relevance in a world from which the Soviet submarine fleet has largely disappeared, but in which their governments are vitally interested in projecting power (e.g. for peace-keeping in the Balkans). Again, it seems fair to say that tight designs preclude the sort of flexibility which is now so clearly necessary.

Note that mission flexibility includes a geographical element. It is more and more difficult to say in advance where a navy will operate. Even in the past, governments could not really be certain that their fleets would be confined to regional waters. For example, the Royal Australian Navy built up before World War II was intended mainly to defend Australia. However, it was also part of a larger Empire fleet. The logic was that by participating in the larger effort, Australia could gain some influence over Imperial decisions and could demand Empire participation in her local defence. In fact through the 1930s British naval planners assigned the highest priority to the Far East, which was very much what the Australian government of the time sought by its naval participation in the larger effort. From a design point of view, then, Australian ships had to be able to operate wherever the Royal Navy was likely to go. As it happened, when war came in 1939 it came in Europe rather than in the Far East, and the RAN found itself fighting very far from home. It was vitally important, for example, that it had commonality with British warships, so that its ships could operate from British bases. Conversely, the hope was that the Royal Navy could operate from Australia. Again, as it happened, that was largely impossible until 1944, because the British had to concentrate their forces in Europe. However, the Australian thinking was quite sound, and illustrative of the fact that even a regional navy must often operate on a global scale in order to gain its government a say in wider coalition decision-making. The massive contribution of the Australian Army to the European and Desert wars can be seen in much the same light.

Mission obsolescence also applies to the overall shape of the fleet. A small number of very powerful ships concentrated in a battle force are very appropriate to a single concentrated enemy. A more numerous fleet of less capable ships may be appropriate to a world (or a region) in which threats are

smaller but are also uncorrelated and, at least sometimes, nearly simultaneous. The same fleet probably has to meet dispersed contingencies most of the time, yet has to be able to fight in a high-threat environment some of the time. Note that high-threat need not mean superpower opposition; it took very capable ships to operate in the highest-threat areas of the Persian Gulf in 1991. It would seem to follow that the ideal medium fleet consists of a fair number of individually very capable ships, each of which can effectively project national power in a lower-order situation.

One might see the RAN cruisers of the interwar period as prototypes for such ships. In a high threat situation, they could function as integral parts of a larger multi-national fleet. It was obvious that Australia could not, herself, afford to build such a fleet, no matter how grave the threat. In lesser contingencies, a cruiser was an ideal self-contained means of projecting power. She carried both large numbers of men and substantial shore-bombardment fire power with which to support them. She was not an amphibious warfare ship, but her boats could land armed personnel under many circumstances. Conversely, it would take substantial shore firepower, which generally did not exist, to deal with the cruiser.

This potential for multi-role surface ship capability effectively died out after World War II, when the key escort role demanded specialized anti-aircraft and anti-submarine weapons. Now, however, it may be back with the advent of large vertical launchers. Certainly a U.S. BURKE or TICONDEROGA must be considered a multi-role warship, capable of attacking shore as well as air and sea targets. This new capability should not, of course, be confused with the much heavier sustained firepower offered by an aircraft carrier. However, a carrier cannot operate freely without consorts, which form a concentrated fleet. A medium navy, with limited resources, may well find multi-role surface ships, which can operate individually with a fair chance of success, much more attractive.

Note that power projection means both attacks on targets abroad and their less violent equivalent, presence. Ultimately presence is unlikely to have much impact unless the ships displaying themselves have an obvious potential to do damage if provoked. Although this may seem quite obvious, most current Western warships have little capacity to attack shore targets except by using their guns and, to a limited extent, their embarked helicopters (developed versions of Harpoon may offer some additional—but very limited—shore attack firepower). It is difficult to find ships so armed individually impressive. In effect they impress by the implication that real strike assets (carriers) will deal with anyone trifling with the surface ships. That thinking is probably not

conscious, but it seems inevitable that eventually the Third World targets of naval presence will be able to tell the difference.

Power projection inevitably includes the support of troops landed ashore. That raises two separate kinds of question. One is a ship's suitability to accommodate headquarters facilities (and the availability of data links of various sorts). The other is the actual weaponry intended to support the troops ashore, the balance of volume of fire against explosive power per projectile. Note current U.S. attempts to reduce the amphibious footprint (including sheer numbers) by retaining as much as possible of the landing force off shore. Clearly that applies both to firepower and to headquarters staffs. Both efforts depend on the degree to which the ship or ships offshore can communicate with the troops fighting ashore.

Power projection at longer ranges involves dealing with key Third World targets, which may often be in bunkers. For example, in many Third World countries, the only target which really matters is probably the command bunker. This reality is unlikely to change over half a century, but the likely victims' air defences will undoubtedly improve.

One important aspect of presence is that ships are effective precisely because they can be seen; stealth can be a positive disadvantage. Moreover, a ship on a presence mission is inherently a target. It may be less obvious that presence may be an important mission during a war between two other parties. During the Iran-Iraq war, U.S. ships (such as USS STARK) were placed in the Gulf in hopes that their presence would discourage both parties from attacking ships there. The idea, it seems, was that inevitably errors would occur, and if U.S. ships were hit the United States might retaliate with devastating effect, tipping the balance of the war. As it happened, the outcome of the attack on USS STARK was not what might have been expected, yet inevitably the idea will recur.

The most likely economic issue is personnel; over the next few decades the entire West faces serious demographic problems. The birth rate in wealthy countries is relatively low; the sheer number of adults of military age is falling, and will continue to fall until it recovers somewhat due to the demographic echo of the 'baby boom.' At the same time our wealth makes our citizens longer-lived, so the population as a whole is ageing. One implication is that it will be more and more difficult to fill the important jobs in the society as a whole; salaries for key jobs, for example, will rise. Since the services compete with the civilian economy for people talented enough to fill important jobs, the

cost of manning will rise. Alternatively, and more probably, the services will have to make do with fewer people.

The smaller the total naval personnel base, the greater the pressure both to limit manning per ship and to make do with fewer ships. Since the combat load on the fleet is likely to increase (due to more numerous simultaneous crises), the implication would seem to be that afloat support will have to be reduced as much as possible. An underway replenishment ship cannot offer naval presence the way a carrier or a cruiser can. Obviously it can support sustained presence, but alternatively it may be easier to provide the carrier or cruiser with more stores, fuel, and weapons.

Then there is the question of threats to ships. To what extent will the weapons themselves become substantially more lethal? Conversely, if lethality does NOT increase markedly, we may be willing to invest more in ship survivability, in the expectation that our ships' passive defences will not soon be overwhelmed. Survivability matters because ships carry out presence missions far more often than they execute attacks. In fact the government paying for the navy must hope that presence fends off a war. In that role ships will be attacked, perhaps fairly frequently, and generally without warning. Their active defences will be of little moment, because rules of engagement (ROE) will generally prohibit pro-active measures. Modern weapons technology often will prevent a ship's commander from knowing whether he is under attack at all.

For example, when the Iraqi Mirage attacked USS STARK, the main electronic warning to the ship was that she was being 'painted' by the airplane's radar. That did not in itself indicate anything; an airplane examining ships would use her radar the same way. The fire control mode of the radar consisted in activating a computer function inside the airplane, a function not evident to any listener (the radar has a track-while-scan mode). There was a brief unambiguous warning when the Exocet's seeker was turned on, but by then it was far too late for the ship to spoil the attack by attacking the airplane. The missile was launched at such short range that there was not really time to deal with it. In this particular case, the ship's Tactical Action Officer was lulled by the mistaken belief (probably based on his other belief that the only potential attackers were Iranians, using a different missile) that the airplane's radar had to be locked on before attacking. The CO of another ship in much the same position had run a missile up on his rail and illuminated an approaching Iraqi airplane, possibly scaring its pilot off; but the incident seems to demonstrate mainly that presence operations can be dangerous.



The implication seems to be that passive protection is more, not less, valuable—if an argument can be made that the threats a ship will probably meet over her lifetime are finite and containable.

The end of the Cold War, and more importantly the apparent end of the massive Soviet military R&D machine, make such a hope reasonable. Developing new weapons is quite expensive. A major power (like the Soviet Union of the past) may be motivated to invest in new technology, so to guess its capabilities we ought to look at what is possible. A collection of minor states with very limited individual resources will probably not develop new anti-ship weapons radically different from what is currently available. For example, although several new missiles are currently under development, it is by no means clear how many of them will ever enter service (the Franco-German supersonic ANF and a variety of Russian missiles come to mind). See the Appendix for a description of likely threats.

### **Survivability**

Modern surface combatants have limited survivability, because they are products of the Cold War. For much of that period the major powers assumed that a hot war, if it came, would be very short. It would end either with both sides drawing back from the precipice, or with a nuclear holocaust. In either case, a ship put out of action for six weeks might as well be sunk, except for the value placed on keeping her crew alive. From a design point of view, then, quite moderate damage could be equated to fatal damage. There was little interest, moreover, in designing ships which, like their forebears, would degrade gracefully under fire. To be fair, until the late 1970s or early 1980s electronics were so delicate that any major hit could be expected to disable a ship altogether. Major damage, like the fire on board USS STARK, required extensive rewiring, which might take months or even years. Electronics are now far more robust—as is constantly demonstrated by home computers subject to remarkable levels of abuse.

Paradoxically, the STARK incident reveals that a modern surface combatant can survive considerable missile damage. STARK was hit by two Exocets, one of which exploded. The other burned and touched off a serious fire. The ship was endangered mainly by the weight of the fire-fighting water taken aboard. We now know that an alternative technique of damage control would probably have put out the fire before very much water would have come aboard. It was not employed because the ship's damage control experts, her

senior petty officers, died when the missile hit. The implication is that the ship needs either to disperse the spaces which important personnel occupy when off duty, or that some form of expert system is needed to back up the usual damage controllers. Neither step is particularly difficult or controversial (expert damage control systems are now being fitted to U.S. warships). The larger implication is that, had the ship's combat direction system not been wiped out by fire, she would probably have been able to fight after the missiles hit.

For that matter, HMS SHEFFIELD was not sunk by the Exocet which struck her during the Falklands War. She was abandoned by her crew due to the smoke (created by the hit) which filled the ship. Much later she foundered in a storm, the water entering through the hole the missile had been made. The ship had lost much of her inherent stability because her oil fuel (in her double bottom) had burnt out and because of the weight of fire fighting water left on her upper decks). USS STARK actually survived two Exocet hits, although she was very badly damaged. The fact that neither hull was destroyed by the missile hits suggests that a ship can be designed to survive missile attack. The key point is that an anti-ship cruise missile does a finite amount of damage. It is unlikely to sink a ship outright. Even the small and old Israeli destroyer EILAT took two large missile hits before her loss.

In the case of STARK, combat direction died because the ship's CIC was burned out. Without the CIC and the computers and terminals connected directly to it, the ship could not fight, whatever the state of her (intact) missile launcher and her radars. When STARK was designed, CICs were necessarily centralized, because computers tended to be quite massive. A quarter-century later small personal computers greatly outperform the ship's single central processor. Several navies (including the RAN, on the ANZAC class) are installing fully-distributed combat direction systems. As it happens, these systems are *electronically* but not *physically* distributed. A single hit can still wipe out CIC with its combat direction system, leaving the ship afloat but totally ineffective. However, with the rise of distributed combat centre systems, it is now possible to build multiple CICs into a ship (the secondary CIC is probably best used as an automated damage control centre, working with an expert damage control system; the ship's data bus can carry both combat and own-ship data). It is possible, moreover, to envisage a ship with a fully physically distributed combat direction system using virtual reality, in which operators would be spread through the ship (it is not clear whether live operators would stand for such a concept, however). Lest all of this seem like science fiction, several years ago the Taiwanese seriously considered this

configuration for their last PERRY-class frigate. Some descriptions of the new Israeli EILAT suggest that she is arranged for multi-CIC operation.

The more vulnerable the ship, the more pressure there is on her commander to shoot down any airplane apparently approaching her. That sort of pressure makes for extremely unfortunate incidents. The VINCENNES incident, in which a U.S. cruiser shot down an Iranian airliner in 1988, is probably traceable to exactly this sort of vulnerability. The missiles on which the ship relied inevitably had a finite minimum range. The ship's commander had to decide whether to fire before the potential attacker came within range. He had reason, based on the intelligence information he was given, to believe that the Iranians planned to attack his ship. Radar does not in itself identify an incoming airplane or missile. The less vulnerable the ship, the more time a commander will be able to spend deciding whether to fire.

Depending on the size of its warhead, the damage a missile does can be associated with a fixed length: the bigger the warhead, the greater the length of ship destroyed. It follows that the longer the ship, the greater the proportion outside the area directly damaged by a single warhead. Moreover, the effects of an exploding warhead can be contained—if a ship is properly designed. Few if any modern anti-ship missile warheads are capable actually of sinking a substantial ship with one or two hits, unless they happen to hit a magazine and cause a mass detonation. They generally hit above the waterline (Penguin hits at the waterline, but its warhead is quite small).

Survivability against most kinds of missiles will depend on how well the vital elements of the ship have been spread out along her length. Ship volume can buy protection. Some major near-term possibilities are:

- Insensitive munitions may make mass detonation of magazines virtually impossible
- Electric drive (unified propulsion and auxiliaries) makes it easier to split the prime mover up, so that it is impossible to immobilize the ship by disabling one powerplant. Too, propeller shafts, which are subject to whipping, can be eliminated, by placing motors adjacent to the propellers. In an extreme version of this concept, tractor propellers can be added to the usual ones at the stern, so that the ship can continue even if her stern is blown off. Eliminating long propeller shafts also allows better use to be made of the internal volume of the ship. A unified powerplant is planned for the projected U.S. DD21. There are, of course, difficulties. Electric drive is generally a good deal heavier than geared shafting. It is

difficult to unify prime mover and auxiliary plants because each has a very different demand cycle. Finally, spreading gas turbine generators through a ship entails complex ducting, which may be difficult to fit into a small hull. Even so, particularly with the advent of compact high-power electric motors, spreading out the powerplant would seem to offer important advantages in survivability.

- Elements of an active-array radar can be spread around a ship's superstructure rather than being concentrated, as now; in that case no single hit will be able to knock out the ship's entire radar system. In any case, a properly designed array radar will keep working even if some of the elements of the array have been destroyed.

All of this means that it is possible to design a surface warship which can keep fighting even after taking one or more missile hits.

The other main threat to surface warships is underwater attack. The worst threat is an under-the-keel explosion, which can break a ship's back. Most current torpedoes (and many mines) are designed specifically to inflict under-the-keel damage. The explosion creates a gas bubble, which rises to bounce against the keel, actually lifting the ship out of the water. The bubble contracts, the ship comes back down, and then it expands, rises, and hits again. Two or three bounces can snap a ship in half. At the least the ship suffers very severe shock damage. Paradoxically, this is much worse than if the torpedo actually hits the ship, in which case it destroys the hull over a limited length.

If a ship is large enough, she can be designed with a soft keel and with substantial strength in her sides. Instead of pressing against the keel (and lifting the ship), the bubble breaks through the soft keel and vents into the ship. Clearly this is not a happy situation, but it is better than allowing the ship to break up. To limit the effect of venting, the ship must be compartmented, and her vital systems duplicated and spread out. At some lesser degree of strengthening (and overall ship size), the 'box' under the keel in which a torpedo or mine must explode to do fatal damage can be drastically reduced. That in turn can impose considerable difficulties on the torpedo seeker and exploder or on the mine exploder.

### **The Littoral Problem**

Future naval warfare is at least as likely in littoral as in deep waters. The littoral presents some special environmental problems for each kind of warfare. They are summarized below.

- **AAW**: radar signals reflect from an irregular shoreline, making it very difficult to identify radars by standard ELINT techniques (the pulse trains tend to blur). Quite aside from the usual problems of ducting and multipath, ducting conditions exist over land (where they are more difficult to predict). Terrain clearly causes problems, since approaching aircraft or missiles can avoid detection until they are very close to their targets. The enemy may also be able to take better advantage of passive sensors, or even of a shore-based net tracking ships off the coast. Using such a net, anti-ship missiles may be launched without any recourse to specific radars associated with specific launchers: warning time may be very short.
- **ASUW**: existing anti-ship missiles may be ill-adapted to attacking targets in port or very close to a coastline, because they may too easily lock onto the wrong ship or even onto shore features. Attacks may therefore become impossible under apparently reasonable rules of engagement.
- **ASW**: shallow-water and underwater terrain greatly complicate sonar operation. Ships may not detect submarines until they are inside torpedo attack range. Submarines may commonly sit on a shallow bottom awaiting their targets; when they are not running motors or propellers, they are essentially immune to passive sonars.

There are several possible approaches to these problems. As for AAW, the U.S. Navy has found that by netting the radars of several ships (in the CEC system), it can often make up for terrain problems. Airborne ESM platforms, particularly multiple ones, may be able to make up for the multipath problem. As in the use of radar offshore, the key is netting with a very high data rate (and with sufficiently powerful onboard computers to process that data). It is probably necessary to have some sort of airborne radar to deal with the problem of cruise missiles and aircraft flying overland before attacking; the U.S. Navy will probably ultimately adopt an active seeker for a later anti-cruise-missile version of its Standard Missile. An alternative might be an advanced IR seeker, to pick up the airframe heat of the incoming target. Another would be to use the airborne platform to produce the illuminating signal on which the defensive missile homes.

Perhaps the most important point to be made in littoral AAW is that warning time will likely be very short, so that it is impossible to depend entirely on an active defence of any kind (this includes electronic countermeasures); this is the strongest reason to design ships so that they can survive a few missile hits and keep fighting.

For ASUW, the key issues are precision surveillance and the precision delivery of weapons. Surveillance data must be keyed to geographical position (which is not as trivial as it sounds, but which is certainly not impossible). Probably the key to precision weapon delivery is a geographically-keyed missile guidance system, such as one incorporating GPS. Note that the problem is not merely a desire to avoid undue casualties ashore. Weapons capacity, particularly for an all-surface force, is very limited. Wasted weapons cannot easily be replaced. Clearly helicopter-based anti-ship weapons, such as Hellfire or Sea Skua or Penguin, can help, but they, too have to be delivered very precisely. Experience shows that aircrew may find it difficult to distinguish the appropriate targets in a crowded harbour.

ASW offers some interesting possibilities. One is to use submarines as precursors, to prepare the area for the surface force. They may, for example, use unmanned underwater vehicles (UUVs) to explore an area, even to 'ping' so as to provoke enemy reactions. Alternatively, UUVs might be used to plant grids of underwater sensors, say upward-looking sonars (reliable acoustic path devices). Probably the key issue here is the extent to which the submarine can communicate with (I) UUVs and (II) a nearby surface force.

As for (I), there is current interest, at least in the United States, in high-capacity acoustic links. Apparently experimental links are capable of carrying images over a range measured in kilometers (this work has been done at NUWC New London). The key seems to be a computer powerful enough to adjust the link continuously to overcome multi-path effects. On the basis of this work, NUWC is proposing a future type of submarine which would support large UUVs (Mantas), which in turn would search and even attack targets tens of kilometers away. Clearly, the larger the submarine, the more adaptable it is to such enhancements. That might apply to a large diesel-electric submarine with a very powerful computer-based combat direction system.

As for (II), the obvious solution is quick burst communication via a satellite net (not directly between submarine and surface force). Currently that requires a mast antenna. Again, some new technology may be interesting. The

U.S. Navy and DARPA are currently working on a buoyant cable antenna for submarines which can receive and transmit UHF satellite signals.

There is also considerable current interest, at least in the United States, in multi-static ASW for shallow water areas. For example, a shipboard helicopter (or a countermeasures launcher) can deploy an explosive array. Several ships can listen to the explosion and its echoes, using their towed arrays. If all of their data are combined, a map of the area, including submarines, can very quickly be produced. This technique is apparently much more effective than, say, individual searches using a ship and her onboard helicopter (with dipping sonar). It offers longer-range propagation, because the explosive ping includes low-frequency components. As in the case of AAW, much depends on shipboard computer and communications (data link) capacity.

The point of all this is that surface forces will almost inevitably find themselves operating in littoral areas. That may mean seizing control of an area of littoral to support an amphibious operation; or it may mean operating in shallow water for a sustained period (e.g. to escort shipping); or it may mean exposing ships to attack while operating (for presence) in or near a potentially hostile port. In any case, an individual ship's effective sonar range is likely to be quite short, possibly less than a submarine's torpedo range. The submarine may have to use a non-acoustic sensor, such as a periscope, so there may be a considerable payoff in deploying countermeasures such as periscope-detection radars and even lasers. At the least, it will probably be essential to net together the sensor pictures of ships in a group, as the U.S. Navy is now planning to do with advanced versions of its SQQ-89. Note, incidentally, that there is no current effective countermeasure against wake-following torpedoes, which are standard on board 'Kilo' class export submarines. Ships will, therefore, quite possibly be torpedoed; as in the case of AAW, it would be preferable if they could continue to fight after one hit (at the least, the track of the torpedo might be used to localize the submarine for counterattack). In the past, when ASW ships were very numerous, it was assumed that submarines would concentrate on the ships being escorted. Now that escorts are themselves quite expensive, it would seem at least possible that the submarines would follow a roll-back strategy, concentrating initially on the escorts. Hence it can be argued that to be effective ASW escorts need substantial survivability—which can be bought by making them relatively large. This does carry implications for maneuverability and draft, but they seem less important than survivability.

### **Some Economic Considerations**

First, hull steel is relatively inexpensive. At least half the price of a warship goes into combat systems and weapons. It is possible to design and build a ship fitted 'for but not with' some combat system elements, which can be added later. The most prominent case in point is the U.S. SPRUANCE class, which began life essentially as empty boxes with the appropriate machinery and wiring. This choice was made because the U.S. Navy had wanted a pair of new classes, one a missile (AAW) destroyer and one an ASW destroyer. To save money, both were designed for the same hull—hull steel was cheap. Because the AAW mission required far more in the way of electronics and weapons, the hull had to be large; the ASW version, then, seemed empty. In subsequent years that empty space proved extremely useful. In effect, the ships were bought on the installment plan. As a more recent example, the Thai carrier CHAKRI NAREUBET was delivered without most of her electronics, which are still being bought.

Second, manning (which is a real cost, and which is becoming more expensive) need not be proportional to hull size. The current U.S. goal, in DD 21, is a crew of 95 for a 12,000 ton ship. That is to be achieved partly by 'smart ship' initiatives (such as revising damage control organization) and partly by moving functions off the ship (thanks to reliable satellite communication). Improved computers and artificial intelligence are to reduce the numbers needed at sensor controls and in CIC. While many are skeptical about the success of this effort, there is little question that manning can be drastically reduced.

Within electronic systems, the overwhelming fraction of development cost goes to software rather than hardware. That has an interesting potential consequence. Software is very easy to reproduce, albeit difficult to create and test. It would seem to follow that the fraction of development cost borne by any particular ship can fall if enough ships of identical type are built. As a variation on this theme, sufficiently modular software (applicable across a range of programs) offers similar benefits. Celsius has claimed exactly this advantage for the 9LV Mk 3 software used in the ANZAC class.

Among electronic components, high-capability air defence systems are generally the dominant cost. It seems likely that a relatively small (frigate-size) ship equipped with such a system, or even re-equipped with one, will not cost too much less than a ship of twice the displacement equipped with the same system. In the past, warships have often been priced by the ton. It was not that steel was more expensive than it is now, but rather that, given a larger hull,



naval staffs tended to fill it with more equipment. Now there is a solution to this temptation. The larger hull can be filled with vertical launcher cells. Empty, they cost very little. A navy can always opt not to fill them when it first buys the ship. Even if they are filled, that expense is generally easy to distinguish from shipbuilding costs.

Overall, economics demand that warships be very durable, so that small numbers bought per year provide an adequately large force. Durability means combat survivability but it also means amenability to upgrade as technology changes. The likelihood or need that platforms be long-lasting should focus us on their long-term characteristics. An important question, then, is just what limits the effective lifetime of a ship (assuming it is not obsolescence)? Is it the lifetime of the piping? Fatigue in the hull? In a modern ship, is it insufficient capacity in data busses as computer speeds grow? These factors are as much limiters of useful life as are future growth stability margins and hull strength margins.

If ship numbers are very limited, strategic mobility may become even more important than it currently is. Note that in many projections likely enemies are local rather than global, without access to open-ocean surveillance systems. A transiting ship can, therefore, afford to produce a considerable signature as the price of very high speed. In a war (hot or cold) against a major power, surveillance will likely be widespread.

### **Moore's Law**

Probably the two most striking technological facts of the end of this century are Moore's Law and the emergence of satellite technology. Any guess as to the appropriate shape of a fleet for the next century ought to take them into account.

Moore's Law, which has held up remarkably well for the last three decades, predicts that computer capability will roughly double every eighteen months. That is a thousand-fold increase in fifteen years. Ships are becoming more, not less, durable, at least during peacetime. Moore's Law would seem to imply that ship and fleet design concepts should assume that signal-processing capability will improve dramatically during their lifetimes. Imagine, for example, that it takes about a decade to pass from concept to completion of the first ship of a class. Then about five years into the life of the first of class computer capacity ought to be about a thousand times better than it was when

the class was conceived. For example, a surface ship might be designed with low radar cross section. Clearly radar reflection cannot be eliminated altogether, at least in a ship with serious capability, but it can be reduced drastically. One important counter to such design practice would be improved signal processing. Moore's Law would seem to suggest that signal processing will defeat most stealthy techniques early, rather than late, in a ship's career. There are, to be sure, exceptions. It is unlikely that commercial radars will be provided with the best signal processors. Ships intended to deal with, say, smugglers will probably find that their stealth features retain more of their value for longer.

The problem is that stealthiness built into the structure of a ship cannot easily be improved, at least drastically, over time. The basic shape of the hull cannot be altered. Radar absorbing material can, it is true, be wrapped around that shape, but its characteristics would not seem to change drastically over time. At the same time, Moore's Law implies that the signal processors built into sensors can relatively easily be replaced, since the point of the law is that processors of the same size and cost become enormously more powerful.

It is also probably still quite profitable to invest in stealthy sensors. Like the sensors which attempt to detect a stealthy ship, they can probably be upgraded to match improved detection technology.

Perhaps a better way to think of Moore's Law is as a demand that the procurement cycle be split into two. One, the part dealing with buying large platforms and heavy equipment, cannot really be accelerated. For it, the implication of Moore's Law seems to be that whatever is bought ought not to be affected very drastically by improvements in command/control or in signal processing. The procurement of electronics, on the other hand, ought to be greatly accelerated, and a very short operating and life cycle ought to be accepted, even welcomed. That is roughly what the civilian world already does. Many large businesses buy (or even lease) computers on a two or three year cycle. Even individuals find themselves replacing their computers every few years.

For a ship, the hull and machinery are clearly long-term items. Weaponry might seem to fall between long- and short-term. The U.S. experience seems to show that weapons, such as the Standard and Tomahawk missiles, can be upgraded to embody improvements in electronics and in the command/control systems which direct the missiles.

This is, presumably, the place to advocate ‘open architecture’ of all sorts. In a major surface unit, that means a bussed command system, the elements of which are relatively easy to replace. Within the electronics, it means at the least thinking through upgrade paths. Upgrade lifetime is likely to be short.

All this having been said, the question remains whether Moore’s Law will really continue to hold. Many market analysts now say that the personal computer market, which may drive the profitability of the electronic chip makers, is close to saturation, at least in the United States. Many computer owners are finding that they really do not need new machines to run the existing applications, and new applications which demand much more powerful chips seem not to be emerging. At the same time, the cost of a plant to fabricate markedly more powerful chips is rising rapidly, because more power generally means new technologies to make smaller elements.

For much of its life, Moore’s Law was driven (economically) by the needs of the Cold War military and by major corporations. Then the focus shifted, it seems, to personal or desktop computers—many of which were used by business. This is the market which now seems to be at the point of saturation, with unit prices falling so quickly that profitability is being squeezed out. It is not so clear where the economic impetus for more powerful computers is now arising. It may be that business buyers still demand so much computer power that high-end chip-makers can easily survive, and can easily invest in more hardware.

Even if computer hardware development stalls, it seems likely that effective computer power will continue to grow for some time. The rapid growth of hardware power has made it possible for software developers to write quite inefficiently, always confident that growing computing power would solve their problems. There is even the cynical view that software is often written inefficiently in the deliberate hope of forcing consumers to buy ever more powerful computers. Either view suggests that current hardware is generally inefficiently used. If there should be a slack period in hardware development, economic effort could easily shift to software, and much tighter codes might appear.

### **The Impact of Space Systems**

Then there is the impact, or the potential impact, of space systems. For the U.S. Navy, the rise of space systems transformed surface combatants, from

auxiliaries to carriers into capital ships. That is, surface ships fell from their dominant positions not because their weapons were outclassed in striking power, but because they lacked reach. Capital ships were always defined as those ships which, generally, could be sunk only by their own kind. Although that has not been strictly true for many years (a submarine could generally sink a battleship), it was still meaningful at the outbreak of World War II. At that time, carrier aircraft generally could not expect to sink battleships, and the carrier's reconnaissance reach was not such as to guarantee it against being surprised by a fast battleship running in during darkness. By 1945, this was no longer a serious proposition, on either count. As long as the reach of a surface warship did not go much beyond the horizon, it remained true.

The advent of missiles did not in itself change matters, because reach is determined by sensing range. The range of missiles such as Harpoon and Exocet is determined by the range of a ship's ESM. Under some (ducting) conditions, radar can reach well beyond the horizon, but that is hardly a universal capability. Similarly, a surface warship's horizon can be extended by her embarked helicopter(s) or UAV(s), but given limited fuel and maintenance capacities, they cannot fly continuously. They are almost certainly used on a cued basis, which again means that the ship's sensors impose the main limit on her reach.<sup>1</sup>

During the Cold War, first the Soviets and then the U.S. Navy found a need to provide deployed units with targeting-quality data beyond their horizons. That could be done only by deploying external sensors with very long reach, and relaying their information to the likely shooters. Because the sensors were not always in position, they could not provide a ship with real-time warning of, say, air attack. They could provide very early warning (in the U.S. Outer Air Battle concept), and they could provide the basis for a ship to fire long-range missiles. These systems provided the desired degree of reach. They were hardly inexpensive, and it would be well beyond the resources of a medium navy to build its own equivalents. However, the ideas involved

---

<sup>1</sup> In the past, the longest-range shipboard sensor was HF/DF. HF ground waves can reach as far as 180 nm from a ship. Given the rise of satellite systems in place of HF radio, it seems unlikely that HF will continue to be very useful for this purpose. L-band signals, e.g. from an SPS-49 radar, are generally subject to tropospheric scatter, so they can be detected at a like range, say about 200 to 250 nm (longer with high-gain antennas at both ends). Under non-ducting conditions microwave signals can be detected at the radar horizon, with is  $4/3$  the visual horizon. Apparently some degree of ducting is common, which is why microwave ESM sets are generally associated with anti-ship missiles. Effective range seems to be 40 to 60 nm.

deserve examination and, possibly, adaptation. They are usually described as techniques for Over-the-Horizon Targeting (OTH-T), which should probably be distinguished from OTH surveillance. The main difference is that surveillance is continuous and provides real-time warning, whereas targeting can be contingent, and need not pick up suddenly-arising threats.

The initial Soviet system used reconnaissance aircraft cued by HF/DF stations ashore. The aircraft, mainly Bear-Ds, linked their OTH radar pictures down to surface combatants and submarines which had been moved into place on the basis of the original HF/DF (and other intelligence) data. System connectivity requirements were limited, in that the ship merely had to be ordered into position, while the air crew could be briefed at take-off. The bomber had sufficient search capacity to make up for any error in target position prediction. The only high-capacity link involved was that which provided aircraft radar data to the ship. The entire system focussed on a particular target, and it might be characterized in modern terms as HITS (high-interest target system).

The initial Soviet system was flawed in that the mere appearance of the radar-equipped bomber warned the target that it was about to be hit.<sup>2</sup> If the target fleet had sufficient anti-aircraft capability, it might even be able to destroy the bomber. There was also a significant time lag between reception of the bomber's target data and the missile attack itself. As a missile flew out towards the target, it sent radar video back to the launching ship or submarine. Guidance commands were sent on the basis of the video. Apparently the launch platform could not (or typically did not) receive both radar bomber video and missile video simultaneously (destruction of the bomber therefore could not upset an attack in progress). Thus there had to be some prediction of target motion to compensate for the time lag, which was likely to be measured in hours. Presumably a target could escape attack by executing a radical maneuver as soon as the radar bomber left, or as soon as it had been successfully jammed.

This system was displaced by a fully space-borne one, in which targets were detected by passive satellites (EORSATs). They were identified by radar type; it is not clear to what extent, if any, the Soviets went the further step to radar fingerprinting. Active radar satellites (RORSATs) developed track information on which targeting could be based. As in the earlier system, a central command authority cued the prospective shooter (surface or submarine) into position to receive satellite data and then to attack. The satellite was separately cued to dump data at a specified time and place. Apparently there

---

<sup>2</sup> The word in the U.S. fleet was 'Bears in the morning, missiles in the afternoon.'

was no capability for the shooter to query a passing satellite. Because the satellites were all quite distinctive, their orbits were plotted, and the resulting ephemeris widely distributed within the U.S. Navy. It was, therefore, possible to turn off electronics when EORSATs flew overhead, or to maneuver to reduce the cross-section presented to RORSATs.

Like its predecessor, the satellite-borne system depended on emissions by the target. In this case, however, the emissions were not by long-range HF radio, but rather were the continuous radar emissions which the target could be expected to produce. It entered service just as the U.S. Navy was largely abandoning HF radio in favor of satellite communication, which seemed to offer much better covertness (there is no evidence, however, that the Soviet system was conceived with this shift in mind). One more obvious advantage of the new Soviet system was that it offered global coverage, whereas the accuracy of HF/DF cuts declined as the targets were further from the DF stations (and the radar bombers needed fixed bases).

To the extent that the system as a whole extended a horizon, the horizon in question was that at the fleet command centre which planned attacks on high-value units. Countermeasures against the Soviet system were intended to reduce the confidence the headquarters could enjoy.

The U.S. approach was rather different. The basis of the tactical space-based systems the U.S. Navy placed in service beginning in the early 1970s was the fleet's concern with the threat of Soviet anti-ship missiles, the surface platforms for which might spend most of their time beyond the horizon of the fleet's own sensors (including its radar aircraft). The problem first became acute when the Soviets deployed a substantial fleet to the Mediterranean in 1967. The problem was described as OTH-T, over-the-horizon targeting: the fleet needed some way of knowing where the Soviets were, beyond its own horizon, so that the Soviet ships could be attacked pre-emptively.

The U.S. Navy built special intelligence data fusion centres called Fleet Ocean Surveillance Information Facilities (and Centres), FOSIFs and FOSICs. Like the wartime Admiralty's OIC, they built up a picture of Soviet naval behavior from whatever sources were available, including regular overflights of the Mediterranean by electronic intelligence aircraft. Situation reports were regularly transmitted to the fleet, updated whenever important information came to hand. Although the techniques were vastly more sophisticated than they had been during the two World Wars, the basic concept was the same.

There was, however, an interesting twist. In the two World Wars, the enemy's fleet was often the primary target. During the Cold War, the carriers in the Mediterranean were primarily a means of attacking targets ashore. Dealing with enemy warships was a distraction, better left to other weapons. By the end of the 1960s Soviet nuclear submarines were a major threat to U.S. carriers, and a new class of U.S. nuclear submarines (LOS ANGELES) had been designed specifically to escort them. Given the new surface attack threat, the submariners naturally offered a counter. The escorting submarine could fire a new long-range cruise missile at the Soviet ships. The missile envisaged would have been supersonic, and the submariners proposed a huge new craft to carry it in numbers.

Now came the rub. A submarine had a very limited sensor horizon. It had no radar search aircraft with which to refine approximate data from classical intelligence sources. Yet, given the very limited number of carriers and the limited number of aircraft they could operate, it would clearly pay to unload the long-range anti-ship mission onto the submarine.

The solution was to handle intelligence data much more like sensor data, and to try to locate targets so precisely that the missile would likely find them as it approached the indicated areas. That data, moreover, would have to be transmitted at very high speed, since the submarine likely would not expose an antenna for very long. The submariners called the information system they envisaged SSIXS, the Submarine Information Exchange System.

That left the question of just how the offending Soviet ships were to be located. Only space-based sensors could cover the whole earth. The choices were active and passive radar (i.e. ESM). Active radar had the advantage of being able to pick up non-cooperating targets, but on the other hand most ships in the world were non-targets. An active system covering the world would soon be swamped with data. A passive system could, at least in theory, identify ships—if they kept some sort of emitter running.

As it happened, the U.S. government already used satellites to map out the Soviet air defence radars which American bombers were likely to face. Indeed, the first satellite for this purpose, GRAB, had been built by the Naval Research Laboratory. Thus, the natural choice for the primary ship-locating sensor was a space-borne radar detector. On the earth, such a detector cannot locate a ship; it can only deduce a line of bearing to the emitter, because it cannot measure target range. However, the line of bearing from space extends

down through the surface of the earth, and the location of the surface absolutely determines how far from the satellite the ship is. The sensing satellite was White Cloud. It picked up the top lobes of standard Soviet radars, some of which were unlikely to be turned off.

Had the anti-ship missile been fast enough, a single target location might have been enough. That is, the target could not have moved very far while the missile was in flight. Data even a few minutes late might have sufficed. However, the Chief of Naval Operations, Admiral Elmo Zumwalt, rejected the huge submarine proposed to carry the supersonic anti-ship missile. By extension, that killed the missile—but not the role for which it was conceived. Instead, Zumwalt ordered the development of an anti-ship version of the new strategic cruise missile, which became Tomahawk. It could fit the torpedo tubes of existing submarines.

It was also subsonic. It would take perhaps half an hour to reach a ship target. If all the missile had was the ship's position at launch time, it would spend a considerable time simply searching for the target—and most likely being shot down as it passed by. The solution was to estimate the path the ship would take, based on past positions obtained both by satellites and by other sensors, and on knowledge of the ship's capabilities. As long as the ship's commander was unaware that his ship was under surveillance, he was unlikely to take evasive action. The passive system envisaged would certainly not reveal just what it was watching at any given time.

The great problem, then, was to know which ship the satellite picked up at any one time. After all, the Soviets operated dozens of ships equipped with its major radars. Each fleet operated many sister ships. If the system picked up one ship, then mistakenly identified a ship detected later as the same ship, the line drawn between the two positions (to measure ship course and speed) would be altogether misleading.

The solution was radar fingerprinting. A radar, particularly a nearly hand-made major naval radar, imposes inadvertent variations on each pulse it puts out, just as a gun imposes identifying marks on the bullet it fires. Given a major effort to measure those identifying characteristics for each important Soviet ship, the U.S. system could produce the tracking data it needed. To do that, it had to enter the track data into a very powerful computer, because it had to track virtually all Soviet warships continuously. Once all were being tracked, a commander ashore could decide which data to flash to the submarine which would fire the Tomahawk.



The same system solved the carrier commanders' warning problem. A computer on board a carrier could assemble the data streaming out of a FOSIC, such as that at Rota, Spain, into a picture of what was happening beyond the ship's horizon.

By 1974 the U.S. Navy was building these components into a system. Data from various sensors, including White Cloud, would flow into intelligence centres inside Fleet Command Centres (FCCs) ashore, just as the World War II OIC had operated within the Admiralty. The carriers would all eventually have their own picture-keeping computers, called TFCCs (Tactical Flag Command Centres). They corresponded to the wide-area plots aboard flagships, the main difference being the sheer quantity of data involved. The FCCs would also feed Submarine Operating Authorities, which would send data via a new SSIXS.

The ships receiving the satellite picture had to correlate the time-late information from the fusion centre (the FCC) with their own sensor data. Correlation required special computers with special software.

To handle the sheer mass of data involved, the FCC would be connected to the TFCC via a satellite link. Just as these ideas were maturing, the Royal Navy was giving up its large-deck carrier force. With the carriers it lost not only its ability to strike at ships at a distance, but also the radar early warning aircraft which could detect ships at ranges up to about 200 miles. The Royal Navy thus found the new U.S. concept, that a fleet's horizon could be extended by using off-board sensors and a sensor fusion centre, very attractive. The British equivalent to the U.S. FCC was the centre at Northwood; the system was OPCON. By the mid-1970s the British had their own satellite communications link. Later the French developed a somewhat similar system, SYSCOM.

In the British case, there was no long-range missile, but instead there was the Sea Harrier. Although the Sea Harrier could, in theory, search for targets, in fact any such search would have made it very vulnerable—just as a searching Tomahawk would have been vulnerable. From an anti-ship perspective, then, the Sea Harrier was nearly a manned Tomahawk, and it needed the same sort of supporting data. There were, of course important differences. For example, a Sea Harrier could be sent out on the basis of very incomplete data, since it could return to its carrier if it found nothing. Once launched, a Tomahawk could not be retrieved.

Perhaps the most striking feature of these developments was the merger of intelligence collection systems and operational sensors. That actually was not new; the OIC of World War II was, in effect, very nearly an operational sensing system. Perhaps the key difference was in the precision the global sensing/intelligence systems of the 1970s and beyond, which made it possible for them to target long-range missiles.

Clearly these satellite sensing systems were limited. The satellites involved pass only periodically over any given patch of ocean. It would take a considerable number of satellites to provide continuous coverage. The value of satellite coverage, then, depends on how quickly that which is observed changes. Ships move relatively slowly, so satellites make effective observers. It costs a great deal more to devise a satellite system suitable for tracking aircraft. Note, incidentally, that periodic satellite observation of aircraft is probably most useful if the aircraft fly a long distance, since in that case there is the best chance that they will be detected more than once during flight (hence, that course and speed can be measured). Thus, a satellite system capable of seeing aircraft is probably most effective against very long-range bombers and least effective against short-range fighters—or missiles.

The U.S. ship-tracking system demonstrated its value during the Gulf War blockade of Iraq. Ships assigned to the embargo were all fitted with a U.S. computer system called JOTS (the Joint Operational Tactical System), which functioned as a kind of mini-TFCC. It displayed a tactical picture developed at fusion centres ashore, based on a mixture of data, including that derived from satellites. Without the tactical picture, it would have been impossible for the relatively small number of ships available to have covered the enormous sea area through which merchant ships could pass as they approached the Gulf. JOTS in turn could not have functioned without the combination of space-based surveillance and space-based communications. Its later incarnations, such as NACCIS and JMCIS, equip many NATO warships. The British and the French developed their own information-fusion systems (the British system is closely linked to the U.S. one). These systems were clearly worthwhile even though neither country built a satellite sensing system comparable to that created by the U.S. Navy (which was supplemented by information from other U.S. satellites). Each navy had its own intelligence sources, and at least the British systems were supplemented by information from the U.S. Navy.

Access to data gathered largely by space-based sensors, necessarily transmitted by space-based communications systems, transformed the U.S. surface fleet. Prior to the advent of Tomahawk and the space sensors, U.S. surface warships, like their counterparts in other navies, were escorts. The fleet's long-range punch resided entirely in its carriers and in its strategic submarines. Now surface ships had the offensive reach of carriers, albeit nothing like the same weight of fire. That was a revolutionary development. The space systems did not, of course, make surface ships into carrier surrogates. For example, they did not provide the sort of real-time air warning needed for successful fleet air defence against low-flying threats.

Both the U.S. and the Soviet systems required specialized satellites. However, satellites of various types are now proliferating. It is reasonable to ask whether within a few years some country will be able to assemble an open-ocean surveillance system of its own. This seems unlikely. The twin keys to both the U.S. and the Soviet systems were electronic reconnaissance satellites, with their very wide search swaths, and elaborate naval intelligence systems. Certainly there are now radar satellites capable of detecting and even of recognizing ships at sea, but they have very narrow search swaths and thus are unlikely to detect a given ship at any time in the open ocean. They are not at all equivalent to the Cold War RORSATs.

There is an important point to be made, however. Commercial imaging satellites are already in service. Although there must be some question as to how complete and timely their coverage is, certainly they offer those without national reconnaissance systems an unprecedented degree of access to images of other countries. It is at least plausible that such imagery can routinely detect preparations for land attacks, simply because such operations are so massive, and because they take so long to set up (the question is whether anyone would necessarily know where to look). In that case conventional ground operations may lose any element of surprise. Sea-basing is likely to be a very different proposition, simply because ships move and hence are unlikely to be detected by narrow-swath imaging satellites. Amphibious operations may thus gain an important advantage in an age of increasing satellite-based transparency.

## Conclusions

What is a medium-size navy to do, then? It will probably rely mainly or completely on surface combatants. To make them truly effective it needs to connect them to some kind of wide-area sensing system. Its sensors need not be space-based; there will probably be alternatives effective in the navy's home area of operations. The most important tactical implication of carrier-less operation will be the lack of airborne early warning (land-based aircraft probably cannot operate continuously over ships well out to sea).<sup>3</sup> It will be essential, then, for the ships to have some sort of highly capable quick-reaction air defence system, simply to overcome possible attacks. Even given such a system, it will have to be accepted that ships will suffer some hits. Passive survivability will be extremely important, even more so than in a fleet enjoying organic air protection (in which case ships still need considerable survivability).

The ships' real value will be offensive, using ship-launched missiles to gain the necessary range. Operating those missiles will require satellite links to provide targeting data. The efficacy of the ships as power projectors will depend on the number of weapons they can accommodate. Note that offensive operation includes covering amphibious ships as they move towards an objective area and as they land troops; and also providing those troops with covering fire, probably well inland. Covering fire may well have to include dealing with enemy armored counter-attacks, using missiles or long-range guns. That in turn requires the ships to be able to detect movements well beyond the horizon. Ships' helicopters, properly equipped, ought to be able to accomplish this task. Note that the demand that the helicopter do much more than the usual anti-ship/ASW role probably implies a considerably larger helicopter and that in turn forces up the size of the ship operating it. The British will probably demand this sort of capability in the follow-on AEW radar to replace their current type.

The power projection role naturally brings up important command/control issues. A medium-size navy is probably associated with a medium-size army, or at the least with medium-capacity amphibious lift. It

---

<sup>3</sup> During the 1950s and 1960s, the U.S. Navy operated large land-based early warning aircraft over its deployed fleets, but they supplemented carrier-based EW aircraft. It appears that by the mid-1950s at the earliest, the land-based aircraft were used mainly either for electronic reconnaissance or to extend the U.S. continental air defence system. In either case, they did not contribute to the fleet's early warning needs, because they could not spend enough time over a distant naval formation. Note that these aircraft (EC-121s) had considerably longer endurance than modern jets.

would therefore seem essential that whatever ground forces are lifted are as efficient as possible, with minimum overhead. For example, a headquarters ashore requires substantial protection. This is much the same situation as with artillery. The more that can be kept afloat, in a relatively safe area offshore, the fewer valuable troops who need be wasted protecting a rear area. Because a medium-size navy can afford only a relatively small number of major warships, they must inevitably perform multiple tasks—one of which is likely to be to accommodate some headquarters functions during a power-projection operation, at least for a time. This role would seem to demand substantial volume on board the surface combatants, as well as computer capacity and communications capacity. There may also be an important role for helicopters or UAVs as ‘poor man’s satellite’ links for over-the-horizon use of standard line-of-sight tactical radios.

The requirement for substantial armament, probably in vertical launchers, dictates substantial unit size, probably 8000 to 12000 tons. The same size offers serious anti-aircraft defence (while carrying a powerful surface missile armament), as well as good survivability and good seakeeping. Size also offers volume for command/control functions.

Given a good enough anti-aircraft system, the ships envisaged can also cover other ships in a typical power projection or sea control mission. For example, the troop transports used for power projection are unlikely to have much in the way of organic air defences. Because the anti-air element of the ship’s electronic system will probably be by far the most expensive part, the ship’s cost will be little affected by her overall size and by the number of cruise missile launchers aboard. There is some experience to back this up. The European ‘Horizon’ frigate, which has no cruise missile capability, would have cost somewhat more than the roughly equivalent U.S. BURKE, which can carry cruise missiles in her rather larger vertical cells. There is another way to look at this. One might calculate the cost per missile, or the cost per launcher cell. The fixed cost of the electronics, most of it for air defence, is spread over those cells. The fewer cells, the higher the fixed cost, because the ship wrapped around the cells does not become too much more expensive as the number grows. Cutting the number of launch cells is not good economics.<sup>4</sup>

---

<sup>4</sup> This may seem to violate common sense. The reality is illustrated by some recent history. In 1958 the U.S. Navy faced a destroyer crisis: all of its World War II-built destroyers were running out of hull lifetime. The new ADAMS class guided missile destroyers seemed very expensive (at about \$40 million each). Surely something much cheaper could be had. The proposed solution was to cut missile numbers, from 40 to 12, using the existing missile system (i.e., the existing electronics). The operational officers who proposed this solution were shocked to discover that it

In accord with current practice, the ship needs a helicopter and hangar; again, larger size offers better seakeeping and hence the ability to operate the helicopter a larger fraction of the time. Quite aside from its use in ASW, the helicopter is valuable for dealing with light surface craft. Experience in the Gulf suggests that a helicopter is essential in any embargo, as ships' boats often cannot operate in seas in which merchant ships easily steam past smaller warships. As noted above, if the main purpose of the fleet is often power projection, the helicopter becomes an essential element of power projection capability. For the future it may be possible to use UAVs instead, but one would have to suspect that the manned helicopter's inherent flexibility will continue to be valued.

One interesting question remains. Is there any point in buying smaller ships, say, of frigate displacement? They may not be much cheaper to run (wavemaking resistance falls with length, so the larger ship may not require much more power for cruising speed), they may not have significantly smaller crews, and they may actually be noisier (and worse sonar platforms). They may require less manpower, but creative approaches to ship operation and maintenance (as in DD 21) may well shrink that advantage dramatically. Their main advantage may be political: those buying the ships may imagine they are a better deal. They will be wrong. The larger ships are likely to be far more capable, not too much more expensive to run, and much easier both to fit out and to modernize. As evidence for this proposition, note that the U.S. Navy does not plan to replace its current frigate force when the ships are retired; instead, it is moving towards a homogenous force of large surface combatants such as the proposed DD 21. That has been the consistent conclusion of several studies conducted from 1989 on.

The conclusion is that, absent aircraft carriers, the next best platform for the primary naval missions—for strike and for power projection—is a large surface combatant with substantial inherent capability, which can take care of itself and also of other ships under its protection. This is not a plea for

---

saved almost no money at all. Worse, their casual attempts at improvement (better range and a better sonar ) caused the proposed ship to grow dramatically, to the point where it was as large as the then missile frigate (1950s U.S. terminology—later redesignated a missile cruiser). In the end, it cost little more to adopt a much more capable missile system (Terrier vice Tartar, which later equated to Standard ER vice MR). The replacement cheap mass production *destroyer* was built as the BELKNAP class missile *cruiser*.

particular ships (e.g. DD 21) or weapons (such as Tomahawk or a future gun system).

That is not to say that a fleet should be restricted to large surface combatants. Other types of ships obviously have valuable contributions to make. For example, in a strike situation submarines can provide invaluable intelligence and warning information, thanks to their stealth. They may also be very valuable for their ability to attack with limited numbers of land-attack missiles from unexpected directions. However, they have important inherent limitations. They lack internal volume and weapons capacity, and they cannot be replenished at sea for sustained operations. They also lack continuous connectivity.

There is also a role for patrol craft. They are far less expensive, both to buy and to operate, than frigates or larger surface combatants. It is important to understand why. It is not that they are so small, but rather that they carry so little in the way of weaponry and command/control. Ship steel is cheap; it might well be argued that under many circumstances it would not be too much more expensive to build a larger patrol vessel with much the same armament and equipment on board. Such a vessel might be a much better sea-keeper, and that might make a substantial difference to her crew's efficiency. It is certainly possible to envisage a fleet of patrol craft large enough so that they would be worth converting to frigates in an emergency. That was, after all, an important theme in the recent proposal for the Malaysian-Australian OPV.

In the end, though, medium means limited resources, which have to be spent carefully. Navies are valuable because they offer flexibility, and flexibility generally requires large hulls. Those hulls need not be bought fully-equipped, because if they are large enough they can accommodate what may be needed later on. However, the smaller the hull, the more difficult it will be to shoehorn in sophisticated capabilities, and the less such improvements will buy in terms of numbers of weapons on target—not to mention operating lifetime and survivability.

## **APPENDIX: THREAT PROJECTIONS**

### **Anti-ship missiles**

The great question is whether available technology is exploited. Current missiles are extremely simple. Their seekers generally lock on to the centroid of the ship's radar cross section (so RAM can be applied to shift the centre of attack away from the ship's vitals). They inevitably hit above the waterline, where their effect is limited. They are also vulnerable to ECM, because they generally telegraph their lock-on; they do not appear to continue to search, and (except for Exocet Block II) they do not follow a very evasive path to the target. Surely designers can do much better; but will they? Or will the main development of the next few decades be a competition between advocates of supersonic missiles and those who continue to prefer relatively stealthier subsonic ones?

If we assume that future threats are generally wielded by smaller countries, then the missiles may be sophisticated, but they will not appear in great numbers. Anti-saturation systems are not as important as quick-reaction ones. A return to dealing with a great-power threat would change matters.

Except for very simple ECM techniques, most countermeasures require a considerable knowledge of the missile seeker. The single most likely development is software control of all seeker functions, which means very easy modification. There are already radars which are fully software controlled. In the case of a missile, control would include both the waveform and the missile's tactics (as in Exocet II). Almost certainly current array technology will extend to missiles, allowing them to scan randomly for targets and to simulate search while actually locked on (a technique already available in cruder analog form to some missiles).

One would have to conclude that the choice will be either to destroy the missile in flight or to accept that at least some missiles will hit, and to design ships to survive such hits and to continue to fight. Hard kill may become more difficult if next-generation missiles are designed to dive under ships (for maximum exploitation of available warhead weight). No such weapons currently exist. As a consequence, close-in defences are practicable, since the missile must fly the last few thousand meters of its trajectory through the air. A diver might enter the water at about the outer range of close-in weapons, so that the ship's defensive system might register a successful defence as the weapon neared the point of explosion.



From a tactician's point of view an underwater-attack weapon would actually be superior to current types, simply because its effects can much more easily be observed: the ship, once hit, breaks in half and sinks. By way of contrast, a current missile might well hit a well-designed ship and explode, without destroying it or disabling it. The choice of above-water attack was motivated entirely by its technical simplicity—which was really important when the main current missiles were conceived in the 1960s. One might be surprised that so little progress has been achieved in the thirty years since then, or one might conclude that anti-ship missiles enjoy a very low priority with their apparently indiscriminating buyers. The latter seems far more reasonable. As evidence, note the poor commercial success rate of most anti-ship missile projects.

### **Underwater weapons (mines and torpedoes)**

These weapons probably will not change very much over time; they are already a serious enough problem, and they seem to exploit the available computing power to an extent far beyond that in missiles. One likely development would be better discrimination against decoys of all types. Current soft-kill anti-torpedo systems will probably have to give way to hard-kill systems (which present very serious technical challenges). Even now it seems arguable that wake-followers, which are not new, are impossible to decoy effectively.

The great developmental question in this area is whether underwater rockets based on the Russian Shkval will appear. Shkval itself, the 200-knot torpedo weapon, is unusable because it is unguided, and it has a nuclear warhead. However, for some time the Russians have been advertising a homing version, which runs out at very high speed, then slows to search. Apparently a test version exists.

Another development would be increased deployment of rising mines, which are particularly difficult to detect and to evade, and which can have very wide lethal areas. These weapons are now being promoted actively by both China and Russia. They vary from simple unguided rockets to guided weapons faster than conventional torpedoes.

### **Unconventional attacks**

There are two categories. One is conventional in delivery but unconventional in operation: anti-material attacks (such as graphite fibers, to

short out electrical plants) and chemical/biological weapons. Many Third World countries currently have chemical or biological attack programs. However, none is likely to make such an attack against a ship in close proximity, on a presence mission. Attacks will much more likely be made against ships at sea or in hostile bases (using unconventional attack techniques), and ROE will therefore probably allow counterattacks against the vehicles carrying the weapons.

The other category is unconventional delivery of essentially conventional weapons, such as limpet mines delivered by divers. Such attacks are difficult to avoid, particularly if a ship is on a presence mission in a foreign port. Perhaps the best that can be said is that the less detectable the attacker, the smaller the explosive charge he can deliver.