NRAC 89-2

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NAVAL RESEARCH ADVISORY COMMITTEE REPORT

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT

APRIL 1989

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OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, DEVELOPMENT AND ACQUISITION)
WASHINGTON, D.C. 20350-1000

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EXECUTIVE SUMMARY

The panel was tasked to study the automation of ship systems and equipment, and to determine those functions most readily and appropriately automated aboard future surface combatants. It was also tasked to assess available and reliable technologies with direct applicability to the automation of shipboard functions, and to suggest candidates for additional research and development to further improve warfighting capability while reducing manpower requirements.

The approach to achieving the tasking was to: 1) evaluate the current state and availability of technology; 2) identify functional areas of potential application; 3) develop a philosophy for the application of technology for automation; and 4) identify and prioritize near- and far-term applications that have potentially high payoffs. As part of this effort, the panel scheduled briefings from industry, academic and governmental sources, and reviewed a number of reports and studies prepared by recognized authorities in the field of automation.

The panel drew a number of conclusions as a result of this study.

1. Automation will be essential to ensure survivable and effective surface combatants in the warfare environment of the next century.

2. High payoff automation technologies are available and reliable. They can enhance combat effectiveness, reduce manpower costs, and reduce manpower skill requirements. At the same time, they can increase systems availability, and may be introduced in a phased manner.

3. Simplification and rationalization of shipboard processes and functions are prerequisite to efficient automation. The systems engineering discipline is essential to the selection of processes and functions to be automated.

4. Excessive use of standards and specifications will inhibit cost-effective implementation of automation technology.

5. Systems engineering design and implementation of integrated, complex shipboard systems requires a single program manager with authority, responsibility and accountability for the entire ship.

6. Critical enabling technologies for shipboard automation include:

- Fiber optics;
- Smart sensors;
- Expert systems;
- Distributed processing and Local Area Networks (LANs); and
- Computer-Aided Logistics Systems (CALS).

7. Insufficient emphasis has been placed on advanced technology demonstration programs and facilities to assure effective transition of automation into the fleet.

8. Models and other analytical tools to adequately assess the cost and warfighting benefits of automation do not now exist.

Although in the past automation technology may not have been mature enough for reliable application to ship systems, the panel is convinced that today's technology can be effectively and profitably applied. The panel recommended that the Secretary of the Navy

(SECNAV) promulgate policy endorsing shipboard automation, and establish a Plan of Action and Milestones (POA&M) to:

- Immediately introduce existing low risk automation into the fleet;

- Provide a surface ship dedicated to research and development with the capability to accommodate rapid prototyping of automated systems;

- Facilitate the introduction of new technologies and automated capabilities, exploiting modularity to accommodate backfit;

- Limit ship design standards to hardware functions and interfaces, and to software languages;

- Cooperate with industry and academia to support vigorous research and development in the information and computing sciences; and

- Fund a continuing advanced technology demonstration program as a mechanism for transition of automation into the fleet.

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TERMS OF REFERENCE
SPECIFIC TASKING

- DETERMINE THE FUNCTIONS THAT MUST BE PERFORMED ABOARD A FUTURE SURFACE COMBATANT, AND IDENTIFY THOSE FUNCTIONS MOST READILY AUTOMATED.
- ASSESS AUTOMATION AND ROBOTIC TECHNOLOGIES THAT BEST SUPPORT THE CHANGE OF FUNCTIONAL ALLOCATION FROM MAN TO MACHINE.
- INVESTIGATE THE LIFE CYCLE COST IMPLICATION OF SHIPBOARD AUTOMATION THROUGH THE DEVELOPMENT AND IMPLEMENTATION OF A COST MODEL THAT INCORPORATES ALL MANPOWER COST.
- RECOMMEND FUNCTIONS FOR AUTOMATION ABOARD FUTURE SURFACE COMBATANTS, AND RECOMMEND CANDIDATES FOR RETROFIT TO EXISTING SHIPS.
- IN CONJUNCTION WITH THE AFFORDABILITY AND AVAILABILITY OF NEW TECHNOLOGY AND THE RAPID ACQUISITION OF RAPIDLY ADVANCING TECHNOLOGIES PANELS, IDENTIFY SUPPORTING TECHNOLOGIES REQUIRING GREATER RESEARCH AND DEVELOPMENT (R&D) EMPHASIS TO PERMIT A MAXIMUM IMPROVEMENT IN WARFIGHTING CAPABILITY AND REDUCTION IN MANPOWER REQUIREMENTS THROUGH SHIPBOARD AUTOMATION.

GENERAL CONCLUSION

AUTOMATION IS ESSENTIAL IF EFFECTIVE COMBATANTS ARE TO BE BUILT TO MEET THE EVOLVING THREAT

BACKGROUND

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
BACKGROUND

• STEAM WINCH	1800s
• AUTO LOADERS 6" GUN WORCHESTER 8" GUN SALEM	1946
• BOILER CONTROL WATER LEVEL CONTROL	1960
• AUTOMATED ENGINEERING SPRUANCE DD 963	1968
• AEGIS WEAPON SYSTEM	1981

Background

Automation aboard Navy ships is not new. One of the first examples of shipboard automation was the steam winch in the early 1800s that not only eased the life of the sailor, but also increased combat effectiveness. Subsequently, the introduction of the hydraulic servo made possible the use of large caliber guns such as on the HMS DREADNAUGHT. The automatic 8"/55 caliber gun of the SALEM Class was the epitome of the large caliber gun loading and firing systems.

The automatic boiler feed water control is an example of essential automation without which a warfighting capability would have been impossible. Although automatic feed water controls were available for the 600-pound boilers of World War II, their use was "optional" and, in fact, automated controls were seldom used. Nevertheless, without automation, today's 1200-pound systems would be impractical.

In 1968, extensive automation was introduced to the machinery spaces of SPRUANCE Class destroyers with the installation of the Machinery Centralized Control System (MCCS). Although the operating concept of this highly effective automated system was to free manpower from the ship's machinery spaces which were essentially designed to be unmanned under normal cruising conditions, fleet commanders, whose engineering experience was with steam ships, decided that the automatic systems should be monitored by the crew. Fortunately, the era marked by this type of reaction to shipboard automation is passing, but the lesson learned is that innovation that is not accepted by the user may result not only in the loss of automation benefits, but also in a reduction of combat effectiveness.

The AEGIS combat system, the most recent and extensive use of Navy shipboard automation, is the first attempt to integrate a ship's weapons into a true "weapon system." AEGIS automates the ship's weapons--detection, classification, engagement, and launch of ordnance--while integrating them into one system. It demonstrates the movement toward making the ship itself a single weapon system.

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
BACKGROUND (CONTINUED)

• CNO DIRECTED STUDY TO IMPROVE SHIPS THROUGH APPLICATION OF EMERGING TECHNOLOGY	NOV 1986
• OP-03 INITIATES "REVOLUTION AT SEA" - SCFRS - GROUP MIKE - SOCS	NOV 1986
• SOCS STUDY - PROFILE OF FUTURE COMBATANTS - AUTOMATION GREATEST PAYOFF	MAR 1988
• CNO SUBSCRIBES	APR 1988

Background (Continued)

In November 1986, the Chief of Naval Operations (CNO) directed the Deputy-- now Assistant--CNO for Surface Warfare (OP-03) to study potential improvements to the characteristics and performance of surface ships and ship systems through the development and application of emerging technologies. OP-03 responded by initiating three in-depth studies, collectively called "Revolution At Sea." These studies included:

- Surface Combatant Force Requirements Study (SCFRS)
- Surface Combatants of the 21st Century (Group MIKE)
- Ship Operational Characteristics Study (SOCS)

The SCFRS report assessed and validated the numbers, types, and capabilities of surface combatants needed during the next 25 years. Group MIKE focused on the 21st century: developing enhanced surface combatant operating requirements documents; revising Office of the Chief of Naval Operations (OPNAV) guidance (directives, plans and policies); and designing a new family of surface combatants.

The SOCS analyzed United States' national objectives, naval missions, the geopolitical environment, and the threat expected in the early 21st century to determine the necessary operational characteristics for the 21st century surface combatant to perform its mission against the forecasted threat. Operational concepts for the 21st century combatants were assessed to identify legal, institutional, operational, and cultural factors influencing the determination of ship characteristics, and policies were recommended for improving surface combatant design. The SOCS aggressively examined shipboard operational and maintenance requirements that, in turn, drive manpower requirements. The study recommended shipboard functions which could be enhanced, reduced, eliminated, or transferred by changes in policy or design, or through automation.

SOCS analyzed 17 different functional areas ranging from ship control, navigation, damage control, and signature reduction to survivability, crew support, and administration. A set of options was developed for each area and then quantified as to its impact on size, weight, and manpower requirements of 21st century surface combatants. The results were further synthesized into a cohesive, sensible set of 12 recommendations considered "imperative characteristics" that would maximize ordnance on target and yield a high return in terms of volume and manpower, warfighting and force multiplication. These characteristics included:

- Cooperative engagement (in all mission areas the ability of the battle force to exchange the widest range of data and information);
- Integrated machinery systems;
- Survivability and the ability to "fight hurt;"
- Embedded readiness assessment, mission planning, and training;
- Condition-based maintenance;
- Torpedo self-defense;
- Colocation of ship control and Combat Information Center (CIC);
- Access control and security;
- Alternative use of volume;
- Smooth topsides;
- New information management;
- Organic aviation and other off-board vehicles.

SOCS concluded that "increased automation of ship functions and systems is inevitable in all areas including combat and ship support operations." Upon its completion in April 1988, CNO was briefed on the study's conclusions and recommendations. He enthusiastically endorsed the SOCS findings.

SHIP OPERATIONAL CHARACTERISTICS STUDY QUOTE

"VIRTUALLY EVERY OPTION DEFINED FOR IMPROVING SHIP OPERATIONAL CHARACTERISTICS THAT RESULTED FROM THE FUNCTIONAL ANALYSIS DONE IN THIS STUDY INCLUDED SOME FORM OF AUTOMATION."

THE NAVAL RESEARCH ADVISORY COMMITTEE PANEL ON AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT CONCURS.

APPROACH

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
APPROACH

- EVALUATION OF STATE AND AVAILABILITY OF TECHNOLOGY
- WHERE MIGHT IT BE APPLIED
- PHILOSOPHY OF APPLICATION
- IDENTIFICATION OF NEAR AND FAR TERM PAYOFFS

Approach

The Ship Systems and Equipment Automation Panel used a standard approach to this study and the development of its conclusions and recommendations. First, the state of automation technology, including its availability and reliability, was reviewed and evaluated. As part of this effort, ten briefings from industry, academic and government sources were scheduled and various references provided by authorities in the field were reviewed. In the second phase of the study, ship-related functional areas where automation could have a significant payoff were identified.

Early in the study it became apparent that a critical part of the application process is the adoption of an automation philosophy that simplifies and rationalizes shipboard functions targeted for automation. Finally, the panel prepared a prioritized set of near-term and far-term applications of automation that have, in the panel's opinion, a high payoff for the Navy.

AVAILABLE AND RELIABLE TECHNOLOGIES

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
CURRENTLY AVAILABLE AND RELIABLE TECHNOLOGY
(INFORMATION TECHNOLOGY)

EXPERT SYSTEMS	THOUSANDS OF RULE-BASED SYSTEMS RULE-BASED SYSTEM SHELLS
COMPUTERS	20-25 MIPS WORK STATIONS PORTABLE PERSONAL COMPUTERS
DISPLAYS	HIGH RESOLUTION: 1280 x 1024 COLOR AND GRAY LEVEL AVAILABLE
NETWORKING	100-MEGABIT/SEC FIBER OPTIC LANs
MEMORY	1-MEGABIT CHIPS HUNDREDS OF MEGABYTE MAGNETIC DISKS THOUSANDS OF MEGABYTE OPTICAL DISKS
HIGH-VOLUME PROCESSING	MASSIVELY PARALLEL COMPUTERS SPECIAL PURPOSE PROCESSORS VHSIC CHIPS
DATA BASES	DISTRIBUTED DATA BASES, ROBUST AND WITH QUICK ACCESS

Currently Available and Reliable Technology (Information Technology)

Over the past five years, improvements in commercial information handling technology have resulted in tremendously expanded capability and potential for application. The following overview illustrates advances in specific available information technologies.

- **Expert Systems**

Expert systems, based on the rule-based problem-solving paradigm developed by Artificial Intelligence (AI) researchers, have emerged as a mature technology, one that supports thousands of applications and a half-billion dollar industry. In the Air Force, logistics applications alone are estimated to have saved well over $250 million in the past two years.

One reason for the rapid penetration of this technology is that so-called expert systems shells enable experts to create new applications by adding knowledge only, without programming, in the same way that a spreadsheet user reaches conclusions by adding numbers to spreadsheets, without programming. Extremely simple shell systems can be built with packages that run on standard personal computers. Extremely powerful systems, using hundreds or thousands of rules, can be built with packages that run on standard upper-end 80386-based or 68020-based personal computers.

- **Computers**

At the beginning of this decade, using a dedicated personal computer meant sacrificing more sophisticated large computer tools, and being constrained by tiny memories and slow microprocessors. The computing capability now available in high-powered work stations costing $10-20K dwarfs that of many 1980 mainframes, and facilitates applications that were impossible only a few years ago.

- **Displays**

High-resolution displays provide users paper-like resolution, if necessary, in gray levels, color, or both. Dials and gauges are displayed rather than implemented in hardware. Parts of the screen turn red or blink to draw attention to problems. In applications requiring extreme robustness, plasma panels are available, with some sacrifice of resolution along with color.

- **Networks**

In its heyday, time sharing delivered cost-effective computing to multiple users and enabled information sharing. Local Area Networks (LANs) are now rapidly replacing time sharing. Work stations and personal computers provide the computing capability, and the networks have changed the focus from information sharing to data distribution (such as the use of LANs for electronic mail) and software availability.

Many organizations download software from central file systems to individual machines, increasing the flexibility of the hardware to perform a multitude of functions as dictated by needs and circumstances. For example, a machine may function alternatively for problem solving and training, or may, in the manufacturing environment, be capable of making a number of different parts, switching quickly from one to another with reprogramming.

- **Memory**

Rapidly advancing disk technology opens the door to many applications that would be too demanding otherwise. Today, a 20-pound portable computer can carry (on a 100-megabyte hard disk) roughly the amount of information in 100 textbooks, each 500 pages long. Whole encyclopedias are available in Compact Disk (CD) packages that can be read on machines costing approximately $1000. Hardened rotating memory, either the traditional magnetic or the new optical CD, is available in the hundreds of megabytes range. Write Once and Read Many (WORM) disks allow highly reliable, fast and secure mass memories for shipboard applications.

Eventually, the steady march of Very Large Scale Integration (VLSI) technology may eliminate the need for rotating memory altogether. Megabit chips are rapidly displacing 256K chips. Cards are available with more than 20 megabytes of those 1-megabit chips. By comparison, the IBM XT personal computer, on the leading edge of commercial technology just a few years ago, had only 10 megabytes of hard disk storage.

- **High-volume Processing**

Embedded special-purpose signal processors have proliferated for number-crunching applications. In the high-priced, general purpose range, machines costing a few million dollars now provide more than 1000 million instructions per second (mips) compared to a few tens of mips ten years ago. These new machines make many image and signal handling applications practical for the first time, but software is still in the basic research stage and hardware militarization for shipboard use is unlikely in the near term.

- **Data bases**

Data base technology now supports the reliable storage of and rapid access to large amounts of data. Data are supplied by and available to either human users or applications programs, including expert systems.

Established software technology and hardware redundancy ensures that critical data in these data bases survive any single-point hardware failure. In the event one computer, controller or disk drive crashes, another can assume its duties with hardly a hiccup.

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
CURRENTLY AVAILABLE AND RELIABLE TECHNOLOGY
(INFORMATION TECHNOLOGY CONTINUED)

SENSORS	EMBEDDED MICROPROCESSORS VHSIC CHIPS
DATA SECURITY	NSA-APPROVED ENCRYPTION CHIPS VHSIC CHIPS
MAN-MACHINE INTERACTION	STANDARDIZED INTERFACES
TRAINING	EMBEDDED TUTORIALS INTEGRATED HELP SYSTEMS
INTERACTIVE SYSTEMS	SOFTWARE-DRIVEN VIDEO
INFORMATION MANAGEMENT	PAPERLESS INFORMATION PROCESSING
INFORMATION CAPTURE	ALPHANUMERIC IMAGE UNDERSTANDING LIMITED GRAPHICS UNDERSTANDING

Currently Available and Reliable Technology (Information Technology) (Continued)

- **Sensors**

Sensors that see, hear, and feel gather information for the interpretation of situations and the guidance of devices. Smart sensors facilitate remote machinery operation. Valves can be turned, auxiliary engines can be started, machinery can be brought up or shut down--all with a guarantee that the action will progress as it should.

Some sensor packages now incorporate processor chips that increase local capability. Signals can be interpreted, and only conclusions, not raw data, transmitted to central systems. Limiting communication with central systems to situation change messages, periodic "I'm OK" messages, and sensor malfunction messages will relieve the load on the central system and initiate self-correction of identified faults.

- **Data Security**

Very High Speed Integrated Circuit (VHSIC) chips encrypt information faster than most communications systems can transmit it. The encryption process is no longer a bottleneck for information distribution. Disk technology and access recording provide further security enhancement for electronic systems.

- **Man-Machine Interfaces**

Myriad software is available for the Macintosh and IBM MS Windows environments featuring a uniform, icon-based method. Consequently, once trained in the use of one spreadsheet or word processing package, the user can easily employ other similar applications because the displays and keyboard functions are virtually the same. Touch screens and mouse controls provide further simplification and utility. Training requirements are dramatically reduced, and users are more flexible, even able to use unfamiliar applications to accomplish a task in a quick turnaround or emergency situation.

- **Training**

Nearly all popular personal computer and work station software comes with on-line training and help facilities. Training is accelerated by immediate feedback, and occurs within the working environment. Learning is self-paced and easily measured. Most people learn to use sophisticated software without ever opening a textbook or a reference manual. Simplifying training in this way helps to make people multifunctional.

- **Interactive Systems**

Interactive optical disk systems are now used in a variety of applications, including in the training of technicians and managers. Imagery stored on optical disks is accessed within lessons controlled by software to demonstrate people performing the skill being taught.

- **Information Management**

Office automation offers electronic systems for mail, document preparation, form handling, filing and retrieving, and other traditional office activities. Development emphasized human engineering to make automated office systems efficient and easy to use.

Nevertheless, few offices are truly paper-free for two reasons: 1) A certain amount of paper is necessary for external communication; and 2) human inertia. The first of these is not a problem on ships; the second can be handled by command.

- **Information Capture**

Moving to the paperless ship requires the capture of written material currently available in no other form. Fortunately, document scanners and their associated software have matured greatly, making it relatively easy to convert the textual parts of existing manuals and other printed material to digital form.

Generally speaking, however, the software for dealing with graphic material still has limited capability. The technology to recognize lines and represent them as vectors inside a computer is not well developed. A technical end-run around this software problem may be possible: high-capacity video disks may make it possible to store graphic material in the form of images without re-representation in more traditional digital forms.

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
CURRENTLY AVAILABLE AND RELIABLE TECHNOLOGY
(MANUFACTURING AND MATERIAL HANDLING)

- **MANUFACTURING TECHNOLOGY**
  - NUMERICAL & COMPUTER CONTROL (CAM, CIM, ICAM, ETC.)
  - RAPID ACQUISITION OF MANUFACTURED PARTS (RAMP, ETC.)
  - AUTOMATIC PROCESS PLANNING
  - AUTOMATIC PRODUCTION & INVENTORY CONTROL
  - MATERIAL REQUIREMENTS PLANNING (MRP)
  - AUTOMATIC STORAGE & RETRIEVAL, GUIDED VEHICLES & ROBOTS

- **MATERIAL HANDLING TECHNOLOGY**
  - TRANSPORTERS, CONVEYORS, HOISTS, TRAILERS, ROBOTS
  - MANIPULATORS & POSITIONERS
  - SORTERS (IMA & DEPOTS)

Currently Available and Reliable Technology (Manufacturing and Material Handling)

The operation, logistics support and maintenance of ships have long employed some degree of automation in the form of powered devices. Actuators and positioners are key elements of control systems. Moving and restraining devices aid material handling and processing. The latest automation technology being applied to the manufacturing and transportation industries offers significant opportunity to reduce crew numbers and to increase the efficiency of resupply and servicing.

Controller technology enabled Computer-Aided Manufacturing (CAM), and has facilitated the integration of manufacturing capabilities (CIM and ICAM). These advances include the ability to rapidly reconfigure manufacturing and minimize set-up time. The Navy's Rapid Acquisition of Manufactured Parts (RAMP) program has assimilated much of this technology. Automated systems are also available for process planning, production, inventory control, Material Requirements Planning (MRP), storage and retrieval.

A host of material handling, positioning, and sorting technologies are in use in the transportation industries. Each of these technologies offers the Navy worthwhile advantages in operational capability and cost-effectiveness.

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
AN EMERGING TECHNOLOGY EXAMPLE
(EXPERT SYSTEMS)

MUCH OF AUTOMATION DEPENDS ON THE EXPERT SYSTEM TECHNOLOGY THAT HAS EMERGED OVER THE PAST TEN YEARS FROM AI RESEARCH. FORTUNATELY, A SECOND GENERATION OF EXPERT SYSTEM TECHNOLOGY IS EMERGING THAT IS MORE RELEVANT TO NAVY NEEDS.

An Emerging Technology Example (Expert Systems)

Much of automation depends on the expert systems technology that has emerged over the past ten years from AI research. Fortunately, a second generation of expert systems technology is emerging that is more relevant to Navy needs.

The first generation of expert systems technology was driven by technology. The technologists found applications that were highly constrained along a number of dimensions to ensure more rapid processing and a higher probability of success. The new, second generation expert systems technology is problem-driven. Problem-oriented technologists are developing the technology necessary to deal with problems that are too difficult to be resolved by the limited approach established by the first generation of expert systems.

First generation systems are also intended to solve problems. The operator supplies data and waits for an answer, perhaps asking a few questions about the status. Second generation expert systems can operate in that fashion, but they may also function as an associate, helping an operator rather than simply being directed by one. In many cases, it is difficult, impossible, or otherwise undesirable to replace a human operator entirely. Nevertheless, it can be crucially important for a system to work with an operator, managing the presentation of information on the screen, ensuring that no obvious errors go unnoticed, and enforcing policy.

While first generation expert systems are based almost exclusively on the rule-based problem solving paradigm and, generally, run alone on their own computer, second generation expert systems are often embedded in larger systems. They are sometimes based on rules, but they also may be based on search, constraint propagation, or any of a dozen other problem-solving paradigms developed by Al researchers. These embedded expert systems may only be a small part of the actual software, albeit a key part.

First generation systems solve problems that are amenable to stand-alone work stations, while second generation systems typically require constant access to information stored on mainframes. The former solve problems requiring only a few hundred or a few thousand records. Some second generation systems deal with orders of magnitude more data.

First generation systems solve problems that do not require instant answers. Second generation systems can control diverse operations such as chemical plants and airports, which require instant answers. Some second generation systems can even learn to function better by identifying data regularities.

First generation systems solve non-critical problems. A hardware crash requiring an hour or a day for software recovery causes annoyance, but not disaster. Some second generation systems can recover within three minutes after hardware recovery, making these systems more flexible and dependable for critical functions.

A key to realizing the benefits of emerging technologies is effective integration of system elements to optimize system capability.

APPLICATION
TO
NAVAL SYSTEMS

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT TECHNOLOGY APPLICATIONS

FUNCTIONS	TECHNOLOGIES: HI VOL PROC	WORK STATION	DISPLAYS	NETWORK	MEMORY	SENSORS	DATA SECURITY	MAN-MACHINE	EMBEDDED TUTORIALS	PAPERLESS INFO MGMT	DIGITIZE PAPER DATA	ES	DATA BASES	REMOTE MECH AUTO
SHIP CONTROL		X	X	X	X	X	X	X	X	X	X			X
INT MACH SYS		X	X	X	X	X		X	X	X	X	X		X
SIG CONTROL		X	X	X	X	X	X	X	X	X		X	X	
COMMS		X	X	X	X	X	X	X	X	X		X		
NAVIGATION		X	X	X	X	X	X		X	X	X		X	
COMBAT SYS	X	X	X	X	X	X	X	X	X	X	X	X	X	
DAMAGE CONTROL		X	X	X	X	X		X	X	X	X	X	X	X
MAINTENANCE		X	X	X	X	X		X	X	X	X		X	X
LOGISTICS		X	X	X	X	X		X	X	X	X	X	X	X
TRAINING		X	X	X	X			X	X	X	X			
ADMINISTRATION		X	X	X	X		X	X	X	X	X			
SECURITY PHYSICAL		X	X	X		X	X	X	X	X		X	X	
CREW SUPPORT														

Technology Applications

These two charts show the application of the previously discussed information technologies to shipboard functions identified in the SOCS. As indicated by the number of checked boxes, there is already an impressive amount of reliable automation technology for shipboard use today. In addition, new technology is continually emerging for further enhancement of warfighting, survivability, and effectiveness, and for the reduction of manpower and life cycle cost.

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT TECHNOLOGY APPLICATIONS (CONTINUED)

FUNCTIONS	TECHNOLOGIES: ACTIVATE	POSITION	RESTRAIN	STORE	CONTROL ENVIRONMENT	SENSE POSITION & MOVE	MAINT INVENT RECORDS	ORDER MATERIAL	PROCESS MATERIAL	SCRAPE SCRUB PROTECT	MOBIL SYSTEMS
SHIP CONTROL	X	X	X		X	X				X	
INT MACH SYS	X	X	X		X	X	X			X	
SIG CONTROL					X	X					
COMMS					X	X					
NAVIGATION					X	X					
COMBAT SYS	X	X	X	X	X	X	X	X	X	X	X
DAMAGE CONTROL	X	X	X	X	X	X	X	X	X	X	X
MAINTENANCE	X	X	X	X	X	X	X	X	X	X	X
LOGISTICS	X	X	X	X	X	X	X	X	X	X	X
TRAINING	X	X	X	X	X	X	X	X	X	X	X
ADMINISTRATION					X	X	X	X	X	X	X
SECURITY PHYSICAL					X		X	X	X	X	X
CREW SUPPORT		X	X	X	X	X	X	X	X	X	

FIRST PRINCIPLE OF AUTOMATION APPLICATION:

SIMPLIFY AND RATIONALIZE BEFORE YOU ADOPT SOLUTIONS

EXAMPLES OF AUTOMATION APPLICATION

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
EXAMPLES OF AUTOMATION APPLICATION

- **NOW**
  - PAPERLESS SHIP
  - EXPERT SYSTEMS
  - RAPID ACCESS TO TIMELY INFORMATION
- **NEAR TERM WITH INCREMENTAL BACKFIT OPPORTUNITIES**
  - EMBEDDED TRAINING
  - SURVIVABILITY ENHANCEMENT
  - INTEGRATED MACHINERY CONTROL
  - MAINTENANCE/REPAIR
  - AUTOMATED MATERIAL HANDLING
  - SIGNATURE MANAGEMENT
- **FAR TERM**
  - DISTRIBUTED INTEGRATED SHIP CONTROL

Examples of Automation Application

Technology exists today to allow implementation of automation capabilities for all the shipboard systems and functions identified in this report. Several examples of automation application are discussed here, and areas that should receive immediate implementation action include: paperless ships, expert systems and rapid access to timely information. The greatest immediate payoffs, increased warfighting capability and decreased crew size, can also be realized by these three applications. Additionally, a shore-based "paper repository" for paperless ships and expert systems promises significant cost savings, and would free entry level sailors for more technical tasks.

The near-term implementation recommendations represent available technology, but will require systems engineering and design to adapt this technology to the ship's operational concepts. These application areas are recommended for a phased implementation on backfit ships, while new design ships should receive full implementation. The maintenance and repair application is the best example of the payoff achieved by simplifying and rationalizing the current process before automation. It is conceivable that in excess of a 50 percent manhour reduction could be realized just by simplifying the maintenance process, employing more reliable systems, and reducing preventive maintenance requirements.

The far-term implementation recommendation requires new ship construction and represents a significant departure from current ship control methodologies. This recommendation represents the largest advantage to increasing the efficiency and survivability of the ship, but also requires the greatest cultural and systems engineering changes--a real break with tradition. These application examples will be discussed in greater detail subsequently.

AN EXAMPLE OF AUTOMATION APPLICATION

NOW

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AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
PAPERLESS SHIP

- **GOALS**
  - ELIMINATE TONS OF PAPER
    - -- CG 36 TONS, 1800 CU. FT.
    - -- 70% TECH & OP MAN, 15% SUPPLY RECORDS
  - INCREASE ORDNANCE LOADOUT
  - DECREASE OFF-SHIP COSTS
  - IMPROVE MAINTENANCE/AVAILABILITY
- **DRIVERS**
  - INCREASED DEMAND FOR PAPER
  - COMPETITION FOR SPACE & WEIGHT
  - BETTER USE OF ENTRY LEVEL SAILORS
  - COMPLEXITY OF SYSTEMS
- **IMPLEMENTATION CHALLENGES**
  - MAJOR INSTITUTIONAL CHANGE
  - INTRODUCES LOCAL AREA NETWORKING
    - -- TO OTHER THAN WEAPON SYSTEM CONTROL
  - CONFIGURATION MANAGEMENT

Paperless Ship

Paper, as a storage medium, blocks the efficient use of information on board ships. Technology exists today to receive, store, retrieve, reproduce, catalog, distribute, control and secure information in electronic form. The goal of the Navy is to increase ordnance on target in a cost-effective manner by freeing up manpower for war-related tasks and reducing space and weight in order to load additional ordnance.

The demand for additional paper-dependent data, and the complexity of onboard systems coupled with available technology, are the primary drivers toward development of a "paperless ship" environment. The primary limiting factor in the implementation of the paperless ship is not technology, but tradition and culture. The issue of cultural sensitivity is less a problem for the eventual users of the system than for the designers and procurers who may not be as computer literate as tomorrow's crews who are members of the computer and video generation.

Another implementation challenge is that tools do not currently exist to efficiently transfer the configuration management of paper documentation to electronic media.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
PAPERLESS SHIP (CONTINUED)

- **BENEFITS**
  - SPACE SAVED
  - INCREASE WEAPON LOADOUT BY 15-20%
  - FEWER ERRORS
  - DECREASE MAINTENANCE MANHOURS BY 25-50%
  - SIGNIFICANT ON & OFF SHIP COST SAVINGS
  - OPPORTUNITY FOR SECURITY ENHANCEMENT
  - PROVIDES COST-EFFECTIVE ENVIRONMENT FOR EXPERT SYSTEMS AND AI MATURITY
  - PROVIDES ENVIRONMENT FOR OPERATOR ASSOCIATE
  - OVERALL INCREASE IN PRODUCTIVITY

Paperless Ship (Continued)

The panel believes that the paperless ship can benefit the Navy in all onboard systems and at many shore-based activities. Life cycle cost saving and more ordnance on target are the overriding benefits. Significant other benefits also accrue from implementing the paperless ship, including an increase in operational availability of systems by reducing logistics delay times and maintenance delays through the use of electronic data processing. As paperless ship designs are implemented, the use of expert systems and artificial intelligence will increase, thus further reducing manpower and skill requirements while allowing rapid decision making and accurate situation assessment. The operator associate evolution can occur by allowing the computer to do clerking procedures management, message routing, and crew training--tasks that today are manpower-dependent.

The paperless ship also enhances security. The elimination of paper, coupled with no removable disks, automatic records of computer access, full data encryption, and erasable memory, strengthens onboard security.

In summary, the paperless ship is an opportunity to significantly increase crew productivity while simultaneously increasing the warfighting capability of our fleet in a cost-effective manner.

EXAMPLES OF AUTOMATION APPLICATION

NEAR TERM WITH INCREMENTAL BACKFIT

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
SURVIVABILITY AND INTEGRATED MACHINERY CONTROL

- **GOALS**
  - SURVIVABLE PROPULSION AND ASSURED ELECTRICAL POWER
  - FLEXIBLE IN OPERATION AND ARRANGEMENT
  - RELIABLE, MAINTAINABLE AND EFFICIENT

- **DRIVERS**
  - REQUIREMENT FOR TOTAL SHIP INTEGRATION
    - -- SHIP CONTROL AND WEAPON SYSTEMS
    - -- CASUALTY ANTICIPATION

Survivability and Integrated Machinery Control

The concept of an integrated ship is fairly new. Until recently, ships were collections of weapons and machinery. Integration was accomplished through the mind and eye of the captain. This state of affairs was marginally acceptable in a simpler age of sub-sonic aircraft, torpedoes, submarines that announced their presence, and ordnance from the barrel of a gun. Today it is not. In the 21st century, a ship must be an integrated weapon system.

In the area of survivability and machinery control, the goal of the U.S. Navy must be to build ships that can fight in the threat environment of the 21st century. This means survivable propulsion and electrical systems. These systems must be flexible in operation and efficient in arrangement. They must be reliable, maintainable, and efficient in material and manpower resources.

The challenge for the U.S. Navy is to acknowledge that machinery and damage control are part of a ship's weapon system. The Navy has always recognized the importance of survivability, albeit with varying degrees of emphasis. The overriding imperative today, driven by the threat, is a requirement for total ship integration. Casualties, both ship and equipment, must be anticipated, including those that may be inflicted by an enemy. Ship control and combat systems direction can no longer operate separately.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT SURVIVABILITY AND INTEGRATED MACHINERY CONTROL (CONTINUED)

- **IMPLEMENTATION CHALLENGES**
  - ACKNOWLEDGE REQUIREMENT FOR MACHINERY/DAMAGE CONTROL AUTOMATION
  - BREAK WITH TRADITION
  - DEFINE INTEGRATED SYSTEM
  - INTEGRATE EXISTING FRAGMENTED PROGRAMS
- **BENEFITS**
  - IMPROVED SHIP AS WARFIGHTING SYSTEM
  - REDUCED MANPOWER
  - INCREASED RELIABILITY
  - RAPID CASUALTY CORRECTION
  - INCREASED INFORMATION FLOW RATE
  - READINESS IN-DEPTH

Survivability and Integrated Machinery Control (Continued)

The traditional tie between the function of damage control and engineering casualty control has always been close; however, in shipboard weapons and operations departments, damage control has not been viewed as an adjunct to offensive action. Ordnance on target has not been a province of engineers and hull technicians.

Against this background, and in view of a traditional reluctance on the part of naval officers as engineers to accept automation (the Navy also had a difficult time going from sail to steam), the idea of an "integrated" machinery system is foreign and the supporting technology is alien. The idea that a ship's propulsion system must be controlled as part of a ship's signature is a difficult concept for naval architects and designers to accept. The most difficult challenge, however, may be the mind set of the unrestricted line officer. The engineering plant on the SPRUANCE Class was built as a partially integrated system. In practice, the automated features of these ships were mostly rejected by the line officers who make the rules on how ships will be operated at sea. This situation must change and is in the process of doing so.

The SOCS is a beginning. The study is particularly important because it was researched and written by unrestricted line officers. It is now time for implementation. The initial step must be to define an integrated ship survivability system. The basis of such a system must be a machinery control system that is totally integrated with both the ship combat and ship control systems. The ship's systems architect must propose, but the line officers must understand.

The benefit of automation and a machinery control system integrated with a ship's combat and control systems will be a surface combatant that can meet the 21st century threat. Other benefits include manpower cost savings particularly because of a reduction in training requirements. "Smart" sensors and equipment should also reduce the number of required personnel.

Automated systems are reliable today and should become more so in the future. The benefits of rapid and reliable smart sensor systems, combined with expert decision systems, will considerably improve damage control responsiveness. Information systems supported by computer-based distributed systems, fiber optics, wireless communications instruments, and networking will revolutionize damage control.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT MAINTENANCE/REPAIR

- **GOALS**
  - GREATLY REDUCE CORRECTIVE AND FACILITIES MAINTENANCE
  - ELIMINATE MOST SCHEDULED MAINTENANCE
  - INCREASE AVAILABILITY OF EQUIPMENT
- **DRIVERS**
  - WASTED MANPOWER
  - DIFFICULT AND DATED EQUIPMENT
  - BETTER USE OF MANPOWER SKILLS
- **IMPLEMENTATION CHALLENGES**
  - SIMPLIFY DESIGNS WHERE POSSIBLE
  - DESIGN FOR HIGH RELIABILITY
  - BETTER USE OF SENSORS TO REDUCE MAINTENANCE
  - INTRODUCTION OF EXPERT SYSTEMS
  - EMBEDDED TRAINING
- **BENEFITS**
  - REDUCED MANPOWER NEEDS FOR MAINTENANCE
  - LONGER MEAN TIME BETWEEN FAILURE
  - BETTER USE OF ENTRY-LEVEL SAILORS
  - INCREASED COMBAT READINESS

Maintenance/Repair

Shipboard maintenance is manpower intensive, and will consume an estimated 26 percent of the total workload aboard future DDG 51 Class ships. Automation of maintenance and ship repair to reduce manpower requirements is a desirable, achievable goal.

First, it must be determined if the process can be simplified before it is automated or, better still, if the design can be such that the maintenance function is eliminated. For example, better use of sensors, design for high reliability and prevention of single point failures will reduce maintenance. Moreover, what has been eliminated will not need automation.

If a maintenance function is automated, the panel believes that the use of expert systems to provide user-friendly, interactive maintenance aids and embedded training will result in more efficient performance by entry-level sailors. The desired end result is enhanced combat readiness.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
AUTOMATED MATERIAL HANDLING

- **GOAL**
  - OPTIMIZE MATERIAL HANDLING
- **DRIVERS**
  - SIMPLIFY LOADING AND HANDLING
  - REDUCE MANPOWER THROUGH AUTOMATION
  - FASTER SERVICING
- **IMPLEMENTATION CHALLENGES**
  - TAP ADVANCING TECHNOLOGIES FOR MANUFACTURING AND MATERIAL HANDLING
  - MODULARIZE TO FACILITATE RECONFIGURATION AND LOADING OF COMBAT SYSTEMS
  - CONTAINERIZE CONSUMABLES
- **BENEFITS**
  - REDUCTION IN TIME, MANPOWER, AND COST
  - INCREASE IN AVAILABILITY AND SURVIVABILITY

Automated Material Handling

Significant advances in the technology for manufacturing and material handling are available for use on ships now. Automation and computer-assisted designs reduce the time and the manpower required for the loading and handling of consumables. Movers, positioners, and other automated material handling equipment enhance the work capacity of individual crew members and reduce the manpower needed to operate, resupply and maintain ship systems. Weapons, spare parts, tools, and test equipment can be loaded, stored and moved much more quickly and efficiently with the aid of automated devices.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
SIGNATURE MANAGEMENT

- **GOALS**
  - DYNAMIC AND BALANCED CONTROL OF ALL OBSERVABLES
    - RCS, IR, ACOUSTIC
    - ACTIVE EMISSIONS (INCLUDING COMMS)
  - CONTROL SYSTEM INTEGRATED WITH COUNTERMEASURES AND SHIP ASPECT/MANEUVERING
- **DRIVERS**
  - INCREASING THREAT CAPABILITY
    - STANDOFF SURVEILLANCE/TARGETING
    - ADVANCED WEAPON SEEKERS (IR, RADAR, ARM, ACOUSTIC)
    - REDUCED RCS/BATTLE SPACE
    - SUPERSONIC SEA SKIMMER
    - SATURATION TACTICS
- **BENEFITS**
  - DEGRADE/DENY ENEMY SURVEILLANCE AND TARGETING DATA
  - SIGNATURE IMPLICATIONS OF TACTICAL DECISIONS
  - REAL TIME ADVICE ON HOW TO IMPROVE SURVIVABILITY
  - ENHANCED COUNTERMEASURE EFFECTIVENESS

Signature Management

Signature management could be an important early application of automation. What is needed is dynamic reactive control of <u>all</u> important signatures--not just Radar Cross-Section (RCS). Infrared Radiation (IR), acoustic, and all Radio Frequency (RF) emissions can provide the enemy with useful surveillance and targeting information. Signature management should also be integrated with all combat systems, in particular, Electronic Countermeasures (ECM), propulsion, IR management, decoy launch, and ship maneuvering.

The advancing threat is the principal driver in this area, as illustrated by some of the enemy capabilities listed on this viewgraph. Certainly, standoff targeting, dual mode seekers, reduced battle space and supersonic, low-flying sea skimmers increase the need for an automated signature management system.

The benefits of signature management are many. First, it denies or degrades the enemy's surveillance and targeting capability. Carefully managed signatures, coupled with good countermeasures (ECM, decoys, etc.), can lure the enemy into a range where bombers and submarines can be engaged, rather than just missiles or torpedoes. The objective is to destroy the archer rather than just the arrow. An integrated system should be able to assess, in real time, the enemy's capability to detect and "lock-on" to targeted ships, as well as to provide signature implications and options for tactical decisions such as communications and ship maneuvering. A major objective is to provide real time "advice" on improving ships' survivability--the ability to get to and stay in the fight--prior to damage control and "man the life boats."

AN EXAMPLE OF AUTOMATION APPLICATION

FAR TERM

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
DISTRIBUTED INTEGRATED SHIP OPERATION

- **GOAL**
  - OPTIMIZE THE WARFIGHTING EFFECTIVENESS OF A SHIP AS A SYSTEM
- **DRIVERS**
  - NAVAL CONFLICT CONTINUES ITS INFORMATION-INTENSIVE EVOLUTION
  - THREAT SOPHISTICATION AND SPEED
  - THREAT EXPANSION TO THE THIRD WORLD
  - INTERDEPENDENCY

Distributed Integrated Ship Operation

A future Distributed Integrated Ship Control (DISC) system can be viewed as the highest order decision aid available to a commanding officer to improve his ship's warfighting effectiveness. Information to support this decision-aiding tool will be gathered and processed from (eventually) all ship subsystems (e.g., combat, communications, logistics, propulsion, damage control, navigation, environmental). Once gathered and processed, the information will be distributed and displayed for interaction throughout the ship via common interfaces. For example, the integration of ship and environmental data and navigational information could improve a ship's offensive capability. In addition, the distributed system offers survivability benefits through its redundancy.

As naval operations (or conflicts) become increasingly more information intensive, readily available and easily accessed, processed information provided by DISC will contribute more directly to the ability to operate and engage ships as systems. Two trends in technology development drive this enormous increase in required information: 1) increasing combat systems capability, and 2) decreasing cost of sophisticated weaponry. The former creates an environment where more data are available for processing and use. The latter results in availability of "first class" technology (e.g., Exocet) to Third World nations. Both trends demand continuing optimization of the interface between ship systems (sensors/processors) and its crew (operators/decision-makers).

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
DISTRIBUTED INTEGRATED SHIP OPERATION
(CONTINUED)

- **IMPLEMENTATION CHALLENGES**
  - ACCEPTANCE OF FIBER OPTIC LAN
  - COMMON HARDWARE/SOFTWARE MMI
  - UNINTERRUPTED PERFORMANCE
- **BENEFITS**
  - CONTINUOUS ASSESSMENT OF EXTERNAL/INTERNAL DATA
  - RAPID DECISION SUPPORT
  - EDGE IN INFORMATION WAR
  - IMPROVED OFFENSIVE CAPABILITY
  - INCREASED SURVIVABILITY
  - ARCHITECTURE FOR INTRA-/INTER-SHIP COMPATIBILITY
  - TRAINING, LOGISTICS, ADMINISTRATIVE SPINOFFS
  - AVAILABILITY

Distributed Integrated Ship Operation (Continued)

Although tested components for a fully integrated ship control system are not available off-the-shelf, the basic enabling technologies--fiber optics, LANs, sensors, expert systems, work stations, and high resolution displays--are all sufficiently developed to begin the rationalized, modular implementation of a DISC approach now. Benefits accruing from the implementation of an ever-evolving, more capable DISC system include increased offensive capability, increased survivability, and decreased use of manpower for activities that do not contribute to warfighting effectiveness.

Furthermore, the availability of technology to continuously assess all available, pertinent data enables ship-as-a-system development now, and in the near term, battle-group-as-a-system (cooperative engagement) capability as well. Both of these capabilities are required if future combatants are to remain effective against the evolving threat as the opponent's systems continue to improve, and sophisticated weapons are put into use by Third World nations.

CONCLUSIONS

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT CONCLUSIONS

1. AUTOMATION WILL BE ESSENTIAL TO ENSURE SURVIVABLE AND EFFECTIVE SURFACE COMBATANTS IN THE WARFARE ENVIRONMENT OF THE NEXT CENTURY.

2. HIGH PAYOFF AUTOMATION TECHNOLOGIES:
   - ARE AVAILABLE NOW
   - ARE RELIABLE
   - CAN ENHANCE COMBAT EFFECTIVENESS
   - CAN REDUCE MANPOWER COSTS
   - CAN REDUCE MANPOWER SKILL REQUIREMENTS
   - CAN INCREASE SYSTEMS AVAILABILITY
   - CAN BE INTRODUCED IN A PHASED MANNER

3. SIMPLIFICATION AND RATIONALIZATION OF SHIPBOARD PROCESSES AND FUNCTIONS ARE PREREQUISITES TO EFFICIENT AUTOMATION.
   SYSTEMS
   ENGINEERING DISCIPLINE IS ESSENTIAL TO SELECTION OF PROCESSES AND FUNCTIONS TO BE AUTOMATED.

4.
   EXCESSIVE USE OF STANDARDS AND SPECIFICATIONS WILL INHIBIT COST-EFFECTIVE IMPLEMENTATION OF AUTOMATION TECHNOLOGY.

Conclusions

In the year 2010 and beyond, the character of naval warfare will be influenced, if not dominated, by very low signal-to-noise and extremely short time lines. In World War II, reaction times in the surface combatant battle environment could typically be measured in minutes. Today, with higher speed aircraft and cruise missiles, reaction times are measured in minutes and seconds. In the next century, with a few observable and/or very high speed missiles in a stressed environment as the driving threat, surface combatants must be able to react within seconds. Delayed actions in response to such threats, whether to engage or to react to damage, will be less than fully effective and may well jeopardize the survival of the surface combatant. It is this consideration that leads the panel to the strong conclusion that automation, intelligently and robustly applied, will be a fundamental requirement for surface combatants in the 21st century.

The panel acknowledges that automation technology used aboard ships in the past may not have been mature enough to permit reliable and robust systems, and in some cases, the technology may have been incorrectly applied. The panel is convinced, however, that the state of the technology today is such that, when properly implemented, automation can produce effective, reliable and robust shipboard systems which can enhance the warfighting capability and survivability of current and future surface combatants. Well suited for introduction in a phased manner, automation technology can provide early and lasting reductions in manpower costs, as well as improvements to ship system availability.

There is a tendency among automation advocates to press for automation of all functions which technology can automate. This tendency should be strongly discouraged. The experience of automation introduction into industry--in the view of the panel equally applicable to shipboard application--shows clearly that simplification and rationalization of shipboard processes and functions is essential as a first step in the systems engineering process which must be part of the automation discipline. In other words, simplify the system(s)/function(s) first--eschew tradition in this step, if possible. Strive toward viewing manpower in the automated environment as multifunctional; design to combine people with intelligent aids; attempt to eliminate the need for specialists. Once the system is simplified and rationalized, prioritize that which is to be automated. Automate the "thinking" of the system components first.

While appreciating the importance of standards and specifications in the military procurement system, it is the panel's opinion--beginning to be widely shared in the defense industry--that the excessive use and imposition of detailed standards and specifications can actually inhibit the development of modern, reliable and cost-effective systems for military use. This is particularly true in computing and information handling, which are fundamental building blocks of automation. Careful and enlightened attention in this area is considered essential.

NRAC

AUTOMATION OF SHIP SYSTEMS AND EQUIPMENT
CONCLUSIONS (CONTINUED)

5. SYSTEMS ENGINEERING DESIGN AND IMPLEMENTATION OF INTEGRATED, COMPLEX SHIPBOARD SYSTEMS REQUIRES A SINGLE PROGRAM MANAGER WITH AUTHORITY, RESPONSIBILITY, AND ACCOUNTABILITY FOR THE ENTIRE SHIP.

6. CRITICAL ENABLING TECHNOLOGIES FOR SHIPBOARD AUTOMATION ARE:
   - FIBER OPTICS
   - SMART SENSORS
   - EXPERT SYSTEMS
   - DISTRIBUTED PROCESSING AND LOCAL AREA NETWORKS (LANs)
   - COMPUTER-AIDED LOGISTICS SYSTEMS (CALS)

7. INSUFFICIENT EMPHASIS HAS BEEN PLACED ON ADVANCED TECHNOLOGY DEMONSTRATION PROGRAMS AND FACILITIES TO ASSURE EFFECTIVE TRANSITION OF AUTOMATION INTO THE FLEET.

8. MODELS AND OTHER ANALYTICAL TOOLS TO ADEQUATELY ASSESS THE COST AND WARFIGHTING BENEFITS OF AUTOMATION DO NOT NOW EXIST.

Conclusions (Continued)

The organizational challenges to effective and efficient implementation of automation into surface combatants are significant, and the panel has chosen not to identify or recommend a specific organizational structure for this purpose. The panel is convinced, however, that creation of an "automation czar" would be unwise. Rather, in the view of the panel, successful implementation of automation in a specific ship class, including management and direction of the associated systems engineering effort, mandates that the ship's program manager, with the responsibility, authority and accountability for the entire ship, be in charge of the effort. The panel does not believe that automation can be successfully implemented if the lines of management authority and accountability are diffuse and/or blurred.

In examining the feasibility for expanded use of automation in naval combatants, the panel is convinced that the enabling technologies--those which are critical to successful implementation--are available, if not already in place, albeit, not necessarily in use by the Navy today. These technologies include fiber optics (of which the pace of introduction into Navy ships has been glacial), smart sensors, expert systems, distributed processing and local area networks, and automated logistics. It is the view of the panel that the Navy should focus their efforts to accelerate understanding and expertise in these areas to facilitate wide shipboard application. Industry assistance should be sought, rather than attempting to establish this expertise where it may not exist in the Navy technical community.

The panel believes that specific steps can be taken to improve the chances of success of DOD's effort to incorporate advanced technology effectively into military systems. It is the unanimous view of the panel that shipboard automation demonstrations should be included in the Navy's Advanced Technology Demonstration (6.3A) program. While some automation projects clearly can be conducted on board fleet units (such as a paperless ship demonstration), many cannot. It is the conclusion of the panel that it would be a wise investment for the Navy to dedicate a surface (combatant) ship to research and development, so as to have the appropriate platform for demonstration and evaluation of advanced concepts and systems, including automation.

The panel was requested to determine the existence of models capable of assessing cost-effectiveness of automation on board combatant ships. After reasonable investigation, the panel has concluded that models and other analytical tools to adequately assess the cost and warfighting benefits of automation do not now exist. The development of such tools should be undertaken in parallel with the effort to automate.

RECOMMENDATIONS

- SECNAV PROMULGATE POLICY ENDORSING SHIPBOARD AUTOMATION.
  - ESTABLISH ORGANIZATIONAL STRUCTURE TO ENSURE EFFECTIVE IMPLEMENTATION BY SHIP PROGRAM MANAGER
  - REQUIRE DEVELOPMENT OF METRICS TO ASSESS IMPLEMENTATION PLAN AND PROGRESS
  - ENSURE SYSTEMS ENGINEERING APPROACH TO PLACE STRONG EMPHASIS ON SIMPLIFICATION AND RATIONALIZATION OF SHIPBOARD FUNCTIONS BEFORE AUTOMATING
  - PROVIDE FOR PAPERLESS SHIP

- PROVIDE A SURFACE SHIP DEDICATED TO R&D WITH CAPABILITY TO ACCOMMODATE RAPID PROTOTYPING OF AUTOMATED SYSTEMS.

- INTRODUCE EXISTING LOW RISK AUTOMATION TO THE FLEET NOW. DEMONSTRATE PROTOTYPES IN MULTIPLE SHIP CLASSES AND BOTH FLEETS.
  - PAPERLESS SHIP
  - EXPERT SYSTEMS
  - EMBEDDED TRAINING
  - SURVIVABILITY ENHANCEMENT
  - MAINTENANCE SIMPLIFICATION

RECOMMENDATIONS
(CONTINUED)

- TO FACILITATE INTRODUCTION OF NEW TECHNOLOGIES AND AUTOMATED CAPABILITIES, INITIAL DESIGNS SHOULD EXPLOIT MODULARITY AND OTHER SUCH MECHANISMS IN ORDER TO ACCOMMODATE BACKFIT.

- LIMIT SHIP DESIGN STANDARDS TO HARDWARE FUNCTIONS AND INTERFACES, AND SOFTWARE LANGUAGES. USE COMMON MAN-MACHINE INTERFACE METHODOLOGIES BETWEEN SUBSYSTEMS.

- IN COOPERATION WITH INDUSTRY AND ACADEMIA, SUPPORT A VIGOROUS R&D PROGRAM IN THE INFORMATION AND COMPUTING SCIENCES.

- FUND A CONTINUING ADVANCED TECHNOLOGY DEMONSTRATION PROGRAM AS A MECHANISM FOR TRANSITION OF AUTOMATION INTO THE FLEET.

- SECNAV APPROVE POA&M TO IMPLEMENT ABOVE RECOMMENDATIONS.

COMMENT

"THERE IS NOTHING MORE DIFFICULT TO CARRY OUT, NOR MORE DOUBTFUL OF SUCCESS, NOR MORE DANGEROUS TO HANDLE, THAN TO INITIATE A NEW ORDER OF THINGS. FOR THE REFORMER HAS ENEMIES IN ALL WHO PROFIT BY THE OLD ORDER, AND ONLY LUKEWARM DEFENDERS IN ALL THOSE WHO WOULD PROFIT BY THE NEW ORDER. THIS QUALITY OF LUKEWARMNESS ARISES PARTLY FROM A FEAR OF ADVERSARIES, WHO HAVE THE LAW ON THEIR SIDE, AND PARTLY FROM THE INCREDULITY OF MANKIND, WHO DO NOT TRULY BELIEVE IN ANYTHING NEW UNTIL THEY HAVE HAD ACTUAL EXPERIENCE OF IT."

Machiavelli
The Prince

APPENDIX A
RESPONSIVENESS TO TERMS OF REFERENCE

- DETERMINE THE FUNCTIONS THAT MUST BE PERFORMED ABOARD A FUTURE SURFACE COMBATANT, AND IDENTIFY THOSE FUNCTIONS MOST READILY AUTOMATED.
  - DONE.
- ASSESS AUTOMATION AND ROBOTIC TECHNOLOGIES THAT BEST SUPPORT THE CHANGE OF FUNCTIONAL ALLOCATION FROM MAN TO MACHINE.
  - DONE.
- INVESTIGATE THE LIFE CYCLE COST IMPLICATION OF SHIPBOARD AUTOMATION THROUGH THE DEVELOPMENT AND IMPLEMENTATION OF A COST MODEL THAT INCORPORATES ALL MANPOWER COSTS.
  - ADEQUATE MODELS DO NOT EXIST AND DEVELOPMENT OF AN ALL-INCLUSIVE MODEL IN ONE WEEK WAS TOO DIFFICULT AN ASSIGNMENT FOR THE PANEL.
- RECOMMEND FUNCTIONS FOR AUTOMATION ABOARD FUTURE SURFACE COMBATANTS, AND RECOMMEND CANDIDATES FOR RETROFIT TO EXISTING SHIPS.
  - DONE.
- IN CONJUNCTION WITH THE AFFORDABILITY AND AVAILABILITY OF NEW TECHNOLOGY AND THE RAPID ACQUISITION OF RAPIDLY ADVANCING TECHNOLOGIES PANELS, IDENTIFY SUPPORTING TECHNOLOGIES REQUIRING GREATER R&D EMPHASIS TO PERMIT A MAXIMUM IMPROVEMENT IN WARFIGHTING CAPABILITY AND REDUCTION IN MANPOWER REQUIREMENTS THROUGH SHIPBOARD AUTOMATION.
  - DONE.

APPENDIX B
GLOSSARY

AI	Artificial Intelligence
CALS	Computer-Aided Logistics System
CAM	Computer-Aided Manufacturing
CD	Compact Disk
CIC	Combat Information Center
CIM	Computer-Integrated Manufacturing
CNO	Chief of Naval Operations
DISC	Distributed Integrated Ship Control
DOD	Department of Defense
ECM	Electronic Countermeasures
Group MIKE	Study of Surface Combatants of the 21st Century
ICAM	Integrated Computer-Aided Manufacturing
IMA	Intermediate Maintenance Activity
IR	Infrared Radiation
LAN	Local Area Network
MCCS	Machinery Centralized Control System
mips	Million Instructions Per Second
MRP	Material Requirements Planning
NRAC	Naval Research Advisory Committee
NSA	National Security Agency
OPNAV	Office of the Chief of Naval Operations
POA&M	Plan of Action and Milestones
R&D	Research and Development
RAMP	Rapid Acquisition of Manufactured Parts
RCS	Radar Cross-Section
RF	Radio Frequency
SCFRS	Surface Combatant Force Requirements Study
SECNAV	Secretary of the Navy
SOCS	Ship Operational Characteristics Study
VHSIC	Very High Speed Integrated Circuit
VLSI	Very Large Scale Integrated
WORM	Write Once and Read Many