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6. AUTHOR(S)
Doerry, Norbert H., CDR USN,
Austin, III, William. H.,
Strasel, Erik

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Sea Systems Command
1333Issac Hull Ave. S.E.
Washington Navy Yard, 20376-3101

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This paper describes how the Naval Sea Systems Command (NAVSEA), Space and Naval Warfare Systems Command (SPAWAR) and the Center for Naval Analysis (CNA) assessed basic program requirements and explored a range of alternatives for fielding a new Joint Maritime Command and Control Capability (JCC(X)). It focuses attention on the early stages of the Concept Exploration Phase of Ship Acquisition, specifically the Analysis of Alternatives (AoA). Specific areas studied include staff size, mission space, topside arrangement, survivability, speed, habitability and manning. Additionally, this paper describes the development of an Operational Architecture (OA) used to define the command functions, associated Information Exchange Requirements (IER), and associated command and control spaces and potential equipments for different JCC(X) alternatives.

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JCC(X) Concept Exploration

CDR Norbert H. Doerry, USN, Ph.D., Wm. H. Austin III, Erik Strasel

ABSTRACT

This paper describes how the Center for Naval Analysis (CNA) in conjunction with the Naval Sea Systems Command (NAVSEA), and the Space and Naval Warfare Systems Command (SPAWAR) assessed basic program requirements and explored a range of alternatives for fielding a new Joint Maritime Command and Control Capability (JCC(X)). It focuses attention on the early stages of the Concept Exploration Phase of Ship Acquisition, specifically the Analysis of Alternatives (AoA). Specific areas studied include staff size, mission space, topside arrangement, survivability, speed, habitability and manning. Additionally, this paper describes the development of an Operational Architecture (OA) used to define the command functions, associated Information Exchange Requirements (IERs), and associated command and control spaces and potential equipments for different JCC(X) alternatives.

INTRODUCTION

The U.S. Navy currently operates four command ships: Two AGFs converted from LPDs and two LCCs. Figure 1 shows the Navy's youngest command ship (commissioned in 1971), USS MOUNT WHITNEY (LCC 20). All four ships are approaching the end of their service lives and need replacement. More importantly, the advent of Network Centric Warfare and joint operations has significantly changed the roles that command ships fulfill. While the current ships have been heavily modified to serve in a joint warfare capacity, they cannot be optimized and are in many ways unable to meet current operational command and control needs.

The Joint Maritime Command and Control Capability (JCC(X)) Program was initiated following the completion of a Mission Area Analysis (MAA) in March 1999, requested by OPNAV N86*. A Mission Need Statement (MNS) was subsequently developed to address the deficiencies identified in the MAA. The MNS was validated and approved by the Chief of Naval Operations (CNO) in September 1999. It specifically states that "JCC(X) will provide an embarked Joint Force Commander (JFC) and staff with mission capability for joint campaign battle management. It will employ the information superiority that results from advanced C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance). JCC(X) will also provide an embarked numbered Fleet commander and staff with the same capabilities for operational control of assigned U.S. Naval and allied forces"

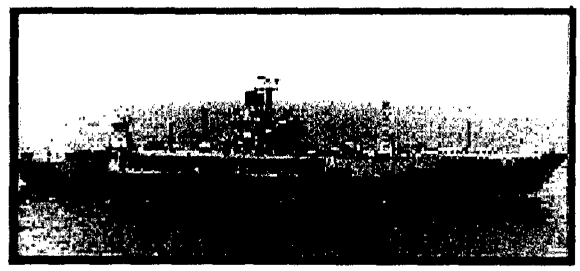

Figure 1: USS MOUNT WHITNEY LCC 20

It further states, "The JCC(X) will provide a sea-based campaign battle management mission package, staffing, and the terrestrial and space C4ISR hardware/software mission package(s) to support an embarked Joint Force Commander (JFC) and staff, as well as Fleet and component commanders and associated staffs. JCC(X) will support efficient, multifaceted operations to include joint, naval, interagency, multi-national and non-governmental organization operations. JCC(X) will provide interoperability with the joint C4ISR support elements airborne, afloat and ashore, in theater and out of theater. Interoperability with other nations will be provided as may be deemed necessary."

Validation and signature of the MNS led to a decision to begin the Concept Exploration (CE) Phase for JCC(X). Following a milestone

*Currently N76 following reorganization

decision, the Center for Naval Analysis (CNA) initiated a series of studies to further define JCC(X). Naval Sea Systems Command (NAVSEA) in partnership with the Space and Naval Warfare Systems Command (SPAWAR) assisted CNA in conducting a series of studies more commonly referred to as an Analysis of Alternatives (AoA). Other activities commonly associated with Concept Exploration include:

- Development of an Operational Requirements Document (ORD)
- Development of other required documentation including an Acquisition Strategy (AS), C4I Support Plan (C4ISP), Test and Evaluation Strategy, Cost Analysis Requirements Document (CARD), and Program Life Cycle Cost Estimate (PLCCE).
- Development of system level specifications presented as either a "how to" specification or a "performance" specification (P-spec)
- Development of procurement documents including a Request For Proposal (RFP), Statement Of Work (SOW) and Source Selection Plan (SSP)
- Development of a cost estimate for design and construction in support of the Planning, Programming, and Budgeting System (PPBS)

Note that a "ship design" is not one of the principal products of the Concept Exploration phase. This does not mean that ship designs are not developed during Concept Exploration. It means that designs are high level conceptual representations with only enough detail to assess their relative merits against other alternatives. For the JCC(X) AoA over sixty ship design concepts were developed as tools for understanding and assessing requirements.

Since CE is a broad multi-faceted phase of early systems acquisition, this paper concentrates on only the AoA portion of the CE phase and reviews in detail those efforts that addressed specific ship design features. Specifically this paper describes the efforts to bracket the major functional design areas that drive acquisition and life cycle costs. These areas include hull size, speed, survivability and manning. Efforts to assess existing ship designs to determine if conversions, modified repeat designs, or service life extension could provide the required capability will also be discussed.

ANALYSIS OF ALTERNATIVES

AoA guidance for JCC(X) was provided by the Assistant Secretary of the Navy for Research Development and Acquisitions (ASN(RDA)) as an attachment to the Milestone 0 decision letter in November 1999. This letter directed a two part AoA. Part I required a study to evaluate the utility of a distributed command and control system versus a dedicated ship. Part II, if needed, would then evaluate the best options to satisfy the mission requirements. This guidance was interpreted as direction to determine if C4ISR systems had advanced to the point where land based facilities could be used exclusively to accomplish the command and control mission, or if command and control could be a dedicated ship or distributed capability across multiple ships.

OPNAV proposed and ASN(RDA) approved an AoA study director. In keeping with other recent programs OPNAV chose CNA to lead the JCC(X) AoA. PMS377, part of the Program Executive Office for Expeditionary Warfare (PEO EXW), was designated as the Program Management Office (PMO) responsible for overall program management. NAVSEA 05D, Surface Ship Design And Systems Engineering Group was assigned responsibility for supporting the AoA, and conducting fact finding and ship design concept studies. SPAWAR 053 was tasked by the NAVSEA Ship Design Manager (SDM) to assist in C4ISR system definition and topside design studies.

A JCC(X) Oversight Group (JOG) was assembled from senior representatives (flag officers and senior executive service civilians) from the Office of Secretary of Defense for Planning, Acquisition and Evaluation (OSD/PA&E), Deputy Assistant Secretary of the Navy for C4I Systems (DASN(C4I)), Deputy Assistant Secretary of the Navy for Ships (DASN(Ship)), Joint Forces Command (JFCOM), Unified Pacific Command (PACOM), U.S. Unified Central Command (CENTCOM), Chief of Naval Operations (OPNAV N6, N7 and N8), Commander in Chief of Atlantic Fleet (CINCLANTFLT), Commander in Chief of Pacific Fleet (CINCPACFLT, Numbered Fleet Commanders, U.S. Navy Central Command (COMUSNAVCENT), Program Executive Officer for Expeditionary Warfare (PEO EXW), Marine Corps Combat Development Command (MCCDC) and Marine Corps District Washington Policy and Procedures office (DCMC/PPO). This group met on a predetermined schedule to assess the interim findings of the AoA. Six meetings were held over a one year period. During each meeting the JOG reviewed available data and considered eliminating alternatives and/or suggested new areas for study.

AoA PART I

The first step for the JCC(X) team was defining joint command and control requirements with the principal issue becoming the identification of all the functional areas needed to support a 3 star Joint Force Commander (JFC), his staff, component commanders and their staffs, plus other government agencies, and allied and coalition staffs with mission capabilities for joint campaign battle management. Defining this federated organization of staffs, referred to as a Combined Joint Task Force (CJTF) established the minimum requirement for functional capabilities and facilities.

Understanding how the location of the CJTF staff affected the interaction between component staff and other organizations required the development of a Concept of Operations (CONOPS). The CONOPS provided an operational context for the definition of the JCC(X) systems. The JCC(X) CONOPS identified three primary mission scenarios; humanitarian relief operation, regional conflicts, and major theater conflict. It also set the framework for which component staffs might be involved during various operations. The key question now became could operational level command and control for these operations be achieved entirely from the rear.

The answer to this question came from various satellite communications studies that showed that while significant advancements are expected in the next decade, 100% connectivity can not be guaranteed. The AoA part I studies also concluded that the US cannot rely solely on overseas command and control facilities. These results thus pointed to the need for an afloat command and control capability. They did not however determine or provide sufficient information to determine if a dedicated command and control ship was required.

AoA Part I results were briefed to the JOG and endorsed by the OSD Overarching Integrated Product Team (OIPT) on 21 March 2000 which directed that Part II of the AoA begin.

AoA PART II

AoA part II began in April 2000 and included efforts to further understand and define the C4ISR operational requirements, required functions, staffs, and associated information exchange requirements (IERs) needed to support an afloat CJTF. The AoA also sought to examine in more detail the alternatives for distributing the command and control capability across multiple platforms, or creating dedicated command ships using both existing and new designs. It also examined extending the service life of the existing command ship and converting other ships for use as command ships.

An AoA is designed to be a very high comparison of varying levels of performance to ranges of cost. The JCC(X) AoA limited itself to examining design variables that resulted in cost changes on an assumed order of $50M or more in acquisition cost. Specific requirements known to have significant cost impact included embarked staff size, survivability, ship speed and crewing requirements. Ship crewing options included Military Sealift Command (MSC) with Navy detachments, or an all Navy crew. Also examined was the costs delta of providing improved habitability standards up to and including MSC standards for all crew regardless if MSC or military.

Narrowing the range of options required a better understanding of staff size. It was assumed from the beginning that staff size would be a primary driver for designing habitability spaces and command facilities, both of which would require significant ship volume. Extensive review of Joint Publications, historical records and interviews with existing component staffs revealed a wide range of potential staff sizes.

As demonstrated in the CONOPS the function and makeup of the staff changes based on the mission. A CJTF is a composite of multiple service representatives, augmented and supported by other major staffs. Other staffs include, the Joint Force Air Component Commander (JFACC), Joint Maritime Component Commander (JFMCC) and the Joint Force Land Component Commander (JFLCC). The makeup and relative location of these component staffs to one another is scenario dependent. Not all components are required for every mission, nor are they necessarily required to be located in a single area. Multiple studies were subsequently initiated to capture a notional range for staff personnel and required facility space covering the greatest variety of missions.

Other studies were initiated with ranges of staff and mission space to assess relative costs of different size ships and the potential impact to other programs including the CVN(X) and LHA(R). These studies were called Design Space Studies (DSS) and were used to assess ship characteristics such as varying staff sizes, including habitability space, mission area, and topside space required for antennas and sensors. A study was also conducted to examine the required crew to support a large CJTF staff. This study looked at using civilian mariners (CIVMARs) from the Military Sealift Command (MSC) in lieu of or in addition to Navy crewing to reduce annual and total operating cost and, and increase time on station.

A JCC(X) Architecture was also initiated to identify and delineate the command and control functional requirements and Information Exchange Requirements (IERs) for all staff elements. The evolution of the JCC(X) architecture supported the development of the Operational Requirements Document (ORD) and C4I Support Plan (C4ISP) in addition to providing valuable insight into the complexity of the JCC(X) mission system. The architecture was also an asset in the AoA studies and was used as a tool to help quantify staff manning and system requirements.

STAFF SIZE

CNA noted in their review of staff size[1] that "staff size and facility issues are more crucial in a ship than a command center ashore because ships are more expensive to build, much more difficult to enlarge after initial construction, and require significant "hotel facilities" for personnel and as well as operating spaces and systems." It is for these reasons that multiple studies were conducted to assess the relative size of a CJTF staff.

One study looked to combine existing component staffs to determining the optimum staff size if co-located. The principal assumption for this study was that eliminating duplicity across functions common to two or more components could reduce staff personnel. Another study used the Architecture (discussed later) to assess the total staff required to conduct the volume of information exchange required for controlling a mission.

While these studies in general supported one another and provided relative ranges of required personnel, they failed to provide a single hard metric for design. Several issues could not be resolved: first was how might technology and changes in doctrine decrease the staff personnel requirements; second, was what level of conflict should JCC(X) be designed to support?

The AoA concluded that a combined staff size of between 1200 to 1600 personnel will be required to support a major theater conflict, while a combined staff of between 600 and 800 will be required for a regional conflict, or provide humanitarian aid. See figure 2. Lower numbers might be achievable due to technology advances but at increased risk and at a higher cost to develop new systems.

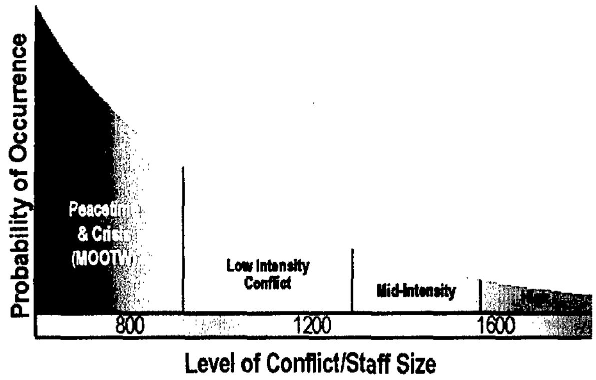

Figure 2: Staff size versus Level of Conflict

Distributing the component staffs across multiple platforms was found to increased the total number of staff personnel required since some duplicative functions across component staffs could not be eliminated. Additional costs were also realized due to the need to buy multiple sets of C4ISR equipment to outfit multiple platforms.

MISSION SPACE

Mission space was another JCC(X) ship design driver. Mission space includes facilities for planning and orchestrating missions as well as normal office space for staff personnel. It also includes area for C4ISR equipment and a limited amount of dedicated storage space. Using the existing command ships as a baseline, a study was initiated that examined the current footprint required for existing systems. System space considered the area for the human operator, area required for maintenance and aisles between multiple systems.

The existing command ships have between 25000 and 27000 square feet of mission space for between 400 and 450 staff personnel, but the space is heavily constrained and no longer includes adequate aisle space or system maintenance space. Removing the constraints and using current design criteria resulted in a need for between 45000 and 51000 square feet (4180 and 4738 sq meters) of mission space to properly support the existing command ship staffs. Using the above as a basis for a parametric analysis, a minimum of 70000 square feet (6500 sq meters) was found to be required to support an 800 person staff.

Allocating this space to component staffs and distributing the staffs to other platforms revealed a significant impact to the primary missions of the other ships. As an example distributing either a JFMCC or JLFCC to a big deck amphibious ship had the potential to eliminate a sizeable portion of the ships vehicle decks which effectively negated it primary mission of transporting and landing assault troops.

DESIGN SPACE STUDIES

Running concurrently with the studies to assess staff size and mission space were design space studies (DSS) that were used to help bracket the total engineering design space. Ship design concepts were assembled using a building block approach for developing alternatives. To be more precise, basic assumptions for major requirements including the number of staff to be embarked, facility space, propulsion type, topside space and habitability standard lead to a mixture of alternatives in which cost versus performance trade-off could be evaluated to derive optimal ship characteristics. Four sets of systematic studies were conducted to gain an understanding of the cost and performance impact of combining these key ship features.

DSS 1: Identifying a Starting Point

The first set of ship specific studies were designed to provide cost vs. performance data and help determine the required budget to support JCC(X). They also served as examples to solicit feedback from the fleet and Joint Commands. Twenty-four ship concepts were systematically developed to determine the impact of the following design variables:

- Sustained Speed
  - 20+ knots
  - 28+ knots
- Survivability / Manning
  - Commercial Standards / MSC
  - Enhanced Passive / MSC

- Enhanced Passive / Navy
- Self Defense / Navy

- Embarked Staff Size
  - 350
  - 600
  - 1200

Sustained speed was assessed based on the use of diesel propulsion versus gas turbines. Survivability was assessed across a range of capabilities starting with standard commercial ship practices as certified by the U.S. Coast Guard, and classed to American Bureau of. Standards (ABS). Enhanced Passive added survivability features to the commercial baseline ship. Featured added included the addition of Navy damage control (DC) standards included a double loop fire main and DC Lockers, hull strengthening, take home power, and additional smoke and flooding sensors. Adding more features to the enhanced commercial baseline created concepts with basic self-defense. Features included Nixie with Anti-torpedo torpedo (ATT) and Advanced Electronics Warfare Counter Measures.

ASSET MONO-LA was the Navy's modeling tool used to develop these ship concepts in sufficient detail to determine basic characteristics, (e.g., length, displacement, etc.) and provide sufficient detail to prepare cost estimates. In addition these concepts provided a basis from which to conduct a total ship survivability study to compare the effectiveness of four levels of assumed survivability.

One of the effective ways to present the results of the DSS 1 studies was the use of contour charts, as shown in Figure 3. Contour charts provided a graphical presentation of how ship characteristics such as displacement, acquisition cost and life cycle cost varied across the design space spanned by the 24 variants. At this stage of the analysis, precise cost numbers were not called for, but by using different colors or patterns for different ranges of values, the impact of different requirements could easily be seen.

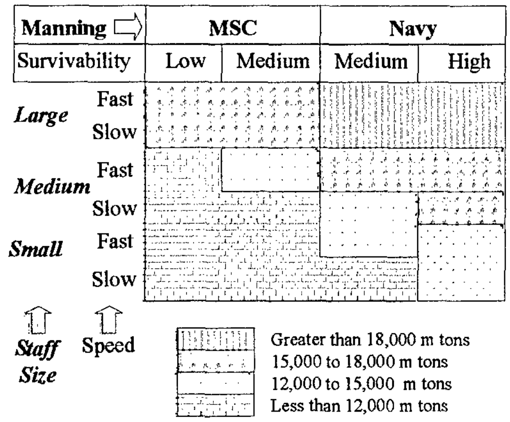

Figure 3 DSS 1 Contour Charts

The conclusions drawn from this initial study where:

- The acquisition cost delta for increasing the sustained speed from 20+ knots to 28+ knots was approximately $100M.
- The acquisition cost delta for increasing the embarked staff size from 350 to 600 was about $100M. The acquisition cost delta for increasing the embarked staff size from 600 to 1200 was about $200M.
- The survivability analysis showed that a relatively small investment in passive survivability features over a pure commercial design provided a significant improvement in survivability.
- Concepts with ship self-defense weapons were shown to perform well against anticipated threats, but cost was considerably higher than other options.
- While relatively large cost and survivability performance deltas were calculated in comparing the Enhanced Passive/MSC and the Enhanced Passive/Navy, on closer examination the differences were attributed principally to the characteristics of ship systems assumed. These different levels of performance of ship systems (e.g. fire fighting, damage control etc.) are normally associated with MSC or Navy Manning. In reality, MSC manning is not inconsistent with the shipboard systems associated with Navy Manning. There is no reason that MSC cannot man and operate a ship equipped with Navy fire fighting systems,

for example. This result forced us to look in greater detail into the issues associated with MSC and Navy manning.

- A side study showed that the acquisition cost difference between ships with identical capability but manned by Navy or MSC was small. Lifecycle costs however, favor the MSC solution primarily because MSC can use less personnel to operate a ship. MSC operators are also typically older and more experienced than their Navy counterparts.
- In developing manning estimates for the MSC variants, we discovered that the size of the Military Detachment would rival and in some cases exceed the size of the MSC crew.

DSS 2: Exploring Survivability Options

A second set of studies was based upon the desire to further explore specific design options using selected survivability improvements to assess the performance of low cost alternatives. To accomplish this goal, the NAVSEA survivability community provided a list of desired features that when added to a pure commercial ship would provide additional survivability performance. These features were then categorized by the community as high, medium or low cost based on their anticipated impact on the acquisition cost of JCC(X). High cost survivability items were those that were estimated to cost more than $20M to implement, examples are self-defense systems like RAM and Variable Frequency Radars. Low cost items were those estimated to cost less than $1M to implement, examples include extra DC lockers and dual loop wet firemain. Medium cost items were those estimated to cost between $1M and $20M to implement, examples include CIWS and signature reduction features.

The survivability features were also divided by what leg of the survivability triangle they supported: susceptibility, vulnerability or recoverability. This was done because of a desire to evaluate which leg provided a more cost-effective solution for a given level of total ship survivability performance.
A baseline ship concept was developed for DSS-2 by modifying the Commercial, 600 staff, 20-knot variant from DSS 1. This concept was modified by first converting it to Navy manning. Navy manning was assumed because DSS 1 identified several anomalies in the way that ASSET MONO-LA, the Navy's modeling tool, treated MSC concepts. Assuming Navy manning provided us with more consistent results. Furthermore we concluded from DSS 1 that the impact in ship design between MSC and Navy manning was not substantial, hence assuming Navy manning would not impact survivability decisions.

In an effort to streamline the AoA process a decision was made to incorporate all of the low cost survivability features in the DSS-2 baseline. The thought was that even if a low cost feature was included, that was not cost effective, and was later deleted; the cost of its addition at this stage of design was well within the cost estimating error of the overall ship cost. Furthermore, the study generally was interested in cost differences between variants, which further reduced the impact of constant low cost changes.

The baseline for DSS 2 also included several additional survivability features shown to be cost effective in the Survivability Analysis from DSS 1, even though they were not in the low cost category. Examples include an advanced degaussing system similar to that specified for LPD 17 and signature reduction efforts.

Even after incorporating all of the low cost features in the baseline, we still had multiple features to consider for incorporation into JCC(X). It would have been cost and time prohibitive to develop ship concepts and perform survivability analysis on each combination of the 20 plus features relative to the AoA timeline. Instead we chose to do a total of nine ship concepts and extrapolate the cost and performance of the other realistic survivability feature combinations.

The nine variants studied were developed as follows:

- Baseline variant
- Modified Baseline variant

- 3 variants for different levels of cost optimized to prevent the ship from getting hit
- 2 variants for different levels of cost optimized to prevent the loss of the ship
- 2 variants for different levels of cost optimized to prevent the loss of the mission

The Modified Baseline variant added a few self-defense systems that were thought by many to significantly improve survivability. The "Preventing the ship from getting hit" options addressed the strategy of improving survivability by significantly emphasizing the susceptibility over vulnerability and recoverability. The remaining four variants substituted different mixes of vulnerability and recoverability features to minimize the impact of weapons hits.

In developing the cost and survivability analysis of these nine variants, the impact of each of the survivability features, or group of survivability features, was identified separately where possible. This allowed us to extrapolate the performance and cost of concepts for which we did not develop models in the ASSET MONO-LA tool. For different categories of threats, all of the modeled and extrapolated points were plotted on a Survivability vs. Acquisition Cost Delta graph to obtain a response surface (Figure 4). Concepts that fall below the Response Surface are sub-optimal with respect to the Survivability Metric. These graphs clearly showed a distinctive "knee in the curve". At that area the slope of the response surface slope changed from large increases in survivability with a relatively small increase in acquisition cost to small increases in survivability with a relatively large increases in acquisition cost. Performance improvement beyond this knee is possible, but at increasingly higher cost per unit of improvement.

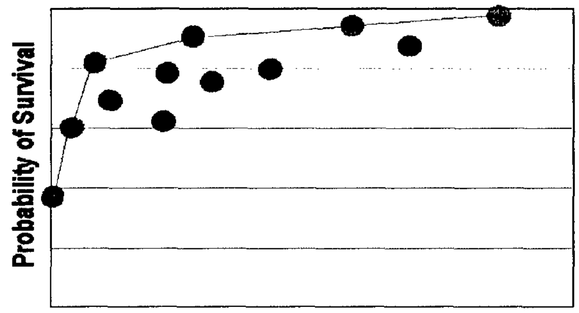

Figure 4 DSS 2 Survivability Response Surface

Identifying the impact of survivability features separately, and including them on the graph, significantly improved our understanding of the cost of improved survivability. One of the surprises from this analysis was that several of the modeled concepts we thought would be close to the response surface were not.

DSS 3: Habitability and Staff Size

DSS 1 and DSS 2 provided significant insight into the composition of the embarked staffs, the support these staffs needed, and the volume, weight, and cost of systems needed to accomplish the JCC(X) mission. This new knowledge warranted further evaluation, especially in the area of habitability. Thus DSS 3 was initiated.

DSS 3 consisted of fourteen ship concepts. In addition to examining the cost impact of Navy vs. MSC manning, DSS 3 examined three levels of habitability (reduced, baseline and enhanced) for embarked staff across the following range:

- 1600 staff
- 1200 with surge to 1600 staff
- 1200 staff
- 800 with surge to 1200 staff
- 800 staff
- 500 with surge to 800 staff
- 500 staff

The surge options recognized the fact that for a substantial fraction of the service life of JCC(X), the actual embarked staff could be significantly smaller than that needed for the worst case scenario. A ship designed for surge would normally house a smaller staff in generous habitability areas but be able to accommodate a larger staff with fold down berthing in those spaces. Theses studies investigated if significant savings in acquisition costs were possible by using a surge approach.

Habitability variations were modeled by providing varying amounts of berthing area per person and varying the sharing of berthing compartments. We investigated three levels of habitability in DSS 3, Reduced, Baseline, Enhanced, where the baseline was approximately equal to the current habitability standards being incorporated in current designs. In each case we provided the ASSET MONO-LA model with an area for berthing and allowed the program to determine the other habitability spaces required.

The conclusions drawn from DSS 3 were:

- Lead ship acquisition cost increases by about $34M for each 100 additional staff.
- The cost of the surge options fell about 65% of the way between the options representing the lower and higher staff numbers
- MSC manned ships cost slightly more in acquisition due to an increase in required habitability space, but annual Operating and Support (O&S) costs were about $10M less due to the decrease in required crew manning.

DSS 4: Clarify Costs

DSS 4 does not investigate a systematic series of changes, but rather responds to issues that were raised during the previous efforts. While DSS 1,2 and 3 provided information to the decision makers and allowed a narrowing down of the options, DSS 4 was primarily aimed at clarifying the assumptions and providing support for the cost estimation and budgetary process.

During post DSS 3 review and analysis we determined that the manning assumptions used in previous studies did not account for about 10% of the operating and support personnel required to allow the staff to accomplish the designated missions. During AoA presentations and other reviews, manual corrections were performed to account for these changes. The first two ship concepts studied under DSS 4 were designed to verify the results of the manual corrections using a consistent methodology.

Throughout the JCC(X) design space study process, there has been a requirement for higher speed. A faster transit allows for reduced crisis response time. DSS 1 showed that increasing speed from 20 to 28 knots increased acquisition costs approximately $100M. DSS 4 is investigating the effect on ship size and acquisition cost of raising the speed to 30+ and 35+ knots.

DSS 4 is still on going, so no results are currently available.

SLEPS, CONVERSIONS, AND MODIFIED REPEATS

The DSS studies provided data for assessing new designs but the AoA guidance also called for examining Service Life Extension Programs (SLEPs), conversions and modified repeat designs as potential alternatives to designing and constructing a totally new ship. To address this requirement NAVSEA initiated another series of studies.

Service Life Extension Program (SLEP)

A SLEP extends the usable life cycle of a ship by improving its reliability and often its capabilities at a lower cost than building a new platform. Our investigation showed that a SLEP on LCC 19 and LCC 20 would cost roughly half of a new design JCC(X). Despite the apparent savings, a SLEP was determined to not be cost effective because it would only extend the life of the ship by 10-15 years, whereas a new ship program can provide ships with life spans of 40 years. Furthermore, the existing ships, even after a service life extension, are generally expected to experience escalating operating costs over their shortened life spans due to their aging infrastructure. In addition, performing a SLEP poses additional challenges in that these ships are not easily configured to provide the flexibility required in supporting different embarked staffs envisioned for JCC(X).

Conversions

An acquisition strategy of converting an existing ship to fulfill a new mission is often pursued to reduce acquisition cost and deliver the desired ship earlier by maintaining the overall structure, hull, and as many systems as possible of the existing ship. Since major spaces must be re-outfitted, significant engineering effort is still needed. Similar to SLEP ships, conversions are rarely optimized for their new mission and suffer from a limited service life, as most are procured midway through their service life. Procuring sufficient numbers of adequate ships to make a class of similar ships is often difficult. If a class consists of several unique ships, using engineering packages across multiple ships is difficult. The engineering costs escalate due to the unique requirements of each ship and negate some of the savings of a conversion. Installation work during a conversion takes place in the cramped confines of the ship as opposed to off-ship locations such as the yard or shop. In addition to the installation costs inherent in all ship constructions, conversions also include both rip-out and modifications costs.

Although converted ships present certain challenges, their use can be beneficial in certain situations. In cases where a long service life is not required, conversions can make sense. They allow for the testing of concepts and the development of requirements for future classes of ships. Conversions also make sense when the Navy has a surplus of a particular class of Ready Reserve ships. Conversions are appropriate when the conversion is localized to a small portion of the ship, preferably with easy access to the exterior of the ship. Finally, conversions make sense when only a few ships with extensive new capability are required.

To support the JCC(X) AOA, four conversion candidates where studied: CG-47 class cruisers, T-AO-187 class Fleet Oilers, Destroyer / Submarine Tenders, and Commercial Cruise Ships. The CG-47 class cruiser conversion could only support a limited staff, and was not comparable to any new design concepts. Mainly because of the limited remaining service life of the converted ships, none of the other conversion candidates provided Total Ownership Cost savings over a new design JCC(X).

Modified Repeat

Modified repeat designs are intended to reduce Total Ownership Cost (TOC) by re-using the design of a hull, propulsion system and as many of the auxiliary systems of an existing ship design as possible. Savings are anticipated in three areas:

1. Re-use of engineering products from the parent ship
2. Reduction in Production costs through the learning curve
3. Reduction in Logistical Support costs through commonality with the parent ship.

Like SLEPs and conversions, the arrangement of the modified-repeat ship is constrained by the existing design and is rarely optimized for the new mission. Furthermore, capability is often purchased that is not required. An example is an LHD like ship which would provide excess capabilities in the form of extra flight deck, a well deck, and hospital spaces. In other cases, systems and components may be obsolete since ships currently in production were designed 10+ years previously

Modified repeats do make sense for certain situations. If the Operational Requirements for the new design and old design are nearly identical then a mod-repeat can make sense. Other significant design requirements such as habitability, air conditioning, and pollution control must be the same or similar, and therefore necessitates a fairly young (such as a ship in production) candidate for mod-repeat given the recent increase in pollution prevention and control regulations. There is generally no advantage to repeat designs that are out of production. In fact there is a penalty in terms of overall program cost: "... if we need less than three ships to perform a mission similar to a designed ship, than an attempt to repeat the design seems beneficial, providing requirements have not changed significantly and the original ship is relatively new. To construct a large class of ships or one with significantly different requirements than an earlier design, it is sensible to develop a totally new design." (Covich and Hammes 1983) [2]

To support the JCC(X) AOA, four modified repeat candidates where studied: LHD 8 Amphibious Assault Ship, LMSR Sealift Ships, LPD 17 Amphibious Assault Ship, and T-AKE Cargo ship. Of these four concepts, only the T-AKE and LMSR modified repeat concepts were cost competitive with, but not significantly cheaper than a new design.

The results of the JCC(X) studies clearly showed that SLEPs and Conversions can have a lower acquisition cost than a new design, but they result in higher TOC. Modified Repeat Designs, under certain conditions and with the right set of requirements may have a TOC comparable to a new design. .

COMBINED MSC AND NAVY MANNING

MSC operates ships at a lower cost than comparable ships operated by the all Navy crews. This was shown in DSS 1 as well as through experience with the conversion of Naval auxiliaries to MSC operation (T-AFS, T-AE and T-AOE). However, issues other than cost required the most study effort.

The primary issue was damage control. The Navy damage control philosophy is based on preventing exploding ordnance from compromising the ship's mission and causing a loss of the ship. The MSC damage control philosophy is based on controlling a main space fire and preventing the loss of life. This difference in philosophy has resulted in differing equipment and doctrines between Navy and MSC crewed ships.

To quantify these differences, NAVSEA and MSC damage control experts held a series of meetings to discuss the differences in objectives, training and equipment. The primary difference was found to be the amount of shipboard training and the amount and type of damage control equipment supplied to the two types of ships. The MSC crews are trained in very similar fire fighting and damage control techniques, many are ex-Navy personnel and they are capable of performing similar tasks. The NAVSEA and MSC damage control experts jointly concluded that both Navy personnel and MSC civilian mariners, if properly trained, could successfully perform damage control procedures in exploding ordnance induced damage scenarios. The design, outfit and operation of the ship will affect the survivability and success of the ship to a much greater extent than the organization that provides the crew.

OPERATIONAL ARCHITECTURE

Integral to developing the host of alternatives to be studied during the AoA was the development of C4ISR architecture to capture and diagram the mission and systems required to field a new joint command and control capability. Architectures are a method of capturing and depicting the operational activities, system functionality and interoperability standards required to support a specific concept. Architectures provide the standards for designing and building the required software, hardware and data networks. The end product of this architecture is a definition of the relationships between the various elements that comprise Joint Command and Control (including both hardware and people) and a detailed understanding of information needs, interfaces and interoperability requirements.

The need for architectures is called out in DoD 5000.2, which requires a process to assess requirement and measures of performance of existing, and planned information systems. The JCC(X) Architecture was developed using the principles and guidelines contained in C4ISR Architecture Framework, Version 2.0, which defines a coordinated DoD wide approach for C4ISR architecture development, presentation, and integration. The development of

Architectures is complex and beyond the scope of this paper, but a top-level discussion is worthwhile to understand the process and its impact on the AoA.

The process begins by querying all potential users to determine who requires what information, who will be sending and receiving, and how the information is to be exchanged. This "who", "what" and "how" is referred to as an Information Exchange Requirement (IER) and is one of the principal outputs of an architecture. The other outputs include graphical, textural and tabular products developed in the course of defining the specific characteristics and interfaces of the systems required to support the top level overview (OV-1). These architectural products are referred to as "views" and provide information in ever increasing levels of detail. The JCC(X) Architecture is comprised of three separate, but interrelated views, the OA, SA and TA

Operational Architecture (OA)

The Operational Architecture (OA) View describes "what" is to be built, identifying the processes and information requirements. Our OA focused on the mission requirements, activities, and information exchange needs of the JTF, subordinate commands, Allied/Coalition commands and government and non-government organizations across a wide array of missions ranging from Humanitarian Assistance/Disaster Relief (HA/DR) to Major Theatre War (MTW).

Systems Architecture (SA)

The Systems Architecture (SA) View describes "how" the process and information requirements identified in the OA are to be implemented. This portion of the process focuses on system functionality vice actual systems, and depicts how multiple system types link and integrate based upon the capabilities and operation of particular system types within the architecture. It provides Functional Node descriptions to support the development of the C4ISR portion of the Performance Specifications and Support Plan. Functional Nodes are defined as nodes that support the operations of command nodes. Additionally, the SA identifies and depicts the DoD system type requirements for elements such as security, interoperability, and reach-back.

Technical Architecture (TA)

The Technical Architecture (TA) View identifies the standards to support interoperability interfaces. The TA consists of identifying the applicable portions of existing technical guidance documentation, tailoring those portions as needed in accordance within the latitude allowed, and filling in any gaps.

To date only the operational views have been completed for JCCX, but the effort has provided significant input to the requirements definition including a range of possible staffs sizes that might embark a JCCX and the identification of over 4700 IERs. The Combined Joint Task Force, is a combination of component staffs Allied/Coalition commands, government and non-government organizations. As a result of the Architecture work we now know that a centrally located composite staff can range between 800 and 1600 depending on the mission. We also know that this multi-faceted group has over 4700 information exchange requirements which require a sizable amount of C4I throughput and dictates a minimal topside square footage to support the wide array of antennas and sensors.

AOA RESULTS

Part I of the AOA completed in March 2000 and concluded that an Afloat capability was required, but did not sufficiently demonstrate that a dedicated ship was needed. Thus Part II of the AoA initially focused on fully distributing the joint command and control capabilities across existing and future ships including the big deck amphibious transports (LHA/LHD) and the carriers (CVN).

In January 2001, the AOA demonstrated that the fully distributed option was not affordable. Based on details learned from the architecture it was determined that even a small component staff of between 150 to 250 persons would seriously impact the primary mission of the existing and planned future ships. Of primary concern was the fact that the mission of command and control was directly in conflict with the mission to either land Marines or launch aircraft. Using scenarios from the CONOPS the JCC(X) team showed that command and control for a major operation gets in the way of the tactical maneuvering requirements for the big deck amphibious warfare ships and aircraft carriers.

This alternative became cost prohibitive from a systems acquisition standpoint since multiple copies of mission equipment were required as staffs were dispersed across different platforms. The amount of bandwidth also went up as staffs were distributed and IERs between staff organizations moved from internal on a single platform to external across multiple platforms.

In March 2001, the AOA demonstrated that extending the service life of the existing command ships, or converting other ships into command ships was not economically desirable. Modified repeat designs were shown to be not significantly cheaper, if at all, than a new design command ship.

The final results of the AOA were presented in July 2001. During this meeting the JOG was asked to agree on three points:

1. That the AOA had completed its original tasking, and there were no additional issues that needed to be addressed by this group.

2. The AOA provided sufficient information for the Navy and DOD to develop preferred alternatives and to support development of an Operational Requirements Document.

3. There was no need for another meeting of the JOG.

The JOG membership concurred on all points. Subsequently CNA was directed to prepare the final report, and the Navy formally requested OSD/PAE to approve completion of the AOA when the report became available.

Specific endorsements and recommendation from the JOG included:

1. A dedicated ship design is required
2. New construction is preferred -- no reason exists to specify a modified repeat or conversion.
3. If a single ship is to host the a full CJTF including Marine Air Ground Task Force (MAGTF) component then the JCC(X) should be designed to support a staff of 1500.
4. If these component staffs and functions can be distributed between 2 ships, then the JCC(X) should be designed to accommodate a staff of 800 with two ship deployed in theater when the need arises.
5. Survivability features identified by the "Knee in the Curve" represent a cost effectiveness approach to selecting desired features.
6. MSC operation of the ship is acceptable.
7. The number of ships purchased depends on the staff size selected.

CONCLUSIONS

The studies performed by the JCC(X) team during the AoA were designed to examine numerous variables associated with ship design, assess the impact of each variable on the total ship, and then pull together the details and cost data to facilitate trading off one alternative against another in a continuous process of elimination. As design concepts were identified, analyzed and costed they were ranked against each other until only a handful of feasible alternatives, each with slightly different capabilities, could be presented to senior military leadership.

The Future

The Navy is now in the process of presenting its preferred alternatives for to the Navy a Requirements Board (NRB) and a Navy Requirements Oversight Council (NROC). The internal Navy review of the Draft ORD is complete, and an updated Draft ORD is being prepared for joint review. Assuming the ORD is approved by the Joint Requirements Oversight

Council (JROC), and the MDA approves, JCC(X) will enter the next phase of advanced concept exploration (System Development & Demonstration) by initiating a competitive functional design effort in FY 2003. Detailed design and construction is expected to begin in FY 2006, with an Initial Operational Capability (IOC) expected in FY 2013.

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CDR Norbert Doerry, USN, Ph.D. is currently the Assistant Acquisition Manager for LHD in the Amphibious Program Office, PMS377. As an Engineering Duty Officer he served in the Naval Sea Systems Command as the JCC(X) Ship Design Manager from 1998 to 2001 and the Technical Director for IPS from 1991 to 1995. He also served as an Assistant Project Officer for Aircraft Carrier repair and new construction at SUPSHIP Newport News. A 1983 U.S. Naval Academy graduate in Electrical Engineering, CDR Doerry earned his Doctorate in Naval Electrical Power Systems from the Massachusetts Institute of Technology in 1991.

Mr. Wm. H. Austin, III is currently the Host Platform Manager for the JCC(X) program in the Amphibious Program Office, PMS377, joining the program in July 00. Prior assignments in NAVSEA include Life Cycle Manager for the LCC 19 Class, Project lead for amphibious and auxiliary ship modernization, and Weight/Stability Engineer for combatant and amphibious ships. He is a 1999 graduate of the Defense Systems Management College (DSMC) in acquisition management and holds a Bachelors of Science degree in Civil Engineering from Old Dominion University.

Erik Strasel P.E. is currently program manger for JCC(X) at CSC Advanced Marine Center in Washington, DC. He is a 1977 graduate of Webb Institute of Naval Architecture.