COPY NO._____

NRAC 89-3

NRAC

NAVAL RESEARCH ADVISORY COMMITTEE REPORT

NEXT GENERATION COMPUTER RESOURCES

FEBRUARY 1989

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

NAVAL RESEARCH ADVISORY COMMITTEE

NEXT GENERATION COMPUTER RESOURCES

FEBRUARY 1989

Executive Summary

The Goal

To deploy effective computational resources at reasonable cost.

Findings

- Technology developments
- Computer market developments
- Navy system developments

Recommendations

- Mandate *widely used, Commercial* Standards.
- Encourage Use of *Ruggedized* Equipment.
- Change the Status of the UYKs.
- Mandate Standards at the *System* Level Only.
- Reorient Prototyping Effort.

Executive Summary

The Goal and the Problem

Naval weapons systems are critically dependant on both ordinary and sophisticated computing resources. Accordingly, US strength in computer technology should give the Navy a major technical advantage relative to potential adversaries. Today, however, mission-critical shipboard computers are not as powerful as ordinary commercial computers. Accordingly, the Navy must alter the way it manages its computer resources in order to achieve its goal: **deployment of effective computational resources at reasonable cost.**

Findings

To manage computer resources better, the Panel found that several factors, some surprising, must be kept in mind:

- Embedded microprocessors are proliferating
- Reliability is up; logistics problems down
- Ruggedized and militarized versions of commercial computers exist
- Valuable, encapsulated software exists
- Much productivity enhancing computer technology is currently available and reliable
- The Navy can influence but not dictate commercial developments
- The computer industry is now maturing to the point of adopting standards
- Industry arrives at standards at a pace that assures their widespread use
- A small number of de facto standards dominate the market
- Commercial pressure ensures stability
- Data Rights issues can be resolved
- Navy programs such as AN/BSY-2 and AEGIS are departing from Navy standards
- Many shipboard mission-critical computers are in protected environments
- Navy shipboard personnel are aggressively computer literate
- Navy policy of Instruction Set Architecture standards is no longer appropriate
- The Navy is falling behind

Recommendations

In view of the findings, the Panel makes the following recommendations, each of which is explained in detail in the body of this report:

- **The Navy should mandate** ***widely used, commercial*** **standards for its computing resources. The Navy should resist the temptation to have its own unique standards.**
- **The Navy should encourage the use of ruggedized equipment. Many mission critical systems operate in protected environments where full militarization is too much of a price to pay for up-to-date performance.**
- **The Navy should move toward rapid elimination of Government Furnished Equipment (GFE) status for the UYK computers. Similarly, the Navy should move toward rapid transfer of upgrade budgets into project offices to force careful cost-benefit tradeoff. Rewriting existing UYK software in Ada should be considered seriously.**
- **The Navy should mandate standards at the** ***system level*** **(i.e., communications protocols, applications interfaces, and environmental survival) only. Mandating Navy-wide standards at a lower level can be counterproductive.**
- **The Navy should reorient its planned prototyping effort. The purpose should be to demonstrate commercial standards at work and to support the upgrading of computing capability on current ships.**

Implementation

- OP-098 should promulgate a revised operational requirement (see draft in Appendix IV).
- OP-945 should rewrite OPNAVINST 5200.28 to move toward elimination of the GFE status of the UYKs, to invert the waiver process in favor of commercialized and ruggedized equipment, and to require the use of widely used commercial standards.
- SPAWAR-32 should revise the NGCR technical approach.

Outline

- Executive Summary
- Introduction
- Findings
- The NGCR Project
- Question and Conclusions
- Recommendations
- Implementing Actions
- Appendices

Introduction:
The Goal and the Problem

- Both ordinary and sophisticated computing are required to deal with increasingly difficult threats.
- Deployed computers in today's Naval Warfare Systems are less capable and more expensive than ordinary commercial computers.
- The Navy's Goal: To deploy effective computational resources at reasonable cost.
- Navy's Next Generation Computer Resources project has correct goal but is based on questionable assumptions.
- The NGCR project must be made more sensitive to:
  - Technology developments
  - Computer market developments
  - Navy system developments

Introduction: The Goal and the Problem

Computers are an essential part of all naval warfare systems. They appear both in deeply embedded applications such as control of an AEGIS radar and in highly visible applications such as AEGIS command and control. Both kinds of computing help the Navy to counter the increasingly sophisticated and dangerous threats that come about as a result of reduced observables and increased speeds seen in situation development.

Because the US is the world leader in computer technology, the Navy has an opportunity to capitalize on a major advantage. The problem is that the Navy has had great difficulty keeping its deployed computer resources technically abreast of those available in the rapidly advancing commercial market. Congress and the Navy are eager to correct this situation.

Therefore, to effectively counter the threat, the US Navy must consistently **deploy effective computational resources at reasonable cost.**

Accordingly, the Navy has formulated an Operational Requirement (OR) for a Next Generation Computer Resources (NGCR) project. This Panel has reviewed the OR and the NGCR project in conjunction with the problem. The project's goal is correct but the project itself is overly constrained by past Navy practices and assumptions, including those embodied in the OR.

As briefed to the Panel, the NGCR project is carefully constructed, and correct given one set of practices and assumptions, but the panel worries that the practices and assumptions are those of the recent past, not those of the present and future. In particular, **we take issue with the following assumptions**, all of which seem embodied in the NGCR project approach as it stands:

- The Navy has a profusion of unique computing requirements that:
  - cannot be met by commercial computer systems and associated standards
  - can be addressed without reference to particular weapons systems.
- The Navy can develop significant computer systems cost effectively.
- The Navy should adapt (vice adopt) commercial standards for Navy-wide use.
- The Navy must pay to develop computers which meet its needs.
- Computers are materially different from other electronics components.
- Computer reliability and maintainability create big logistics problems.
- Computers embedded in mission critical systems require full militarization.
- And most important, (taken verbatim from the Operational Requirement for NGCR), "A family of Navy standard, militarized computers is the most cost effective, efficient means to meet ... [the Navy's] information processing and combat system needs."

The Panel has found significant, but not yet widely recognized changes in computer technology, the computer marketplace, and Navy systems to which not only the NGCR project but also Navy policy and practices for management of computer resources need to be more sensitive.

- The technology moves so fast, it is easy to make mistakes by basing decisions on assumptions that were correct just a few years ago, but which are no longer correct.
- Similarly the state of the commercial world moves fast too. Yesterday's important markets can be too small to attract the attention of the industry leaders. Commercial trends come out of nowhere to change everyone's thinking.
- Navy systems developers react to these trends, causing the reality of Navy systems to overtake official Navy policy.

Ten years ago, personal computers were curiosities and the term *workstation* had not yet been coined. Five years ago the trend was toward more and more software incompatibility; today, the major industry players seem determined to fight it out on the basis of hardware cost/performance, standardizing themselves out of the software business. The original AEGIS design incorporated AN/UYK computers because commercial computing technology did not meet its needs; today, the majority of AEGIS processing is provided by commercial microprocessors.

In addition, the NGCR project approach needs to be made more specific. A clearer statement of requirements and approach will guarantee that the "oral tradition" on which correct action depends is not lost due to the inevitable changes in personnel and budgets.

Introduction:
The Terms of Reference

- Make recommendations to help the Navy deploy effective computational resources, at reasonable cost, in the 1990s and beyond
- Written before NGCR project conceived
- Evaluation of NGCR Project became the Panel's primary, but not exclusive, focus.
- This report addresses the Terms of Reference and recommends modifications to NGCR program and Navy policies.

Introduction: The Terms of Reference

The Panel's Terms of Reference appears in Appendix I. Its essential charge is to make recommendations that will help the Navy to deploy effective computational resources, at reasonable cost, in the 1990's and beyond. The Terms of Reference was developed after the DoD report to Congress in 1984 and before the submission in late 1987 of the **Development Options Paper (DOP)**. The DoD report stated that the Navy would phase out its current generation of standard embedded computer resources by 1990. The DOP described potential approaches to NGCR.

The Terms of Reference was approved in April 1987. Between approval in April 87 and study initiation in April 1988, the NGCR program was established and the DOP submitted. On 29 April 1988, a Navy Decision Briefing resulted in the approval by OP-098 and OP-094 of the approach recommended by SPAWAR and the establishment of $140M in funding for the NGCR Program. The approach is an open systems architecture with published interface standards derived through joint Navy/industry working groups.

The approved approach included many program challenges as expressed by NAVSEA and NAVAIR. It was recognized that there was a need for the NRAC Panel on NGCR to validate the technical approach. The Navy needed an independent look at the issues raised in the DOP and a validation of its conclusions. As the study progressed, it became clear that not only some of the DOP's conclusions but also some of the assumptions given in the Operational Requirement were highly questionable. Accordingly, the panel expanded its efforts to address these issues as well.

Overall, this report addresses all issues in the Terms of Reference and makes recommendations in terms of modifications to the current NGCR program and to Navy policies.

The Panel's briefing program is reviewed in Appendix II.

Introduction: Members of the Panel

- Computer scientists and engineers, system engineers, and retired naval officers
- No major computer manufacturers
- Dr. Patrick H. Winston, Chairman

Dr. Albert E. Babbitt
Mr. Richard A. Baugh
Dr. Albert E. Brandenstein
Mr. Kenneth C. Dahlberg
Dr. Edward Lieblein
VADM Joseph Metcalf, III USN (Ret.)
Dr. Harriett B. Rigas
Dr. Albert P. Sheppard
Dr. Thomas P. Sleight
CAPT Chandler Swallow, USN (Ret.)
Dr. J. Richard Williams
Mr. Ted E. Senator (executive secretary)

Introduction: Members of the Panel

The panel was composed of experts in three areas: computer science and engineering, system engineering, and naval operations. To avoid potential conflicts of interest, major computer manufacturers were not included. However, major computer manufacturers were invited to brief the panel.

Dr. Winston is a Professor of Computer Science at MIT and Director of the MIT Artificial Intelligence Laboratory. He has been an NRAC member since 1984.

Dr. Babbitt is the Special Assistant to the President of the TITAN Corporation. He has retired from IBM Federal Systems where he held a variety of senior technical management positions.

Mr. Baugh is Director of Engineering at GE Moorestown. Previous assignments included Director of Naval System Engineering and Manager of AEGIS System Design at RCA. He is the author of a book entitled "Computer Control of Modern Radar" and many technical papers.

Dr. Brandenstein is the Vice President for Advanced Systems at the BDM Corporation. He was formerly at the Defense Advanced Research Projects Agency (DARPA), serving as the first head of the Prototyping Office and as the Deputy Director of the Strategic Technology Office.

Mr. Dahlberg is the Manager of the Surface Ship Systems Division of Hughes Aircraft Company.

Dr. Lieblein is the Senior Vice President of Tartan Laboratories. He was formerly the Director of Computer Software and Systems in the Office of the Secretary of Defense. He served as acting DoD Senior Official for Mission Critical Computer Resources and Chairman of the Defense Computer Resources Board.

VADM Metcalf is the former Deputy Chief of Naval Operations for Surface Warfare. In this position he launched the "Revolution at Sea," a major effort to reexamine the design of US naval surface ships for the twenty-first century.

Dr. Rigas is a Professor and Chair of the Department of Electrical Engineering at Michigan State University. She is a former head of the Electrical and Computer Engineering Department at the Naval Postgraduate School. She is active in the IEEE computer society. Her research is in the areas of CAD tools for computer design.

Dr. Sheppard is the Vice President for Interdisciplinary Programs and Acting Vice President for Information Technology at the Georgia Institute of Technology. His technical interests include research and applications of robotics, computers, microprocessor software and applications and electronic instrumentation.

Dr. Sleight is the Director's Assistant for Computing and Information Systems at the Johns Hopkins University Applied Physics Laboratory. He participated in the design of computer systems for several weapons systems including AEGIS and in reviews of previous generations of Navy computing.

CAPT Swallow is a former surface warfare officer with a specialty in electronics. He participated in the operational development of the original concepts of the Naval Tactical Data System (NTDS) for many years and commanded both a guided missile destroyer and cruiser prior to retiring from the Navy. Subsequently he worked as a program manager in Sperry Corporation's Defense Computer Products Division.

Dr. Williams is the Dean of Engineering at California State University, Long Beach. He is a recognized expert in computer applications and a former NRAC member. He chaired the NRAC Panel on Integrated Avionics.

Findings:
Technology developments

- Embedded microprocessors are proliferating
- Reliability is up; logistics problems down
- Ruggedized and militarized versions of commercial computers exist
- Valuable, encapsulated software exists
- Much productivity enhancing computer technology is currently available and reliable

Findings: Technology Developments

There are many generally accepted, generally correct truisms. Computers and computer memory are becoming faster and cheaper at the same time. Software is an increasingly dominant part of system cost. High level languages save development cost and time. But beyond these truisms, there are less obvious, but equally important, technology developments that must be factored into the NGCR approach if the Navy is to achieve its goal.

Embedded Microprocessors Are Proliferating

In the old days, the computer was the expensive thing and all systems paid homage to the central mainframe, often proudly displayed in central computer rooms behind glass walls for all to see and appreciate (hence the term *glass-house computing* calls to mind the central mainframe metaphor).

Today, however, rapidly advancing microprocessor technology has enabled system builders to move the computing to where the problem is, embedding a computer in a system by including a board, or even a corner of a board, in the system design.

This means that the glass-house computer (in the Navy's case, the current generation UYKs) is destined to bear a decreasing portion of the total computing burden. This trend requires an inversion of the traditional way of thinking and how the compromises are made.

- In the old days, the system had to conform to the demands imposed by glass-house computing.
- Today, the computer and the way it is interfaced to the weapons system can be determined by the needs of the weapons system itself.

Reliability Is Up; Logistics Problems Down

The increase in reliability that accompanies each new generation of computer technology has had two effects. Computers are now more reliable than many electronics components, alleviating the requirement for standards formerly imposed by logistics. Delays in fielding the next generation of computer technology which are due to lag times to fully militarize the hardware can now do more harm than good. These delays not only deprive the Navy of the additional warfighting capability that new computer technology could provide, but may also decrease reliability by institutionalizing an older technology. An old MIL-SPEC computer is likely to be less reliable as well as less capable and more expensive than a newer commercial or ruggedized machine.

Today, a key result of the proliferation of microprocessors is that computers no longer deserve special status as if they were substantially different from an analog-to-digital converter or a microwave amplifier. Computers were different in the past because they were expensive resources shared by different mission critical systems.

This is not to say that there is no logistics problem; it is just that the logistics and training problem for modern computer resources is no different from that of the other reliable types of electronic equipment in general. System reliability is gained through system design with appropriate redundancy.

Ruggedized and Militarized Versions of Commercial Computers Exist

The panel found that both ruggedized and fully militarized versions of commercial computer architectures are available in today's market, and the panel believes that a Navy policy of buying Non-Developmental Items (NDI) would provide additional stimulus to this market.

In many cases, the vendors are not the original computer manufacturers themselves. Instead, they are third party value- added resellers. Manufacturers cooperate with these vendors providing required technical data and, in some cases, by guaranteeing a product lifetime. One beneficial side effect is that third party vendors provide a "preselection" of viable commercial architectures that circumvents the problems pursuant to a Government selection of one commercial architecture.

Representative vendors include the following:

Vendor	Commercial Equivalent
Rugged Digital	VAX (ruggedized)
Raytheon	VAX (militarized)
Genisco	Sun Workstation (ruggedized)
Rolm Mil-Spec Computers	MIPS, Data General (militarized)
Harris	HP 320 (ruggedized)

Valuable, Encapsulated Software Exists

Computers are useful only when programmed. The major costs of making a computer a useful part of a system are software costs. Software packages hammered out on the commercial anvil should be used, *as is*, wherever possible, even if not written in Ada, and commercial interface standards should be adopted, *as is*, to insure that such software can be used, *as is*.

Commercial database packages provide a good example. Tested and debugged through commercial practice, with development amortized over thousands of commercial users, these products are sure to be better than anything the Navy could afford to produce, test, and debug for its own exclusive use. Commercial real-time executives are another example. In this case, considerable reduction in both development time and cost are achieved.

Much productivity enhancing computer technology is currently available and reliable

Many unanticipated developments have occurred in computer technology in the past several years. This trend is expected to continue. Few of these innovations could have been accurately foreseen as little as five years ago. This productivity enhancing computer technology is both available and reliable. It has passed the most rigorous operational test ever devised, *market acceptance*, and its effective use depends on being "plugged-in" to the world of standard commercial computer products. The list of currently available and reliable computer technology appears as Appendix III and is taken from the NRAC Report on Automation of Ship Systems and Equipment, performed in the summer of 1988. Note that these technologies are not routinely deployed in naval warfare systems today.

Findings:
Computer market developments

- The Navy can influence but not dictate commercial developments
- Computer industry is now maturing to the point of adopting standards
- Industry arrives at standards at a pace that assures their widespread use
- A small number of de facto standards dominate the market
- Commercial pressure ensures stability
- Data Rights issues can be resolved

Findings: Computer Market Developments

The panel has found several important developments in the computer market that affect the Navy's management of computer resources.

The Navy Can Influence but not Dictate Commercial Developments

In the early days of computing, a few hundred computers was big business for major computer firms. Now a few hundred computers is at most a minor business for a small computer firm or a small division of a major firm. Therefore, the Navy no longer has a major share of the computer market. The panel doubts that Navy spending can effectively accelerate the development of commercial standards. The amount of money invested in computer architecture development by a single manufacturer alone (DEC) far exceeds the amount the Navy could afford to spend.

What the Navy can do, however, is become a part of the commercial computer marketplace by actively participating in groups such as X/OPEN. While the Navy is a small fraction of the overall market, it is a single large user. So while it is unlikely that the Navy can effectively stimulate the market to produce to its own standards, it is likely that the Navy could influence commercial standards to meet Navy needs.

Computer industry is now maturing to the point of adopting standards

In recent years, somewhat surprisingly, the major and minor hardware vendors have apparently decided that the market will no longer tolerate incompatible software systems. One reason is the proliferation of networks. Another is the cost of maintaining separate versions of programs with identical functionality. And still another is fear customers now have of being shut out should they make an exclusionary choice. Whatever the reason, there is significant movement toward software standards for operating systems, network communication, and applications interfaces. The vendors will compete on the price/performance characteristics of their "iron" rather than on the features of their proprietary software.

Industry arrives at standards at a pace that assures their widespread use

The adoption of standards always involves a delicate balance. If standards are adopted for an innovative technology, there may be unresolved bugs or undefined areas in the standard. More important, there would be no guarantee that use of the standard would ever become widespread. The possibility of an officially promulgated standard incorporated in few computer systems would be all too real. On the other hand, if standards are not adopted until a particular technology is widespread, there is a danger that there will be several differing implementations of a technology representing large investments, so no one will be able to afford to adopt the standard.

The panel believes that the marketplace, in most cases, is the most efficient mechanism for making these compromises. Participating actively in the marketplace is the best mechanism for a user, especially a large user, to ensure that its requirements are met by a standard.

A Small Number of *de facto* Standards Dominate the Market

Sometimes there a supposition is made that only two choices exist: a single, rigidly enforced standard or chaos. But in fact, ordinary commercial pressures dictate that only a few standards can qualify as *widely used* at any time. For example, there are today only a few widely used microprocessor families. Fierce competition among the makers and value added resellers of those families ensures a competitive market with low prices for users.

Commercial Pressures Ensure Stability

Similarly, no company can survive if it fails to provide long- term stability for its customers at whatever level the customers' problems dictate. Accordingly, platforms offered by the major manufacturers rarely

change when viewed from a perspective of software compatibility, even though they may change every two or three years from the perspective of hardware implementation technology.

Data rights issues can be resolved

Concern about data rights is pervasive. The primary reason the Government insists on data rights is to provide an opportunity to develop other or sufficient suppliers and to modify the design in the event that the original manufacturer is unable or unwilling to support the Government. In the commercial marketplace it is rare that such rights are provided to the purchaser of equipment or software. Instead, guarantees of supply are negotiated in special situations. In some Government circles, the data rights issue has been carried into the competitive arena. One view is that demanding data rights made sense when the Navy's approach to computing was to specify and acquire newly designed computers, mandate their use, and provide them as Government Furnished Equipment (GFE). Then second sources were required to ensure competition and there could be no second sources without enabling data down to a very low level.

The issue of data rights lessens when open standards are used and when multiple suppliers are available, as in the microprocessor arena. In any event, data rights are not necessary when the approach is to choose ruggedized or fully militarized equipment from among several of the commercially popular designs. With this approach, the fact that there are several options, not just one option, ensures competition.

The AN/BSY-2 system design is an example of how data rights are handled today. Commercial microprocessors (Motorola 68020/68030's) are used extensively. BSY-2 system requirements necessitate small modifications to firmware. Despite the data rights issue, the system contractor is able to negotiate an acceptable arrangement with Motorola. A key advantage of using the 68030 is the ability to utilize commercial software. An Ada development system and a relational data base management system (both commercially available) require slight modifications; nevertheless, the cost and schedule savings resulting from their use is significant.

Findings:
Navy system developments

- Navy programs such as AN/BSY-2 and AEGIS are departing from Navy standards
- Many shipboard mission-critical computers are in protected environments
- Navy shipboard personnel are aggressively computer literate
- Navy policy of Instruction Set Architecture standards is no longer appropriate
- The Navy is falling behind

Findings: Navy system developments

Navy systems developers have reacted to technology and computer market developments, causing the reality of Navy systems to overtake official Navy policy.

Navy Programs Are Departing from Navy Standards

In some sense, the next generation of computers has already arrived. Realizing that the computing needs of sophisticated systems cannot be met with today's Navy standard AN/UYK computer, systems builders are incorporating embedded computer resources into their systems at a rapid rate. Soon only a small percentage of a new ship's computer power will be in its Navy Standard AN/UYK Computers no matter what else happens.

Examples of this phenomenon are apparent in the air, surface, and submarine systems. For the next generation of tactical aircraft, for example, the Joint Integrated Avionics Working Group (JIAWG) will not use standard Navy computers. Instead, JIAWG is developing standards for system (vice computer) backplanes that are tied to the avionics platform requirements.

AEGIS is another prime example, graphically illustrated page 20.

The AN/BSY-2 design provides still another example. The current system design employs AN/UYK-43's for BMC3, EMSP (AN/UYS-2) for sonar signal processing, and 68020/68030's for sonar control, BMC3, fire control, bus control and displays. The design is estimated to contain 2502 MIP's, of which 924 are provided by the EMSP, only 6 by the AN/UYK-43, and the remainder by the commercial microprocessors. The system architecture is under evaluation for possible elimination of the 2 AN/UYK-43's. The development cycle includes two years for the militarization of 68020/68030's plus memories, I/O devices and buses.

Thus, utilization of widely used commercial standards can be feasible and cost effective, even though some standards may require modification to meet the needs of a high performance, complex system development.

Many Shipboard Mission-Critical Computers Are in Protected Environments

Conventional wisdom holds that there are two kinds of computing: mission critical (which must be fully militarized) and the rest (of which there is very little). The panel found, however, that much of the mission-critical computing takes place in protected computer rooms where full militarization makes little sense, especially when it forces a severe performance penalty. Accordingly, the panel thinks that conventional wisdom should be reoriented to concentrate on protected versus non protected environments, reserving full militarization for shipboard locations where it is really needed.

Navy Shipboard Personnel Are Aggressively Computer Literate

One of the panels most inspiring moments was aboard the USS VALLEY FORGE, listening to highly articulate officers and men who have grown up during the time when computer games and school computers are commonplace. These people not only have no fear of computers, they have conspicuous disdain for software that is not up to familiar standards in terms of user friendliness, embedded training, and above all, capability. Telling them that sacrifices had to be made to fit everything into low capacity militarized memories left them incredulous and totally unconvinced.

Navy policy of Instruction Set Architecture standards is no longer appropriate

The Navy policy of instruction set architecture standards, which has resulted in the current generation of Navy Standard Embedded Computer Resources (SECR), was appropriate before the changes discussed in the previous text took effect. Now that technology, the computer marketplace, and Navy systems developments have significantly different characteristics, this policy is no longer appropriate and, in fact, is

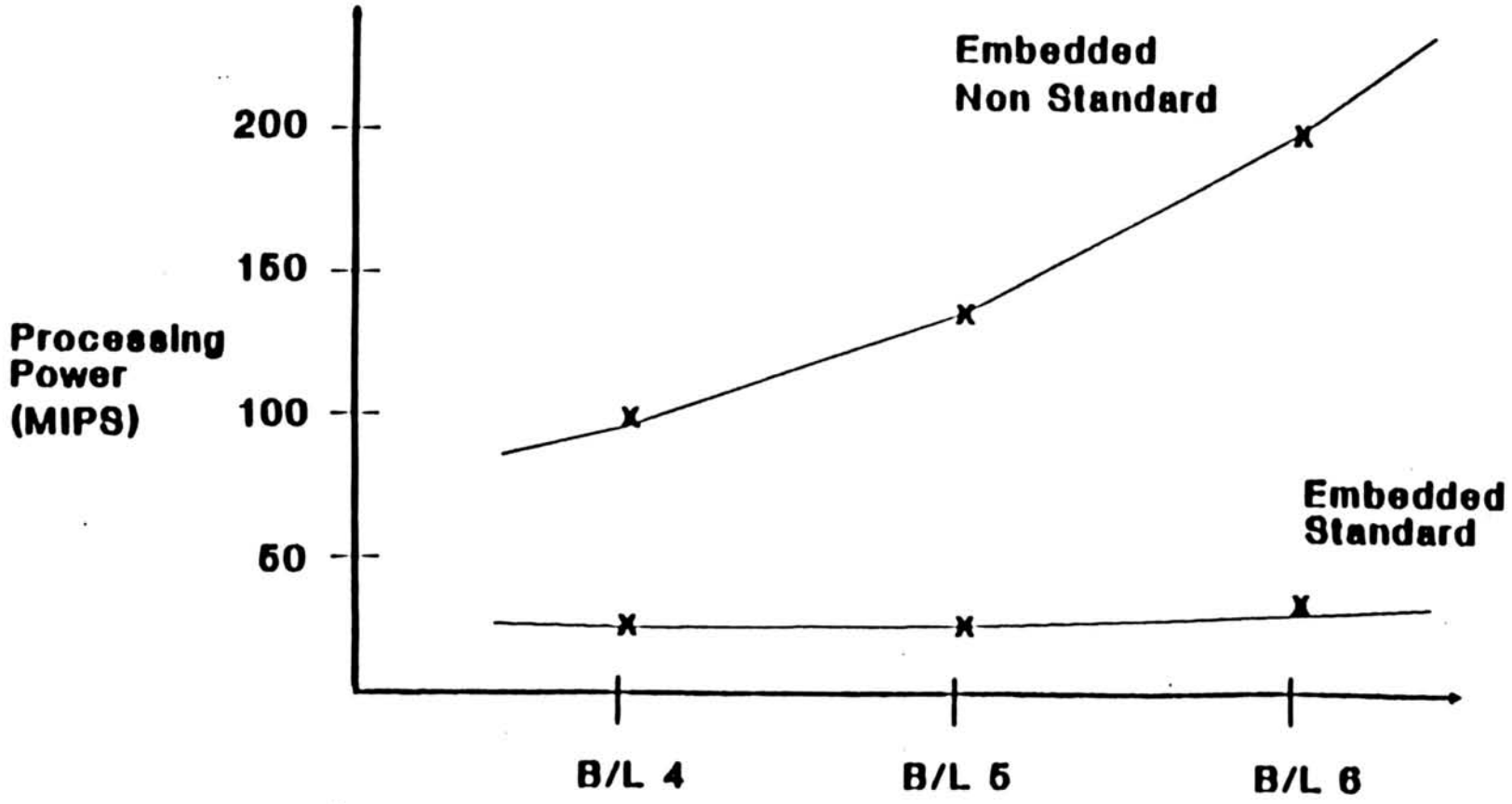
partially responsible for the Navy's difficulties in deploying computing technology equivalent to ordinary commercial computers.

The Navy is falling behind

Navy standard computers are not improving at the same rate as commercial computer technology. Further, they require significant Navy investment to develop, and their use introduces delays in deployment. Page 24 illustrates these last two points.

STANDARD VERSUS NON-STANDARD COMPUTERS

AEGIS SHIP BASELINE TRENDS



Findings: AEGIS Computing Trends

The preceeding graph ilustrated that Navy Standard GFE computers comprise about 25% of processing power in AEGIS Baseline 4, but decrease significantly in Baseline 6, as additional MIPS are added primarily through use of commercial microprocessors. There are several possible interpretations of this data. One interpretation is that there is a policy determined component of AEGIS computing provided by UYK's and a requirements determined component provided by commercial microprocessors. Another more significant interpretation is that there are two kinds of computing in AEGIS: general purpose centralized processing and special purpose deeply embedded processing. Also worth noting are the differences in uses of the two types of computers. UYK's are used in the central computer room for radar control, weapon control, ASW, and BMC3, which is a protected environment where full militarization is not required. Commercial microprocessors are embedded in the radar, in environments less protected than the central computer rooms where the fully militarized UYKs reside.

A key point is that as far as AEGIS is concerned, the next generation of computer resources is already here, due not to a Navy wide standard computer development effort, but rather to the unavoidable consequences of the system's evolution.

AEGIS system processing power is about 100 MIPS in Baseline 4, 27 of which are provided by AN/UYK-43's and 44's. In comparison, ordinary personal computers used aboard USS VALLEY FORGE, primarily for routine administrative functions, provide between 5-10 MIPS.

Findings:
Current Navy Standard Embedded Computer Resources

Name	Production	Delivered/Remaining
CP-642 (NTDS)	1957-1964	363/0
AN/UYK-7	1971-1987	2,500/0
AN/UYK-20	1973-1987	4,826/0
AN/AYK-14	1980-199X	5,000/4,500
AN/UYS-1	1981-1992	1,000/1,000
AN/UYK-44	1984-199X	1,739/2,661
AN/UYK-43	1984-199X	350/1,465
AN/UYS-2	1989-199X	17/1,800

- Navy computer production lifetimes are unusually long.
- Production volume is unusually low.
- Deployment often lags first delivery considerably—AN/UYK-43 will not be deployed in AEGIS until 1990.
- Navy specific ISAs inhibit the use of widely-available commercial software
- The Navy often pays high prices for ordinary software—Ada compiler required $50M Navy funding (FY-84 through FY-88)

Findings: Current Navy Standard Embedded Computer Resources

The Navy's past policy has been to specify Navy-unique instruction set architecture (ISA) standards for the AN/UYK series of computers.

This policy was appropriate when the Navy was a major customer and a technology leader in the computer market, when computers were expensive shared resources and all software was written from scratch. Now circumstances have changed and the policy is no longer appropriate.

As seen in the preceeding table, production lifetimes are unusually long compared to commercial products and volume has been unusually small. Deployment significantly lags production because incorporation into systems takes time, and lifetime in the fleet can be long. These factors combine to ensure that mission critical computing is done today by computers that are, on average, far behind the commercial state of the art.

In addition, Navy programs use non-standard computers when the Navy standards do not meet their needs. Thus, limited Navy specific standards can cause the unintended effect of increasing, rather than decreasing, the number of types of computers deployed in the Fleet.

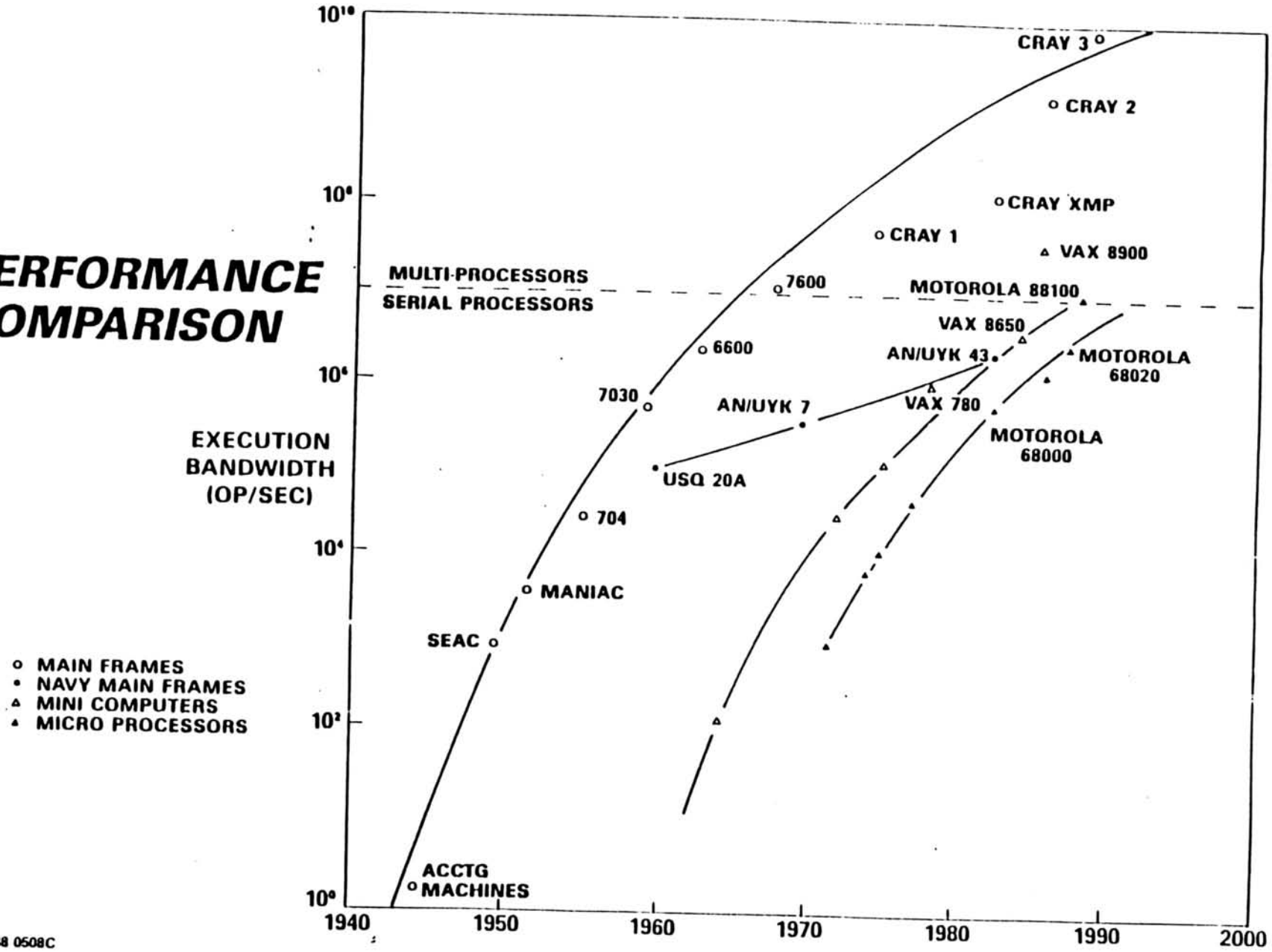
Equally important, Navy specific ISAs inhibit the use of widely available commercial software. The result is that the Navy must often pay high prices for software applications and tools that run on its standard computers when equivalent software that runs on widely used commercial computers costs much less.

For example, validated Ada compilers exist for almost all widely used commercial computer architectures, such as the VAX and 68030, and no Government funds were needed to develop these compilers. This situation contrasts with the UYK's: The Navy has spent approximately $50M for the Ada Language System, Navy (ALS/N).

Today, UYKs can be viewed as special purpose computers for running existing code which would be too costly to rewrite. Viewed this way, the Navy needs a better defined transition plan for how that software will get rewritten or otherwise cease to be a permanent problem. Program specific UYK upgrades may be necessary to retain the existing software base, but care should be taken to avoid major new software that is UYK dependent.

On the other hand, the newest UYKs are good computers, so the objective should be to ensure that there are alternatives to the UYKs, not to exclude UYKs from future competitions. As with any other contenders, UYK vendors should be free to improve them with their own funds, market them as NDI equipment, and take advantage of the fact that they are already in the logistics system.

PERFORMANCE COMPARISON



88 0508C

The chart on page 24 illustrates the performance characteristics of the UYK-43 and its predecessors as well as several popular commercial computers. Long production lifetimes, low production volumes, and instruction set architecture compatibility have resulted in a much lower rate of improvement in Navy computers compared to commercial computers in addition to the problems noted earlier.

The NGCR Project: Background

- DoD Report to Congress - Current Standards to Phase Out by 1990 (1984)
- Tentative Operational Requirement (December 1985)
- NGCR DOP Submitted by SPAWAR (October 1987)
- Congressional Direction (FY-88)
  - Established NGCR funding
  - Prohibited Current System Upgrades
- Navy announces Dual Approach (April 1988)
  - Upgrades to meet near term needs
  - NGCR to meet long term needs
- NGCR Decision (April 1988)
- NRAC panel on NGCR (April 1988-January 1989)
- Congressional Direction (FY-89)
  - Accepts dual approach, but
  - Fund NGCR first
- Milestone I (February 1989)

The NGCR Project: Background

Recognizing the limitations on competition and the inability to utilize modern computing technology in mission critical naval warfare systems, Congress directed the Navy in the Defense Authorization Act of 1984 to develop a plan for a new generation of embedded computer resources. OSD's response in a letter from Dr. DeLauer was to announce cessation dates of January 1990, 1991, and 1992 for new starts using the AN/AYK-14, AN/UYK-44, and AN/UYK-43, respectively, with procurement of final spares and a buy out. The HASC response directed the Navy to adhere to these cessation dates and establish funding for the next generation of computer resources.

The Navy promulgated a Tentative Operational Requirement (TOR) in December 1985.

SPAWAR submitted a Development Options Paper (DOP) to the CNO in October 87.

In FY-88 Congress established NGCR funding and prohibited upgrades to the current generation of SECR.

In March 1988 the Navy announced its strategy to move to a next generation of computer resources. ASN (RE&S) informed the committee chairmen of the four Congressional committees (HASC, SASC, HAC and SAC) in letters dated 21 March 1988 that the Navy was pursuing a dual approach to meet its computing needs in the 1990's and beyond. This dual approach consisted of product improvements to current SECR based on specific weapons systems requirements for the near-term (until 1995) and the development of NGCR to meet the long term need (1996 and beyond).

On 29 April 1988 an OPNAV decision briefing was held to decide on a level of funding and a technical approach. The results of the meeting were announced in CNO ltr Ser 982D/8U53123 of 13 May 1988. This letter tasked COMSPAWARSYSCOM to proceed with the NGCR program and committed to funding levels of $140M covering fiscal years 1988 through 1996.

The letter also noted that the final determination of the technical approach would be made following the report of the NRAC panel on NGCR in early 1989.

Congress accepted the dual approach in FY-89 but directed that the Navy fund NGCR before spending funds to upgrade current SECR products.

A Milestone I Navy Program Decision Meeting is scheduled for February 1989.

The NGCR Project: The Operational Requirement

For:

- "A family of Navy standard militarized computers"

Flaws:

- Makes questionable technical and management assumptions
  - Navy standard militarized computers is the best approach
  - Historical logistics characteristics are unchanged by technology
  - Still developing "gray box" computers
- Is not tied to system requirements
- Does not take advantage of available commercial software

The NGCR Project: The Operational Requirement

The operational requirement assumes that a family of Navy standard militarized computers is the most cost effective, efficient means to meet information processing and combat systems needs. This was true when past Navy computer standards efforts were initiated, but it is definitely not true today. Today the military no longer leads the commercial world in computer technology nor does it have a major impact in the marketplace.

Both ruggedized and fully militarized off-the-shelf NDI products are available which appear to meet environmental requirements. Computer standards have begun to emerge that provide application portability, vendor independence, and interoperability. SPAWAR has recognized that ruggedized equipment is sometimes the appropriate solution and has begun to make provision for this in their NGCR technical approach.

The OR also includes standard logistics requirements, but it fails to recognize that the current reliability of computer equipment (and with a required MTBF greater than 3 years) may obviate the need for a full logistics support tail.

Embedded microprocessors turn computers into just another piece of electronics. The logistics implication is that these embedded computers should be treated as just another system board instead of a Navy wide resource requiring separate support.

Consequently, the panel encourages the Navy to reassess the logistics issue as part of the NGCR program.

Next, the OR implies that the need is for a *computer*, not for computing resources, which fails to recognize that computing is no longer done exclusively in big gray boxes with flashing lights. Irreversibly, the trend is toward embedded computers, where the processor and even its memory are all on a single card or part of a card. Hence the communication medium becomes a system bus, not a computer backplane. AN/BSY-2 and the cooperative engagement design approach for AEGIS are already using this approach.

Finally, the OR is not tied to the requirements of any particular weapons system or set of systems. Without such a tie, tough problems may be overlooked in the search for generic solutions. Consequently, there can be no guarantee that the results will satisfy any actual weapons system need.

The NGCR Project: SPAWAR Has Considered Four Alternatives

- Higher order language standard (Ada only)
- Instruction set architecture (current approach)
- Project unique commercial interface standards
- Joint Industry/Navy Standards (recommended by SPAWAR)

But we have some concerns ...

- Solution might be to change logistics system
- Natural forces encourage commonality
- Project-unique computer RDT&E cost overestimated
- Cost for certification facilities past 1996 omitted
- Solution involves more general policy changes
- Need is for computer resources vice computers

The panel recommends a fifth alternative: *project selection of specific commercial/Navy standards.*

The NGCR Project: SPAWAR Has Considered Four Alternatives

SPAWAR responded to the Tentative Operational Requirement which stated that a family of Navy standard militarized computers is the most cost effective, efficient means to meet the Navy's information processing and combat systems needs. Quite properly, the resulting DOP embraces an open, competition stimulating approach and argues for the following goals:

- Open architecture
- "Ruggedized" Mil-SPEC
- Higher Level Standards (vice ISA standards)
- Three domains of mission critical computing

Within this context, the DOP discussed four alternative technical approaches. A higher order language standard only (e.g., Ada) and the current approach of an instruction set architecture were ruled out for not meeting the requirement. The panel agrees that the DOP is correct in eliminating both of these alternatives. Standardizing only at the higher order language level would be ineffective. Standardizing instruction set architectures would only maintain the status quo.

The fourth alternative, the approach of Joint Navy/Industry standards, was developed into four fiscal options. This approach was based on the adoption of "open architectures." Only the least expensive of these options was within cost guidelines.

The DOP emphasizes the distinction between open and closed architectures. It argues for an open architecture to provide competition. It claims that the Navy unique ISA's are by definition a closed architecture. But a proprietary architecture can be open if the appropriate interface standards are made available for others to produce components. There are, in fact, cases of development of coprocessors for UYK's by different vendors. The problem with the UYK's is not that they are closed architectures but rather that they are Navy-unique as opposed to widely used commercial architectures.

The third alternative, project unique commercial standards were ruled out based on a cost analysis. The panel questions SPAWAR's analysis of this alternative, which the panel prefers to label project *specific* commercial standards.

Concerns about SPAWAR's Evaluation

First, section 7.2.3 of the DOP states "The goals in alternative #3 of increasing competition and maximizing the use of NDI without a full set of interconnectivity standards increase O&M,N costs, as the existing Navy maintenance, training and supply support systems are geared to acquisition approaches with a limited number of suppliers. As a consequence, #3 is not compatible with the traditional Navy logistics support environment." The panel believes that this fails to recognize that the solution to the problem may be to modify the logistics system to effectively and efficiently support computer equipment.

Second, the DOP assumes that program managers, left to their own devices, would be likely to to select inappropriate computer equipment (when, in fact, natural pressures would encourage commonality).

Third, the cost analysis assumes that commercial computers will not meet Navy computing requirements and that the various projects will have to fund computer RDT&E to meet requirements and further assumes the result would be custom Navy computers (vice NDI) While the DOP recognizes that commonality may occur, it doesn't factor this into the numbers.

Fourth, the cost analysis fails to recognize costs that will be incurred beyond 1996 to operate and maintain the certification facilities at the time when NGCR are to actually go into the deployment phase.

SPAWAR was tasked to develop standards, whereas we believe the challenge is to find the best way to meet the Navy's computing needs. The solution involves not only changes to SPAWAR's approach, but more general policy changes.

SPAWAR focuses too much on computers vice embedded computational components and systems.

This gives rise to a fifth alternative: *project selection of specific commercial/Navy standards.* In this alternative the Navy, with industry support, would directly contribute to the evolution of commercial standards. The Navy would take the lead only if no standards effort were underway to satisfy needs established by the SYSCOM's. Navy projects would be required to use commercial standards, as is currently done in many industries. This alternative attempts to take advantage of the existing momentum

within industry to use commercial standards, to avoid the creation of Navy unique standards and to avoid project unique solutions when unnecessary. At this time it seems inappropriate for the Navy to develop and prototype unique standards; but at the same time the Navy should continue to push commercial standards efforts toward Navy needs. The role of the standards office would be to facilitate the common selection of project specific commercial standards among various projects.

The NGCR Project: SPAWAR Approach Has Four Elements

The approved implementation approach consists of four components. Joint Industry–Navy Working Groups are to create standards for different levels of computer system interconnects and for software. The Navy is to let contracts to prototype components meeting these standards. Navy would develop an accreditation facility to "approve" products manufactured by industry for use as NGCR components. Navy policy would be to favor computer products on the "approved" list.

We have several concerns with this approach. First we worry that the standards to be developed are not the correct set. Next, the standards are to be *based on* commercial standards, instead of *selected from* existing commercial standards. There is no independent validation of the developed standards by recognized technical experts or, more importantly, by users. Prototyping could give a decided competitive advantage to the selected contractor in the production of actual products. The result would tend to favor Navy unique computer resources instead of commercial architectures.

The panel is particularly concerned about what will happen when this approach is modified to take into account the concerns of the project offices. If an acquisition strategy which develops a small number of suppliers is adopted, the approach will be similar to what is done today with the UYKs, except a long lead time item of standards development would be added. If a decentralized acquisition strategy is adopted, other risks appear. Unless widely used commercial standards are adopted without change, it is far from certain that components procured from different manufacturers would function as a single computer.

The approach taken to prototyping also causes significant concerns, especially when its cost (50% of NGCR budget) is considered. If the goal is to adopt widely used commercial standards, it is not clear why the Navy must pay to develop prototypes. One justification could be to guarantee that different implementations of a standard are, in fact, equivalent. Experience reveals, however, that a given system will likely require some modification to an adopted standard, so the potential benefit of interchangeability which might otherwise be provided by the certification process will not occur. Another justification for prototyping could be to remove technical risk from development. This justification is valid for technologies in which the Navy has to "go it alone," but does not apply for computer technology in which the Navy cannot afford even a fraction of the amount industry invests. Prototyping in this case is likely to result in a Navy-unique computer or to be unnecessary. An additional concern is that the NGCR program as currently funded provides for protoyping of the lowest performance/risk components only—precisely those for which prototyping benefits are least likely to occur and commercial standards exist.

The panel sees virtue in building prototypes provided that they support the following purposes:

- Facilitate transition process.
- Demonstrate technology and encourage its use.

On the other hand, the following should be avoided:

- Falling into the Navy-unique computer trap.
- Confusing certification with technology development.

SPAWAR proposes to build prototypes in order to guarantee that there will be a family of computing components that work together to meet the Navy's computing requirements. We believe that there is a danger that such prototyping can evolve toward a de facto Navy standard computer and can confuse certification with technology development. Accordingly, the panel believes that prototyping should be supported in conjunction with a major system development or improvement effort.

In terms of policy, the SPAWAR approach proposes one standard in each of three domains as indicated on the next page. While the panel strongly agrees with the use of commercial standards, it does not agree that a single commercial standard in each domain should be dictated by policy. In some areas, standardization on only one alternative is counter to commercial trends and can result in significant curtailment of competition. This panel recommends a policy that requires the use of commercial standards except where they significantly curtail performance or can be proven not to be cost effective.

The NGCR Project: SPAWAR Has Recommended Three Areas for Standards

- Multiprocessor Interconnects
  - Backplane
  - High Performance Backplane
  - Switch Network
- MultiSystem Interconnects
  - Safenet I / (Local Area Network)
  - Safenet II / (Local Area Network)
  - High Performance Local Area Network
- Software
  - Network Operating System
  - Network Data Base Management System
  - Programming Support Environment
  - Graphics Language / Interface

But we have some concerns ...

- Multiprocessor interconnect standards are sometimes unnecessary and otherwise inappropriate.
- Evolving commercial software standards will meet Navy needs without modification.

The NGCR Project: SPAWAR Has Recommended Three Areas for Standards

The approved Navy approach to NGCR concentrates on the development of Joint Navy–Industry standards for different levels of interfaces in computer systems. The three standards proposed for Multiprocessor and Multisystem interconnects correspond to the three domains of mission critical computing. We call these domains deeply embedded, glass-house, and super-sophisticated.

These three domains correspond roughly to the low, medium, and high performance domains identified in the Operational Requirement and the DOP. The DOP correctly identifies the present predominant type of computer architecture currently characteristic of each domain (i.e., backplane bus for deeply embedded, backplane bus for glass-house and switch-network for super-sophisticated). There should be an additional distinction between the two types of backplane busses:—The backplane bus for deeply embedded computer applications is a system bus, for the entire system in which the embedded computer is embedded. The backplane bus for the glass-house case is actually the backplane bus of a **computer system** which in its entirety is embedded in the combat system.

Singular standards for multiprocessor interconnects will have adverse effects in all three domains of mission critical computing. In the deeply embedded domain, the computer is indistinguishable from other electronics components. A standard backplane would overly constrain the system designer. The key to this domain is a system backplane, not a computer backplane.

For the glass-house domain, a standard backplane is insufficient to assure that a collection of components will be a computer. An overall computer architecture (of which the backplane is a necessary but insufficient part) must be available. The key here is not to develop a multi-purpose Navy backplane standard, but to directly employ whichever commercial backplane is appropriate for a given application. As we explain elsewhere, we conclude that SPAWAR should limit its role in the backplane area.

SPAWAR has selected FutureBus as the NGCR backplane standard. While there appears to be considerable commercial interest in this bus, we question the adoption of a bus that has not yet been validated by the marketplace. The fundamental concern is that adoption of a Navy-wide bus standard requires that either a projection be made about future commercial trends or that there be an inherent delay in fielding the best technology. Mandating use of commercial standards, as a general rule, without specifying them explicitly on a Navy-wide basis can avoid this problem.

Another fundamental concern is that any bus which meets the needs of multiple systems must allow for user-defined additions, which thereby defeating the purpose of a Navy-wide bus standard (because modifications would preclude interchangeability between different systems). The lesson learned from this is that even though SPAWAR's bus selection seems appropriate, the choice still does not meet the intended objectives, calling into question the whole idea of backplane standardization. The panel concludes that the SPAWAR concept of employing a single internal backplane bus standard for all Navy applications is inappropriate.

For the special purpose processing domain, in which the limits of computational performance are stressed, a standard interconnect approach would inhibit the technology development necessary to achieve the required performance.

Local area network standards are necessary. The selection of a standard in this area is both possible and necessary. SPAWAR's selection and stimulation of the SAFENET standard seems likely to turn out well, but only if it becomes widely used commercially.

Software standards are also essential, but despite (or maybe because of) this, there is no need for the Navy to develop them. Software standards are emerging rapidly in the commercial marketplace, and they are focused at providing application portability across different vendors. The Navy's requirements for software standards are no different than industry requirements; hence the Navy should employ commercial standards directly without any adaptation.

Overall, the panel is encouraged by the influence SPAWAR is exerting on the commercial standards community, but the long-term success of these standards' initiatives should be judged by the amount of commercial equipment and software that employs the standard. A standard that is not used in commercial systems is not likely to be the right choice for defense systems.

The NGCR Project: Concerns Raised by Briefers

Concerns of the System Commands:

- Lack of understanding of real system requirements
  - JIAWG not planning to use NGCR products
  - Does not meet immediate and future needs of AEGIS
- Lack of a detailed transition plan
- Lack of sufficient attention to environmental and logistics issues
- Program managers responsible for building computers out of components

Concerns of Industry:

- Participation driven by fear, not enthusiasm
- Return on investment too low
- Standards may become exclusionary
- The Navy should not insist on full data rights

The NGCR Project: Concerns Raised by Briefers

Both industry and the systems commands raised concerns about the NGCR technical approach during their briefings to the panel. Systems commands concerns include those of program offices and computer standards offices.

Concerns of the System Commands

The strongest concern of the program offices responsible for the development of weapons systems was that the NGCR approach did not reflect an understanding of the real requirements for embedded computer resources in weapons systems.

The aviation community has no plans to utilize NGCR products. They expect to use the AYK-14 in current avionics systems and JIAWG produced avionics in the future.

The AEGIS community feels that upgrades to the UYK-43 are the best way to meet their glass-house computing needs. Interestingly, UYK-43's are a small (and getting smaller) part of AEGIS computing power.

The systems commands were also concerned with lack of attention to environmental and logistics issues, lack of a detailed transition plan, and their perception that program managers would have to expend significant efforts to construct computers out of certified components through a mix-and-match approach.

Concerns of Industry

Industry has participated in the standards working groups for NGCR. However their participation appears to be motivated by a fear of being left out and by a need to gather intelligence about the Navy's technical program planning, rather than by any genuine support of the concept. For the most part, the representatives are engineers and marketeers from the defense, not the commercial, community.

The most commonly voiced concern has to do with the proposal that vendors must take their components through a certification process with no guarantee of sales. Many felt that the economics of this approach for components limited to a Navy market would stifle, rather than stimulate, competition because few vendors would decide to participate without a guaranteed return on investment.

In addition, there is concern that departure from commercial standards could result in domination of a Navy standard computer products market by a small set of entrenched vendors. By contrast, suppliers are willing to produce ruggedized and fully militarized NDI computers based on commercially popular systems as demonstrated by the existing list of vigorous suppliers.

Industry is also concerned about data rights. They do not want to provide "build-to-print" data packages for their commercial computer products.

Question:
Why Have Standards?

Key Considerations:

- ☐ Standards that lock in handicapping, obsolete technologies are bad.
- ☐ Commercial standards keep up with technology better than military standards.
- ☐ Both de facto and sanctioned commercial standards should be used.

Benefits:

- ☐ Manufacturing economy of scale (for hardware)
- ☐ Developmental economy of scale
- ☐ Training economy of scale
- ☐ Software capture
- ☐ Interoperability
- ☐ Interchangeability

Question: Why Have Standards?

A fundamental question raised by the previous concerns is "Why have standards?"

Clearly, standards have both good and bad features. Standards that inhibit technological innovation are bad. Standards that allow for widespread use and reuse of resources are valuable. As noted in the findings of this report, commercial standards tend to keep up with technology better than military standards, due to the natural forces in the commercial market.

A final consideration is that there are two types of standards. Some standards are never mandated but arise naturally in the market. Others are sanctioned by various standards organizations. Both types of standards are valuable and should be used.

The DOP (section 2.3) identifies four benefits of computer system standards: production/procurement economies of scale, logistics supportability (training, documentation, sparing, etc.), avoidance of RDT&E costs to develop similar computers, and more effective systems integration (interoperability).

Page 39 lists manufacturing economies of scale, developmental economies of scale, training economies of scale, software capture, interoperability, and interchangeability as benefits of standards.

There are some important differences between these benefits, however, especially when adaptations are considered. Adapting a standard results in "falling off a cliff" with regards to some of the benefits of standardization, and "sliding down a steep slope" with regards to the other benefits.

The gravest danger is that the Navy will be unable to resist the temptation to adapt rather than adopt. This would result in the loss of the important advantages of commercial standards.

- Lost economies of scale in manufacturing
- Lost validation by the marketplace
- Lost opportunities to cut costs and delays
- Lost access to commercial software (applications, shells, and development tools and environments)

Perhaps the most severe loss is the loss of the commercial software base. The panel believes that the savings in hardware costs from using ruggedized and fully militarized commercial equipment would be accompanied by a much greater savings in software development costs.

It is essential that the Navy employ widely used commercial standards. Obtaining an IEEE standards number for what is essentially a Navy-unique computer standard would not provide the advantages of the large commercial computer base. On the other hand, working with standards organizations to assure that Navy requirements are included in widely used commercial standards is to be loudly applauded.

Conclusions

- Industry support is thin.
- Dangerous temptation to adapt (vice adopt) is present.
- Concern with logistics is misplaced.
- Prototyping of computers, independent of specific systems requirements, is inappropriate.

Changes are necessary to both the NGCR technical approach and to Navy policies and procedures for computer resources.

Conclusions

The panel believes:

- Industry's apparent cooperation with the NGCR project is driven more by fear of missing out, rather than enthusiasm.
- Inclination toward joint standards instead of commercial standards is likely to lead to self-defeating tinkering that will prevent access to commercial software base.
- Continued concern with logistics "problem" of non-standard computers is misplaced.
- Creating system independent standards does not necessarily produce standards that are useful in any particular system.

On the last point, the panel feels that there are, roughly, two kinds of computing: ordinary and supersophisticated.

- For ordinary computing, the commercial standards will do.
- For supersophisticated computing, any standards that are not system oriented will just get in the way.

Accordingly, the panel believes that the NGCR project needs some redirection to ensure that the goal of deploying effective computational resources, at reasonable cost, is achieved.

Recommendation (policy): Mandate *widely used, Commercial* Standards

---

Cut delay and costs by:

- **Adopting widely used commercial standards**
  - **Avoiding adaptation**
  - **Exploiting commercial software**
- **Continue to participate aggressively in commercial standards organizations**

Recommendation (policy): Encourage Use of *Ruggedized* Equipment

- ☐ Modify policy to recognize exposed vs. protected computing (vice mission critical vs. non-mission critical)
- ☐ Modify policy to stress mission critical systems (vice mission critical computers)
- ☐ Collect data on environmental requirements versus shipboard location
- ☐ Develop "ruggedized" MIL-SPEC standard
- ☐ Invert the waiver process; default to commercial and ruggedized equipment rather than full MIL-SPEC
- ☐ Prototype a weapons system using ruggedized equipment and commercial standards

Recommendation (policy): Change the Status of the UYKs

- Move toward rapid elimination of GFE status; treat as NDI
- Move toward rapid transfer of upgrade budgets into project offices to force careful cost-benefit tradeoff
- Study the transition question; consider rewriting software in Ada

Recommendation (NGCR): Mandate Standards at the *System* Level Only

- Limit Navy-wide standards to the *system level*
  - Communications protocols
  - Applications interfaces
  - Environmental survival
- System builders should have major role in determining which standards to use for system internals

Recommendation (NGCR): Reorient Prototyping Effort

- *Do not* prototype standard Navy-wide computer resources
- *Do* prototype computer resources for a specific major weapons system using ruggedized commercial equipment and incorporating widely used commercial standards
  - Identify and solve real problems
  - Demonstrate feasibility of the approach
  - Provide transition path for current systems
  - Address system requirements early
  - Update logistics system for computer resources
- Reoriented prototyping effort is essential to achieve the Navy's goal: deployment of effective computational resources at reasonable cost

Implementing Actions

Navy Computer Resources Policy

- OP-098: Promulgate revised operational requirement (see draft in Appendix IV)
- OP-945: Rewrite OPNAVINST 5200.28
  - Move toward elimination of the GFE status of the UYKs.
  - Invert the waiver process.
  - Require use of widely used commercial standards.

NGCR Project

- Reorient prototyping effort to focus on:
  - demonstration of commercial standards and encouragement of their use
  - upgrading of computing capability on current ships
- Limit Navy-wide standards to system level

Implementing Actions

Specific actions to implement the panel's recommendations are required. Significant changes to Navy policy regarding mission critical computer resources as well as modifications to the NGCR technical approach are essential if the Navy is to be able to deploy effective computational resources, at reasonable cost, in the 1990's and beyond.

Policy

The Operational Requirement for NGCR must be rewritten. As it stands it leaves open the possibility of a major development effort that could result in the development of a "gray-box" version of a Next Generation Computer. Rewriting the OR will ensure that the Navy's objectives are clear; it should be noted that it will formalize elements of the NGCR technical approach that are being pursued appropriately by SPAWAR despite the constraints of the current OR. The panel has provided a draft for a rewritten OR as Appendix IV. Major differences with the current OR include the emphasis on ability to deploy computing power rather than the development of a computer, the ability to use commercialized, industrialized, ruggedized, and fully militarized computer equipment as dictated by the demands of the particular mission critical system, and the need to modify logistics approaches for rapidly advancing computer technology.

A related required change is to rewrite OPNAV INSTRUCTION 5200.28, "Life Cycle Management of Mission-Critical Computer Resources (MCCR) for Navy Systems Managed Under the Research, Development and Acquisition (RDA) Process." Section 6, "Standards", and enclosure (1), "Navy Standard Embedded Computer Resources (SECR) Program, both must be extensively revised and their intent must be completely changed. Specific changes to include in the rewrite are:

- Eliminate the GFE status of the UYKs. This should be done as soon as feasible, with a reasonable transition.
- Invert the waiver process. Require specific warfare e sponsor approval and full cost analysis to justify use of fully militarized in lieu of ruggedized or commercial computer resources.
- Require use of widely used commercial standards in system designs, while leaving the choice of which specific standards to select for a given system to the project office.

When you think in terms of mission critical versus other, there is a tendency to go with the universal, full MIL-SPEC default, rather than go to the extra work of waivering down to a fully adequate, much cheaper, and often more functional alternative.

Accordingly, the panel recommends that the default be to use existing or ruggedized commercial equipment **unless a waiver for full MIL-SPEC is obtained with full justification including a cost analysis.**

NGCR Project

The panel agrees that firm Navy-wide standards are required at the system level to ensure that systems can communicate with each other and to ensure that systems have adequate survivability.

However, the panel does not believe that the Navy should adhere to a single, firm, Navy-wide standard for such system internals as a computer backplane. Instead, Navy programs should select standards for specific systems from among the widely used commercial standards without adaptation.

Accordingly, the panel believes that the NGCR prototyping effort should be focused on upgrading the computing capability on current ships, not on facilitating the adaptation of commercial standards for Navy use.

- Communications protocols
- Applications interfaces
- Environmental survival

Appendix I: Terms of Reference

Terms of Reference
for the Naval Research Advisory Committee (NRAC) panel on Next Generation Computer Resources (NGCR)

Since the 1960s, the Navy's policy has been to use standard computer equipment for mission-critical systems. The use of standard equipment has simplified logistics and maintenance, especially at sea. Moreover, the use of standard equipment, specified at the instruction-set level, has simplified the movement of software from one generation of computers to the next.

Unfortunately, the standardization policy has limited the Navy's ability to benefit from the increase in performance and the decrease in cost associated with modern computer technology. In many cases, mission-critical computing is done on machines that lack the speed and memory of ordinary personal computers.

Also, working with severely limited computers has dissipated a great deal of programming effort, leading to software that is more expensive and less capable.

Recognizing these deficiencies, Congress has directed the Navy to replace its current generation of computer resources in the early 1990's. In light of this direction from Congress, the NRAC panel on computer resources is to make recommendations that will help the Navy to deploy effective computational resources, at reasonable cost, in the 1990s and beyond.

In particular, the following questions are to be addressed:

- How can the Navy maintain adequate standards for computer-equipment reliability, especially in combat, without paying an unreasonable price in either purchase cost, life-cycle cost, or capability?
- How can the Navy ensure the timely incorporation of cost-reducing and capability-enhancing hardware technology. In particular, what is the best approach to militarizing existing commercial equipment?
- How should the Navy select a standard interface architecture. Is there an existing interface architecture that will support today's needs as well as future needs imposed by distributed computing and massively-parallel computers?
- How can the Navy ensure that a variety of machines, adequately filling the power-cost-size space, will be available?
- How can the Navy ensure that emerging software technology, particularly from Artificial Intelligence, can be adequately supported?
- How can the Navy ensure a balance between hardware costs and software costs such that reduced hardware costs will not be more than offset by increased programming costs?

Appendix II: Briefings

The panel was briefed as follows:

- Meeting 1: OP-945 (sponsor), SPAWAR-32 (developer), Bill Smith (background)
- Meeting 2: NAVAIR (AIR-01, AIR-546), NAVSEA (PS-400, PS-412); UNISYS, CDC, AT&T; NSPCC; EIA; AFSC; HASC
- Meeting 3: NOSC; SAE, X/OPEN; Genisco, Rolm, Rugged, IBM; USS VALLEY FORGE; NRAC panel on Interoperability
- Meeting 4: Grace Hopper, DEC; OSD; NBS
- Meeting 5: NAVSEA-06V; OP-945, SPAWAR-32; HASC

The objective of the first meeting was to become familiar with the DOP, with past Navy practices for computer resources development, with the status of the NGCR program, and with the requirements for standard embedded computer resources in the Navy. Briefers included the OPNAV sponsor, RADM Harry Quast (OP-945), the Systems Command developer (SPAWAR-32), RADM Robert Topping, and Mr. Bill Smith, formerly of ASN (RE&S).

The objective of the second meeting was to learn about the current Navy standards program for shipboard and aircraft embedded applications, to learn what the computer requirements of system development project offices are, and to understand current logistics policies and procedures for MCCR. Briefers included NAVSEA and NAVAIR, with representation from both the system development project offices and standard computer development offices. RADM Friichteniicht (AIR-01) and RADM(Sel) Hood (PMS-400B) attended. The Naval Ships Parts Control Center (NSPCC) discussed integrated logistics support for MCCR. Manufacturers of the current Navy standard embedded computer resources (UNISYS, Control Data and AT&T) discussed their experiences and lessons learned in producing Navy computers and their concerns about the NGCR program. Additional briefings at the second meeting included the Air Force Systems Command (to discuss Air Force MCCR); the Electronic Industries Association (discussing the MCCR market and industry concerns); Mr. Tom Hahn of the House Armed Services Committee staff discussed Congressional guidance and concerns; RADM Quast returned to summarize the Navy's objective in NGCR, the need for an independent look by the NRAC panel, and provided an updated program status.

The third meeting was held at the Naval Ocean Systems Center (NOSC) in San Diego. The panel visited the USS VALLEY FORGE (CG-50) to gain a better understanding of the environment in which Navy mission critical computer resources operate. Briefers included a representative sample of ruggedized and fully militarized computer manufacturers and computer standards organizations. NOSC provided a summary of Navy 6.2 efforts in support of the NGCR program and the Chairman of the NRAC Panel on Interoperability summarized the work of that panel.

The fourth meeting was primarily a working session. Briefers included RADM Grace Hopper, USN (Ret.) in conjunction with a representative from a major commercial computer manufacturer, the Digital Equipment Corporation. A representative from the office of the Director, Defense Research and Engineering (Research and Advanced Technology) discussed the overall DoD perspective on NGCR. The Director of the Institute for Computer Science and Technology at the National Institutes of Standards and Technology (NIST/ICST) discussed various issues relating to development of computer standards.

The purpose of the fifth and final meeting was to discuss issues raised during the course of the study with the OPNAV sponsor and the SYSCOM developer and to be updated on the NGCR program from both a programmatic and technical viewpoint, as well as to complete the draft report. In addition, the views of the submarine combat systems developers were presented by NAVSEA-06V (RADM Volgeneau).

Appendix III: Currently Available and Reliable Computer Technology

Expert systems	1000's of rule-based systems Rule-based system shells
Computers	20-25 MIP workstations 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 100s of megabyte magnetic disks 1000s of megabyte optical disks
High-volume processing	Massively parallel computers Special purpose processors Massively parallel processors VHSIC chips
Databases	Distributed databases Quick access Robust
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

The list of currently available and reliable computer technology is taken from the NRAC Report on Automation of Ship Systems and Equipment, performed in the summer of 1988. The key point to note is that all of these provide vastly improved productivity, that their effective use depends on being "plugged-in" to the world of standard commercial computer products, that they have passed the most rigorous operational test ever devised (market acceptance), and that they are not routinely deployed in naval warfare systems in the US Navy today.

Appendix IV: Proposed Operational Requirement

Operational Requirement for Next Generation Computer Resources

1. General Description of Operational Requirement. Embedded computer resources are essential components of naval warfare systems. Since the 1960's the Navy's policy has been to use Standard Embedded Computer Resources (SECR). Use of SECR has simplified logistics and maintenance, especially at sea. These computers have been militarized to meet the environmental needs imposed by the Navy's operating environment. They have been specified at the Instruction Set Architecture (ISA) level and provided as Government Furnished Equipment (GFE) to weapons systems developers.

Unfortunately, the standardization policy has severely limited the Navy's ability to benefit from the increases in performance and decreases in cost associated with modern computer technology. In many cases, mission critical computing is done on machines that lack the speed and memory of ordinary personal computers. Increased reliability of computer technology and the proliferation of microprocessors has resulted in the blurring of the distinction between computers and other electronics components. The Navy is a small part of the computer marketplace, limiting its ability to develop state-of-the-art computer systems at reasonable cost.

Recognizing the limitations on competition and the inability to utilize modern computing technology in naval warfare systems, Congress directed the Navy to develop a new approach and replace its generation of SECR not later than 1996. ASN (RE&S) informed the committee chairmen of the four Congressional committees (HASC, SASC, HAC and SAC) in letters dated 21 March 1988 that the Navy was pursuing a dual approach to meet its computing needs in the 1990's and beyond. This dual approach consisted of product improvements to current SECR based on specific weapons systems requirements for the near-term (until 1995) and the development of Next Generation Computer Resources (NGCR) to meet the long term need (1996 and beyond). On 29 April 1988 an OPNAV decision briefing was held to decide on a level of funding and a technical approach. The result of the meeting were announced in CNO ltr Ser 982D/8U53123 of 13 May 1988. This letter tasked COMSPAWARSYSCOM to proceed with the NGCR program and committed to funding levels of $140M covering fiscal years 1988 through 1996. The letter also noted that the final determination of the technical approach would be made following the report of the NRAC panel on NGCR in early 1989.

This operational requirement is to provide the ability for the Navy to deploy effective computing at reasonable cost in future naval warfare systems. Naval warfare systems will require embedded computing power that:

- provides for effective weapons employment
- increases operational readiness
- has affordable life cycle cost
- supports timely tactical decisions, multisource correlation and tracking, intelligence data processing, near real time database management, and asset management
- allows for interoperability between and within systems supporting all warfare areas

Deploying effective computing power at reasonable cost while maintaining combat reliability requires the utilization of widely used commercial computing standards in multiple environmental conditions. It is specifically NOT for the development of a "Next Generation Computer." It is for those activities necessary to ensure the availability of adequate computing power at reasonable cost for incorporation into naval warfare systems. These activities include:

- Prototyping computer resources for a specific major weapons system using ruggedized commercial equipment, commercial software tools and applications, Ada, and incorporating widely used commercial standards.
- Participating in commercial standards development efforts to ensure that they include Navy requirements.

2. Threat. Not applicable. Threat is applicable to mission critical naval warfare systems as a whole, not to individual components. Because computer resources are embedded in a full range of mission critical naval warfare systems, the ability to utilize a full range of environmentally hardened computer resources is required.

3. Shortcomings of Existing Computer Resources for Naval Warfare Systems. Existing SECR have Navy unique ISA's. These ISA's do not allow for use of rapidly advancing commercially available computer technology in naval warfare systems. They exclude use of commercial software applications and tools (e.g., database management systems and Ada Compilers), resulting in greatly increased life cycle software costs and greatly limiting the operational capabilities of naval warfare systems. They are unable to meet the required processing needs for both existing and planned naval warfare systems. Their size limits the amount of processing power that can be incorporated into naval warfare systems. They prohibit the Navy from taking advantage of the state of the art in US commercial computer technology. They result in increased costs both from limitations on competition (design and production) and from the inability to leverage the vast commercial computing technology base.

4. Capabilities Required. The ability to fully utilize computer technology (both hardware and software) in mission critical systems at a level equivalent to the US commercial state-of-the-art at reasonable cost, while maintaining adequate standards for combat reliability, is essential to the effective performance of all naval warfare missions. Computer capabilities required in naval warfare systems include:

- small, single function component processors which are essentially indistinguishable from other electronics components within a complex system and communicate with other system components over a system (vice a computer) backplane
- medium performance processors that are equivalent to widely used commercial computer systems that typically communicate with other systems over a local area network
- high performance special purpose processors for applications such as signal processing and symbolic processing, which are typically at the leading edge of computer technology and which require unique design decisions dependent on the particular application.

These computer capabilities are required to operate in environments ranging from protected to exposed, dependent on the particular naval warfare system in which the computer is to be embedded. The capability for a system designer to select the required degree of environmental hardening without paying additional cost for unnecessary additional hardening is essential. These levels of environmental hardening include commercialized, industrialized, ruggedized, and militarized. Standardization is required for intersystems communication (to provide interoperability and Battle Force integration) and for applications portability (to allow for use of software applications on multiple types of hardware and operating systems). Utilization of widely used commercial computer standards (hardware and software) is essential to avoid vastly increased life cycle costs and decreased operational capabilities that result from Navy-unique developments.

5. Cost Summary. TBD

6. Platforms/Quantities. NGCR will be employed in surface, subsurface, air and space platforms, shore bases, and within expendable weapons in large quantities. The following numbers are considered minimums:

100,000	embedded processing components
8,000	ordinary computing systems
2,000	sophisticated, high-performance special purpose computers

7. Integrated Logistics Support (ILS).

a. Navy policy on ILS (SECNAVINST 5000.39, OPNAVINST 5000.49, etc.) is designed for systems that have a typical lifetime in the Fleet of 30 years and whose underlying technology changes slowly, if at all. These systems are characterized by short Mean Time Between Failure (MTBF). Their availability is maintained by strong spare parts support and an extensive maintenance training system. Computer technology, on the other hand, has a typical generation time of about two years and a useful lifetime on the order of ten years. Furthermore, the reliability of modern computer resources is measured in years, not days or hours. A MTBF of greater than 3 operational years (26,280 hours) will be the minimum goal for NGCR systems.

b. It is recognized that modification and tailoring of Navy ILS procedures will be necessary in order to allow for the use of required computing power in naval warfare systems. Full Navy ILS policy may be appropriate for the systems in which NGCR are included, but not for the NGCR themselves. A key consideration shall be the recognition that there are few if any reasons to treat embedded computer resources as distinct from other naval warfare system electronic components and that exact "build-to-print" replacements are unnecessary and inefficient.

c. MIL-STD-1388 Logistic Support Analysis (LSA) must be tailored to recognize the changing characteristics of modern computing systems and components and shall be initiated and performed concurrently with RDT&E. The LSA shall identify any required modifications and tailoring of Navy logistics procedures necessitated by the unique characteristics of computing technology. These will include the definition of total resources required for logistics support, identification of any specific requirements necessary to ensure operational supportability and to control ownership costs and determination of the optimal support concept.

d. Logistics and logistics support costs shall be major factors in source selections and in RDT&E efforts, and shall be weighted not less than performance considerations. An ILS manager shall be established immediately upon program initiation. Statements of Work and Contract Data Requirements List items shall reflect logistics requirements outlined in this OR. RDT&E funding shall be separately identified within the program for logistic planning and analysis, and an analysis of the impact of the increases in computer reliability and testability for the specific naval warfare systems in which NGCR will be embedded.

e. Manpower, personnel, and training requirements will be documented and validated in accordance with OPNAVINST 1500.8M and 5311.7. These requirements must recognize the impact of highly reliable computing resources in Naval Warfare Systems and adjust manpower and training requirements accordingly. Man-machine interfaces will take advantage of the best available widely used commercial practices in accordance with the developing agency's human factors instructions. The Logistics Review Group (LRG) shall ensure compliance with these requirements prior to Milestone I (or equivalent).

8. Related Efforts. Almost all major systems developments will benefit from this program. Related efforts include:

- Standard Embedded Computer Resources (SECR) projects
- Navy Standard Signal Processor projects
- VHSIC Program
- Ada and the Ada Language System, Navy (ALS/N)
- Computer Security

9. Acquisition Strategy. End product NGCR components will not be acquired under this program. These will be acquired as part of system development projects which are users of NGCR. Acquisitions under the NGCR Program will be limited to those necessary to demonstrate and validate the ability to utilize widely used commercial computer standards in all environmental conditions. Full and open competition will be sought. Milestones for the NGCR Project are:

Milestone	Date
I	2nd Qtr, FY-89
II	4th Qtr, FY-92
III	TBD
IOC	1st Qtr, FY-96

The NGCR Initial Operational Capability is defined as the first IOC of a naval warfare system entirely based on widely used commercial computing standards.