PERFORMANCE OPTIMIZATION IN SURFACE WARSHIP DESIGN

by

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ABSTRACT

Official Defense Department doctrine ties the determination of performance requirements for new classes of surface warships directly to demonstrated operational needs. A close review of procurement policies indicates that final ship characteristics are actually the result of a number of pressures, biases, and arbitrary decisions — a process which is generally divorced from objective analysis, and is based primarily upon political considerations.

Consensus among ship designers and operators favors development of surface platforms primarily optimized to identified mission requirements. Attempts by the Navy to develop such a capability and primary factors which have inhibited such a procurement strategy are examined in detail.

The immense and disjointed structure of the ship acquisition organization, and the continued inability of the Navy to develop adequate measures of effectiveness for entire ship systems are the primary obstacles to the development of a design and procurement process optimized to specific operational requirements.

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INTRODUCTION

The combatant surface ship is one of the most complex systems man has ever attempted to design, produce, and operate. To achieve an optimum combination of combat, control, and habitability subsystems for the minimum cost continues to be a near monumental problem for the ship designer. In recent decades this problem has grown in proportion to the explosion of weapons systems and platform technology that has easily priced the most sophisticated vessels out of consideration. Exacerbating this situation is the irrevocability of many of the initial design decisions resulting from an inability to test and evaluate the resulting ship prior to the full-scale production decision. Clearly the analysis that generates the final design is critical to producing a unit that will satisfy operational requirements some five to ten years in the future — and will be adequate for accepting modification to fulfill fleet needs in excess of 30 years after commissioning.

In the past two decades the Navy has gone through two major procurement concepts, and is moving toward a third, in what has largely been an unsuccessful effort to optimize surface ship performance within some cost constraint. Under stated development practices, the determination of combat system configuration for surface ships involves a long analytical and iterative process to fit a combat vessel into an established mission requirement, while remaining within imposed cost constraints (i.e. "fitting a ship to a mission"). The Deputy Chief of Naval Operations for Surface Warfare (OP-03) is charged with establishing force requirements and delineating specific needs, constraints, and other design criteria to design offices in the Naval Sea Systems Command (NAVSEA). OP-03 initiates studies and receives analytical support from a variety of agencies involved with combat systems development, operational test and evaluation, tactical development and evaluation, and force level/force mix systems analysis (see Figure I). Through iterative dialogue with NAVSEA, a product is hammered out that is supposed to represent the best possible answer to fleet needs in the identified warfare areas.

In reality, a final ship design is the product of a large number of inputs, pressures, and constraints — many of which can be predicted even prior to conception, and most of which are entirely independent of any analytical process.

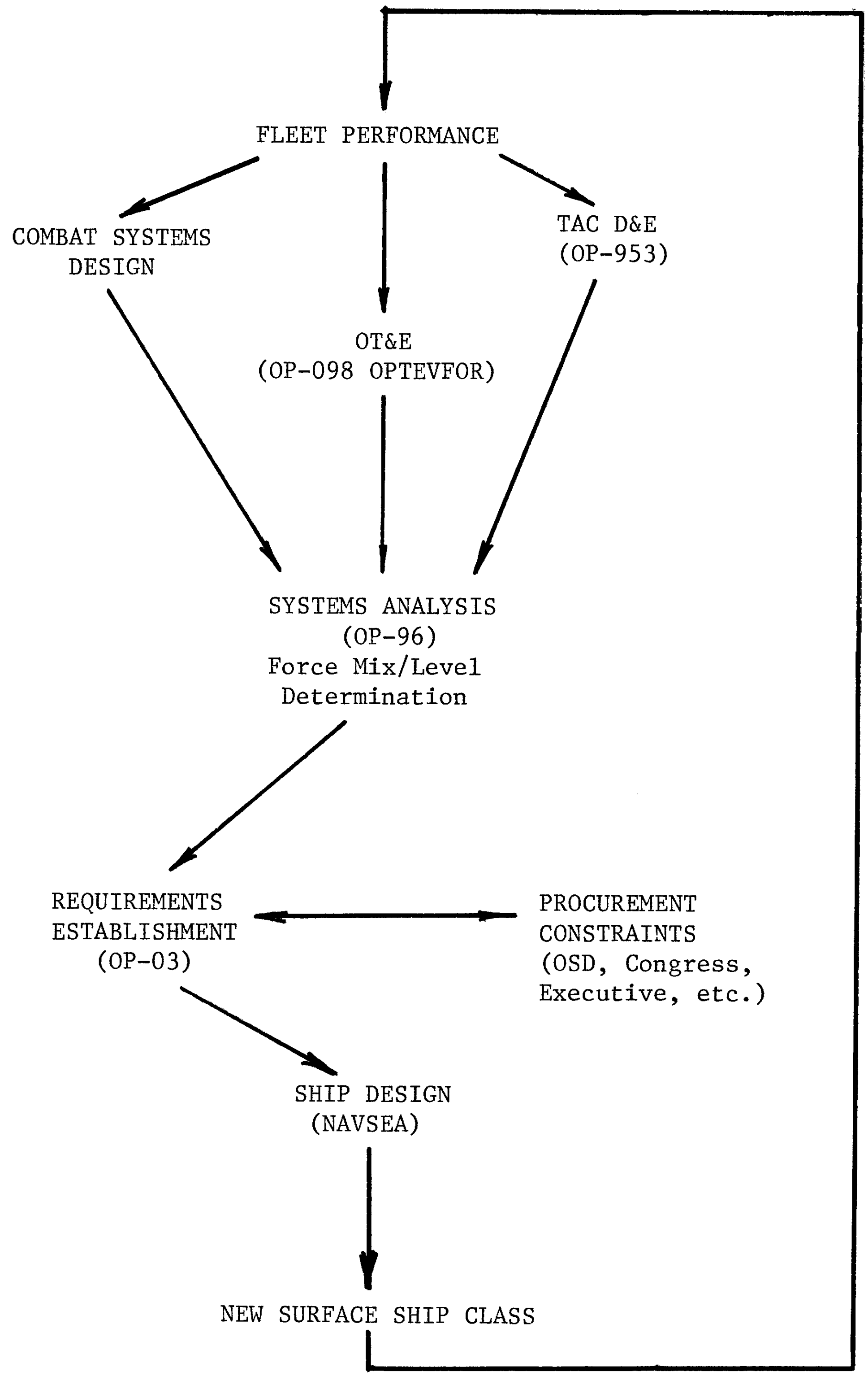

Figure I. The Surface Warship Design Process

As a result, it is usually not until _after_ a combat ship enters the fleet that serious consideration is given to its mission, that operational deficiencies are noted, and that programs are initiated and funded to enable it to carry out assigned tasks.

Minimum unit production cost for a low capability ship currently exceeds $250 million a copy (exclusive of approved but uninstalled modifications). With growing questions in the Department of Defense and Congress about the operational validity of surface combatants in the next century, the Navy has reached a point where program funding has become increasingly tied to "proof" of platform need and operational effectiveness. The inability to provide such quantitative proof has made program validity easily questionable, and continues to keep major decisions of program direction out of Navy hands altogether.

The objective of this study is to describe the Navy's ship design process and analyze the critical decisions of platform and payload determination at each step of their development. The severe limitations of attempting to "fit" a notional ship into a set of expected operational scenarios is recognized, but it is clear that the ship development system as it exists does not generate a product that is oriented or optimized toward any set parameters of mission effectiveness. The idealized process of relating specific ship missions to operational scenarios in an overall national security strategy has been termed a "dreamworld" approach by many Navy designers and analysts. Yet this is a dreamworld that continues to be propagated by the molding and modification of the developmental process and design-related documents to fit into that established framework. Such an analytical framework also lends itself to long range planning and budget justification, yet it has not proven to be particularly effective in either role.

The critical failing is not that the Navy doesn't design good ships, but that prior to fleet introduction, no one really knows how good those ships are — or whether they are what the fleet really needs.

Section I of this study is a broad overview of the current ship procurement process in the Department of Defense. It reflects the "official" doctrine of how major ship construction programs are presently identified, initiated, and molded to fulfill specific operational needs. The section represents the "ideal" of how ships are designed into identified mission requirements.

Sections IIA and IIB trace the design and development processes that produced the Navy's latest two classes of ocean escort — the DD-963 and the FFG-7. These are particularly pertinent since each project developed new acquisition policies intended to overcome past procurement deficiencies and to maximize performance within acceptable cost constraints. The objective for studying each ship program is to demonstrate the actual detachment of analytical procedure from the requirements derivation and design process. In each case the primary configuration decisions were based on constrained criteria only subjectively related to performance. Section IIC reviews current ship development programs to provide an overview of the current direction of ongoing ship design projects and procurement policies.

Section III follows the stages of the program development process to provide a more in-depth analysis of each stage of operation. The focus is on the resulting product in terms of available inputs. The process is traced from the finalized design back through the establishment of individual ship requirements, force level/mix analysis, and the derivation of various analytical inputs. The effect of non-Navy Department agencies (e.g. the Office of the Secretary of Defense (OSD), Congress, the Executive) are treated in broad overview. These activities certainly have a significant impact on the direction of Navy procurement programs, but a direct alteration of their functions is not within the purview of the Department of the Navy.

A final factor which has a major bearing on the entire design process is the character of the structure of the design and analysis organization. A simple analysis of the functional processes of design is inadequate to explain away the many obvious deficiencies of the entire system. It is only through an appreciation of the bureaucratic structure which operates this system — and provides primary system intertia — that one can come to grips with the tremendous obstacles which confront a rapid movement to a more efficient and effective design process.

The conclusion of the study is aimed not at developing an alternate design process but at trying to determine if a more effective process can be achieved. Not an insignificant body of opinion, both within and outside of the Department of the Navy, holds that, despite admitted limitations, the system is the best that can be expected given its operating constraints. If this is indeed true, then the thrust of change can be constructively directed at the elimination of costly and time-consuming functions which do not contribute to, and may even inhibit, the design process. The lack of communication and degree of parochialism which exists at each level of the design process is remarkable in light of the amount of systems integration that must go into the final product. If only to provide the first overview of the decisionmaking process at each level, and the effects of those decisions on the final design, this study will have served a purpose.

I. Surface Ship Procurement

The generation of naval force requirements involves the translation of appropriation authority, world situations, and executive guidance into Navy programs. The "official" process begins with the specification of national interests by the President and his advisors (see Figure II). National objectives are defined to assure satisfaction of the interests in the face of foreign pressures and trends. Strategies are developed and forged into a National Military Strategy to achieve the security objectives in the face of foreign threats.[1]

Planning guidelines based on National Security Council (NSC) directives are provided to the military agencies in the Defense Policy and Planning Guidance (DPPG) memoranda. This guidance presents cases in the form of possible wartime scenarios which are intended primarily to guide the services in programming their resources into a particular force structure. This high-level programming guidance is intended to have a strong and direct influence on the derivation of ship requirements.

Navy requirements are derived from comparing the capabilities of the present and programmed force to the needs of the National Military Strategy and the difficulties provided by the threat to Navy mission accomplishment. The CNO develops the CNO Program Planning Guidance (CPPG) which describes Navy roles and missions, and furnishes broad Navy planning guidance. The CNO Program Analysis Memorandum (CPAM) treats missions and support areas in terms of cost and capabilities, and furnishes the basis for consideration of broad program options.

In this basic mission framework, platform/systems combinations are developed to fulfill identified tasks. Quantities needed to operate in accordance with approved tactical doctrine are then determined, and a balanced combination of platform/systems and level results. Force mix analysis is conducted to determine the different types of ships with unique capabilities that the Navy needs to carry out its missions. The current naval force with programmed changes is extrapolated into the future and modified according to the platform/system needs and the allied commit-

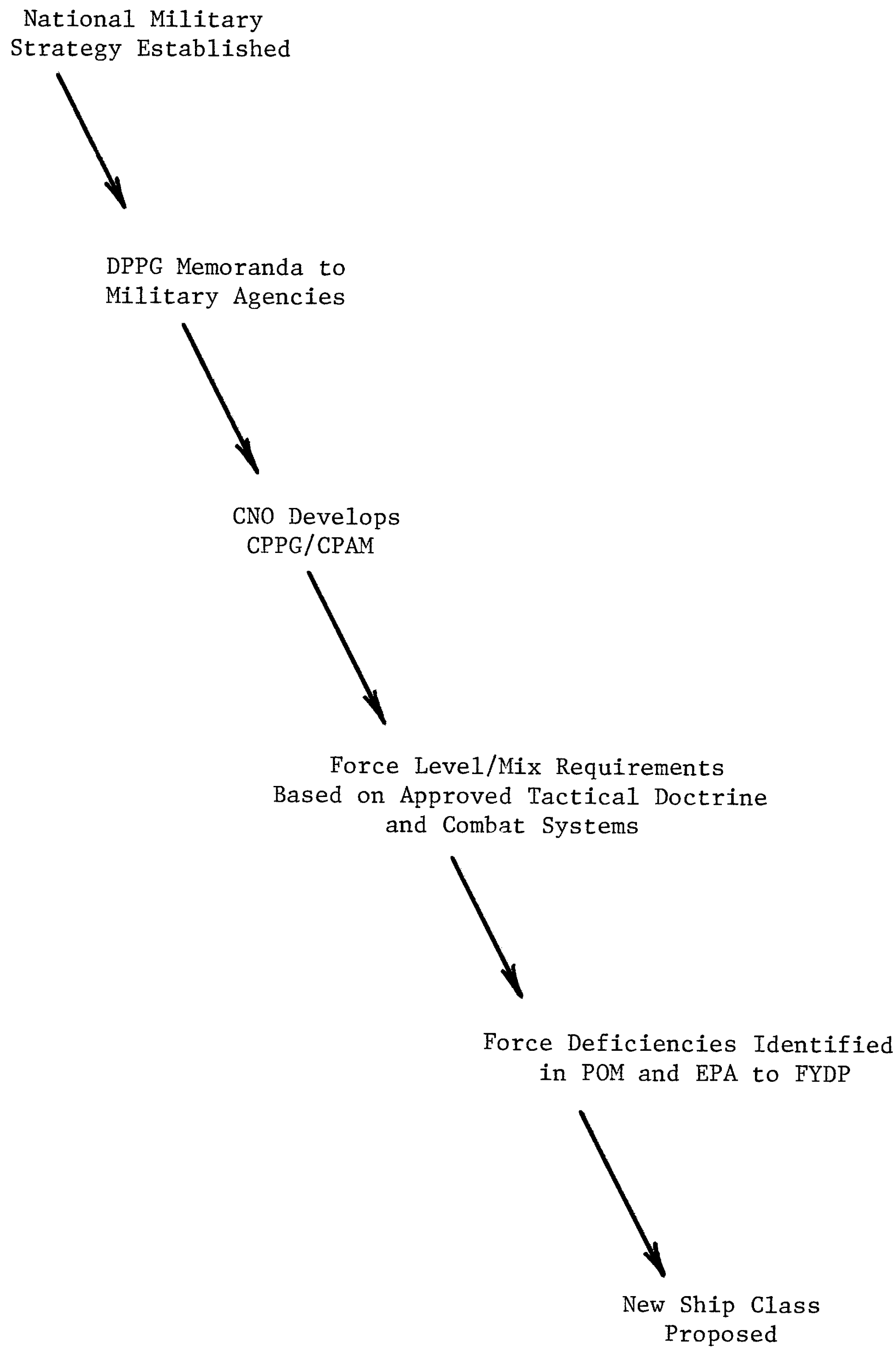

Figure II. Derivation of Surface Warship Requirements

ments. A proposed force structure results from these deliberations.

The identified force structure requirements are ultimately expressed in the Program Objective Memorandum (POM) and Extended Planning Annex (EPA). These documents are submitted annually by the Navy as proposed revisions to the Five Year Defense Program (FYDP).

Current DOD acquisition policies (e.g. DOD Directive 5000.1 of 18 Jan 1977) require that a clear tie and perspective be maintained between the identified "mission need" and what is being developed in the program, in its execution, and in its supporting documentation (see Figure III). The Acquisition Phase for a naval surface combatant commences when a mission need is submitted to and approved by the Secretary of Defense. This approval— a Mission Element Need Statement or MENS — directs the Navy to develop systematically and progressively alternative system concepts to satisfy the approved need. In the Major System Acquisition Process this is known as Program Initiation (Milestone "0").

Once the Program Initiation Phase is entered, the Office of the CNO (OPNAV) prepares and transmits the Operational Requirements (OR) to the appropriate Ship Acquisition Project Manager (SHAPM) in NAVSEA. The OR is the basic document for all Navy acquisition programs and initiates the conceptual effort to meet the operational need. NAVSEA develops and translates the ship's mission and operational requirements into a consistent set of design constraints and parameters. For most ship acquisition programs, the major parameter established by the OR is a tentative cost constraint setting a "Design-to-Cost" (DTC) target.

In response to the OR a Development Proposal (DP) is prepared. The DP states the OR's need, time frame, issues, program objectives and alternatives, effectiveness, risk, achievement milestones, and other factors. During the preparation of the DP there is iterative dialogue between OPNAV and NAVSEA, with OPNAV developing the requirements and NAVSEA developing the related ship studies. NAVSEA performs trade-off studies to develop whole ship designs compatible with ship mission requirements and standards, including determination of platform alternatives and optimum mission suites. The results of these studies are incorporated in the Navy Decision Coordinating Paper (NDCP) and presented to the CNO Executive Board (CEB) for review and decision.

MENS Submitted to SECDEF

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Acquisition Phase - Alternative System Concept Exploration

↓

Program Initiation Phase
- CNO Submits OR to NAVSEA
- NAVSEA Submits DP to CNO
- Tradeoff Studies Conducted

↓

Feasibility/Conceptual Phase
- Feasibility Studies
- CNO Submits TLR to NAVSEA
- NAVSEA Submits TLS to CNO
- DSARC I

↓

Preliminary Design Phase
- FBL Established
- TLR/TLS Finalized
- Payload "Freeze"
- DSARC II

↓

Contract Design Phase
- ABL and Contract Bid Package Developed
- DSARC III

↓

Detail Design and Construction Phase

Figure III. Phases of Surface Warship Procurement

The NDCP defines program issues, the considerations which support the operational need, program objectives, program plans, and performance parameters. This document establishes the conceptual development program and serves as the basis for preparation of the Decision Coordinating Paper (DCP).

When the DP is forwarded to OPNAV, the SHAPM begins preparing the Ship Acquisition Plan (SHAP). The SHAP outline is a plan of action and milestones for accomplishing the acquisition with the intent that the probable ship concept will ultimately be implemented.

Upon authorization to start the Feasibility/Conceptual Phase of the acquisition process, the SHAPM initiates feasibility studies to determine a preliminary ship concept. Concurrently, OPNAV begins to prepare the first draft of the Top Level Requirements (TLR).

The TLR is promulgated and approved by the CNO and defines the operational requirements of the ship to be produced. As a minimum, the TLR states the ship's mission, operational requirements, major configuration constraints, maintenance and supply support concepts, manning limitations, and minimum operational standards. It defines what OPNAV expects from the product as obtained from the producer, NAVSEA. From a continuous iterative dialogue between OPNAV and NAVSEA, a clear understanding of the requirements is gained. The system proposed in the TLR is then better defined in terms of specific performance characteristics, schedule, and cost. In addition, alternative hardware systems, tactics, and technologies are considered to ensure that the most effective, efficient, and economical system is acquired to fulfill the need. In parallel with this refinement of the TLR, the Top Level Specifications (TLS) is begun by NAVSEA.

The TLS translates the TLR into a description of the ship, providing a bridge between the TLR and the contract specifications that are developed for the procurement of the vessel. It states what the producer, NAVSEA, intends to provide as a solution to fleet requirements as determined by OPNAV. Through iterative dialogue and feasibility studies the ship and ship systems are narrowed down to a preliminary concept. The designer develops alternative configurations at the ship system level which reflect varying operational requirements and which are translated into comparable ship acquisition cost estimates. These alternatives, each satisfying a unique set of operational requirements with an associated cost, are then traded off until OPNAV selects an alternative that offers the desired balance between operational requirements and cost. The TLS and TLR are companion documents which are kept current throughout the design phase to continuously reflect the specifications of the requirements/design product.

During the conceptual stage the SHAPM begins the first Test and Evaluation Master Plan (TEMP). The TEMP is the controlling document which defines the test and evaluation requirements for each acquisition program.

Also during the Conceptual Phase, the Decision Coordinating Paper (DCP) is developed and is issued prior to the DSARC I (Defense Systems Acquisition Review Council) review. The purpose of the DCP is to support the DSARC review and the Defense Secretary's decision-making process throughout the ship acquisition phase. It is the principal document for recording the essential information on a program. This information includes need/threat, concept, milestones, thresholds, issues and risks, alternatives, management plan, supporting rationale for the decisions, and affordability in terms of project budget. The DCP also serves to record the Defense Secretary's decision. To meet each DSARC decision point (milestone) for ship programs, DCP I, II, and III are developed when preparing to start the preliminary design, contract design, and detail design respectively. The DCP III is updated for the follow-ship procurement DSARC review.

DSARC I is the decision point where the Secretary of Defense considers to approve or disapprove the ship acquisition. The documents supporting DSARC I are the DCP, the preliminary TLR, the Conceptual Baseline (CBL) with its DTC goal, and the first TEMP and SHAP outlines.

The <u>Preliminary Design Phase</u> commences when approval is received from the Secretary of Defense after DSARC I. This phase is the period of the ship acquisition when the technical characteristics of the alternatives proposed during the conceptual phase are established, delineated, and validated. Tradeoffs and reductions to remain within the cost constraints are the essence of this design phase. The main product of this phase is the Functional Baseline (FBL), which is reflected in the TLR and TLS.

It is sometime beyond DSARC I that OPNAV is to establish a military payload "freeze". It is also during this time frame that OPNAV, in conjunction with the SHAPM, will start to develop the Tactical Operational Requirement (TOR). The TOR describes, in operational terms, all of the requirements that have been established for the ship to perform its assigned mission.

During this phase of acquisition, the preliminary TLR and TLS are developed concurrently into final form for issue prior to DSARC II. The preliminary design process establishes the FBL and provides the information required to present the program for Department of the Navy (DON) Systems Acquisition Review Council (DNSARC) review and DSARC decision. DCP II, which updates DCP I, should support the decision made by the Secretary of Defense to enter the full-scale engineering development in the Contract Design Phase.

When approval is received to proceed, the Contract Design Phase develops the FBL into an Allocated Baseline (ABL) and develops a suitable contract bid package for the prospective shipbuilder. The final TLS is issued prior to DSARC III. To obtain program approval for lead and follow ships at DSARC III, evidence has to be presented that the systems, subsystems, and equipments proposed as a part of the ship system will have a reasonable degree of success. To obtain this evidence, the TEMP is invoked.

With the completion of this phase of acquisition the ABL, consisting of the performance oriented contract specifications and drawings governing the development of all shipboard systems, has been accomplished. The DCP III, which is an update of DCP II, supports the decision by the Secretary of Defense to enter production/development in the Detail Design and Construction Phase.

The idealized design and development process for each new class of ship is an exhausting administrative exercise which consumes at least several years. The ultimate objective of the multi-layered review process is to ensure that the ship that is bought is the best possible product that can be obtained for the money.

This current developmental framework resulted from major defense systems acquisition problems experienced in the 1960s and early 1970s. Cost overruns, construction delays, and a failure of major systems to meet performance requirements led to the imposition of this process requiring continuous project review and justification. A determination of the validity of the process in achieving its stated goals requires an understanding of the failure of previous procurement concepts. The DD-963 and FFG-7 class acquisition programs are the two most significant attempts in recent years by the Navy to maximize total ship performance within cost and manning constraints.

IIA. The DD-963 Class Acquisition Program

The Total Package Procurement (TPP) concept for the acquisition of naval ships was introduced by Secretary of Defense Robert McNamara in 1965. This process entailed Concept Formulation/Contract Definition (CF/CD) which, through competition in industry, led to the development of a design, and the contract for the procurement of new ships built to that design. Up until that time shipbuilders had dealt with the ship construction aspect only — their bidding based entirely upon a design developed and provided by the Navy. The primary objectives of CF/CD were, 1) to minimize costs through competitive design and bidding — and then to control that cost with a total package procurement contract, and 2) to spur innovative design and construction concepts.

Concept formulation was performed by the Navy to verify the compatibility of all performance requirements. At the outset of the contract definition phase, the Navy's requirements for a new ship design were transmitted to the prospective contractors in terms of ranges of performance characteristics. Their responses were to reflect a balanced design solution considering performance criteria, design standards, and production techniques. This process emphasized the industry's responsibility for the ultimate satisfactory performance of the ship.

The end product of Contract Definition was a proposal from each would-be contractor for Total Package Procurement. This included a set of ship plans and specifications developed by the contractor in response to the Navy's requirements. The Navy then chose that contractor whose ship design and plans for construction were considered the most cost-effective.

Three ship acquisition programs were defined and developed by the CF/CD process: the Fast Deployment Logisitics ship (cancelled upon completion of CF/CD), the LHA Amphibious Assault ship, and the DD-963 Spruance class destroyer.

In 1966 Secretary of Defense McNamara proposed the DX/DXG program for a new class of ocean escorts needed to replace the aging 2200 ton World War

II destroyers in the fleet. As the first director of the Navy's Systems Analysis Division (OP-96), Admiral Elmo Zumwalt headed the "Major Fleet Escort Study" which was issued on August 5, 1967.[2] The study was an in-depth analysis of the future escort requirements of the U. S. fleet. Likely operating scenarios were developed, future threats postulated, and notional ship types developed to determine trade-off values with escorted units. Two ASW (anti-submarine warfare) destroyers — DXs — and two ASW/AAW (anti-air warfare) destroyers — DXGs — with various power plants were investigated and optimized into high, medium, and low threat scenarios. The results of the analysis recommended a minimum fleet escort level of 242, with a specified combination of missile and ASW escort ships. These ships were to be of mixed conventional and nuclear power plants.

The DX escort was envisioned by OPNAV and the Secretary of the Navy (SECNAV) as a low-capability, inexpensive successor to the DE-1052 Knox class — an approximate displacement of 4000 to 6000 tons and an estimated cost of $40 to $45 million. The notional DXG(N) — a higher capability, nuclear powered ship — was seen as almost half again as large and as costly as the DX. Follow-on studies noted a general fleet dissatisfaction with the speed and reliability of existing escort classes for aircraft carrier escort duty. This tended to add a strong bias against construction of additional single screw ships with a top speed less than 30 knots.

The pre-solicitation conference for the DX/DXG program was conducted for the prospective contractors on October 27, 1963.[3] No final number of destroyers to be produced was stipulated, but a minimum for the DX-type was set at 20. Various guidelines and constraints were set down from the start which were to severely restrict the desired design innovation. It was noted that historically 75% of ship operating costs were attributable to personnel. A premium was therefore stipulated on reducing life-cycle cost by reducing ship manning. Procurement of foreign combat systems was permitted to the extent of the restrictive Buy American Act.[4] This had the effect of limiting combat systems candidates to the few choices available from American producers.[5]

The Operational Requirements (OR) for the combat system suite actually went far beyond a statement of required performance, and listed the specific equipment that was to appear on the platform. The OR stated that the selection of weapons and sensors was governed by the ship missions and the availability of armament. It was explicitly stipulated that only operationally proven systems would be utilized.

> No new, untried weapons and sensors are desired or will be permitted. The Department of Defense has invested large sums over the years in designing, testing, and approving weapons and sensors to fulfill specific operational requirements. The ship procurement program is not the time to incur additional costs in designing and qualifying new systems.[6]

The general belief at the time was that the DX would be complemented by an extensive class of high-capability missile escorts. The DX was therefore given an ASW/shore bombardment capability with the following systems being stipulated in the OR: ASROC (Anti-Submarine Rocket), torpedoes, ASW helicopter, two gun mounts, and an AAW point defense system (limited to ship self-defense). With the restrictions of the Buy American Act and the necessity of using only proven equipment, the specific system options were drastically curtailed. Only one type of ASROC (the MK-16), helicopter (the SH-2), torpedo (the MK-46), and AAW point defense system (BPDMS AIM-7) fulfilled these criteria. The only real decision was in the type of gun mount to install. The old 5"/38 was relatively incapable and too heavily manned when considered against the newer 5"/54 mounts. Of the two 5"/54 mounts available, the heavyweight — MK-42 — had twice the rate of fire and ready service rounds, and 20^{o} greater elevation than the newer, lightweight MK-45. The decision to select the MK-45 was based not on performance characteristics in anticipated scenarios, but on the fact that the lightweight mounts would save 15 men — each calculated to add a 20 year sustained cost of over $170,000 to the ship.[7]

Consideration was given to possible combat systems conversion and improvement (e.g. the replacement of one 5"/54 with the 8"/55, and the replacement of the MK-16 ASROC with the MK-26 Tartar AAW and ASROC launcher) but these considerations would be dependent upon the hull design and power plant — both of which were left up to the individual contractor.

In February of 1968 the Navy issued a Request for Proposal (RFP) to various contractors soliciting proposals outlining preliminary designs for construction of the DX. The RFP specified maximum speed, cruise speed and range, and requirements on seakeeping as well as the specific payload, weapons, and electronics packages. The RFP indicated the capabilities and systems that the Navy required in the ship, and defined the optimal ship design as the one meeting those requirements at the minimum life cycle cost.

In July of 1968 three competitors were chosen — Litton, General Dynamics, and Bath Iron Works — and each awarded $10 million and 9 months to come up with a system, a production plan, and a bid. The Navy's objective was to maximize innovation and minimize cost through open competition.

Due to editing and subsystem integration requirements, the ultimate contractor, Litton, had only three months to complete all of the original work and major decisions relating to the final design.[8] In this time constraint the "older" naval architects at Litton reportedly decided to concentrate on giving the Navy what they thought the Navy really wanted in the DX — not necessarily what the RFP said. It was felt that the RFP requirement "...and systems analysis vernacular had been forced on ... (the Navy) ... by DOD."[9] The ultimate designers felt that the Navy really wanted a ship with greater capabilities than those specified, did not really want to go with the low manning requirements needed, would not accept unusually low design margins, and really wanted a gas turbine ship (even though no power plant had been specified in the RFP).

The lack of time available for hull testing led to a series of conservative decisions and "inevitable" mistakes.[10] Over-estimated power requirements based on inadequate scaling discriminated sharply against some power plant types. The only gas turbines approved for use by the Navy (the LM-2500) came in only one size. With the chosen hull form, it required a little more than two gas turbines to make maximum speed and one half of a turbine to make cruise speed. This would mean poor fuel consumption, an unwieldy three turbine plant, and a big ship.

An analysis of various power plants indicated that for the required performance, the cheapest candidate would be a CODAG (combination diesel and gas turbine). In order of increasing expense, the remaining candidate plants were three gas turbines, steam, and four gas turbines. Despite the promise shown by CODAG, Litton decided that it was too late to change from the original turbine design. The decision was made to go with three gas turbines in Litton's DP to the Navy in April of 1969. Soon afterwards, due to uncertainties relating to the combining gear for the three turbine plant, the decision was made to add the fourth turbine. Litton had earlier admitted that such an addition would greatly increase life cycle costs.[11] The resulting ship is considered to be at least 50% overpowered. Subsequent analysis has indicated that given greater time for hull design and testing, a longer ship could have been developed to take advantage of the lower power requirement, and the number of gas turbines required reduced from four to two.[12]

The resulting DD-963 has not proven to be an unsuccessful ship, but certainly the original aims of the CF/CD development concept were not achieved. It has been generally accepted both within Litton and among those involved in the DX program in the Navy, that Litton's primary aim was not to find the cheapest ship meeting the RFP's requirements, but rather to maximize the probability that Litton got the production contract. Litton continually tried to second guess the Navy's evaluation board.[13] There was no incentive to produce a cheap ship, only one that was cheaper than those designed by the competitors. Litton had never built a destroyer before and proposed to do it in a new, automated shipyard which fit together prefabricated modules of the hull. As Admiral Zumwalt recalled, "Litton took a lot longer time and spent a lot more money getting into production than it had expected to, or could recover from the Navy under the contracts."[14]

The contract that the Navy signed in June of 1970 called for Litton to provide thirty 8000 ton DD-963s at $100 million a copy. Despite the fact that the combat system had not changed, this represented quite a growth over the 4000 to 6000 ton, $45 million low capability ship originally envisioned for the DX program. Admiral Zumwalt later termed the growth a "miraculous metamorphosis" into a far too expensive ship with relatively austere capabilities for its size.[15] It would be this reaction to the growth of the DX that was to have a profound effect on the design of the follow-on escort class.

Certainly the Navy shares the largest portion of responsibility for the platform that it got in the DD-963. The requirement for the follow-on to the DE-1052 class had certainly been anticipated for a number of years, yet the final design decisions were forced into a three month period (the Navy spent another year deciding on the contract winner).[16] The Navy was not really looking for an integrated design to fulfill specified missions as much as it was simply looking for a hull to carry the combat system that had already been chosen. The RFP stipulated rough requirements, but the Navy provided no input to the contractors as to what it was willing to pay for an increase in individual capabilities. The design process was therefore largely open-ended, and led to a much more expensive platform than the Navy could probably have gotten with equal performance capabilities. The competitive process did not spur innovation so much as it served to shut off communication between the Navy and the individual contractors. As a result, the designers complained of having to guess what the Navy wanted, what it would be willing to pay, and what tradeoffs it would accept.[17]

Criticisms of the design and development of the DD-963 (as well as the LHA) led to a reappraisal of the CF/CD process. In the concept formulation stage it was noted that a needlessly large number of costly and protracted studies (often independent) were being done by many diverse agencies. Ship's mission statements were either non-existent or so broadly stated that any variety of ship's weapons systems could satisfy them. The contract definition type of procurement was seen severely to restrict the selection to a narrow set of already produced weapons systems. Performance data and costs were not available to study groups for more advanced combat systems, so the resulting CF/CD process could not achieve the desired result of performance optimization. As a result of the DD-963 experience the Navy decided to turn back to its own design activity in NAVSEA — the Naval Ship Engineering Center (NAVSEC) — for the design of follow ship classes.

The Total Package Procurement acquisition approach, of a single contract package for development and production for an entire ship class, was deemed unsuccessful for naval ship acquisition. The TPP approach gave way to the concept of "Design-to-Cost."

The Design-to-Cost (DTC) concept was introduced by DOD Directive 5000.1 in 1971. The intent of DTC was to make the unit cost of a weapon system conform to a value which had been established either prior to or very early in the design. The DTC concept has been defined as:

> Trading performance for cost until we are assured that a balance is achievable wherein needed military performance can be provided at a price we can afford for the quantity we need.[18]

A close look was also taken at the way that OPNAV had handled ship procurement up to 1971. The CNO staff was found deficient in that:[19]

1) There was no single organization for the establishemnt of ship characteristics for all types of ships. Efforts to establish ship characteristics extended into months as various concerned offices on the CNO's staff debated the specific requirements for the ship.

2) There was no standard procedure as to how the requirement derivation was to be achieved — thus each new program developed along a different track.

3) Since the process was seldom done the same way twice, those who were to establish the requirements were almost always unfamiliar with what to do.

This situation was seen to need some correction at the same time that DTC was gaining momentum in the Department of Defense. As a result, studies in 1971 and 1972 led to the establishment of the Office of Ship Acquisition and Improvement (OP-97) within OPNAV. OP-97 was disestablished and replaced by the Ship Acquisition Panel in 1974 after two years of leading the requirement/design dialogue.

Even with the introduction of DTC and the return of the design process to the Navy, it was recognized that there would have to be a fundamental change in the relationship between OPNAV and the Naval Material Command (NAVMAT) in order to produce a ship that would meet identified fleet needs. Communications between OPNAV and NAVMAT had traditionally been poor. This was in part caused by the lack of an adequate documentation process for OPNAV to submit operational requirements to NAVSEA (a subordinate command of NAVMAT) for design solutions. Definitions for required ship system performance ranged from a mixture of detailed hardware specifications for radars, weapons, and electronics, to extreme generalities (e.g. "best obtainable seakeeping qualities"). Certain requirements and performance were mentioned at great length by OPNAV while others were only casually mentioned or ignored.[20]

Prior to 1971 design activity was concentrated outside of NAVMAT with advice only being requested on a "what if" basis. The analysis groups in OPNAV, while recognized as being capable of performing force-level type operational analyses, lacked the technical depth in ship engineering needed to assess to a sufficient level of detail whether the specified requirements were compatible with the available technology, specified equipment, and cost constraints. The result was a back and forth dialogue between OPNAV and NAVMAT that ultimately resulted in the final characteristics definition. This definition was usually characterized by a mixture between hardware and performance specifications without any certainty as to systems compatibility. The DLGN-36 class is one ship that has been particularly singled out for its high level of compatibility problems at time of delivery.[21]

Decisions were often made by designers unknown to OPNAV or contrary to unspecified OPNAV requirements. There was often no documentation for the rationale of OPNAV decisions, and new personnel tended to generate change orders in terms of their own perceived requirements.

It was to alleviate these dialogue problems between OPNAV and NAVMAT that the Top Level Requirements (TLR) and Top Level Specifications (TLS) were developed. The objective of the TLR was to provide an adequate document for the specification of ship requirements to the designers in NAVSEA. The optimum system to meet those requirements, within cost constraints, would then be transmitted back to OPNAV through the TLS. The intent was to allow the ship designer — one more closely related to ship performance characteristics and integration requirements — to accept the burden from OPNAV of matching specific hardware to identified performance requirements.

It was Design-to-Cost and the TLR/TLS concept that served as the basis for the FFG-7 ship acquisition program.

IIB. The FFG-7 Class Acquisition Program

Early in 1970 it was determined to investigate development of a follow-on ocean escort class to the DD-963. It was obvious that the acquisition cost of the DD-963 class would preclude the huge buy of that ship necessary to fill the growing escort gap created by the decommissioning of the Navy's World War II vintage destroyers. Thus the PF (Patrol Frigate) program initiated by CNO Admiral Elmo Zumwalt in September of 1970 became the attempt to get the inexpensive, low-capability escort that the Navy had originally envisioned for the DD-963 program.

Preliminary studies indicated that a large number of ships in the 3000 to 3500 ton range would be the most feasible buy. Compulsory guidance provided by the Office of the Secretary of Defense had tied all weapons systems procurement to support of a NATO war in Europe. The effectiveness of all systems had to be proven in that environment. For the PF program (as well as Zumwalt's concurrently proposed Sea Control Ship), this meant that it was placed, hypothetically, into a 1980s variation of the Battle of the Atlantic. Given this scenario, a severe cost constraint, and the absence of AAW systems on most existing frigates, the CNO's subjective concept of the PF became a missilized ocean escort. The size and speed constraints would preclude a carrier escort role, and extensive ASW and shore bombardment capability was intentionally deleted. Thus the mission that the PF was designed around was that of an AAW ocean escort to supplement existing ASW forces in merchant, naval amphibious, and auxiliary ship convoys.[22]

The PF became the first combatant to be designed under the new Design-to-Cost philosophy. Estimated total program costs were based primarily on historical data from recent similar shipbuilding programs — such as the DE-1052 and the DD-963 — modified to reflect anticipated differences in such areas as procurement approach, systems engineering, program management, and ship configuration. The FFG-7 conceptual design phase was characterized by a large number of system level trade-off studies, resulting in the selection of characteristics for a single screw ship with primarily AAW capability. It was estimated that the ship would cost approximately $50 million and displace about 3700 tons. All PF program cost estimates were officially catagorized as "Class F" at this program stage. Class F is defined by OPNAV instruction as a "... ball park estimate ... generally calculated by merely escalating to current dollars an empirical cost for a similar ship and adding factors for expected changes in design, accounting procedures, or other economic considerations."[23] The cost constraint required that the entire ship system be designed to perform a specific mission just well enough so that the system would be "cost optimized" rather than "performance optimized" within given mission requirements. This involved deciding what each subsystem had to contribute to the total ship system, and passing the cost optimized rather than the performance optimized guidance to the ship designers.[24]

In contrast to the DD-963 development, it was decided that the PF would be an "in-house" design with shipbuilder assistance. Ship system design would be started by NAVSEC immediately upon completion of preliminary design, and developed for about four months. At this time, a competitively-selected lead shipbuilder would be brought in to participate in the final preparation of specifications and to prepare the detail design. This shipbuilder would then be awarded a contract to complete detail design and to construct the lead ship. Of the eight contending shipyards, the lead ship contract was eventually awarded to Bath Iron Works.

In June of 1971, as the ship proceeded into preliminary design, the CNO established a follow-ship cost constraint of $45 million and a displacement constraint of 3400 tons. Soon afterwards, an additional constraint on ship's manning was established at 185. Although the basic ship characteristics had been set, the CNO issued guidance directing that these characteristics be changed, if necessary, in order to keep the ship within the cost and displacement limits.[25]

The "design-to" constraints imposed by the CNO of $45 million and 3400 tons were actually 10% below the feasibility estimates developed by NAVSEC. The actual cost estimate for the selected PF design never went below $50 million, but NAVSEC spent a great deal of time and effort in trying to reduce that cost by reducing the size and other methods.[26]

The selection of the 3400 ton limit was called a "...pretty unrealistic goal" by NAVSEC's PF designers.[27] The displacement estimate for the selected design was actually 3695 tons. It has since been determined that an error was made in the transmission of this displacement figure to OPNAV. At the time that the maximum displacement decision was made, OPNAV thought that the design was for a 3470 ton ship from which only 70 tons would have to be cut, rather than 290 tons. This was a constraint which, as one designer put it, "... gave us pains for years thereafter."[28]

The manning constraint of 185 also did not reflect the true design requirement. NAVMAT studies showed that condition I manning (with no maintenance being performed) required 192 people. Condition III and condition V manning required 225 to 231. Vice Admiral Price, who was the officer in charge of the design as OP-03, decided to man the ship with condition I requirements, with the assumption that the Navy would develop a program of shore-based maintenance for each ship. Seven people were then cut from the 192-man requirement and the 185 figure arrived at.[29]

The overriding objective of the PF design effort was first to reduce the design to within the specified constraints, and then to control the design to remain within the constraints. Many of the participants within NAVMAT felt that the "design-to" constraints were dictated within the office of the CNO without adequate communication or dialogue with those responsible for the technical aspects of the ship design in NAVSEC.[30] Although the CNO set a limitation of 3400 tons, it is clear that he did not particularly want a 3400 ton escort. What he wanted was a $45 million escort with certain performance capabilities which happened to result in a ship design of 3400 tons. The displacement constraint was specified because a direct relationship was seen between weight and cost, with weight growth being much easier to monitor on a day to day basis.[31] The manning constraint was established with the idea that reduced manning would hold down ship size and also decrease ship life cycle cost.

In light of the DD-963 experience, the CNO's fears of cost escalation were not unfounded. With the Navy about to drop below a level of 500 ships for the first time since World War II it was deemed of primary importance to get a large number of hulls into the water as soon as possible. The $45 million acquisition cost was based on a fixed procurement plan for 49 follow ships (7 ships in FY 1975, 11 in FY 1976, 10 in FY 1977, 10 in FY 1978, and 11 in FY 1979). OPNAV saw an increase in unit cost resulting in a decrease in the total number of units procured. Zumwalt noted that for the price of one DLGN (Admiral Rickover's "enormously expensive ...pets", as the CNO called them) the Navy could have 2½ DD-963s or 5 PFs. Zumwalt saw either alternative as providing more fighting power than the single ship.[32]

In reviewing the acquisition policy of the FFG-7 (the later designation of the PF program), a primary question that must be addressed is whether DTC resulted in a more efficient design, or whether the somewhat arbitrary constraints on ship size and manning resulted in a ship lacking in basic capability. It was never adequately determined whether a higher performance ship could be produced for the same cost — or indeed what the cost/performance tradeoffs were. CNO guidance was explicit in placing performance consideration far behind those of cost, displacement, and manning. The DD-963 has been widely criticized for its lack of firepower in relation to its size, but the Spruance hull was designed with over a thousand tons of margin for major combat systems additions. By contrast, the FFG-7 was made specifically "tight", with a growth margin (after some preplanned configuration changes)[33] of only 50 tons. Obviously whatever the Navy got in the FFG-7, it is pretty much going to have to live with.[34]

Determination of the ship's performance characteristics was made primarily through subjective mission definition, systems availability, and weight limitations. The mission of the FFG-7 as stated in the Approved Characteristics of 24 October 1972 is:

> To provide self-defense and effectively supplement planned and existing escorts in the protection of underway replenishment groups, amphibious forces, and military mercantile shipping against sub-surface, air, and surface threats; and to conduct ASW operations in conjunction with other sea control forces tasked to ensure our use of essential sea lines of communication.[35]

The FFG-7 was intended to supplement the planned and existing fleet of escort ships and to operate primarily with non-strike forces. As such, the PF was envisioned as an AAW ship with limited ASW and anti-surface capability, and without excessive speed.

No speed requirement was specified for the ship, but the CNO stipulated that the PF would have one-half of a DD-963 power plant with whatever performance that resulted.[36] Two LM-2500 gas turbines were utilized, and a single shaft was chosen for a savings of $3 million and about 400 tons over a twin screw ship.[37] The resulting speed made the FFG-7 unacceptable for carrier escort duty as had been anticipated.

During the early feasibility studies when the initial characteristics of the FFG-7 were established, a large number of trade-off studies were made to analyze the performance and cost impact of numerous payload mixes and platform features. Since the FFG-7 would be a supplement to existing escorts, the ASROC capability was deleted and the single purpose MK-13 missile launcher installed. The utilization of a lower capability sonar was selected for a 96 ton saving.

It was determined that a lightweight OTO Melara gun mount would save at least 16 tons over the MK-45 5"/54 that was being installed on the DD-963s, and that the OTO's MK-87 gun fire control system would save 1½ tons over the 5"/54's MK-86 system. The 35mm OTO Melara was originally stipulated for installation, but due to questionable capabilities and availability, the gun was given minimal priority in the design (as evidenced by its ultimate location and poor field of fire).[38]

In all, 1469 tons of capability and equipment were deleted from the original notional PF design and 205 tons added to bring the ship into displacement constraints. Of that 1469 tons, 614 tons related directly to combat systems capability and 239 tons to the crew reduction from 253 to 185. Of the 205 tons added, only 47 tons were directly related to military performance — thus illustrating, as one designer pointed out, "... that it is difficult to design a warship in a peacetime environment."[39]

Quite clearly the DTC philosophy did accomplish its principal objective in constraining the unit production cost of the FFG-7. It has been established that the FFG-7 would have displaced closer to 5000 tons (a 40% increase) without DTC.[40] The question of whether or not the FFG-7 is fully capable for its assigned mission is one that is much more difficult to answer. In order to keep the design "tight" a fine distinction had to be drawn between minimal essential performance requirements and excessive performance capabilities. In the absence of any adequate method to quantify performance for the entire ship system, the determination of capability remains rather subjective and strongly dependent upon individual perception of naval requirements. This issue, the crux of the performance/cost tradeoff process, will be discussed in detail in later sections.

IIC. Current Ship Development Programs

In the wake of the DD-963 and FFG-7 programs, combatant ship design proposals blossomed to encompass the rapidly developing platform and combat systems technologies. A general consensus developed in the Navy that the FFG-7 would remain the least expensive fleet escort that the Navy could produce. With the current procurement cost exceeding $250 million a copy (in 1980 dollars) the "minimum" price is not insignificant. In the face of a limited procurement budget and escalating ship costs, the Navy has increasingly found itself unable to provide adequate justification for embarking into completely new avenues of technological development.

Air Capable Platforms

The Sea Control Ship (SCS) was seen by then-CNO Admiral Zumwalt as a key element of his "low-mix" force in the early 1970s. Nominally envisioned as a 14,000 ton, $120 million low capability air platform (3 VSTOL aircraft and 14 helicopters) for military convoy protection, the SCS received a cool reception in Congress and died altogether under Zumwalt's successor.

The question of a follow-on carrier to CVN-70 went through numerous gyrations between a medium-sized CV (or CVV), a conventional fossil-fueled large CV, and a repeat of the Nimitz class CVN. Congressional authorization and presidential concurrence were finally received for the last proposal — CVN-71 — in late 1979.

Advanced Naval Vehicles

The development of advanced platform technology in the early 1970s was expected by many to shape the future of the surface fleet. Under the encompassing label of "Advanced Naval Vehicles" the most promising and heavily funded designs were the air cushion vehicle (ACV), the surface effect ship (SES), and the hydrofoil craft.

The ACV was utilized for the "JEFF" prototype landing craft and was eventually incorporated as a major operational adjunct to the LSD-41 amphibious ship program.

The SES was the Navy's most heavily-backed ANV. Basically an air cushion vehicle with water-penetrating side walls, the SES has virtually unlimited size potential with speed limits over 100 knots. The concept was envisioned for use both as a platform for high performance aircraft and as a high speed fleet escort to succeed the DD-963 (the DSX Program) and the FFG-7 (the FFSG program). Problems of underway maintenance and increasing development costs raised serious doubts about the program, and it was the Navy's inability analytically to "prove" the military worth of such a high performance surface craft to OSD and Congress that eventually resulted in a halt of prototype development.

After a decade of testing a number of patrol hydrofoils the Navy pushed for a major NATO buy of the craft in the early 1970s. Significant differences soon arose among the buying parties — primarily Italy and Germany — as to the craft size and configuration. This conflict, coupled with increasing foreign doubt as to U. S. acquisition intentions, led to a dissolution of the NATO program. The United States had intended to authorize the purchase of 30 PHMs (patrol hydrofoils) in 1975, but as a result of cost growth and schedule slippage only six were authorized for purchase in 1976 (and these primarily to sustain German interest in the program). The primary problem was, again, the inability of the Navy to "sell" the PHM concept to OSD and Congress. The craft had significant speed capabilities, but were severely payload limited, did not have particularly good operating or maintenance records, and required significant support facilities. Against these drawbacks the Navy could not demonstrate a satisfactory military need for the product. The last five of the six PHMs are currently under construction, but Secretary of Defense Harold Brown expressed the predominant OSD and Congressional sentiments when he stated in 1978, "I continue to think the program is of very limited value..."[41]

A final ANV program that showed significant promise in the eyes of some designers was the SWATH (Small Water-Plane Area Twin Hull). About ten years old, the concept showed significant improvement in seakeeping ability that could double helicopter operating time underway. The major development problem is the lack of an active sponsor in OPNAV to persuade OSD and Congress that the military utility is worth the development expense.

Aegis

In November of 1963 the Advanced Surface Missile System (ASMS) project was inaugurated to develop a surface-to-air missile system with the "tightest" possible reaction time. A total system designation package was developed and the Aegis Weapon System Engineering Development contract signed with RCA in December of 1969. The Aegis system became operationally capable in 1974 and assumed the unique position (in terms of conventional U. S. ship design) of a combat system in search of a hull.

Aegis was originally scheduled for the DLGN-38 (later CG-38) class, but when Congress reduced that class form 23 to 5 ships in 1971 it was evident that the class would be completed too early for the AAW system. In January of 1972 the CNO proposed a DG class designed specifically for Aegis. At the same time, Congress began investigating the question of limiting high-capability strike group warships to nuclear propulsion. In May of 1973 the Secretary of the Navy directed consideration of both a gas turbine-powered DG and a nuclear powered DLGN for Aegis. By the end of the year both of these proposals had been cancelled and the CSGN strike cruiser was under consideration. Also proposed was the backfitting of Aegis into USS Long Beach (CGN-9). In June of 1975 the Secretary of Defense directed the development of both a gas turbine ship and the CSGN to carry Aegis. In April of 1976 Congress rejected the CSGN proposal, and later that year the President rejected the CGN-9 backfit.

While this was going on, work had been done to adapt Aegis to the basic DD-963 hull and power plant. By April of 1976 the preliminary design of the DDG-47 was completed. The Secretary of Defense approved the DDG-47 program in December of 1976 and Congress authorized it in 1977. Plans also proceeded for a nuclear-powered cruiser class of Aegis ships — the CGN-42. By the end of 1979 this program had been shelved due to excessive cost.

The unique aspect of the DDG-47 program is the "topside down" design philosophy — the ship design being somewhat driven by the combat system package. To facilitate the development program the project was chartered in NAVSEA and the project manager, Rear Admiral Wayne E. Meyer, was given the authority and direct responsibility for development of both the ship and the combat system. With the possible exception of the Polaris program, this was the first time that a single officer would be given full responsibility for the successful development of a warship.[42]

Displacing 1000 tons more than the DD-963, the lead CG-47 (the hull designation was changed in January of 1980) is under construction by Litton Industries and is scheduled for delivery in January of 1983. The Navy hopes to purchase two CG-47s for each carrier.

Surface Escorts

The number of available fleet escorts continues to be a perceived deficiency by the Navy, and one that must be addressed in the immediate future. The DD-931/945 and DDG-31/37 classes are scheduled to begin retiring in the mid-1980s, and the DDG-2, FF-1040/1052, and CG-16/26 classes in the mid-1990s. With a seven year development time for a new warship class (utilizing existing combat systems) developments for the follow-ship classes to the DD-963 and FFG-7 have been under consideration for several years. The failure to obtain ANV funding has focused consideration on conventional hulls and combat systems — with serious question as to the availability of acquisition money on the one hand, and technological capability to meet the 21st century threat on the other.

The CNO issued an OR for a follow-on to the FFG-7 — the FFGX — in 1977. Preliminary conceptual studies were begun, but with strong competition from more critical projects the program never gained momentum. In late 1979 the CNO proposed a completely new concept of developing a class of small, inexpensive frigates for use by the naval reserve forces. The proposed FFX is nominally envisioned as one half of an FFG-7 — about 1800 tons and 270 feet — with an austere armament. The impetus behind the concept is not completely evident, but strong criticism from various factions has already arisen against the FFX idea.

The Spruance class is currently close to completion with the last of the series of 30 launched in 1979. Four missile-equipped DD-963s — DDG-993 - 996 (the Kidd class) — originally ordered by the Iranian Navy will join the U. S. fleet, and what will probably be the last Spruance — DD-997 — has also been authorized.

Study has been underway for some time in OPNAV and NAVSEA as to the follow-on class to the DD-963 which will replace the DDG-2 class in the late 1980s and early 1990s. In December of 1975 the DDX program was initiated by NAVSEA. The primary purpose of the program was to draw conclusions on desired characteristics for the Navy's next generation of destroyer in order to provide some orientation to the Navy's research and development (R&D) programs. Evaluations of alternate combat suites were made and ship feasibility studies were initiated in March of 1977.[43]

In October of 1977 the CNO issued the OR for the proposed DDM, with the DDX characteristics being incorporated into that program. Eight alternative ship programs were studied for the DDM — all of which retained the basic hull and propulsion plant of the DD-963 as directed by the OR. In March of 1978 the DDM designation was officially changed by OPNAV to the DDX. In April of 1978, the DDX OR was cancelled by the CNO, primarily because of a disagreement within OPNAV on the validity of the DDX mission as described in the OR. By that time the DP was essentially complete, although no longer valid.

Shortly after the cancellation of the DDX OR, a new study effort was initiated to determine the future combatant requirements of the Navy. In response to a CNO request, OP-03 issued the DDX Study Directive which established the CNO DDX Study Group. The objective of the study was to define alternative capabilities of a surface combatant capable of supporting battle group operations and fulfilling cruiser/destroyer missions. Boundaries on the desired ship size ranged from a low of 3500 tons and $200 million (FY 1979) to a high of 8900 tons and $700 million. Fiscal year 1984 was defined as the funding year for the lead ship of the class. What was desired was a "mid-mix" ship — significantly less expensive than the DDG-47 and yet significantly more capable than the FFG-7.[44]

NAVSEC was given responsibility for overall preliminary ship configuration. The alternatives selected by the DDX study group for analysis included 11 basic alternatives, four of which were existing classes (FFG-7, DD-963, DDG-993, and DDG-47). The seven new baseline DDX alternatives ranged in capability from the FFG-7 to the DDG-47. The study group report was distributed in June of 1979, but by December, when approval was given to enter the conceptual phase, the combat system was still far from being set. Strong pressure had been applied by the Aegis community to provide at least some

Aegis capability to the class. The problem then became one of size and cost growth as the DDGX (as it was now designated) began to resemble the CG-47 design. In addition to some Aegis capability, vertical launched missiles and a VSTOL or helo capability were considered likely. Cost and weight constraints would drop the CG-47's 5"/54 mounts in favor of a 76mm gun (ostensibly to provide some kind of warlike appearance to the otherwise flush decks). The specific procurement arrangements have not been decided upon, but indications are that a DTC base (with possible size restrictions as applied to the FFG-7) would be utilized with greater contractor involvement in the initial design and development.

As the only active design program for a new (but not authorized) ship class currently ongoing in the Navy, the DDGX is widely regarded as a "last shot" prospect for the surface fleet.[45] Strong competition is likely from industrial and Congressional factions who are pushing for additional or modified FFG-7s, DD-963s, and CG-47s as an alternative to embarking on a costly new design and development program.

The use of Design-to-Cost in the FFG-7 development program has been widely praised for its resulting in a ship optimized to a low procurement cost. Although ideally suited to the production of a "low-mix" platform, it is not clear how DTC can be modified to allow platform optimization to any specified level of higher system performance. The success of DTC has been the willingness to completely subordinate performance to cost constraints. The ship projects described in this section demonstrate the Navy's desire to embark on programs optimized to some specific performance requirement. The Navy's ability to obtain program funding for the number of ships desired will largely depend on an ability to demonstrate an incremental performance increase with cost. DTC cannot do this. A system that might is still awaiting development.

IIIA. The Ship Design Process

The Deputy CNO for Surface Warfare (OP-03) is charged with determining requirements, force levels, and major characteristics of ships of all classes other than submarines and aircraft carriers. In the area of Research, Development, Test and Evaluation (RDT&E) OP-03 determines surface ship requirements, establishes priorities, coordinates integration and assimilation into the fleet, and recommends approval for service use of surface systems, weapons, and equipment. OP-03 is resource sponsor for about 25% of the Navy budget and controls about 70% of the major naval vessels.[46]

It is the job of OP-03 to accept and synthesize the inputs from systems analysis, OT&E, tactical development and evaluation (Tac D&E), and combat systems development activities, and to provide fleet requirements to NAVSEA for ship design and production within specified constraints. Ideally, the NAVSEA designer develops several notional ships, each reflecting a different set of operational requirements. These are translated into comparable ship acquisition cost estimates. These alternatives, each satisfying a unique set of operational requirements with an associated cost, are then traded off until OP-03 selects a combination which offers the desired performance/cost balance.

There are two primary approaches which can be taken in the design of a new ship.[47]

1) "Topside Down" — This involves the design of the whole combat system and all of the subelements to meet a set of established performance requirements. In other words, designing a ship to fulfill a specified mission.

2) "Bottom Up" — This approach starts with a group of separately developed combat subsystms and equipments, and pulls them together into an integrated combat system on an established platform.

All recent Navy ship designs (with the limited exception of the CG-47) have been based on the "bottom up" approach. This is more economical and entails less risk, but it has resulted in the delineation of ship specifications in terms of specific equipments rather than acutal ship requirements.

The bottom up approach has been universally criticized by the ship design community for its failure to allow the designers to perform any real subsystem and equipment tradeoffs. The predominant feeling in NAVSEA has been that OPNAV analysis groups are capable of performing force level analysis but lack the technical depth of ship engineering needed to evaluate, to a sufficient level of detail, whether the requirements for the ship are compatible with the specified equipment. The TLR and TLS were developed to try and overcome this perceived deficiency.

The objective of the TLR is to specify operational requirements and the TLS to match hardware to those requirements. A survey of various combatant TLRs indicates that this objective has not been met. The TLR does list performance requirements, but in every case these general requirements are coupled with a partial hardware list and further performance contraints that restrict hardware selection to a few or a single model.[48] For the most part, this is the result of a predetermination in OPNAV — molded by a variety of forces — as to what the proposed ship should be before NAVSEA is ever brought into the design picture. From the perspective of NAVSEA designers, subsequent communications with OPNAV are most often restricted to a series of "what if" questions regarding combat systems options. There is little or no explanation of intent, and often little time for NAVSEA to respond with adequate technical depth.[49]

There is certainly some basis for the charge that OPNAV does not effectively use the design expertise that is available in NAVSEA. The DDX study group was established in 1978 to select configuration alternatives for the proposed ship. The group consisted of seven naval officers appointed by OP-03 (1 rear admiral, 2 captains, 3 commanders, and 1 lieutenant commander). In order to get "up to speed" on current U. S. Navy programs as quickly as possible, over forty briefings were made to the study group on subjects ranging from ordnance and electronics development programs to habitability. The study work was done on a "... very demanding time schedule, and, in general, in a rather informal way."[50] The OPNAV study was carried out despite the fact that a DDX program had been initiated by NAVSEA in 1975 — over two and a half years earlier — to evaluate DDX combat systems alternatives.

There is a strong feeling in NAVSEA that OPNAV not only does not specifically know what it wants in a ship, but is not exactly sure when it wants a new ship at all. The EPA (Extended Planning Annex) is supposed to provide this guidance for OPNAV, but cases still exist, as in the DDX, where NAVSEA initiates preliminary ship studies to fulfill follow-on requirements it sees coming up, but for which OPNAV has not yet established an OR. Even when an OR is promulgated, the design is often perceived as being driven by a simple follow-on timetable — i.e. "it's about time to build another ship"[51] — rather than an established mission requirement for a particular platform. Both the FFGX and DDX had such origins. The Navy has expended tremendous resources in the conceptualization of the DDX without ever having established that it has missions that cannot be fulfilled by ships already in production.

The primary problems in the OPNAV/NAVSEA interface include:

1) Tremendous outside constraints which severely limit OPNAV choices in determining ship characteristics;

2) Lack of meaningful dialogue coupled with a poor OPNAV understanding of the design impact of various performance criteria;

3) The failure of OPNAV to quantify total ship performance to provide for meaningful cost tradeoffs.

A modern combatant is comprised of approximately one hundred highly integrated major subystems. In order to provide adequate interface and support for each subsystem the entire ship design must, at some point, be addressed as a single unit. The impact that a single combat subsystem has on the overall ship design — in terms of weight; center of gravity; power, water, and other support requirements; maintenance; and personnel is only marginally understood in OPNAV and is seldom adequately addressed in the stipulation of hardware requirements.[52]

The primary configuration dialogue that exists between OPNAV and NAVSEA is a series of inquiries regarding subsystem impact in terms of dollars (or other design constraints). Primary NAVSEA analysis is aimed at generating answers to OPNAV questions rather than driving an integrated approach by operator and designer to maximize performance. From the NAVSEA point of view, OPNAV seldom seems to know what it wants in terms of specific performance requirements, but rather designs into established size/cost constraints. It is not uncommon in development programs for the TLR to be adjusted to reflect requirements that have been or can be met, rather than to delineate requirements that must be met to perform an identified mission. As a result, the

TLR most often simply reflects the design rather than guides it.[53]

Even to this extent, OPNAV seldom addresses the design problem directly to NAVSEA. The majority of surface line officers assigned to be OPNAV program sponsors have been criticized for not understanding the design process and not being capable of communicating a request for what they actually want. The result is a total system composed of disparate blocks that must be integrated through costly land-based test sites or other means prior to ship construction. As the PF project manager put it, "... we create only 'shopping list' ships occasioned by necessity."[54]

The lack of OPNAV/NAVSEA communication leads to such results as the imposition of arbitrary constraints imposed exclusive of design considerations. The FFG-7 is an excellent example of a ship arbitrarily constrained by displacement with the actual intention of controlling cost. It is entirely possible that a larger hull, providing greater design margin for future growth, could have been constructed for the same unit cost. Even if the unit cost had risen slightly, the increase in hull flexibility might have proven cost-effective. The DDGX is facing a similar constraint without adequate justification. Designers complain of having to guess what the CNO <u>actually</u> wants in a platform by what he <u>says</u> he wants, and then "leaning" the design in that direction.[55]

Arbitrary or unexplained constraints are imposed at a variety of levels in OPNAV often well removed from any NAVSEA contact. An established characteristic for the LSD-41 class was a sustained speed requirement two knots greater than that of the amphibious fleet — without justification. A reason offered by an OPNAV program sponsor for the additional two knots was because, as commanding officer of an LST-1179 class ship, he could never keep up with the fleet. He claimed that the LST didn't make designed speed and wanted to guarantee that the LSD-41 would maintain sustained speed. In his view, the best way to do it was to increase the requirement above and beyond what was actually needed.[56] The requirement for two additional knots may seem small to an operator, but might require a major power plant reconfiguration at the design level with a massive impact on the entire ship design and cost. Adequate design documentation and improved communications between OPNAV and NAVSEA could eliminate many such problems.

It is the responsibility of NAVSEA to perform "trade-off" studies to develop whole ship designs compatible with mission requirements. Although design constraints may be established by OPNAV, the trade-off consideration is fundamentally performance versus cost. Within a maximum acquisition cost combat subsystems are ideally subjected to rigorous evaluation until an optimum balance of total ship performance is achieved to meet established mission requirements. In reality such tradeoffs are seldom made.

The SQS-53 sonar was chosen for the DD-963 without a determination as to whether the increased performance was worth the additional weight and cost over other models. No study was made to determine if the fleet really needed this performance.[57] The MK-45 5"/54 gun has evolved as the Navy's primary surface gun system — yet the gun development and subsequent selection choice for a number of ship classes was based almost solely on its low manning requirements. It remains to be seen whether the performance tradeoff for the newer system is worth the decreased operating expense.

The general feeling in NAVSEA is that it is not the designer's role to assess performance — that this role belongs to OPNAV (just as OPNAV keeps saying).[58] But the primary problem is the inability of OPNAV to quantify total ship performance.

Tools have been developed by NAVSEA to establish marginal cost factors about a baseline design for the commodities of weight, space, electrical power, manning, etc. It is possible to estimate the shipboard cost influence of a wide variety of subsystems without the necessity of specific design studies. The designer can thus determine the least cost ship for a specified performance level. In a notional 3500 ton destroyer design, the following figures give an example of the approximate marginal cost per unit of the indicated parameters:[59]

Parameter	Cost Factor
Manning	\$23,300/man
Electric Power	\$742/KW
Space	\$336/ft^2

Using the appropriate cost factors, the total influence of ship cost for competing subsystems can be determined by simply multiplying the parameter quantities by the appropriate marginal cost and summing the results.

Designers have the capability of determining incremental costs, but the factors are virtually useless since there has been no method developed of determining incremental performance values — i.e., there are no corresponding marginal performance factors to work with. It can readily be calculated what the cost impact is of adding one knot to a ship's speed, but no one can quantitatively determine what one additional knot does for the ship's performance. The cost increase may be calculated at 2%, but what is the corresponding performance increase? If the performance increase cannot be determined, NAVSEA asks, how does OPNAV know that that is what it is willing to pay for? This is really the fundamental question that NAVSEA would like answered, and it is waiting for OPNAV to supply that answer.

In July and August of 1979 an engineering workshop commissioned by NAVSEA was conducted at the Center for Advanced Engineering Study at MIT.[60] It was the purpose of the workshop to investigate the process of ship design at NAVSEA and make recommendations to bring greater effectiveness to the organization in turning out optimum ship systems.

The primary problem focused on by the study is the lack of NAVSEA impact on ship configuration decisions. As a result, NAVSEA's role has largely become one of ship procurement rather than systems design. A major cause for this was identified as the increasing isolation of NAVSEA designers from the decisionmaking process. Whereas the old Bureau of Ships was equal in status to the line community under the Secretary of the Navy, the succeeding NAVSEA directorates are subordinate to the line and located in the chain of command several levels below the CNO.[61] The result is a lack of real influence on OPNAV decisions and an effective isolation from the political environment which determines the fate of projects.

Much of the loss of status is beyond effective NAVSEA control, but a number of deficiencies were identified within the organization which inhibit the overall design objectives. A primary problem was seen as the lack of innovation in total ship design. It was noted that no formal method exists for anticipating future ship and system needs, and that there is no formal process to obtain R&D community inputs at the early stages of design. SHAPMs tend to focus narrowly on procurement costs and schedules, with a reluctance to "make waves" or take risks by embarking on innovative design paths. Most

NAVSEA studies and activities were characterized as being "reactive" in nature — used primarily to justify previous decisions.

The workshop also noted a general lack of knowledge of the correlation between subsystem parameters and the total ship system, and a lack of continuity between design projects. This, coupled with delays in establishing ships' missions, has resulted in "crash" design efforts for most ship classes. A review of current project design decisions tends to bear out each of the identified deficiencies.

The study group approached the topic and generated its recommendations on the presumption that greater NAVSEA influence at all levels of the OPNAV decisionmaking process actually <u>can</u> make a difference in optimizing ship design, development, and performance. A thorough analysis of the process by which OPNAV establishes its ships requirements is necessary to conclude whether that contention is indeed valid.

IIIB. The Establishment of Surface Ship Performance Requirements

It is the role of OP-03 within OPNAV to establish force requirements and ship characteristics for the majority of combatant classes. Inputs are obtained from the areas of combat systems development, tactical development and evaluation, and operational test and evaluation which are analyzed primarily through OPNAV's Systems Analysis Division (OP-96). Specific performance requirements and constraints are developed and communicated to NAVSEA for the production of ship designs.

There exists no set program in OPNAV for the initiation of new ship construction projects. Among the ways that the need for a new class of ship is identified in OPNAV are:[62]

1) By OP-03 as the result of a) the need to replace old ships (e.g. the LX/LSD-41) or, b) a major new shipborne weapon system is ready to go to sea (e.g. Aegis DX, DDG-47).

2) By OP-96 as the result of having examined new threats, translated them to new missions and scenarios, and having decided that new hardware is necessary (e.g. DX/DD-963).

3) By the CNO himself as a result of advice by the CNO Executive Board, other admirals, or anyone else who can influence his thinking (e.g. PF/FFG-7, SCS, CSGN, CVN-71, FFX).

Over the past two decades the Navy has constructed only ten new classes of combatant escorts (see Appendix II). With an expected service life for a given ship type fairly well established (25 to 30 years for most classes depending upon class value, modernization, and upkeep) there is a service-wide feeling that the Navy should be better able to anticipate its needs and establish some type of design and development continuity. It was for this purpose that the Extended Planning Annex (EPA) was established in the early 1970s. The objective of the EPA is to help various activities better to anticipate impending design needs by establishing a schedule of replacement times for active Navy ships. Unfortunately, the EPA does little more than establish a replacement schedule based upon anticipated obsolesence of current units in terms of a general service life expectation. There is no direct correlation to combat subsystem development or anticipated threats.

As such, little guidance is provided to help the future platform designer anticipate hardware or capability requirements.

Ship design and construction currently takes upwards of seven years. The problem of being able to anticipate fleet needs even that far into the future is difficult to overcome in this age of rapid technological advance. Nevertheless, with the exception of the CG-47, no recent ships have been commissioned with combat systems that hadn't been designed, built, and proven prior to the initiation of the platform design. The primary causes for the last minute design effort that seems to plague each class are the result of 1) non-technical pressures both inside of and outside of OPNAV placing constraints on the program unrelated to ship performance, and 2) the failure of systems analysis to "prove" design value and thereby overcome arbitrary constraints.

The Office of the Secretary of Defense

In the early 1960s the U. S. Navy's acquisition policies were brought into DOD's Planning, Programming, and Budgeting System. The objective of the centralized system is to provide for maximum cost-effectiveness by preventing parallel acquisition programs in the services, providing a systems analysis approach to the determination of integrated defense requirements, and providing a DOD review system to redirect or cancel high risk programs which cannot be brought in under cost constraints.

In order for a Navy ship acquisition program to be carried out, the project must receive initial and periodic approval by OSD and must be included in the DOD FYDP. The Navy's overall force planning system is a fairly extensive process with the objective of obtaining OSD, and more important, Congressional approval for desired programs.

Approved "major programs" in DOD (i.e. RDT&E costs in excess of $50 million or estimated production costs in excess of $200 million)[63] must be documented with Development Concept Papers (DCPs). DCPs are developed for major milestone decisions in the life of the major program and are reviewed and updated at each stage of the Defense Systems Acquisition Review Council (DSARC). Approval must be obtained from the Secretary of Defense at each of four DSARC levels in order for a project to proceed.

It is the concern of the OSD offices of Program Analysis and Evaluation

(PA&E) and Research and Engineering (DDR&E) to review Navy ship programs and to determine whether they adequately fulfill a real military need. PA&E and DDR&E examine the Navy's analysis, technology, scenarios, and assumptions. During DSARC they determine the military value of a force having the new advanced ship as compared with an alternative force attempting to accomplish the same mission.[64]

Although the DOD review process does not appear to have made many significant long-range alterations in the Navy's procurement plans it nevertheless serves as an additional level of analysis and decisionmaking to inhibit long-range planning efforts. As dependent as ship procurement is on individual opinion and personality, the turnover of DOD personnel injects new force ideas which often preclude serious planning on any longer basis than the next budgetary cycle. The turnover also presents the problem (experienced throughout procurement activities) of continually having to educate personnel in the planning and acquisition process. One DOD analyst has noted with some concern the fact that the DOD acquisition process for major combat systems is not well understood by most DOD personnel who are responsible for it.[65]

Despite the fact that the Navy usually gets what it wants from DOD (although that "want" is usually oriented to what it thinks it can get included in the FYDP) there nevertheless exists an undercurrent of hostility toward OSD activities at the upper levels of the Department of the Navy. A large number of senior personnel have never forgiven Robert McNamara for reducing individual service prerogative in the area of procurement. A widespread feeling is that OSD is staffed by analysts who have little practical appreciation for defense needs and think strictly in terms of dollars.[66]

This relationship is exacerbated by the tendancy of OSD to study questions that many in the naval hierarchy would rather not see brought up. The individual platform sponsors in OPNAV (the Deputy CNO for Submarine Warfare (OP-02), Surface Warfare (OP-03), and Air Warfare (OP-05) — widely referred to as the "barons") have traditionally taken assiduous care to avoid questioning the validity of each others' programs. OSD has often invited hostility by probing for cost-effective solutions regardless of warfare specialty (e.g. by questioning the validity of the surface fleet, by investigating the use of diesel submarines, by analyzing the use of land-based aircraft to supplement or supplant the aircraft carrier, and by questioning the cost-effectiveness of nuclear propulsion.)[67]

It is for these, among other reasons, that the Navy has seen its traditional ally as the service-oriented U. S. Congress rather than the Office of the Secretary of Defense.

The United States Congress

The entire DOD budgetary process involves a number of set steps. The JCS force proposals are sent to the Secretary of Defense and are then integrated into the proposed FYDP. Individual service program plans are prepared and correlated into the OSD program. Detailed budget estimates for each service are consolidated by the Secretary of Defense, OMB, and the President. The FYDP is then finalized and the first year presented to Congress.

Obviously, program inclusion in the DOD budget does not guarantee that it will be funded — nor does exclusion from the original budget guarantee that it will not be. Budget estimates are considered by both the Armed Services Committee and the Appropriations Committee of both the House of Representatives and the Senate. The Armed Services committees are responsible for authorizing legislation to permit appropriations to be made, while the Appropriations committees are responsible for appropriating the funds. This wide Congressional program control began with the Military Construction Authorization Act of 1961 which stipulated that no funds could be appropriated for defense procurement of aircraft, missiles, or naval vessels unless preceded by Armed Services committee authorization. By 1963 all R&D carried out by DOD required such authority. The authority has continued to increase over the years, and today almost all procurement, all R&D, and military construction are directly authorized by the Armed Services committees before funds are appropriated.[68] The result of this arrangement is that the Armed Services committee action establishes the maximum amount which may be appropriated by Congress. As such, the Navy must not only sell its ship programs to OSD, OMB, and the President, but its case must be presented to four separate Congressional committees as well as to the entire House and Senate.

The increasing interest of the individual committees in military appropriations, despite the decline in the DOD budget as a percentage of the overall federal budget, is indicated by the tremendous increase in the number of committee hearings conducted since FY 1963. The following figures show the number of pages of printed testimony for each committee for FY 1963 and

FY 1973:[69]

	Armed Services Committee		Appropriations Committee	
	Senate	House	Senate	House
1963	570	835	1787	3376
1973	4387	2917	5308	8588

Over the years Congress has shown an increasing desire to control not only the DOD budget but program allocation. This is partly because of Congressional fear that if the Pentagon is left to its own devices, it will keep and cut all of the "wrong" things.[70] Congress has also found that the tremendous production expenditures involved make good political levers.[71]

There are a number of factors that work both for and against the Navy's position in selling ship programs to Congress. The nature of the process of selection of committee members is such that individual members are aligned with defense procurement interests (i.e. they often have major defense contractors in their home districts). As each major system has to be sold individually to Congress, the services have historically found it much more difficult to sell many different, cheap, limited single-purpose systems — such as Zumwalt's low-mix options — than to sell a few super-systems that can do everything. For one thing, the Congressional committees do not have time to evaluate complex mixes of units, and for another, there is great sensitivity to knowingly supplying American fighting men with anything but the best.[72] An example of this is the 1974 Congressional act (sponsored primarily by Admiral Rickover through his "special relationship" with Congress) which stipulated that all combatant ships in the Navy's strike forces be nuclear powered. Analysis presented in 1975 by OSD "convincingly demonstrated" that nuclear ships are more expensive to acquire and operate over their service lives than their conventional counterparts.[73] Other legislative restrictions include the Buy American Act which has effectively ruled out consideration of foreign-produced combat systems despite considerations of higher capability and lower cost.

Congressional decisions have played a major role in many recent ship classes that the Navy has purchased or considered.

— Congressional bias for large, multi-purpose ships was held responsible for the death of the SCS concept — the "key element of the 'low' side of the spectrum of sea-based air capability."[74] Admiral Zumwalt, the primary SCS sponsor as CNO, placed a large share of the blame for program cancellation on Admiral Rickover, whom he accused of interference in design contract award and a strong anti-SCS lobbying effort in Congress.[75]

— Congress has been held to blame for a large share of the cost and size growth of the DD-963. Admiral Zumwalt has noted suspiciously that Litton's DD-963 construction site is located in Pascagoula, Mississippi — home state of Senate Armed Services Committee Chariman John Stennis (Zumwalt also noted an "atmosphere of irregularity" in the fact that Litton's president — Roy Ash — was a strong supporter of President Nixon, and was later elevated by Nixon to the position of Director of OMB).[76]

— Congress has been considered a primary impetus behind the DDG-47 class in its insistence that the Aegis system complete development and go to sea on something.[77]

— The DD-997 — an additional Spruance class destroyer — was authorized in FY 1978 at the urging of Senator Stennis for the primary purpose of keeping the Pascagoula shipyard in work.[78]

— One of the primary considerations in the design of the DDGX has been that of survivability. Ordinarily this would not have received tremendous emphasis at the characteristics definition stage, but Congressional charges of poor survivability in the FFG-7 automatically pushed the question to prominence in the next ship design.[79] As a Litton designer has noted, "the Navy brass ... take as their goal maximizing naval effectiveness subject to congressional behavior."[80]

The Navy has yet to approach its stated goal of 250 escorts to support fleet operations. With the combined tendencies of Congress to limit shipbuilding funds on the one hand, but to demand that the Navy only purchase the best on the other, the escort fleet has been steadily moving away from that 250 ship goal. This situation has recently spawned the interesting concept of the FFX.

Officially, the FFX is to be a very low capability convoy escort for training and manning by the naval reserve forces. The World War II vintage destroyers now being used by the reserves are approaching the end of their service lives. Normally, aging active escorts would be relegated to reserve use to be replaced by new escorts for the active fleet. But official statements indicate that the predominantly 1200 psi engineering plants of the current active escorts are unsuitable for reserve operation and that a small gas turbine derivative (such as CODAG) is preferred.[81] A general feeling in OP-03 is that the CNO does not really want an escort for the reserves, but as Congress has traditionally taken the role of guardian of the reserve forces, this is the best chance the CNO has of getting a large number of austere platforms past Congressional approval. Congress will put a little "gold plating" on the ships to bring them up to an active fleet's low-mix capability, and then once built, the Navy can integrate them right into active fleet roles with predominantly active crews.[82] This scenario is primarily conjecture from non-decisionmaking personnel, yet such a motive by the CNO could certainly be considered opportunistic.

One of the most significant cases of factors outside of OPNAV controlling the development of a ship procurement program is that of the CVN-70 follow-on project. A major disagreement both within and outside of the Navy ensued throughout the 1970s as to what the follow-ship to the three ship CVN-68 Nimitz class should be. Admiral Zumwalt as CNO was pushing for the low-cost SCS — a concept rejected by Congress as lacking in air capability. Carrier and nuclear forces inside of the Navy, supported by President Nixon, were pushing for the CVN-71.

NAVSEA began development of the conventional CVV in September of 1972. The project was abruptly cancelled in early 1973 "... due to fears of the Navy brass that rumors of the project were jeopardizing the then-current effort to secure Congressional approval of another large nuclear carrier."[83] The CVV project was revived at a low profile in the fall of 1973, but few people in NAVSEC knew that it was going on. The CVV design, as envisioned in 1974, was basically 60,000 tons, one half of a CV-67 class conventional power plant, and a capability for 50 to 60 aircraft.

In August of 1974 Congressional legislation was passed providing that all combatant ships in the Navy's strike forces be nuclear powered. The CVV program was aborted and NAVSEA thinking reoriented to a CVN. With the support of President Ford, the Navy recommended a fourth CVN-68 for the FY 1976 budget. That recommendation was not accepted and the CVNX study group in NAVSEA looked at a smaller CVN in the fall of 1975. In the summer of 1976, with presidential support, Congress appropriated long lead funding for CVN-71.

After the 1976 election, President Ford reversed himself and came out in favor of a smaller fossil-fueled CV. President Carter supported this proposal. All long-lead funding for CVN-71 was rescinded by Congress, but no long-lead funding was provided for the follow-on CV.

In March of 1977 the CVV design effort was begun. Due to time and cost constraints imposed by the CNO (who was hoping for FY 1979 funding) the ensuing design study was characterized as a "...hectic series ... in a fire drill mode."[84] A three month conceptual design effort was squeezed into six weeks. But in March of 1977 Congress refused to reprogram funds to enable the CVV preliminary design to start, so the FY 1979 CVV procurement option was lost. As one designer summed up the problem, "the majority on the House committee which had to approve the reprogramming action were large nuclear carrier advocates who opposed the Congressional majority who favored the CVV."[85]

In the summer of 1977 Congress demanded that the Navy embark on a comprehensive reexamination of all sea-based platform alternatives. Without a concept design report ever having been completed, Congress authorized funds for a preliminary design to begin. Thus NAVSEC was simultaneously studying the fundamental program concepts while it was conducting specific trade-off studies.

Menawhile, momentum was growing in Congress for CVN-71, and such authorization was passed in 1978. The FY 1979 budget was vetoed by President Carter, and the failure to override by Congress resulted in CVN deletion. The President repeated his desire for a CVV, and in October of 1978 the CNO proposed a modified CV-67 design. In 1979, Congressional debate centered on a CVV versus a modified CV-67. But once again momentum was growing for a nuclear carrier, and the President finally acquiesced in CVN-71 authorization in late 1979.

The NAVSEC aircraft carrier design focus has followed the following pattern since 1974:

1974	CV
1975	CVNX
1976	CVN-71/CVV
1977	CVV/CVN-71/CV-41/VSS/DDV
1978	CVV/CVN-71
1979	CVV/CV-67
1980	CVN-71

Obviously the acceleration, deceleration, starts, and stops of the design efforts originating in the political arena seriously degraded the effectiveness of NAVSEC in producing an optimum platform. The standard joke in NAVSEC was, "Which carrier are we designing today?"[86] Authorization and funds for long-range planning frequently came unexpectedly and very late — when few design personnel were available to be assigned to the CV program. Design managers found themselves losing credibility with the engineers. Since the engineers didn't expect their work to be used, they made little attempt to be innovative or creative.[87]

Despite the political machinations it was ultimately intransigience at the executive level rather than the Congressional level that held up final approval of the CVN. The Navy got the carrier it wanted (or at least the one that the aviation and nuclear power factions wanted), and Congress was the driving force behind the authorization.

There is acknowledgement in the Department of the Navy that some Congressional action worked to the detriment of a number of Navy-sponsored programs. Insistence on high capability platforms killed the low-mix air-capable ship. Failure to look at procurement items from a total systems approach has resulted in force incongruities (thus cancellation of VSTOL aircraft R&D while a preliminary VSTOL CV project was approved and inadequate authorization for land-based support for the FFG-7 and PHM). But the naval hierarchy tends to view these problems as primarily the Navy's failure to sell Congress on total programs as opposed to individual systems. As one ranking officer in the Office of the Secretary of the Navy put it, "Congress is the best friend that the Navy has."[88] The ability of the Navy largely to get what it wants despite OSD or presidential disapproval is evidence of that.

The Deputy CNO for Surface Warfare (OP-03)

The determination of size, capability, and number of platforms to buy in a given class is largely the result of an intuitive reasoning process on the part of OPNAV as to the amount of acquisition money that can be worked into the DOD budget and sold to Congress in a given fiscal environment. The tradeoff has generally been between buying a medium number of high capability ships (favored by Congress) or buying a few high capability ships and a large number of low capability ships (Zumwalt's "high-low" — favored by OSD). The result has usually been that the high capability ships price themselves out of existence (e.g. CSGN and CGN-42), and that the low capability ships grow in size and cost, until the Navy ends up with a medium number of medium capability ships (e.g. DD-963) — a result which seems to please no one.

Forces within OPNAV itself played a major role in derailing the high-low concept in the early 1970s. Admiral Zumwalt was a surface line sailor whose destroyer background led him to focus on the low capability escort role and a philosophy that in almost any situation two or more ships are better than one. Unfortunately he did not share the special relationship with Congress of Admiral Rickover. Rickover continually preached the doctrine of modern and capable (i.e. nuclear powered) ships as the only force that could fight a real war.[89] His lobbying in Congress around the CNO resulted in the 1974 act requiring nuclear propulsion for all major combatant construction and, in Zumwalt's view, largely killed the high-low concept.[90] Low-mix came to a stop with Zumwalt's successor, Admiral James Holloway, whose aviation background focused his attention on the carrier strike group with its high-mix CVN and CSGN as the best options for the future Navy.

A rough determination of the division of the procurement budget in OPNAV is largely the result of tradeoffs and deals between the platform sponsors in OPNAV. A true balance of power has been deemed to exist in the organization, with the primary concern of each "baron" being to maintain his own prominence in the OPNAV organization.[91] The system is accepted as it is largely because it is felt that the internal competition will produce the best fleet balance. One result however, is that a lot of analysis that might "threaten" one of the sponsors is never done, and a lot of the "tough" questions about the Navy's future are never asked.[92] Another result is that the OPNAV sponsors undertake most of their analytical effort in response to various administrative and Congressional challenges. The primary analytical thrust is to justify positions rather than to move ahead into long range planning. OP-03 introduced the Surface Warfare Plan (SWP) in the mid-1970s to try and provide central planning focus for fleet development and procurement programs. The SWP is a fairly extensive analysis of fleet deficiencies, but the long range planning aspects are very limited and the mechanism for correcting shortfalls does not provide for any degree of coordination with activities outside of OP-03. The SWP is more a list of problems than a plan for providing solutions.

Even within the production constraints that are imposed by Congress, OSD, and the warfare communities in OPNAV on surface ship design, there is still a great deal of prerogative left to OP-03 in establishing and transmitting requirements to NAVSEA for development. The primary problem continues to be the lack of quantifiable measures of effectiveness to bring the decisionmaking process away from the "arbitrary" and "intuitive" reasoning that is now used to establish ship characteristics. To be sure, there are numerous practical problems to trying to quantify performance. A purely analytical basis for ship design presupposes a knowledge of:

1) The final combat system configuration of the ship being designed;

2) The configuration and tactical doctrine of the rest of the fleet when the ship enters service;

3) Realistic assumptions about the nature of enemy equipment and operaional doctrine from 7 to 37 years in the future.

Despite the fact that tremendous analytical facilities are available, and numerous expensive fleet studies are carried out each year, the general feeling in OP-03 is that any meaningful study would be too complex to carry out, that arbitrary constraints imposed down the line would negate the study findings, and that subjective reasoning by experienced operators is a far better indication of fleet needs. Unfortunately, requirements generation is often too heavily dependent on the intuition of experts in the Pentagon navy and seldom reflects information and opinions from current fleet and force commanders.[93] It must be pointed out though, that fleet operating limitations may preclude the collection of enough meaningful data to make the exploitation of such a source of information worth the time and expense.

There is no tendency in OP-03 to look at ships designs from an integrated combat systems approach. The triple threat environment — ASW, AAW, and SUW (Anti-Surface Warfare) — is viewed as three distinct threats, and the tactical and systems solutions are seen as combat system versus combat system rather than platform versus platform. Despite official doctrine to the contrary, OP-03 focus is primarily on improved combat systems in each warfare area, not on integrated ship configurations with a maximum <u>overall</u> performance in a fleet environment. Systems integration as it exists, is limited solely to assuring that various dissimilar subsystems can be connected and will work together.

The establishment of characteristics for a new ship class begins with the prioritizing of the three warfare missions — ASW, AAW, SUW. This is intuitively established in OP-03 by looking at current fleet units and deciding what the fleet needs more of. For example, the FFG-7 became an AAW escort because most existing fleet escorts were primarily ASW. It is then taken as "given" that certain equipments are associated with these missions. As cost and displacement constraints are imposed on the design, equipments are dropped from the low end of the warfare mission list until the desired ship size is achieved. The three warfare missions have basically the following associated equipments:[94]

AAW - 2D and 3D air search radars, missile launch and control systems, IFF, missile fire control system

ASW - sonar, ASROC, torpedoes, ASW helicopter

SUW - surface search radar, gun, gun fire control system

The FFG-7, as primarily an AAW escort, had ASROC deleted from the ship requirements, was given a low capability sonar, and was fitted with only a very limited capability gun system. No formal analysis was done to determine how a 76mm gun would fit into existing fleet operations, or if it would be even more cost effective to delete the gun, sonar, and torpedoes altogether. It was subjectively determined by individuals in OP-03 that as an escort, the FFG-7 should carry a gun and some kind of ASW capability.

Although the expressed feeling in OPNAV and NAVSEA is that there should be an analytical basis for the selection of hardware to fulfill mission requirements, the limited availability of such hardware largely precludes that process. Current DOD directives require that combat subsystems be available and proven prior to finalization of ship design. The objective is to preclude cost and development time overruns by restricting the introduction of high-risk technology. The requirement has achieved its purpose in past ship classes, but it severely restricts the options available to OPNAV in specifying ship requirements in the TLR. For example, if only a 5" gun is available for installation, OPNAV cannot levy the requirement for anything other than a 5" gun in the TLR. It also makes little sense for OPNAV to describe the requirements for a specific 5" gun if only the MK-45 5"/54 is available and practical for use. With foreign equipments excluded, OPNAV has a choice of no more than two or three systems to choose from in each combat systems category. On each platform it is generally cost constraint, not performance, that determines which of the two or three systems is to be used.

Nevertheless, considerations of hull and propulsion generally dominate requirements decisions while the ship's proposed combat system and concept of operations are subjectively determined. Most ship mission analysis doesn't take place until after the platform has entered the fleet.

One result of the "bargaining" approach within OP-03 to establish ship characteristics is a general failure to look at the ship as a whole unit and reduce many of the arbitrary constraints which work their way into the design. Some examples of arbitrary ship characteristics — the basis for which has not been analytically established, but which have been rigidly adhered to — include:[95]

— A 45 day stores requirement

— Endurance to independently transit the Atlantic Ocean at top speed

— Establishment of a maximum weight allowance for military payload

— Selection of a ship's speed

— Establishment of habitability requirements

A review of escort ship ORs and TLRs shows a standard pattern in many areas that indicates that certain performance requirements were chosen simply because they appeared that way on the last OR or TLR that was issued. Possibly in the absence of any analysis to prove the contrary, the TLR author in OP-03 could not think of any good reason to change performance requirements such as speed and endurance that had remained constant for years. The design impact of such criteria are largely unknown to the TLR originator, and the increased cost for increased performance requirements is never determined.

One area of seemingly arbitrary requirement establishment that has had a most profound impact on U. S. warship design is that of habitability. A NAVSEA study pointed out the following shift in design priorities for U. S. warships since World War II:[96]

		World War II	1970s
Design Priority	1.	Weapons	Electronics
	2.	Propulsion	Habitability
	3.	Electronics	Endurance
	4.	Endurance	Weapons
	5.	Habitability	Propulsion

In almost every warship class in the past three decades, habitability considerations — primarily in terms of space allotted per man — have continued to play an increasingly important role in design. Minimum environmental control standards were established by OPNAV in 1965 for all naval ships.[97] The following chart provides some comparison between minimum standards and space allocated in the DD-963 class ships:[98]

Space	Minimum Rqmt (ft^2)	DD-963 Space Allocated (ft^2)
Officers' Staterooms	1277	1748
Wardroom	532	702
Crew Berthing	4837	6087
Crew's Mess	882	1086
Crew's Rec Room and Library	140	480
Laundry	373	638
Post Office	68	96
Barber Shop	56	105
All Habitability Spaces	15,651	20,911

Excess Space Allotted 5260 ft^2 (33% over the minimum requirement)

In the development of the FFG-7 the CNO termed the 1965 standards as "outdated", and a revision is now underway in OPNAV. Preliminary indication is that the minimum standards will be raised still further.[99]

As more volume has been allocated to habitability, a decreasing volume and weight has tended to be devoted to military payload. Of the eight most recent classes of escort ships introduced into the fleet, the FFG-7 ranks next to last in allocation of weight to payload (9.0%), followed only by the DD-963 (8.5%).[100] Habitability review boards are manned predominantly by fleet personnel who give recommendation to the CNO as to desired minimum living standards. With no direct platform orientation, there is no understanding by board personnel as to what performance trade-offs have to be made to increase habitability standards. As such, there is little motivation to investigate austere options which may contribute to overall ship performance.

The ostensible objective of improving habitability conditions is to increase crew job satisfaction and thus improve personnel retention. Although such a connection might "seem" logical, there has been no actual analysis done to prove that such a correlation exists. On the contrary, motivational research has indicated that removing items of dissatisfaction from the working environment does not lead to job satisfaction. The general consensus among fleet operators is that men would rather be valued members of a well-armed crew with a high prospect for victory than live in comfort on a visibly under-armed ship with marginal capabilities.[101] The critical manning problems that the Navy is presently facing will probably result in even higher habitability standards. Without analysis to prove the benefit of this incentive, the Navy many very well be exacerbating its retention and ship performance problems in its efforts to solve them.

There are, of course, a number of forces which come into play in the allocation of platform space. Activities outside of OP-03, who often have little appreciation of the overall ship concept, often wield significant leverage in reserving some areas on a proposed platform. The Bureau of Medicine and Surgery has been particularly single out as such an activity. In the FFG-7 class, lengthy negotiations were conducted in order to get the Bureau to reduce a demand of 336 ft^2 for a medical treatment room to the 200 ft^2 that had been allotted that space in the design.

The general attitude toward the TLR in OP-03 is reflective of its limited value to the design effort. There is currently no set doctrine for the assignment of TLR authorship. It might be presumed that most surface ship TLRs would originate in OP-32 (Surface Warfare Division of OP-03), but the actual intent in assignment seems to be one of spreading the administrative workload around. One OPNAV division head noted that in his two years of experience in OP-03 he could discern no set pattern for TLR assignment.[102]

The original instruction outlining the TLR/TLS system was issued by OP-97 — the Office of Ship Acquisition and Improvement — and maintained by that office until its disestablishment in 1974. Cognizance over the instruction then passed to OP-37 — Ship Acquisition and Amphibious, MLSF, Mine, and Special Warfare Division — as a collateral duty, where it has long since slid into obsolescence. The TLR as it exists is considered more of an administrative burden in OPNAV than a useful planning tool.[103] Virtually everyone in OPNAV who has some interest in ships is on the TLR routing list, and it literally takes years for the document to work its way through the system. Those individuals who have authority to make changes to the TLR tend to feel the obligation to do so — seldom with adequate analysis or documentation. As a result, the TLR often bears little relationship to what is actually being designed and constructed. The FFG-7 was commissioned in 1977, yet Change One to the 1975 TLR was still circulating through OPNAV on its way to approval in late 1979.[104]

A large measure of this problem is disagreement in OPNAV as to what the actual use of the TLR should be — whether it is strictly a document to transmit initial requirements to NAVSEA, or whether it should be maintained along with the ship's development to reflect current requirements and design. At the present time it really does neither — and there is little confidence expressed in its actual utility.

To a large extent, the administrative organization in both OPNAV and NAVSEA simply seems to drive itself — often independent of the design objective. For example, the Concept Exploration Report for the FFG-7 — which summarizes the basic concept definition, technical tradeoffs, and rationale leading to the PF characteristics — is officially dated July of 1971, but was actually written a year later. The document was predated because the SHAPM determined that a Concept Exploration Report was necessary for design justification even though it had long been irrelevant.[105]

Although OP-03 maintains large staffs to develop required ship characteristics there is little or no input into new ship design below the highest levels — where decisions are largely based on intuition.[106] The predominant focus at almost all levels in OP-03, and in OPNAV, is on the production of platforms and on the production of combat systems as separate units. The question of overall integration into a ship system is left up to NAVSEA, and the question of overall integration into fleet operations is left up to the fleet. The primary function of OP-32 is actually fleet modernization — a job which reflects the primary procurement philosophy of the surface community.

Since the beginning of the decline of the escort fleet in the late 1960s, the predominant thrust in OPNAV has been to produce as many hulls as possible toward the elusive 250 ship goal. No great emphasis has been placed on specific combat systems configuration since intransigience in such an area could jeopardize acquisition of platforms, and because OPNAV has always figured that it can reconfigure the platforms to whatever it wants once they are in the water. As such, fleet modernization programs have become the primary activity in OP-03 and are well established as adjuncts to the design and acquisition programs.

A major factor in the control of cost and time overruns in the FFG-7 class was strict configuration control. The design plan changes themselves are tremendously expensive — often more so than the actual equipment changes that result. It has often proven cheaper to build the ship the "wrong" way and have a section ripped out and rebuilt later, than simply to build it right the first time.[107] An early design "freeze" brought the FFG-7 within cost and time constraints, yet before the first ship was ever completed the Navy knew that it was not what it wanted as a final product. Each FFG-7 currently has a $42 million conversion backlog.[108] This includes such items as providing two LAMPS III helicopters and dismantling all three berthing compartments to make space for the "actual" complement.

Such design changes are most often blamed on changes in mission requirements or unforeseen technological developments — but this is seldom the case. Few configuration changes involve items which were not, or could not have been anticipated early in the design process. The real problems are a lack of design continuity, the "rushed" nature of most design projects which preclude a reasonable analysis of ship requirements and systems integration, and inadequate communications between the actual decisionmakers.

IIIC. The Use of Systems Analysis in Ship Requirements Derivation

In the area of ship requirements determination it is the objective of systems analysis to identify various force and platform alternative configurations, and select those which put available resources to their most productive use. It is established policy of both the Defense and Navy departments that studies and analyses be used as essential tools of acquisition management.[109]

It is generally recognized that the success of modern warships is much more dependent upon the successful integration of surveillance, communications, and targetting capabilities of combined sea, air, and land forces than on the number of guns or missile launchers placed on any single ship.[110] Analysis in the ship derivation process seeks to define specific capabilities needed to fulfill identified missions and tasks in force operations. This involves long range planning to outline future naval missions and develop realistic operational scenarios for force employment. Current and future force deficiencies are determined in those scenarios, and suitable levels and mixes of platforms are developed to fulfill identified mission requirements. In essence, the goal of systems analysis is to develop an optimum number and mix of warships specifically configured to carry out defined tasks.

In practice, most systems analysis is either superfluous to the design process or is utilized after the ship has been designed in order to identify a suitable mission for the new platform.

A number of OPNAV divisions carry out varying levels of long range planning, but OP-06 — Deputy CNO for Plans, Policy, and Operations — is specifically charged with developing long range force level requirements. The division charged with using systems analysis to evaluate the relative effectiveness of alternative programs (including ship development programs) is OP-96 — the Systems Analysis and Long Range Objectives Division. Specific studies and analyses may be conducted by in-house organizations (within the Department of the Navy), by affiliated organizations, or by outside organizations under contract or grant. The organization primarily affiliated with

OP-96 for contracted studies is the Center for Naval Analysis.

The development of valid operational scenarios is based first of all, on adequate long range plans integrating perceived threats and mission requirements through the life of a proposed ship class. The primary constraint on useful long range planning is the inability adequately to assess a threat level 30, 20, or even 10 years in the future. On the other hand, combat system development is basically an evolutionary process, and reasonable assessment coupled with solid analytical technique provides some basis on which to make a force level/mix evaluation.

It is a generally accepted fact in OPNAV that little meaningful long range planning is conducted by the Navy. OP-06 does some long range planning but none of it is done in terms of force structure. OP-96 provides analytical capability for OPNAV as well as the Office of the Secretary of the Navy, and long range force structure planning is vested in OP-965 — the Extended Planning Branch. But this division is not a strategic planning office and no continuous broad strategic studies are carried out. The major problems are seen as a lack of personnel (OP-965 had only four of seven billets filled in early 1980) and, more important, lack of CNO attention to analysis of broad strategic goals. As one OP-96 analyst pointed out, "A lot of people think they are doing long range planning around here, but nobody really is."[111]

It is the function of OP-965 to generate the annual CPAM (CNO Program Analysis Memorandum). Each CPAM describes the current FYDP program, identifies Navy issues, and develops alternatives based on the decrement and increment levels specified in the CPPG (CNO Policy and Planning Guidance). The CPAMs are then reviewed by the CEB (CNO Executive Board) and the impact of these alternatives on CNO objectives are identified. The CPAM is developed to provide the CNO with alternatives for responding to the Defense Secretary's fiscal guidance. Upon receipt of OSD planning and programming guidance, the CNO, using the program alternatives listed in the summary CPAM, makes major decisions and issues CNO program and fiscal guidance for the detailed development of the Navy POM (Program Objectives Memorandum).

Ideally the CPAM is generated by the CNO, with analytical support from OP-96, and reflects his own personal view of Navy objectives and force levels. In reality, the CPAM is drafted by OP-965 with little or no CNO input and is simply sent up to him for his signature.[112] As such, the CNO uses no formal documentation process to develop his own mission philosophy with which to mold Navy programs. The general attitude has developed in OP-96 that over the past decade or more the CNO has gradually lost touch with broad Navy planning functions.[113] Due to the necessity of lobbying for individual projects, the past few CNOs have tended to get bogged down in narrow issues — such as the promotion of the CVN — and thus have failed to provide broad direction to naval project development. It is generally felt that Navy planning should reflect the CNO's personal policies, but that in most cases the CNO's policies have never really been formulated or stated. A contributing problem is the structure of the Congressional appropriation system. Although DOD establishes a five year defense planning program, Congress appropriates and authorizes funds annually. As such, long term programs must be presented and justified by the Navy every year, with complete reversals of congressional attitudes not uncommon. This uncertainty of program funding is a major factor that works against long range planning and forces the CNO to channel so much of his time into Congressional lobbying efforts.

Recognition of the long range planning deficiency in OPNAV led Admiral Hayward, in January of 1980, to establish OP-00X — a new long range planning group with a direct tie to the CNO. The objective of OP-00X is to develop a meaningful long range planning and decisionmaking capability. It is expected that the new office will take over the CPAM and other planning documents from OP-965 and will establish them as a true basis for CNO planning guidance.[114] It is significant to note that the CNO's desire to upgrade the Navy's long range planning capability resulted not in the reorganization of existing groups, but rather in the establishment of a completely new organization within his own sphere of influence. This is a strong reflection of the practical inability of the CNO to effect even a moderate reorganization of his own offices without facing stringent opposition.

The group primarily charged with the development of force mix/level analysis for OPNAV is OP-96. Established in 1966 under Admiral Elmo Zumwalt, it turned out the "Major Fleet Escort Study" a year later — a massive work which helped to shape all subsequent escort programs, and a study which is still considered to be one of the major analytical works to be produced by the Navy. The Major Fleet Escort Study is now considered to be the only comprehensive work on force analysis to be produced by the division itself.

Serious systems analysis efforts in the Navy date back to the establishment of ASWORG (ASW Operations Research Group) in 1942. Analytical functions rapidly developed after the war, and in 1962 the primary operations analysis groups which were affiliated with the Navy — the Operations Evaluation Group (OEG), the Naval Warfare Analysis Group (NAVWAG), and the Institue for Naval Studies (INS) — were joined into the Center for Naval Analysis at the University of Rochester. Today, the Center for Naval Analysis (CNA) is the primary analysis affiliate of OPNAV and does the majority of force level/ mix analysis for OP-96. As the demands for program analysis have increased, increasingly larger amounts have been contracted out. Today, OP-96 is primarily a contract administrator, doing little in-house analytical work.[115] This is due to a shortage of analysis personnel in OP-96 (despite the number of operations analysts turned out by the Naval Postgraduate School), and due to OP-96's preoccupation with dealing with near-term problems — "reactionary analysis." The major studies that are currently produced, such as "Sea Plan 2000", are most often responses to specific analytical challenges from the political arena. As one officer put it, OP-96 is too busy "putting out fires" on a daily basis to be worried about planning for tomorrow.[116]

This lack of involvement in real planning analysis by OP-96 has largely manifested itself in a lack of direction to CNA and other study contractors. Under established doctrine, OP-96 analysts are tasked with developing study programs for CNA. At least 75% of CNA studies must have Navy approval. The remaining 25% of the study funds and effort are for use in areas determined by CNA to be of Navy interest. A Navy liaison officer attached to CNA noted that definitive direction from OP-96 is almost non-existent.[117] Study topics are not formally presented to CNA, but through iterative dialogue and subjective determination CNA comes to a consensus of what they think the Navy wants, and then they submit a program covering those areas. It is seldom that the Navy disapproves of a CNA study topic, and in those cases, CNA usually includes those studies in its program anyway. The liaison officer noted that he could only recall one CNA study proposal in the past year being turned down by the Navy. In that case the rejection was intitiated by a low-level operational commander because he had remembered the same study having been done the year before.

The volume of analysis turned out by CNA is tremendous, but the largest part of it tends to be general and repetitious — the same basic study, or an update, being done every year or so — with the same basic results. Without any firm guidelines or specific program ties from OPNAV, there is no sense of urgency to start studies, or even to complete them. An observer of CNA operations noted that there is some status attached to seeing how long an analyst can drag a specific study out.[118] It has also been noted that CNA civilian analysts lack an appreciation for naval operating conditions and constraints — particularly with regard to limitations and capabilities of available fleet personnel. Past studies have also been criticized for their predominantly "theological" nature (e.g. Can you have "power projection" without "sea control"?) with little or no practical value.[119]

The apparent result of this analytical production is an endless flow of executive summaries from "in-basket" to "out-basket" throughout OPNAV with no real attempt being made to tie the analysis to any decisionmaking process. The level of funding that supports CNA alone is adequate justification to initiate a critical review of privately contracted analysis.[120] One observer summed the current value of CNA this way, "If we did away with CNA tomorrow and used the money to buy two more frigates, the Navy would be a lot better off."[121] This is an argument that could probably be extended to a number of Navy offices and affiliates.

The primary question that must be answered is that, given proper direction, orientation, and tie-in to the decisionmaking process, could OP-96 and its contractors provide a quality of analysis that would give specific direction to planners in establishing surface ship requirements (e.g. is it possible to determine through systems analysis whether, in given operational scenarios, a 5"/54 gun is more cost-effective than two 76mm mounts on a planned class of ship)? There are some planners who answer point blank that it is not possible, and that it is the prime mission of operations analysis to serve in the reactive mode of decision justification and the fending off of program challenges by analysis groups in OSD, Congress, OMB, etc.

There are certainly outside constraints which must be considered in the question. Just as in other OPNAV divisions, OP-96 is "restricted" from

from dealing with studies which might upset the balance of power between the warfare "barons". The "hard" questions, one OP-96 analyst noted, are not only not studied, they are never even mentioned in jest.[122]

The outcome of any detailed analytical study is directly dependent upon what goes into that study. For naval force analysis these inputs center on:

1) Accurate threat assessment and projection;

2) Inputs from existing or developmental technology;

3) Feedback from operational test and evaluation;

4) Realistic tactical operating doctrine.

Threat analysis is obviously the major weak link in the analysis effort. Nevertheless, the very doctrinaire nature of Soviet naval operations and acquisition programs, coupled with development times similar to those of U. S. projects, have resulted in no real surprises having been sprung on U. S. planners. An adequate lead time of at least several years has always been available to react to new developments. If this were the only analysis weakness it would not serve as a major obstacle to valuable study outputs.

Certainly a major problem is the lack of any formal communications link between OP-96 and the various research laboratories and technical facilities that are actively developing new combat systems and platforms.[123] There exist no reliable means for OP-96 (as well as the rest of OPNAV and NAVSEA) to know in advance what new technologies and equipment are under development and going to be available in the time frame of the ship design programs that are under consideration.[124] Despite the many years (even decades) of development time that go into most combat systems, OP-96 officers have little official knowledge of what is going on outside of their own office complex in the Pentagon. They usually deal with new projects as they spring onto the scene at the last minute — often as configuration changes to an already-designed ship. Likewise, the feedback from OPNAV and operators back to the combat systems designers is often minimal. Most new combat systems are designed in something of a vacuum, with engineers guessing what OPNAV and the fleet want — regardless of total ship impact — and the fleet trying to find uses for the equipment that is actually turned out. Combat systems development is discussed further in section IIID.

Operational test and evaluation information is virtually non-existant to the force analyst or designer, because OT&E has never really been performed on more than a subsystem level. The specific limitations of OT&E are discussed in section IIIE.

The final input to force level analysis, and generally the focal point of criticism about the inadequacies of the analytical effort is the lack of approved or developed tactical employment doctrine. As will be discussed in section IIIF, tactical development and evaluation is an area which, up until recently, has received little attention, and is not likely, at least in the near future, to produce any meaningful operational guidelines. The result is that combat system designers, ship designers, and force analysts have been independently developing their own tactical doctrine in which to design and test their own products. When combat systems and ships arrive in the fleet, individual operators most often use (or misuse) the systems based on intuitive application, with little or no knowledge of the design scenarios. By way of example, the primary tactical formation used by CNA for the majority of its convoy force mix studies appears in no Navy tactical publication and is apparently widely unknown to fleet operators and planners.

Due largely to these deficiencies, there are no major fleet force level/mix studies conducted on a continuing basis which take inputs from all areas of development and evaluation, and provide analysis useful in force planning decisions. Although such projects as "Seamix", "Seawar", and "Alternative Battle Groups " studies have been carried out, the apparent effect of these programs on actual force decisions or ship design is negligible. Executive summaries appear, presentations are made, and then the study results slide into oblivion until someone in OP-96 or CNA decides that it is time to do the study over again.

A notable study conducted through OP-96 and NAVSEA was the Advanced Naval Vehicles Concepts Evaluation reported on in 1978.[125] The objective of the study was to examine the potential military worth, technical feasibility, and affordability of various generic classes of "advanced" vehicles for the Navy of the 1980 to 2000 era. The study was conducted by a group of design engineers who, with a lack of applicable data, made their own assumptions about combat systems availability and integration, and operational concepts of high performance vehicles. The lack of such data, or serious attempts to generate it, has been one of the major obstacles in the Navy's attempts to obtain ANV prototype funding. One of the principal conclusions reached by the study was that any meaningful analysis is entirely dependent upon much greater understanding and communication between naval operators, ship designers, and combat systems engineers.[126]

As part of the ANV study a major war game was conducted in 1977 at the Center for War Gaming, Naval War College. Due to the limitations of the facility (the best war gaming facility that the Navy has), subjective determination of platform capabilities, and a lack of developed operational concepts, the game was unable to derive quantitative results regarding platform effectiveness. The program limitations were all known before the game was run. The war gaming system has no simulation capability (it is a computer-assisted direct action play) and the Navy has no graphic simulators for concept evaluation. Since the results were predetermined, it has to questioned as to why the time and effort were expended in the utilization of the facility. As one analyst assigned to the war gaming center put it, "It was good public affairs material for us and for NAVMAT."[127]

Of course a major force level simulation utilizing all possible inputs is unlikely to provide the solution to force level/mix problems. All simulations are highly dependent upon the largely subjective inputs of the assigned analysts. In addition, the sheer size and complexity of a major simulation can be awesome. In 1965 a computer simulation was developed to model an air-to-air and air-to-ground battle situation to compare the A-7, F-5, and F-4 aircraft. The Air Force constructed a huge model which simulated an entire air war. As a DOD systems analyst explained the results, "It was so complicated that nobody could really figure out what was going on in the model... It was a gigantic setup that put forth reams and reams of data, and there wasn't anybody that could analyze the thing and understand it."[128]

The limitations of simulations are obvious, yet the alternative is to rely totally on subjective determination of requirements that may not hold up under rudimentary analytical scrutiny. A good practical example of current ship requirements analysis in OP-96 is represented by the FFX concept. The mission and size of the proposed ship were established in the OR (i.e. protection of economic strategic lines of communication/one half the size of and FFG-7). OP-96 determination of combat system requirements consisted basically of an officer developing a ten minute block diagram of equipments to fit into his subjective conception of what was needed to counter a generally (and not entirely accurately) perceived threat.[129] When questioned as to what analysis this notional ship concept would be put through to test the design, the response reflected both a realization of design constraints well separated from the analytical community, as well as a recognition of the limitations of the analytical effort in OP-96 — "Why waste time doing analysis when it's obvious what the ship should look like?"[130]

The bureaucratic frustration of the Navy's analytical community in attempting to provide program direction is probably best summed up by one OP-96 branch head who stated, "Sometimes I get the feeling that _no one_ knows what's going on. It all seems like one big fire drill."[131]

IIID. Combat Subsystems Development

A primary obstacle to greater integration of design effort down to the combat system level is the preponderant view throughout the Navy — reflected in combat systems employment doctrine — that successful naval battles are not a function of integrated fleet operations but rather are, in the most basic sense, a series of one-on-one, combat system-versus-combat system engagements. The focus is on creating combat systems that have individual performance characteristics that exceed those of the enemy. As Rear Admiral A.R. Gralles, former commander of the old NAVORDSYSCOM put it,

> In the air, on the surface, and below the surface, however glamorous our ships and aircraft, they are in the final analysis, only launching platforms designed to place effective weapons systems in the right place at the right time.

Indeed, the current state of tactical development provides little alternative to this view. Even if strong communications did exist between ship designers and combat systems engineers, it is doubtful whether any more positive direction could be provided regarding fleet requirements. Individual combat systems development takes an average of seven years — as long as the subsequent platform development. Thus it may be over 14 years before a new combat system appears aboard a new ship (by which time it could already be obsolescent in relation to the deployed systems of an adversary). For a useful ship lifetime of 25 to 30 years, a platform may need to be refitted with a new combat system suite two or three times. Planning for future combat systems adaptability requires either strong insight into anticipated combat systems requirements and developments, or the factoring of excess margin into a platform's displacement capacity during its initial design (an expensive prospect with an uncertain payoff).

On the other hand, the failure to address combat systems development from an entire ship standpoint is increasingly forcing the ship designer to make critical choices among very few combat systems alternatives. This often results in excessive performance in some warfare areas while providing inadequate performance in others. Weight alone is not the only critical factor.

One combat system may make demands on ship support facilities such as electric power, cooling water, compressed air, etc., to the extent that another combat system cannot be operated at the same time. As one combat systems designer has pointed out, combat systems research and development is inherently an open-loop process that focuses on maximum operational performance goals. System resource allocation constraints become competing development goals. Unless externally constrainted, R&D will produce only high capability ship options. This is a primary reason for the failure to keep low-mix ships at a low cost while keeping them mission capable.[132]

A commonly-cited example of the divergence of technological development and operational need is that of the AN/SQS-26 sonar currently installed on most fleet escorts. A conscious decision was made in the technical community in the early 1960s to concentrate on the development of active detection and localization sonar systems at the expense of passive capability. An extremely high-powered unit, the SQS-26's active detection capability at even medium ranges does not offset its tendency to serve as a beacon for enemy submarines. With the predominant sonar search doctrine centering on passive detection and concealment, the high-cost, high-powered, SQS-26 system has not been assigned a major role in most ASW operational scenarios.

In task force operations — the primary design scenario of all surface warships — mission deficiencies can be covered by other platforms fitted with the required high-mix capabilities. But as often as not, modern warships are called upon to operate independently to establish presence in critical world areas. With the proliferation of cheap, precision-guided munitions that has occurred in the past decade, the prospect of independent ship operations with deficient performance capabilities in certain warfare areas is becoming increasingly risky.

A problem which increased design communications cannot overcome is the selection of combat systems based on other than performance requirements. The primary consideration in the selection of the 76mm OTO Melara gun for the FFG-7 was a gesture toward NATO standardization (and probably a desire for reciprocity). When development of the originally selected 35mm OTO did not keep up with the FFG-7 schedule, the fallback was restricted to other OTO Melara models. The 76mm was purchased as the United States was pressing to obtain a major Italian commitment in the NATO PHM program. The gun was given no design priority on the FFG-7 platform, where the primary selection criteria were minimum weight and low manning requirement rather than fleet utility. The 76mm met these basic requirements, and the question of how the gun is to be integrated into the ship mission has largely been left up to the individual fleet operators.

It is unfortunate that performance consideration has not been the driving force in the investigation of foreign combat systems capabilities. The surface-to-surface missile is one area where the U. S. could have benefitted from a foreign system test and evaluation program. Proven missiles such as the Gabriel, Exocet, Otomat, and Penguin have been available on the foreign market for years, yet U. S. ships either carried no SSM capability or modified surface-to-air systems throughout the years of development leading up to initial Harpoon deployment in 1977. There is little doubt that congressional restrictions have severely limited fleet performance capabilities through a narrow selection of production options. Certainly a cost/benefit analysis of such restrictions with regard to combat systems is long overdue.

One area where combat system/ship designer dialogue would be of value is in creating a mutual awareness of the environment in which subsystems must operate. As one ship designer has pointed out, it remains to be seen whether or not today's low-manned, highly-automated, complicated systems will have as high a reliability as the less sophisiticated and more rugged systems of the past.[133] Subsystem designers often seem to lose sight of the fact that their hardware must be operated by a Navy crew in a hostile shipboard environment. Excellent examples of this exist in the ASW field where crew training is a primary adjunct to equipment performance. Lack of funding and time for necessary schools, coupled with inadequate exercise time and a high personnel turnover rate has rendered such systems as passive LAVA all but useless on many platforms. No doubt a fine piece of equipment in the laboratory, it does little more than take up space in many ships.

A concept which has been circulating through OPNAV and NAVMAT for some time as a possible solution to the problems of combat suite obsolescence and limited mission capabilities is that of Seamod. Seamod is a concept of modularized combat systems which ideally could be dropped in and pulled out of an accomodating platform to allow a quick retrofit of a new or necessary weapon system. The concept itself appears promising, but the practical development problems have stifled any real progress. As Seamod critics have pointed out:[134]

1) It has not been adequately demonstrated that the decreased costs of systems modernization will offset the increased development and acquisition costs of modularized units.

2) We cannot estimate combat systems needs up to 30 years in the future, let alone estimate the space, weight, and power margins that will have to be designed into module platforms.

3) We cannot even adequately interface the few combat systems elements that we have today. We are nowhere near having systems that "plug in."

Certainly the problems are great, but some NAVSEA designers feel that Seamod is not developing simply because no one is really trying to put all of the pieces together and make it work. It is widely viewed as a high R&D and high risk program — concepts anathema to today's procurement and design communities.[135]

IIIE. Operational Test and Evaluation

Under current DOD acquisition policies test and evaluation must serve as the basis of development and production decisions. T&E is charged with providing the best information possible concerning the military utility of a prospective system, its operational effectiveness, and its operational suitability — including reliability, organization, and doctrine and tactics for system deployment. Established policy calls for a development program based on periodic performance demonstrations. The pacing function in all programs should be demonstration of actual achievement of program objectives.[136]

The concept of "independent evaluation" is a basic requirement for providing information for acquisition milestone decisions. OPTEVFOR (Operational Test and Evaluation Force) is the independent test and evaluation organization for the Navy which assesses operational suitability for candidate and production systems. In OPNAV, T&E policy and guidance are exercised through Director, RDT&E (OP-098). T&E staff support for Director, RDT&E is provided by the Assistant Director RDT&E (OP-098c) and the T&E Division (OP-983). COMOPTEVFOR is assigned concurrent duty as OP-098c.

Aside from production decisions, systems OT&E should provide valuable input into the planning process by identifying actual systems performance parameters for force level tactical analysis. A major shortcoming in force analysis has been the lack of comprehensive and reliable data as to how combat systems actually operate in a fleet environment.

The current OT&E process in the Navy has been strongly criticized for its failure to provide support in these critical areas. With the necessity of having to commit funding to program development years in advance, and with little latitude to shift sizeable sums of money between appropriations, program development decisions have not proven flexible enough to be dependent upon T&E decisions. In a survey of DOD's practices in OT&E, the GAO criticized the Navy for continuing to conduct full-scale OT&E will after systems have been deployed, when information on operational effectiveness should be available from operating forces.[137]

Systems are often sent to the fleet for a determination of performance capabilities long after they have been in full-scale production. In some cases, such as the Harpoon missile (in which over-the-horizon targetting is a long way from being realized) this is unavoidable without seriously detracting from fleet capabilities. But in the majority of cases it is the result of a continued inability to establish exactly what T&E is supposed to determine, and exactly how it is supposed to determine it.

Operational evaluation is limited almost exclusively to single system evaluation in operational scenarios and tactical employment often arbitrarily developed by OPTEVFOR. It is agreed by most designers and operators that total evaluation should be conducted in a ship systems environment and a battle group environment, but there exist no published guidelines for the establishment and conduct of fleet exercises to carry out such evaluations. As will be discussed in section IIIF, tactical employment doctrine is far from established, and lags platform deployment by decades.

Of more immediate concern to OPNAV and OPTEVFOR is the fact that the planning and conduct of OT&E requires the expenditure of scarce resources such as ship and aircraft operating time, targets, ordnance, instrumentation, and manpower. An investigation conducted in 1974 on the feasibility of conducting a total ship Operational Appraisal of USS Virginia concluded that it would be a truly mammoth undertaking in terms of money, time, material, and fleet units. There would also be a high risk that variables such as crew training, environment, and material readiness that existed at the time, would be likely to influence the outcome and cause erroneous conclusions to be reached.[138] Fiscal limitations already result in a less than optimum level of training readiness. The CNO has determined that 21 days of ship steaming time per quarter is the desired optimum, with 16 days considered necessary for minimum training. In 1978 an average operational tempo of only 14 days per quarter was budgeted.[139] With most ships unable to meet minimum training standards, little time is left over for systems T&E. In certain systems, such a sonar, crew training plays a much greater role in systems capability than the equipment itself. Thus, although a realistic view of performance can be attained, optimum equipment performance usually cannot.

The assessment that seems to have been reached by most experts is that T&E at the battle group level and the total ship level are not cost effective. In March of 1978 the Navy conducted a complete system follow-on

OT&E exercise on USS Virginia (CGN-38). The estimated cost of the exercise exceeded $5 million (less than 10% of which came from CGN-38 program acquisition funds). By the time the report was completed, two of the three follow ships of the class had already been delivered to the Navy and the combat systems equipment for the remaining ship had already been bought.[140]

There is also a tendency to perform initial T&E on developed systems and then provide no meaningful follow-up after system deployment. As such, we have no assessment to determine how operationally suitable our deployed systems are as the threat changes, as our weapons inventory changes, and as equipment modifications are made. Such assessments could provide valuable direction to planners of future systems and tests. Contributing to this discontinuity in test and evaluation is the fact that at nearly every level of naval organization different offices are responsible for systems maintenance than those that supervised the original acquisition. There seldom seems to be any transfer of operational data between the two offices.[141]

Although the primary objective of OT&E is to generate assessments of operational effectiveness and military worth, OPNAV has taken little part in providing direction to this effort. It is OPNAV that identifies the need for a system and its OR, but responsibility for integrating OT&E with each program is left to OPTEVFOR and the program manager. As one NAVSEA test engineer sees it, OPTEVFOR considers OT&E as much of an art as a science.

> The principle (sic) value derived is often unplanned, resulting not from the stated objectives but from the realistic conditions that are interjected. It would appear that this approach to OT&E would better be classified as random experimentation than controlled T&E.[142]

In the absence of OPNAV direction, criteria for T&E are often based not on any real operational need but rather "nice to have."[143]

The deficiencies of OT&E have not been adequately addressed in OPNAV primarily because no one in OPNAV seems to know exactly what the testing is expected to accomplish. As one observer has put it, "The paradox of military planning is that it must be reasonably precise to quite imprecise future contingencies."[144] Without having any operational tactics or operational scenarios developed, OPNAV is content to let the design engineers and fleet operators assume responsibility for equipment performance. The pervasive attitude in OPNAV continues to be that war itself is the final testing mechanism. When war occurs, we can determine our exact deficiencies. Until that time, the priority is on getting hulls and equipment into the water.

IIIF. Tactical Development and Evaluation

The one area that has served as the focus of criticism of ship and combat system designers, and force planners is that of tactical development and evaluation (Tac D&E) in the U. S. Navy. The inability to develop valid operational scenarios for force planning and testing, and the inability to develop suitable measures of effectiveness for systems tradeoff is generally blamed on the failure to develop adequate employment doctrine.

The claim is certainly not without basis. The lead ship of the FFG-7 class was launched in 1976, yet the Navy's Tac D&E program for 1979 included a project to outline the FFG-7 capabilities and missions — including a description and list of capabilities of individual equipment and weapons.[145] In addition, the project tasking called for the development of preliminary tactical information for ship employment in AAW, ASW, and SUW engagements. The FFG-7 was developed primarily for convoy escort duty. An additional project in the FY 1979 Tac D&E program called for the development of tactics to employ surface combatants for ASW protection of merchant ship convoys, amphibious groups, and underway replenishment groups. In a multi-billion dollar acquisition program it seems that such questions would have been addressed and settled prior to the initiation of the ship design. How did the Navy know that it needed the FFG-7 if it didn't specifically know what it was going to do with it? The situation reflects a common fleet complaint that the arrival of new systems (and ships) are often a surprise to all concerned and are usually followed by a flurry of activity to devise ways to use them.[146]

Historically it has been OPTEVFOR which has been tasked to determine performance parameters of new weapons systems and to develop initial employment doctrine. But OPTEVFOR provides only a baseline doctrine for one-on-one combat system matchups. Little investigation is initiated into system performance in task group scenarios. OPTEVFOR project officers designing tests to evaluate new systems are unable to utilize fleet approved tactics — even for deployed equipment — because little fleet approved tactics exist. "For any given tactical problem," noted one OPTEVFOR officer, "tactical guidance ranges from nonexistent to hopelessly voluminous, from clear to contradictory, from specific to general, from creative to procedural."[147] Although the Navy's Tac D&E effort has produced significant amounts of tactics on paper, it "... has yet to produce comprehensive or coherently organized tactical guidance for the fleet. Nor has it produced a clear game plan for achieving this goal."[148] It has been observed that OPTEVFOR has played a dominant role in Tac D&E mostly by default.[149]

There is much disagreement even in the fleet as to what tactical doctrine should consist of. At the present, performance parameters are collected for many fleet combat systems and the observed data provided to unit commanders for individual digestion and subjective correlation. To many operators this is seen as adequate support. But many officers feel that this approach produces information that is too voluminous and disjointed to be adequately understood, and that resultant employment doctrine is too subjectively developed over extremely short periods of time to result in anything approaching optimal employment. There has been a growing argument over the past decade for the establishment of a system of analytic and procedural tools for the execution of sound tactical decisions.

High level recognition of the problems of tactical development resulted in major study efforts in the early 1970s to develop ways to identify and tackle the perceived problems. It was noted that a profound interest in tactical employment that existed in World War II had considerably waned by the 1970s. This was due, among other things, to increasingly complex combat systems, lack of adequate battle experience to test concepts, and, in the absence of war, a drift of command attention to other areas of readiness.[150] It was noted that new technology had come to be thought of as the primary solution to continuous variations in the threat. Major programs had been developed for defining new weapons systems, but no formal mechanisms existed for the development of new tactical applications and the translation of exercise analyses and data into improved tactical procedures for operational employment of these technological products.[151]

Fleet exercises were recognized as the best objective measure of U. S. naval capability short of war. But with a large spectrum of organizations competing for fleet exercise time and data, and a severe limit on operating time, fleet exercises concentrated almost exclusively on basic training and evaluation of unit readiness rather than tactical evaluation. There were few comprehensive programs, and exercise analysis remained relatively qualitative. Of the exercise evaluation that was done, it was noted at the time that, "The volumes of those reports tend to stand in isolation as heavy labors, unnoted, unread — certainly unstudied — and leading to nowhere."[152]

Although a good substitute for costly fleet exercises, little use had been made of tactical simulators. The electronic war gaming facility at the Naval War College is primarily a training device, more suited to strategic studies than to simulation of tactical problems. Extensive use had been made of computer simulations by contract agencies, such as CNA, but such studies tended to be limited in scope, of short duration, lacking in any operational fleet input, and totally dependent upon tactical doctrine devised by the individual running the simulation.

A major source of tactical deficiency was noted to be inadequate training of officers rotating into fleet staff billets. A comprehensive study of factors inhibiting improvement in fleet tactical performance came to the following conclusions:[153]

1) The inherent complexity of the warfare problem exceeds the qualitative capability of staff officers to comprehend fully and interrelate the many environmental, operational, and hardware variables.

2) The assignment of officers inadequately educated in tactical concepts to fleet staff billets coupled with the necessary rotation of experienced personnel significantly degrades staff capability. The resulting staff performance contributes to the pattern of recurring discrepancies and limited tactical innovation.

3) Improvements in training programs to eliminate chronic, recurring operational discrepancies are inhibited by lack of clear, functional responsibilities among fleet, type, and training commands.

Up through the 1960s, the Naval War College was the only higher educational institution in the Navy that could be expected to provide the basis for the tactical thinking needed to cope with the changing naval threats. But by the early 1970s the curriculum and published papers showed an increasing orientation toward the geopolitical, strategic, and economic rather than the tactical.[154] Limited information was produced relevant to the tactical development process. As a result, critics held that fleet exercises were being planned by staff officers who were not functionally equipped for the job.[155]

The predominant attitude outside of the operational forces was that it was fundamentally the job of the fleet to develop its own tactical doctrine. The commander of the First Fleet noted in 1971 that it was expected of operating personnel to; 1) create tactics; 2) design efficient operating tests; 3) record data; 4) reconstruct and analyze fleet exercises; and 5) constructively update tactics and rewrite operational procedures. "Financial support to the fleet in these tasks has been minimal, and provided on a short term, ad hoc basis."[156]

A 1972 synposium of the Office of Naval Research identified the objectives of Tac D&E as:[157]

1) The development and improvement of tactics; and

2) The provision of data on fleet performance of systems as an input for defining technical requirements and performing issue analysis.

The causes for the inadequacy of Tac D&E up through 1972 were identified as:

1) Failure to treat it seriously;

2) Lack of communication and coordination between personnel involved in Tac D&E; and

3) Inadequate direction and support from senior managers in OPNAV and in the fleet.

In July of 1973, as a result of identified deficiencies, a CNO instruction established an inter-type Tac D&E program in the Navy and assigned Tac D&E to OP-095 (Director, ASW and Ocean Surveillance Programs). To carry out this assignment, the Tactical Readiness Division (OP-953) was created.

The term "inter-type" was meant to restrict Tac D&E activities to interactions between different types of platforms in relatively large size fleet engagements. This restriction was made so that the warfare codes OP-02, OP-03, and OP-05 would not lose jurisdiction over their respective platform interests (i.e. "intra-type"). The program objective was the development of tactical doctrine for optimum employment of weapons systems (in addition to OPTEVFOR tactical efforts).

Although a large planning organization was set up, and funds channelled in, there has not been a great deal of evidence that significant strides have been made in the Tac D&E effort up through 1980. The primary problems that continue to plague the program are:

1) Lack of command attention at all levels; and

2) The continuing inability to quantify the basic objective.

In 1972 the president of the Naval War College, Vice Admiral Stansfield Turner, "reintroduced" tactics into the curriculum — a subject that had last appeared by name in 1958.[159] Turner's objective was to deemphasize information on functional naval warfare and concentrate on those aspects that would enhance a student's capabilities for making sound tactical decisions. Although the objectives were clearly stated, the changes have not been marked. Current tactical courses tend to have a generalized planning and employment focus of a very basic nature. Naval Warfare Publications seldom appear in the course reading lists (perhaps reflecting the general opinion that the NWP series provides very limited tactical guidance), and the gaming facilities (even with the electronic system update) are no more amenable to tactical studies and evaluation. Although only partial lists of student research projects and reports are maintained by the War College, a review of the reports kept on file (those considered "important") indicates little interest in tactical subjects. A recent requirement has been levied that most students undertake <u>some</u> tactical research during their course of instruction.

The general attitude of the Naval War College staff indicates a very broad interpretation of tactical training responsibility. As one senior officer put it, "the War College is not a technically-oriented postgraduate school, nor is it a super-TAO (Tactical Action Officer) course. The objective here is to stress force planning for the fleet, task force, and task group commander."[160] Although it was recognized that a large gap existed between the lowest and highest levels of tactical instruction in the Navy, it was not felt that the War College was the facility to take up the slack. One senior instructor noted that,

> Many lieutenant commanders look me up when they leave the War College and tell me that they don't know any more about fighting a destroyer than they did when they entered. Of course not! Tactical employment at that level is not our objective. We are not trying to prepare them for their next tour, we are preparing them for a career.[161]

The only other significant training course in the Navy for tactical employment doctrine has continued to be the TAO school. This is primarily a department head level course for middle grade lieutenants. It has a narrow technical focus on mostly single platform operations and no real Tac D&E input or investigation. The recognition of major gaps in tactical training — for junior and senior officers — has led to the recent concept development of an expansive TAO program to cover the entire surface line officer's career. This is being coupled with a newly devised tactics curriculum at the Naval Postgraduate School. The effectiveness of these programs will be several years in the judging.

The new Tac D&E organization undertook a complete reorganization of the tactical publication system. A new and expansive numbering system was devised which incorporates planned publications of detailed systems performance analysis of both U. S. and enemy units. The project is a truly massive one. Even though little new information or analysis has appeared or is planned, those involved with the program express skepticism about chances for its ultimate completion. For the foreseeable future U. S. tactical publications will probably continue to be a "... disjointed ... and unmanageable collection of documents which sometimes overlap or contradict and are rapidly becoming too numerous to be read or digested."[162] The primary thrust continues to center on publication of raw performance data. The correlation and establishment of published tactical doctrine awaits further infusion of staff and funding.

Although OP-953 was heralded as a major step in the development of fleet tactical doctrine, it currently appears that such development may be a long time in providing any new products for fleet or analytical use. The OP-953 staff complains of funding and manning deficiencies and, up until recently, a lack of authority or visibility (in 1979 OP-953 was upgraded to a flag billet under Rear Admiral Allen E. Hill — specifically to give it more authority and emphasis in the OPNAV organization). The predominant concept held by OP-953 is that they are primarily a clearinghouse for tactics initiated at the fleet level. The basic principle of Tac D&E, as one officer pointed out, is that "Tactics for the fleet must be developed by the fleet."[163] Baseline tactics for new equipment are still the responsibility of OPTEVFOR, with OP-953's charter giving them evaluation responsibility <u>only</u> for platforms and equipment that have been operationally deployed (i.e. concepts that are

7 to 40 years old).

This continued reliance on fleet performance and fleet initiated tactics presents something of a paradox. OP-953 evaluates fleet exercises but has no input to their planning — nor does it want such input. While relying on the operating forces for tactical innovation, the predominant feeling remains that the fleet is a major weak link even in tactical practice and evaluation. Although OP-953's stated mission is fleet support, no one in the division really seems to expect any more out of the fleet than has been produced since World War II.[164]

In the absence of actual combat, a variety of inspections, examinations, and management programs have arisen to help facilitate maintenance of fleet readiness. In this profusion of staff authority, tactical readiness was long lost in the shuffle. It has been pointed out that many commanding officers have been relieved of command for failing engineering examinations (even though their ships could still get underway and operate) but that none have been relieved for tactical incompetence. There is no test for tactical competence. In the atmosphere of "... bean-counting and card-punching requirements ...burgeoning staffs, dwindling operating forces, and prolonged peacetime operations,"[165] little interest has been demonstrated in tactical proficiency at any fleet level.

With a preoccupation with near term problems, tactical employment is a topic that is usually brought up in the minutes just prior to the commencement of a fleet exercise. As a practical activity, fleet exercises are seldom more than training exercises for a ship's officers and crew, and usually center on the primary objective of not embarrassing the ship in the presence of the force commander. So little underway time is available, and submarine and aircraft services so scarce, that the opportunity to run several iterations of a problem does not exist. New or experimental tactics are seldom considered, and the entire subject of tactics is immediately dropped when and exercise is over. It is a topic that is seldom discussed and almost never initiated by the commanding officer (due largely to most commanding officers' lack of familiarity with their own ships' high technology combat systems). "Talk to fleet officers about tactics, and there is mostly the responding awkwardness of men who wish they had though more about them."[166]

Severe fleet operating limitations and the fleet preoccupation with material and administration over operations is understood in tactical support organizations (many of whose staff officers are newly rotated from fleet billets), yet they cling tenaciously to the idea that tactics is basically a fleet responsibility.

There are, to be sure, some hopeful signs in the Tac D&E field. Interest and attention by both the fleet and the CNO have steadily been growing. New tactical training courses have been developed which may spur interest and innovation in the field, and methods are being devised to rate commanding officers in tactical proficiency (just as they are rated on personnel retention). But despite these advances, even OP-953 admits that Tac D&E can never achieve the prominent fleet position that it requires without a commensurate reduction in other fleet inspections, examinations, and administrative requirements. Queried as to when Tac D&E will be the preeminent fleet concern, one senior staff officer in OP-953 replied, "Not before I'm retired, dead, and buried."[167]

Although the recent OPNAV focus has been on promoting tactical effort and interest, the flurry of activity has served effectively to mask the real problem of Tac D&E — that of developing a suitable definition of platform, intertype, and intratype tactical doctrine. To date, the offices and units involved in Tac D&E have continually emphasized their role of collection and correlation, but have passed on responsibility for tactical development because there is no clear understanding of what it is that is trying to be developed.

Only one ship class in the fleet — the FF-1052 Knox class — has an OPNAV approved platform tactical manual. With its appearance in 1979, the manual lagged ship introduction by some ten years. More such manuals are planned, but it is not expected that every ship class will ever have one, nor is it expected that the introduction of the manuals will approach the fleet introduction of the ship by less than five to ten years.[168] Aside from a general lack of funds and staff to produce the manuals, the reason given for the laggard development is that fleet operations must be observed and evaluated before tactics can be devised. This is an admittedly curious explanation. Combat systems development leads the host platform by a minimum of about seven years. With a seven year ship development time, another ten years for tactical manual promulgation results in a 24 year delay in official operating procedures following initial system conception (that is _if_ the manual is produced for the class). A review of the FF-1052 tactical manual reveals that it is little more than a general information book on combat systems parameters — a compilation of the various combat system technical manuals, the Ship's Information Book, and the ship's Weapons Doctrine. As one CIC officer described it, "It's great for studying for a SWO board (Surface Warfare Officer's oral examination), but it has no practical use."

It was obvious that OP-953 felt the necessity of producing something by way of tactical guidance, and a publication that should easily precede a ship class into construction appearing 15 years after the fact is the result.

What OP-03, NAVSEA, and systems analysis activities want from the Tac D&E effort is approved tactical doctrine for developing operational scenarios, and valid measures of effectiveness to make cost/performance tradeoffs. In the FF-1052 platform tactical manual itself, OP-953 provides four different viewpoints of what tactics can be (from combat systems performance information to established operating doctrine) and selects none as the desired goal or model. Experience has shown that once that first step is taken toward providing operational doctrine of varying combinations of combat systems, platforms, and threat levels, the degree of problem complexity rapidly approaches infinity. Subjective decisions must be made at every step, and it is considered far easier (and safer) to leave those decisions up to the individual commanding officer. Nevertheless, any effort to achieve an optimum performance level for various combat systems requires some forethought and the establishment of basic operational guidelines. What is necessary is for the concerned OPNAV offices and fleet representatives to develop a concept of what can feasibly be attained by way of Tac D&E. There is no lack of criticism of the current state of fleet tactics, but there is also no clear idea of a solution, or indeed of which way to go.

Certainly much more emphasis on tactical training and readiness is needed at all levels. Tactical development should be the preeminent concern of all staffs and operating units. At the same time, a consensus must be reached as to the practical limitation of tactical doctrine development. In areas where operational scenarios can be developed for combat system and platform tests, tactical simulators should be utilized for the iterative studies rather than total reliance upon the fleet. Where valid operational scenarios cannot be developed, then other methods of evaluation (quantitative of qualitative) will have to be devised.

In all cases, a strong communications link from OP-953 to OP-03, analysis facilities, the technical design community, research labs, and the fleet is an absolute necessity to establish program guidelines and to maintain a central focus on project objectives and limitations. At the present time, NAVSEA presumes that OPNAV can provide quantitative performance evaluations and measures for design tradeoffs — just as NAVSEA can provide the dollar figures. Everyone in OPNAV seems to know that they are very limited in the tactical guidelines that they can produce, but no one is willing to admit it. At the same time, most fleet officers seem to feel that extensive tactics have been developed for the testing and introduction of new systems, and that these guidelines have simply not been promulgated for operational use.[169] Everyone is looking somewhere else for the solution. No one, it seems, is addressing the real problem.

IV. Conclusion and Recommendations

The inevitable response that one gets in presenting ship design problems is "So what? — the Navy ultimately gets its ships and Congress gets to build them where it wants." One former head of an OPNAV ship's characteristics board want so far as to state that the current design process is probably the best that can be expected — that it consistently turns out the best ships that the Navy can buy.[170] This may be true, but the results of most ship design efforts do not convincingly support the argument.

With the explosion of new technology in the post-World War II decades, the Navy is now in the unique position of having to make very discriminating choices about which of a multitude of paths of research and development to follow. Up through World War II it was hardly possible to envision a combat system or platform that could not be afforded in reasonable numbers. There were no parallels to the CSGN or B-1 and no need for a procurement strategy such as "high-low" mix. In the present day only a small number of potential R&D paths can be funded. Combat systems development is basically evolutionary, but with development periods of up to 20 years it takes a great deal of intuition to guess where the payoffs are going to lie (both in terms of operability and in adequately meeting the threat). It is increasingly difficult to be able to project threats far enough into the future to be able to plan adequately now.

Congress and OSD are increasingly hesitant to fund technology for its own sake, with the presumption that a utility will become evident down the line. A good example of this is the SES. No one really knows what the operational advantages of a 100 knot platform are (particularly in light of high maintenance requirements and development costs), but OP-03 continued to forge ahead with the program because the new platform dimension could possibly prove promising in the future (and also because of a growing fear in OP-03 that technological developments are leaving the surface fleet behind).

As a result of these funding dilemmas, most factions in the ship development process are content to let the current system churn along as constraints, pressures, and biases from countless sources mold the final product. An advantage of this system that should not be minimized is the unpredictability of our development process for our enemies. We know that another power cannot design to counter our fleet capabilities 20 years down the road because we cannot anticipate those capabilities ourselves.

The argument is also put forward that it really makes no difference what our ships are like as built. The only true test of design is combat, and we can "fix" our ships to meet the real threat when war breaks out. But history does not lend pratical validity to this contention. Certainly there were many reconfigurations of warships during World War II, but every major combat system used during the war was designed and developed prior to the war's outbreak. With a minimum development time of five to seven years there is little prospect of developing and deploying new combat systems to counter wartime threats. The only development that simulated a tremendous technological breakthrough in the Pacific war (other than the atomic bomb) was the introduction of the kamikaze. No effective defense was known or developed, and only its late entry into the war prevented it from playing a major role in deciding the outcome. Failure of the United States to plan now to predict and counter such a technological breakthrough could prove disastrous in a future war. It is no longer a feasible option to sit back and see what happens. With all of the limitations of threat analysis and operational scenario development considered, it is clearly important that every effort be made to predict and design the systems now that we will need at the turn of the century.

Our development process has also assumed that a force designed to fight a NATO war in battle group operations is capable of handling any lower level of conflict. This contention is increasingly coming into question — particularly in light of the recent massive proliferation of cheap, precision-guided munitions.

A classic example of constrained design leading to a marginally useful ship class is considered to be that of the USS Dealey (DE-1006). Envisioned as a low-cost, mass-produced ocean escort class, the ships were built for a mission they were never assigned, and were found unacceptable for anything else.[171]

The Spruance and Perry classes are more recent examples of such potential mistakes. The versatility of the DD-963 hull has been widely hailed as a tremendous planning decision. Yet such a claim does not correspond with the facts of its development. The hull configuration and design margins were driven by power plant considerations (i.e. the size of the LM-2500 gas turbine) as well as arbitrary decisions by Litton designers. If the Navy had clung to its conceptual DX design, it is likely that the Aegis system would still be looking for a suitable hull. The Spruance class as it stands is decidedly oversized, overpowered, and underarmed. The only seriously considered combat system modification — the 8"/55 gun — appears to be dead, and it remains to be seen whether the relatively small crews will be able to maintain the ships in a high state of readiness. Nevertheless, the hull has proven itself to be highly versatile and it will probably serve as a good basic platform for combat systems modification into the next century.

At the other end of the spectrum, the FFG-7 was a highly constrained design with virtually no growth margin. Since the combat system was lowest on the design priority list, it remains to be seen whether the Navy is not commissioning another Dealey class.

Both ship classes (the DD-963 and FFG-7) have been well-received by the fleet, and, with the possible exception of maintainability, both have received good performance marks. But it must be emphasized that the ultimate performance of either class was not predetermined by any systematic analysis during the design phase.

It currently appears that problems of design constraints are going to get tougher before they get any easier. The primary design consideration of cost is rapidly being replaced by a crisis of personnel availability. It is not unlikely that future ship acquisition programs will be based on "design-to-manning" as well as "design-to-cost". Right now the operational limitations of the manning inadequacies that exist do not seem to be fully appreciated at the higher planning levels (e.g. the project manager for the CG-47 class, upon being informed of an expected lack of adequate personnel to man his ships, brushed the problem aside with the suggestion that mercenaries be hired).[172] As such, the need to supplant men with higher capability (and more expensive) systems may not be realized until a crisis is at hand.

It obviously is desirable to optimize warship performance (within cost and manning constraints) to ensure that we are making a good long-term investment with our funds. The question is, to what extent is performance optimization possible?

Many of the development problems outlined in this study may well prove to be practically insurmountable. The development of rigid operational scenarios and measures of effectiveness for platform analysis are too dependent upon subjective input and are too complex to be able to provide definitive design solutions. But it is equally obvious that the personnel and facilities that are currently available at all levels are not being effectively utilized to achieve the primary objective of analytically narrowing design choices so that the best ship can be designed for the money. In every case, the acquisition system does not produce ships, but rather warships are a byproduct of the system's operation.

The primary obstacle to achieving a development process based on objective analysis lies not in the limitations of the analytical process, but rather in the complete subordination of the design and operational communities to political decisionmakers. Tremendous numbers of studies are done and volumes of analysis generated in the name of ship requirements derivation. But in each instance, the few substantive decisions involved in a ship class initiation are the result of high-level tradeoffs in the political arena.

This situation is aggravated by an organizational parochialism within the Navy. There is almost no focus at any design level on the ultimate product — only on individual functions at hand. The lack of communications between planning and design staffs result in arbitrary, non-justifiable decisions driving a design. There is often a lack of understanding of objectives and design impacts, and a complete absence of design continuity between projects. Ship programs are viewed most often as "something to be gotten over with as quickly as possible," with success being measured in terms of ability to get a design into the water rather than being based upon ultimate ship performance in battle scenarios. Ship production has become largely an administrative, rather than a design exercise.

In August of 1975 a former Litton designer published a fairly scathing attack on the role of the Navy and Litton Industries in the DD-963 design project.[173] Although fairly specific charges of dishonesty in naval systems analysis were made in a widely read naval professional publication (the

U. S. Naval Institute Proceedings), the article elicited no direct response on its primary theme (a fact lamented by the author in a letter published six months later). The charges may have been irrefutable, but more likely no one in the Navy or Litton really cared. The contract had been let, the ships were being produced, the DD-963 decisionmakers in OPNAV had moved on, and the entire design project considered ancient history.

An overview of the ship design organization tends to lead one to believe that the institution of fairly simple changes in DON managerial practices could provide much greater efficiency in the design and development process. On the surface of the problem this seems to be a credible assumption. But such a simplistic approach ignores many of the prime motivating factors that maintain the system intact. Although most people in the design process recognize the basic problems, there are strong pressures in the Department of the Navy — unrelated to the actual design objectives — that continue to inhibit change.

The ostensible mission of the entire ship design and development process is to turn out optimum platforms for the fleet. There have been only two ship development programs in recent history (Polaris and Aegis) in which even one individual has been able to provide some personal identification with the ultimate program objective. The vast majority of DON personnel are involved in only tiny facets of the overall process, and are afforded the opportunity to make few if any design impact decisions.

It has been observed that DON planning personnel fall basically into "high level" and "low level" categories.[174] The "high level" officers deal only with broad and theoretical evaluations of force concepts. Although platforms and combat systems are finite in number, they tend to be addressed only in the abstract. The "low level" officers focus narrowly on minor systems and components as individual units. There is no consideration of operational employment in conjunction with other systems and projects. As a result, few is any individuals see the entire ship system — in terms of a hardware product — as the ultimate objective of the design and development effort.

In the absence of clearly defined mission objectives, the primary focus of most DON personnel has shifted to that of personal career enhancement. The vast numbers of senior naval personnel in the various OPNAV offices provide the prime arena for "front-runners" seeking high-level sponsorship to the top.

In this atmosphere of personal contact and competition, the established organization of OPNAV command relationships has evolved into a network of personal contacts in which the actual development work is carried out. Jobs tend to take on a distinctively individual flavor, with each new officer launching into pet projects that usually die out as soon as he is relieved.

Total combat system and platform development time generally spans at least a 14 year period, yet average officer tour lengths in OPNAV run between two and three years. Thus every OPNAV office sees a complete personnel turnover at least 5 times in the design and development of a total ship system. With each new decisionmaker interjecting his own subjective or intuitive design inputs — seldom with written documentation — ship design requirements are almost always in a state of flux. The ultimate output is much like a game of roulette, with the final combat system suite being dependent upon the time that the design "freeze" is invoked (generally when production funding is obtained).

Without spending time in the OPNAV offices it is impossible to comprehend the extent to which actual functions have become divorced from billet titles, and the extent that project coordination depends on individual personalities. It is not readily apparent, even to those working in OPNAV, exactly who is responsible for exactly what. A query about some aspect of a project's development invariably results in a series of phone calls to try and identify the individual, not the billet, that is handling that particular area. The entire administrative structure is fairly fluid, with responsibilities floating about as officers come and go. The billet turnover process has been characterized as very poor (resulting in project inconsistency), but this is a natural development of an assignment of responsibility that does not clearly follow organizational lines.

Without a doubt, the bureaucratic structure of the organization goes a long way in explaining the nature of the system outputs and the resistance to change. The system as it exists serves the primary needs of those officers that drive it.

There is a pervading feeling that all of the analysis done in defining specific ship requirements is little more than a waste of time. Actual decisionmaking is perceived as an intuitive process conducted strictly "at the top". There is generally no personal identification with ship characteristics below the flag officer level. Those individuals who do work their way into positions where they can make design inputs or changes seem to feel the obligation to do so — regardless of whether quantitative analysis is available to guide their decisions. No officer will readily admit that his own personal experiences are not adequate to qualify him to make subjective performance decisions. An example was offered of the effort that went into cost/performance analyses to prove the utility of limited NTDS and helo haul-down systems for the FFG-7 modernization. A new OP-03 division head almost cut the programs with the stroke of a pen and the subjective evaluation that the added capability wasn't worth the expense. He had once been commanding officer of a destroyer and had operated just fine without those things. For the officers who had done the extensive cost/benefit analysis it all seemed like one big exercise.[175]

Certainly the size of staffs involved in ship development contribute to the lack of mission orientation and the focus on extraneous goals. Senior commanders coming ashore from individual command of hundreds of men and ships worth hundreds of millions of dollars are dropped into crowded cubicles as one among many in relatively junior Pentagon positions. They are so far removed from the decisionmaking process (even trivial decisions compared with those made by an operational commanding officer) and the corporate reward system that they have little motivation even to investigate overall project missions. At every level, the majority of individual effort seems to center on responding to budgetary questions or challenges from above, than to pursuing actively innovative research and analysis.

Even outside of the Department of the Navy there is no great desire expressed for system change. The limitations and problems at each level are largely understood, but interested factions — OSD, Congress, the Executive — are reluctant to decry the subjective nature of ship requirements derivation for fear of having to assume a greater measure of responsibility for product performance themselves. Although such an approach may not be consciously made, there are certainly enough agencies and personnel involved in the ship development process to disperse the blame when things go wrong and to accept responsibility when things go right.

Although the limitations of the current structure of the design and development process within the Department of the Navy are well understood by most Navy offices, parochialism to the lowest level has resulted in continuous finger-pointing and fault-finding rather than real efforts to overcome the difficulties.

NAVSEA designers complain of lack of requirement justification from OP-03; OP-96 complains of lack of technical design information from combat systems designers; combat systems designers complain of lack of performance feedback or design direction from OPNAV; etc. Little effort appears to be expended by individuals to go out and find solutions to their problems.

Communications failure is even a major problem within individual staffs, with officers often not knowing what a man in the next office is working on. NAVSEA underwent a recent organizational change that moved various design activities within their Crystal City building complex. Telephones are seldom utilized for the discussion of engineering specifications, and so the movement of design offices to different building floors in some cases caused a complete severing of personal contact between designers.

Such design contraints as bureaucratic inertia, outside influence, and lack of quantitative performance measures might not be solved by a central project focus, but certainly a widespread understanding of program objectives could help to put such problems in perspective and improve overall design effectiveness in the Department of the Navy. With almost every office on DON producing a different picture of what the Navy needs it is not surprising that OSD, the Executive, and Congress feel no compunction about making their own program decisions and modifications.

Admiral Zumwalt pointed out that "... it can truly be said that no single person in the Navy really has control over even the highest priority or clear-cut program efforts."[176] Most Navy officials point to the fact that there is no one individual in charge of an entire shipbuilding program as the crux of the development problems. One NAVSEA designer put the feeling this way:

> What means do we have for the ship designer to be

> personally identified with the project? I think of the Messerschmitt airplane, and I know who's responsible. I think of the FFG-7 and I'm not sure. Where in the system is the reward for excellence and the penalty for failure? It seems that we can design poor ships and no one pays a price. It seems that if we design a good ship no one gets any credit. I think that's a serious deficiency.[177]

It is widely agreed in most DON offices that what is needed to provide consistently good platforms is something of a shipbuilding "czar" to take responsibility for each class. The rationale is that such an organization would force one individual and one central office to focus solely on the objective of producing the best platform for the money. It would be able to prioritize and balance the various opposing interests to prevent inconsequential or arbitrary decisions from driving the design. Ship classes that are pointed to as successful products of such development organizations are the Polaris SSBN under Rear Admiral William F. Raborn, and the Aegis CG-47 under Rear Admiral Wayne E. Meyer.

Certainly individual responsibility in those cases was largely responsible for successful program development. Projects go nowhere in the Navy without active, continuous, and influential sponsors. In each case a program must be "sold" to authorization and funding activities, and it takes a powerful hand to keep projects from drifting off track.

Rear Admiral Meyer's success with Aegis has been his ability to outlast his competition. He has remained with the program virtually since its inception, and has steadily moved up through the ranks in it, molding it to his own ideas, as his opponents and competitors were transferred or retired. To OPNAV and NAVSEA officers involved with the project, the Aegis program _is_ Wayne Meyer. It is considered something of a "religion" to him and his staff — and he preaches it as such every chance that he gets. One civilian Aegis staff member likened Rear Admiral Meyer to a "bible-belt preacher — he makes you _believe_ in it."[178] At the Aegis/CG-47 design offices in Crystal City there is no question as to what project is developing or what the objective is. The word "Aegis" is painted or posted in every passageway and there is a great sense of urgency that seems to drive all activity.

To be sure, Rear Admiral Meyer has played a major role in marshalling efforts to get the Aegis program to sea. But the contention that such a brand of program management could make _any_ ship development project a success is highly questionable. The Polaris and Aegis programs are unique in the history of ship development as virtually pure "topside down" designs. Both were well-defined combat systems looking for a platform to take them to sea. For the Polaris, this involved the lengthening of a conventional SSN hull — for the Aegis, this involved squeezing the combat system onto a standard Spruance platform. In both cases the program manager took a part in determining system configuration and major performance characteristics — but only from the viewpoint of technical feasibility, not operational need. The only major operational decision in the Polaris program was how many missiles to place in each boat — a question resolved largely by arbitrary selection. The Aegis program basically took a Spruance combat systems suite "as is" — retaining the two MK-45 5"/54 mounts, ASROC, LAMPS, torpedoes, etc. — and making only electronic equipment changes and structural modifications to accommodate the Aegis system. In neither case, Polaris or Aegis, were any cost/performance tradeoffs done to determine marginal utility of system capability. Both were high-mix platforms in which a desire to possess the combat system capability overrode most costing considerations. Few other ship classes have been so open-ended.

The identification and assignment of a project "czar" to a given program is an unresolved problem. Rear Admiral Meyer was not so much selected to head Aegis in its early stages as he personally managed to cling to the program on its way up (if he had had the misfortune to hang his star on the SCS, SES, or any other defunct project he would probably be retired by now). It is a unique individual who is prepared to sacrifice his career for a high-risk program that he believes in, and it is questionable as to how many other "topside down" warships built around a highly defined combat system will be developed. Since the tools and organization are not available to identify clearly an optimal combat suite made up of disparate subsystems, it is not easy to see how a project manager could attach himself to such a platform with unswerving devotion. The Aegis program simply involved putting the combat system package to sea, not a decision of major iterations among a number of subsystems. At any rate, of all of the platforms that are proposed only a small number are actually built — and the production decision is one that is usually made after basic combat suite determination.

Assigning a "czar" to each new platform proposal is probably not going to ensure any greater degree of subsystem justification or any greater number of platforms constructed. An overall program manager — assigned for the life of the program — can facilitate the management project of getting a platform to sea, but it is unlikely, without basic organizational changes at much lower levels, that such a position would result in any greater platform optimization. An overall program "czar" is desirable to provide project focus and serve as a central justification office for all development decisions, but other changes are needed to more effectively carry out the design and development process.

An area of combat systems development that is often looked to as a possible model for ship acquisition is that of the procurement of military aircraft. But in terms of mission identification, performance evaluation, and ability to utilize competitive development and design processes there exists a vast difference between ship and aircraft acquisition programs.

As a tightly constrained combat system, aircraft performance requirements are relatively easy to delineate (i.e. some combination of being able to fly higher, faster, be more maneuverable, and carry a heavier payload than enemy aircraft). Most of these parameters are easily measurable, and aircraft are used in combat on enough occasions to determine operational capabilities. The relatively low design and production costs of aircraft make it easier to foster industrial competition and purchase under a "fly-before-buy" doctrine.

None of these factors are similar for ship procurement. Outside of prolonged full-scale combat there exist no adequate measures of effectiveness or testing process for a total ship system. Providing funds for several contractors to tool up and produce different models is not feasible in terms of the costs involved.

It has been suggested that the fostering of greater design competition within the Navy could produce a better product. But the Navy is still faced with the basic problem of determining selection criteria based on performance, and the acquisition organization provides for no one individual or office to make the final selection determination. With the continued inability to measure performance of a paper design, and a personal reward to designers only for design acceptance — not product performance — it is doubtful that such competition would cause a departure of the decisionmaking process from the political arena.

In summary, the current ship design process is a tremendous, unwieldy organization that has no capacity for generating performance optimized platforms. Tremendous amounts of money, effort, and time are expended by the Navy to delineate ship performance requirements — parameters that are invariably overruled by subjective and arbitrary inputs. There is no structural provision in the Department of the Navy for one individual to take charge of the design and development process and initiate a major system alteration. Operational command functions pass directly through the naval hierarchy to the Secretary of Defense. The CNO has largely taken over the lobbying and political role of the Secretary of the Navy (although remaining nominally in charge of all Navy functions), and the Office of the Secretary of the Navy has evolved into little more than that of a figurehead position. The development of so many power centers and spheres of influence have largely eliminated the capacity of the Department of the Navy to contract its own size and functions down to manageable levels.

Despite these severe structural limitations both within, and outside of the Department of the Navy, it is nevertheless possible to identify a number of areas which can and should be addressed to bring greater efficiency to the ship design process. The following areas are ones which need to be addressed if a move toward platform optimization is to be achieved:

— The development of a consolidated, long-range planning capability to project, as accurately as possible, future naval requirements. This should take the form of one major continuing effort rather than an endless series of short, redundant studies. The limitations of dependence on one set of subjective inputs being understood, it is far better that naval development programs be given some definitive direction rather than being allowed to drift aimlessly, subject to numerous disparate pressures.

— The development of a solid communications link throughout the planning and design chains of command — preferably by rotation of officers through billets from technical facilities, to systems analysis groups, to requirements determination offices, to Congressional/OSD liaison, and to design offices. This should occur in conjunction with the establishment of a basic organizational framework to bring all of the activities involved in ship design into a viable development chain so that a true project focus can be realized. At a minimum, this might enable combat systems designers to better optimize their systems to the most critical constraints (e.g. cost, manning, weight, etc.).

— The placement of primary emphasis on Tac D&E and OT&E as the pre-eminent functions of fleet operations. This should be followed by the development of communications networks and support facilities to identify clearly definable inter- and intratype tactics for use in operational scenarios for combat systems and platform development. This should also spur identification of tactical limitations and the development of alternate means of performance qualification.

— The integration and focus of systems analysis activities on providing solid input into the ship development process. Ideally this would lead to the development of standard measures of effectiveness for valid cost/performance tradeoffs. A critical appraisal of systems analysis activities, particularly civilian contract agencies, should be made to determine their cost-effectiveness to the Navy. Those that are not providing a justifiable input into the development process should be severed from Navy contracts.

— A strict appraisal made of the number of personnel involved in planning activities in the Department of the Navy. If the primary subjective decisions are most effectively made by a small number of individuals, then superfluous groups should be cut out of the design and development process.

— The development of an administrative procedure to document clearly all design decisions and decision rationale. This would hopefully lead to a minimizing of the imposition of arbitrary and undocumented design constraints.

— The development of feedback channels from fleet operators back through OT&E, OPNAV, and ship and combat systems designers to provide some preliminary focus to the evaluation of fleet needs. This should be done in conjunction with wider evaluation of foreign combat systems to provide a much broader base for alternate configuration decisions.

— A reevaluation of the relative value of basic and arbitrary contraints on ship design such as excessive habitability standards.

— Increased efforts made to encourage a total defense approach to naval mission performance. There should exist no concepts of naval development which are considered anathema, sacrosanct, or otherwise inelgible for cost/benefit analysis. Ignoring challenges to the future of surface ships, aircraft carriers, and an all-nuclear submarine fleet does not make such challenges go away, and indeed increases the likelihood that necessary naval capabilities might be arbitrarily cut off by outside agencies.

— A service-wide recognition of what can and cannot be quantitatively accomplished through the current planning and design organizations, Navy documents and spokesmen continue to propagate the myth that combat platforms are designed exclusively through the use of quantitative systems analysis. Although individuals don't see this in their own offices, they tend to content themselves with the belief that it is being done somewhere else. A common recognition and expression of the fact that it is really done nowhere would provide a much more realistic atmosphere in which to carry out the ship design process.

Obviously the major roadblocks to change in the ship design process emanate from the Navy itself. The system as it exists serves the individual interests of those involved in the organization, and there is a natural inertia that prohibits movement to a system that might not. It can also be argued that constraints outside of the Department of the Navy will still act to negate any effects of system reorganization. This contention might well be true, but under the current method of doing business tremendous amounts of money, material, and manpower continue to be expended in churning out multi-billion dollar projects of often dubious value. The system as it exists is just not responsive to the true operational needs of the fleet —

whatever those needs can be determined to be.

It is necessary in the overall picture to determine exactly what our design and development limitations are, to establish fleet needs as well as possible, and to design combat platforms which represent the best possible performance characteristics within cost and manning constraints. As one former NAVSEC designer put it, "We could go a long way in improving the way that we build ships, it's just that no one has ever really tried."[179]

Appendix I. Spruance, Perry, and Ticonderoga Class Design Specifications

	DD-963 Spruance	FFG-7 Perry	CG-47 Ticonderoga
Commissioned	1975	1977	(1982)
Displacement (tons)	8010	3537	9055
Length (ft)	560	439	560
Speed (kts)	30+	28	30+
Complement	296	185	320
Armament	1 Sea Sparrow Lchr	1 MK-13 SM-1 Lchr	2 MK-26 SM-2 Lchrs
	ASROC Lchr		ASROC Lchr
	2 MK-45 5"/54	1 76mm OTO	2 MK-45 5"/54
	Harpoon SSM	Harpoon SSM	Harpoon SSM
	*Phalanx	*Phalanx	Phalanx
	MK-32 Torpedo Tubes	MK-32 Torpedo Tubes	MK-32 Torpedo Tubes
	*2 LAMPS III	*2 LAMPS III	2 LAMPS III
	MK-36 RBOC	MK-36 RBOC	MK-36 RBOC
	NTDS	*NTDS	NTDS
Electonics A/S Radar	SPS-40	SPS-49	SPS-49
S/S Radar	SPS-55	SPS-55	SPS-55
FCS	MK-86 (SPQ-9/ SPG-60)	MK-92	MK-86 (SPQ-9) Aegis (SPY-1)
Sonar	SQS-53	SQS-56	SQS-53
Passive Sonar		*SQR-19 (TACTAS)	SQR-19 (TACTAS)
Elex Warfare	SLQ-32	SLQ-32	SLQ-32
Range (NM/kts)	6000/20	5000/18	6000/20
Propulsion	4 LM-2500 Gas Turbine	2 LM-2500 Gas Turbine	4 LM-2500 Gas Turbine
Shaft Horsepower	80,000	40,000	80,000

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*-planned modification
A/S - air search
S/S - surface search
FCS - fire control system
Lchr - launcher
RBOC - Rapid Blooming Offboard Chaff
NTDS - Naval Tactical Data System
LAMPS - Light Airborne Multi-Purpose System

Appendix II. Escort Classes Constructed 1960 to 1980

	Laid Down	Lead Ship	Number in Class
Cruisers	1962	CG-26 Belknap	9
	1963	CGN-35 Truxton	1
	1970	CGN-36 California	2
	1972	CGN-38 Virginia	4
Destroyers	1972	DD-963 Spruance	30
Frigates	1961	FF-1037 Bronstein	2
	1962	FF-1040 Garcia	10
	1962	FFG-1 Brooke	6
	1965	FF-1052 Knox	46
	1975	FFG-7 Perry	75 (?)

Appendix III. Glossary

AAW - Anti-Air Warfare

ABL - Allocated Baseline

ACV - Air-Cushion Vehicle

ANV - Advanced Naval Vehicle

ASMS - Advanced Surface Missile System

ASROC - Anti-Submarine Rocket

ASW - Anti-Submarine Warfare

BPDMS - Basic Point Defense Missile System

BUMED - Bureau of Medicine and Surgery

CBL - Conceptual Baseline

CEB - CNO Executive Board

CF/CD - Concept Formulation/Contract Definition

CIC - Combat Information Center

CNA - Center for Naval Analysis

CNO - Chief of Naval Operations

CODAG - Combination Diesel and Gas

COMOPTEVFOR - Commander, Operational Test and Evaluation Force

CPAM - CNO Program Analysis Memorandum

CPPG - CNO Program Planning Guidance

DCP - Decision Coordinating Paper

DDR&E - OSD Office of Research and Engineering

DNSARC - DON Systems Acquisition Review Council

DOD - Department of Defense

DON - Department of the Navy

DP - Development Proposal

DPPG - Defense Policy and Planning Guidance

DSARC - Defense Systems Acquisition Review Council

DTC - Design-to-Cost

EPA - Extended Planning Annex

FBL - Functional Baseline

FYDP - Five Year Defense Program

GAO - Government Accounting Office

IFF - Identification, Friend or Foe

INS - Institute for Naval Studies (CNA)

ISSM - Interim Surface-to-Surface Missile

JCS - Joint Chiefs of Staff

KW - Kilowatt

LAMPS - Light Airborne Multi-Purpose System

MENS - Mission Element Need Statement

MIT - Massachusetts Institute of Technology

NATO - North Atlantic Treaty Organization

NAVMAT - Naval Material Command

NAVSEA - Naval Sea Systems Command

NAVSEC - Naval Ship Engineering Center

NAVWAG - Naval Warfare Analysis Group (CNA)

NDCP - Navy Decision Coordinating Paper

NSC - National Security Council

NWP - Naval Warfare Publication

OEG - Operations Evaluation Group (CNA)

OMB - Office of Management and Budget

OPNAV - Office of the CNO

OPTEVFOR - Operational Test and Evaluation Force

OP-00X - CNO Long Range Planning Group

OP-02 - Deputy CNO for Submarine Warfare

OP-03 - Deputy CNO for Surface Warfare

OP-32 - Surface Warfare Division (OP-03)

OP-35 - Surface Combat Systems Division (OP-03)

OP-37 - Ship Acquisition and Amphibious, MLSF, Mine, and Special Warfare Division (OP-03)

OP-05 - Deputy CNO for Air Warfare

OP-06 - Deputy CNO for Plans, Policy, and Operations

OP-095 - Director, ASW and Ocean Surveillance Programs

OP-953 - Tactical Readiness Division (OP-095)

OP-96 - Systems Analysis and Long Range Objectives Division

OP-965 - Extended Planning Branch (OP-96)

OP-97 - Office of Ship Acquisition and Improvement

OP-098 - Director, RDT&E

OP-983 - T&E Division

OR - Operational Requirement

OSD - Office of the Secretary of Defense

OSN - Office of the Secretary of the Navy

PA&E - DOD Office of Program Analysis and Evaluation

POM - Program Objective Memorandum

R&D - Research and Development

RDT&E - Research, Development, Test, and Evaluation

RFP - Request for Proposal

SECDEF - Secretary of Defense

SECNAV - Secretary of the Navy

SES - Surface Effect Ship

SHAP - Ship Acquisition Plan

SHAPM - Ship Acquisition Program Manager

SUW - Anti-Surface Warfare

SWATH - Small Water-Plane Area Twin Hull

SWO - Surface Warfare Officer

SWP - Surface Warfare Plan

TAC D&E - Tactical Development and Evaluation

TAO - Tactical Action Officer

TEMP - Test and Evaluation Master Plan

TLR - Top Level Requirement

TLS - Top Level Specifications

TPP - Total Package Procurement

TOR - Tactical Operational Requirements

VSTOL - Vertical/Short Take-off and Landing (Aircraft)

FOOTNOTES

[1]See Preston E. Law, "Accomodating Antenna Systems in the Ship Design Process," Naval Engineers Journal (February 1979), 65-75; Reuven Leopold, "U. S. Naval Ship Design: Platforms vs. Payloads," United States Naval Institute Proceedings (August 1975), 30-37; Alan J. Ramsbotham, "Combat Systems Engineering — Revolutionary Change; Evolutionary Progress," Naval Engineers Journal (June 1974), 56-66; Robert R. Robins and Paul A. Rogers, "Combat System Acquisition for Naval Surface Combatants," Naval Engineers Journal (February 1978), 79-94; A Structured Analysis of NWP-1, 1040-1, Softech, Inc., Waltham, Mass., May 1, 1978.

[2]Elmo R. Zumwalt, On Watch, (New York, 1976), p. 101

[3]DX/DXG Program and DD Operational Requirements, DX/DXG Pre-solicitation Conference, October 27, 1967.

[4]The Buy American Act was passed in 1933 to give preference to American bidders for U. S. government business. The United States may buy abroad only if the foreign bids are greater than some set percentage below bids by U. S. companies.

[5]Interview II. OPNAV.

[6]DX/DXG Program and DD Operational Requirements, p. 10.

[7]Proposal for Development and Production of DD-963 Class Ships, Litton Systems, Advanced Marine Technology Division, April 3, 1969, p. 30; and, Interview II. OPNAV.

[8]J. W. Devanney, "The DX Competition," United States Naval Institute Proceedings (August 1975), p. 21.

[9]Ibid., p. 22.

[10]Ibid.

[11]Proposal for Development and Production of DD-963 Class Ships, Litton Systems, Advanced Marine Technology Division, April 3, 1969.

[12]Devanney, p. 25.

[13]Interview II. OPNAV.

[14]Zumwalt, p. 151.

[15]Ibid., p. 75.

[16]Devanney, p. 26.

[17] Ibid.

[18] Reuven Leopold, "Should the Navy Design Its Own Ships?," United States Naval Institute Proceedings (May 1975), p. 155.

[19] Ibid., p. 164.

[20] Ibid., p. 168.

[21] Ibid., p. 169.

[22] David G. Clark, "Destroyers for the 21st Century," United States Naval Institute Proceedings (March 1979), p. 27.

[23] Patrol Escort Concept Exploration Report. NAVSEASYSCOM, July 1971. p. 3-2.

[24] John W. Newcomb and Anthony R. DiTrapani, "The Patrol Frigate Program — A New Approach to Ship Design and Acquisition," Naval Engineers Journal (August 1973), p. 87.

[25] Clark Graham and Michael Nickelsburg, "Design to Cost — A Viable Concept in Ship Design," Naval Engineers Journal (April 1976), p. 219.

[26] George D. Kerr, "FFG (PF) Case Study — FFG (PF) Program Conception to Contract BL Circulation," Naval Ship Design Workshop at MIT, July 1979, p. 3.

[27] Ibid., p.5.

[28] Ibid.

[29] Ibid.

[30] Graham, p. 218.

[31] Ibid., p. 220.

[32] Zumwalt, p. 81.

[33] Systems planned for later installation included LAMPS III, TACTAS, Helo Recovery System, Fin Stabilizers, Vulcan/Phalanx CIWS, and Link 11 NTDS.

[34] John D. Beecher, "FFG-7: The Concept and Design," United States Naval Institute Proceedings (March 1978), p. 149.

[35] Graham, p. 225.

[36] Kerr, p. 5.

[37] Graham, p. 228.

[38] Kerr, p. 17.

[39] Graham, p. 231.

[40] Ibid., p. 230

[41] U. S. Department of Defense, Annual Defense Department Report, FY 1979, Washington, D.C., 1978, p. 173.

[42] Todd Blades, "DDG-47: Aegis On Its Way to Sea," United States Naval Institute Proceedings (January 1979, p. 104.

[43] James Raber, "DDX Study," Naval Ship Design Workshop at MIT, July 1979, p. 2.

[44] Ibid., p.8.

[45] Interview V. NAVSEA; Interview XIII. NAVSEA.

[46] Department of the Navy RDT&E Management Guide, NAVSO P-2457 (Rev 1-75), January 1, 1975, p. E-11.

[47] Reuven Leopold, Edward C. Svendsun, and Harvey G. Kloehn, "Warship Design/Combat Subsystem Integration — A Complex Problem Unnecessarily Overcomplicated," Naval Engineers Journal (August 1972), p. 42.

[48] Ibid., p. 49.

[49] Interview XIII. NAVSEA.

[50] Raber, p. 12.

[51] Interview V. NAVSEA.

[52] Clark Graham, "The Impact of Subsystems on Naval Ship Design," Naval Engineers Journal (December 1975), p. 15.

[53] Jack Berner, "LSD-41 Program Study," Naval Ship Design Workshop at MIT, July 25, 1979, p. 6.

[54] E.J. Otth, "Comment" (re: Leopold, "Warship Design/Combat Subsystem Integration...") Naval Engineers Journal (August 1972), p. 54.

[55] Interview XIII. NAVSEA.

[56] Berner, p. 6.

[57] Clark Graham, "What Every Subsystem Engineer Should Know About Ship Design — But Does Not Ask," Naval Engineers Journal (June 1978), p. 85.

[58] Interview V. NAVSEA.

[59]James J. Sejd, "Marginal Cost — A Tool in Designing to Cost," Naval Engineers Journal (December 1974), p. 56.

[60]Myron Tribus, "Report of a Workshop on NAVSEA Engineering," Center for Advanced Engineering Study, Department of Ocean Engineering, MIT. September 21, 1979.

[61]Ibid., p.1.

[62]Leopold, "Should the Navy Design Its Own Ships?," p. 164.

[63]Department of the Navy RDT&E Management Guide, p. 2-18.

[64]Ronald E. Adler, "The Advanced Naval Ship and Its Combat System," Naval Engineers Journal (June 1974), p. 70.

[65]Interview XI. Naval Research Laboratory.

[66]Interview VIII. OPNAV.

[67]Interview IV. OPNAV; Interview V. NAVSEA; Interview VI. OPNAV.

[68]Nancy J. Bearg and Edwin A. Deagle, Jr., "Congress and the Defense Budget," in American Defense Policy, 4th ed., ed. John E. Endicott and Roy W. Stafford, Jr., (Baltimore, 1977), p. 337.

[69]Ibid., p. 341.

[70]Les Aspin, "The Defense Budget and Foreign Policy: The Role of Congress," in American Defense Policy, 4th ed., ed. John E. Endicott and Roy W. Stafford, Jr., (Baltimore, 1977), p. 325.

[71]Devanney, p. 28.

[72]Ibid.

[73]U. S. Department of Defense, Annual Defense Department Report, FY 1976 and 7T, Washington, D.C., 1975, p. III-73.

[74]U. S. Department of Defense, Annual Defense Department Report, FY 1975, Washington, D.C., 1974, p. 121.

[75]Zumwalt, p. 117.

[76]Ibid., p. 150.

[77]Interview V. NAVSEA.

[78]Interview VII. OPNAV; Interview VIII. OPNAV.

[79]Raber, p. 8.

[80] Devanney, p. 29.

[81] Interview IX. OPNAV.

[82] Interview VII. OPNAV.

[83] Robert Riggins, "CVV Case Study — Part 1," Naval Ship Design Workshop at MIT, July 1979, p. 2.

[84] Ibid. p. 6.

[85] Ibid., p. 11.

[86] Ibid., p. 6.

[87] Ibid., p. 7.

[88] Interview VIII. OPNAV.

[89] Christopher C. Wright, "Developing Maritime Force Structure Options for the U. S. Defense Program," Unpublished thesis, MIT, 1976, p. 25.

[90] Zumwalt, p. 101.

[91] Interview VIII. OPNAV.

[92] Interview V. NAVSEA.

[93] A Structured Analysis of NWP-1.

[94] Leopold, "Warship Design and Combat Subsystem Integration — A Complex Problem Unnecessarily Overcomplicated," pp. 40-41.

[95] Adler, p. 69.

[96] J. W. Kehoe, "Warship Design: Ours and Theirs," in To Use the Sea, 2nd ed., ed. F.C. Rouse, (Annapolis, Md, 1977), p. 209.

[97] Environmental Control Standards. OPNAV Instruction 9330.5A, OP-37C, August 30, 1965.

[98] Proposal for Development and Production of DD-963 Class Ships, p. 1-49.

[99] Interview V. NAVSEA.

[100] Graham, "Design to Cost — A Viable Concept in Ship Design," p. 221.

[102] Interview VII. OPNAV.

[103] Interview VII. OPNAV.

[104] Interview VII. OPNAV.

[105] Kerr, p. 6.

[106] e.g. see Benen, p. 3.

[107] Interview XI. Naval Research Laboratory; Interview XII. NAVSEA.

[108] Interview VII. OPNAV.

[109] Department of the Navy RDT&E Management Guide, p. 2-8.

[110] Leopold, "U. S. Naval Ship Design: Platforms vs. Payloads," p. 33.

[111] Interview VIII. OPNAV.

[112] Interview VI. OPNAV.

[113] Interview IV. OPNAV; Interview VI. OPNAV.

[114] Interview IV. OPNAV.

[115] Ibid.

[116] Interview VI. OPNAV.

[117] Interview III. CNA.

[118] Ibid.

[119] Interview IV. OPNAV.

[120] The Center for Naval Analysis has made enough money off of Navy contracts to build a large new office building in Alexandria, Virginia — large enough that it is currently renting office space back to OPNAV.

[121] Interview III. CNA.

[122] Interview IV. OPNAV.

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