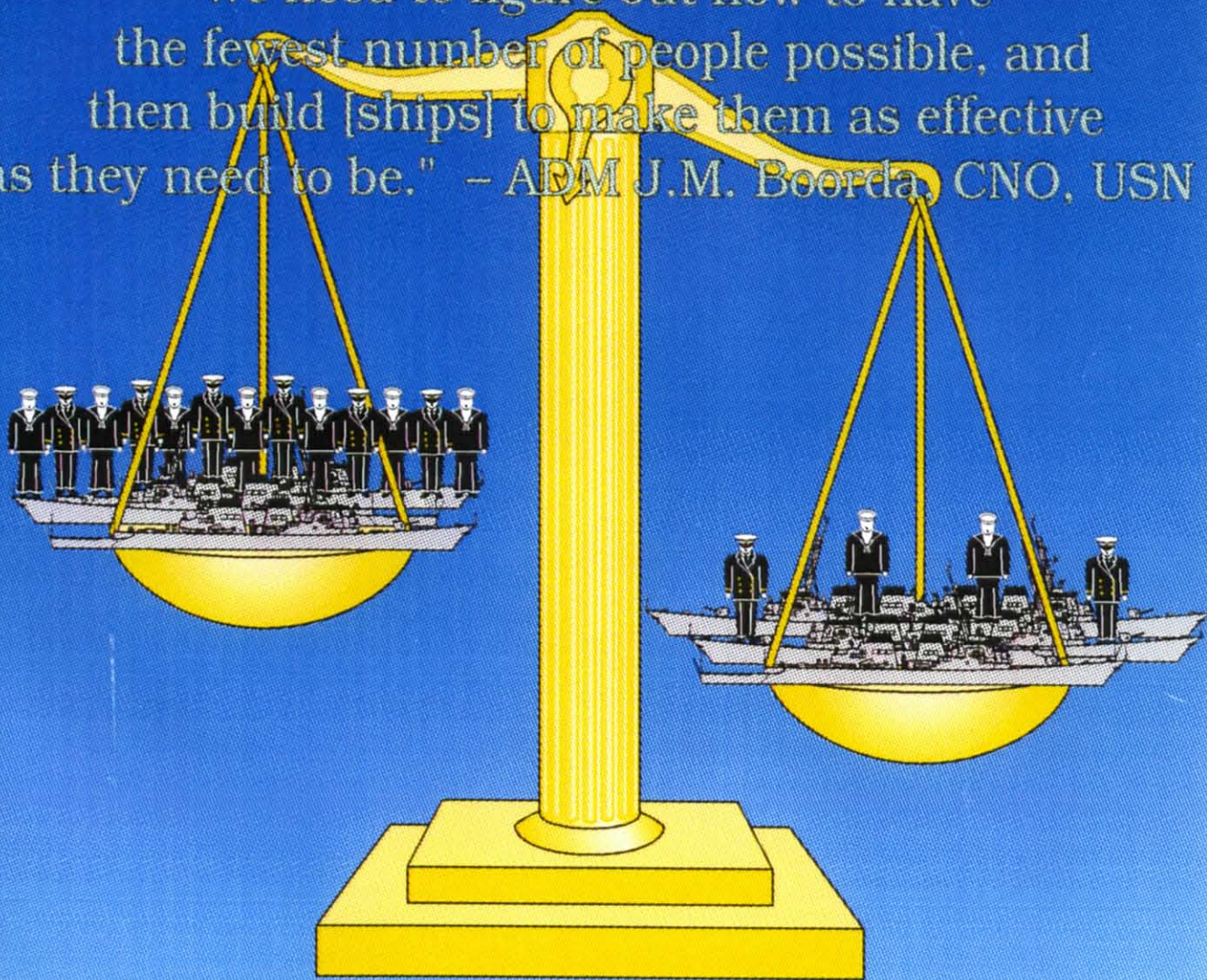




# REDUCED SHIP MANNING

**November 1995**

"We need to figure out how to have the fewest number of people possible, and then build [ships] to make them as effective as they need to be." – ADM J.M. Boorda, CNO, USN



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## **EXECUTIVE SUMMARY**

### **PURPOSE OF STUDY**

In the current post-Cold War era of down-sizing and reduced budgets, the Navy, tasked with new and expanded missions, is expected to do more with less. In this climate, approaches to reduced ship manning, without sacrificing readiness or jeopardizing mission, would be of great benefit inasmuch as manpower-related expenses combine to consume about 60% of the budget. With that background, the Panel reviewed reduced manning concepts and technologies with the potential to enable significant ship manning reductions. The Panel then evaluated the impact of automation on ship design and training.

### **OBSERVATIONS**

Technology is not a roadblock to reduced manning. The application of proven, currently available technology, such as low cost, high speed computers, object-oriented software, open-system architecture, friendly graphical user interfaces, shipboard fiber optic networks, networked digital communications, reliable equipment health monitoring systems, automated ship positioning systems, and corrosion and wear resistant coatings, would yield substantial manpower savings.

Other than the "Law of the Sea" requirement for a posted lookout, there are no legal impediments to crew reduction. Barriers can, however, be found in an unwillingness to break with culture and tradition, in self-imposed policies that inhibit or discourage manpower reduction, in a pervasive perception in the Fleet that manpower is a "free" commodity and need not be constrained, and in a risk aversion philosophy founded on a lack of confidence in earlier attempts at automation.

Foreign navies, also faced with draconian budgetary constraints, have ventured into crew reduction through automation. The results are mixed, with greater success evident in ships designed initially for reduced crews, as compared with those in which the reductions have been imposed as a back-fit. Although the foreign experience is not directly applicable because of differences in mission, size, and national culture, their "lessons learned" were useful in the Panel's deliberations.

Automation is already impacting the ways in which the Navy trains its personnel. The use of multi-media training has reduced learning time and improved individual performance. Embedded training ensures that technicians and operators train on the same systems that they maintain and use.

The Navy has the opportunity to revolutionize the process by which ships are designed so that crew size becomes a principal consideration. The Surface Combatant for the 21st Century (SC-21) Program, now in the early stage of concept definition, should be the vehicle for this radical change. Manpower reductions in the current fleet should be approached through the insertion of technology for automation (which will require some funding up-front) and the revision of restrictive policies (which does not require funding but does require a commitment to reduce manning).





## **RECOMMENDATIONS**

### **PURGE INHIBITING POLICY DIRECTIVES**

The Panel found that manpower-related policy, doctrine and procedures (at all levels of command) tend to impose additional manning requirements and inhibit reductions. Historically, the availability of manpower encourages the continuation of full manning and provides little or no incentive for reduction even when automation is introduced that replaces a manned function. The Chief of Naval Operations (CNO) should conduct a thorough, top-down review of manpower and personnel directives to identify and purge those that are in conflict with the goal to reduce manning. All retained manpower-increasing policy directives should be justified by quantitative risk analysis.

### **REVISE THE ROC/POE DOCUMENTS**

The Ship Manning Document (SMD) is based on ship missions and capabilities and on the Condition III watches specified in the ship's Required Operational Capability (ROC)/Projected Operational Environmental (POE) document. Because there are currently no incentives to constrain manpower, watch requirements are inflated. The Deputy Chief of Naval Operations (Resources, Warfare Requirements and Assessments (N8)) should revise the methodology for development of ROC/POE to reflect an emphasis on manpower reduction through strict control of requirements. As technology is injected to automate ship functions, billet reductions should be generated and formalized during periodic document reviews.

### **DISPEL THE MYTH OF "FREE" MANPOWER**

At all levels of command in the Fleet, there seems to be a general perception that manpower is a "free" commodity. Thus, there is no inclination to either conserve or reduce manning since there is no "cost" to the user. The CNO should establish in the Fleet a system of accountability for the real cost of manpower and create at the Fleet and Type Commander levels a manning budget in the personnel (MP,N) account, with responsibilities similar to Operating Target (OPTAR) accounting in the operations and maintenance (O&M,N) account.

### **REVOLUTIONIZE SHIP AND SHIP SYSTEMS DESIGN**

The design process for new classes of ships does not focus enough attention on the need to reduce the manpower required for operations and maintenance. Specifications for new ship systems, both forward-fit and back-fit, are similarly underconstrained. The CNO should revise the process for the design of new classes of ships such that the potential cost of manpower becomes a visible and accountable factor in the dialog between the platform sponsor and the ship program manager, as are factors such as displacement and payload. New ship systems should, likewise, be required to justify manpower increases. Mechanisms that provide incentives for attention to manning issues should be established at every level.



## **FOCUS ON THE SC-21**

The SC-21 Program is in the early phase of concept formulation. The Mission Need Statement for the ship specifies automation to a degree sufficient to realize significant manpower reductions. The program does not appear to be adequately funded to pursue that critical objective. The CNO should increase funding for the SC-21 Program to enable a revolutionary approach to the design of the ship and a thorough review and resolution of manning issues. Ties to Fleet Process Teams such as Force 21 (COMNAVSURFPAC Study Group) should be institutionalized.

## **DEMONSTRATE TECHNOLOGY**

Proven technologies are available with the power to reduce shipboard watch standing and maintenance manpower requirements. Some reluctance to apply those technologies is founded on a lack of confidence in the reliability of advanced systems and the absence of incentives to automate functions. The CNO should propose an initiative to demonstrate reduced manning technologies in a deployable fleet ship.

## **SUMMARY**

The Panel believes that the Navy stands on the threshold of a new era in which highly capable ships can be made more cost-effective through the introduction of automation and the technologies that enable significantly reduced manning. The savings realized should be returned to the Fleet in additional ships and weapons.

## **The Terms of Reference**

- Review current approach to ships manning
- Review previous reduced-manning studies
- Review manning concepts in foreign navies
- Identify high-impact emerging technologies
- Evaluate impact on training
- Evaluate impact on alternative ship designs
- Evaluate impact on policies

### Terms of Reference

The Terms of Reference directed the Panel to study how technology could be used to reduce ships manning.







## Reduced Manning Panel Membership

- |                                       |                    |                                       |
|---------------------------------------|--------------------|---------------------------------------|
| • <b><u>Chairperson</u></b>           |                    |                                       |
| Dr. Patrick H. Winston                | Professor          | Massachusetts Institute of Technology |
| • <b><u>Vice Chairperson</u></b>      |                    |                                       |
| Mr. Reginald D. Low                   | Vice President     | GDE Systems, Inc.                     |
| • <b><u>Panel Members</u></b>         |                    |                                       |
| Dr. Delores Etter                     | Professor          | University of Colorado                |
| Dr. Daniel N. Held                    | Vice President     | Westinghouse, Norden Systems, Inc.    |
| Dr. Lee D. Hieb, M.D.                 |                    |                                       |
| Bernard M. Kauderer                   | VADM, USN (Ret)    | Kauderer Associates                   |
| Edwin R. Kohn                         | VADM, USN (Ret)    | Private Consultant                    |
| Dr. Reuven Leopold                    | President and CEO  | SYNTEK Technologies Corp.             |
| Joseph Metcalf, III                   | VADM, USN (Ret)    | Private Consultant                    |
| Dr. Irene C. Peden                    | Professor Emeritus | University of Washington              |
| • <b><u>Executive Secretary</u></b>   |                    |                                       |
| Robert J. Hogan                       | CAPT, USN          | NAVSEA                                |
| • <b><u>ASN(RD&amp;A) Sponsor</u></b> |                    |                                       |
| George R. Sterner                     | VADM, USN          | Commander, NAVSEA                     |

### Reduced Manning Panel Membership

Panel members were selected to ensure representation from a balanced, broad perspective, with participants from military, industrial, academic, and medical backgrounds.



## **Studies**

### **Previous**

- The Ships Operational Characteristics Study (1988)
- Report of the Reduced Manning Studies Coordination Group (UK, 1989)

### **Contemporary**

- Review of ROC/POE (N863D PAT)
- Smart Manning Study (N86)

### Studies

In the course of its work, the Panel members examined many previous studies and noted that at least two contemporary studies are underway.

Among the previous studies, the Panel noted that the Ships Operational Characteristics Study of 1988 was particularly well executed and contains a great deal of material that remains highly relevant to ships manning and to other factors in ship design. Accordingly, the Panel decided to reprint the executive summary of that study in appendix A of this report.





## Site Visits

- Great Lakes Naval Training Center, IL
- ICAS Facility, Norfolk, VA
- NAVMAC, Memphis, TN
- Royal Navy, Plymouth and Bath, UK
- Dutch Navy, The Hague and Den Helder
- USS Kitty Hawk (CV 63)
- USNS San Diego (TAFS )
- USS Cape St. George (CG 71)
- USS Willamette (AO 180)

### Site Visits

In the course of its work, the Panel visited various Navy shore facilities for a firsthand look at training, condition-based maintenance, and the manning process.

A subgroup of the Panel also visited the British Navy and the Dutch Navy, both of which are actively working to reduce ships manning.

Finally, the panel members visited a variety of ships, including a civilian-manned supply ship.





## **Representative Briefings**

- The Required Operating Characteristics/Projected Operating Environment (ROC/POE) process
- NAVMAC manpower determination process
- Condition-Based Maintenance
- Damage control
- Coatings and preservation
- Training innovations
- The Surface Combatant 21 (SC-21) program
- The ARPA program Ship Systems Automation (SSA)

### Representative Briefings

The Panel received many briefs, including presentations on the SC-21 program and the ARPA program, both of which will have a strong influence on the way ships are manned in the twenty-first century.



## **Two Views**

- The expense-side view:  
It is about saving money and reducing the defense budget
- The opportunity view:  
It is about getting the most warfighting capability out of a reduced budget

### Two Views

Reducing manning, viewed as a way of saving money so as to enable budget reduction, is an expense-side subject that has attracted little attention. Times have changed, however. Now, budget reduction is a fact, and the subject of manning should be viewed from the perspective of providing the maximum value from the available funding. From that perspective, manning is an opportunity-side question, not an expense-side question.





## **Where Do You Start?**

- Watch standing and damage control are not the problems---the people are there to maintain and preserve the ship.
- Maintenance and preservation are not the problems---the people are there to stand watch and control damage.

### Where Do You Start?

Because most sailors aboard a naval combatant have many diverse duties, automation of some functions can lead to a drop in labor hours without a consequent drop in billets. Accordingly, the introduction of technology aimed at manning reduction must simultaneously reduce the number of people required; for example, to fight the ship, control damage, repair equipment, and prevent surface corrosion. Among such activities, manning reductions in warfighting functions and damage control have to be achieved without loss of capability so as not to diminish the effectiveness of a ship:

- To fight
- To avoid being hit
- To continue to fight even when damaged

Even though reduced manning technology has to decrease work across-the-board to be effective, warfighting functions deserve special emphasis.



## **Admiral J.M. Boorda, USN, CNO**

“ For my entire thirty-nine year career, we always talked about buying ships and manning them with people....I think we need to think about things differently now. **We need to figure out how to have the fewest number of people possible**, and then build [ships] to make them as effective as they need to be.”

### Admiral J.M. Boorda, USN, Chief of Naval Operations

Just about everyone has strong feelings about reduced ships manning. Admiral Boorda, for example, has expressed himself clearly on the issue.

Some individuals, especially in informal discussions, pressed the view that ships manning should be left alone and suggested that emphasis should be placed on reducing the number of Navy personnel ashore instead. Other individuals pressed the view that Navy experience leads to tangible and intangible societal benefits that ought to be considered when thinking about reduced ships manning. The Panel did not explore such views, judging them to be beyond the scope of what the Panel was directed to study in its Terms of Reference.



## Conclusions

- Technology is not a roadblock---manning can be reduced substantially using proven demonstrated technology
- The roadblocks are to be found in culture and tradition:
  - Incentives and deterrents
  - Unnecessarily risk averse self-imposed policy

### Conclusions

The Panel identified many manpower-reducing technologies that not only exist, but also have been demonstrated on ships, yet remain underexploited. When the Panel enquired as to why there has not been more progress in manpower reduction, the most common answer was "culture" or "tradition."

Generally, on further probing, the Panel was able to translate "culture" and "tradition" to a lack of incentive for manpower reduction, or more to the point, to the presence of incentive to increase manpower.

There is a lack of incentive to decrease manpower because manpower is viewed by ship commanders, and even type commanders, as a "free" commodity.

There is an incentive to increase manpower because a lack of manpower is viewed as exposing commanding officers to casualty risks for which they are likely to be held accountable by the Navy, and by public opinion and Congress if a casualty is great enough. Such risk aversion often leads to self-imposed policies that manifest due diligence and cover all the bases, albeit at a high cumulative manpower cost.





## **Our Path to Our Conclusions**

- Technology at work
- Training innovations
- Policy problems
- Manning reality
- Foreign Navies
- An approach to ship design
- Findings & recommendations

### Our Path to Our Conclusions

The remainder of the study consists of a tour through the observations that most influenced the Panel. The report concludes with findings and recommendations.



## **Demonstrated Enabling Technologies**

- Low Cost, High Speed Computers
- Low-cost CD-ROM memory
- Graphical User Interfaces (GUIs )
- Large High Resolution Flat Panel Displays
- Expert Systems
- Reliable Sensors
- Fiber Optic Networks
- Object Oriented Software and Open-System Architecture
- Corrosion and Wear Resistant Coatings
- Automated Geopositioning

### Demonstrated Enabling Technologies

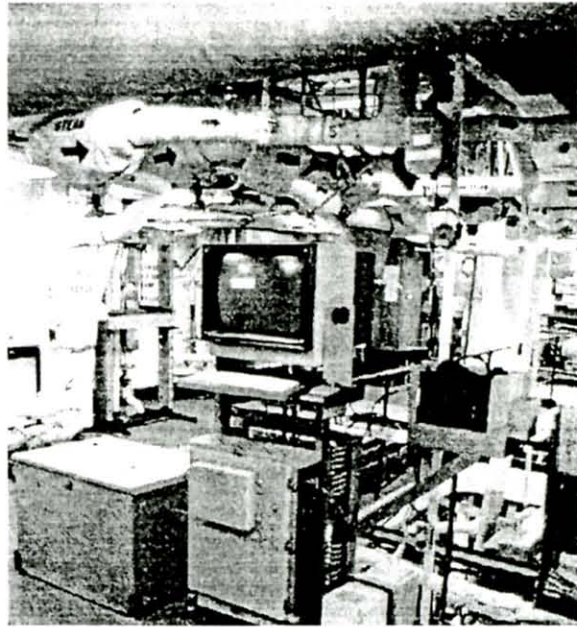
The Panel's first focus was on technology. During the past five to ten years, amazing progress has been made. The technologies listed above are representative of technologies that have moved beyond the merely "existing" level to the "already demonstrated and well established" levels. Such technologies have enormous potential to reduce manning requirements today.





## Condition-Based Maintenance

- **Established by OPNAVINST 4700.7J**
- **Applies Enabling Technologies**
- **First step is Integrated Condition Assessment System (ICAS)**
- **Currently installed on 20 ships**
- **Savings projected at 6000 organizational labor hours per year on DD974**



ICAS on DD974

### Condition-Based Maintenance

As established by OPNAVINST 4700.7J, the Navy is taking steps to implement the philosophy of condition-based maintenance. This philosophy dictates doing maintenance when the condition of equipment suggests maintenance, rather than when specified by a preventive maintenance program or demanded by a failure.

In particular, the Integrated Condition Assessment System (ICAS) is a computer-based, on-line, real-time system that monitors the condition of ships systems and provides expert advice to ships personnel, enabling them to perform maintenance tasks only when needed.

ICAS includes an expert system that monitors a variety of pressure, temperature, flow rate, and other sensors to ascertain machinery and equipment "health," to note trends, and to formulate recommended actions.

ICAS also provides fast, reliable links to technical documentation such as Interactive Electronic Technical Manuals (IETMs) that provide information needed for conducting maintenance or repairs. Links also can be provided to computer-based training information to further supplement information supplied in the IETMs.

To date, ICAS installations have been completed on 20 ships, with projected savings of an average of 6000 hours per DD974 ship per year of organizational labor.

The Panel noted, however, that the primary driver for the introduction of ICAS is the desire to do maintenance better, not to reduce manpower.

## **Job Performance Aids**

### **Examples:**

- Interactive Electronic Technical Manuals (IETM)
  - Interactiveness is an experience equalizer
  - Electronic distribution reduces errors
  - Currently deployed in DD963s
- "Gold Disks" for electronic troubleshooting
  - Provides circuit card diagnostics capability
  - Offers 10:1 reduction in troubleshooting time
  - Extensively deployed ashore and afloat

### Job Performance Aids

Conversion of legacy, paper-based technical manuals to digital form offers excellent opportunities to reduce infrastructure cost while meeting the technical requirements of the 21st century weapons systems. The Navy has already begun to digitize a variety of technical manuals with clearly identifiable benefits: the digital technical manuals are easily and accurately kept up-to-date; they provide on-line access to technical data; and they provide information in a format that enables maintenance personnel to do a better job.

Interactive electronic technical manuals are being deployed on DD963 class ships for the maintenance of the LM2500 turbine engine.

Another example of the use of digitized data is the issuance of the so-called "Gold Disks." These CD-ROMs guide maintenance personnel through printed-circuit board troubleshooting procedures. Conversations with maintenance personnel indicate a 10-to-1 reduction in troubleshooting time.

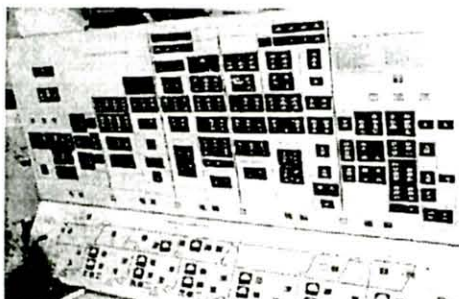
"Gold Disks" are used in both the Combat and Hull, Machinery, and Electrical (HM&E) arenas.



The Panel noted that the primary driver for the introduction of job performance aids is the desire to do maintenance better, not to reduce manpower.

## Survivability Technology

- Damage Control Systems (DCS) that exploit enabling technologies are in service today in U.S. & foreign navies
- PC Computer-Based DCS currently installed on USS Anzio & further installations planned



Traditional Damage Control Console



Typical Console in Fully Integrated DCS on Israeli SAR-5

### Survivability Technology

The Navy currently uses what appears to be time-honored, but excessively manpower-intensive methods in damage control.

Damage control response is commanded from a Damage Control Central (DCC) location. This room is connected by sound-powered telephones to each of the damage control lockers. In the DCC and in each of the lockers, "phone talkers" man the telephone circuits, and in the DCC a "plotter" prints the entries onto a grease board. An additional pair of phone talkers man the sound-powered phone communicating between the DCC and the Bridge. For a 963 class destroyer there are 6 phone talkers in the DCC alone. Communication between a damage control locker and a damage control team working within the ship is conducted via written messages and messengers or "runners." The damage control message is authored by the "scene leader."

Thus, the movement of a message starting at the location of a fire is as follows: a message is hand-written and then carried by the runner to a damage control locker, where the message is read by a phone talker to another phone talker in the DCC on a sound-powered telephone. The phone talker in DCC then writes the message down and hands it to a plotter who transcribes it onto a grease board. Some particularly salient messages are subsequently relayed to the Bridge by yet another pair of phone talkers.

Modern damage control systems, currently coming into operational service in both the U.S. and Israeli navies, have a computer-based communications system. Information is entered via terminals in the damage control lockers, and that information then appears simultaneously and automatically in the DCC and on the Bridge, eliminating the DCC plotter and all phone talkers.

More advanced systems are also starting to appear as demonstrations on U.S. ships. These more advanced systems provide information on combat-systems status and ship stability, as well as expert assistance in combating fires.

The Panel noted that the primary driver for the introduction of such modern systems is the desire to have faster, more accurate information transfer and more reasoned prosecution of emergencies, not to reduce manpower.

## **Preservation Technology**

- Effective, environmentally responsive internal and external coatings exist
- External coating life improved 300%
- Implementation impeded by product cost (and by environmental concerns)
- R&D continuing in industry and government

### Preservation Technology

Both industry and government have developed environmentally responsive, high-durability, extended-life coatings that are available for shipboard use today. Examples are: (1) higher durability, higher gloss, odorless, water-based paints; (2) higher durability non-skid coatings; (3) epoxy tiles; and (4) flame spray aluminum.

A 300% improvement in life expectancy of exterior paints and non-skid coatings is currently achievable. Implementation benefits include significantly reduced maintenance labor.

Deployment of available improved coatings is budget-limited, however. Current NAVSEA implementation plans range from one to twelve years.

Investment in R&D continues in both government and industry. Continuing improvements in environmentally responsive, maintenance reducing coatings can be expected. A clear example is the Navy's continuing R&D investment in "Unicoat." Unicoat is a family of "self-priming" topcoats developed for the corrosion protection of metal and non-metal structures. A 50% reduction in painting time coupled with approximately a 50% reduction in Volatile Organic Components (VOC) has already been achieved. Zero VOC discharge is expected by the year 2000 with the planned continuing R&D program.



The Panel noted that the primary driver for the introduction of such improved coatings is to address environmental issues, to reduce the cost of materials and contractor application, and to improve ship appearance, not to reduce manpower.



## **Existing Watch Standing Technology**

- Global Positioning System (GPS)
- Automated route planning
- Electronic charting & navigation
- Collision avoidance systems
- Electronic log keeping



UK Type 23 Frigate

### Existing Watch Standing Technology

During recent years, Global Positioning Satellites have enabled the development of automated geopositioning systems that establish position with amazing accuracy. Digital charts and search procedures (developed in the field of Artificial Intelligence and elsewhere) add the capability to plan routes so as to satisfy appropriate criteria (for example, shortest distance, minimal structural damage, or least fuel).





## Proposed Watch Standing Technology ARPA SSN688 Example

### **Before**

- PBB Operator
- PNB Operator
- Classifier
- Logkeeper
- Fire Control Coordinator
- Sonar Supervisor
- Auxiliary/Fathometer
- Workload Sharer
- Sonar Phones
- Sonar Repair Technician
- Plot Coordinator
- Time/Bearing Plot Evaluator
- Time/Bearing Plotter
- Contact Bearing Recorder
- Geographic Plotter
- Geographic Plot Evaluator
- Time Range Plot
- Contact Evaluation Plotter

### **Enabling Technologies**

- High Performance Distributed Computing
- Advanced Human-Computer Interaction
- Massively Parallel Signal Processing
- Advanced Artificial Intelligence
- Object-Oriented Databases

### **After**

- Scene Assessment Officer
- Workload Sharer

### Proposed Watch Standing Technology

Although geopositioning technology has progressed dramatically, technology for other aspects of watch standing remains to be developed. More specifically, there is a need for more demonstration and development of technology aimed at fighting the ship.

Accordingly, much of ARPA's Ships' System Automation program is aimed at developing ship-fighting technology.

In an initial feasibility demonstration, the ARPA program showed that it is possible to perform the tasks of SSN-688 sonar and plotting party watch standers by one or two operators working with a highly capable, highly automated Tactical Scene Operator Associate System. Using this system, the operators focus on assessing and monitoring sonar (detection, classification, tracking, and evaluation of acoustic underwater signals) and contact management (the generation of the current tactical picture based on all reported tactical sensor information) rather than data logging, reporting, or manipulating data.

Some of the emerging technologies cited by ARPA that make the development of such a Tactical Scene Operator Associate System possible include:

- High Performance Distributed Computing: High speed networks will enable multiple high-speed computers to work together cooperatively and robustly.



- **Advanced Human-Computer Interaction:** Advanced techniques for data visualization and information presentation will permit operators to review more information in a shorter period of time. New software tools will allow rapid prototyping and tailoring of display interfaces to meet evolving operating requirements.
- **Massively Parallel Signal Processing:** High performance array processors on a common data backplane will allow energy across all bearings and frequencies to be processed automatically. Processing algorithms for energy detection, feature recognition, and energy tracking will allow automatic detection, false alarm rejection, and identification of target signals.
- **Advanced Artificial Intelligence:** Emerging methods from the artificial intelligence community will enable much of the decision logic of operators to be replicated by software algorithms.
- **Object-Oriented Databases and Information Management:** The communication, storage, and retrieval of information is one of the primary tasks performed by tactical sensor operators. The reason for having several operators in plotting parties is simply to ensure that all the information on all contacts of interest is communicated, cataloged, and retrieved. Much of this work can be done automatically.

The ARPA program is, of course, an ambitious, high-risk, high-payoff program, as ARPA programs ought to be. Nevertheless, there are some relatively low-lying fruits to be picked, and the Panel felt that the program is sure to lead to substantial reductions in the manpower required to fight a ship, while simultaneously improving the ship's warfighting capability.

## **Technology Summary**

- Enabling technologies have been demonstrated in maintenance, preservation, survivability, and watch standing
- Applications have been introduced to improve performance, not to reduce manning
- Manning reduction opportunities are underexploited

### Technology Summary

Many important technologies have been introduced in many areas, but in general, the driver for such technology introductions has been improved performance. Accordingly, considerable potential for manpower reduction remains.







## **We Can Train in New Ways**

- Multimedia training: students benefit from motivating graphics, video, sound, hot links
  - Reduces training time
  - Improves individual performance
- Embedded training: operators and maintainers train on the systems they operate
  - Merges operational and maintenance training, with potential for Navy Enlisted Classification (NEC) reduction
  - Ensures that operation and training hardware and software are the same

### We Can Train in New Ways

Having addressed technology, the Panel turned its attention to the impact of technology on training.

When you train using modern multimedia technology, training is more fun, and when you have fun, you learn faster and better. At least, such is the experience of the Service Schools Command at Great Lakes. They have demonstrated that students learn more quickly, score higher on tests, and require fewer instructors when the students are trained in an electronic classroom with a liberal use of animated simulations.

The current focus at the Service Schools Command is maintenance training of individual enlisted personnel. Twenty-two percent fewer training days are needed using the new training technologies.

The Navy is making progress in the use of multimedia training as is evident by the efforts at Great Lakes Service Schools Command. Efforts are in place to expand the reach of the multimedia curriculum to include other disciplines.

The same technology that enables improvements in shore training could have an equally important impact when used to improve embedded training systems.

Embedded training systems are not new, of course. Existing systems already reduce costs by reducing the time required for shore training and by reducing the number of shore-based instructors.

The Navy recognizes the importance of embedded training, as demonstrated by the inclusion of an embedded training requirement in the procurement of new equipment. However, embedded training is often sacrificed to accommodate cost overruns in other areas, even though emerging training technologies increase the benefits of embedded training. Accordingly, it is in the best interest of the Navy that much higher priority be given to embedded training when cost trade-offs must be made.

The Panel noted that the primary drivers for the introduction of multimedia training and embedded training are to improve performance and reduce schoolhouse time, not to reduce manning.

As the training community looks at ways to improve its ability to train, it should also address the impact that training can have on manning, making reduced manning one of its goals. To reach the reduced manning goal, the Navy must expand its use of multimedia training, protect the embedded training budgets associated with new procurements, and explore opportunities to back-fit technology.

## **We Should Train in New Ways**

- Condition-based maintenance systems aid in detailed diagnosis
- Job performance aids reduce the need for detailed training in repair procedures
- Video conferencing moves experience from shore to ship or ship to ship

### We Should Train In New Ways

We need to train in new ways to take advantage of the technologies that are already available:

- Condition-based maintenance systems make it easier for maintenance personnel trained in their use to identify when equipment needs work and what should be done.
- Job performance aids lead maintenance personnel through repair procedures, filling a substantial part of the role of a senior, more experienced tutor.
- Video teleconferencing provides the sailor with real-time access to technical experts ashore or on another ship.

We have been training sailors to specialize in one type of equipment or another, spending a lot of time preparing him or her with just-in-case training, which anticipates problems that might occur. We should provide sailors with more general training, enabling them to use conditioned-based maintenance systems (which help them diagnose a broader range of equipment) and job performance aids (which help them repair that broader range of equipment). Thus, we should move toward general-purpose schoolhouse training, coupled with special-purpose training that occurs when a problem actually emerges. With such training, the sailor is a generalist who becomes a just-in-time specialist, created on the spot with a



job performance aid.

Generally, the Panel was encouraged by the considerable use of new technology in training, but such encouragement naturally stimulated an appetite for even more. In particular, the Panel feels that there is an enormous opportunity to push harder, bringing together multimedia training, embedded training for equipment operation, condition-based maintenance systems, on-line technical manuals, and job performance aids into integrated systems with standard interfaces. Such systems would have two substantial benefits: they would enable one person to both operate and maintain a piece of equipment; and they would enable one person to be cross-trained to both operate and maintain multiple pieces of equipment.



## **Policies, Doctrine, & Procedure**

- There are no *legal* impediments to reduced manning, other than the “Law of the Sea” requirement for a posted lookout
- Risk aversion causes a specific, exceptional casualty to be treated as if it were a general, statistical regularity
- Many manning policies, doctrines, and procedures are self-imposed, usually by a Type Commander, Fleet Commander, or OPNAV

### Policies, Doctrine, & Procedures

Noting that the Navy is deploying technology with manning reduction potential, but without strong emphasis on manning reduction, the Panel turned its attention to policy.

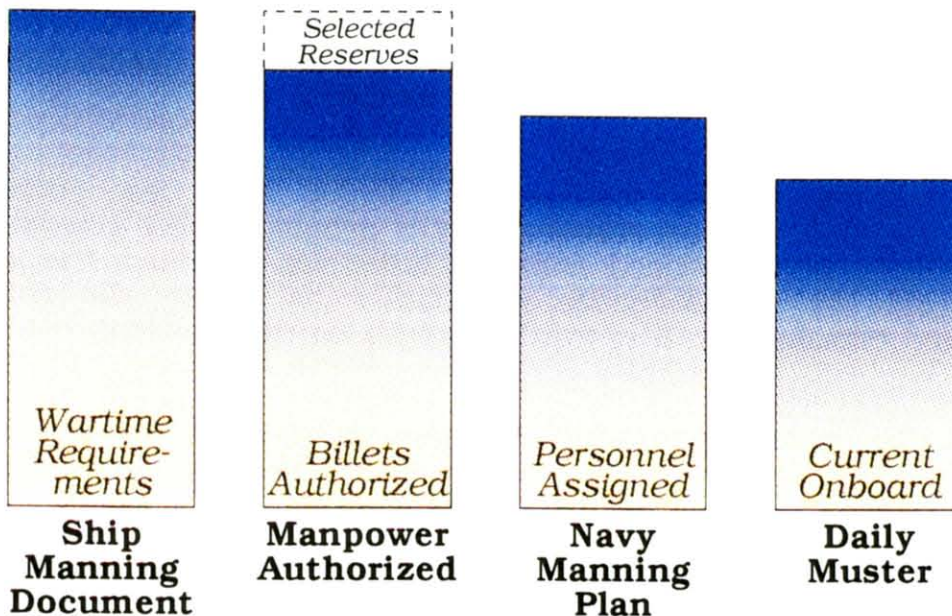
Although some policies are externally imposed (by environmental requirements, for example), others are unnecessarily self-imposed, often as a result of excessively strong risk aversion, which in turn is a consequence of traditions that dictate who is accountable for casualties of various sorts.

In such an atmosphere, there is a tendency to treat an easily debugged problem or once-in-a-generation failure as if it were endemic. A system that causes one ship on one occasion to go dead in the water becomes a pariah system forever.

In order to “trust our instruments” the chain-of-command must determine what is an acceptable level of risk and the chain-of-command must accept that risk for the commanding officer. This in itself will require a reexamination of one of the very core beliefs of the Navy; that of total accountability and responsibility of the seagoing commander.



## Ship Manning Process



### Ship Manning Process

One set of obviously relevant policies are those by which manning is determined. Accordingly, the Panel looked closely at such policies.

The Preliminary Ship Manpower Requirement Document is developed by Naval Sea Systems Command during the initial design. Subsequent to a ship's commissioning, the Naval Manpower Analysis Center (NAVMAC) validates the document by on-ship work studies.

In the determination of personnel requirements, many factors are considered, including ship characteristics, Required Operational Capabilities (ROC) established by the Office of the Chief of Naval Operations (e.g., N86), workload studies, and various manpower standards developed by the U.S. Navy. The product of this effort is the Ships Manning Document (SMD) which formalizes, for a class of ships, the manpower billets required one month after wartime mobilization (M+1). NAVMAC conducts a zero-based review of SMDs every four years.

The number of people assigned to a ship is generally less than specified in the SMD. First, at the Chief of Naval Operations level, fiscal-year funding considerations determine the percentage of M+1 billets in the SMD which will be funded for active duty personnel. The remaining billets are assigned to the selective reserves. For example, 92% of the billets may be funded for the active personnel and the balance to the selected reserves. The result is the Manpower Authorization (MPA).



Next, the Chief of Naval Personnel considers the inventory of active duty personnel available during the fiscal year to develop a Navy Manning Plan (NMP), which is a "fair share" distribution plan. This determination might reduce the number of people assigned to a ship to 88% of the billet requirements.

Finally, in home port on any given day, off-ship training, one-time special on-ship training, shore duty, leave, personnel in transit, and other such reductions limit the ship's productive work force, reducing the daily accounting of people aboard (muster) to something like 75% of the ship's SMD requirement.

Even though a ship will usually deploy with the authorized manpower, the commanding officer's lack of people in port considerably inhibits any interest in reduced manning initiatives. Instead, the lack of available people as viewed by the commander is felt by the chain-of-command and translates into upward pressure on the development of the SMD.

Thus, the manning process focuses on explicit at-sea, at-war considerations, but in-port considerations have a definite, albeit indirect effect.

Accordingly, the Panel felt that the manning process needs some revision to deal with in-port needs and to balance upward pressures on manning with technology-based downward pressures.

## Manpower Comparison

	Dutch M Frigate 3500 Tons	British Type 23 4000 Tons	U.S. FFG-7 4000 Tons	U.S. DD 963 8000 Tons
<b>Operational</b>	60	78	80	122
<b>Weapons Engr.</b>	23	18	41	103
<b>Mech Engr.</b>	35 24%	42 25%	47 24%	78 22%
<b>Supply</b>	28 19%	26 16%	32 16%	53 15%
<b>Totals</b>	<b>146</b>	<b>164</b>	<b>200</b>	<b>356</b>

\* % of Manning

### Manpower Comparison

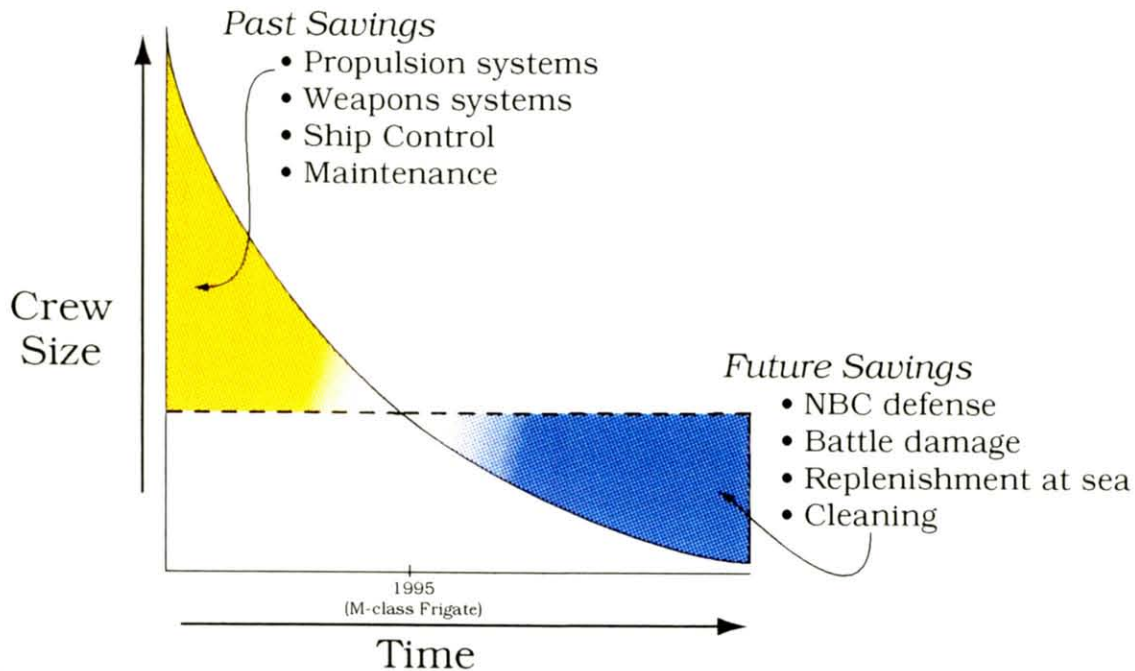
In addition to studying our own Navy, the Panel studied manpower reduction efforts in the British and Dutch navies. The Panel undertook to study these foreign navies with a view toward looking at technology that has been put to use on combatants, not with a view toward looking for models of what the U.S. Navy should be, because foreign navies have different missions, different sizes, different deployment habits, and they are embedded in different cultures.

One striking consistency emerged: from navy to navy and over a wide range of total ship manpower, the fraction of the manpower devoted to each area is approximately the same. This reinforces the view that concentrating technology on just one area may have little impact on manpower reduction, because so many people have secondary responsibilities in other areas. Eliminating preservation work still leaves the sailors aboard to control damage. Eliminating damage control work still leaves the sailor aboard to preserve the ship.





## Dutch Navy's Experience



### Dutch Navy's Experience

The Panel noted that the Dutch Navy views itself, as suggested by the graphic, as having reduced manning primarily by using manning reduction technology in propulsion, weapons systems, ship control, and maintenance. As they see it, technology will continue to help in warfighting and other operational areas, but the more mundane, manpower intensive areas such as cleaning, ship preservation, damage control, and replenishment at sea will require more people than those necessary to fight the ship. To continue the manpower trend downward, more technology initiatives need be directed in such areas.



## **Dutch Navy's Lessons Learned**

- If a upgrade solution adds billets, it is not the right solution.
- Reduced ship manning requires the acceptance of more risk in some areas.
- Ships with reduced manning must be fully manned with trained personnel.
- Manpower reduction must be an integral part of ship design---removing billets from existing ships is difficult.

### Dutch Navy's Lessons Learned

The Dutch feel that they have been able to meet mission requirements while reducing manpower needs by using a structured and disciplined approach to ship design. Functional analysis combined with other methods determine the human and automation interface requirements. Manning reduction is the result of human-machine trade-off decisions that are part of the systematic decomposition of the functions of the systems. Human factors engineers are used early in the design process. The net result is a fighting ship requiring fewer crew members.

In discussions with ship designers at The Hague and with ship operators in Den Helder, several points of philosophy emerged:

- There is a consensus at all levels in the Dutch Navy that manning reduction is essential.
- If an upgrade solution to a problem adds billets, it is the wrong solution.
- To embrace the concept of reduced ship manning, one has to accept higher risk in some areas.
- Ships with reduced manning must be fully manned with trained personnel.

- Manpower reduction must be an integral part of ship design; removing billets from existing ships is difficult.



## Minimum Manning Design Imperatives

- First, require design to meet warfighting space and manpower requirements
- Require all functions to compete for **capped** space and manpower, with priority to warfighting functions
- Design all systems to **connect** required functions **to manpower reducing technology**

### Minimum Manning Design Imperatives

Although manpower has always been a consideration in the design of naval ships, the cost of that manpower has not. As a result, over the years the overall use of manpower changed little, in spite of technology which promised reductions. The core problem is that there has been little incentive to effect reductions either on the part of the requirements setter or the ship designers. One notable exception is to be found in the design of the FFG-7 class. Former CNO Admiral Zumwalt attempted to constrain manpower by setting a requirement limit. Many feel that the experiment failed because intended shore support was not maintained.

The design philosophy of the manpower intensive ship of WWII and before has continued. For example, with no change from those who set requirements in the way a ship will operate, the ship's bridge continues to be designed to accommodate a throng. Except for manpower reductions accompanying the decline of crew-served weapons and manpower savings accompanying the introduction of gas-turbine engines, technology has not had a substantial impact.

If the manpower requirements to fight and operate a ship can be reduced as a fall-out of technology introduction, then ship manpower design criteria should be revised accordingly. In general, this has not happened; tradition and practices associated with past ways of doing business have driven ship design. Perhaps the most significant impediment

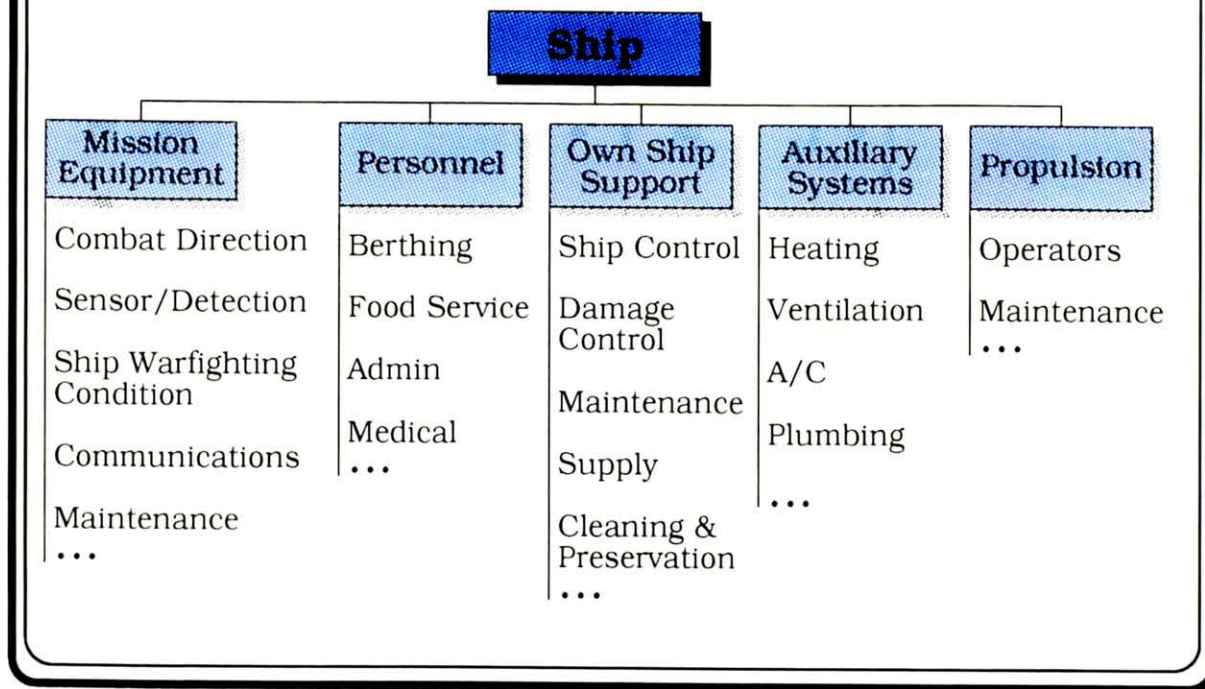
to reducing manpower is the long-standing situation wherein neither the ship builder nor the operator has to pay for the manpower they either design into a ship or use to run it. In effect, manpower has been a "free" commodity; thus, there has been no incentive to decrease the number of shipboard people. Recent design practice seems to continue this trend. In our newest ships, for example, large offices serve the paper on which personnel records are kept. Paper manuals still line the spacious walls of log rooms and weapons control spaces.

In the design of a ship, the impact of unnecessary manpower goes beyond cost; in many cases it directly translates into a reduction in warfighting capability and readiness. This paradigm must be broken. Technology and revised operating practices must combine to reduce manpower requirements, and the design focus must be on satisfying warfighting requirements. All systems, whether they serve people, machines, or weapons must be designed on a criteria of minimum manpower.

Accordingly, we offer, as a sample, an alternative approach characterized by the following:

- First, as in all reasonable approaches to design, the warfighting purpose of a ship is paramount.
- Second, so as to create targets for designers to work toward, a rational, achievable cap is specified on manpower just as a cap is specified on weight in aircraft design. The Panel felt that asking instead for a minimally manned ship would be to provide a license for inaction as people argue that their equipment or function is minimally manned.
- Third, so as to facilitate reaching the target, ship designers are required to connect functions to established manpower-reducing technologies in a manner outlined on the following pages.

# A Generic Design for Minimum Manning



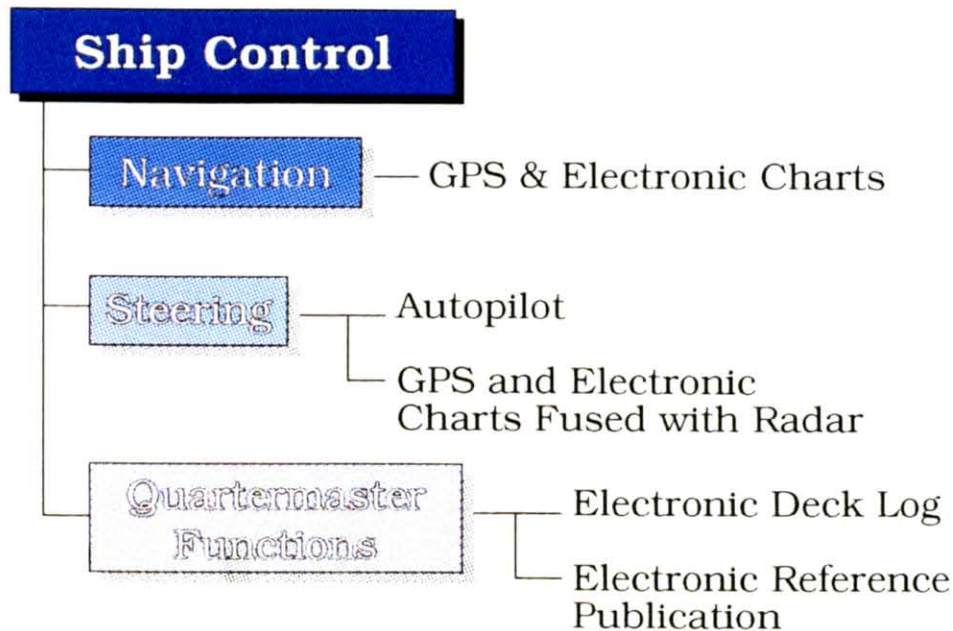
## A Generic Design for Minimum Manning

The process of connecting functions to established manpower-reducing technologies starts by dividing ship functions into areas. In one possible partitioning, the ship functions (that is, the things people do aboard a ship) are divided into five areas.





## Minimum Manning Automation Candidate



### Minimum Manning Automation Candidate

The partitioning and subpartitioning of functions are, ultimately, required to connect to manpower reducing technology.

For example, ship control is a functional area under the overall area of OWN SHIP SUPPORT. Shown under Ship Control are three automation candidates that have the potential to reduce manpower:

**NAVIGATION:** GPS provides positional information. It is a clear example of the potential of technology to enable manpower savings. The electronic chart would replace the paper chart and the labor intensive requirement of keeping charts filed and up-to-date. When used for piloting, the electronic chart would replace navigation teams. The use of GPS and electronic charts could eliminate the function of quartermaster and simplify the tasks of the navigator.

**STEERING:** Automatic Cruise Control expands the notion of automatic steering by adding the dimension of automatically following a preset course and speed. The steering function can be installed at various locations in the ship, such as the combat information center, and except for the requirement for a lookout, could functionally replace the bridge. Radar can be fused with electronic charts to provide a full multi-dimensional picture of the ship's position and the environment around it.

QUARTERMASTER FUNCTIONS: The quartermaster functions of log-keeping and the maintenance of reference publications are excellent candidates for automation.



## Minimum Manning Design Proposed Process

- Reestablish the ships characteristics board (SCIB) responsible for requirements and characteristics for new ship classes and changes to old ship classes.
- The SCIB specifies the manpower allowance for new ship class designs.
- Design the ship utilizing functional analysis, technology, operating procedures, removal of functions, etc. to meet that allowance.
- If the resulting design will not satisfy requirements then alternatives will be submitted to the SCIB for resolution.

### Minimum Manning Design Proposed Process

By way of illustration, we note that one way to create the analog of a customer in the commercial world would be to reestablish the Ships Characteristics Board (SCIB). The SCIB would specify a manpower allowance for new ships and manpower changes for old. The SCIB would arrive at these allowances through an objective assessment of what should be attainable, in close cooperation with fleet representatives, designers, and engineers. Overall allowances would reflect limits placed on functions and systems.

New ships would be designed to meet the manpower allowance established by the SCIB. If the resulting design does not meet the manpower allowance, alternative designs would be presented to the SCIB for resolution.

Thus, the SCIB would both provide visibility and establish a mechanism for attacking the difficult problem of manpower reduction. The SCIB could be the force that exerts downward pressure on manpower by removing the roadblocks to technology and by providing proponentcy for the design imperatives discussed earlier. Minimally, the reestablishment of the SCIB would demonstrate that the senior leaders in the Navy are interested in, and are serious about, manpower reductions.





## **Minimum Manning Design Expected Impact**

- Warfighting functions performed by normal steaming watch standers
- Damage control functions performed by support personnel

### Expected Impact

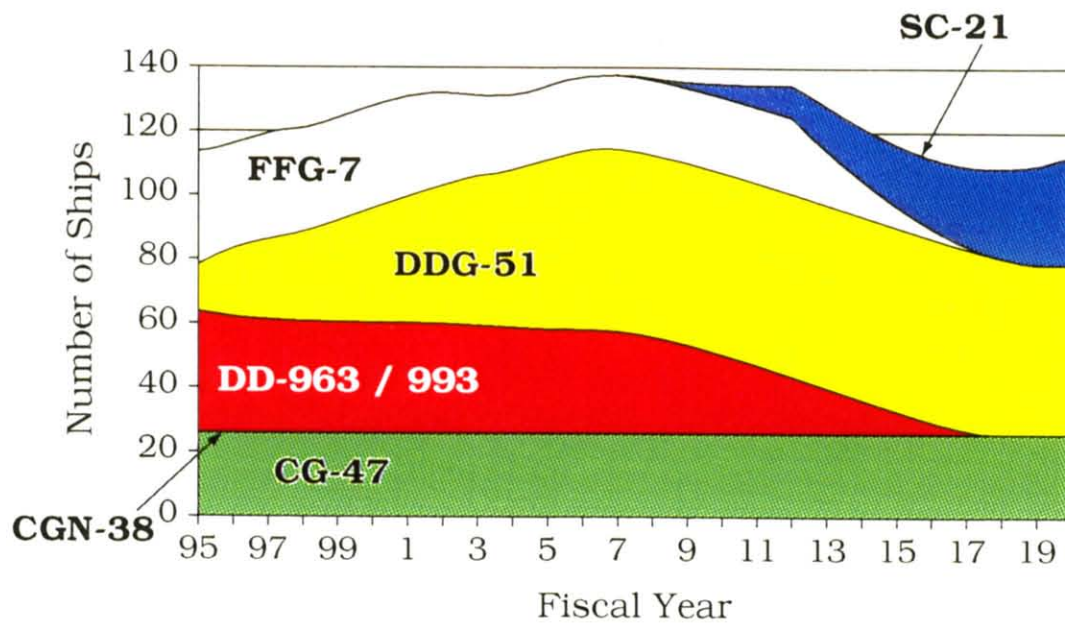
The most obvious impact of a change in design philosophy will be to increase the warfighting capability relative to the size of a ship.

With proper design and automation, the Panel believes necessary ship control and warfighting functions can be performed by people on a normal steaming watch. The ship will always be ready to fight.

Condition I will consist primarily of moving people to damage control stations. The fact that a warship must be able to contain damage does not mean that dedicated manpower for the damage control function need be designed into a minimum manned ship; on the contrary, support persons will form the damage control parties.



## The U.S. Warship Fleet for the Next 25 Years



The U.S. Warship Fleet for the Next 25 Years

Given what could be done with a fresh design, there is a temptation to do nothing by way of current policy or back-fit. The problem with such a temptation is that 80% of the ships of the U.S. Navy of 2020 are in the water now.



## **Elements of Comprehensive Attack**

- Change policies, e.g.
  - Manning the bridge
  - Manning the signal bridge
- Backfit technology, e.g.
  - Remote equipment and space monitoring
  - Integrated GPS/Radar navigation system
- Revise SC-21 ship design approach, e.g.
  - Focus on warfighting
  - Other functions compete for manpower

### Elements of Comprehensive Attack

Plainly, much can be accomplished but only with a broad attack. Because we cannot wait for the next generation of ships, we must seize upon obvious policy changes and affordable back-fits now.

On the other hand, we cannot neglect the next generation. According to material in the standard SC-21 brief, 80% of the SC-21's characteristics will be fixed during the next three years. At the current rate of spending, this means there is just 18 million dollars standing between knowing almost nothing, not even approximate size, and a nearly frozen design.





## **Opportunities**

- Train just-in-time generalists, rather than just-in-case specialists, to reduce NEC manpower
- Develop metrics relating training to warfighting effectiveness, operational readiness, and manning

### Opportunities

In the training dimension, technology insertion is well underway, as reflected by the introduction of multimedia training in the schoolhouse, on-line technical manuals and on-line job performance aids on board.

One especially significant benefit is that it becomes possible to take the training to the problem, both in time and space, reducing the need to train in the schoolhouse for all possible eventualities on board.

Such technology insertion in training should continue rapidly, with special emphasis on seizing opportunities for coordinated effort, so as to work toward, for example, readily reusable software and standard interfaces.

However, to justify such technology insertions quantitatively, a set of metrics should be developed to ensure that the twin goals of improved operational readiness and warfighting capability are being met. As it stands, the Navy measures how people perform in the schoolhouse and operational readiness. However, the Navy does not seem to have metrics and methodologies that directly relate increased training expenditures and new training technologies to improvements in readiness. The development of such metrics and methodologies is important, because improved training is often suggested as a way to reduce manpower.

Thus, the Navy needs to understand, quantitatively, exactly what effect improved training actually has on operational readiness.

## Policy

- *Finding:*  
Other than the “Law of the Sea” requirement for a posted lookout, there are no legal impediments to reduced manning. Manpower related policy, doctrine, and procedures originated in OPNAV and at Fleet and Type Commands, tend to impose additional manning requirements and inhibit reductions.
- *Recommendation:*  
The CNO should conduct a thorough, top down, quantitative review of manpower and personnel directives to identify and purge those that are in conflict with the goal to reduce manning. All retained manpower-increasing policies should be justified by quantitative risk analysis.

### Policy

The study concludes by offering six recommendations that the Panel feels would lead to reduced ships manning, while potentially increasing warfighting capability substantially and certainly not reducing warfighting capability significantly.

The first three of the six recommendations focus on policy changes that would lead to reduced manpower. Of these, the first calls for a policy review to remove obsolete or excessively risk-averse policies.





## **“Free” Manpower**

- *Finding:*  
At all levels of command in the Fleet, manpower is viewed as a “free” commodity, and is therefore not constrained.
- *Recommendation:*  
The CNO should establish, in the Fleet, a system of accountability for the management of manpower, and create a manning budget in the (MP, N) account, with responsibilities similar to OPTAR in the O&M,N account.

### “Free” Manpower

This recommendation suggests the adoption of a policy whereby manning is no longer viewed as a “free” commodity, but rather as something that has to be paid for and traded off against other items for which real money is spent.



## **Required Operational Capabilities (ROC)**

- *Finding:*  
The Ship Manpower Document (SMD) is based on ship capabilities and Condition III watches specified in the ship's Required Operational Capability (ROC)/Projected Operational Environment (POE) document. Watch requirements are often underconstrained.
- *Recommendation:*  
N8 should revise methodology for development of ROC/POE to increase emphasis on manpower reduction throughout the process. N8 should ensure that injections of new technology generate billet reductions.

### Required Operational Capabilities (ROC)

This recommendation proposes to introduce downward manpower pressure in the formulation of the Ships Manning Document, offsetting existing upward pressures.



## Ship and Ship System Design

- *Finding:*  
In the design of new ship classes, and in the specification of capabilities for new systems, backfit as well as forward fit, little consideration is given to minimizing required operations and maintenance manpower.
- *Recommendation:*  
The CNO should revise the process for ship and ship system design such that the cost of manpower is a visible and accountable factor in the dialog between the platform sponsor and the program manager.

### Ship and Ship Systems Design

The final three recommendations deal with future ships. The first of these proposes to elevate the importance of manpower in the negotiations between the provider and the customer.





## SC-21

- *Finding:*  
The Mission Need Statement (MNS) for the 21st century combatant, SC-21, specifies automation to the degree sufficient to realize significant manpower reductions. The program does not appear to be adequately funded for that task; more funding would, for example, enable stronger ties to Fleet teams.
- *Recommendation:*
  - The CNO should increase funding for SC-21 study.
  - Institutionalize stronger ties to Fleet teams, such as Force 21.
  - Establish a new design approach that makes reduced manning second only to warfighting.

### SC-21

In view of its importance to the Navy in the next century, this recommendation suggests the injection of adequate funding, more fleet participation, and a new methodology into the SC-21 program.



## Technology

- *Finding:*  
Proven technologies have the power to reduce shipboard watch standing and maintenance manpower requirements. Technology is not a roadblock; application is required.
- *Recommendation:*  
The CNO should establish an initiative aimed at demonstrating reduced manning technologies and concepts in a deployable fleet ship.

### Technology

Finally, this recommendation, to be undertaken with cooperation from the Chief of Naval Research (CNR), proposes an initiative aimed at demonstrating manpower reduction technology so as to move important technologies over the risk-aversion threshold. Note that the proposed ship is not to be a test ship nor an experimental ship; it is a deployable fleet ship, for no other kind of ship could have the necessary demonstration capability. Note also that it is not a ship for demonstrating new technology in general; the focus must be on ships manning to have a substantive effect on manpower reduction.





## **Appendix A: Executive Summary, Ships Operational**

### **Characteristics Study, 1988**

*Definition of embedded training-* Training capabilities are being designed into equipment/weapon system

Technologies that provide a broad spectrum of deployed training are necessary for maximizing readiness. This is an issue that promises to become increasingly important as manning is reduced under pressure from drivers other than training. Payoffs for embedded training include reduced costs via reduced training time, reduced numbers of shore based instructors, and reduced human error rates.

Embedded training opportunities and simulation are normally incorporated in the material development process. However, in the past training has been sacrificed to accommodate cost overruns in other areas. New and emerging training technologies make possible enhanced individual performance levels and reduced learning times. It is thus in the best interest of the Navy that much higher priority be given to training when cost tradeoffs must be made.

It is the Service Schools Command at Great Lakes experience that students learn more quickly and that fewer training personnel are needed when the electronic classroom and animated simulation approach to training are employed. The current focus at the Service Schools Command is maintenance training of individual enlisted personnel. It is estimated that 22% fewer training days are needed as an outcome of the new training technologies. Animation not only reduces learning time and eliminates the need for a laboratory instructor, but also increases understanding.

#### **WE SHOULD TRAIN IN NEW WAYS**

We need to train in new ways to take advantage of the technologies that are already available. Expert systems to diagnose problems are available in most disciplines today. These systems enable the users to have real-time access to diagnostics to aide in the assessment of the conditions at hand. We must teach the utilization of these tools to improve the technical performance of our people.

Job performance aids offer another splendid opportunity to take advantage of enabling technology. We must change the approach to training to make the sailor a generalist rather than a specialist. By taking advantage of the job performance aid, the sailor trained as a generalist can become a "Just-in-time" specialist. We can further expand this to Video Teleconferencing, where the sailor can have real-time access to technical expert ashore and to the Interactive Electronic Technical Manuals, where the sailor has access to digitized technical information that has been tailored to correcting the problem at hand. All of these technologies are existing and lend themselves to the concept of a generalist.

## PROGRESS

The Navy is making progress in the use of multimedia training as is evident by the efforts at Great Lakes Service Schools Command. Efforts are in place to expand the outreach of the multimedia curriculum to include other disciplines. This approach to training will continue to be the way of the future.

The Navy recognizes the importance of embedded training, including the requirement in the procurement of new equipment. However, this requirement is often sacrificed due to the cost overruns in other areas of the procurement.

## PROBLEMS

As the Navy progresses in the area of the electronic classroom and multimedia training, there are problems. The application of electronic classrooms and multimedia training is limited. The Navy is expanding its use of this medium, but not at a substantial enough rate to take advantage of this established yet still evolving technology.

As stated earlier, the implementation of embedded training is also slowed as the requirement is often raided to offset the costs of other areas of the procurement.

These problems are further compounded by the fact that there are no real metrics. The Navy has no system to measure the impact that multimedia and embedded training has on operational readiness or warfighting capability. This absence of metrics allows the funding of these training initiatives to be a target of opportunity to alleviate other shortfalls.

## OPPORTUNITIES

The Navy should take advantage of the opportunities that training technology offers. The Navy should train its sailors to be generalists and provide the Job Performance Aids that will allow the sailor to be a "Just in Time" specialist.

As the training community looks at ways to improve its ability to train, it should also address the impact that training can have on manning. The training community should have reduced manning as one of its goals. It needs to lead the effort to reduce the manpower necessary to operate the Navy and take advantage of the technology available.

To accomplish this the Navy must expand its utilization of multimedia training. Also, it must protect the embedded training budgets associated with new procurements as well as exploring the opportunities to back-fit this technology. To aid in this effort a set of metrics must be developed to ensure that the goals of improved operational readiness and warfighting capability are being met or as expected, exceeded.





**REPORT OF THE**  
**SHIP OPERATIONAL CHARACTERISTICS STUDY**  
**ON**  
**THE OPERATIONAL CHARACTERISTICS OF THE**  
**SURFACE COMBATANT OF THE YEAR 2010**

**CHIEF OF NAVAL OPERATIONS**

**STAFF (OP-03K)**  
**26 APRIL 1988**

**WASHINGTON, D.C.**





DEPARTMENT OF THE NAVY  
OFFICE OF THE CHIEF OF NAVAL OPERATIONS  
WASHINGTON DC 20350-2000

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SECRET (Unclassified upon removal of enclosure (2))

From: Chief of Naval Operations  
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Subj: PROMULGATION OF THE REPORT OF THE SHIP OPERATIONAL  
CHARACTERISTICS STUDY (SOCS) (U)

Encl: (1) Volume I (Operational Report) of the Report of the Ship  
Operational Characteristics Study (U)  
(2) Volume II (Analyses and Background) of the Report of  
the Ship Operational Characteristics Study (U)

1. The SOCS was convened in February 1987, to recommend the operational characteristics to be incorporated into surface combatants of the year 2010. SOCS membership included unrestricted line officers from Washington headquarters staffs and from the staffs of the Fleet Commanders-in-Chief and the Surface Force Commanders. Many restricted line and staff officers, DOD civilians, and experienced contractors assisted in this effort.

2. An early, key event in the Study was the SOCS Symposium, a three day meeting of fleet and headquarters representatives held in April 1987, at the Naval Weapons Station, Yorktown, Virginia. The 45 participants considered: the threat in the year 2010; present and future functions of surface combatants; the role of automation; and the crewing of ships. The Symposium results were briefed to a panel of Flag Officers headed by Commander-in-Chief, U.S. Atlantic Fleet. The Symposium's recommendations, and the results of four succeeding meetings with fleet representatives, have guided the SOCS throughout and are reflected in the final report.

3. An information briefing encapsulating the results of the Study was given by the Study Director to CINCPACFLT, COMNAVSURFPAC, COMNAVSURFLANT, and DEPCINCLANTFLT and to members of their staffs in early March 1988. In late March the briefing was given successively to the Revolution at Sea (Group MIKE) Review Group, to Group MIKE, and to the CNO and VCNO. Subsequent information briefings were given to members of the PDRC and to Surface Warfare Flag Officers and other Surface Warfare Officers.



Subj: PROMULGATION OF THE REPORT OF THE SHIP OPERATIONAL  
CHARACTERISTICS STUDY (SOCS) (U)

4. Following the SOCS briefing, the CNO stated that he "subscribes to all these recommendations." At the same time, he cautioned that affordability would always be an issue and charged OP-03 with working on this and other aspects of moving forward with the 21st century surface combatant, keeping the process "tightly under control."

5. Enclosures (1) and (2) are the final written report of the SOCS. The Operational Report, volume I, contains the top level view of the results of the Study, much in the same way as those results were presented in the Flag level briefings in March, but with some additional information. Volume II is larger and contains the supporting information, the background and the analysis, associated with the results in Volume I.

6. Broad dissemination of the results of the SOCS is recommended. Requests for additional copies of the Report should be forwarded to: Chief of Naval Operations (OP-03C), Navy Department, Washington, D.C. 20350-2000; phone inquiries to AV 227-9572 or Comm (202)697-9572.



J. J. D. QUIST  
Assistant Chief of Naval Operations  
(Surface Warfare)

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945B, 961C, 098, 07, 71D, 08, 80, 815, 01, 113,  
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04, 412C, 05, 551G, 06)

Director, Surface Combatant Force Requirement Study  
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## FOREWORD

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The Ship Operational Characteristics Study (SOCS) was convened in February 1987, by the Deputy Chief of Naval Operations (Surface Warfare). The Study was to recommend the required characteristics of the surface combatant ship of the year 2010 as determined by Fleet and Headquarters Unrestricted Line (URL) operators. This is the report of that study.

The report is in two volumes. The first, the Operational Report, is an unclassified document which describes the principal results of the Study. In the interest of brevity, and to allow volume I to be unclassified, it contains very little information substantiating our conclusions. That information is in volume II, Analysis and Background, which is classified SECRET.

Volume I summarizes the Study results and can be used when an overview is all that is needed or when an unclassified distillation of the Study is required. It will be necessary to refer to volume II to find out how we approached the challenge of determining operational characteristics of the 21st century surface combatant. Volume II addresses our methods and assumptions and provides the results of 17 Functional Analyses, mini-studies of the threat, ~~traditions~~, policies, operating procedures, and structural considerations affecting the future surface combatant. Volume II, like volume I, provides the results and recommendations of the Study; volume II can stand alone, as there is nothing in the Operational Report which is not also in Analysis and Background. Volume II also: explains the relationship of the Ship Operational Characteristics Study to the other efforts which make up "Revolution at Sea"; provides some historical perspectives; and contains the threat analysis on which much of our work is based.



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## SECTION 1. INTRODUCTION

This report details the operational characteristics that must be embodied in the design of the 21st century surface combatant to enable it to perform its missions against the forecast threat. The required operational characteristics were developed from analysis of U.S. National objectives, naval missions, the geopolitical environment, and the threat expected in the early 21st century. The report also addresses shortfalls in earlier warship designs identified by representatives of the operating forces-- this is, among other things, a Fleet study.

The 21st century combatant will be capable of both independent and Battle Force operations. The ability to operate independently requires a stout self-defense capability in every mission area UP, OUT and DOWN, and an offensive capability in at least one major mission area. To operate effectively with and contribute to a Battle Force requires speed consistent with that of a CV, the ability to contribute to the protection of the carrier and combat logistics ships and system compatibility with the other ships and aircraft in the force.

We have not undertaken to define the 21st century surface combatant's hull form. The study concentrated on identifying required operational characteristics that would be suitable with any of the hull forms with which we have become familiar. The operational characteristics recommended in this study for surface combatants will also be applicable to other 21st century ships such as a large capacity missile carrier and ships of the Amphibious, Combat Logistics and Mine Forces.

The principal objective of this study was to maximize the 21st century warship's ability to put ordnance on target. One means of putting more ordnance on target is by increasing the ship's volume that is available for weapons. Having more weapons (or decreasing the volume devoted to "overhead") is however, only one facet of the solution. Ordnance on target improvements have been defined to include an improved ability to get to the fight, e.g., endurance, stealth and ship/system availability; improved readiness; improved combat performance (training); improved probability of hit per weapon launched; and an improved ability to stay in the fight, i.e., survivability and the ability to "fight hurt." Each recommendation in this study responds to the objective of increasing ordnance on target.

We made some difficult choices and prioritized every option and characteristic based on operational factors. We realize that priorities will change based on technological advances, affordability (which we were not required to consider at all), and changes in the threat. In acknowledging that the priorities will change, Volume II, Analysis and Background, details the methodology, rationale, logic and analysis which resulted in our priorities. The process should be useful even when different measures of effectiveness, such as cost, are used to reprioritize the characteristics. The operational flavor, which is so extremely important, hopefully will be retained.

Some of the characteristics and opportunities recommended in this study are already being pursued in active Navy programs. This is recognized, applauded and was not considered a reason for their exclusion. Instead, we took the opportunity to provide additional support to these programs.



## SECTION 2. IMPERATIVE CHARACTERISTICS

Twelve Imperative operational characteristics were identified as the result of the analysis. Many of these operational characteristics are force multipliers. They will significantly improve the capability of the surface combatant to put ordnance on target in the 21st century. Many other desirable characteristics and opportunities were identified; many are recommended for implementation and all are noted in this study, but twelve Imperative Characteristics are the warfighting drivers.

The twelve Imperatives are listed in four priority categories. This prioritization is intended to provide operational guidance for funding or other constraints that might prevent pursuit of all the Imperatives immediately and completely. The twelve Imperative Operational Characteristics for the 21st century combatant are:

### PRIORITY A

- Cooperative Engagement in all Mission Areas
- Integrated Machinery Systems
- Survivability and the Ability to "Fight Hurt"

### PRIORITY B

- Embedded Readiness Assessment, Mission Planning, and Training
- Condition Based Maintenance
- Torpedo Self-Defense

### PRIORITY C

- Collocation of Ship Control and CIC
- Access Control and Security
- Alternative Use of Volume

### PRIORITY D

- Smooth Topsides
- New Information Management
- Organic Aviation and other Off-Board Vehicles

#### 2.1 Cooperative Engagement In All Mission Areas

We define cooperative engagement as an integrated and coordinated combat data and action system at the Battle Force level. The concept must be applicable UP, OUT, and DOWN and not limited to AAW.

The characteristics of cooperative engagement can be clustered into the three general areas of Intership Data Exchange, External Weapon Control, and Automation and Integration.

### Intership Data Exchange

- All data relating to detection, classification and targeting must be available to all the ships in the Battle Force.
- Data exchange must employ low probability of intercept techniques and communications equipment.

### External Weapon Control

- Each ship must have the capability of controlling weapons fired from other platforms. This feature is called "forward pass" in AAW. Longer range weapons for AAW and ASW are required to expand this capability beyond ASUW and Strike.

### Automation and Integration

- Integration of offboard data with ship-generated information.
- Automation and integration of environmental data both in the local area and in potential target areas.
- An integrated decoy and deception capability at the Battle Force level. Decoy placement in time and space must be coordinated to avoid one platform decoying an incoming weapon into another friendly platform.
- An automated "combat maneuvering" system.

A cooperative engagement capability will extend the battle space by an order of magnitude. This will be done because each ship in the battle force will "see" the entire battle space. It will be as though every sensor and weapon in the battle force were aboard each individual ship.

The existence of cooperative engagement bounds the survivability design problem. Ship design should permit the "last ditch" launch of weapons by a damaged ship for the control of other platforms, thus putting the weapons at the disposal of the Battle Force Commander. The 21st century surface combatant should be designed not to go out of action with full magazines if its weapons are needed by the force.

The system will have a force multiplying effect on weapons availability. Today each ship has control of its own weapons. With the 21st century system described, each platform will have access to additional weapons from other ships. This will be extremely important since analysis from the Surface Combatant Force Requirements Study indicated that the Soviets will be able to penetrate the Battle Force AAW defenses only by saturating a particular threat axis. A forward pass system will help to maximize U.S. battle force capability to respond to a concentrated AAW attack designed to saturate defensive resources. This capability assumes that long range AAW and ASW weapons will also be developed. Without long range weapons the benefits of the "Forward Pass" capability will be limited to ASUW and Strike, and constrained by Battle Force geometry.



Integration of onboard and offboard combat system data with individual ship control data will permit effective combat maneuvering. For example, the data and maneuvering capability should exist to permit the ship to present its optimal aspect to the launch platform an enemy weapon-launching platform. The optimal aspect could be determined by a fundamental linear program (MIN/MAX) that considers the following aspect sensitive factors and constraints:

- Aspect that will minimize the threat platform's and weapon's probability of detecting the ship
- Aspect that will minimize the probability of a hit given that the weapon detects the ship
- Aspect that will minimize damage given that a hit occurs
- Aspect that will maximize the ship's close-in weapon defensive capability
- Aspects that can be presented to the weapon based on remaining reaction time and turning rate.

Such a system will also permit selected, automated initiation of "anticipatory" damage control action in the threatened section of the ship while the weapon is still incoming. The automated combat maneuvering function would have to feature the capability for crew intervention when appropriate. Figure 1 shows an example of the type of data that would be required, a sample display that might be generated and a potential problem solution.

## 2.2 Integrated Machinery

A new and different, integrated propulsion and machinery system is recommended because of the survivability, effectiveness and stealth requirements which will be levied on the 21st century combatant. Several technological opportunities that are available currently, or soon will be, show promise of satisfying all of the operational requirements we foresee for the 21st century surface combatant.

The 21st century combatant must have reduced ship signatures (particularly acoustic, infrared and the propulsion constituent of wake) to realize the flexibility that will be required for forward area operations. There will be a requirement for excess power for directed energy weapons systems. Endurance must be improved to reduce dependence on combat logistic ships. Survivability will necessitate alternate paths both for power and information, the distribution of equipment throughout the ship, and physical separation among vital components. The sensitivity of shaft and gear alignment to shock is a problem that must be addressed. Equipment must be more reliable and maintainable. Increased reliability of electric power, in fact assured electric power, will be essential to support the information and computing demands of the 21st century surface combatant. Machinery size and weight must be reduced and endurance speeds must be increased. The propulsion system must be made more fuel efficient to improve independent operational range. Finally, the integrated monitoring and control systems coming into use

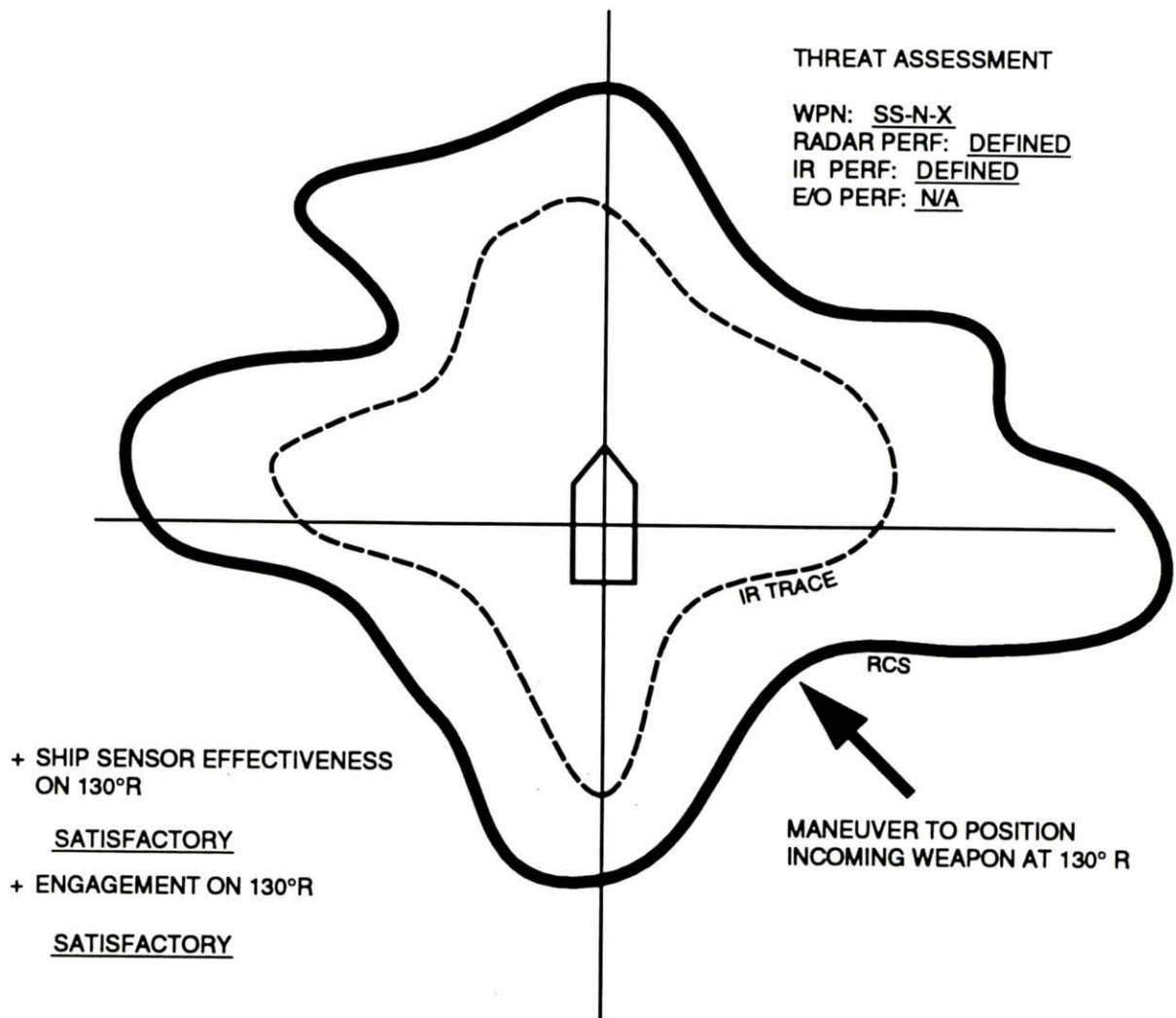
now for propulsion must be applied as well to auxiliary and electrical generation systems.

The required machinery characteristics are summarized under four headings:

Flexibility of Operation

- Distributed propulsive power that is redundant and has physical separation (to enhance survivability)
- Cross-connectability (to enhance combat effectiveness and survivability)

FIGURE 1  
MANEUVER TO MINIMIZE TARGETABILITY  
AND LIMIT DAMAGE





- Arrangement flexibility (to reduce machinery volume and allow increased ordnance)
- Propulsion derived ship service power (to decrease overhead and improve fuel efficiency).

#### Expanded Power Distribution

- Integrated power source (to provide pulsed power to directed energy weapons and high power sensors from installed propulsion and ship service power sources).
- Advanced power distribution (to assure continuous electrical power to vital loads).

#### Low Signature Operation

- Reduced acoustic signatures (to exploit threat acoustics and limit own ship detectability)
- Reduced radar cross-section and infrared emissions (to reduce vulnerability and improve potential to gain advantage of surprise)
- Reduced propulsion constituent of wake.

#### Improved Availability and Efficiency

- Integrated machinery monitoring and control (to reduce inspection and repair man-hours and to minimize watchstander manning)
- High reliability and maintainability (to increase system readiness, reduce repair man-hours and minimize maintenance manning)
- Efficient, high power density machinery (to maximize endurance, speed and range and reduce tankage requirements)
- Electrically driven auxiliaries (to provide uniform source of power and to eliminate steam, hydraulic and pneumatic distribution systems)
- Exploit superconductivity as the technology develops.

This characteristic, Integrated Machinery, is the only one in which we are recommending a specific solution to the operational characteristics we prescribe. There are two reasons for doing so, (1) the combination of systems and equipment noted above appears to fill the bill and also appears to be capable of introduction in time to be proven and available for the 21st century surface combatant, and (2) the change to a new machinery system is so fundamental to building the future surface combatant and to its performance that the propulsion, auxiliaries and electrical generation systems decisions will affect every other aspect of the 21st century ship. We should commit to a new propulsion system now.

### Advantages of Integrated, Electric Drive Machinery

Integrated distributed electric drive will provide arrangement flexibility and cross-connect capability and incorporate inherently quiet machines. These attributes are key to increasing ship survivability. Electric drive integrated with propulsion-derived ship service power generation will result in weight reduction and improved fuel efficiency. The adoption of intercooled, regenerative gas turbines can contribute to improve fuel efficiency and reduced infrared signatures associated with exhaust emissions.

Growth margin for powering future weapon systems is inherent in integrated electric drive. Propulsion energy would be redirected to defense (jamming, etc.), active sensing (ASW acoustic projectors, etc.), or weapons power (rail guns and directed energy weapons). Large amounts of electric power open the possibilities for a new family of future weapon systems and sensors.

Electric drives are applicable not only to monohulls, but to podded monohulls and other advanced hull forms, such as SWATH, without requiring new machinery technology. Future higher power-density drives and/or smaller diameter applications can exploit advances in superconducting dc electrical machinery technologies.

Estimates of the impact of incorporating an integrated, distributed electric drive machinery system in a 21st century combatant, relative to the space, weight and manpower estimates were derived in an earlier feasibility study for a baseline cruiser application. They are:

BASELINE		FUTURE
4 PROPULSION GT 4 SHIP SERVICE GT	MACHINERY COMPONENTS	4 PROPULSION GT 2 SHIP SERVICE GT
13,800 TONS	FULL LOAD SHIP DISPLACEMENT	12,500 TONS
350,000 ft <sup>3</sup>	MACHINERY VOLUME	300,000 ft <sup>3</sup>
BASELINE COST	BASIC SHIP CONSTRUCTION COST	-5 TO -10%
30 MEN	MACHINERY MANNING	17 MEN

### 2.3 Survivability and the Ability to "Fight Hurt"

Survivability and damage control are treated as a single issue because the 21st century combatant should integrate the two into an effective total system. Survivability and damage control involve all steps from avoiding detection, avoiding targeting and avoiding getting hit, to minimizing damage when hit, damage control and restoration after being hit and "Fighting Hurt".



It might seem reasonable to insist that combatants be sufficiently stealthy to avoid detection. However, our analysis of naval combatant roles, missions and threats in the 21st century suggests that this is unrealistic and would be endlessly expensive. A forward strategy requires ships to be within the enemy's search area for long periods and the probability of detection is cumulative over time. Seeking to make ships invisible, that is to remove all observables, would not be the best allocation of resources. Preventing classification and targeting of our ships is always appropriate, more likely achievable, and should be our objective. Having forced the enemy to increase his targeting time and decrease his firing range, we can increase our survivability by taking advantage of the opportunity to destroy his launch platforms.

Figure 2 illustrates the investment approach we advocate. Signature levels are shown on the vertical axis and the horizontal axis is a time line, stretching from now into the future. The signature levels of surface combatants is shown declining (DDG 51 will be a big step), while technology improves our decoys and deceptive techniques. Beyond the cross-over point, we will have done enough. Signatures will be sufficiently low to permit our decoys and deceptive techniques to be effective and targeting of our ships by the enemy to be extremely difficult.

Each ship's ability to survive also will be dependent on a close-in defensive system and the coordinated use of decoys and deception. In the area of close-in defense it is considered of paramount importance that our efforts be concentrated on killing torpedoes.

Given that ships in combat will be hit, and the Fleet's position is that the Navy must plan for its ships to be hit, ships must be built to an operational survivability standard. The ship as a whole has not been built to an operational survivability standard to date. The standard we propose is:

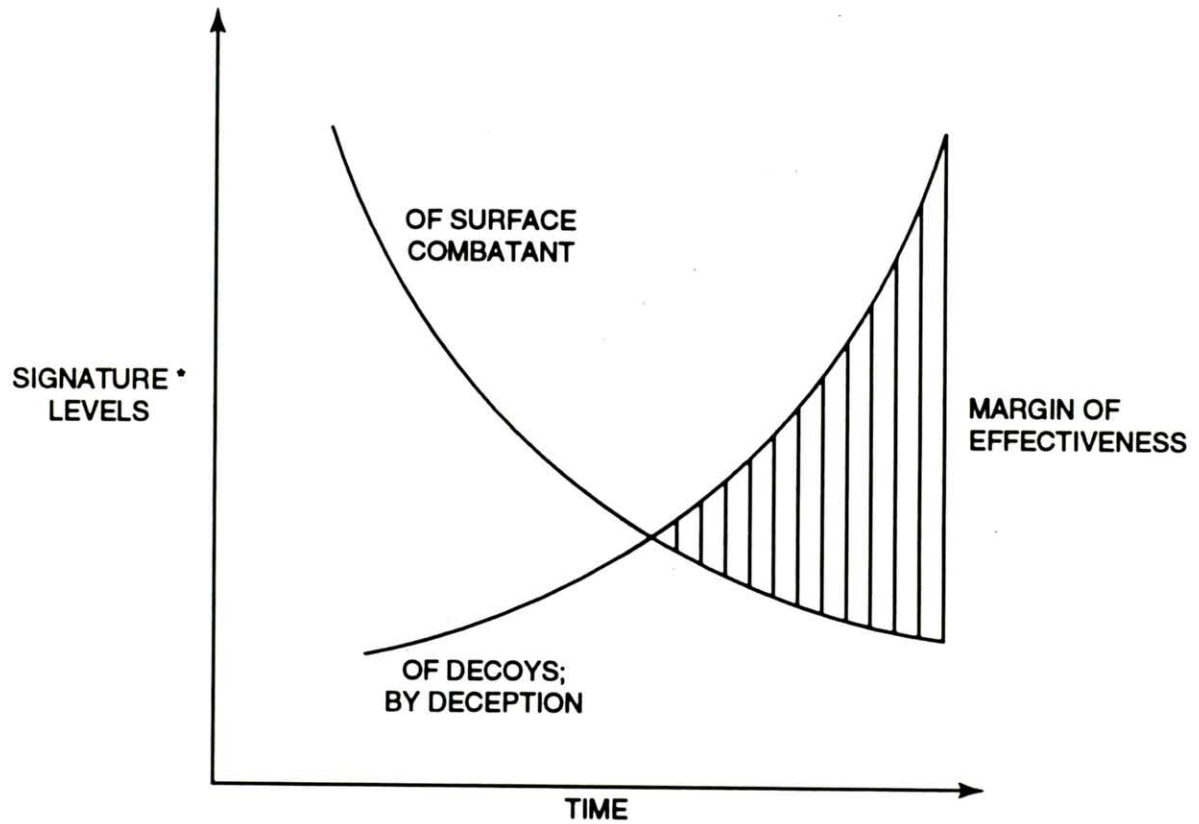
- The ship must be able to continue to fight following one hit by an anti-ship cruise missile with a nominal one metric ton warhead.
- The ship must survive two ASCM hits or one torpedo hit under the keel.
- Survivability design must allow a ship to empty its magazines for the use of others.

No ship should go out of action with full magazines if the tactical situation dictates a need for the weapons in those magazines and a cooperative engagement capability exists.

When a combatant of the 21st century is hit, damage should be minimized because of design criteria to prevent such damage. The keel should be strengthened to protect against underwater shock. Internal arrangements should incorporate the placement of armor and/or liquid barriers (e.g. potable water) around critical spaces to protect against enemy weapons. Internal arrangements of equipment should employ separation to ensure survivability and redundant paths for electrical and electronic systems power and information.

Damage control and damage assessment must be significantly automated and a revolutionary, "anticipatory" system (one which can prepare the ship for specific damage) should be included. By integrating shipboard status information and combat system data it will be possible to minimize the effect of a weapon hit. Anticipatory damage control will significantly increase the ship's ability to survive and continue to fight when hit. As part of the system, each compartment's condition will be monitored and trend analyses will be performed automatically. Monitoring even the most remote tanks and compartments will include tank levels and temperatures, indications of fire and flooding, and determination of particulate and agent concentration by detection systems in manned and secure spaces. If sensor system uses fiber optics cables embedded in the hull for data transmission, structural stress can be measured by deflections in the cable. With such a system damage assessment should be simplified greatly.

**FIGURE 2  
STEALTH CRITERIA**



**\* A SIMILAR PLOT MUST BE DEVELOPED FOR EACH TYPE OF SIGNATURE, I.E., RADAR CROSS-SECTION, IR, ETC.**



The sum of the recommended survivability and damage control characteristics will result in a ship that is very difficult to target because decoys will appear identical to the ship; if hit, will suffer minimum damage because of combat maneuvering and a priori damage control action; and is designed to survivability standards that will enable it to "fight hurt". Furthermore, each of these ships will be designed to continue to contribute to the battle after being hit, either by continued use of its own combat capability because of the ship's increased design resiliency or because of its ability to launch its weapons for the use of other ships in cooperative engagement.

#### 2.4 Embedded Readiness Assessment, Mission Planning and Training

The Commanding Officer of a 21st century combatant must be able to perform mission and battle planning, conduct realistic combat training for ship's teams at all levels, and assess in real time the readiness of the ship system systems and crew.

To support such requirements and maximize the effectiveness of 21st century warships, future equipment designs must specify an embedded test, calibration and alignment capability. Commanding Officers will need real time access to the condition of equipments. The C.O. must know that they are functioning, be assured that they are aligned and be able to operate them as systems. All aspects of the combat system, propulsion, auxiliaries and damage control, must be integrated. Overlaying this integrated ship system must be a scenario generation capability on the operational equipment. This will allow the Commanding Officer to allocate maintenance resources, to conduct training and to do battle planning and mission planning, and to game tactics, especially in preparation for combat.

The system should also be designed to measure performance; not only the performance of individual equipment and operators, but the performance of ship systems and teams up to and including full participation in battle force training and operations (see subsection 2.5, below). With such a capability the ship will finally be able to support the training and readiness for which the commanding officer has always been responsible, but for which the ship was never before configured in this sense. The ship's systems will support operator, maintainer and team training.

#### 2.5 Condition Based Maintenance

The dual challenge of increased system sophistication and decreased maintenance manning in future combatants can be met through the adoption of new maintenance technology. "Condition based maintenance" is a concept that seizes on technological advances and offers a new approach.

Under this approach, system monitoring and analysis will replace the current concepts of organizational preventive and corrective maintenance. The objective is to identify maintenance tasks by detecting degraded or potentially degraded performance, rather than responding to



failures with corrective maintenance and scheduling the "open and inspect" tasks of preventive maintenance. The implementation of condition based maintenance requires a new philosophy of system and equipment design, repair procedures and maintenance training.

Unattended embedded sensors will continuously monitor the condition of all equipment, including hull, mechanical and electrical equipment. Manned system monitoring stations will automatically collect the data and assist in keeping system and equipment status, analyze the signals using expert systems or other techniques to determine when action is required, and direct maintenance actions.

It is recognized that most maintenance will be performed by either operators who are working off-watch, or technicians who are cross-trained. Diagnostic and other maintenance guides will assist maintenance personnel to identify failed parts to be replaced, performed required alignment and check out the system. If any of these maintenance support functions cannot be embedded in the equipment, they will be incorporated into portable maintenance aids. The embedded or portable aids will also be linked to the spares accounting and maintenance history systems, in order to assist the repairman and record the maintenance action.

These conceptual changes require redefinition of the responsibilities for maintenance training ashore and afloat. Shore facilities are positioned best to equip maintenance personnel with systems concepts, common maintenance procedures, and the use of maintenance aids. Configuration-specific maintenance training will be performed better aboard ship, utilizing the same kind of embedded training devices and "train like you will fight" approach that are recommended separately for operator and team training.

If combatant ships are to meet the challenge of 2010 by carrying more complex systems and smaller crews, then maintenance must be supported by revolutionary changes in the Navy's maintenance policy, system and equipment maintainability concept, and approach to maintenance training.

## 2.6 Torpedo Self-Defense

There is an imbalance in warship self-defense. Defensive weakness in this case results from a combination of enemy capability, the likelihood of attack, and the lack of defensive capability. Defense against torpedoes is the weakness that needs the most attention.

The Soviets have been emphasizing torpedo development and designing new attack class submarines at an impressive rate. They have imposing torpedo arsenal when analyzed from any aspect: variety, capability, warhead size, or quantity. According to some estimates, a hit by one of the Soviets' largest diameter torpedoes could put a CV out of action. The recent important change is that the Soviet attack submarines now being built are both fast and quiet. During the 1980's the Soviets have introduced four quiet classes of attack submarines, the KILo, SIERRA, AKULA and MIKE. Quieter submarines will likely



encourage Soviet submarine commanders to be more aggressive and permit torpedo attacks to play an expanded role in their ASUW tactics.

The vast majority of Soviet submarines cannot fire cruise missiles; all can launch torpedoes. Torpedo tube launched cruise missiles are a possibility but the advantages, from the Soviet viewpoint, of a torpedo attack are beginning to outweigh the advantages of a cruise missile attack. All of the above suggests that torpedo attacks will likely compete with cruise missiles as the primary method of surface warship attack in the future. A change of emphasis in Soviet ASUW attack tactics-- from cruise missiles to torpedoes--although not guaranteed, should not be unexpected.

The U.S. must concentrate on a torpedo defense system that will destroy an incoming torpedo. It is insufficient to simply decoy the torpedo because there will be many torpedoes in the water during an attack and decoyed torpedoes remain a threat to a ship conducting radical evasive maneuvers as well as to other ships in the Battle Force (or to an escorted force).

A decoy and deception capability should be part of the system but is insufficient by itself. Destruction of torpedoes fired at surface ships must be the heart of the system and the R&D focus. Surface ship torpedo defense must be integrated with the combat maneuvering system to allow the ship to minimize signatures presented to the threat torpedo and maximize survivability if hit.

## 2.7 Collocation of Ship Control and CIC

The combatants of the 21st century must have ship control collocated with CIC below decks. The current location of the bridge is a tradition, a hold-over which is no longer required. In earlier times when the officer of the deck was required to sight the fall of shot, or when combat took place within visual range of combatants, there was a need for a topside bridge position for the officer of the deck. Such a requirement no longer exists in combat.

For the 21st century combatant, maneuvering must be integrated with the combat, damage control, and survivability functions of the ship. Collocation is an acknowledgment that ship control is a warfighting function. The ship control decision maker must have access to CIC's data for proper ship control in combat. Since the 21st century combatant will be foremost a combatant, ship control should be located and designed as part of this warfighting capability.

The ship control system should provide direct control of the rudder and engines. Location of primary ship control below decks will require panoramic, indirect, visual and audio sensing and display. Modern video, audio and periscope systems should satisfy these requirements. The ship control system should also have a combat auto pilot which will (among other things) take required action, minimizing aspects for targeting and automated damage control (as previously discussed) unless overridden by the officer of the deck.



A secondary conn/restricted maneuvering station should be located topside to permit the officer of the deck direct access to and control of special evolutions. This secondary conning station should have direct viewing, be no larger than a 747 cockpit, and permit direct control of the helm and throttle by the conning officer. It is envisioned that the secondary conn/restricted maneuvering station will be used for maneuvering in restricted waters, coming alongside for replenishment, and in other non-combat situations. A remote control (a control box which is portable) will permit conning elsewhere, outside the secondary conn/restricted maneuvering station, when it is necessary to see the sides of the ship.

## 2.8 Access Control and Security

Warships have always been comparatively vulnerable in port because ships are designed to be underway. We have attacked ships in port to exploit that vulnerability; LT Somers, USN lost his life placing a mine alongside a Royal Navy ship in the War of 1812. The inport threat has now become a danger that must be dealt with and one which will become even more severe during the next 20 years. Measures must be taken to counter the potential in port vulnerability to attack by forces ranging from individual terrorists to Soviet special attack (SPETSNAZ) units.

One of the most important recommendations with regard to access control and security is for a rapid and accurate personnel identification process. The process must be convenient, rapid, and each individual must be identified with certainty. Examples of such a device would be a palm print reader or a retina scan. Every person coming aboard ship in port would have to be recognized by the system. If the person is recognized, access would be permitted, otherwise the person would be barred. The system must ensure access control and it must be routine and convenient. It must be inconvenient to circumvent the system.

There must be a single access control point, which may also be a defensible and protected command post. It is no longer sufficient that the quarter deck area, traditionally used for ceremonial purposes, be the primary access to the ship. It doesn't matter where the Ambassador is greeted, that can be the quarterdeck, but there must be a single access control point for the ship. Security, not ceremony, must be the primary concern. A self-defense command post is needed, from which crewmen are able to maintain surveillance of the area in the vicinity of the ship.

High-powered lighting above and below the water will be needed, as well as other swimmer defense systems. We do not propose that these drive the configuration of the ship; this support can come from shore.

The security force, and there should be only one to meet all security requirements, must be given proper training and equipment, and allowed to maintain its proficiency. Security force members must be marksmen with weapons suitable for use inside a warship; they must have the necessary protective equipment, have communications equipment which function s inside the confines of the ship, etc. Their training must include "advance and maneuver," "room clearing" and other



techniques they are likely to need if called into action. They must also be intimately familiar with all the details of their ship; they should be instructors for other sailors learning ship systems.

The 21st century combatant must also be capable of monitoring and analyzing its provisions and water for contaminants.

Finally, but of utmost importance, the ship's information systems must be secure. Only if the integrity of the information systems onboard ship is assured will sensitive personnel data and classified information be justifiably included on the information network.

## 2.9 Alternative Use of Volume

The oldest new idea recommended by the Ship Operational Characteristics Study is the alternative use of volume. Hammocks rigged on the gundeck of USS CONSTITUTION illustrate the concept we have in mind. Conflicting design requirements arise from the desire to maximize wartime combat potential while providing adequate peacetime habitability. The partial solution we recommend is to design ships to make alternative use of volume.

The Navy must recruit sailors to serve aboard ships. A ship is the sailor's home away from home and most of his time spent aboard ship will be during peacetime. Relatively generous habitability standards are appropriate, especially in peacetime, nevertheless they are a large component of overhead, non-warfighting space aboard ships. In order to maximize warfighting capability while simultaneously satisfying those functions one normally associates with a "home," we propose that future combatants be designed for alternative use of interior volume.

First, there should be wartime as well as peacetime habitability standards. These standards must then be used by the ship designers to identify spaces which can be used differently during peacetime and wartime. Suppose, for example, that when the internal arrangement of the 21st century warship is decided, one or more of the several berthing compartments is positioned adjacent to weapons launchers and that the up-front costs associated with providing proper weapons security, a fire suppressant system, and hard points for mounting chocks are accepted. Then the space could be used for habitability (as a berthing space) during peacetime and would be available for conversion to additional weapons storage for wartime. The habitants of the compartments in peacetime would be assigned to other berthing compartments within the ship, when the wartime weapons load was taken aboard. The number of people in several berthing compartments would increase but remain within the wartime habitability standard. As another example, a storeroom, used during peacetime for storage of personal items, might be converted with the use of bladders into a wartime fuel storage area. These examples, meant to demonstrate the flexibility of the concept, are depicted in Figure 3.

Preliminary analysis revealed that the size of current staterooms, bunkrooms and other spaces which may be convertible during wartime approximate in size several of the spaces which provide normal

warfighting functions. That is to say the primary design changes would be location of the spaces and functional suitability rather than significant changes in the volume of the spaces. An example of the potential volume available for wartime conversion, consider the following alternative (wartime) use of traditional spaces. The volumes quoted are from DDG 51.

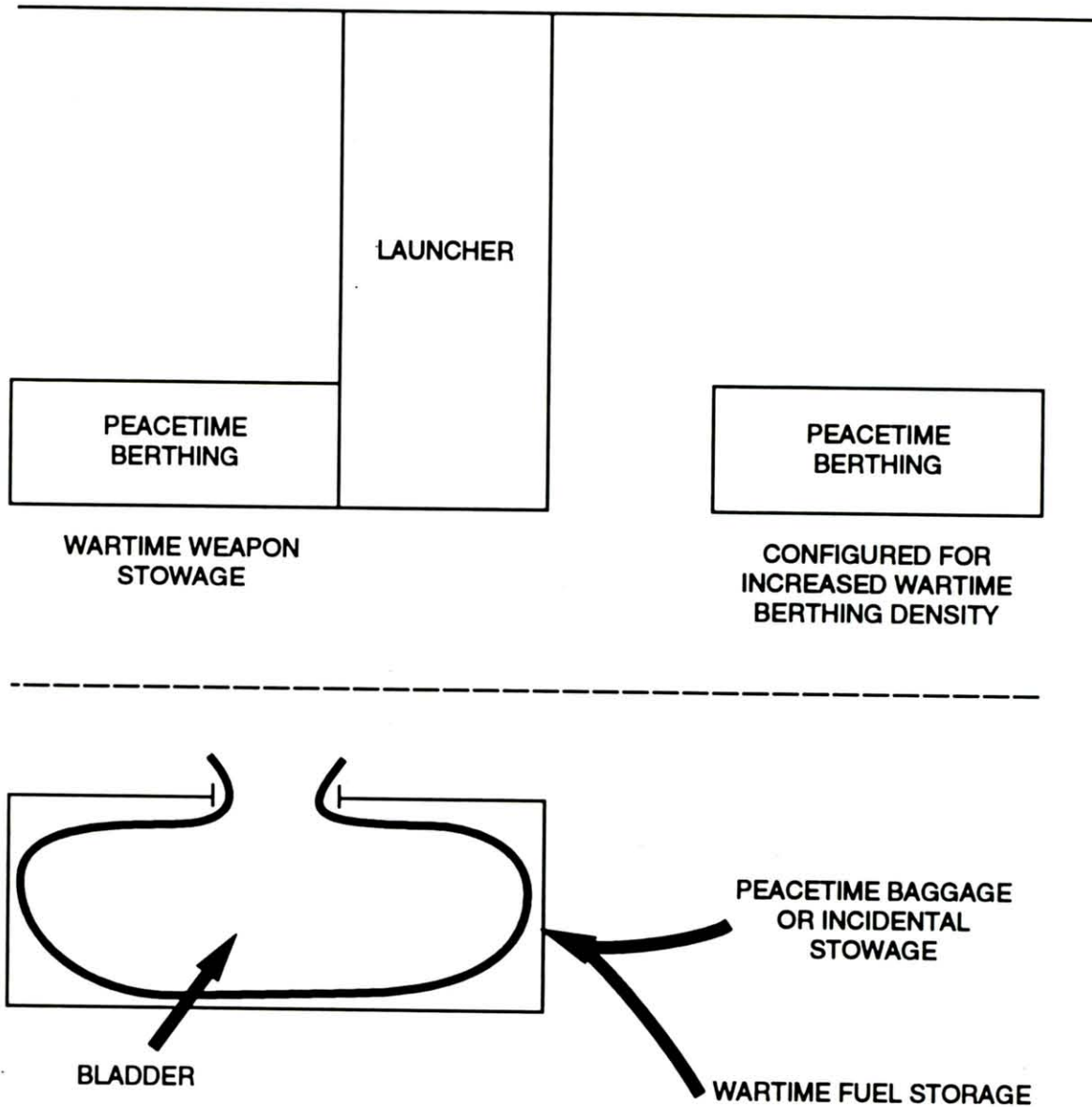
<u>PEACETIME USE</u>	<u>VOLUME</u>	<u>WARTIME USE</u>
4 of 14 staterooms (25% of total)	4000 ft <sup>3</sup>	5"/54 projectile magazine (89% increase)
2 of 7 crew living space (13% of total)	7000 ft <sup>3</sup>	20 VLS missiles/canisters plus 2000 cu. ft. of handling space (21% increase)
CPO/crew baggage storage (70% of total)	2500 ft <sup>3</sup>	CIWS magazine (119% increase)
Ship's Store Storeroom #1 (32% of total)	2600 ft <sup>3</sup>	5"/54 powder magazine (96% increase)

## 2.10 Smooth Topsides

There are several objectives to smoothing a combatant's topside:

- Reducing radar cross-section

**FIGURE 3  
ALTERNATIVE USE OF VOLUME**





- Improving safety
- Facilitating cold and/or heavy weather operations
- Reducing electro-magnetic interference
- Decreasing maintenance.

These objectives can be addressed in some cases by minor changes and in other cases will require significant technology gains.

The first requirement involves seamanship equipment which is currently available. The FF 1052 class frigates have keel anchors, DDG 51 will have some retractable fitting and rigid inflatable boats. These must become standard warship design features. Improvements must be made in reducing the amount of underway replenishment rigging; the burden of special rigging, insofar as possible, must be placed on the delivering ship. These approaches respond to the requirement to reduce the ship's radar cross-section.

Conformal sensor and communications arrays will be important factors in smoothing the topsides of ships. Exhausting combustion gasses through the hull will help eliminate the requirement for stacks and funnels. The smooth topsides should embody ice shedding characteristics in both shaping and the selection of materials.

It is recommended that an entirely new stern design be undertaken. A new stern design is in order because of the increasing number of devices and "things" that must be launched, towed and recovered; e.g. passive sonar arrays, active arrays in the future, torpedo defense systems and (we recommend) the ship's boats. Launching boats from the stern should be much safer than launching them from the sides of a ship, especially in heavy seas. A new stern design will also increase the options for launching and recovering the surface and sub-surface running, remotely operated vehicles that will likely be standard items the 21st century combatant.

### 2.11 New Information Management

The surface combatant of the early 21st century will be an information intensive ship. It will be necessary to reduce data storage volume requirements, improve the quality of support data, and reduce the data handling workload. The information of concern includes tactical data, technical data, maintenance related support and reporting system data, and administrative data such as that for personnel, training and pay records.

The Paperless Ship study documented the need for data storage media other than paper. Collecting data from USS WADSWORTH (FFG 9), VINCENNES (CG 49) and ATLANTA (SSN 712), the study located and measured the weights and volumes of paper and paper containers shown in Figure 4.

The opportunity to decrease overhead (non-warfighting) volume and weight is real and could improve stability because of the significant weight



high in surface ships. The shipboard data requirement must first be established and then non-paper storage media must be selected to reduce weight and volume, facilitate retrieval and usage and accommodate shipboard peculiarities.

**FIGURE 4**  
**SHIPBOARD PAPER WEIGHT AND VOLUME**

	FFG 9	CG 49	SSN 712
<b>WEIGHT</b> (TONS)			
<u>PAPER</u>	13.9	26.6	7.7
<u>CONTAINERS</u>	<u>6.7</u>	<u>9.3</u>	<u>2.4</u>
TOTAL	20.6	35.9	10.1
PERCENT ABOVE THE MAIN DECK	40%	65%	NA
<b>VOLUME</b> (CU. FT.)			
<u>REFERENCE MATERIALS</u> (PUBS, CHARTS, ...)	566	1016	250
<u>IN-USE MATERIAL</u> (MSGS; LOGS, RECORDS, ...)	169	401	127
<u>STOCK MATERIAL</u> (BLANK FORMS, LOGS, PAPER)	169	401	70
----- TOTALS	<u>904</u>	<u>1818</u>	<u>447</u>

The 21st century combatants should also be "cashless." Problems arise aboard ship simply due to the fact that sailors are required by our shipboard procedures to carry cash. Society is moving away from cash and ships should follow suit. A ship is the ultimate company store. The risk of uncollectable debts is nil and there is no reason to require sailors to carry cash. Cashflow type machines can provide cash for liberty and accept unused cash upon the sailors return. The entire personnel pay system should be automated and shipboard transactions should be cashless.

The assumption that every surface combatant must be administratively self-supporting must be challenged. Not only can some administrative functions be moved ashore, but several may be performed more effectively there because of data access.

For the 21st century combatant, an automated message handling system is required. The system must emulate an efficient radio room and provide message receipt, sorting, routing, drafting, encrypting and transmitting. Paper copies should be uncommon. We need an automated, end-to-end message handling system because message volume is increasing, radiomen watchstander requirements are growing and many radiomen tasks can be performed more effectively by machine. Consider the following definitions for message volume from Operational Station Books of the DD 931 class (1959 vintage) and DDG 51 (1989):

<u>Load Definition</u>	<u>DD 931</u> <u>Msgs per day</u>	<u>DDG 51</u> <u>Msgs per day</u>
Light	less than 150	less than 300
Average	150-250	300-700
Heavy	over 250	over 700

During the 30 years between DD 931 and DDG 51 the anticipated light message load doubled and the anticipated heavy load nearly tripled. Expert systems should be considered to screen incoming message traffic for redundant or duplicate messages and the use of video transmissions should increase. Message handlers with a clipboard must be a thing of the past. The automated system should also draft, format and encrypt outgoing messages; select the appropriate transmitter and transmit the message. It is recommended that all outgoing messages except distress signals be encrypted to enhance security.

Flag hoist and flashing light will be eliminated and replaced by a high speed, automated, secure, line-of-sight communications system.

In summary, the 21st century combatant must have modern, non-paper, tactical and technical data bases; it must provide quality support to maintainers; it must get sailors out of the paperwork business as much as possible; and it must have an automated, efficient communications handling system.



## 2.12 Organic Aviation and Offboard Vehicles

All major surface combatants of the 21st century must have the capability of embarking aviation and other offboard vehicles. The requirement responds to the forecast threat. The range between participants in future engagements, the minimum response time to engage future incoming weapons and the sophistication of the battle in general will require offboard vehicles.

The aviation vehicles may be rotary or fixed wing. The other offboard vehicles may be remote or autonomous; tethered or untethered; and may include any combination of air, surface and subsurface systems. Lighter than air vehicles should also be considered. Surface running vehicles are limited in sensor range but have several significant advantages. In addition to inherent survivability and endurance attributes, there are some tasks which a surface running vehicle might perform very effectively, such as prepositioned torpedo defense. Surface running autonomous vehicles carrying torpedo destruction devices offer promise for the 21st century.

Offboard vehicles must be capable of being launched and recovered in all weather conditions, insofar as possible. If the weather will allow the war, the ship must be able to fight; its remote vehicles will be needed.

There is also a requirement that these vehicles be stowed flush (enclosed storage). Emphasis has previously been placed on minimizing topside protuberances to decrease radar cross section; specifying enclosed storage is partly in response to that requirement. Additional advantages of enclosed storage include alternative use of volume and the ability to load, maintain, and repair the vehicles during inclement weather.

There must be automatic and modern fire fighting equipment associated with the organic air and offboard vehicles. Permanently installed and mobile fire fighting systems which involve gases, liquids, foams, and other fire suppressants and fire extinguishing methods must be incorporated into the design of the 21st century combatant.

Finally, it is imperative that the organic aviation and offboard vehicle support packages be configured as modules to promote flexibility. The modular configuration will permit the enclosed environment used to store and support aircraft and other offboard vehicles to be used for other warfare functions during special missions.



### SECTION 3. MANPOWER AND VOLUME SUMMARY

The principal uses of volume aboard combatants are for propulsion, crew support and combat systems. The apportionment of total enclosed volume which will be allocated to the several major purposes in DDG 51, for example, is:

Propulsion & Auxiliaries		35%
Crew Support		30%
Combat System		20%
Supply Support		4%
Maintenance		2%
Ship Control		2%
Communications		2%
Navigation & Piloting		2%
Damage Control		1%
Security & Integrity	approx.	1%
Administration	approx.	1%
Aviation Operations	approx.	0.5%

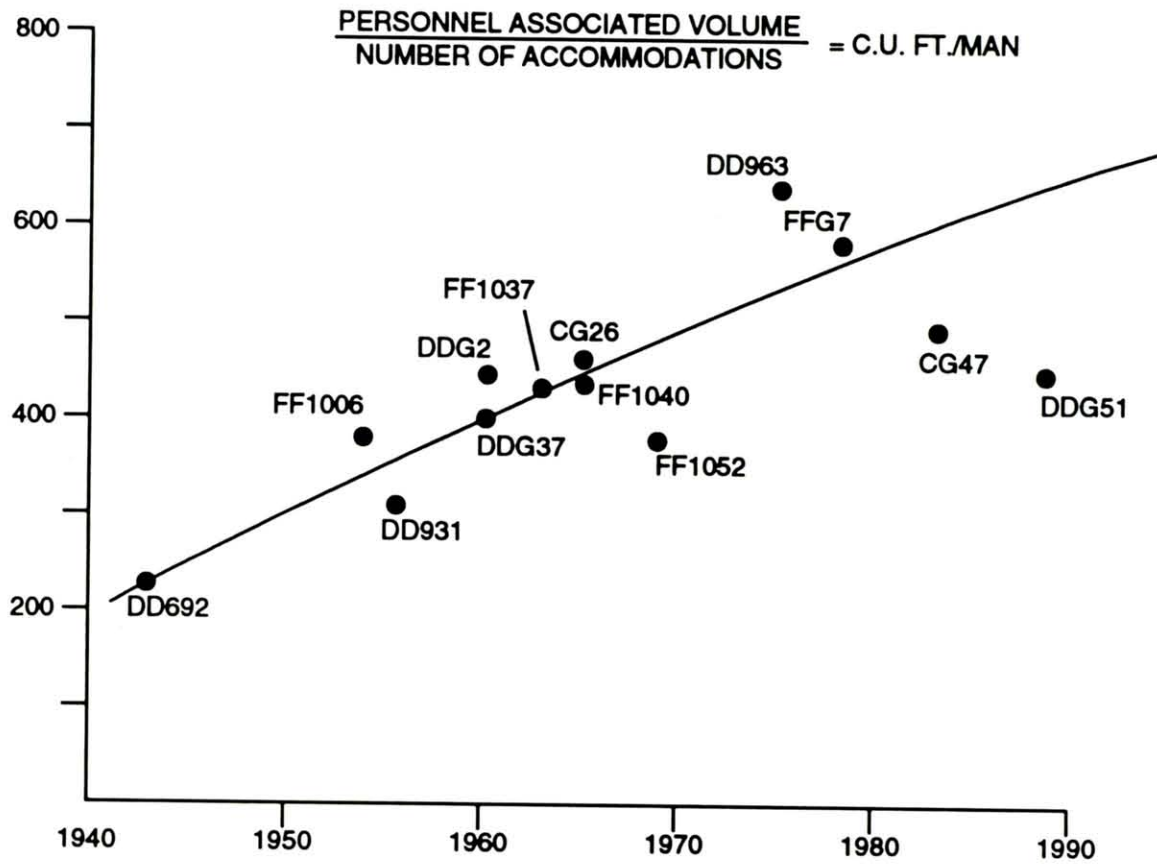
Crew support, as the second largest volume requirement, is an obvious place to focus when trying to maximize combat volume or minimize overhead (non-combat) volume. This study's sensitivity with the "ship as a home" issue has been detailed in Volume II. Therefore, rather than attempt to reduce general habitability standards and personal amenities, opportunities for reducing manpower requirements were investigated as a means of affecting the Crew Support volume.

The volume category of "crew support" includes passageway volume, which is unaffected by a reduction in manpower. Passageway volume accounts for 10 percent of the ship's volume, leaving 20 percent of the total that can be affected by shipboard manpower reduction. The personnel associated volume aboard U.S. combatants had been steadily increasing with the introduction of each new combatant ship class, until it was reduced for FFG 7. Aboard DDG 51, the personnel associated volume (crew support volume minus passageway volume) amounts to approximately 488 cubic feet per man. The trend in personnel support volume aboard U.S. combatants is shown in Figure 5.

Inherent in several of the Imperative Characteristics are manpower savings through automation, collocation, equipment improvements, consolidation, reduced maintenance, moving some tasks ashore, and generally facilitating more efficient performance. To insure that the manpower reduction opportunities identified within each Imperative Characteristic did not result in double counting, and to avoid eliminating

watchstanders without accounting for the time they spend performing maintenance, an independent "bottom-up" manpower analysis was also performed. The "bottom-up" look at manpower requirements responded to the characteristics of the 21st century combatant as recommended in this study and began by identifying all Condition III watches and watchstanders.

FIGURE 5  
COMBATANT PERSONNEL SUPPORT VOLUME





The next step was to insure sufficient manpower to satisfy maintenance requirements (preventive maintenance, corrective maintenance, and facilities maintenance) and own unit support (administration and special evolutions). Sailors had to be added to satisfy maintenance and own unit support requirements. The next step was to identify all Condition I watches and watchstanders. There were sufficient personnel to man all the Condition I watches. The final step in the "bottom-up" manpower analysis was to satisfy the damage control personnel requirements while at Condition I. However, no additional personnel were required for damage control.

The sequence is consistent with, and in fact made use of, the manpower determination model used by the Naval Sea Systems Command. The study concluded that the manpower requirement of the 21st century combatants would be maintenance and not watchstander limited.

Figure 6 demonstrates the manpower impact of each Imperative Characteristic. The manpower savings are consistent with the "bottom-up" analysis. Differences were resolved by taking the conservative result. The left hand standpipe represents the 147 watchstanders and the 142 non-watchstanders planned for DDG 51, an enlisted crew of 289. The other six standpipes represent the cumulative reductions to that crew that might be possible with the incorporation of the six Imperative Characteristics which will have an impact on manpower. That is, if all six were implemented in the 21st century surface combatant, the cumulative savings in manpower are estimated at one-third (approximately 100 members) of the crew of DDG 51.

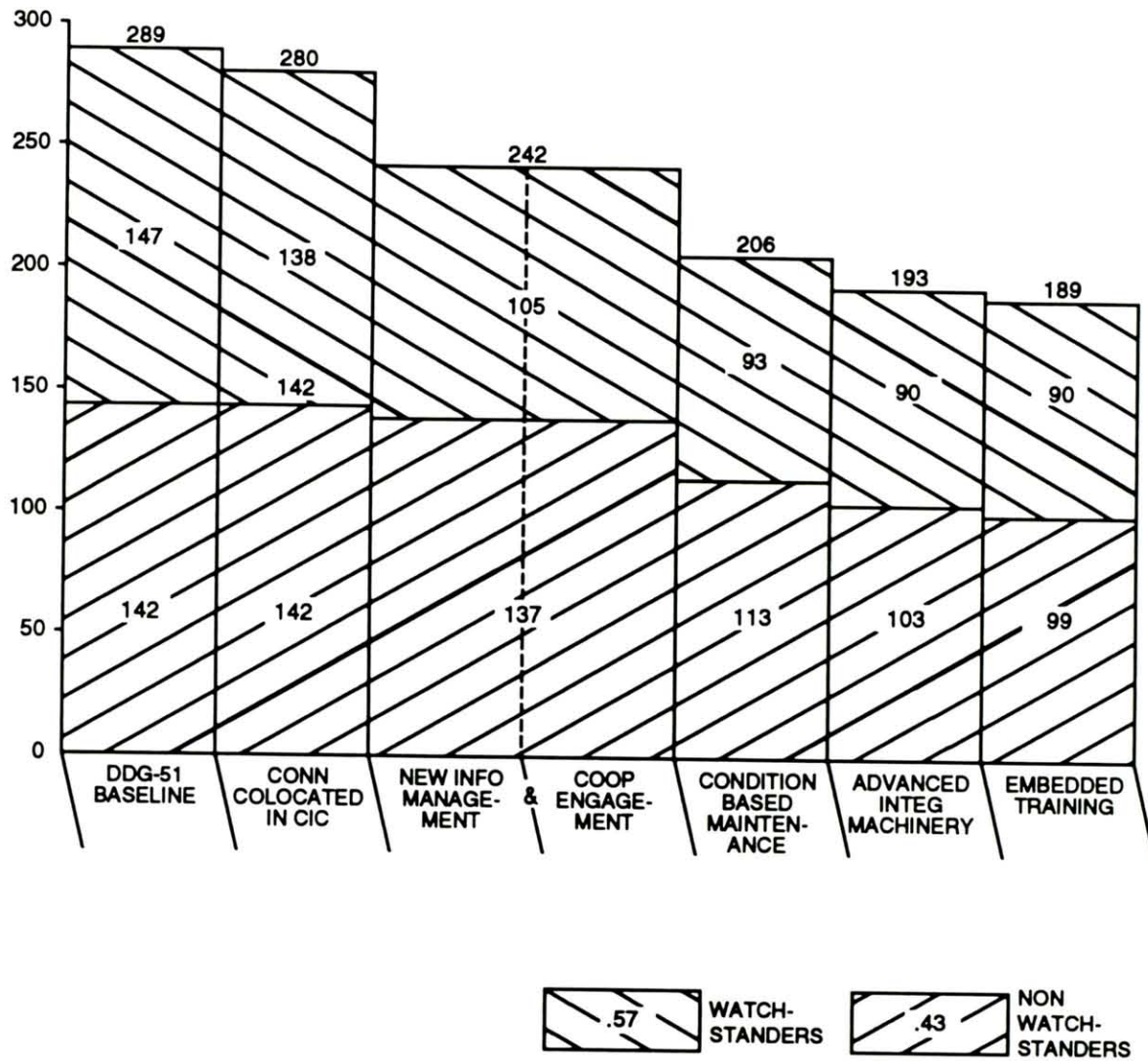
Although the corresponding volume reductions, at 488 cubic feet per man, have a very significant impact, they are not the only non-combat volume savings identified. Calculations indicate additional volume savings associated with the collocation of ship control and CIC, the incorporation of advanced integrated machinery, and the alternative use of volume, in addition to others.

This reduction in overhead (non-combatant) volume offers two options: the warship can be reduced in size, or the savings can be used for combat functions such as additional weapon storage. For the purpose of this analysis it is assumed that the volume will be converted to combat functions. The combat system volume of DDG 51 was nearly 20% of the ship's enclosed volume. Adoption of the Imperative Characteristics should increase the combat volume to approximately 36% of total ship volume. The improvement for each of the eight Imperative Characteristics which have an impact on volume is shown in Figure 7.

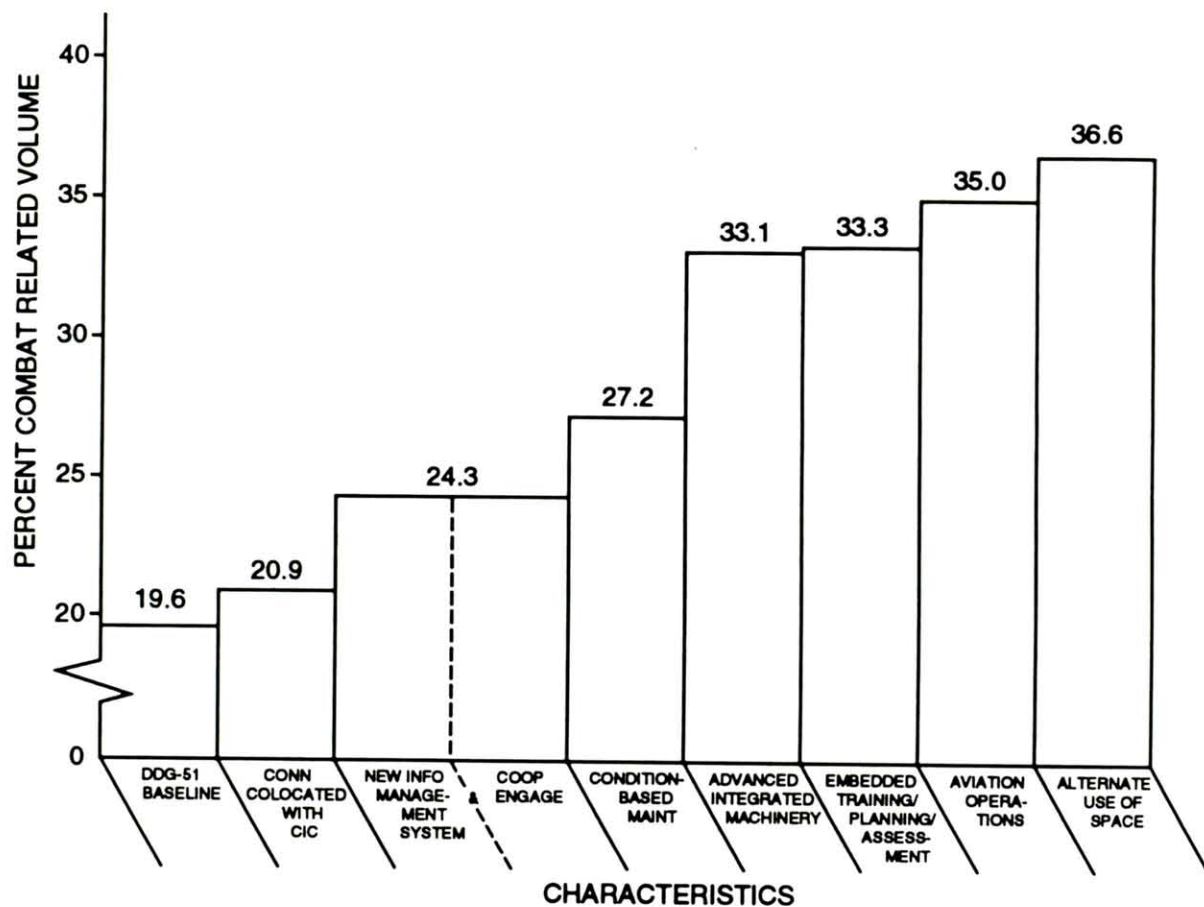
In summary, the twelve Imperative Characteristics have the potential for reducing the enlisted crew size by about one-third relative to DDG 51, and increasing combat density from less than 20 percent of the total ship.



**FIGURE 6**  
**POTENTIAL IMPACT OF CHARACTERISTICS**  
**ON ENLISTED MANPOWER**



**FIGURE 7**  
**POTENTIAL IMPACT OF CHARACTERISTICS**  
**ON COMBAT SYSTEM VOLUME**



## SECTION 4. OTHER SELECTED CHARACTERISTICS

These characteristics do not have the force multiplying or warfighting impact of the Imperative Characteristics but will improve operational capability. Many of these "other characteristics" are also attractive because they will be relatively inexpensive and easily implemented. The characteristics are prioritized from an operational perspective using the same criteria with which the twelve imperatives were prioritized.

### Survivable Navigation System

Analysis of the threat and environment forecast for the 21st century suggests that each combatant should have at least one survivable navigation system. A survivable system is defined as one which does not require vulnerable offboard subsystems such as LORAN transmitters or satellites. Examples of survivable navigation systems include inertial systems, celestial trackers, and bottom contour navigation systems. For example, it may be feasible to program optical trackers associated with laser systems to allow tracking of celestial bodies automatically for navigation purposes.

A precise navigation system is an Imperative Characteristic because without precision navigation, cooperative engagements will be impossible. The survivable navigation systems do not appear to lend themselves to the high precision of NAVSTAR/GPS, but one or more survivable navigation systems is none-the-less a real operational requirement for the 21st century combatant and should be as precise as possible.

### Advanced Internal Communications System

Modern warships must have modern Interior Communications (IC) systems. The system must have the features of modern computerized business telephones including no single point failure; modular expansion capability; and the capability for call forwarding, call transfer, automatic dialing, call conferencing, and call interrupt. The need for these features has been stated in a formal Operational Requirement, OR-141-03-89.

This Study recommends that the required features of the IC system (as identified in the OR) be expanded to include a remote, man-on-the-move capability. An integral part of the IC system should be a hands-free (on the belt or hardhat) transceiver for use by damage control parties and at special evolution stations such as replenishment and air operations. The system must be electromagnetically compatible and permit movement throughout the ship. Consideration should be given to having both secure and non-secure modes.

### Improved IFF for Combined Arms Operations

A Tentative Operational Requirement drafted in 1984 stated that,



"The lack of an interoperable IFF system among NATO nations has been identified as the most urgent AAW problem in Central Europe."

The problem has not been solved and will become more serious as the U.S. pursues combined arms operations at sea. Even among U.S. forces the blue-on-blue problem is real. Submarine commanders are uncomfortable working in close proximity (within weapon range) of U.S. surface warships because of their justifiable lack of confidence in being recognized as friendly platforms. Improved IFF, in all warfare areas, is a high operational priority. The initial focus should be on resolving U.S. surface, subsurface and air platform problems, with eventual expansion to include allies.

#### Automatic Jam/Anti-Jam Management

Control of the electromagnetic (EM) and electro-optic (EO) spectra will play a critical role in determining which adversary enjoys the upper hand in future combat. Control is not to imply unencumbered use of the spectra or complete denial of them to the enemy. The management of shipboard jamming and anti-jamming equipment is required to coordinate electronic warfare efforts and minimize interference; to permit accurate, timely, and reliable communication; to maximize the effectiveness of emission control decisions by quick and correct actions; and to provide decision aids to prevent or impair enemy sensor targeting or weapon acquisition and homing. Required reaction times against high speed, low flying, small radar cross-section targets are generally so short that the decision process regarding application of EM/EO jamming and decoying must be capable of automatic implementation with operator override.

#### Digitized Navigation Charts and Automatic Piloting Aids

Electronically stored, generated, updated and displayed navigation charts will save manpower and space. More flexible plots (e.g., selective or auto-scaling, selective centering, electronic overlays) will be available for tactical and piloting application. Corrections to charts can be accomplished via keyboard entry or by the originator transmitting chart information in data form.

This recommended characteristic will reduce manual chart updating, at significant time saving, with improved accuracy, and increase the breadth of charts that can be carried with little space required.

#### Clinical Diagnostics

Each combatant should have access to medical diagnostic systems and to the opinion of medical specialists as appropriate to support the level of medical personnel onboard. The capability should exist, as a minimum, for transmitting vital signs from any ship to any other ship within a Battle Force. This will assist each warship's medical staff with expert advice for diagnostics and in prescribing and performing treatment. Ideally the system would allow Navy-wide or even total U.S.



coverage for expert consultation among medical professionals regarding a case occurring aboard a combatant at sea.

### Modular, Cleanable Heads

There is no reason that shipboard heads should require the amount of maintenance and cleaning manhours that they consume today. Modular heads should be designed without corners or hard-to-clean areas. Adequate ventilation must be provided as well as adequate light and temperature control.

This is an unglamorous issue that has not received sufficient attention and which could improve morale significantly by the application of ingenuity.

### Battle Force Parts Sparing Procedure

There are vital spares that have very low failure rates but which must be carried because of their criticality. Today each ship must carry one of these spares, some of which are large and heavy. With today's vertical replenishment capability and the relative abundance of aircraft within a Battle Force there is no longer a requirement that each ship be entirely independent with respect to spare parts. Very Low usage, critical spares, should be carried by one or two (for redundancy) ships for the entire Battle Force. This consolidation should dramatically reduce the quantities of spare parts that must be carried.

### Crew Physical Readiness

Physical readiness and alertness will be increasingly difficult to maintain as tasks become more automated and sedentary. Systems should be developed to maintain crew members' physical fitness. Systems are also needed which can be used to test a watchstander's alertness periodically and suggest short duration mental or physical diversions to return the watchstander to the standard of attentiveness required at his station.

### Incapacitating Barriers

Areas which contain or provide access to sensitive information or critical equipment and which are normally unoccupied should be protected by incapacitating barriers. For example, stun gas may be released by an automated system if motion or heat is detected in a weapons magazine that suggest the presence of an unauthorized person. The protective system must only incapacitate the individual, rather than do irreversible harm, and the ship must have control over the activation of the system. The concern is that there will be an increasing number of very sensitive areas aboard future combatants, and fewer sailors. Sensitive spaces may be unmanned, especially while in port, and incapacitating barriers are a realistic solution.

### Modular Berthing

Individual bunks or berths might be modular and self contained. They would lend privacy and allow individual selection of environmental conditions (temperature, light, humidity, etc.), a self-contained audio system, video monitor, and reading light.

Much research and development has been done on modular berthing. The available technology and designs should satisfy all shipboard habitability requirements. Modular berthing could support the concept of the ship as a sailor's home and enhance peacetime living without significant increases in overall volume.

### New Concept for Fending Off

Ships could not be required to carry bulky fenders which are difficult to store and unwieldy to use. Rub strips, similar to those installed in automobile doors, may be part of a solution. The various heights of piers and other obstructions will be an obstacle to doing away with fenders but, innovation should solve this fleet problem and contribute to the reduction of radar cross-section associated with removal of fenders and brackets topside.

### Automatic Piloting Aids

Piloting in some restricted waters or channels should have automated assists, with transponders which allow port entry and exit under nearly all weather conditions. Frequently used moorings and channels which are dangerous or difficult to maneuver in should be the first to have automated piloting aids. Precise position, course and speed over the ground, and other data should be provided automatically.

### Block Manning

Current personnel turnover rate is excessive and can hamper a ship's combat readiness seriously. An alternative to the current personnel rotation policy we call "block manning".

Under the block manning concept, personnel rotation would be based on the ship's overhaul and operational cycles. During a major maintenance period one-third to one-half of the crew would rotate at the same time. The crew would then remain stable through refresher training and deployment, until the next major maintenance period.

Implementation of this concept would not be easy. However, the benefits to be gained in terms of unit readiness outweigh the difficulties of system development. If we began now, block manning could be routine by 2010.



## SECTION 5. EXECUTION

The key to success is execution, which in this case is the implementation of the recommended operational characteristics and institutionalizing a process for operator input to warship design. Since the SOCS recommendations include a variety of design changes, new R&D focus, and policy issues, execution will require the integration of several actions and the cooperation of many agencies. The section is included because of the importance of and potential problems with implementation.

First, key policy changes must be made. Concurrently, the operators, fleet-wide, must understand the value of the new policies and operational characteristics, and the community must be involved in the implementation process. Several difficult R&D funding choices must be made in response to policy changes, and the need to insure that critical technology is available for the 21st century combatant, and in pursuit of new solutions to prioritized operational requirements. The operational capability of the 21st century combatant can be further improved by reviewing emerging technology specifically for its applications to the ship, i.e., technology push. Ship designers must be encouraged to consider innovative designs and unique system arrangements to maximize the utility and compatibility of the new operational characteristics.

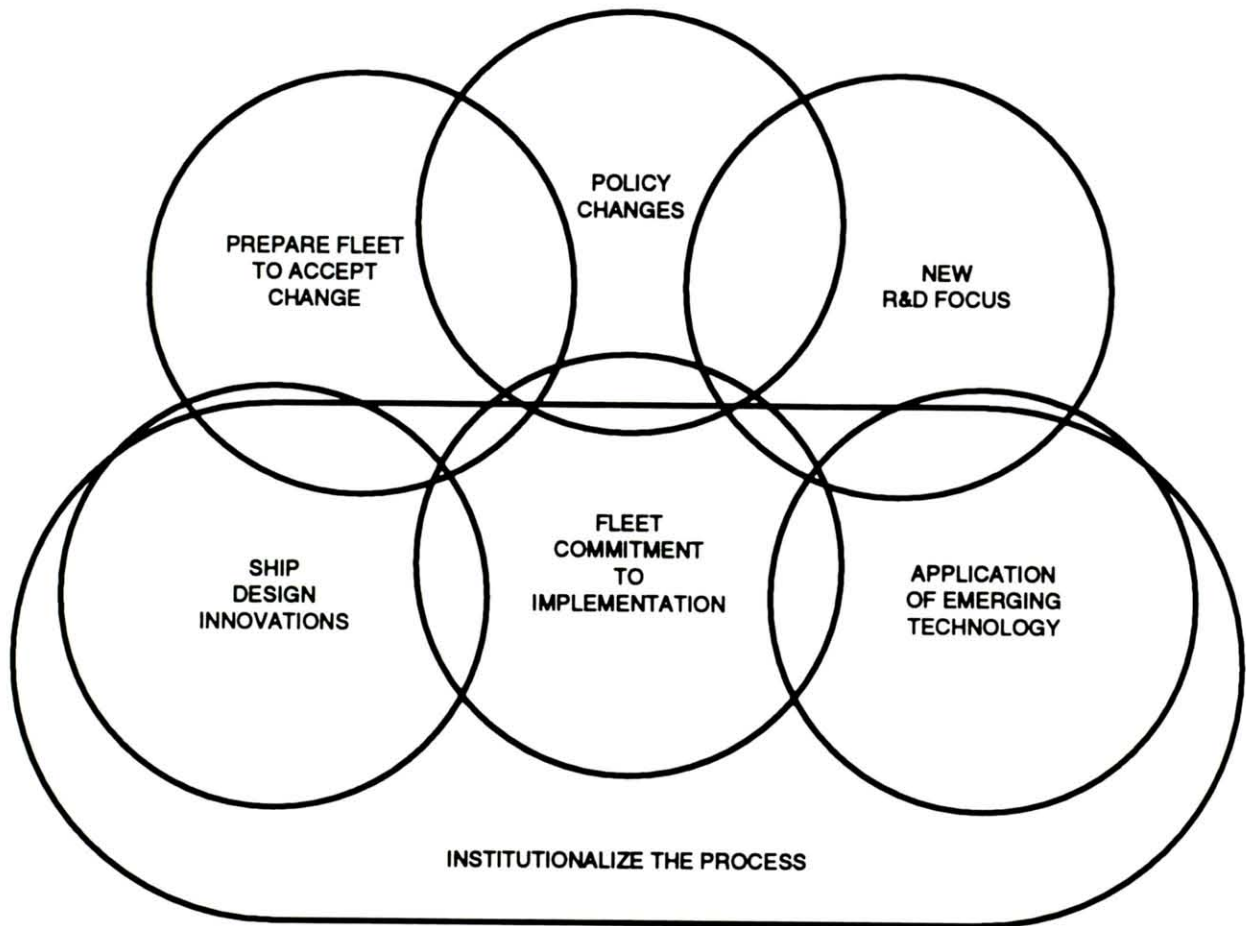
Finally, the entire process, which insures that operational requirements are reflected in the combatant design process, must be institutionalized. The interdependency among the required implementation activities is represented as a Venn diagram in Figure 8.

### Policy Issues

The range of policy issues includes several which must become CNO initiatives as well as some which can be implemented aboard ship. Navy-wide policy issues include both operational and technological standards. Some policy issues support the development of operational characteristics, others are necessary on their merit. The key policy issues recommended by the study are:

- A Survivability Standard
- Peacetime/Wartime Habitability Standards
- Ship Availability Objective
- Signature Objectives
- Condition Based Maintenance
- Embedded Training
- Information Management Goals

**FIGURE 8**  
**IMPLEMENTATION ACTIVITY**





- Tactics Development Procedure
- Power Train Selection
- Automation and Accountability

Survivability standards must be established. Peacetime and wartime habitability standards must be developed. What overall availability (Ao) is required for warships? Can a standard be established? What are our signature objectives, and how do they relate to that theoretical cross-over point with decoys and deceptive techniques? Are we willing to front the costs necessary to permit us to move toward condition based maintenance? Embedded training and readiness assessment are absolutely essential. In peacetime we train for wartime. Ships are inappropriately configured for that today, and we must move to embedded training systems. What are our information management goals? They need to be specified. The paperless ship is a big step in the right direction. The ship of the 21st century should not be developed in isolation from our development of tactics; i.e., those tactical development organizations, such as the Surface Warfare Development Group (SWDG) which up until this time have been dealing only with the ships that exist, ought to engage in the process of postulating tactics for ship design concepts as those concepts are developed. The input of the SWDG with regard to changes that might be made to facilitate tactical employment could be extremely valuable to the ultimate success of the ship. A power train must be selected from among the competing arrangements and systems. The system that SOCS advocates is an integrated distributed electric drive with padded propulsion, intercooled regenerative gas turbine engines and derived ship's service electrical power. We need to make sure that as we continue our move in the direction of automating functions aboard ship, we understand the implications for accountability. Is it enough that the Commanding Officer maintain the equipment to design standards and operate systems the way they were designed? If a casualty occurs as a result of that, is the C.O. absolved of accountability?

### Design Changes

SOCS recommendations will require new designs and design innovation. A hanger for aircraft and off-board vehicles is an example of a new design required by SOCS. The four hangar design alternatives identified in the study are meant to stimulate design innovation and explicitly reinforce the fact that SOCS recommended operational characteristics but tried not to restrict the design alternatives.

The major design changes recommended by the study are:

- Alternative use of volume
- Collocation of ship control and CIC
- Flush stowage of aircraft and other vehicles
- RCS reduction and smooth topside
- New integrated machinery
- Survivability to new standards

- Access control and import defense

### Fleet Acceptance

The Surface Warfare Community must begin immediately to gain acceptance among operators for the policy and design changes that will be forthcoming. The resistance to automation is detailed elsewhere in the report as a specific example of the natural human resistance to change. It will require a dedicated and concerted effort to prepare the Fleet to accept the changes that will be forthcoming. Unless the Fleet takes full part in the revolution at sea, implementation cannot succeed.

### R&D Focus

There must be new focus of R&D effort in response to some of the recommended operational characteristics and new R&D initiatives in response to others. In the propulsion and machinery area, focus is required to ensure that a system will be ready soon. Some current propulsion and machinery R&D may have to be halted. In the area of LPI communications, new initiatives are likely to be appropriate and unique concepts and ideas should be pursued. This R&D area should be expanded.

R&D must be expanded or initiated in the following areas:

- Torpedo defense
- New machinery system
- Provisions and water monitoring
- LPI data exchange
- Indirect visibility improvements
- Forward pass/longer range weapons
- Expert systems
  - sorting data
  - message handling
  - information management
- Decision aiding
- Reliability and maintainability enhancements
- Equipment failure prediction
- Conformal sensors and emitters
- All-weather off-board vehicles
- I.D. processing for access control
- L.O.S. signaling device
- Condition monitoring and control
- "Smart Ship" embedded sensor network
- HM&E to new survival standards



Torpedo defense is a very difficult problem. We think this area has extremely high priority for the ship of the 21st century. The same kind of priority ought to be accorded a new machinery system. Ships must be able to monitor the safety of provisions and water. LPI data exchange techniques which exploit the environment, directivity, and power management need to be developed. Indirect optical surveillance can be accomplished today, but the degree of image definition that we think is needed to have user acceptance and safety is yet to be achieved. Forward pass is a key factor in cooperative engagement and remains a technological challenge. Expert systems are needed for sorting data, handling messages, and managing information in this information-intensive ship. Decision aids are needed for team training and combat management. Reliability and maintainability enhancements are absolutely necessary and will have to be paid for up front, if we are to attain the high system readiness and low maintenance workload that we need. New equipment monitors and expert system analysts will be necessary to keep system status, detect incipient failures, and direct timely maintenance. Conformal external sensors and emitters are going to be necessary in order for us to achieve necessary radar cross-section reductions. The management of emitters, controlling not only transmission frequency, but time and topography on the surfaces of antennae is also necessary to reduce electromagnetic interference. All-weather offboard vehicles are necessary to assure their full-time contribution to the ship's effectiveness. Personnel identification processing for access must be absolute, accurate and convenient. High speed, secure line-of-sight signaling devices are necessary to replace flag hoist and flashing light. The Smart Ship's embedded sensor network is part of the damage control and monitoring system, which will buy ships critical time early in the post-damage phase to re-establish control of damaged areas. Finally, a great deal of HM&E R&D is required to achieve a new survivability standard.

### Application of Emerging Technology

Technology could likely improve the operational characteristics of the 21st century combatant in areas we failed to foresee. Furthermore, there are likely to be military applications at sea of technologies in industrial R&D programs, but not yet known within the defense establishment. To take advantage of these resources a concerted review of technology must be performed with an eye to improving the operational characteristics and capability of the 21st century combatant even beyond what we have proposed. Industry must be brought into the implementation process.

It is also important that technological developments in response to operational requirements be implemented as they become available. A technology timeline is needed to identify the required timing of critical technologies necessary to achieve the operational characteristics recommended for the 21st century surface combatant. The technology timeline will also be a useful tool for recognizing where R&D efforts and funding should be focused over time. In addition, as we see technologies maturing which have a pay-off in reducing overhead and improving warfighting, we will be able to plan to incorporate some or all of them into building subsequent flights of DDG 51.

### Institutionalization of the Process

A revolution at sea was necessary this time, but future changes should be made in response to a continuous input of operational requirements by operators. The process by which the Fleet impacts warship design through identifying and prioritizing operational requirements must be institutionalized. This must be a long term approach; we should continually look ahead and not wait for a revolution at sea to occur every 40-50 years.

### Summary

The Revolution at Sea provided a necessary occasion for operators from the Fleet and headquarters to state operational needs for future combatants. Its success can only be measured by implementation of the recommendations. Implementation is a team effort. Not passive acceptance but active, aggressive, striving for an operationally capable and survivable 21st century combatant is required. Warship design is the responsibility of both the operators and the ship designers. Their active cooperation must be formalized and institutionalized so the U.S. Navy can continue as the preeminent naval power in the world



**Appendix B:****Detailed Briefings/Visits****Title****Briefer**

*Agenda for meeting in Washington, DC*

2-3 May 95

NRAC CHAIR Welcome  
Office of Naval Research Welcome  
Ship Automation Systems

Dr. Jim Colvard  
RADM Pelaez, USN  
CAPT Bob Lowell, USN, ARPA,  
Mr. John Jackson, APL/JHU  
Ms. Evelyn Key, SEA 03H

Engineering for Women at Sea

*Agenda for meeting in Washington, DC*

23-24 May 95

Shipboard Manning  
FFG 7 Lessons Learned in Maintenance  
Pers 5/NAVMAC/Pers 2 Brief  
CBM 2010  
CALS  
Trident Approach  
Ship Safety and Survivability

Bob Bost, SEA 03D  
Marc Borkowski, PMS 335  
CDR Stanley, USN (Lead)  
Dr. Tom McKenna, ONR  
Mr. Cliff Geiger, OPNAV N4B  
CDR Van Mauney, USN  
Mr. Richard Healing, Office of  
SECNAV

*Agenda for meeting at Great Lakes Naval Training Center*

12 June 95

Hosted by  
Electronic Classroom  
Learning Resource Center  
New Initiatives

CAPT Greg Maxwell, USN

*Visit to NAVMAC, Memphis, Tenn*

15 June 95

*Visit to USS Kitty Hawk (CV 63)*

15-16 June 95

*Agenda for meeting in Washington, DC*

27-28 June 95

Manpower

Hon Bernard Rostker, Assistant  
Secretary of the Navy (M&RA)

**Appendix C:****Glossary of terms**

ACTD	Advanced Concept Technology Demonstration
ARPA	Advanced Research Projects Agency
ASN(RD&A)	Assistant Secretary of the Navy (Research, Development and Acquisition)
CD-ROM	Compact Disk-Read Only Memory
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
COMNAVSURFPAC	Commander Naval Surface Force Pacific
DCC	Damage Control Center
DCS	Damage Control System
ETM	Electronic Technical Manual
GPS	Global Positioning System
GUI	Graphical User Interface
HM&E	Hull, Machinery and Electrical
ICAS	Integrated Condition Assessment System
IETM	Interactive Electronic Technical Manual
MNS	Mission Needs Statement
MP,N	Manpower Personnel, Navy
MPA	Manpower Authorization
N8	Deputy Chief of Naval Operations (Resources, Warfare Requirements and Assessments)
NAVMAC	Naval Manpower Analysis Center
NAVSEA	Naval Sea Systems Command
NEC	Navy Enlisted Classification
NMP	Navy Manning Plan
O&M,N	Operations and Maintenance, Navy
OPNAV	Office of the Chief of Naval Operations

OPTAR	Operating Target
POE	Projected Operational Environment
R&D	Research and Development
ROC	Required Operational Capability
SC-21	Surface Combatant for the 21st Century
SCIB	Ships Characteristics Board
SELRES	Selected Reserves
SMD	Ship Manning Document
SOCS	Ships Operational Characteristics Study
UK	United Kingdom
VOC	Volatile Organic Components
WWII	World War II