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Foreword

This volume is a record of the presentations made during the MILITARY ELECTRONICS DEFENCE EXPO (MEDE) '80 Technical Conference. MEDE '80, the fifth of an annual series, took place at the Rhein-Main-Halle in Wiesbaden, West Germany on 7-9 October 1980. Both the exhibition and the conference were successful as evidenced by attendance (8,294 qualified visitors) and by interest.

Fourteen technical sessions, each with multiple papers, were held over the course of three days. The emphasis of military electronics technology in certain areas led to multiple sessions, in the fields of Communications, Simulation, Electro-optics and Radar, for example. Other important areas covered were Electronic Countermeasures, Reconnaissance, Software and IFF. In all, 113 speakers from 11 countries came together to present 74 papers, truly an international forum in a very important technological area.

MEDE has grown during each year of its existence because it serves a definite purpose, that is, to keep the international community aware of developments in the rapidly changing field of electronics, and particularly semiconductor electronics. The continued growth of this event is gratifying to the organisers and is an indication of the strength of the industry.

MILITARY ELECTRONICS DEFENCE EXPO will continue to present the newest developments in electronics and semiconductor device development which so profoundly affect the emergence of new systems and sub-systems for defence electronics. We look forward to seeing you again at future meetings of this exhibition and conference.

Milton S. Kiver
Chairman,
Industrial & Scientific Conference Management Inc.

Technical Session XI **Military Communications - B**
Thursday, 9 October 1980 09:00 - 11:30

Chairman: Kenneth E. Beene, *Sperry-Univac, St. Paul, Minnesota, USA.*

Technical Session XII **Software for Military Systems**
Thursday, 9 October 1980 09:00 - 11:30

Chairman: Kenneth Braun, *Computing Devices Company, Ottawa, Ontario, Canada.*

TITLE:

SHIP SYSTEMS INTEGRATION AND LOCAL COMMUNICATIONS NETWORKS

AUTHOR:

J. F. Carruthers, Commander, Canadian Forces, Project Manager SHINPADS

ABSTRACT:

Naval approaches to shipboard system integration have changed little in the last quarter century. The introduction of the digital computer resulted in some navies moving from a switchboard-intensive architecture to one based on computer switching. Nevertheless, the electronic architecture remained essentially intact with classical subsystem boundaries remaining as firm as ever. Resources remained dedicated to subsystems and a myriad of hardwired interconnects provided dedicated communications between these fixed resources. Whether the failure to develop a flexible communications network constrained architectures, or the lack of advanced integration concepts constrained the development of the required local communications network is a debatable point. The effect has been that ships continue to be designed with an archaic electronic architecture and, as a result, have very poor survivability.

This paper describes an advanced ship systems integration concept entitled SHINPADS* (Shipboard Integrated Processing and Display System). The design is based on: a distributed architecture; the use of standardized components; and a bus-structured "ships central nervous system." The data bus, digital data highway, or local area network (depending on your terminology) is the key element that translates components which classically have been considered as dedicated local resources into reconfigurable global resources. In this manner, although subsystems are functionally identified, individual subsystem components are available through the network to act as backup for similar devices regardless of their location onboard ship.

The SHINPADS concept utilizing the serial data bus provides redundancy and system survivability at a reduced life-cycle cost. This paper provides a short history of the concept, discusses the rationale for the bus structure, describes the network itself, and explains expected system benefits.

INTRODUCTION

1. Between data gathering or communication networks, such as the telephone, telex, and data communication networks, and the high-speed internal interconnections of computers or devices, lies a forgotten world of interconnect systems. The communication specialist is deeply involved in designing and implementing national communication networks, and computer companies are well aware that the internal bus system of a computer is one of the keys to successful computer design. In the area of military vehicle design and, in particular, the design of warships, there is a requirement to provide an interconnection system which possesses characteristics to be found in commercial systems but which also has unique characteristics such as battle-damage tolerance. It is not customary for ship designers to think of the wiring between subsystems and components as an interconnection system in its own right. Rather, a ship is designed based upon hull and payload characteristics with the wiring to interconnect shipboards systems generally being added as necessary to produce a workable combat system.

*SHINPADS is a registered trademark of the Canadian Forces.

2. Regarding the interconnection systems found aboard ship, several different approaches have been adopted based upon national requirements. The approach of the USN, for example, has generally been to provide large switchboards as a means of interconnect integration and to provide redundant paths. During the same time frame, the Canadian Navy has tended to solve the problem by providing dispersed direct wiring between components without passing such cabling through switchboards. Most other naval designers have adopted a course somewhere between these two approaches. Although different philosophies appear to have evolved, it seems that there was no particular intent to derive a philosophy for overall interconnection discipline. Rather, it would appear that the various approaches to interconnection grew as the requirement for an increased number of system interconnects expanded. Perhaps these approaches would remain valid today except for the introduction of the digital computer. Not only has the computer greatly increased the requirement for interconnection bandwidth, due to the greatly increased amount of data to be passed, but it also is a very capable component of any interconnection system. The digital computer, in addition to its normal task of computation, is able to operate as an advanced switching mechanism. Although it was not generally recognized, many subsystems tended to use the digital computer as a central switchboard between components within the subsystem as a replacement for the electrical switchboard fitted in former non-computer-based systems.

3. Historically, the digital computer has been recognized as an expensive and scarce resource. This has led to a tendency to centralize systems with the necessity for a growing number of interconnections required to feed information to the digital computer and return orders and data to the user devices. With the advent of the microprocessor and large-scale integrated digital circuits, the need to use expensive digital computers is no longer necessary. With the availability of a wide variety of low-cost computers, it is now possible to consider an approach to interconnection which will be far less demanding, in that signals need no longer be fed to central points for processing and return. In addition, developments in interconnect technology offer the ship designer the flexibility and capability he has long sought. It is now possible to envision the entire ship interconnection requirement as a single package and to expand the horizons of the designer to consider the entire ship electronic architecture. This perspective of overall ship electronic architecture is considered to be the key to providing many of the characteristics so long sought by naval ship designers.

BACKGROUND

4. In 1974, the Director of Maritime Combat Systems (DMCS) at the Canadian Forces National Defence Headquarters, directed that a design committee be formed to examine Combat System Integration problems encountered during the DDH 280 ship design. The problems included the following:

a. Integration of a wide variety of equipments from many different countries (Canada historically has produced a ship using equipments purchased from many different NATO countries);

b. Ship updates and mid-life conversion were becoming an increasing problem, primarily due to the changes required to wiring or interconnection onboard ship. In some cases, new equipment could not be fitted. Although mechanical or structural changes were minimal, there was insufficient time available to alter the ship's wiring to provide the interconnections required for the new systems;

c. Growing acquisition costs continued to increase despite actual decreases in the price of some components such as digital computers;

d. Mushrooming life-cycle costs;

e. The growth of shipboard software with the increasing problem of its support;

f. The realization that fewer men would be available to man ships of the future, based upon declining population growth and the difficulty of encouraging young men to go to sea; and

g. Recognition of the fact that attempts to militarize or harden electronic components had not been paralleled with an undertaking to provide a more survivable interconnection system. In fact, it was considered that the electronic systems onboard ship represented the most vulnerable aspect of the ship and the key to its survivability. Despite this, little appeared to have been done in the past to provide a survivable electronic architecture for the ship.

5. The horizons of this work were soon expanded to include not only Combat Systems, but all electronic systems aboard ship, whether of a main propulsion machinery control, administrative, or Combat System type. During 1975, this work led to the evolution of an approach to ship integration which acquired the title SHINPADS. The paper outlining this concept (Ref 1) considered all equipment to be part of a global ship system. The concept was verified through parallel industrial studies in 1976/77, and in 1977 work commenced on production of hardware components. The design approach was to utilize NATO equipments wherever they were available. However, it was soon obvious that three critical components were not to be found. These included an inexpensive computer which directly emulated the standard AN/UYK-20 minicomputer. One was subsequently developed in conjunction with Sperry Univac (Ref 7). The necessity for a single display capable of displaying any type of sensor imagery also became apparent, and development of this standard multipurpose display was undertaken by Computing Devices Company (Ref 8). The final missing component was an interconnect system which would enable any component to access information going to every other component of the same type. Again, no suitable candidate was available so the SHINPADS serial data bus was developed in conjunction with Sperry Univac (Ref 6).

6. In all cases, working hardware was constructed, and extensive testing has been conducted to verify the design concepts outlined in this paper. In particular, the serial data bus has been in operation since the spring of 1979, and demonstrations of its unique redundancy, reconfigurability, and survivability have been made to audiences from most NATO countries.

THE CONCEPT

7. Although the interconnect system is a particular piece of hardware, the SHINPADS concept should not be viewed as a collection of hardware but rather as a concept of ship electronic integration and is based upon three factors:

a. A distributed architecture;

b. Standardized displays, computers, software, and input/output; and

c. A bus structured "ships central nervous system" or interconnect system.

The distributed architecture is probably best described by explaining what it isn't, rather than what it is. First, it is not a centralized architecture. Figure 1 shows the structure of a centralized system as opposed to a federated system and a distributed system. These architectures can be thought of as interconnection schemes or as management diagrams of the system hierarchy equivalent to line drawings of any management organization. A centralized system is considered to have major faults in that the centralization represents a point of extreme vulnerability with respect to battle damage. Because centralization also implies large computers with multiprocessing capability, the development of the system software and life-cycle support of that software also proves to be a major problem and serious deficiency with regard to this architecture. The federated architecture has been so named since it is analogous to many nations'

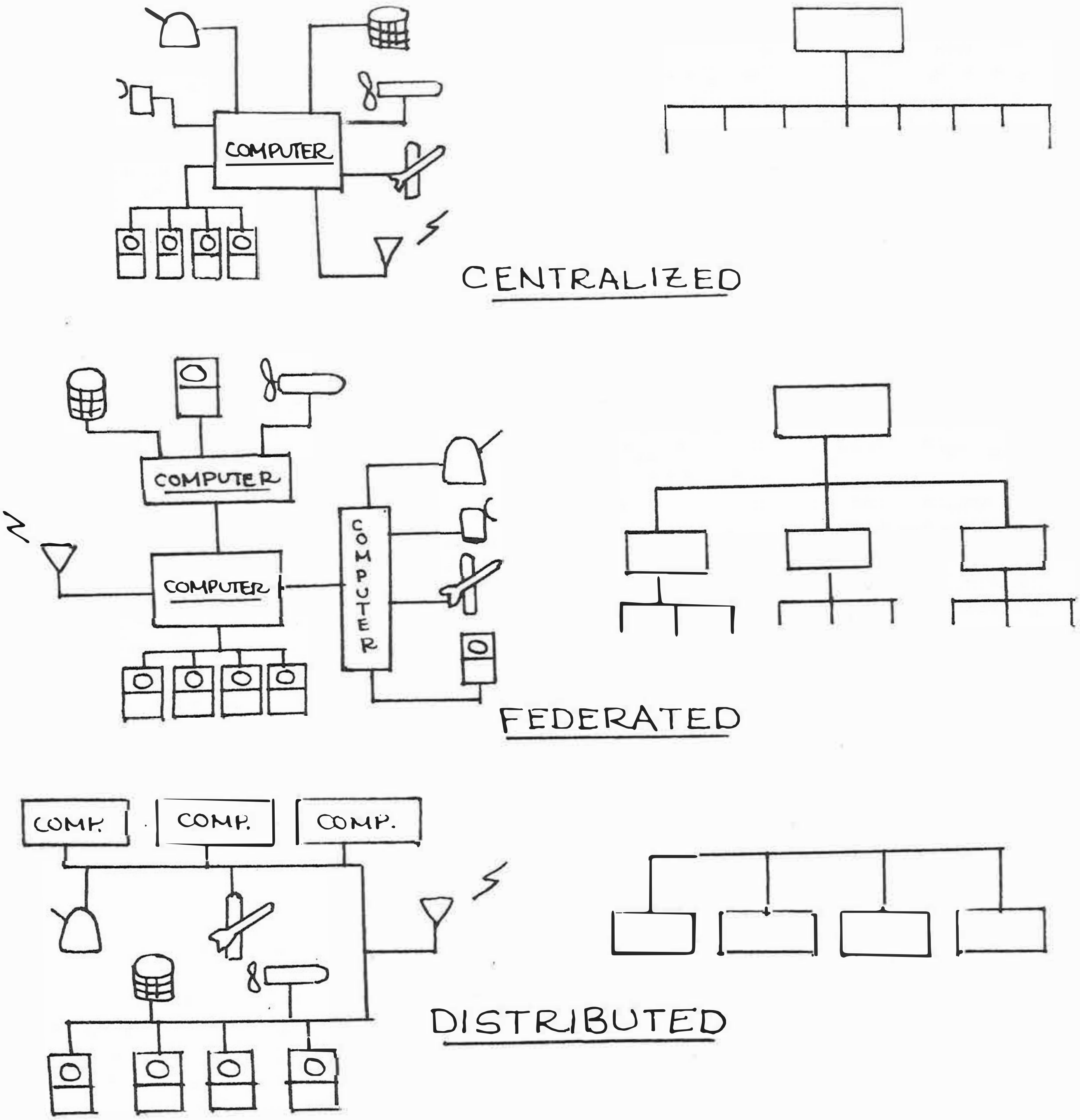


FIGURE 1. ALTERNATIVE SYSTEM ARCHITECTURES

federal systems of government. Subsystems, or provincial entities, have their own resources such as displays, computers, and weapons, and are able to operate in isolation; however, one device (usually the command and control computer) federates or provides overall control of the entire ship's system. This approach can be seen to be superior to a centralized system, in that it is much more tolerant to battle damage. Software development and maintenance are also much easier to handle because a number of smaller packages exist which can be developed, maintained, and replaced independently. Although this architecture is more damage tolerant, it is obvious from the diagram that a problem still exists due to the hierarchy of systems and equipment, since the federating element may fail. If this federating element fails, the ship level capability is lost. Another drawback is the fact that since each subsystem is provincial and its resources are dedicated to it, similar equipments within the ship cannot be used to dynamically replace one another through system reconfiguration. That is, resources remain dedicated resources, rather than the optimum which would be their use as global or ship-wide resources.

8. The distributed architecture shown offers to overcome these problems. In the context of this paper, when the word "distributed" is used, it can be thought of as distribution in three dimensions. These are geographic distribution, functional distribution, and distribution of control. Regarding geographic distribution, the concept is to spread resources of a particular type around the ship, such that battle damage will not result in elimination of all equipments of a particular type. Functional distribution refers to the use of a larger number of small computers, rather than a few large computers and the assignment of functional tasks on a one-to-one basis between these computers and the task. This means that a single small computer will only carry out one major function, so that functions are not mixed within a particular computer. This provides a larger number of small computers, which is important with regards to redundancy, but more importantly ensures that the software is decoupled. Decoupled software is easier to develop (and can be developed by a number of manufacturers in parallel), and far easier to maintain over the ship's life cycle. Distribution of control refers to the absence of a hierarchy of equipments as defined by a wiring system. Of course, a hierarchy of control will exist with regards to the tasks being carried out; however, it is important that no predefined hierarchy (such as would be predefined by existing wiring systems) should exist so that crucial, single-point failures are not possible. Standardization of equipments, software, and input/output interfaces is important from a life-cycle-cost viewpoint, but it is equally important if a practical distributed system is to be constructed. The actual hardware need not be identical from a conceptual point of view, provided that it is capable of emulating or appearing to be identical to other pieces of equipment of the same type. This emulation permits identical software to be used without change, thereby simplifying system design and development, and minimizing costs.

9. The final point of the concept, which logically follows from the architecture described, is the idea that any piece of equipment may replace a similar piece of equipment. This means that in a dynamic manner, any particular computer, display, weapon, etc., can replace a damaged or failed similar piece of equipment, so as to provide the survivability desired. For this to happen, it is clear that all the information, which previously went to each equipment of that type, must now be carried to all equipments of that particular type. In the case of conventional wiring or interconnect systems, this would mean taking all wiring to every computer, display, etc. Since it is a difficult task to wire-in single connections, given the present approach to interconnection, it would be clearly impossible to provide such a system of information distribution using conventional wiring techniques. What is required, then, is an information or data distribution system which is capable of providing any information to any device. This is the key characteristic of the interconnection or data bus system in this concept. Not only does it replace the present wiring, but more importantly, it provides information formerly available to particular equipments to all equipments of the same type, thereby facilitating reconfiguration in the case of failure or battle damage.

10. Figure 2 is a block diagram of the ship when viewed from a SHINPADS concept point of view. This diagram is somewhat different from normal ship diagrams in that it does not depict surface and air weapons systems, command and control equipments, and antisubmarine warfare systems, etc. This is, in fact, the basis of the concept in that one must not look at the ship in terms of the classical subsystems, but rather as a single integrated system. In this manner, all computers, all displays, all weapons, etc., should be considered as ship-wide resources, so that existing equipment on ship can be used in a redundant manner. In conventional architectures, subsystem boundaries define the wiring, and resources are dedicated to those subsystems. This means that in conventional systems, should a computer fail in a particular subsystem, it is generally impossible to consider other ship computers as backups for this equipment. This is not to say that the functional requirement for surface and air or antisubmarine warfare systems is to be ignored. At any instant, a collection of equipments must be operating to carry out the functional task, since this is the purpose of the equipment onboard ship. However, there are obvious advantages to a system in which should some equipments fail, other alternate equipments onboard ship can act to carry out the functional task required. The key is to consider all resources onboard ship as generic types of resources as shown in Figure 2.

PROCESSOR INTEGRATION

11. Imagine such an interconnect system onboard ship, which would permit any equipment of a particular type to be replaced by identical equipment also carried onboard. This replacement would be done in a dynamic manner, without manual operation, and would permit provincial or local equipments to be used in a ship-wide sense to provide redundancy. Figure 3 shows the type of computers of AN/UYK-20 size, which would be utilized onboard a frigate-sized ship. Each block or square represents a separate computer with a single function resident in each computer. Examining the two blocks which are side by side, labeled Fire Control 1 and Engine Control, what are the differences between the machines? Since they are identical machines and since all information is available on the data bus or interconnect system, the only obvious difference between the two is the software, which is resident in a particular machine at a particular time. If this is the case, and should the Engine Control computer fail or be damaged due to battle action, it is clear that the Fire Control 1 computer could replace it, provided the engine control software could be fed into the other machine. The data bus described in this paper has the capability to support software transfers from mass storage devices such as disks, so this is possible. The system shown, then, provides for backup of any computer by all the other computers shown. No additional resources have been added to the ship, yet thirteen backup computers exist for each of the computers shown since all computers onboard ship can be provided with the necessary information and are able to address peripherals such as weapons, which formerly would have been dedicated to a particular machine by dedicated wiring. Also shown on the diagram are examples where some dedicated wiring would be required, as in the case of EW computers labeled ESM and ECM. In this case, the dedicated wiring would be fed to more than one machine to provide simple redundancy; however, it is clear that those computers can disconnect or ignore this dedicated wiring to still act as replacement for any of these other devices or computers shown.

12. The redundancy achieved is phenomenal when compared to conventional or present architectures. A cost-saving is also represented, since the data bus replaces a myriad of dedicated wiring at much lower cost and the computers use standardized executive and input/output handling software with only the application software being unique. Although computers have been used as the example, such an approach is possible when considering other areas of equipment on the ship, as displays, weapons, sensors, etc. The key is that the resources exist within the ship's present allotment of equipment to provide redundancy, and the connection system must support reconfiguration so that devices of the same type can act as backup for other similar devices onboard ship. For this to happen such an interconnect system is required, and the ship designer must consider the ship as an overall integration problem. Past parochial approaches to subsystems, with their own hierarchy and dedication of shipboard resources, cannot provide such survivability and tolerance to failure – characteristics of extreme importance to a warship.

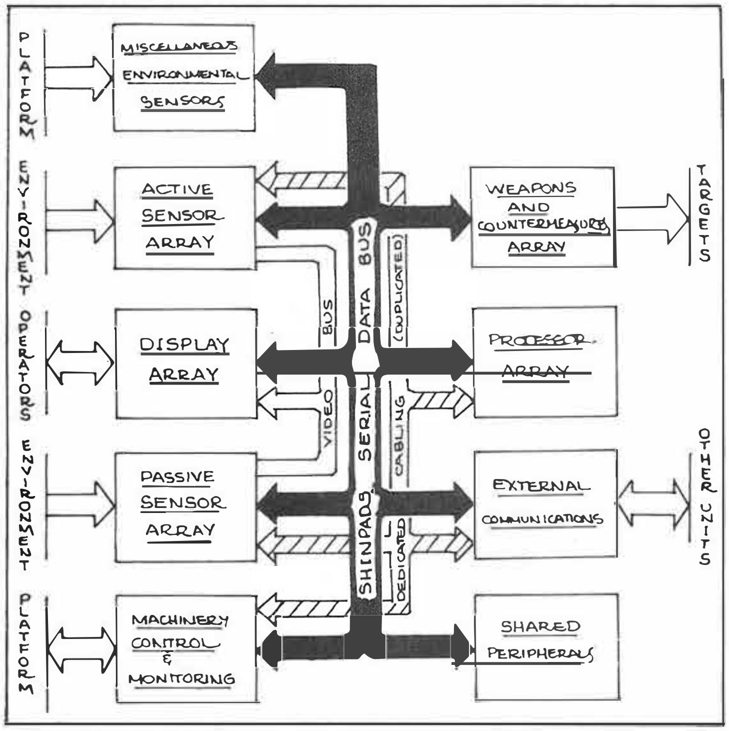


FIGURE 2. SHINPADS TOP LEVEL DIAGRAM

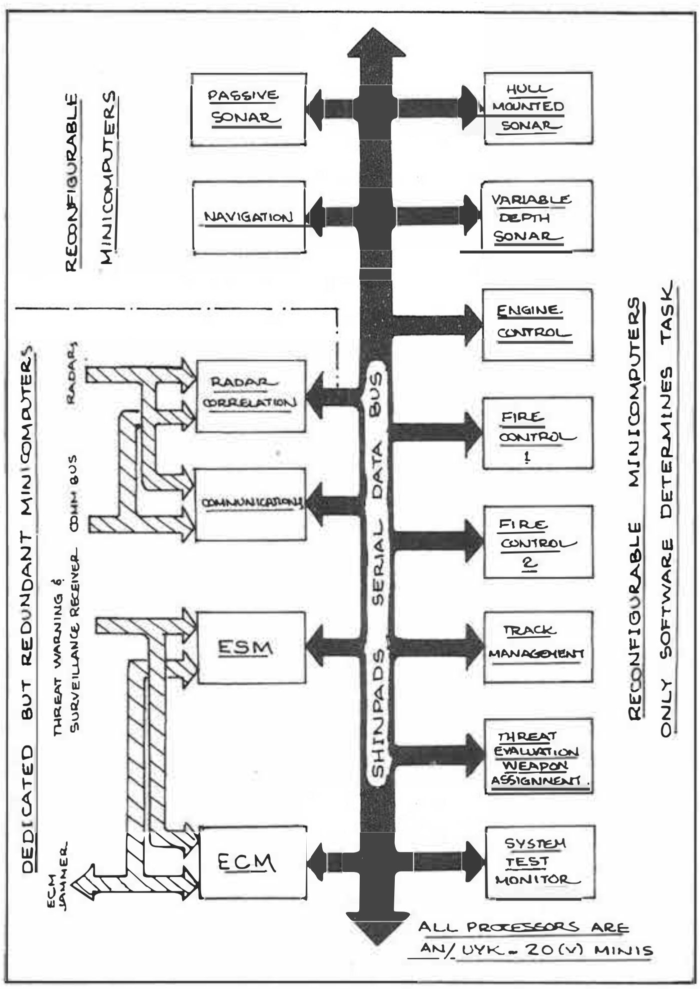


FIGURE 3. PROCESSING SYSTEM ARCHITECTURE

DISPLAY INTEGRATION

13. Another area in which work was pursued as part of the SHINPADS project was the development of a standard, multipurpose display. It was essential that a display be available which was capable of displaying radar, sonar, low-light television, infrared, command and control synthetic, alphanumeric, etc., formats through instantaneous reconfiguration. That is, the display should be capable of switching from a radar with command and control synthetic mode to a passive sonar or fire control mode at the touch of a button, not through switching of hardware or other reconfiguration by manual means. No such display existed so a program was undertaken to develop a display based upon raster television technology, which would be capable of fulfilling this very demanding, multipurpose role. It was also essential that the display be bright enough to be useful on a bridge of a ship, and permit the operations room to work in a high ambient light level. The display was required to be intelligent, with its own distributed processor to carry out its own track updating, intercept calculations, etc. Finally, it was required that the technology be capable of capturing imagery, so that it would be possible to take a single scan on radar and analyze the information over an extended period of time without continuous radar operation. The display which has resulted from this work has many other desirable features and, indeed, is so capable that operational authorities are only now beginning to consider utilizing its characteristics to the utmost advantage.

14. Figure 4 shows the organization of displays within the ship. Suppose, for example, in this architecture, that a man was operating display no. 1 to carry out the function of a sonar operator and that his display equipment failed. In present ships, this would require the repair of that equipment, and the fact that there might be an unused radar display onboard would be of no practical use. If, however, a truly multipurpose display were available and the interconnect system was capable of providing all information to any point, then any other display could act to replace this display. Once again, survivability and fault tolerance have been obtained by considering all the ship's resources.

15. Operational advantages in use of the equipment are also evident when Figure 4 is examined. Since any display can fulfill any function, the Commanding Officer is free to assign ship's men in accordance with the threat. For example, if there were little or no air threat and a high ASW threat, the majority of the operators could act to carry out passive and active sonar or passive electronic warfare display functions. Similarly, in a shore-based situation, such an architecture and equipment capability would permit a single trainer to function successively as a radar trainer, sonar trainer, etc. Aside from these operational features, tremendous savings in spare parts, maintainer training, handbook documentation, etc., are also evident.

WEAPON INTEGRATION

16. The availability of a truly flexible interconnection system such as the SHINPADS data bus also has a very positive effect on the integration of sensors and effectors. As an example, Figure 5 depicts the architecture which might be utilized in integrating weapons onboard a SHINPADS ship. As shown in the diagram, in a majority of cases, present provincial systems with dedicated resources are unbundled at the weapon end as well. (Unbundling means that all the resources formerly tied together by dedicated wiring are freed to plug into the interconnection system at the device level.) In this way, any weapon can be driven by any computer in conjunction with any display.

17. As an example, examine the gun in Figure 5. As part of the distributed intelligence, a microprocessor has been placed between the interconnect system and the gun itself. Up to now, most weapons have been "dumb," in that they possessed no local intelligence and acted on dedicated low-level orders. With the addition of a microcomputer, it is possible to see that a gun may interface by receiving high-level digital commands and, in turn, gun status monitoring can be carried out effectively. In this manner, a gun which previously followed continuous position orders can, in conjunction with its microprocessor, act on orders

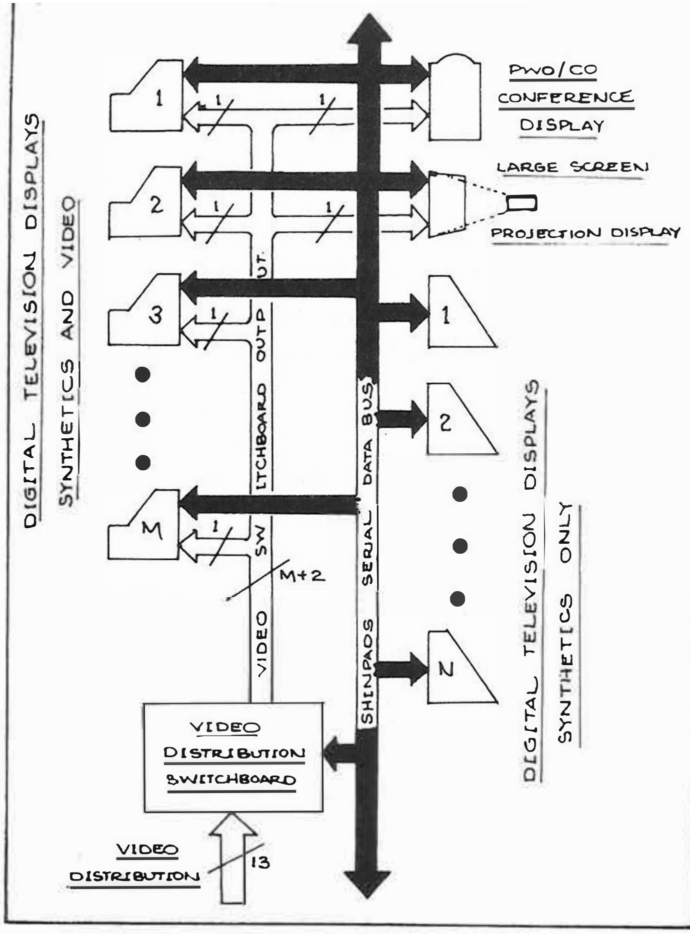


FIGURE 4. DISPLAY INTEGRATION

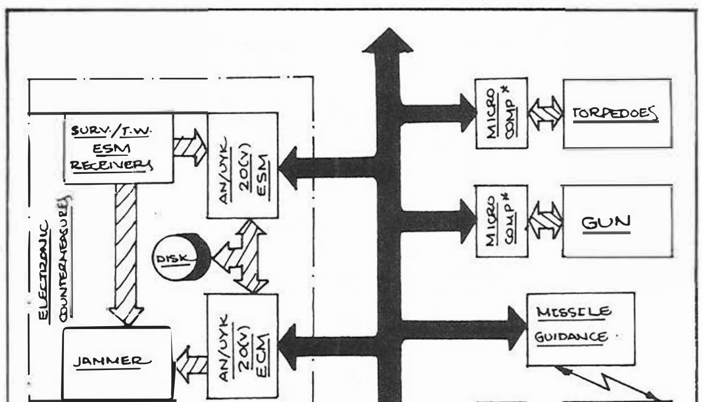


FIGURE 5. WEAPON & COUNTERMEASURES

such as a set of coordinates and rate-of-change, thereby minimizing the orders which must be passed to it. Thus, a gun could, for example, be fired on sonar information to converge on a torpedo bearing line should the need arise. Once again, present restrictions on use of resources aboard ship are removed and the resources may be utilized in accordance with the threat and requirements of the situation.

18. The microcomputer depicted in Figure 5 will be used throughout such a system to provide local or distributed intelligence to former "dumb" devices. A need for an inexpensive, single-board computer is therefore evident. It was also considered extremely important that this computer emulate the standard Navy AN/UYK-20 computer to use the same software and support base. Since no such device existed, development of an AN/UYK-20 emulator known as the AN/UYK-502 microcomputer was undertaken. This microcomputer is also resident in each standard, multipurpose display.

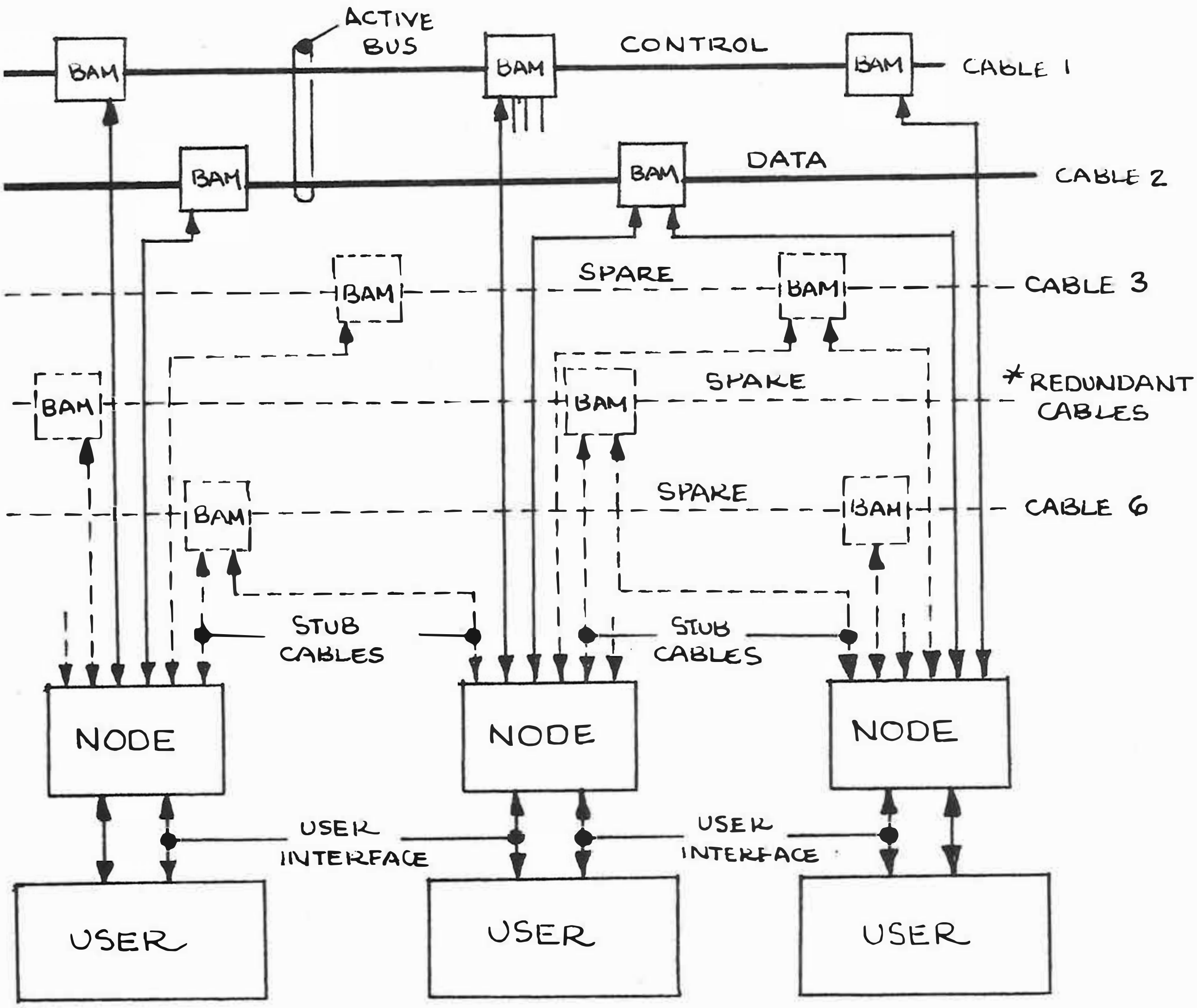
SERIAL DATA BUS

19. One of the key elements in any ship under integration process is the interconnection approach and technology adopted. In the case of a distributed, reconfigurable system such as SHINPADS, the desired system characteristics place, perhaps, the most demanding requirements yet envisioned on a ship interconnection system. Much work has taken place recently in many nations, directed towards replacing present day ship wiring with a data multiplex system. In almost every instance, however, this work has been primarily directed towards ridding the ship of its present mass of wiring. That is, the data bus or multiplex system has been designed primarily to replace wiring. In the case of SHINPADS, not only must the wiring be replaced, but also the more demanding requirements of a survivable, reconfigurable, distributed architecture are imposed. As a result, the SHINPADS serial data bus has incorporated many features which are unique.

20. The SHINPADS data bus was foreseen as an interconnect system which would carry all ship information, including communications data, except for voice. It is considered that voice and data are basically incompatible in that although voice is sent digitally on such ships, a voice transmission system requires rigid time-slotting and fixed-length time slots so that analogue reconstruction can take place at the other end. In contrast, a data network, particularly in the case of computer data, requires asynchronous access with variable-length messages. Although voice and data can be loaded on a single network, such an approach is considered to be a serious compromise and impractical. For these reasons, the Canadian Navy is also developing a voice distribution network known as SHINCOM.

21. As shown in Figure 6 the SHINPADS Serial Data Bus (SDB) consists of a bus transmission system and bus interface through units called nodes. The bus channels are implemented on triaxial cables operating with Manchester encoded waveforms, similar to those utilized in NATO STANAG 4153, operating at a baseband 10-MHz serial bit rate. The node equipment has been designed so that up to six cables can be used in a ship's system, but any two of six bus cables are required to implement an operational data bus. One cable is used for data and another cable for control and arbitration. Any cable can be used for any purpose, and other cables remain dormant as truly redundant backup for the cables in use. The Bus Access Modules (BAMs) shown in Figure 7 are passive transformer coupled taps which can connect a single bus cable, to a maximum of four nodes through stub cables. This 4-to-1 fan-out in conjunction with 64 BAMs on a single cable, provides for up to 256 access ports in the present system.

22. The stub cables which extend from the BAM to the nodes provide for physical separation of the cable and the user equipment so that bus cable runs may be routed in protected areas of the ship and the length of bus cables may be minimized to enhance casualty protection. In addition, Canadian naval architects have considered running the six cables widely dispersed in the ship through piping, so as to provide considerable ballistic protection. The maximum length of the main cable is 300 metres, and the maximum length of the stub cables is 30 metres.



BAM = BUS ACCESS MODULE

* UP TO 6 CABLES MAY BE IMPLEMENTED

FIGURE 6. SERIAL DATA BUS

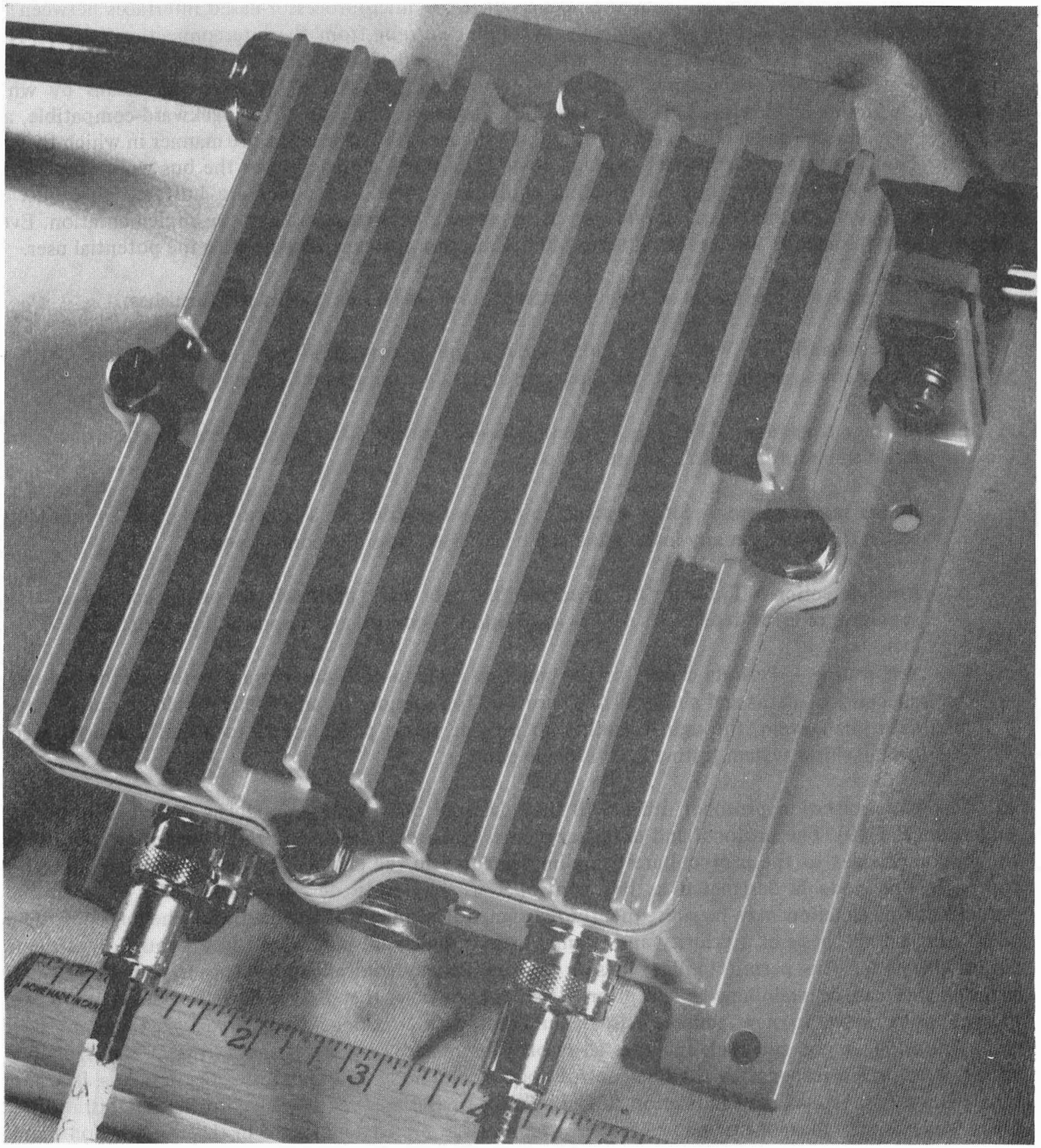


FIGURE 7. 4 PORT BUS ACCESS MODULE – BAM

23. The heart of the serial data bus is the nodes. These are microprocessor-based interfaces between the user equipments which operate to effectively decouple the user from the interconnection system. They allow for standardized interfaces such as MIL-STD-1397 and STANAG 4153. In this manner, existing point-to-point interfaces, compatible with conventional wiring schemes, provide the means by which equipments communicate with the Serial Data Bus. Therefore, the data bus is backward-compatible, and existing subsystem equipments may be "plugged in" to the data bus in the same manner in which they are presently interconnected by dedicated wiring. However, a single connection to the bus would replace the multitude of cables coming into an existing equipment. Also, the nodes are buffered to adjust for differences in input/output transfer rates, so as to allow a heterogeneous system implementation. Every attempt has been made to render the data bus interconnection system transparent to the potential user.

24. The node also provides all the intelligence internal to the data bus system and furnishes:

a. **Bus arbitration** – With a particular node acting as control at any instant and time, with the ability for any other node to assume control should a failure take place;

b. **Message screening** – Provides dynamic reassignment of addresses and the selection of messages based upon information content or type;

c. **Status maintenance** – Since a tight control is exercised on a control cable, the overall system status is apparent at any instant and can be accessed from the control node;

d. **Error detection** – Through CRC checks on the data cable, parity checks on the control cable, and provision of error detection schemes in addition to control and response time-outs; and

e. **Self testing** – Permits checks via the bus from node-to-node and from user-to-user for end-to-end checking of paths and ability of the hardware to function. As an aside it should be noted that the data bus system, through its ability to provide single point access to all information, permits overall ship's system testing from a single point.

25. The bus arbitration protocol utilized in the advanced development model is described in detail by Andersen (Ref 10). The protocol and design approach has been validated through over one year of testing and minor changes to the protocol are being implemented in the engineering development model. In the approach, one node is designated as bus controller as previously described when the interconnect is initialized; this function may be subsequently reassigned if required due to damage. The bus control node polls users on the basis of a priority and normal listings which are maintained in random access memory within the node. This permits polling lists to be modified dynamically so that users with critical timing requirements can be maintained on a priority list. It is obvious that this capability is also required since priority must move to new addresses in conjunction with functions being transferred due to system reconfiguration. A poll sub-cycle includes all priority users and a subset of the normal users. As a node is polled, it returns a response to the bus control node. If the node polled requires the data bus, it returns a transmission request, with an indication of the priority of the message it wishes to send. Arbitration then takes place within the control node based on the message priority indicated in the transmission request. Request queues for four priority levels are provided, and authorization to transmit is given to the user in the system with the highest priority traffic to send. By constructing request queues and allowing polling to operate on a separate cable on a free-wheeling basis, a high data channel utilization is incorporated. Thus, as predicted through software modeling and verified through actual tests, burst traffic conditions and sustained peak loading are handled efficiently.

26. One of the features recently added is provision for special handling of the highest-priority message traffic. When a priority-one request is received by the node effecting bus control, a lower-priority transmission on the data channel will be aborted and the high-priority node will be permitted to begin sending its message. The high-priority message will be routed through the receiving node, via a separate path, to bypass any queues in the receiving node to reach the user ahead of any other messages, thereby minimizing end-to-end delays. Automatic recovery of the aborted message is provided.

27. Of the number of unique features provided for in the data bus, not found in interconnection devices primarily intended to replace wiring, one of the most important is a transport protocol designed for both broadcast and point-to-point mode communications. Messages are source-initiated with no handshake required between source and sink and can be dispatched from a single point to every other user on the bus via a single transmission with simultaneous receipt. Messages are routed and received by using dynamically alterable, logical message identifiers which require the receivers to screen appropriate messages in the broadcast mode. The provision of both physical and logical or content addressing capability is considered essential if a reconfigurable system is to prove capable of sustaining repeated battle damage while reconfiguration is taking place. Testing over the past year has demonstrated to a number of nations that the data bus is the key to providing the reconfiguration and survivability required in a warship.

SUMMARY

28. In considering a design approach aimed at reducing acquisition costs, minimizing life cycle costs, easing update and modification, reducing the manning requirement, providing a manageable approach for software, and, most importantly, providing survivability so essential in a warship, the SHINPADS ship integration approach has been conceived.

A key component in this design approach, as in any ship integration method, is the interconnect system. The provision of a serial data bus with high throughput, tight control, reconfigurability, and tolerance to battle damage is considered to be a key of this concept. The basis, however, of any such integration undertaking is that the resources available on ship must be considered as part of an overall ship's system, and existing resources must be utilized so as to provide backup and reconfigurability. Such a fault-tolerant, reconfigurable architecture is considered essential if warships are to function in a battle environment. It is suggested that the conventional electronic architectures currently being implemented are an extremely weak link, and an architecture such as SHINPADS is essential to a survivable warship.

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