CDR. JAMES F. CARRUTHERS, CANADIAN FORCES

SHINPADS — A NEW SHIP INTEGRATION CONCEPT

THE AUTHOR

is a native of Drumheller, Alberta, Canada. He joined the Royal Canadian Navy in 1961 and attended the Royal Roads Military College from 1961 to 1963, receiving his BE degree in Electrical Engineering. Following Pre-Fleet Training, he was assigned to HMCS Gatineau for watchkeeping and engineering training. Work on the prototype AN/SQS-505 Sonar, ASROC Missile System, and the prototype ASW Data System (ASWDS) followed, including shipboard installation and evaluation of the system in HMCS Terra Nova, during which time he was the "guinea pig" Combat Systems Engineer. Later, during the construction phase of the Canadian Navy's Combined Support Center, he acted as Principal Engineer, subsequently returning to graduate studies at the Nova Scotia Technical College in 1971 from which he received his Ph.D. in Electrical Engineering, designing and building a computer intended for ship machinery health monitoring in the process. Posted to Headquarters in 1974, he served as Project Officer for a mini command and control system known as ADLIPS, his additional interests being that of originating plasma and digital television developments. It was during this period that the SHINPADS concept was first put forward, and following a year at the Canadian Forces Command and Staff College he was promoted to his present rank in 1977 and posted as Head of the Naval Command and Control Design Authority (DCMS 7). Cdr. Carruthers is a registered Professional Engineer (Ontario), and as an author has had several technical papers published on digital design, machinery health monitoring, and the SHINPADS concept. At the present time he is Assistant Director, Maritime Combat Systems, at the National Defense Headquarters in Ottawa where his current responsibilities include all aspects of C^2 systems. A member of ASNE since February 1978, he is also a member of IEEE, U.S. Naval Institute, and the IEEE Computer Society.

ABSTRACT

The SHipboard INtegrated Processing And Display System (SHINPADS) is a Canadian Forces Trademark, and is not really a system. It is rather a concept of ship integration. Not combat system integration or propulsion and machinery system integration but ship integration. It encompasses the entire ship system including all combat system equipments, marine engineering systems, and extending into administrative support hardware. It is a concept based upon the idea of synergism, a property which is best explained by stating the whole is greater than the sum of its constituent parts. When the normal horizons of the subsystem designer are discarded and the entire ship is considered as an entity, the number of constituent parts available increases dramatically. But how does one "get it all together"?

A distributed system approach in which former local subsystem equipments are made to function as global ship resources is the answer. Whereas until recently (where shipboard computers were concerned) "bigger was better," a distributed approach requires more numerous small processors to be considered. Of course information must be made available to all processors, so a high speed data exchange method must be provided. Enter the SHINPADS Data Bus which not only provides this "ship central nervous system" capability but replaces tons of point-to-point wiring in the process. Other aspects of the concept include standardization of hardware, software, and interfacing.

The SHINPADS concept is considered to provide redundancy and system survivability at a reduced life-cycle cost. It is suggested that such survivability cannot otherwise be achieved.

INTRODUCTION

In looking to the future, it is sometimes necessary to go back in time. In going back forty years, it is instructive to determine what are the differences from today and what caused these differences. Many naval engineers would pronounce that the major difference has been the introduction of new equipment. New equipment obviously influences the way in which war is conducted, but should they necessarily affect the way navies design ships, build them, man them, and modify them? While they most certainly alter these characteristics, it is suggested that their effect has been much greater than is warranted.

Looking back forty years, one could come to the conclusion that:

1) Ships were much easier to design especially where coupling of the platform and payload was concerned.
2) Ships were much easier to build in particular where cabling and interconnection of electronic equipment was concerned.
3) Ships were manned in a different manner based upon naval tasks which had to be performed, rather than equipment which had to be served.
4) Ships were much easier to modify in that the systems could be replaced with minimal effect on other ship systems.

If one modern "buzzword" had to be selected to epitimize ships of forty years ago, it would be "distributed." The word "distributed" has recently acquired all sorts of high technology trappings with the computer world embracing it. It appears to be new and revolutionary when compared to present highly centralized structures. However, if we look back a bit further, maybe the concept isn't all that new. In ships of earlier times, officers and men manned gun mounts, directors, engine rooms, et cetera, carrying out their duties and making necessary local decisions with a minimum amount of direction. Consequently, communications between the command and these locations were minimal and the failure of one did not necessarily mean the failure of the other. Indeed, where sufficient capability existed in terms of individuals, one could replace another when circumstances dictated. This loosely coupled system also eased ship design, construction, and modification tasks.

If present systems are judged to be centralized, there must have been a forcing function which caused this to happen. Although there are no doubt many factors which could be considered as having contributed to the centralization trend, one stands out — the development of the digital computer. Control of gun mounts, calculation of fire control orders, selection of weapons, tracking of targets, et cetera; all are tasks which the computer has greatly facilitated. Even though these functions had been carried out locally before, the computer was such a scarce resource that they became concentrated. Consequently, cabling conveyed the necessary local status to a central digital computer; and of course, more cabling carried the resultant decisions back. In this manner, it affected ship design, construction, manning, and modification.

As the large computer grew, so did the organizations created for its care and feeding. Systems began to be designed around the processor instead of being designed as part of the ship. This is the situation now, but is it the way for the future? It is suggested that the past holds the key for the future. Those ship characteristics of earlier days, which many consider to be a thing of the past, may be strengths of the future. The key again is "distribution" — distribution of processing. The SHipboard INtegrated Processing And Display System (SHINPADS) is such a distributed system.

Background

The last Canadian ship design didn't utilize the large computers used by some other Navies, and it did see the processing spread around to some extent. However, the overall design was unsatisfactory in that a single point of failure still existed. In the case of a DDH-280, autonomous subsystems with their own processors could operate as separate entities. However, the overall ship system still depended upon the command and control computer of the CCS 280 System for overall coordination. Since such an organizational structure depends upon a single intelligent element or processor to tie it all together, it is termed a *federated structure.* It is much like the federal government, with autonomous subentities which report to a single element that in theory at least has overall control. Many other factors, such as the proliferation of computers within the ship, and the concentration of vital cabling which could be severed but which could not be duplicated in a cost effective manner, also posed a great handicap. These, and other problems identified with the DDH-280 design, led the Director of Maritime Combat Systems (DMCS) at National Defence Headquarters (NDHQ) to direct that a committee be formed to examine the overall integration problem.

The size of the Canadian Navy could be considered by many to be a handicap, in that our Navy is very small. However, in this instance it proved to be an advantage. The fact that it was so small meant that the committee could, in a workable size group, concentrate expertise covering the entire ship system. The committee included not only up-to-date operators, but naval architects, marine engineers, and others, in addition to the Combat Systems Engineers of DMCS. Because of this, commonalities between marine engineering control problems and combat system control problems could be identified. In this manner, *the committee was able to consider the entire ship as a system.* The initial shock, that a Missile System Engineer first encountered when faced with the fact that the large hulking piece of machinery, known as a propulsion plant, really utilized the same control components as his sophisticated missile, was soon overcome when he realized that he could enjoy cost savings in terms of sparing, training, and life-cycle support by cooperating with marine engineers.

In the course of the deliberations of the committee, many ideas and concepts were put forward with respect to the integration of the ship as an entity. The earliest of these tended to dwell upon subsystems such as surface and air weapon systems, electronic warfare systems, or command and control systems. It took some time before these branched out to include the *entire* ship system. A paper, which considered the overall architecture of the ship, has become associated with the deliberations of the SHINPADS Committee and with the acronym SHINPADS [1], which is a Canadian Forces trademark. It is an electronic architecture for a ship — the entire ship — based upon a distributed processing approach.

The Concept

Deciphering the acronym SHINPADS into its constituent parts helps explain something about what SHINPADS is. However it really doesn't clear up much. SHINPADS is a conceptual design, that is, it's *not* a piece of equipment. One cannot walk up to SHINPADS and kick it, turn it on, et cetera. It is rather an electronic architecture which can be applied to many different ship designs and many different systems — from Hydrofoils to Aircraft Carriers. It could also be applied to aircraft and landbased sites. SHINPADS is a concept — *a concept of ship integration.* The concept is based upon *three* ideas: a) a distributed system approach; b) standardization of devices, software, and interfacing; and c) a ship's "spinal cord" or data bus.

Distributed Architecture

The first question which comes to mind is: *What is meant by a distributed system?* A distributed system can perhaps best be defined as opposed to centralized or federated system.

A centralized system is epitomised by the large multiprocessor installations which have been developed to carry out a wide variety of tasks. In these systems, a number of sub-programs run on a single processor and are considered to be tightly coupled. While there are many advantages to centralized systems, there are considered to be greater disadvantages. In installations such as these all of one's eggs are in one basket, and a single shell hit could wipe out the processing power of a large portion of the ship. Such systems also pose problems during program design and even more problems in later years during maintenance of the software. The software in them is tightly coupled, that is, many functional programs are being processed in *one* computer. Extreme care must be exercised in integrating the functional programs into the single processor. In addition, even more care is required during modification of the software in subsequent changes during its life-cycle.

Another system architecture approach is that of the federated system. The federated system was discussed earlier with respect to the DDH-280 ship system. In a federated system autonomous subsystems are capable of independent operation. However, one computer (the federating computer) is more equal than the others and must function in order to tie the autonomous "provincial" computers together. The main disadvantage of a federated system is this fact — *that overall ship system performance is still concentrated in a single point.*

The distributed architecture of SHINPADS is distributed in *three* ways. These are geographical distribution, functional distribution, and distribution of control. Once the concept of many smaller processors replacing a large one is accepted, it becomes readily apparent that they can be dispersed throughout the ship such that a single hit cannot possibly eliminate all of them. Thus, the term *geographic distribution.* This has other advantages in that the processor can be located in a compartment near its application and need not be connected by a myriad of wires between its point of application and its physical location.

An examination of the contents of any large processor presently in service will reveal that a single processor is indeed carrying out many tasks. Thus, with one processor containing several different types of programs; the interaction of the sub-programs, their scheduling within the computer, et cetera, becomes a major consideration. However, when numerous inexpensive computers are considered, functions may be assigned to processors on a one-to-one basis, as discussed earlier. This is termed *functional distribution.* Now a Programmer can modify the functional program associated with a particular element or equipment without undue concern for the effect on other elements.

Finally, perhaps the greatest drawback of centralized and federated architectures is the problem of "putting all the eggs in one basket." Such approaches contain a single point of control which if destroyed cripples the ship or at least eradicates the federating element of the system. In the SHINPADS approach, control may be carried out by any processor/node combination and will move around. No single element is crucial, and a comprehensive redundancy of control exists. Thus, the notion of *distribution of control.*

Standardization

If one is really serious about the design of the entire ship, the life-cycle costs cannot be ignored. The problem of proliferation of processors and equipments on board our last class of ship was eluded to earlier. In that the sparing, documentation, training, and life-cycle support costs of an equipment are usually many times the original purchase price, the standardization of equipments so as to reduce these overheads should be a prime design factor in any ship design. The minimization of such life-cycle support costs was a driving force in the SHINPADS discussions.

A look at the DDH 280 Class also points out an important area of standardization. A quick tour of the ship should be enough to convince any observer that Canada's ships are truly NATO ships with major equipments from almost every NATO country. For this reason, any plea for NATO standardization falls on sympathetic ears in Canada. Therefore, the work of NATO Group NAIG SG 6 regarding interface standardization [2] was included as a SHINPADS design factor. The criteria as applied in SHINPADS requires all devices to plug into the system via NATO interfaces as proposed by STANAG 4153 [3].

The effects of such a philosophy of standardization can be illustrated by *two* examples; one based on off-the-shelf equipment, the other based on a development to meet the requirement. The choice of processors was limited to a relatively few options when the field was limited to military qualified minicomputers [4]. Although other processors outperformed it in almost every area, the AN/UYK-20 computer was selected. Despite the fact that individual project managers might find a computer better suited to their particular application, the AN/UYK-20 has one outstanding quality. Canadian manufacturers who might develop equipments to meet our specifications should be able to look to wider markets. The UYK-20 had been adopted by the U.S. NAVY as a standard, was being introduced by other NATO Navies, and was being fitted by Australia and Japan. If standardization outside the Canadian Forces was to be considered a factor, there was really no other choice.

The requirement for standard display which would not only meet the machinery control requirements of alpha numerics, graphics (MIMIC, system diagrams, et cetera), TV & IR, but could also provide operational display of radar, and sonar, was judged to be unsatisfied when off-the-shelf equipments were considered. Consequently, one of the developments necessary to support the SHINPADS concept of standardization was the development of display technology capable of supporting these modes of operation. The displays utilized in machinery control applications thus could be the same as those utilized in the combat systems area resulting in shipwide standardization. Anything less than shipwide standardization is something less than standardization.

Data Bussing

One of the bases of this distributed approach is the concept that local resources become global resources. This means that any element which might otherwise be considered part of a subsystem can in a time of need be utilized to fulfill the function of a similar element in any other subsystem. Thus all elements of a single type are considered as one resource. For this to happen, any element must have available the information that any other element has. A simplistic approach might be to consider running the cables that go to every element of that type to every other element of the same type. However, for obvious reasons, this is not practical. Practically speaking, for this to happen a singular means of data distribution is necessary. The thought of all the ships' data being passed through a single conductor may not seem reasonable. However, examination of the worst case data rates for a typical Frigate yields a throughput requirement of somewhat more than two million bits per second (MBS) [5] as shown in TABLE 1. Since a ten MBS data rate is comfortably achieved with today's technology, it appears reasonable to expect that a single conductor could replace all the ships' data cabling. This single data path is termed the SHINPADS Serial Data Bus (SDB).

TABLE 1

SYSTEM DATA RATES — FRIGATE [5]

Equipment Type	System Data Bus Load
Active Sensors	0.4 MBS
Passive Sensors	3.4 KBS
Displays	0.64 MBS
Processors	0.93 MBS
Weapons	4.84 KBS
Communications	24.3 KBS
Machinery Control	36.7 KBS
Peripherali with Buffered Disks	482 KBS
Miscellaneous Sensors	133 KBS
TOTAL	2.02 MBS

The concept of a distributed architecture, equipment standardization, and data processing, which are the kernel of the SHINPADS approach has been described. *But how is a SHINPADS system implemented?* Figure 1 is a SHINPADS top level diagram. After a quick examination of the diagram the initial reaction of a Weapons Officer might be that it's all very nice, but where in the heck is the surface and air weapons system? In examining the diagram we see there are active sensors, displays, processors, and weapons. At any instant a sensor, display, processor, and weapon will be operating to carry out the function of a surface and air weapons system and will therefore form the surface and air weapons system, but approaching the overall ship system design from the conceptual viewpoint of SHINPADS we do not have such a subsystem. If the entire resources of the ship are to be considered from a singular system point of view, we can look at the ship in terms of its different type of elements. Thus all processors, all displays, all sensors, and all weapons (whether hard or soft) can be grouped together. Applying the basis of SHINPADS means distributing the elements, and where possible standardizing them. Therefore, all the processors will be of an identical type as will all the displays. However sensors and weapons may be of many unique types. In considering the ship as a total system it is obvious that division of the resources of the ship into functional grouping or arrays of elements will require a unique method of interconnecting them. As stated previously, if any element is to carry out any other element's job, then all information which is available to any element of that type must be available to each and every element. Therefore the third basis of SHINPADS — the data bus becomes evident.

This conceptual approach should not be considered an advocation of the demise of subsystems. It is simply a different way of looking at the overall ship's resources. Certainly a contractor and Project Manager would be responsible for developing subsystems such as a surface and air weapons system. However, they would be constrained to use standardized elements (a constraint often presently applied) and the architecture for joining these elements together would be predefined with the interests of the overall ship system at heart. Since the data bus is completely transparent to the user and is really a replacement for the wiring, then it can be seen that in actual fact subsystems do exist. Nevertheless, components of one system now can (through the provision of the complete set of information) carry out the job of another element should the need arise.

Processing System Architecture

Figure 2 represents a SHINPADS processing system architecture as an expansion of the processing array block shown in Figure 1. The diagram uses the word "reconfigurable" several times in referring to minicomputer architecture. *What exactly does this mean?* The blocks labelled Engine Control and Fire Control 1 would appear to have no apparent differences. At least on the diagram there appears to be no other differences except

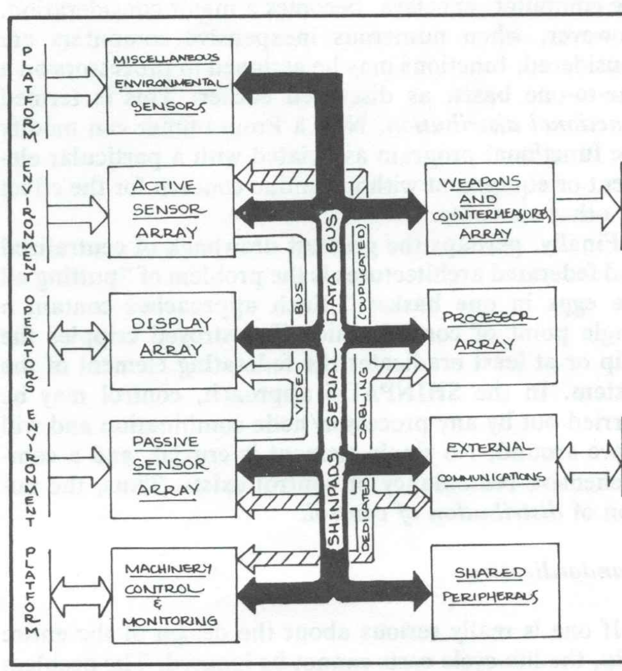

Figure 1. SHINPADS (Canadian Forces Trademark) — Top Level Diagram.

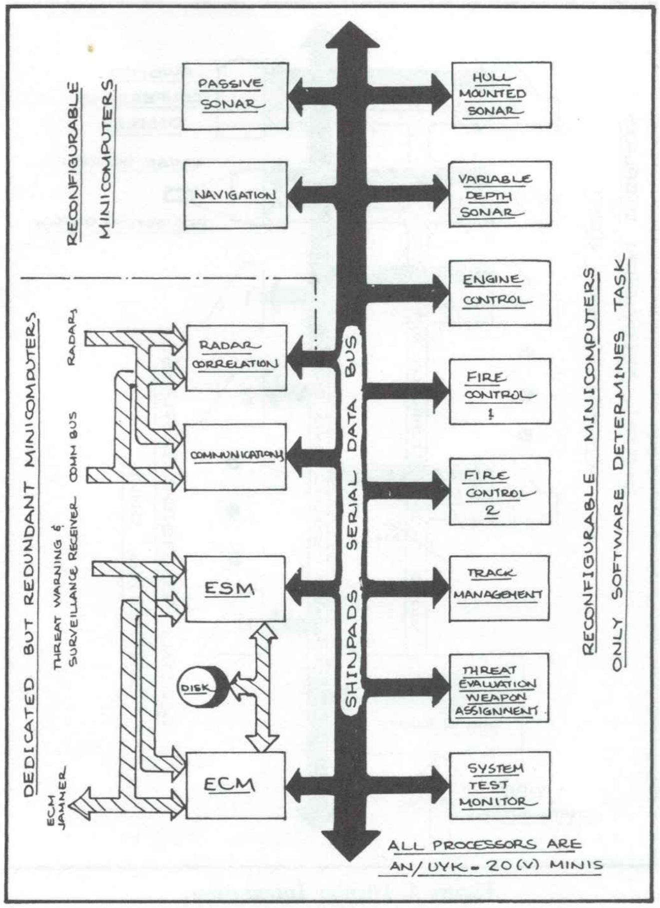

Figure 2. Processing System Architecture.

the labels on the block representing the processors. This not only appears to be true in the diagram, but is true in the ship system. The only difference between the Fire Control Processor and Engine Control Processor is the software loaded in the processor at any instant which defines the task of the designated label. Each processor connects into the data bus via a single connection and therefore has access to all the information that any other processor does. Each processor has coresident with it a cartridge magnetic tape unit of the AN/USH-26 type containing subsets of other programs. Any processor can be reconfigured under command of the bus to load from the local tape storage or reload via the data bus from a large system disk. In this manner the system can be reconfigured. Examining the diagram we see that any of the 14 identified processors of minicomputer size in a typical Frigate could take over the function of the engine control computer should it quit. The engine control computer has therefore not only been duplicated, but it has been replicated and has 13 back-up processors should the command decide that engine control is the most important function and the last function to be eliminated. This sharing of resources made possible by the SHINPADS architecture represents a fantastic increase in survivability — an increase which cannot be attained in any other manner.

The four processors in the bottom left hand corner of the diagram are examples meant to depict those class of devices which may require some dedicated input wiring. For example the ECM and ESM task, due to the high data input requirements of the working environment, must have dedicated inputs. As is shown, when dedicated inputs are required they are fed a minimum of *two* processors so as to provide redundancy. However, in looking at the diagrams we see that any processor can ignore (via electronic means) this dedicated wiring and therefore any processor is capable of carrying on a function such as engine control.

Such a system could be dynamically reconfigurable in an automatic mode under control of the system test monitor processor or could be reconfigured in a manual mode under the control of a maintainer sitting at a console. The functional partitioning of software to fit into the minicomputer size machines not only provides redundancy but provides a loosely coupled software system such that a modification made to any one of the individual minicomputers will not necessarily impact on software in another minicomputer. This is as opposed to the *centralized* approach where a number of the functions shown in separate boxes would be combined into a single processor working under a executive system to carry out the same set of tasks. Although 14 minicomputers are shown in this diagram, this is not the end of the processing requirement for the ship. Somewhat less than 100 large microcomputers will be required to

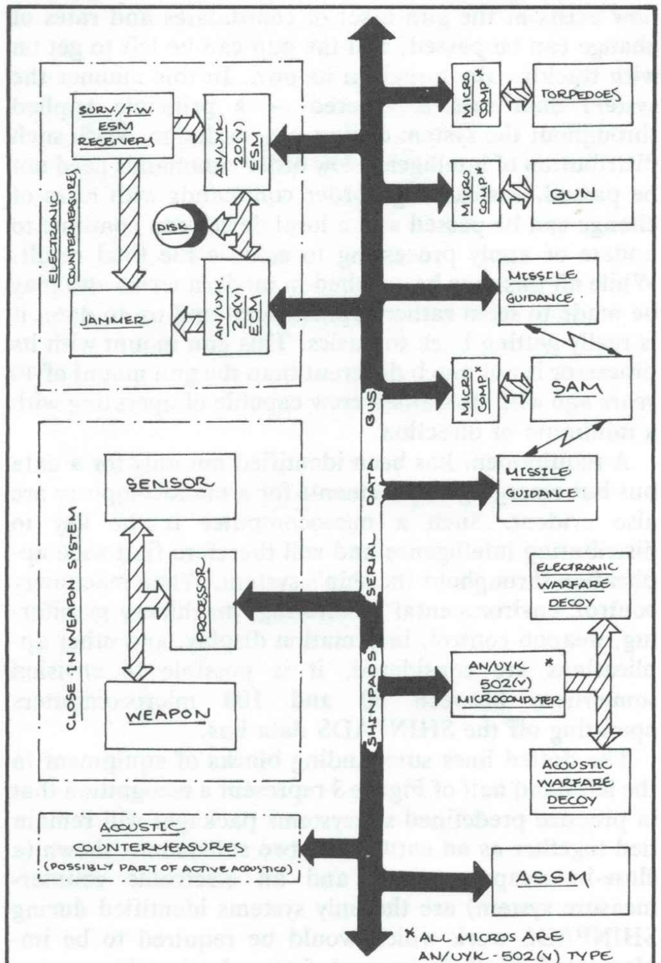

Figure 3. Weapon & Countermeasures.

distribute the intelligence to user devices. If buried microprocessors also are counted, it is probable that a Frigate will utilize in excess of 500 processors.

Weapon Integration

Figure 3 depicts the integration of weapons and countermeasures or hard and soft weapons. Looking at the right hand side of the diagram it is obvious that guns and missiles have been separated from their control element and processors. Such uncoupling or decoupling is said to be the unbundling of subsystem. Unfortunately most weapons, by their nature, are rather dumb — a condition which is inconsistent with their direct attachment to a data bus which is required in order to facilitate their operation as part of the ship's system. The solution is an application of the distribution of processing or intelligence.

In considering the gun, one can see that a block stands between the data bus and the gun. This block represents a microcomputer which contains the distributed system intelligence necessary for integration of the gun into the SHINPADS system. Previously control of the gun or missile launcher required that position orders be passed continuously to the weapon mount so as to keep it on target. If a microprocessor is attached as shown, orders need not be passed continuously. Since processing power now exists at the gun a set of coordinates and rates of change can be passed, and the gun can be left to get on with tracking the target on its own. In this manner the system data rate is lowered — a principle applied throughout the system during system design. With such distribution of intelligence low order commands need not be passed. Instead high order commands with rates of change can be passed and a local device can continue to update or apply processing to achieve the final result. While all this may be couched in modern terms and may be made to seem rather sophisticated and up-to-date, it is really getting back to basics. This gun mount with its processor is not much different than the gun mount of 40 years ago with its trained crew capable of operating with a minimum of direction.

A requirement has been identified not only for a data bus but emerging requirements for a microcomputer are also evident. Such a microcomputer is the key to distributing intelligence and will therefore find wide application throughout the ship's system. When machinery control, environmental monitoring, machinery monitoring, weapon control, information display, and other applications are considered, it is possible to envision somewhere between 50 and 100 microcomputers operating off the SHINPADS data bus.

The dotted lines surrounding blocks of equipment in the left hand half of Figure 3 represent a recognition that in practice predefined subsystems packages will remain tied together as an entity. The two subsystems shown (a close-in weapon system and an electronic countermeasure system) are the only systems identified during SHINPADS work which would be required to be implemented in their present form. A close-in weapon system, such as PHALANX with its weapons, sensors,

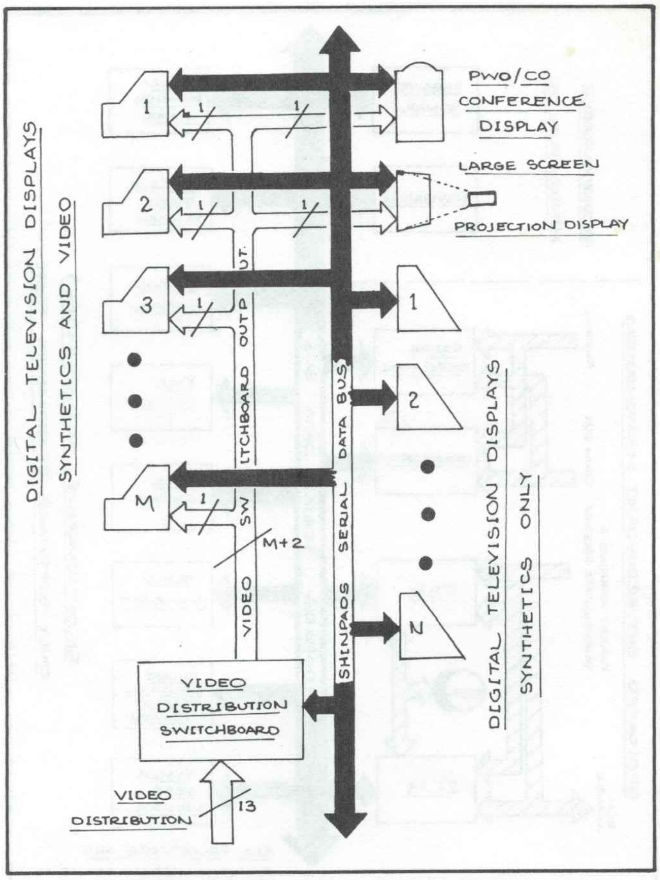

Figure 4. Display Integration.

and processor, represents such a tightly coupled subsystem that unbundling is impractical. However, a SHINPADS application would require that all high level control and monitoring is carried out via the SHINPADS bus. The case for tying front-end equipment into processors in the electronic warfare area has already been mentioned, namely the high data input requirements as defined by the operating environment. A detailed examination of ship system data rates does not, however, indicate any other such subsystems which should not be unbundled.

Display Integration

Although the limited space available in this paper does not permit examination of all the equipment arrays of Figure 1, the acronym SHINPADS highlights the display function which must be considered if the concept is to be even briefly explained. Figure 4 depicts the display integration aspect of SHINPADS. It also indicates that there are generally *two* types of displays. These are devices which are capable of 1) showing digital synthetics only, such as alphanumerics and graphics, and 2) devices which are capable of showing not only synthetics but raw video. Should the operator in Position 1 (at top of the diagram) be carrying out a sonar function, *what would happen if this display were to cease functioning?* From an operational point of view, it would be most desirable if he could transfer to any other of the displays (2 to M) shown in the left half of the diagram, and then carry on the *same* job function that he had been accomplishing on Display 1 prior to its failure. If the Command is to have a ship which is truly flexible, it also would be extremely valuable if displays could be designed to the function as required by the tactical situation rather than being dedicated to a functional piece of equipment with which they were designed to interface. In this manner the Command might want to dedicate all displays on the ship to sonar or acoustic information given a high threat ASW situation in the absence of air and surface threats. Such is the objective of the SHINPADS display architecture. Since all displays in the left half of the diagram are identical, any function can be carried out at any display.

While such an approach may be considered very desirable, it is not obvious that there is any display which is capable of carrying out this function. Since none was available, this became a development area of SHINPADS. Such a display is depicted in Figure 5. The commonality and general purpose application in fact goes further, in that the only difference between synthetics-only display and a video and synthetics display is the presence or absence of a module in the electronics.

In consonance with the distributed approach of SHINPADS each display contains its own resident AN/UYK-502 microcomputer [6]. This microcomputer is capable of carrying out the functions normally associated with a centralized processor. Each display processor would contain a subset of the overall ship-track store based upon the generic function being carried out. The display itself would carry on the dead reckoning of

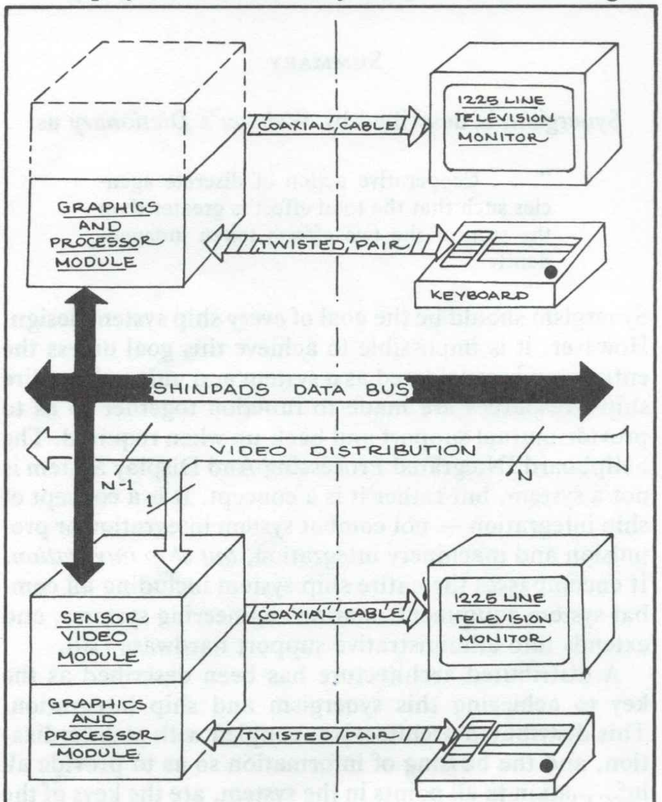

Figure 5. Standard Display.

these tracks, and intercepts, or closest point of approaches, would be calculated within the display. Once again, system intercommunication rates are drastically cut since targets only need to be passed when velocities change.

Equipment Development

Even though SHINPADS is a concept and not a particular set of equipment, it was necessary to carry out equipment development in order to meet the goals of SHINPADS. Demonstration of the concept had to be undertaken in order to satisfy the curiosity of some while calming the misgivings of others. In examining an equipment implementation of this system, an attempt was made to standardize upon U.S. Navy equipments wherever possible. Thus the AN/UYK-20 minicomputer, the AN/USH-26 cartridge magnetic tape, and, for older ship applications, the AN/USQ-69 alphanumeric display were adopted as standard equipment. Likewise large mass storage disks and versatile electrostatic printer/plotters, about to come on the market, were identified as possible standards in these areas. However, *three* items of equipment were *not* available and had to be developed. These were the Serial Data Bus, AN/UYK-20 compatible microcomputer, and multi-function standard display.

AN/UYK-20 Minicomputer [6]

The requirement for a microcomputer or smaller version of a standard minicomputer has already been identified in many applications. It was considered important that this device have all the necessary motherhood features one could possibly desire, namely, minimal cost, minimal size, and minimal power requirements, with maximum performance. Cost became perhaps the overriding criteria — that is cost with an acceptable level of performance. It was decided that a processor with perhaps half the throughput of the AN/UYK-20 standard minicomputer could be produced inexpensively using modern integrated circuit microcomputer technology. For many applications this microprocessor must exist on a single board which can be included in a parent equipment. Fortunately, SPERRY UNIVAC had underway internal development of such a family of processors. It was therefore possible to capitalize upon this industrial work at minimal cost so as to fulfil the SHINPADS requirement for distributed intelligence.

With the investment being made in the AN/UYK-20 processor and standardization on CMS 2, it became very apparent that any processor must emulate the UYK-20. Thus, this microcomputer, the AN/UYK-502, appears to the user as a UYK-20. The standard operating systems for UYK-20, standard bus handlers developed for UYK-20 and other software, could thus be utilized. Fortunately the rate of technological progress also meant that the memory addressing and input/output capabilities of the UYK-20 could be considerably improved. This microprocessor is described in the accompanying paper by Mr. Paul Williams of SPERRY UNIVAC [6].

SHINPADS Serial Data Bus [7]

Developments have been underway in several countries in the area of data buses. The question may therefore arise: *Why carry out development of a data bus for SHINPADS?* Unfortunately almost all other data bus efforts have been directed towards replacing ships cabling with a data bus. Although this was a requirement of the SHINPADS data bus it was only a minor requirement. The major requirement is to provide a medium of information exchange such that the information that was only available to a single element is now available to all other elements in the system [8]. As a result the SHINPADS data bus is unique in that it was designed to support the conceptual architecture of a ship's system rather than being designed as a replacement for the ship's cabling.

Other unique requirements of the *SHINPADS* bus which were adopted as basic design criteria include: a) the requirement to support intercomputer transfers; b) the requirement to implement NATO standard interfacing; c) the necessity for backward compatibility with existing or NATO point-to-point interfaces; d) the ability to operate in a broadcast mode using content addressing; e) the function of distributed control such that any node could assume control of the data bus; and f) transparency to the user such that the data bus appeared to be a piece of wire between equipments.

Before undertaking development work a survey of existing data buses was carried out. In addition to not meeting the majority of the above listed characteristics other data buses were found to involve active components which were considered to offer a serious reliability problem or were not considered capable of meeting TEMPEST requirements. Therefore, work was undertaken to develop a data bus interconnection system capable of supporting the SHINPADS concept. As part of this undertaking it is planned to demonstrate a kernel SHINPADS system involving the data bus, computers, magnetic tape units, displays, et cetera, in the spring of 1979. The following paper by Mr. Richard Kuhns of SPERRY UNIVAC describes the SHINPADS Serial Data Bus in detail [7].

Standard Display [9]

The most recent displays put into service in the Canadian Navy are of a sophisticated random stroke or caligraphic cathode ray tube type. In considering the display architecture of SHINPADS it is clear there is a requirement for a display that is capable of displaying: a) sensor imagery such as radar, sonar, infra-red, low-light TV, et cetera; b) graphics and alphanumerics such as in engine control and administrative applications; c) combinations of imagery plus graphics and alphanumerics; and d) bright imagery such as would be required on the bridge.

An examination of the existing technology quickly led to the conclusion that the only solution was a digital television approach involving RASTER-Scan display with digital storage. Other nations have undertaken development of RASTER-Scan devices but have tended to generate the synthetic imagery by utilizing high-speed emitter-coupled logic. The approach taken in the SHINPADS display was based upon a prediction that memory cost would fall drastically in the years 1974 to 1978. The approach depended greatly upon this large decrease in price since each display contains in excess of seven megabits image memory.

Not only is the display capable of carrying out the wide range of functions demanded by the SHINPADS architecture, but it delivers many unique capabilities not otherwise obtainable. These include: a) perfect registration of synthetics and video imagery; b) an ability to produce montages or composite images involving a combination of sensor inputs; c) sixteen levels of gray scale shading (such that messages from the electronic message log can be viewed by the Captain using the brightest four gray scales while he monitors the progress of the ship from a radar image utilizing the 12 lower gray scales, of the 16); and d) image processing, which is now possible since all sensor data has been digitized and placed in a digital memory.

The display incorporates the UYK-502 processor in addition to four buried microprocessors utilized in controlling the display hardware itself. The distribution of intelligence allows the display to carry out many of the functions which were formally associated with central processor, and therefore, to operate as an intelligent device on the data bus. A more complete description of the display is contained in the paper by Mr. David Thomas of the Computing Devices of Canada [9].

Summary

Synergism is described by *Webster's Dictionary* as:

> ". . . Cooperative action of discrete agencies such that the total effect is greater than the sum of the two effects taken independently."

Synergism should be the goal of *every* ship system design. However, it is impossible to achieve this goal unless the entire ship is considered as a system and unless the entire ship's resources are made to function together so as to provide mutual support and back-up when required. The SHipboard INtegrated Processing And Display System is not a system, but rather it is a concept. It is a concept of ship integration — not combat system integration or propulsion and machinery integration, *but ship integration.* It encompasses the entire ship system including all combat system equipment, marine engineering systems, and extends into administrative support hardware [10].

A distributed architecture has been described as the key to achieving this synergism and ship integration. This distributed architecture, coupled with standardization, and the bussing of information so as to provide all information to all points in the system, are the keys of the SHINPADS concept. As will be seen in the accompanying papers, items such as the data bus provide for survivability within their own structure (replication with the cable is an example). Replication, and its dramatic effect on ships survivability, is a benefit delivered by such an approach — a benefit that is *not* possible if classical structures are considered.

Although SHINPADS is a concept, the necessity of developing *three* pieces of hardware for support of the architecture soon became evident. Development of the SHINPADS Standard Display, the Serial Data Bus, and the AN/UYK-502 processor are currently well under way with completion by the summer of 1979. Thus demonstration of the SHINPADS concept will be achieved prior to the fall of 1979. With this demonstration the concept will be considered to have been developed and the basis for the concept proven. Nevertheless this is not the end. It is instead only the beginning since it will be left to ship system applications to implement the SHINPADS concept in a true ship system.

Conclusion

It is considered that the SHINPADS approach provides an integrated system with a distributed architecture utilizing standard components whose inherent features include reconfigurability, redundancy, and equipment commonality thereby providing increased capability for fewer life-cycle dollars. It is suggested that such combat survivability and decreased life-cycle cost are *not* available with any other approach.

REFERENCES

*[1] Carruthers, J.F., LCdr., CF, "An Integrated Shipboard Processing and Display System — A Proposal," January 1976.

[2] Creation of NATO Group NIAGSG6 on Interface Standardization.

[3] NATO Document AC/141 (IEG/5)D/43 (2nd Revision), *STANAG 4153,* 16 May 1973.

*[4] Carruthers, J.F., LCdr., CF, "A Common Computer for Shipboard Applications," DMCS Background Paper, 9 February 1975.

Carruthers, J.F., LCdr., CF, "SHINPADS — Shipboard Integrated Processing and Display System — Data Rates," August 1976.

[6] Williams, P.F., "AN/UYK-502 Microcomputer Development and Use in Distributed Systems," presented ASNE Day 1979, *Naval Engineers Journal,* Vol. 91, No. 2 (April 1979).

[7] Kuhns, R.C., "SHINPADS Serial Data Bus," presented ASNE Day 1979, *Naval Engineers Journal,* Vol. 91, No. 2 (April 1979).

*[8] Carruthers, J.F., Cdr., CF & P.F. Williams, "SHINPADS — Shipboard Integrated Processing and Display System," *Proceedings of the International Naval Technology EXPO 78,* Rotterdam, Netherlands, 6-8 June 1978.

[9] Thomas, D.M., "SHINPADS Standard Display, presented ASNE Day 1979, *Naval Engineers Journal,* Vol. 91, No. 2 (April 1979).

*[10] Carruthers, J.F., Cdr., CF, "SHINPADS — A Ship Integration Concept," *Proceedings of the FIFTH Ship Control System Symposium,* Annapolis, Md., 30 Oct.—3 Nov. 1978.

*Canadian Forces (CF) design papers available to qualified authorities upon request.