environment, ships must be able to defend themselves against both. Only if it can survive against enemy attack can a warship continue its offensive functions of engaging enemy warships and shore installations.

A steady increase in military aircraft performance over the years has demanded a parallel increase in the capabilities of AAW systems. This led to the introduction in the 1950s of complex, expensive AAW missile systems for surface warships. As the performance of potential targets have grown, the performance demands on modern AAW systems have become very high indeed. For the past decade, naval surface AAW development has been driven primarily by the Soviet cruise missile threat.

Cruise missiles are difficult AAW targets. They fly very fast (as much as several times the speed of sound) and approach their target in ways that are intended to maximize the difficulty of countering them with AAW. For example, "sea-skimmer" versions fly just over the water and cannot be detected by shipboard radars until they are less than two minutes from impact. Cruise missiles may also be programmed to approach at a very high altitude and dive steeply at their target. There are many variations between those extremes. The defense problem is compounded in a coordinated attack by several missiles arriving at their target simultaneously. Since the relatively large size of Soviet cruise missiles limits the number that can be carried by a single ship, submarine, or airplane, a high-saturation attack requires a large aggregation of forces such as might be organized most readily in waters near to Soviet operating bases.

The development of U.S. naval AAW systems in the past decade has proceeded in two general areas in response to the growing cruise missile threat: point defense systems and area systems. The relatively short-range point defense AAW systems are intended to defeat missiles or aircraft approaching the ship on which the system is mounted. Systems of this kind include the NATO Seasparrow and the Phalanx Close-In Weapon System (CIWS) now being deployed in the U.S. fleet. Area systems, on the other hand, are longer-range systems that can extend protection to other ships in the vicinity as well as to the missile ship itself. Included in this category are the older Terrier and Tartar systems, the MK92 system on FFG-7 frigates, and the AEGIS system planned for deployment on the new CG-47-class cruisers. With Seasparrow and Phalanx now being deployed and in production, improvements in area systems currently have priority in AAW system development.

Area AAW improvements include backfit programs (such as the DDG Upgrade and New Threat Upgrade programs mentioned in Chapter II) as well as development of the AEGIS system. AEGIS is by far the most powerful, and most expensive, AAW system ever developed for shipboard use. The system is built around a large phased-array radar system 14/ that can automatically track many targets simultaneously. Using the new, longer-range Standard (SM-2) missile, AEGIS can engage targets at longer range than is possible with the presently deployed Standard (SM-1) missile. Perhaps the biggest improvement in performance offered by AEGIS, however, is in firepower. The automatic multiple-target-tracking capability of its AN/SPY-1 radar, together with other features of the system, will permit AEGIS to deal with a much greater number of AAW targets than was possible with earlier systems. AEGIS is, therefore, particularly well equipped to counter the sort of coordinated cruise missile saturation attack discussed above. Its capabilities do not come cheaply, however. The CG-47-class ships will cost $1.02 billion each. AEGIS is another substantial step in the continuing upgrade of threat and response in AAW.

Modern AAW Missile Systems: Products of an Evolutionary Development

In order to understand the current state of the art in AAW systems as well as future development alternatives, it may be useful to review a little of the technical background of these systems. Surface AAW missile systems have undergone a substantial technical evolution over the past 25 years. The early systems, such as Terrier, were beam-rider missiles that simply "rode out" a beam of electromagnetic energy until they intercepted their target. The major disadvantage of these systems was that the guidance beam tended to diverge and weaken with increasing range, whereas precisely the opposite effect was needed as the missile approached its target. To overcome this problem, semi-active guidance was developed in the late 1950s. In the newer semi-active guidance systems, such as the MK92 system currently used

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14/ A phased-array radar is one in which the antenna faces are physically fixed, rather than being mechanically rotated, and the radar is scanned electronically in azimuth and elevation by sequential phasing of the many elements in its antenna system.

on FFG-7-class frigates, the target is "illuminated" by an electromagnetic beam from the ship's fire control radar, and the missile homes on the energy reflected from the target rather than simply riding out a diverging guidance beam from the ship.

A drawback of this system is its tendency to become saturated during high-density attacks, since an illuminating radar must be devoted exclusively to a single target until that target has been destroyed. One way to overcome this difficulty is to use intermittent semi-active illumination in combination with a "track-while-scan" (TWS) weapon control system (WCS). Another technique uses a WCS-to-missile command link to provide the missile with midcourse guidance commands. With these two midcourse guidance techniques, guidance is not continuous, and several targets may be tracked and illuminated by the same radar. Only in the final phase of interception is continuous, precise guidance necessary. This represents, however, a significant jump in technological sophistication, involving the use of high-speed computers.

The AEGIS system incorporates the features of the latter type described above, using TWS and command midcourse guidance. As configured for the CG-47-class ships, the system will have four illuminators, and therefore will be able to engage at least four targets simultaneously. Since the SM-2 missile requires continuous illumination only during the final phase of its flight, the AEGIS system, with its automatic tracking capability, will be able to control more than four missiles simultaneously for long-range engagements.

New Technologies for AAW Missile Systems: More Firepower for Tomorrow's Warships

Newly emerging technology may provide still further improvements in firepower. New technologies of particular promise are interrupted continuous-wave illumination (ICW) and agile beam fire control radars. 15/

15/ Several concepts for advanced fire control radars could provide the basic capabilities discussed here. These include such specific types as the Flexible Adaptive Radar (FLEXAR) and the Terminal Engagement Radar (TER). As used in this report, "Agile Beam Fire Control Radar" is a generic term encompassing a variety of such specific types.

ICW. This technique permits a single fire control radar to control two or more missiles simultaneously in the final phase of their flight. Engineers now believe it may not be necessary for semi-active AAW missiles to receive continuous terminal illumination. Just as a motion picture is composed of a series of discrete still pictures, a series of discrete illumination pulses could be rapidly switched among multiple targets, providing the necessary homing energy to guide several AAW missiles to their individual targets. If, in fact, interception can be achieved with illumination for less than 50 percent of the time during terminal guidance, then two targets might be engaged simultaneously with a single fire control radar. If that requirement could be reduced still further to less than 25 percent, then four targets could be engaged, etc., thus multiplying firepower. The more advanced techniques in this area, which could provide very high firepower, are sometimes called pulsed continuous wave (PCW) illumination.

Agile Beam Fire Control Radar. An agile beam radar could provide the multiple-target track and illumination capability that would be needed with ICW missiles discussed above. 16/ This concept would apply modern electronic scan (versus older mechanical scan) technology to AAW fire control radars. The fire control radars that are now used as illuminators with missile systems, including AEGIS, employ a large mechanical antenna to generate a simple "pencil beam" of electromagnetic energy that illuminates a single target. The large antenna that forms this narrow beam must be precisely stabilized to compensate for both the ship's and the target's motion. Because of its large inertia, the mechanical antenna cannot be used as an ICW multiple-target illuminator.

16/ This could be accomplished either by moving a single beam among multiple targets or by splitting the radar energy into several beams as range decreases. At maximum range, a fire control radar would need maximum power and aperture (a function of antenna size) applied to a single beam of energy to obtain maximum missile performance. At 70 percent of that range, however, the same performance (signal-to-noise ratio) could be obtained with half the power. An agile beam fire control radar would allow the weapon control system to allocate the energy initially directed at one target to two or more targets as range decreased. The tactical advantage of this capability is the flexibility to trade range for firepower as the battle space decreases.

A long-standing problem in (non-AEGIS) AAW missile systems has been difficulty in "handing off" a target from the search radar to the fire control radar. This handoff must be made before the system can engage the target, and it requires the weapon control system to tell the fire control radar precisely where to look to find the target. The handoff problem occurs when the fire control radar does not acquire the target because the search radar's target position information is not accurate enough to get the target in the narrow tracking beam of the fire control, or "illuminating," radar. An agile beam fire control radar could rapidly scan around even a coarsely designated target, and therefore greatly expedite target acquisition and lock-on.

Agile beam technology may well be the next step in improving AAW firepower. Its capabilities become particularly interesting in a jamming environment (or with low-altitude "sea-skimmer" missiles), in which targets may not be detected until the missiles are very close to impact. In such situations, high firepower against short-range targets is vital.

"Front-End" and "Back-End": Two Ways to Upgrade AAW Systems

Agile beam fire control radar technology also impinges upon the issue of whether to emphasize "front-end" or "back-end"--that is, search radar or fire control radar--improvements to AAW systems. AEGIS, to date, has emphasized the search radar end of the system. This approach puts the new-technology emphasis into that part of the system that detects, tracks, and sorts out targets for possible attack.

Another approach, however, would be to put the technology emphasis on the fire control end and develop a system that could quickly lock on and engage targets initially detected by a less sophisticated sensor than the AN/SPY-1. While the approach taken by AEGIS is perhaps the logical one for maximizing effectiveness (since a target cannot be engaged until it has been detected), emphasizing fire control radar improvements would probably be much less expensive (the radar's size and power are much less) and could provide dramatic firepower improvements. These approaches are not mutually exclusive, and both would contribute to system effectiveness.

The technical factors above are pertinent both to improvement programs for existing AAW systems and to development programs for new systems. Present plans call for the AAW system on the new

DDGX to include the Multi-Function Array Radar (MFAR) system, similar in function to the AN/SPY-1 AEGIS radar. A final decision on the AAW fire control system for the DDGX has not yet been made, but it could include an agile beam radar and ICW if the technology is available.

"Back-End" Improvements: Prospective Low Cost and Weight and Easier Backfit

A new AAW fire control system with agile beam illumination/ ICW technology could also be used to upgrade the capability of currently operational surface combatants. Such a system would be particularly attractive if it permitted the ships to use the new Standard (SM-2) missile (which would give them the advantage of the missile's longer range and higher firepower), if it also permitted them to use the Standard (SM-1) missile (so that the considerable existing inventory of these missiles could continue to be used), and if the system was relatively small and modest in power demand (so that the ship impact and installation cost of the system in backfit would be modest). All of these factors militate toward a change in the "back end," or fire control radar, for backfit AAW improvements.

Although the introduction of the AEGIS system in the surface combatant fleet will usher in new capabilities more commensurate with the cruise missile threat, the high cost of AEGIS ships will probably limit their procurement. Also needed, therefore, are improved AAW systems that are smaller and less costly and that can be more widely distributed in the fleet. Fortunately, the newly emerging technologies discussed here show promise of providing such improvement for a wider spectrum of ships. This could result in a dramatic increase in AAW firepower in the 1990s.

Electronic Countermeasures: Major Factor and Major Uncertainty

AAW is also significantly affected by electronic countermeasures (ECM). ECM involves the employment of electronic devices such as jammers to interfere with an enemy's radar, communications, or other electronic systems. ECM can be very effective in degrading the performance of sophisticated, electronically based systems such as those used in AAW. Because of this, special features are often incorporated to make such systems resistant to ECM. Such features, known collectively as ECCM (for electronic counter-countermeasures), may be effective against some ECM techniques but not against others. The key feature of the technically esoteric subject of ECM/ECCM is that it is highly fluid. A system that is highly resistant to countermeasures today may be severely degraded by some new ECM technique tomorrow, and a new technical or tactical ECCM innovation may restore its effectiveness on the next day. ECM is a significant factor, and a major uncertainty, in assessing the effectiveness of AAW systems and will remain so for the forseeable future. 17/

SURFACE COMBATANTS IN THE 1990s

The trends in naval warfare and the technological developments discussed above appear, on balance, to paint an optimistic picture for surface combatants in the years ahead. Cruise missiles now give surface combatants a long-range strike capability against both ship and land targets. Helicopters, which can provide the long-range surveillance and targeting capabilities required by these weapons, are now being deployed on U.S. surface combatants, and V/STOL aircraft with even greater capability may be available in the future. New towed-array sonar systems now becoming available should extend this partnership between ship and aircraft to ASW as well, and will greatly extend surface combatant engagement range against submarines. New technologies in AAW systems offer the prospect of vastly improved capabilities in the immediate future. Thus, the surface combatant stands to gain substantially in its ability to deal with other

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17/ ECM threats of particular importance to surface combatant AAW systems are jammers that interfere with AAW radars in a manner similar to static on radio. These can be airborne stand-off jammers or jammers accompanying the attacking airplanes. In either case, their effect is to reduce the engagement range of the AAW system or, in the extreme, to defeat its effectiveness altogether. Several approaches may be taken to reduce the effectiveness of jammers. These include using very high power to overwhelm the jammer effects, using sophisticated signal processing to improve the signal-to-noise ratio over the jammer, using a variety of frequencies to force the enemy to spread his jammer power over a wider frequency band, and attempting to destroy the jammer using such things as home-on-jam missiles. All of these approaches, and others as well, will be used in the continuing technical parry and riposte of electronic warfare.

surface ships, submarines, airplanes, and missiles, and is even gaining a previously unknown capability to attack distant land targets.

All of this not only will permit the surface combatant to perform its traditional escort roles more effectively, but also offers the prospect of a more independent offensive role. If such a role develops, this would restore to the surface combatant force some measure of the status in naval strike forces that it enjoyed before World War II. An independent offensive strike role for surface combatants, however, would almost certainly come as a supplement, and a complement, to aircraft carriers, not as a substitute for them. Despite the impressive capabilities of cruise missiles, they carry relatively small payloads (for conventional explosives) and do not have the operational flexibility of a manned aircraft. It is unlikely that non-nuclear cruise missiles will be able to provide the critical mass of offensive firepower needed for major engagements at sea or for major force projection missions ashore. In less-demanding mission scenarios, however, the surface combatant's new capabilities may permit it to perform tasks that now are carried out by carriers.

The value of these capabilities and, indeed, of the capabilities of other naval forces as well must ultimately depend upon their usefulness in accomplishing the Navy's missions. 18/ A major issue before the Congress therefore will be what kind of ships and how many of each will provide the best overall capability in the years ahead. The following chapter presents an illustrative group of program alternatives that respond to different views of how best to accomplish the Navy's missions.

18/ For a discussion of naval mission priority alternatives, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985 (January 1980), Chapter II.

CHAPTER IV. U.S. SURFACE COMBATANTS: PROGRAMS FOR THE 1990s

In considering future naval shipbuilding programs, the Congress faces broad and often difficult choices in selecting for funding, within the inevitable budgetary constraints, those programs that will best enhance U.S. naval power. These choices depend upon a judgment as to what capabilities are most important for future naval forces, and that, in turn, depends upon a judgment about future naval strategy and the character of future naval warfare. This chapter analyzes the ways in which surface combatants embodying the technological advances discussed in Chapter III might contribute to future naval forces, and the role that they might play in naval strategy. The chapter concludes with a discussion of four alternative shipbuilding programs that reflect differing perceptions of naval strategy and its requirements for surface combatants.

THE NAVY'S VIEW: CARRIER BATTLE GROUPS ARE KEY TO VICTORY, BUT SURFACE COMBATANTS ARE ALSO USED IN OTHER ROLES

The Navy believes that the most efficient way to gain and maintain control of the seas is to destroy hostile forces capable of challenging that control. 1/ Carrier battle groups would be used as the instrument of such offensive action. The Navy believes that the very existence of such offensive forces would force the Soviets into a defensive, reactive mode, allowing the United States to capitalize on Soviet geographic disadvantages and compelling the Soviets to concentrate their naval forces in areas close to the Soviet Union where they would pose less of a threat to U.S. sea lines of communication. 2/ Surface combatants would play a key role in these battle groups by providing a

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1/ Testimony of Admiral Thomas B. Hayward, USN, Chief of Naval Operations, in Military Posture and H.R. 6495, Hearings before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services, 96:2 (February and March 1980), Part 3, p. 361.

2/ Ibid.

defense in depth, enabling the carriers to withstand the intensive counterattacks that would attend this strategy. In addition, surface combatants equipped with cruise missiles could contribute to the battle group's offensive punch.

The usefulness of carrier battle groups would by no means be limited to direct confrontations with the Soviets. In the Korean War and again in Vietnam, aircraft carriers were heavily involved in conducting tactical air strikes and providing air support for ground forces. A recent Brookings Institution study examined the actual use of military forces in promoting U.S. political objectives in the period 1946-1975 and found that naval forces were involved in 177 of 215 incidents examined, more than half of which involved aircraft carriers. 3/ Carriers remain the only means of very quickly aggregating a substantial amount of tactical air power on short notice in most areas of the world. Carrier battle groups are therefore an important instrument of national power in a wide range of conflict scenarios, including Third World crisis situations, and can be expected to remain so for the foreseeable future.

Surface action groups (SAGs), which are naval combat units that do not contain an aircraft carrier, are used today in the Middle East and the Caribbean, and might be a form of response appropriate to other crises in the Third World. Their offensive capability will be considerably enhanced by the availability of cruise missiles and might be further enhanced in the future by deployment of V/STOL aircraft aboard small carriers or "air-capable" ships. The concept of a surface action group gives the surface combatant an independent offensive mission once again; if successful, it will provide the Navy with additional flexibility in the employment of its forces.

In addition to these offensively oriented roles, the Navy expects surface combatants to continue their important defensive roles as escorts for underway replenishment groups and convoys, as well as their traditional offensive/defensive role in support of amphibious operations. In each of these roles, the future surface combatant will be faced with more formidable threats, but it will be aided in performing its missions by better weapons and sensor systems.

3/ Barry M. Blechman and Stephen S. Kaplan, Force Without War (Washington, D.C.: The Brookings Institution, 1978), p. 38.

THE BATTLE GROUP OFFENSIVE STRATEGY: ARE THERE PITFALLS?

Current Navy strategy places primary emphasis on the battle group as the basis of naval power. In the event of a full-scale war between the United States and the Soviet Union, battle groups would be the primary offensive strike arm for conducting a frontal assault against Soviet naval forces and bases. This strategy, however, is by no means the only one the Navy may be called upon to execute in the future. Depending upon the circumstances at hand, the national command authority may find it advisable (because of the nature of the crisis, the disposition of Soviet forces, agreements made with allied nations, etc.) for the Navy to pursue some strategy other than a frontal assault on Soviet home bases. The Navy may be required to face a distributed threat by Soviet and/or other naval forces that would require a different mix of ships, including a sufficient number of surface combatants to protect U.S. interests over a relatively long period of time in distant waters. Indeed, recent events in the Middle East have been of this nature, straining the Navy's resources with demands for further standing force deployments.

In addition, some have questioned whether an approaching carrier battle group, with its enormous concentration of power, might induce the Soviets to use nuclear weapons against it. Certainly the temptation would be great, given the difficulty of defeating a battle group with conventional weapons. In addition, use of nuclear weapons at sea would involve minimal collateral damage; it would therefore be a clearcut tactical employment exclusively against military forces.

Even if one takes the most pessimistic view of the prospects for using battle groups to attack Soviet bases, the need for aircraft carriers and their associated surface combatants does not necessarily collapse, although the strategy for their employment may change. If the Navy is prevented from making a frontal assault on enemy naval forces in their basing areas because of factors relating to a particular conflict situation, because of concern about nuclear escalation, or for any other reason, then the strategy of winning through quick destruction of the enemy's naval forces and supporting base structure may have to be revised. In such a situation, a more gradual attrition of enemy forces and a wider distribution of naval forces may be necessary. In this kind of war, or in a war focused in some area of the Third World, a massive, coordinated attack such as the Soviets could organize near their home waters might not materialize, but the U.S. Navy could be faced with the task of opposing the interdicting Soviet naval forces worldwide. In such circumstances, having ships with sufficient capability to withstand the maximum Soviet home-water threat may be less important than having enough ships to oppose a distributed threat in distant waters. 4/

SURFACE COMBATANT SHIP DESIGN ALTERNATIVES

Four different types of surface combatants are discussed in the following section. Employing many of the new technologies discussed in Chapter III, each would have formidable combat capabilities as compared to current warships. The four ship types represent a range of alternatives illustrating how ship design trade-offs can affect the cost, capability, and mission orientation of a warship. Considerations bearing upon such trade-offs are discussed in more detail in Appendix C; an example of how design trade-offs affect ship size and cost is provided in Appendix D. A decision by the Congress as to what mix of these ships to authorize will depend upon its view of future naval requirements. The contributions of these different ship types to alternative naval strategies will be examined at the conclusion of this chapter.

Current Program Surface Combatant Types

AEGIS Cruiser (CG-47). Of all existing or authorized surface combatants, the CG-47 can best meet Navy combat system requirements. Not only will it provide the formidable AAW capability of AEGIS, but it will also have the best available ASW sensors, LAMPS III helicopters, two five-inch guns, ASROC weapons, and cruise missiles, with their long-range strike capability. Only the fact that it is not nuclear powered makes the CG-47 less than a first-line warship in every way. The proven hull and machinery of the existing DD-963 should, however, provide a reliable and capable platform for this powerful combat system. The CG-47 will be an expensive ship, with an estimated unit procurement cost of $1.02 billion (fiscal year 1982 dollars).

4/ For a discussion of naval mission priority alternatives, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985 (January 1980), Chapter II.

New-Design Battle Group Destroyer (DDGX). The DDGX is intended by the Navy to be a battle group surface combatant, contributing both offensively and defensively to battle group capabilities but costing sufficiently less than the CG-47 to allow procurement in adequate numbers. It is currently in the early design stages, and decisions on its final configuration are subject to revision by the Navy as the design process proceeds.

The design for the DDGX is driven by the requirements of the Navy's hypothesized battle group scenario. In this scenario, a battle group would be exposed to an intensive, coordinated attack by aircraft, submarines, and surface ships in which an enemy could launch hundreds of cruise missiles accompanied by intensive electronic countermeasures (ECM). Given this threat, the Navy believes that the DDGX should have a very good AAW capability, with high resistance to jamming, fast reaction time, and high firepower. Its missiles will be launched from the newly developed Vertical Launching System (VLS), which will provide quick reaction time in AAW and flexibility for launching a variety of missile types, such as Tomahawk and ASROC, in addition to AAW missiles. The DDGX will not be fitted with a towed-array sonar, nor will it carry LAMPS helicopters since the Navy assumes these would be available on other ships in the battle group. It will, however, have the electronics necessary to work with LAMPS III, and will be fitted with an emergency landing pad. Its ASW capabilities will be oriented toward active sonar screening, using the large, low-frequency SQS-53 sonar system and the ASROC ASW weapon. The DDGX is being designed to a cost goal of $500 million (fiscal year 1981 dollars) for each follow-on ship after the lead ship.

Additional Types: Higher- and Lower-Cost Alternatives

Two hypothetical alternative surface combatants will be described as illustrative of higher- and lower-cost alternatives to current Navy ship designs.

Nuclear Cruiser (CGN). A nuclear-powered AEGIS cruiser would provide the combat capabilities of the CG-47, together with the additional operational flexibility inherent to the unlimited steaming range of nuclear power. The ship hypothesized here would employ the basic hull and machinery of the Virginia-class (CGN-38) cruiser and would be an updated version of the "improved Virginia class" first proposed to the Congress in the fiscal year 1976 program. The Navy has developed plans for a ship of this type, designated CGN-42. The fiscal year 1978 budget provided $180 million for advance procurement of nuclear components and engineering for the CGN-42, but no further work has been authorized. The CGN-42 was to have basically the same combat system as the CG-47. Being a substantially larger ship, however, it would have greater growth potential as well as the unlimited steaming endurance of nuclear power. The CGN-42 would thus represent a surface combatant with the best capabilities currently achievable. It has been estimated by the Navy that a ship of this kind would cost about $1.43 billion for the lead ship and $1.23 billion for follow-on ships (fiscal year 1981 dollars). 5/

Open Ocean Destroyer (DDGY). This ship, which for convenience is designated DDGY, is illustrative of a warship that would result from different choices on the design trade-off issues discussed in Appendix C. It would be an offensively oriented surface combatant capable of battle group operations, but optimized more for broad ocean operations in the context of a worldwide naval war rather than for the intensive, frontal assault scenario used to derive the DDGX requirements.

The DDGY would carry the same vertical launching system and the same missiles, including cruise missiles, as the DDGX. It would be significantly smaller than the DDGX, however, because of the effect of the design trade-offs discussed below and because, unlike the DDGX, it would not have space and weight capacity for unspecified future growth. 6/

5/ Testimony of Vice Admiral James H. Doyle, Jr., USN, Deputy Chief of Naval Operations for Surface Warfare, in Military Posture and H.R. 6495, Hearings, Part 3, pp. 118-19. The prices given for the CGN include initial nuclear fuel equivalent to about 3 million barrels of oil for a conventionally powered ship.

6/ Provision of space and weight for future growth is a relatively recent development in U.S. design practice. In addition, U.S. designers use relatively large "margins" in their designs. Margins are allowances for unforeseen growth as design and construction progress. These practices tend to produce larger ships for a given payload than would be built in countries such as the Soviet Union or Italy where such allowances are much more austere. For a discussion of this, see J.W. Kehoe, C. Graham, K.S. Brower, and H.A. Meier, "NATO and Soviet Naval Design Practice, Eight Frigates Compared," International Defense Review (7/1980), pp. 1003-10.

In AAW, the DDGY would emphasize "back-end" technology and would use an advanced missile fire control system to achieve high firepower at shorter ranges. It would use the advanced SM-2 AAW missile and would have the long-range area AAW capability of that missile. 7/ Although this system would probably be less capable, particularly in a jamming environment, than the one proposed for the DDGX or AEGIS, it should be considerably less expensive than AEGIS and much more capable than any of the pre-AEGIS AAW systems on existing cruisers and destroyers.

In ASW, the DDGY emphasizes long-range passive detection with a towed-array sonar whereas the DDGX emphasizes active detection using the SQS-53 sonar. The DDGY would also be fitted with an active sonar, but would utilize the smaller SQS-56 rather than the larger, more expensive SQS-53 carried by the DDGX. The DDGY would carry two LAMPS III helicopters, which are essential to its long-range ASW orientation and would also provide it with an independent over-the-horizon surveillance and targeting capability.

The DDGY is assumed to have the same propulsion system as the DDGX; but being a smaller ship, it would be a bit faster. Its range, however, would be about 10 percent less than that of the DDGX.

Finally, the DDGY would be fitted with a gun and a relatively simple gun fire control system suitable for surface engagements and shore bombardment. Although a gun is unlikely to be useful in a modern battle group engagement, it could still be vital for independent patrol and presence operations and for support of amphibious landings.

Emphasizing long-range towed-array ASW rather than shorter-range active sonar, carrying its own helicopters rather than relying upon those from other ships, and mounting a large-caliber

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7/ This concept assumes that high firepower is achieved through the use of the ICW and agile beam illuminator technology described in Chapter III. At long range, the multiple-target engagement technique could not be used because of power limitations. Long-range engagements do not, however, normally have the time urgency of short-range engagements.

gun for antisurface and shore bombardment missions, the DDGY would be better equipped for independent operations outside of the battle group than would the DDGX.

In addition to carrier battle group operations, the DDGY could operate with surface action groups. In this role, its aircraft would provide over-the-horizon surveillance and its towed-array sonar would provide long-range detection of submarines. The DDGY could also operate in support of amphibious landings, providing AAW and ASW protection en route and gunfire support during the assault. It could also operate with frigates in escorting replenishment ships and convoys, substantially increasing the protection provided. Finally, the DDGY could operate independently in patrol and presence or ocean area control missions.

The DDGY would, however, have less capability in its air search radar than the DDGX. The DDGY's AAW capabilities would nevertheless be very good in any but the highest-threat environments, and in future battle groups it would have the advantage of data-linked air target information from the DDGX and AEGIS ships.

Using the size and cost impact estimating factors presented by the Navy in discussing various destroyer trade-off issues, it is estimated that the DDGY would have a full-load displacement of about 5,000 tons and a follow-on ship cost of about $375 million (fiscal year 1982 dollars). Its size and cost rationale is outlined in Appendix D.

Principal characteristics of these four designs are shown in Table 3, and their external profiles are shown in Figure 5.

PROGRAM ALTERNATIVES

The four ship types described above are representative of a spectrum of alternative surface combatant warship designs that could be built in the next decade and beyond. The CGN is a high-quality general-purpose warship with emphasis on capability as opposed to cost considerations. The CG-47 provides essentially the same combat system capability as the CGN but at a significantly lower cost, since the ship is both smaller and conventionally powered. The destroyer designs, DDGX and DDGY, would have somewhat less capability than either of the cruisers but would be less expensive and therefore available in larger numbers for any given level of investment. The DDGX is optimized for battle group operations, and the DDGY is illustrative of a ship somewhat less optimized for battle group operations in the interest of providing a better broad-ocean, independent-operations capability.

Choosing which ships to build among these alternatives, and how many of each to procure, depends upon perceptions about future naval combat. If one believes that offensive strikes against enemy forces and bases in their home waters is the optimal strategy in war, and that this strategy can actually be executed in most contingencies leading to war, then emphasis should be given to procuring high-quality ships designed for the highest threat level.

If, however, one believes that a frontal assault in enemy home waters is not the optimal strategy, or that it might lead to nuclear escalation, then emphasis might better be given to procuring additional ships for the funds available.

In either case, however, high-quality ships would have a role to play. Difficult and dangerous combat missions occur in almost any war, and the best possible capabilities may be essential for success in such situations. The issue is one of emphasis, and of the extent to which high quality justifies having fewer ships than might otherwise be obtained for a given level of investment.

Beyond the quality-versus-quantity issue lies that of how to balance the overall capabilities of the fleet. Should a large number of ships of a single design be procured, or would it be better to procure different designs, each offering a different mix of capabilities? 8/ The answer to these questions also depends upon one's view of the future and upon the degree to which one prefers to hedge against a range of contingencies rather than focusing on a single contingency. The next section outlines four hypothetical 10-year shipbuilding programs that illustrate different approaches to these decisions.

8/ For a discussion of strategy options relevant to these considerations, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985, pp. 7-19.

TABLE 3. CHARACTERISTICS OF ALTERNATIVE SHIP TYPES

	Nuclear Cruiser (CGN-42)	AEGIS Cruiser (CG-47)	Battle Group Destroyer (DDGX) a/	Open Ocean Destroyer (DDGY) b/
Displacement (tons)	12,000	9,100	6,000	5,000
Maximum Speed (knots)	30+	30	29	30
Endurance Speed (knots)	--	20	18	20
AAW Systems				
Search radar	SPY-1	SPY-1	MFAR	3-D c/
Fire control radar	4 MK99	4 MK99	2 MK99 or 2 Agile Beam	2 Agile Beam d/
Launcher system	VLS	VLS	VLS	VLS
Missile capacity	122	122	90	90
Missile type	SM-2	SM-2	SM-2	SM-2
ASW Systems				
Towed-array sonar	SQR-19	SQR-19	None	SQR-19
LAMPS-compatible	Yes	Yes	Yes	Yes
Number of aircraft	Two	Two	None	Two
Hull-mounted sonar	SQS-53	SQS-53	SQS-53	SQS-56
ASW weapons	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes
ASuW Systems				
Missiles	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Land Attack Systems				
Missiles	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Estimated Cost (millions of fiscal year 1982 dollars)	$1,340	$1,018	$550	$375

a/ A final decision on the configuration of the DDGX has not yet been made. The characteristics listed above may be changed by the Navy as the design process progresses.

b/ For DDGY weight and cost rationale, see Appendix D.

c/ SPS-48E 3-D and SPS-49 2-D air radars as used on the latest U.S. ships supplemented by horizon and high-elevation search by agile beam fire control radars. Later units might have a new-generation air search radar.

d/ Agile beam is used here as a generic term that includes such specific concepts as the Terminal Engagement Radar (TER) or Flexible Adaptive Radar (FLEXAR). This system would be capable of simultaneously tracking and engaging multiple targets while supplementing the air search function in the horizon and zenith areas.

Figure 5.
Four Alternative Ship Types