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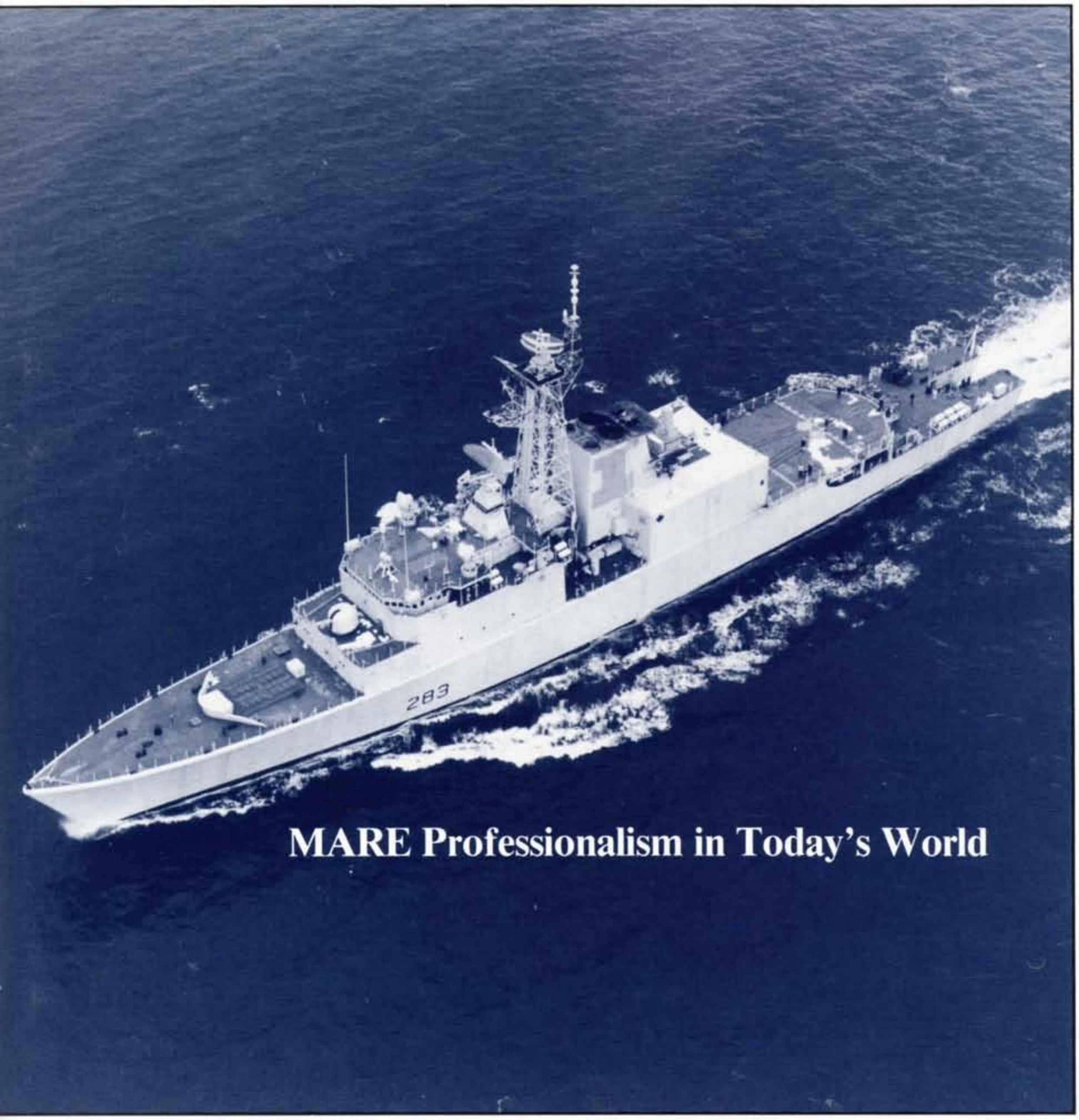
Maritime Engineering Journal

April 1991



Canada

Electrical Propulsion — Good enough to break ice, but is it quiet enough for an ASW ship?


(Transport Canada photo by Paul Heath)

The Canadian Coast Guard icebreaker *Henry Larsen*

. . . page 11

Maritime Engineering Journal

Director General
Maritime Engineering and
Maintenance
Commodore M.T. Saker

OUR COVER

HMCS *Algonquin*, last December, sailing into Halifax Harbour for completion of her TRUMP modernization work. *(Courtesy PMO TRUMP)*

APRIL 1991

DEPARTMENTS

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Editor's Notes

Accountability and sea experience: A few thoughts on the engineering profession

An interesting letter by Messrs Clunis and Gingras appeared in our July 1990 edition regarding engineers within DND not requiring a professional engineering licence. The writers expressed concern that "the situation within the federal civil service creates an environment where incompetent and negligent engineers could continue to work and escape responsibility and accountability for their actions."

High standards of performance, conduct and ethics are indeed legislated and enforced by the provincial professional engineering associations, but it does not follow that they provide the only means of ensuring these standards are met. DND has the option and perhaps even the need, because of the nature of its business, to be "self-regulating." DND engineers *are* held accountable for their work, and this accountability applies right up the chain to the minister of national defence who is accountable to the public through Parliament. Within DND there are avenues for disciplining military and civilian engineers, both, should incompetence be detected.

On this the debate will doubtless continue, but that is a healthy sign. When all is said and done, the effectiveness of our system depends on the integrity and professional culture which exist in the engineering community within DND.

In our lead article LCdr Serge Garon examines this issue from a MARE perspective, and raises the point that MAREs are not just engineers in uniform. In this regard I would like to take a few lines to emphasize the importance of sea experience to the MARE profession. Due to space constraints I will limit my remarks primarily to MSEs and CSEs, but to ensure my dissertation is not seen as just a plumber's view I should mention that Captain Brown (DMCS) agrees with it!

Statements to the effect that a job at sea is not a prerequisite to a career as a MARE MSE or CSE, and that the end goal of an MSE or CSE is not to be a ship's head of department, while strictly correct, appear to have downplayed the importance of sea experience in the eyes of junior engineers. Theoretically, the job of ship's head of department is not a prerequisite to a challenging career; for example, there is no formal policy that says my job as DMEE cannot be done without experience as an EO. *But*, the fact is, maritime engineering is all about personnel, equipment and systems at sea in warships. Thus, it behooves MARE officers and the navy to ensure an adequate level of sea experience in our profession.

Sea experience for all subclassification qualifications has recently been reviewed with this in mind. For MSEs and CSEs, sea experience beyond the 44B/44C requirement does pose a problem in the short term in that not all officers completing subclassification training will be able to go immediately to assistant head of department positions. Selection for these positions will be primarily by merit and those who do not make it on the first go could do so at a later date, depending on their performance in the jobs they are doing.

But I would also like to stress that the best learning experience there is for fully understanding our equipment, systems and personnel is at sea as the head of department. Carrying this responsibility will provide the best base to build on as officers venture into and provide leadership in the many facets of marine and combat system engineering ashore. Selection for head of department positions will also be based primarily on merit.

The navy will continue to develop engineers for leadership roles by expanding knowledge bases, improving "people skills" and providing sea experience. The aim of each of us in the MARE profession is to develop our talents so as to achieve our full potential as maritime engineers, and to have our career portfolios (our résumés, if you will) look as attractive as possible to merit boards and prospective commanding officers. In this respect, sea experience must always be a vital ingredient of our profession.

I hope you enjoy this issue of the ***Journal***. Please do keep your articles and letters coming.

Captain(N) David W. Riis
Director of Marine and Electrical Engineering

Commodore's Corner

By Commodore M.T. Saker

As we are about to put this edition of the ***Journal*** to bed the news from the Gulf seems very encouraging and it looks as though the Coalition Forces have succeeded in their mission. I know that you join me in expressing our heartfelt thanks and congratulations to those who played a direct part in that success. From a naval viewpoint, the performance of our ships and helicopters in the Gulf has been truly impressive, particularly during the increased tempo that followed the commencement of hostilities. Their success has been a credit to those who served in them, to those who kept them in good shape over the years, and to all those who helped get them ready and supported them in the theatre. Bravo Zulu!

Those of us here in National Defence Headquarters have been fighting slightly different, but equally important, battles of our own. Like many other nations, Canada is facing severe financial difficulties and is wrestling with ways to reduce costs and thereby our national debt. Just before Christmas, the NDHQ Review was completed and decisions were reached which resulted in about a nine-percent reduction in Headquarters person-years from the previous year. This was achieved by reprioritizing our work and dropping a number of less important activities (or at least reducing the effort). In my view this is just the beginning of a series of measures that will have to be taken clear across the Forces as we pare down our work to fit the resources

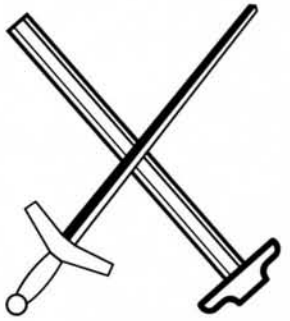
available. We have just begun this activity which over the next year or so will reach out and affect us all. We will be examining all aspects of our work in an effort to achieve greater effectiveness and economy. Some of you, because of your position, will be invited to participate; others, who may have suggestions to offer, should not be shy about coming forward.

It may seem incongruous that at the very time our armed forces were being called into action we were being asked to cut costs and reduce our size. Canada is not alone. The forces of the United States and Britain, to name but two, are being asked to do the same thing. We should not despair. This is not a time to throw our hands up in defeat and abandon our responsibilities. It is a time to address the task at hand and make the necessary adjustments so that Canada can have the most effective armed forces for the available resources.

MARE

MARITIME ENGINEERING JOURNAL OBJECTIVES

- To promote professionalism among maritime engineers and technicians.
- To provide an open forum where topics of interest to the maritime engineering community can be presented and discussed even if they may be controversial.
- To present practical maritime engineering articles.
- To present historical perspectives on current programs, situations and events.
- To provide announcements of programs concerning maritime engineering personnel.
- To provide personnel news not covered by official publications.



MARE Professionalism in Today's World*

By LCdr Serge Garon

***This article is based on the author's presentation to the Central Region MARE Seminar in 1989.**

Introduction

During the past ten years there have been significant changes in the training and career progression of maritime engineers (MAREs) in the Canadian Forces. For marine and combat systems engineers, even the ultimate goal of becoming Head of Department of a ship appears to have lost some importance to other career employment possibilities. There is less sea time than in the recent past, earlier and more involved technical employment, and, it seems, an improvement of the MAREs' status as "engineering professionals."[1] Indeed, it appears that MAREs have become uniformed engineers!

Yet, MAREs still have to accomplish many military tasks, spend time on non-engineering work, and are regularly posted out of jobs at which they have become proficient. Why is this? Weren't MAREs hired to engineer?

This paper examines MARE professionalism in today's engineering society. It attempts to put the MARE into perspective with other professionals, especially the civilian engineer, and to foster a sense of identity about the MARE family. It proposes a MARE professional goal and presents some views which, hopefully, will trigger further thought and discussion.

Misinformation

Many MAREs talk about *job* and *contract*. However, there is no such thing as a MARE contract which either party can breach at will![2] The only related document is the commissioning scroll (a one-way commitment). MAREs are neither employed nor hired to provide a particular engineering service or product. Rather, they are recruited and retained to serve as *engineering officers*.

In return for their full-time dedicated service, MAREs are provided with sufficient financial security so as not to have to look for alternative sources of income. Civilian engineers are sometimes said to have better pay and employment security than MARE officers. However, as witnessed in a pay survey completed by a professional engineering association[3], except at very junior ranks, MARE pay and benefits are comparable to those of civilian engineers. In addition, the MARE's promotion opportunities and job security are generally better.

> "Perhaps MAREs have to understand that what is expected of them is a commitment to service as opposed to performance exclusively in the field of engineering."

With respect to the type of work MAREs perform, statements of frustration are sometimes heard: *"Why do I have to put up with this? Why do I have to go to sea? Why can't I do real engineering?* These questions indicate a misunderstanding between what is expected of MAREs and what they themselves expect to do.

MAREs are not uniformed engineers! The officer-like qualities learned and exercised during training are not simply tickets to have punched — they are a way of life; otherwise, why join the Canadian Forces at all? Perhaps MAREs have to understand and accept, early on in their careers, that what is expected of them is a commitment to service, as opposed to performance exclusively in the field of engineering.

Professionalism and Purpose

Both the civilian engineer and the MARE officer are professionals who use engineering skills and knowledge. However, they do not have the same purpose, the same on-the-job training or the same work environment.

When comparing these two professionals it is useful to begin with certain definitions. Professions can be categorized as being either associational or bureaucratic. Engineering (like medicine, law and the clergy) is normally associational because it is based on a specific field of knowledge. Its practitioners are independent of each other and have direct (associational) relationships with person-clients[4]. In addition they imply the existence of legally constituted professional associations, to which clients may complain if desired.

In contrast, military officership (like the diplomatic service) is a bureaucratic profession whose existence has a political basis. It maintains a high degree of specialization of labour and responsibility within itself, and renders a collective service to the whole of society[4]. Bureaucratic professions usually have very strict rules of conduct (or an internal policing system) somehow supported by law, which are enforced by the senior members of the profession. However, since they are owned and controlled by the client[4], there is no independent association to which the client can complain in case of unsatisfactory service.

Beyond these differences, there are five common professional attributes[4], some of them being of particular interest here:

1. a systematic theory (body of knowledge, whys and hows of one's sphere of competence);

(CFB Halifax photo by MCpl Mike Dolliver)

2. a professional culture (jargon, procedures, etc.);
3. a code of ethics (rules of conduct and self-discipline in society's best interest);
4. community sanction (to perform specific services and to be self-governing); and
5. authority (i.e. sole privilege to deliver a particular service to the community).

The knowledge required of a given professional could be the object of a long debate. But for the purpose of this paper it is probably correct to say that a civilian engineer must principally develop expertise in a given engineering field or systematic theory, and that other topics, such as laws and administrative procedures, will also be studied if pertinent to the application of the selected engineering specialty. Thus, the engineer's level of professionalism can be assumed to be directly related to the level of excellence in the specialty.

The MARE, on the other hand, must systematically, early on in a career, learn how to assess the capabilities and requirements of both the specialist engineer and the naval operator. The MARE must also relate to the realities of manufacturing, maintenance, management, costing, etc., while gaining maintenance and operator skills in a subclassification. At the same time the MARE has to be able to handle a number of secondary duties, management responsibilities and purely military tasks, and still cope with regular disruptive postings.

Should we expect the MARE to achieve excellence in that many apparently unrelated fields? Perhaps a MARE's excellence is required at a different level. The difference is very subtle, but it is fundamental. It is the main reason why the two career progressions are different.

Civilian engineers are hired to provide specific, product-related engineering services. They may choose to remain in a given engineering position for their entire working lives, but should they desire promotion they would have to seek and acquire the requisite experience on their own.

In contrast, a MARE officer's postings are often training postings, or stepping stones. They are selected to make the best immediate use of the MARE's engineering talents, but also (and most importantly) to expose the officer, systematically, to as many different work environments and situations as possible. By the time the MARE reaches high rank there will be this broad base of experience and knowledge — so necessary to achieving excellence in command (or senior leadership) — that can be called upon. Thus the MARE must aim at excellence not as an engineer, but as an engineering officer.

Professionalism is also, and most importantly, legally based on a commitment to service and righteousness according to a code of ethics. For instance, in each province an act of parliament subjects every professional to such a code and to its enforcement (power of self-discipline) by an appropriate professional association or internal policing system. Hence, professional engineers will lose their licenses to practice if they act in conflict with accepted engineering requirements. They also have the moral duty (supported by the code) to inform society about things within their field of knowledge which compromise professional values — even at the risk of being "retired" by the employer.

The concepts of ethics may be said to apply to military professionals as well. This being said, Canadian military officers have no written code of ethics, per se, but we may assume one exists in the form of military traditions, the Oath of Allegiance, Queen's Regulations and Orders, Canadian Forces Administrative Orders and the items that are rated in performance evaluation reports.

The underlying principles of such a military code must be based on[4]: attainment of the objectives for which the profession exists (which might imply violence), and a harmonization of these objectives with the precepts of humane values. More specifically, the code must contain five principal elements[4]: personal honour, obedience and limits of moral freedom, relationships to society as a whole, relationships to existing political institutions and forces, and the moral implications of command responsibility.

Without going into the details, it is evident that the military code has elements which would not be expected in the civilian code; elements such as command, limits of moral freedom and the possible conflict between the objectives of the profession and humane values. These elements and conflicts relate to the fact that the military has license to take lives, inflict extensive damage and, ultimately, to wage war when required by the state.

Thus, even though the capabilities of the armed forces are often used for purposes other than war, the existence of the military profession (ergo the MARE profession) is due exclusively to war or to its possibility. Whereas civilian professionals have a liability limited to their right to practice and to the payment of money (as in damages and fines)[4], *the military profession implies an unlimited liability* on the part of its members (i.e. it may demand the ultimate sacrifice).

In light of what has been said so far, a simple and short definition of the MARE professional goal can now be proposed. The MARE is a full member of the Canadian officer corps, whose primary purpose is the management of organized violence on the international scene[4] on behalf of Canada. The MARE's immediate duty (or technical goal), then, is the management of vast scientific and technical knowledge and skills in support of the primary corporate goal of the Canadian officer corps. Ultimately, the overall duty (long-term goal) of the MARE ought to be the achievement of excellence in command, as for any general list officer.

Conclusion

MARE officers can certainly consider themselves to be engineering professionals and potentially professional senior managers. MAREs are nonetheless very different (although in a subtle way in peace time) from civilian engineers, due to things such as war and its unlimited liability, the bureaucratic aspect of the MARE profession, subordination to the state, diversification of expertise, a systematic career progression towards command (or senior leadership), and a commission to serve in the broadest sense of the word.

More and more, MAREs must gain and use extensive engineering knowledge in order to manage the application of engineering know-how to the needs of the sea element of the Canadian Forces. In that sense they are engineering professionals. However, they remain, first and foremost, professional military officers.

Acknowledgment

The author wishes to thank the following persons for their invaluable assistance during the preparation of this article: Cdr R. Westwood, LCdr R. Greenwood, Lt(USN) S. Surko, LCdr D. Davis and Mrs M. Touchette-Garon.

Notes

1. The phrase "engineering professional" is purposely used as opposed to "professional engineer," the former being related to the broad philosophical meaning of being a professional (in an engineering field), the latter being a legal title.
2. Theme Letter Concept of Service, 1455-1 JAG, dated 24 April, 1989.
3. "Remuneration Survey of Salaried Engineers in Quebec 1989," published by l'Ordre des Ingénieurs du Quebec.
4. "Officer Professional Development Program # 7" reading material.

LCdr Garon is a naval architect (44E) and Ship System Manager for PMO TRUMP. He is also a chartered engineer (UK) and a member of the Royal Institute of Naval Architects (UK), the Canadian Institute of Marine Engineering and L'Ordre des Ingénieurs du Québec. LCdr Garon received a "T.M. Pallas" MSE C of C (Part II) top-student award in 1983.

The Need for an Evolutionary Transition of Computer and Software Technology in Ships

By Cdr Roger Cyr

Introduction

During the 1990s the Canadian navy will take possession of 12 new Canadian patrol frigates and 4 modernized Tribal-class destroyers. Although these ships will be equipped with modern and capable weapons and sensors, their computers and software will be dated and suboptimal on the day they join the fleet. Yet, these computers and software systems reflected state-of-the-art technology at the time the ships were designed. This situation occurred because of the long period of time that has elapsed between the time the ships were designed and when they are to come into service.

Given that it would be very costly to totally replace these systems today, there is a need to upgrade the computer and software suites of these ships in an evolutionary fashion over the years the ships will be in service. In this way modern technologies can be introduced to meet operational requirements at minimal cost.

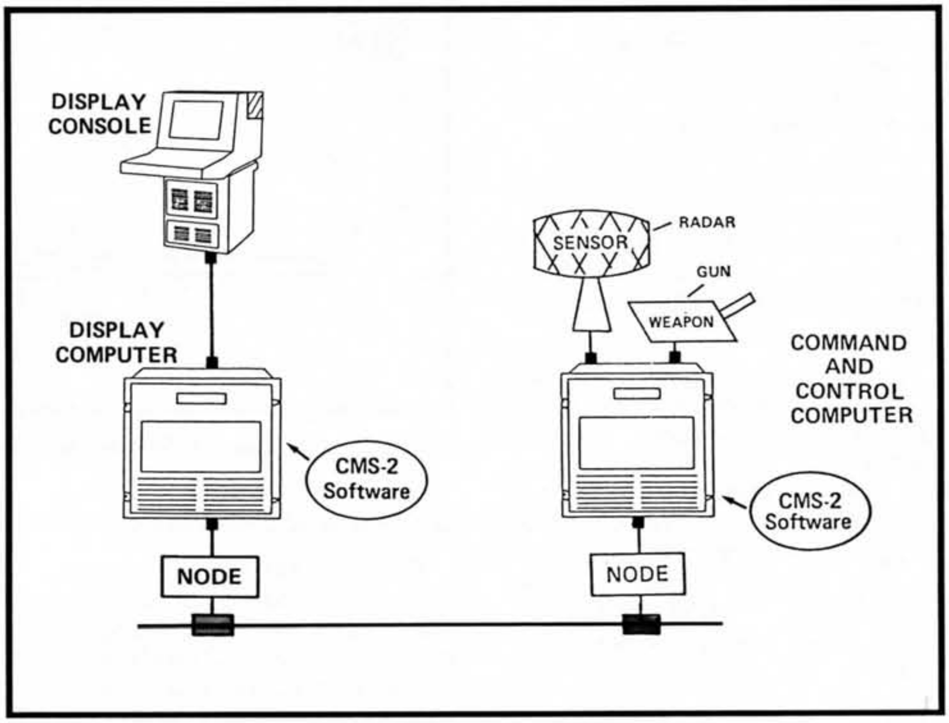


Fig. 1. Simplified SHINPADS Data Bus

Background

The combat suite of the frigates and destroyers incorporates a distributed architecture that uses the SHINPADS system. The Shipboard Integrated Processing and Display System, as conceived by the Canadian navy, is intended to meet shipboard tactical data handling requirements.

The SHINPADS data bus fulfils a total shipboard data flow function that was specifically designed to accommodate system growth. It is a revolutionary concept that allows the system designer to use existing equipment and technology while allowing for the insertion of new equipment and technologies as they become available. The SHINPADS data bus interconnects all the various sensors and weapon subsystems that form the ship's combat suite, providing a tactical data path between them. The bus interconnection also provides a standard interface which readily provides means by which the ship's combat suite may be easily enhanced when windows of opportunity for upgrading equipment present themselves.

There are two basic types of connections to the SHINPDADS data bus: the display connections and the command and control connections (*Figure 1*). The display consoles are connected to the bus via the display computers. These computers are military UYK computers that house the CMS-2 software required to drive the displays. All of the ship's sensors and weapons are connected to the data bus via the command and control computers. There are also military UYK computers that house the CMS-2 software required for the tactical data management of the combat suite. All of the UYK computers are physically connected to the data bus via nodes and bus access modules (BAMs).

Evolving Tactical Requirements of Ships

The tactical and operational requirements in naval ships are in a continual state of change. As a result, there is an ensuing need to continually change the data processing requirements of ships. The open architecture of SHINPADS provides a ready method by which data processing capabilities can be upgraded as the need arises and as more powerful processors become available in the marketplace. Hence, a distributed system based on a data bus lends itself to a graceful upgrade of the data processing capabilities or functions in an evolutionary fashion.

Use of Commercial Products

Advances in data processing will be critical to meeting the tactical needs of our ships. However, because it takes such a long time and is so costly to develop unique military systems, any upgrading of the presently fitted tactical data processing equipment must take advantage of commercial innovations and developments. Emerging commercial technology can then be adapted to military uses.

There is no doubt that ever-shrinking military budgets will force greater dependency on commercial data processing products in the future. Any evolution will have to make use of emerging commercial technologies. The rationale for the shift to commercial products is readily apparent — commercial products take less time to develop and are less costly.

Militarized products cannot keep up with this rapidly changing technology, and as a consequence are rapidly falling further behind in capability. For example, a Motorola-based computer mounted on a single circuit card (weighing about one pound) would have the processing capability of the eight military AN/UYK-505 computers which together weigh about one ton.

Another aspect which makes commercial data processing equipment much more attractive is the availability of software tools and products that are particularly tailored to commercial processors. The software language of choice for the future by both the military and commercial sectors is Ada. There are now more than 300 Ada compilers available to run on commercial processors. However, Ada compilers are just now emerging for the military UYK series of computers. Hence, software for commercial computers has the potential to be significantly less costly than the software developed for military computers. This is simply because of the greater availability of the Ada tools and compilers for commercial computers.

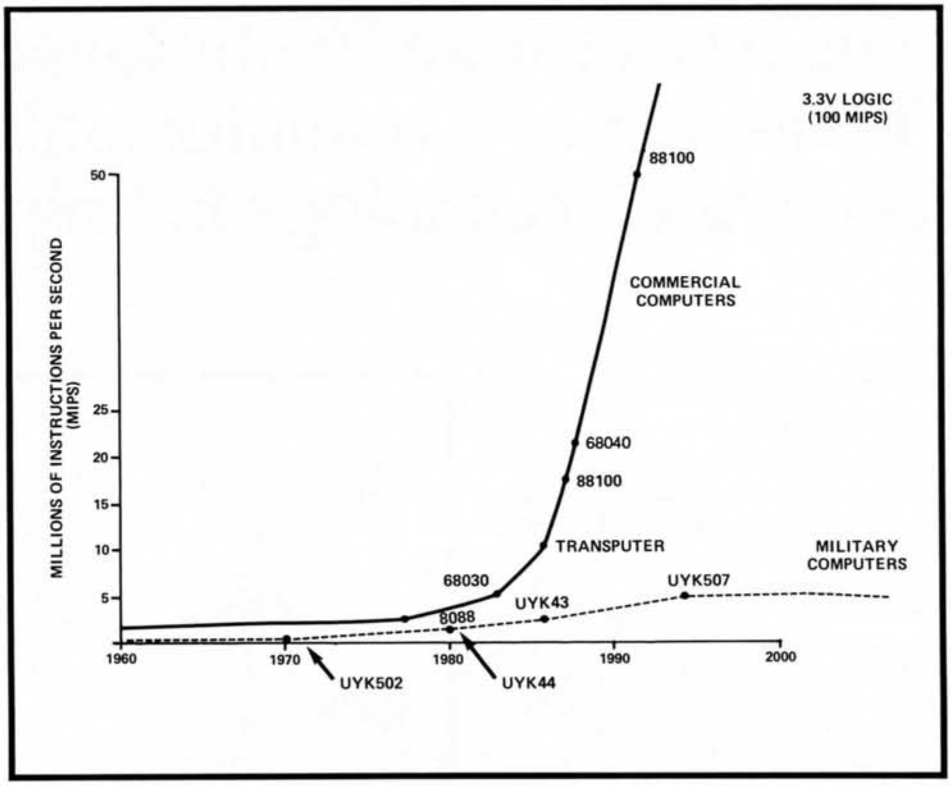


Fig. 2. Comparison of Military and Commercial Development

Deficiencies of Militarized Computers

Change in the data processing industry continues at an incredible pace. Militarized computers lag far behind commercial products with regard to processing speed and memory capacity. As can be seen from *Figure 2*, current militarized processors have about five percent of the speed and memory of current commercial products. These suboptimal computers also cost about ten times more than ruggedized commercial computers. So why do we bother using militarized computers when ruggedized commercial computers are a viable alternative?

The stated primary reason for using militarized computers is their survivability in a hostile environment. The tactical computing needs of our ships can indeed be met with ruggedized commercial products, without the overkill and attendant cost and performance penalties associated with militarized products. It should be noted that the present specifications for militarized computers originated in the 1960s when computer technology was still in its infancy. The militarized computers were then necessary because the commercial equipment of those days tended to be rather fragile. This is not so today.

The industry has changed, and through experience and evolution the equipment built today is simply more rugged and far more reliable. In 1988 when the USS *Stark* was hit by an Iraqi Exocet missile and put out of action, the missile cracked the command and control displays and the militarized UYK computer. A nearby commercial Hewlett-Packard series 9000 computer, however, remained operational — the only computer that could still be used.

Upgrading CPF and TRUMP

The computer hardware and software fitted in the frigates and destroyers will need to be continually upgraded, starting on the day the ships enter service. The design specifications for the Combat Direction System (CDS) of these ships were drawn up some 15 years ago. Since then, there have been many tactical and operational changes which will need to be implemented by the navy to ensure the ships are interoperable with ships of other NATO navies. However, because of the high cost and the time required to develop software, the entire combat software suite of the ships just cannot be rewritten.

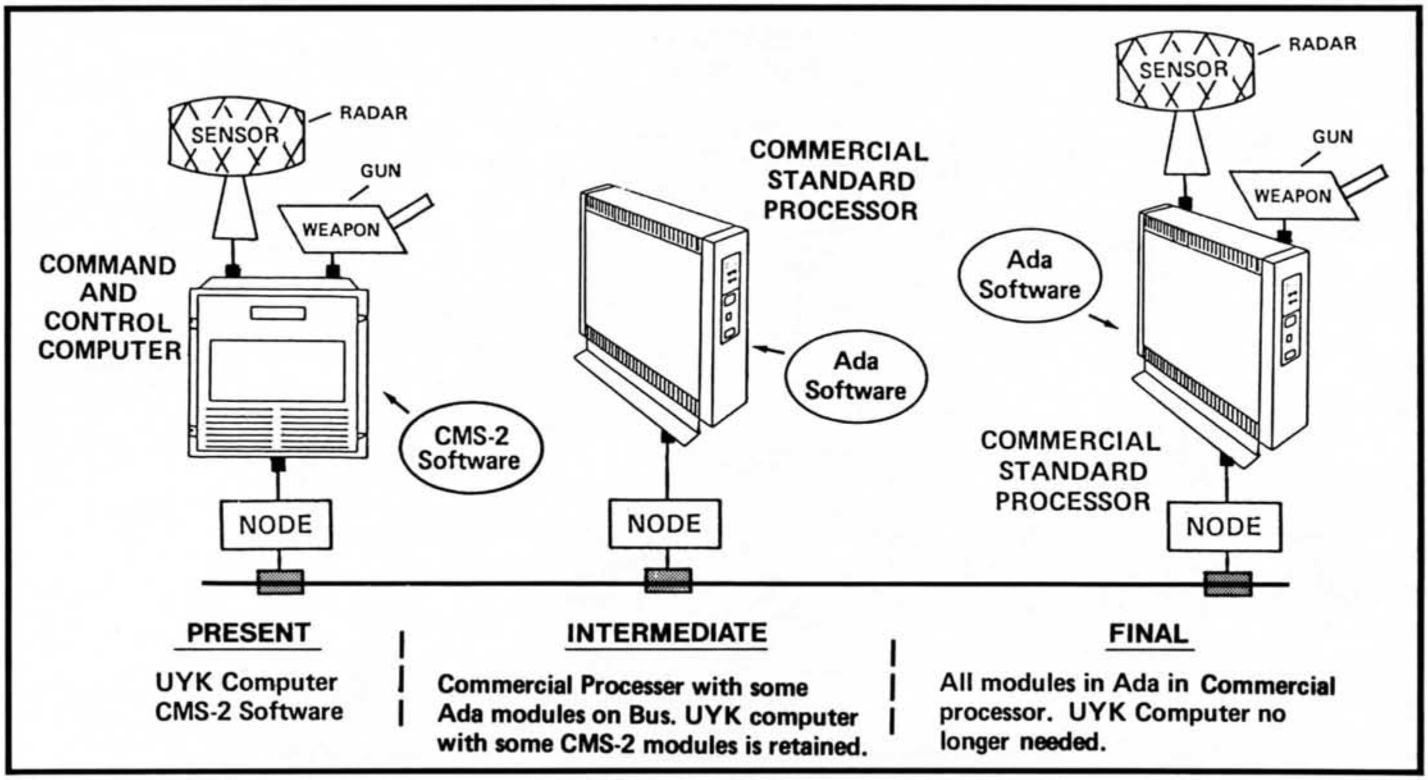


Fig. 3. Gradual Transition from Command and Control Computer to Commercial Processor

Historically, CDS software developed in the traditional language, CMS-2, costs about $200 per instruction to develop. Since the present CDS software of the frigates is about two million instructions, rewriting the entire suite would likely cost some $400 million.

Recently published results of using Ada indicate that substantial savings can be realized by developing software in Ada (at an estimated $65 per instruction). Rewriting the CDS software of the frigates in Ada, then, would cost about $130 million. Even so, it is an expenditure that is just plain unaffordable.

Instead there must be a gradual rewriting of the portions that need to be upgraded to meet changing operational requirements. Such upgrading must reflect current state-of-the-art technology in both the processors and software language, and so must make use of processors that reflect fresh commercial technology, make use of the growth properties of the SHINPADS data bus, and take full advantage of the most commonly used and most economic software language, Ada.

How to Upgrade

Given the need to eventually migrate the CDS software from CMS-2 to Ada, all enhancements or upgrades to the system should be done in Ada. They should also make use of a processor that reflects commercial technology. This could be achieved two ways:

1. by gradually replacing the UYK command and control computers with commercial standard processors; and
2. by gradually replacing the UYK display computers with processors that can be actually embedded into the display.

Replacing the Command and Control Computers

The present command and control computers could be gradually replaced with processors that reflect current commercial technology (*Figure 3*). This gradual replacement could be achieved by introducing the commercial standard processors one at a time as they are required to house new software modules that are programmed in Ada. That is, as each software module presently coded in CMS-2 needs to be upgraded, it is redone in Ada. The new module is then housed in a new machine connected to the data bus. As more and more software modules are redone in Ada, more of the new commercial processors are added to the CDS. Eventually, all software will be in Ada and all of the UYK command and control computers will have been replaced.

Embedded Processors in the Displays

Another method of introducing Ada software, and one which can be progressed concurrently with the replacement of UYK computers, is by embedding microprocessors in the display consoles. These embedded micros would also reflect commercial state-of-the-art technology, and would allow the gradual introduction of Ada software and the eventual replacement of the UYK computers that act as display drivers for the display console (*Figure 4*).

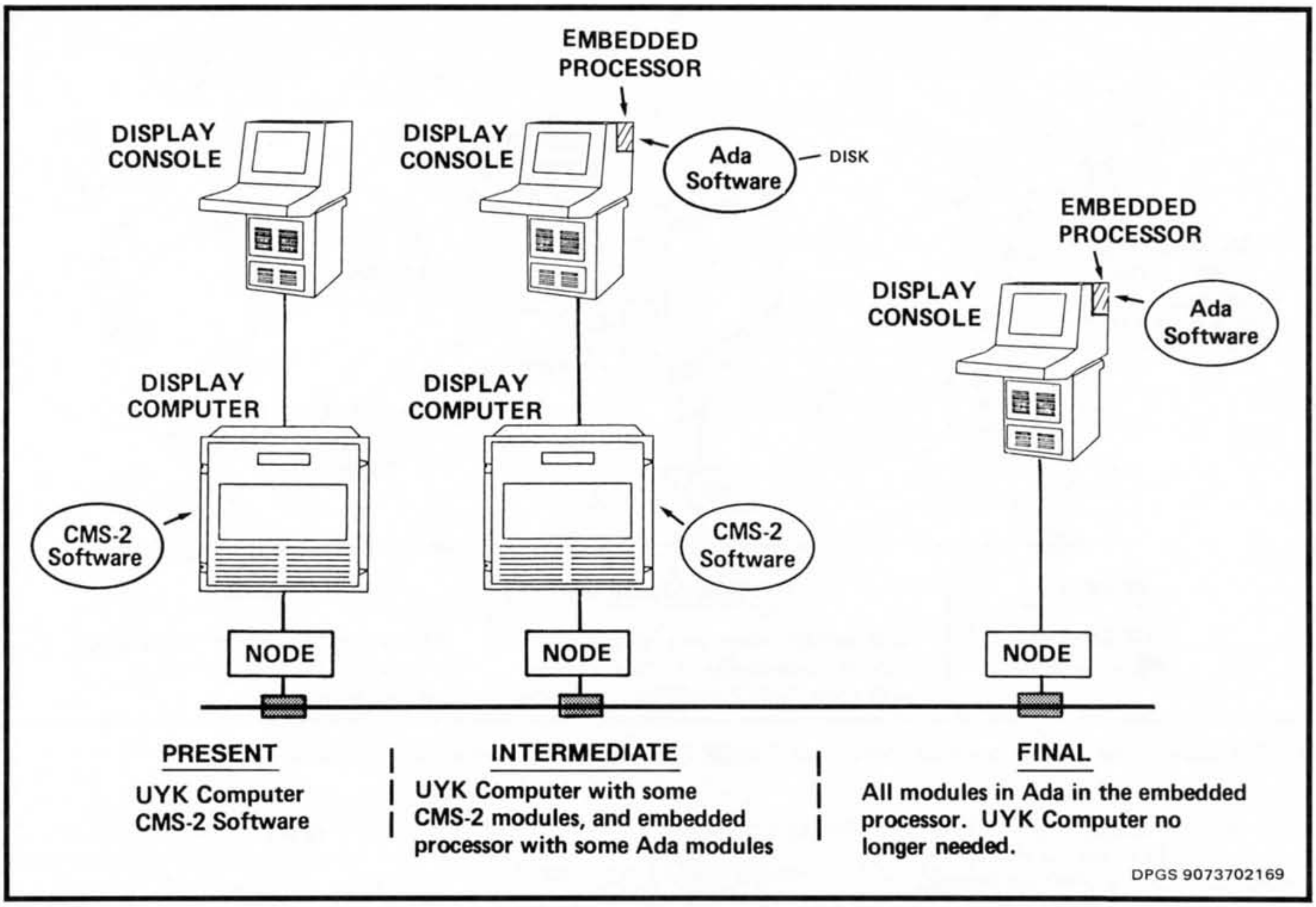


Fig. 4. Gradual Transition from Display Console Computer to Embedded Processor

As each CMS-2 software module that performs display functions needs to be upgraded, it is redone in Ada. The new Ada module would then be housed in a microcomputer card embedded in the display console. Eventually all the software modules now residing in the display computers would be coded in Ada and relocated in microprocessors embedded in the standard displays. The 13 UYK computers that are presently required to drive the displays would no longer be required.

The New Helicopter

The new shipborne helicopter that is currently being procured provides a unique opportunity to start this gradual evolution of computers and software to modern technologies. The new helicopter will need to have a tactical link to the ship's CDS so that the tactical picture may be loaded into the helicopter's CDS prior to its departure on a mission. To do this will require an additional display console, display computer and associated software for the ship. This gives the navy its first chance at a gradual introduction of modern computer and software technologies.

Conclusion

In the years ahead there will be a need to upgrade the computer and software systems of the frigates and destroyers to meet the ever-increasing tactical data flow requirements of naval warfare. Given the excessively high cost of a total replacement of these systems, there is a requirement to initiate an evolutionary transition of these systems to state-of-the-art computers and software. This can be economically achieved by the gradual introduction of modern commercial standard computer hardware and Ada software.

Cdr Cyr is the DMCS 8 section head for naval computer technology at NDHQ.

Naval Engineering Test Establishment

Vibration Investigation on a Type 1200 Icebreaker

By R. Jacobs and J.R. Storey

Introduction

AC/AC electrical propulsion is considered a viable alternative to mechanical propulsion drives for frigate-size naval vessels. The AC/AC variable frequency synchronous motor propulsion system has all the advantages of the electric motor, such as high efficiency, precise speed control and quiet operation. These characteristics make the system an attractive method of propulsion for anti-submarine warfare (ASW) naval ships.

There is some concern, however, that electrical harmonics of the cycloconverter output may be manifesting themselves as mechanical vibrations in the propulsion motors, which would contribute adversely to the acoustic signature of the vessel. This would not be acceptable for ASW naval ships, especially if the vibrations were to exceed the levels now encountered in mechanical propulsion drives.

The Naval Engineering Test Establishment (NETE) recorded vibration and electrical power data measurements from the cycloconverter propulsion system fitted on the Canadian Coast Guard icebreaker *Henry Larsen*, and investigated the relationships between propulsion motor vibrations and the cycloconverter harmonics. The effect of the main diesel alternators on the propulsion motor vibration signatures was also studied during the investigation.

The results of the investigation indicate that the cycloconverter's 4160-V and 1200-V buses contained significant harmonic distortions. However, the only significant correlation between electrical harmonics and propulsion motor vibration was the cycloconverter 1200-V output bus fundamental frequency (variable from 0 to 18 Hz). In the frequency range above 550 Hz, the propulsion motors exhibited low vibration levels at all test speeds. This indicates that the AC/AC system has potential as a low-noise propulsion system.

This paper describes the work conducted on the *Henry Larsen*, and discusses the salient findings of the investigation.

Sea Trials

The propulsion system on the *Henry Larsen* consists of two rigidly mounted 8000-h.p. (1200-VAC) synchronous motors with a speed range of 0 to 180 r.p.m. The propulsion motor speed is directly proportional, by a factor of ten, to the cycloconverter frequency output which is variable from 0 to 18 Hz. The primary electrical supply (4160 VAC, 60 Hz) is generated by three Wartsila 12V32 diesel-powered alternators rated at 6250 kVA each.

The sea trials were performed in July 1988 in Esquimalt, British Columbia. The survey encompassed recording vibration and electrical data during eleven propulsion motor speeds (25, 50, 75, 100, 111, 125, 141, 155, 163, 170 and 180 r.p.m), a crash reversal and a series of turning manoeuvres. (The information gathered during the reversal and turning exercise is not presented in this paper, as only a superficial analysis was performed on the data from those tests.)

The instrumentation used during the survey consisted of two 14-channel instrumentation-quality VHS tape recorders and appropriate transducers. Piezoelectric accelerometers were used to monitor mechanical vibrations, and standard high-voltage electrical sensors were used to monitor voltage and current data.

Electrical power data, consisting of voltage and current time waveforms, were recorded from both the input (4160-V) and output (1200-V) voltage buses. Power factor measurements were also recorded, but only from the starboard propulsion motor 4160-V bus.

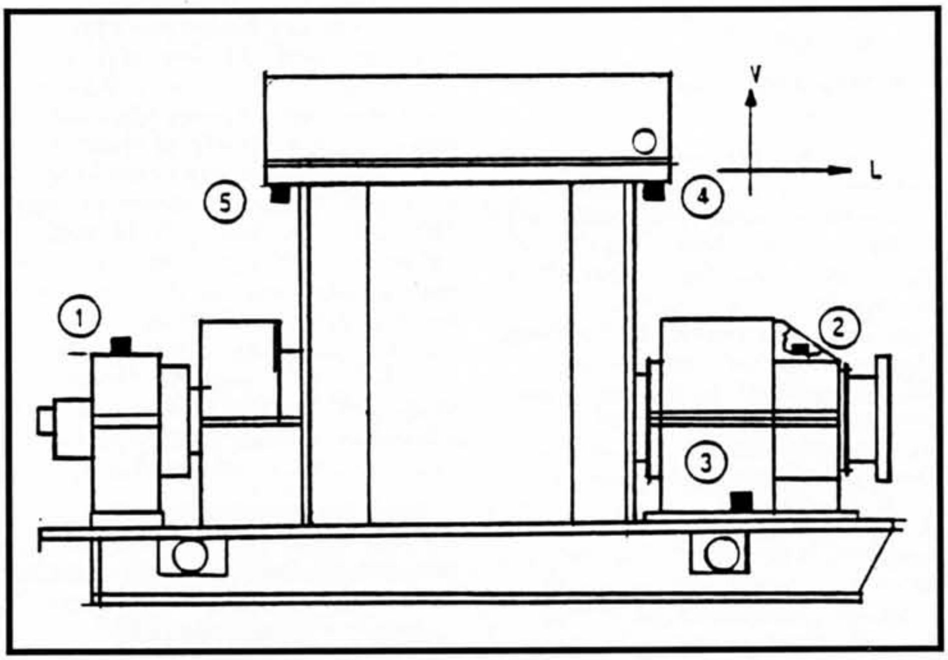


Figure 1. Henry Larsen Propulsion Motor Schematic Showing the Location of the Vibration Sensors

A total of five vibration monitoring locations (*Figure 1*) were employed to measure the vibration generated by each of the main propulsion motors. The pedestals and base of the propulsion motors were considered to be the primary monitoring positions for this investigation, as significant vibrations at these points were expected to be present in the ship's acoustic signature. Only vibration data above a level of 70 VdB (reference 10^{-6} cm/s) was considered significant to the analysis, as propulsion motor vibration amplitudes below this value are normally not considered to be a factor in the underwater noise signature of the ship. The background vibration levels and instrumentation sensitivity were also taken into account when establishing the 70-VdB cut-off level.

Analysis Results

The vibration levels recorded from the primary monitoring positions of both propulsion motors were below 70 VdB above 550 Hz for all test speeds. This indicated that no significant electrical or diesel influence was present on the motor pedestals or base above 550 Hz. The propulsion motor vibration spectra contained several frequency components below 550 Hz, with most components concentrated below 100 Hz. Some of the components were traced to the following sources:

a. main diesel alternators

b. auxiliary diesel generator

c. electrical

d. propulsion system natural frequency

Above- and below-mount propulsion diesel vibration data indicated that the main diesel fundamental (12 Hz) and some harmonics (24 and 30 Hz) were present on the propulsion motors. Background vibration data recorded before the propulsion diesels were operating indicated that the ship's auxiliary diesel generator fundamental (20 Hz) and its first two harmonics (40 and 60 Hz) were also present on the propulsion motors.

Each of the electrical waveforms measured, when observed in the frequency domain, yielded several frequency components. Most components, however, had an amplitude of less than five percent of the fundamental frequency and were not correlated to motor vibrations.

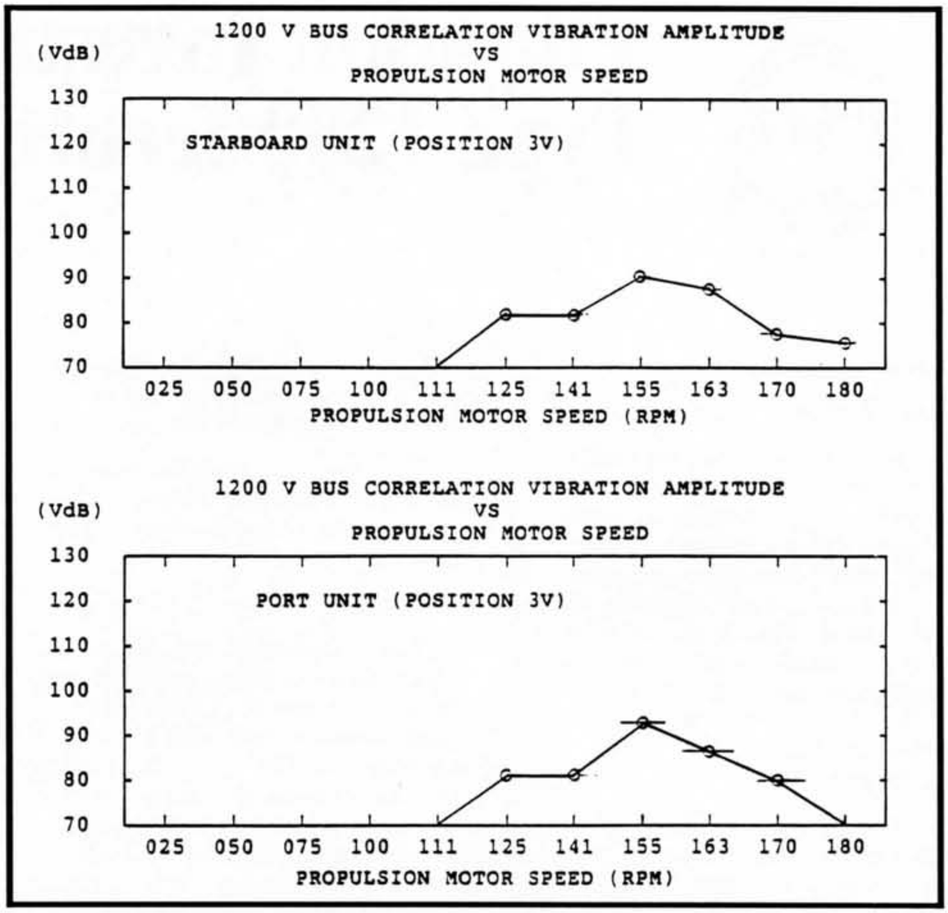


Figure 2. 1200-V Bus Frequency Vibration vs. Motor Speed (Starboard and Port Propulsion Motors)

One significant correlation observed between the electrical and mechanical vibration domains was the propulsion motor 1200-V bus fundamental frequency, variable from 0 to 18 Hz, and mechanical vibrations in the propulsion motors. As shown in *Figure 2*, the 1200-V bus frequency vibration was visible (i.e. 70 VdB or greater) on both motors at primary monitoring point 03V for speeds between 111 and 180 r.p.m., and reached its highest amplitude at 155 r.p.m. *Figure 3* contains a 1200-V bus voltage spectrum superimposed on a propulsion motor vibration plot, both of which were recorded at 170 r.p.m. for the starboard unit. The plot demonstrates the correlation between the electrical and mechanical vibration domains.

Some less significant correlations were also observed. However, they were not consistently present throughout the speed range and were therefore not considered significant.

Manufacturer's literature indicated that the main propulsion shaft line has a torsional natural frequency very near 15 Hz. Although no torsional vibration data was recorded during this survey, the most pronounced linear vibration level observed, at the primary motor monitoring points, was at 15.2 Hz at a motor speed of 155 r.p.m. The amplitude of the 15.2-Hz peak was highest in the axial direction on the rear pedestal of each motor, reaching almost 110 VdB on both units.

Figure 4 shows the octave-band vibration patterns for the base of the propulsion motors (03V) at 155 r.p.m. The source of the vibration was established as the 1200-V bus fundamental frequency, which when coincident with the shaft torsional natural frequency produced the highest recorded vibration amplitudes. The torsional natural frequency (15 Hz) was also observed as a significant component in the propulsion motor vibration spectra at most test speeds. The cycloconverter is programmed to avoid sustained operation at approximately 150 r.p.m. to minimize the effects of the natural frequency.

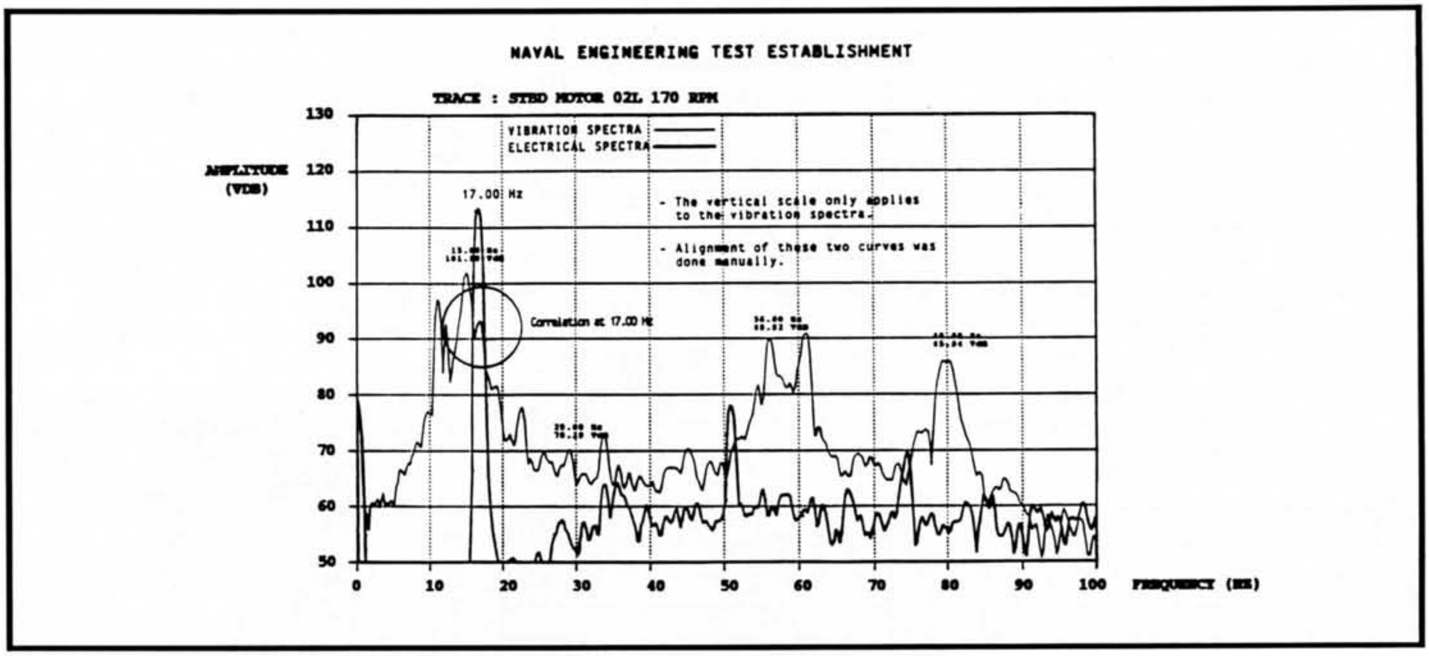


Figure 3. Superimposed Electrical and Vibration Spectra Demonstrating the Correlation between Domains

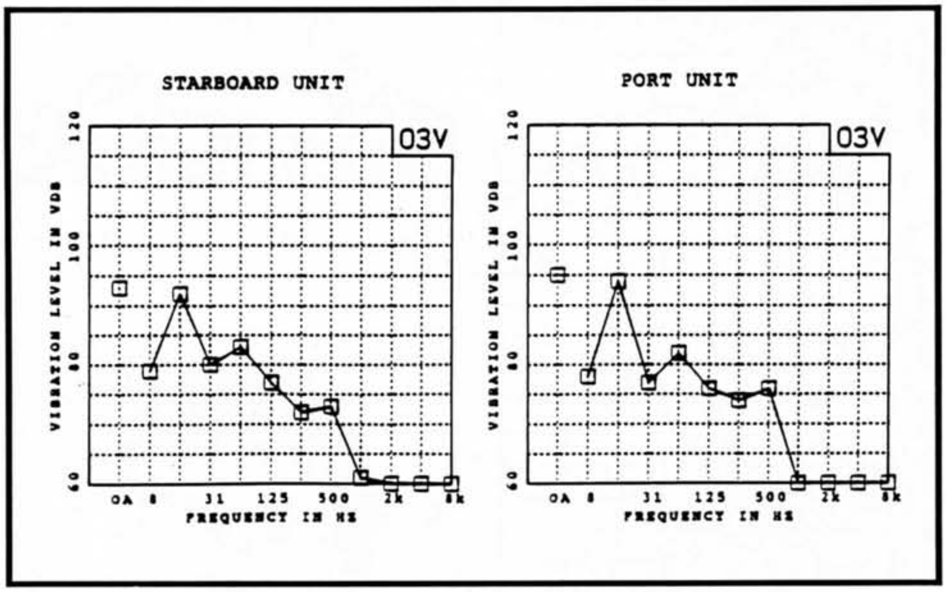


Figure 4. Propulsion Motor Octave-Band Patterns for Monitoring Position 03V at 155 Shaft r.p.m.

A 360-Hz peak was also observed on the propulsion motors. No corresponding electrical peak was consistently observed for this frequency. The 360-Hz peak was present on both motors and was pronounced primarily at speeds below 125 r.p.m.

Several other vibration components were present on the propulsion motors, which had frequencies between 0 and 200 Hz. The sources of many of these components were not identified, as the investigation was primarily concerned with electrically induced vibrations.

Comments

For ship speeds below 20 knots, the speed of a naval frigate is generally equal to one fifth the shaft r.p.m. For the *Henry Larsen*, the shaft speed for quiet operation (10 to 14 knots) corresponds to approximately 70 r.p.m. Vertical direction octave-band vibration plots of the *Henry Larsen* propulsion motors, for a shaft speed of 75 r.p.m., are shown in *Figure 5*. These vibration plots demonstrate the relatively low level vibration output of the cycloconverter propulsion system, especially in the higher octave bands.

Conclusion

The *Henry Larsen* investigation revealed that the most significant correlation between electrical frequency components and mechanical vibrations was the propulsion motor 1200-V bus fundamental frequency. Since the propulsion motors are rigidly mounted, the presence of the 1200-V bus fundamental frequency at the base of the propulsion motors indicates that it will likely be present in the acoustic signature of the ship. Because of the torsional resonance of the shaft, it will be most apparent in the 140-to-160-r.p.m. speed range. It appears that only the 1200-V waveform fundamental frequency (0-18 Hz) is a significant mechanical vibration in this type of AC/AC propulsion system. There were no significant waveform harmonics as was anticipated prior to the investigation.

The torsional natural frequency of the propulsion system was likely responsible for the significant increase in the 1200-V bus fundamental frequency vibration that was observed at 155 r.p.m. This is supported by the noted reduction in the vibration amplitude of the 1200-V bus frequency that occurred as the propulsion motor speed increased beyond 155 r.p.m. The torsional natural frequency vibration (15 Hz) was present as a significant spectral component at

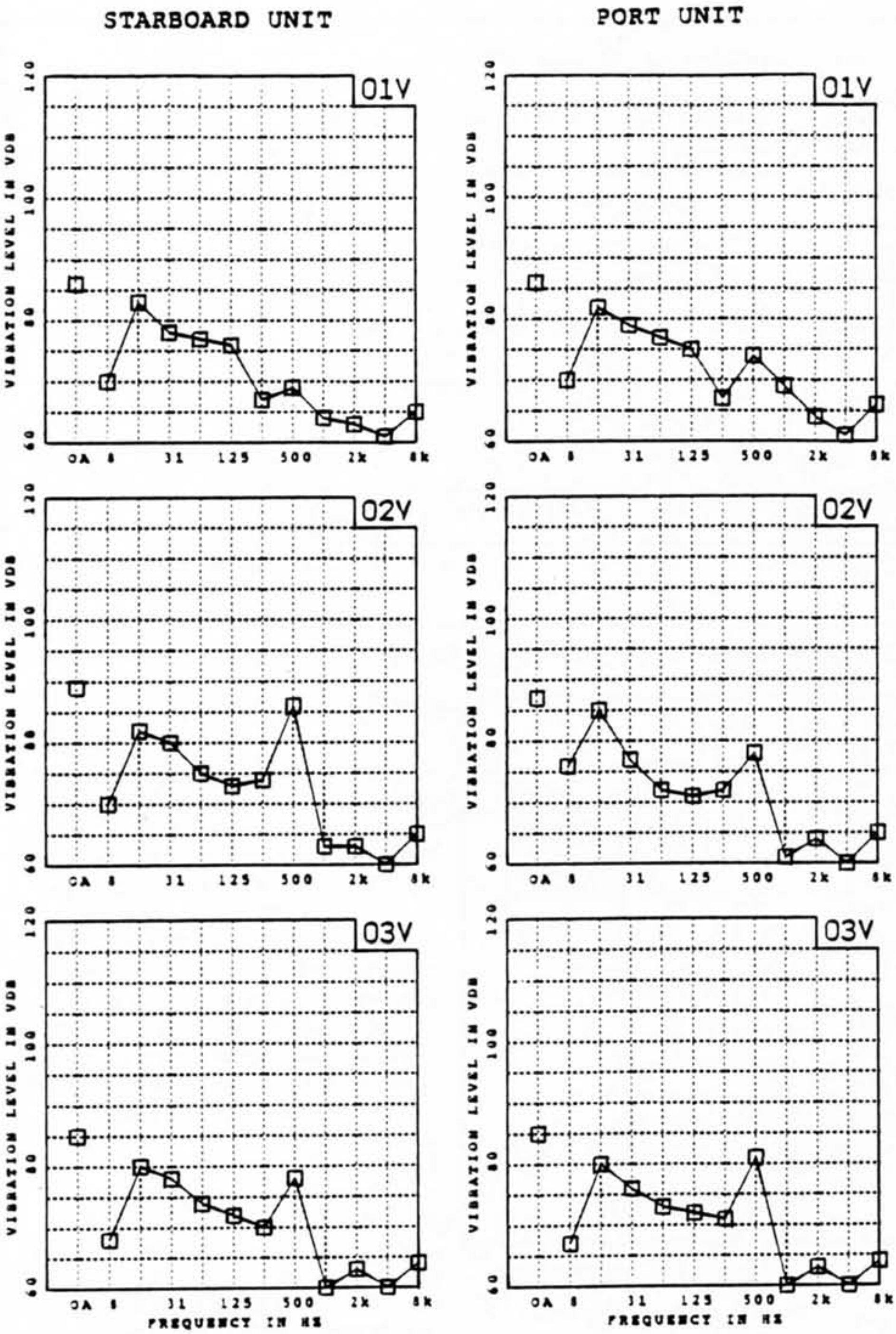
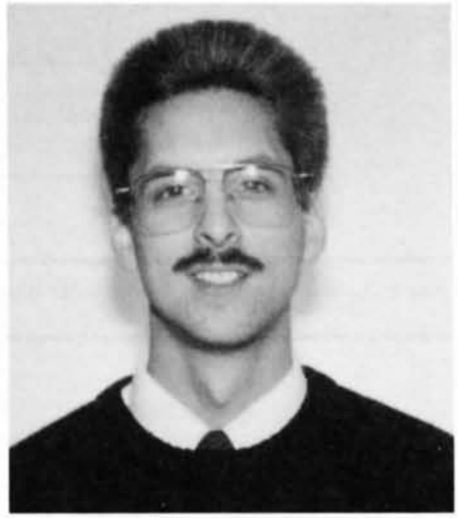


Figure 5. Propulsion Motor Octave-Band Patterns at 75 r.p.m.

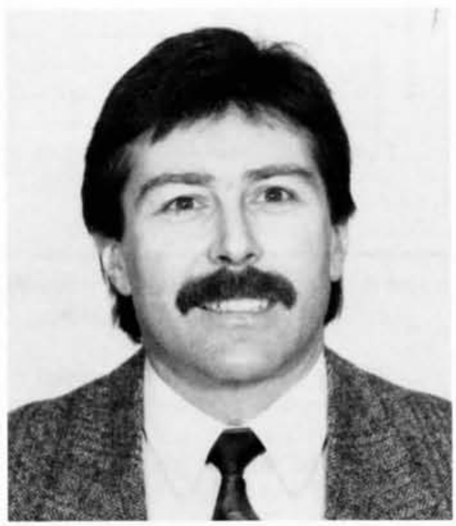
most speeds and will likely be a component in the ship's acoustic signature. Since a new propulsion system could possibly be designed with its primary torsional natural frequency outside the operating range for a warship application, it may therefore be possible to eliminate this particular spectral characteristic.

Some propulsion diesel frequencies were observed on the propulsion motors, indicating a transfer of diesel vibrations to the propulsion motors via the hull structure. The transmission of vibrations from power plant to hull structure can be significantly reduced by using a warship mounting arrangement for the primary diesels.

The propulsion motor vibration spectra, recorded from the pedestals and base, exhibited very low vibration amplitudes at frequencies above 550 Hz for all test speeds. This indicates that the AC/AC propulsion arrangement has potential as a low-noise drive system, provided the diesel alternators are sufficiently isolated and the torsional natural frequency of the main shaft is raised above the maximum operating speed.



R. Jacobs is a project engineer at the Naval Engineering Test Establishment in LaSalle, Quebec.



J.R. Storey is the DMEE 6 senior engineer for shipboard electro-chemical and electrical motor-drive propulsion systems.

AN/SQR-19 Module Reliability during the Early Days

By LCdr(Ret'd) Leo Smit and Lt(N) Chris Putney

Introduction

The U.S.-made AN/SQR-19(V) Towed Array Group was selected several years ago as the sensor of choice for the Canadian Towed Array Sonar System (CANTASS). Manufacture of production SQR-19s commenced in the last quarter of 1985; hence operational usage patterns are only now beginning to emerge for analysis relating to LCMM functions. This article looks at an early reliability appraisal from information gathered by engineering personnel.

Background

The AN/SQR-19 array has been in operational use in HMCS *Fraser* (with ETASS) since January 1987 and in HMCS *Annapolis* (with the CANTASS Advanced Development Model) since April 1988. Approximately 4300 towing hours have been logged by these two ships (as of 31 October, 1989), with individual modules logging up to 2200 hours and 60 deploy/retrieve cycles. Twenty-eight modules have failed or have developed a fault which results in degraded functionality through normal use, and another 20 modules (a complete array) were damaged in an accident.

As the Canadian procurement was so close to the beginning of the USN program, no historical data was available for reliability assessment. The manufacturer estimated the mean time between failures (MTBF) of modules to be 2000 hours, independent of module type — a figure which looks reasonable until one considers that some or all of the failure modes for any specific module can shut down the entire array. Subsequent usage data has been slow to follow, and in any event indications are that Canadian usage (average towing hours/ship/year) may be almost double that of USN ships so we are likely to see usage problems here first.

As a result of a few incidents in early 1987, *Fraser* and *Annapolis* were directed to keep detailed logs of towed array usage and to transcribe the data to an electronic medium for later analysis. The additional burden placed on ship's technicians in maintaining the log was justified by the certainty that when such information became of relevance, it would be irretrievable without a detailed "real time" log.

Developments in late 1988 caused concern over the apparently short life of some modules — a concern amplified by a dwindling spares pool and the long lead-time to establishment of a vehicle for module repair. The time was ripe for a reliability study using actual failure data. The topic was accordingly suggested to the CSE Division at Fleet School Halifax as an appropriate subject for a CSE Application Course term paper.

The AN/SQR-19 Towed Array

A good technical summary of the array is given by LCdr R. Marchand in his article "CANTASS — Bringing ASW into the 21st Century" ***(MEJ: January 1989)***. For this reliability study, we found it useful to group the modules according to general functionality (*Figure 1*).

Some differences between module types are relevant to the expected differences in reliability between types, and are summarized here:

a. the hose material of the Vibration Isolation Modules (VIMs) is different from that of all other modules, except that the last two-thirds of the Heading, Depth and Temperature Module (HDTM) is also VIM material and is directly stressed by the drag of the rest of the array. Other modules have an internal Kevlar strength member;

b. module-coupling electrical paths are 120-pin connectors, except for the VIMs and the forward end of the Telemetry Drive Module (TDM) where the electrical path is triaxial;

c. although functionally similar, the TDM contains more sealed electronic circuit assemblies ("cans") than the HDTM, while the HDTM carries the three non-acoustic sensors for heading, depth and temperature. Acoustic modules all contain the same number of hydrophones, but are grouped in channels: higher frequency types have more channels than lower frequency types, so a higher failure rate for higher frequency module types might result; and,

Function group	Type(Qty)	
VIM	FVIM (1) AVIM (1)	Forward Vibration Isolation Module After " " "
Electronics	TDM (1) HDTM (1)	Telemetry - Drive Modules Heading Depth Temperature Module (performs TD functions for VLFM's)
Acoustics	HFM (2) MFM (2) LFM (4) VLFM (8)	High Freq. Mid Freq. Low Freq. Very Low Freq.

VIM and Electronics modules are also collectively referred to as "Non-acoustic" types.

Fig. 1. General Functionality of Modules

d. during deployment or retrieval modules can experience vastly different, positionally dependent stresses when moving through the level-winder and while on or near the sea surface where turbulence and wave action have significant effect.

Module Failure Modes

Figure 2 shows, in general terms, the types of failures which can be experienced by each of the module types. A module with an electronic defect which falls under the heading "serviceable" would not require retrieval of the array for replacement. In an environment of unlimited spares, these modules would be exchanged for fully serviceable ones at the first opportunity, but in the present support environment they must usually remain in use.

SUMMARY OF AN/SQR-19 MODULE DEFECT CRITICALITY

MODULE TYPE	MECHANICAL DEFECTS UNSERVICEABLE	ELECTRONIC DEFECTS UNSERVICEABLE	 SERVICEABLE
FVIM	1. coupling defects	1. coaxial electrical path	
AVIM	-threads -O-ring seats		
TDM	-pin/socket damage -hose/coupling interface	1. all electronic defects	
HDTM	2. hose wall	1. all drive/telemetry function defects 2. compass	1. temperature 2. depth
VLF, LF, MF, HF	-punctures, cuts, tears	1. fails ARRAY INVASIVE TEST SHEET	
VLF	3. major degradation	2. >1 U/S channel	1. limited channels U/S:
LF	-extensive scuffing -looses Isopar-M a lot	2. >2 U/S channels	-failed HYDROPHONE CAL. TEST SHEET
MF	-for VIMs, permanent stretch > approx 5'	2. >3 U/S channels	-consistently Auto-Zeroes
HF		2. >5 U/S channels	-creates display artifacts

Fig. 2. Summary of AN/SQR-19 Module Defect Criticality

The database presently classifies module failures to be either electrical or mechanical in origin. Degraded modules are classified as being either "in use" or "available for use."

General

"Reliability is the probability of a device performing its purpose adequately for the period of time intended under the operating conditions."[1] Failure analysis is expressed in terms of either the expected number of failures that will occur in a given period, or the average time between failures.

Having studied the target equipment, the steps through which one has to proceed in carrying out a reliability study are:

a. analyze the raw data for missing, misleading or incorrect items. Consciously include all data, or edit it based on sound engineering principles;

b. select a data distribution which best fits the data and meets the logical underlying assumptions;

c. determine MTBF; and,

d. test the results.

Data Analysis

An important factor to remember in a reliability study is that it is not so much the actual failure of a component that is normally considered significant, but the *belief* that it has failed. During 1988 the compasses on many of the Heading-Depth-Temperature Modules were found to give erratic readings at times. They were therefore replaced by spare modules, but the cause was eventually traced to the slow ingress of small amounts of seawater into *any* module coupling. Cleaning and reconnecting couplings would restore the HDTM output. However, since the modules were taken out of service, they were logged as having failed. It is nonetheless noted that inclusion of such data will result in inappropriate use of LCMM resources in over-sparing these modules. We therefore decided that such known instances of incorrectly attributed module failure would *not* be incorporated into the module failure data. They would, however, form an important element of any reliability study of the array as a single entity (which we have not undertaken) which would have a more significant operational (vice support) impact.

Another decision made on examination of the raw data was to consider all degraded modules as failures, as they would in fact be changed-out if sufficient assets existed.

A third decision required in the initial analysis of raw data was determining which type of failure was valid without arbitrarily skewing the data. The problem we had to evaluate was the damage of an entire array through grounding in February 1987, which even now represents 40 percent of the total module failures experienced. On the one hand, it is likely that a ship will occasionally snag its array on something. Over years of study the effect of this on the total database will be averaged out in the "all causes" MTBF. Conversely, in trying to make a reasonable prediction of support requirements we have to acknowledge the major effect this single event has on the MTBF calculation for acoustic modules.

While we acknowledge that there *will be* similar catastrophic events in the future, their effect is best accounted for by estimating the frequency of such losses. In preliminary support estimates, NDHQ project personnel have estimated one accidental loss of an entire array per seven years of towing.

Finally, we considered the validity of analyzing each module by failure modes, but rejected this due to the inherently complex interrelationships and small database.

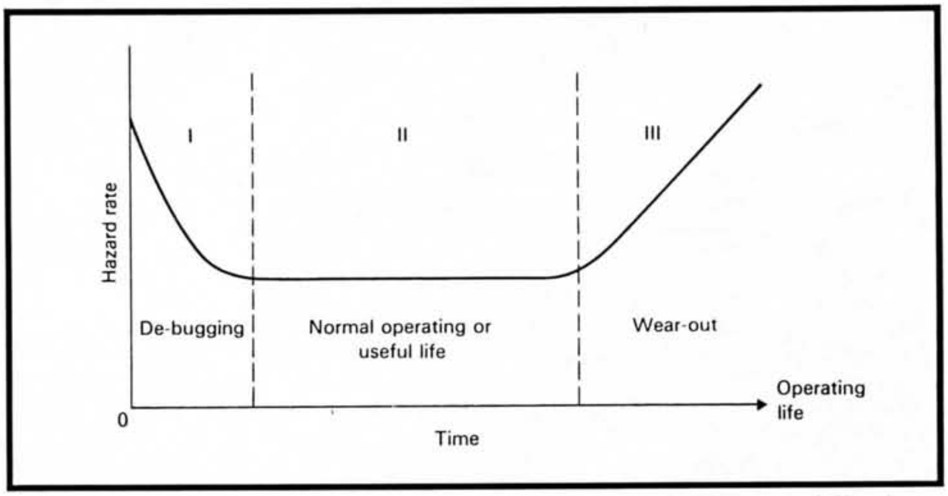


Fig. 3. Typical Electronic Component Hazard Rate as a Function of Age[2]

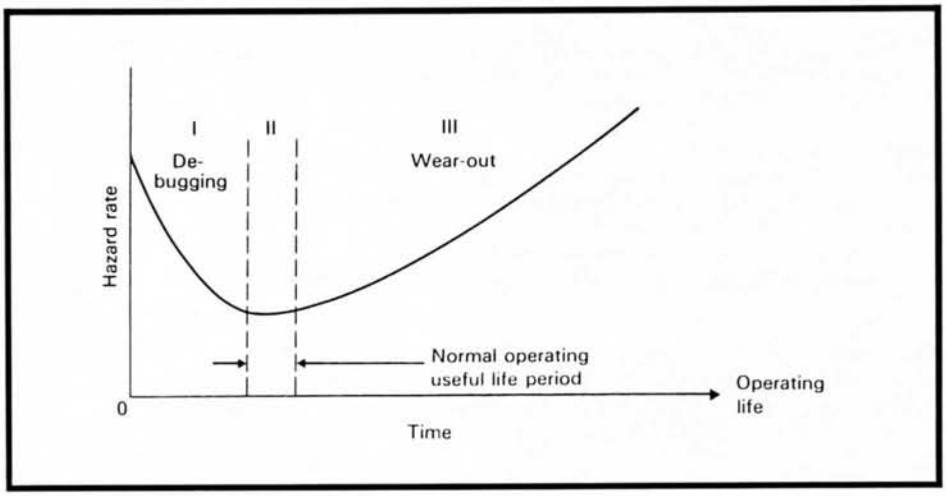


Fig. 4. Typical Mechanical Component Hazard Rate as a Function of Age[2]

Selection of a Data Distribution

Most combat systems are a combination of both mechanical and electronic components which work together. As shown in *Figures 3 and 4*[(2)], electronic and mechanical components do not fail at the same rate through the course of their lifetimes. Electronic equipment has a longer "normal operating" period than mechanical components, whereas mechanical systems have a longer "wear-out" period.

After studying several commonly-used distributions (Poisson, Weibull, Rayleigh, normal, log-normal and exponential), we concluded that the exponential distribution was the most appropriate for this study. The most important factor for this distribution to be applicable was that the hazard rate should be constant. The hazard rate is extensively used in the analysis of repairable systems in which components cycle between operating and failure states. It is also applied to the study of nuclear reactor accidents because it adapts well to a scarcity of data.

Although constant failure rates are valid only during the useful life of a component and are not valid during the debugging or wear-out stages, one assumes the failure rate is constant throughout a component's operating life. In the case of the towed array, modules are constantly failing and being replaced. At any given moment some modules are in the debugging state, some are in the wear-out stage, and some are in the useful life period. Averaging this situation over time, one will find that for a particular module type the failure rate is constant. Such a simplification is also supported by Billinton and Allan: "Data used is often very limited and is insufficient to verify the correct underlying distribution. Consequently it is unrealistic to use a distribution more complicated than the data justifies."[3]

Determining Mean Time Between Failure (MTBF)

The SQR-19 data is especially difficult to quantify because it consists of multiply censored data. Dr. Wayne Nelson, through his work at the General Electric Company, has formulated a method of plotting multiply censored data to obtain engineering information on the distribution of time-to-failure.[4] The complete methodology of this MTBF calculation for multiply censored data is discussed in *Figure 5*.

Testing the Results

Several standard statistical tests were studied. In two cases, the chi-square goodness-of-fit test[5] and Bartlett's test[6], our sample size was still too small to provide a reasonable power of discrimination. A third test, the Kolmogorov-Smirnov test[7] (commonly called the K-S test) can be used with small sample sizes, but at best tests only to a 20-percent level of confidence, at which level our data passed for all module types.

Because we were unable to find a suitable test giving a reasonable level of confidence, an additional, less mathematically rigorous test was devised by the authors to give a better picture of MTBF trends for predicting future requirements. This test, informally called the "death" test, involves manually changing the status of an operational module having the most usage (one of each type) so that it is processed as a failure in the calculations, and reducing its "hours operated" by 0.1 hours. The MTBFs are then recalculated in the normal manner for comparison. Comparative results are discussed in the following sections of this paper.

Example: FVIM Modules

Serial Number	Status	Op Hours	Rank	Hazard	Cumulative Hazard
018	degraded	1460	1	100	170
071	degraded	1081	2	50	70
083	operational	721	3	0	-
089	operational	525	4	0	-
068	failed	100	5	20	20
070	spare	0	6	0	-
090	spare	0	7	0	-
080	spare	0	8	0	-
088	spare	0	9	0	-

This segment describes the methodology developed by Dr. Nelson to determine MTBF of incomplete failure data, using FVIM as the example.

First, order the modules from most to least hours operated, without regard to whether they are censored or failure times. If some censored and failure times are of equal hours, then they should be put into the list in a well-mixed fashion.

Next, obtain the corresponding hazard value for each failure time. The hazard value is the observed conditional probability of failure at a failure time, that is, the percentage of units that ran that length of time and then failed. Algebraically, Hazard=(100/Rank).

Next, for each failure time, calculate the corresponding cumulative hazard value and the hazard value -- the sum of its hazard value and the hazard values of all preceding failure times.

Finally, the cumulative hazard of each failure is plotted versus the time of failure (denoted by "hours operated"). Using least-squares fit, the best linear approximation to the data points is determined; the straight line must pass through the origin. The MTBF is now the number of operating hours corresponding to a cumulative hazard of 100%.

All the above functions have been incorporated in a Lotus 1-2-3 macro.

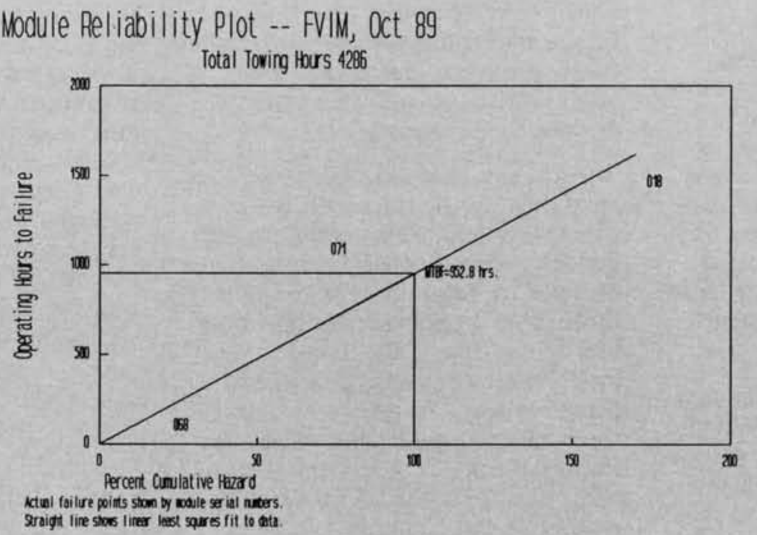
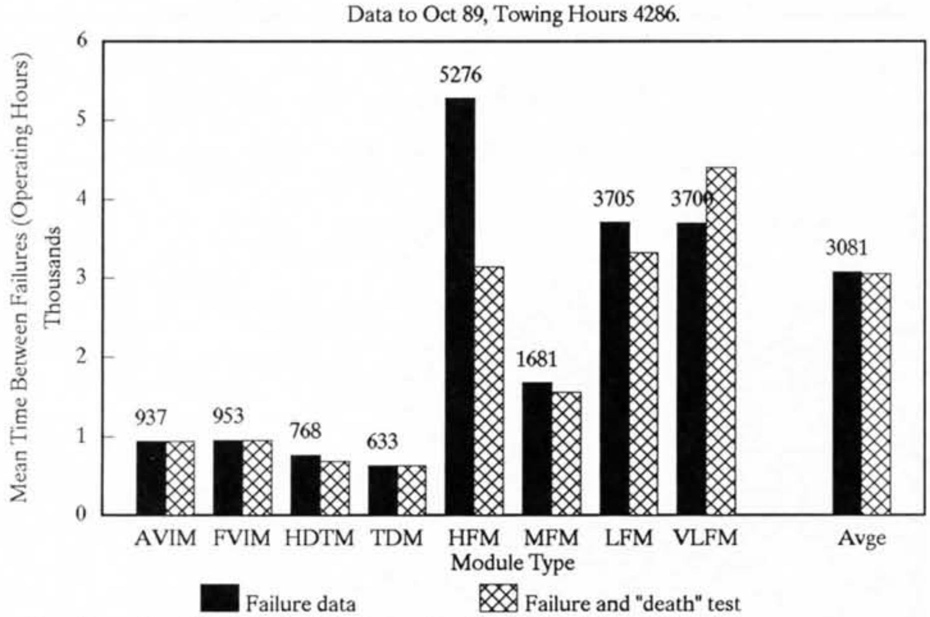


Fig. 5. Hazard Plotting for Incomplete Failure Data[4]



"Avge" is weighted by number of modules of each type comprising a complete array.

Fig. 6. AN/SQR-19 Array MTBF by Module Type

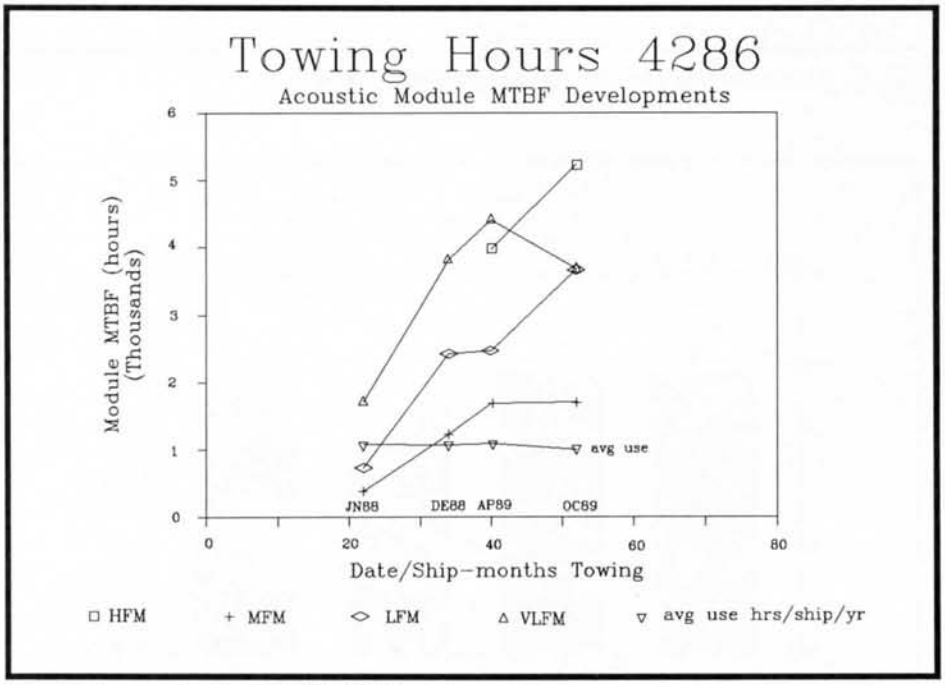


Fig. 7. Acoustic Module MTBF Developments

Results

Figure 6 shows the module MTBFs calculated from the usage logged to October 1989. "Death" test results are included for comparison.

Note that the "death" test has no effect on VIM and TDM modules, as the most-used modules of these types still operational have been used less than some of the failed modules.

HDTMs have all been changed-out at one time or another as a result of the earlier heading data problem. There are therefore several modules, each having logged a few hundred towing hours, as opposed to fewer, more-used modules. Consequently, the "death" test does not give any useful indication for this module type at this time; indeed, the premature replacement of several HDTMs means that the MTBF estimate has been weighted conservatively.

For acoustic modules the "death" test indicates a reasonable degree of confidence can be accorded the MTBF results to date for MF, LF and VLF modules. HF modules are either unusually reliable, or we have been very lucky with the particular HF modules in use!

Note the minuscule change in the weighted average of MTBFs (1xFVIM + 1xAVIM + 1xTDM + 2xHFM + 2xMFM + 4xLFM + 8xVLFM + 1xHDTM)/20 as a result of the "death" test. This we interpret as giving high confidence in predicting the total number of failures likely to be encountered during any usage interval (ship-towing hours), although the composite numbers of failures of each module type may vary.

Figures 7 and 8 show our calculated MTBFs for each module, plotted against a time-base for each occasion of an update for the database. The array usage rate is also shown on each graph. This method of tracking module MTBF should prove particularly useful to the LCMM (at the front end of the program) in giving a degree of confidence in the analysis results and in indicating where an educated guess might be more valid. Also, sudden changes in the MTBF may be indicative of potential problems with modules or their deployment. It is apparent in both figures that data to June 1988 was insufficient for useful analysis. Trends of the latest two data periods, however, show that for many module types the calculated MTBF can be used with some confidence in predicting future repair and inventory requirements.

The greatest confidence in the MTBF results will be for a type such as FVIM or VLFM where the line assumes zero slope, or else alternates between positive and negative slope (but maintains a horizontal trend). It is important to note, however, that although a horizontal line between calculations *may* indicate no change in the MTBF of that type, it more probably indicates that no modules of the type failed *and* that the relative ranking (by hours operated) was unchanged in the interval. (For example, in *Figure 5*, if FVIMs 083 and 089 are each used for another 300 hours without failing, the MTBF for

FVIMs remains unchanged.) Less confidence (or none!) can be attributed to types such as HDTM, HFM, LFM and even TDM. The next update cycle (spring '90) should prove instructive if the usage rate remains constant.

As an aside, it is noteworthy that the original modules of *Fraser*'s present array have had some 700 hours more use than *Annapolis'* original modules. Because of the analysis algorithm used, and assuming no additional failures occur, a failed original *Annapolis* acoustic module becomes a statistical event affecting the type's MTBF only once in the near term; an original *Fraser* acoustic module does so twice: once on failure as a relatively high Hazard Value, and the second time about half a year later when the operating hours of the *Annapolis* modules come to exceed that of the failed module (not particularly apparent in the example of *Figure 5*).

At this time, the module's Hazard Value and corresponding percentage Cumulative Hazard will be reduced, resulting in an increased MTBF. This effect will be greatest for VLFM, next greatest for LFM, and somewhat less for MFM and HFM because of the numbers of each type making up a complete array. (Note that replacement modules will also eventually have this effect when "passing" early failures, but these will be singles with reduced impact.) In the long term, these artificially dynamic effects will average out.

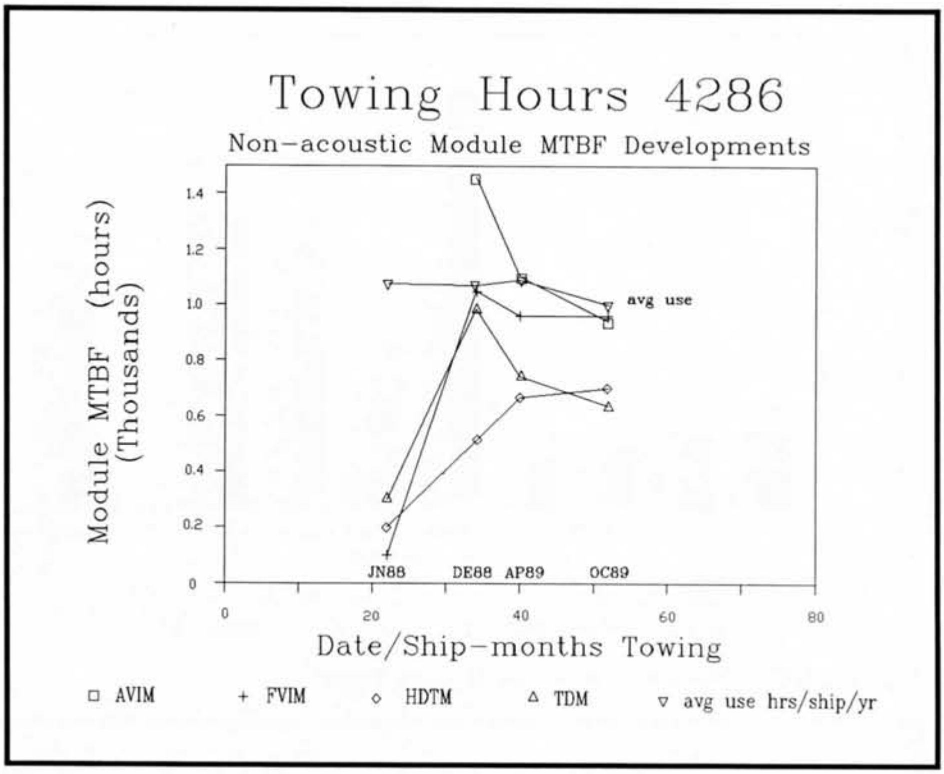


Fig. 8. Non-acoustic Module MTBF Developments

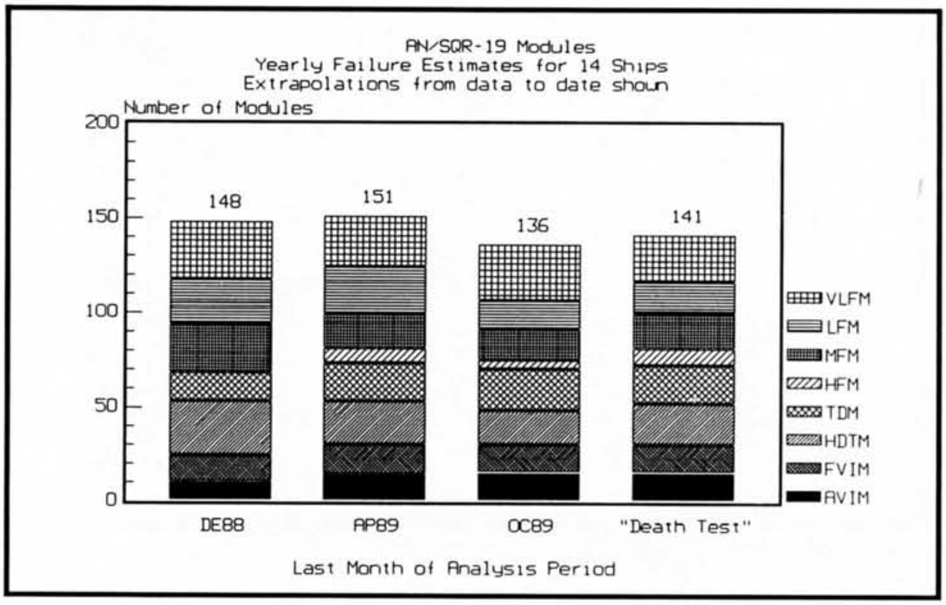


Fig. 9. Yearly Module Failure Estimates for 14 Ships

An Extrapolation

Figure 9 shows, for each of the last three data intervals and for the "death" test of the last interval, the number of modules of each type which can be expected to fail each year once all the intended platforms have been outfitted (12 CPFs and both 265-class ships). Although the numbers vary from one period to another for each module type, the total remains fairly constant. The reduced total for the OC89 MTBF figures is mostly the result of a ten-percent reduction in the usage rate (largely attributable to *Annapolis'* preparations for transfer to the West Coast, and her transit.)

To extend these figures to a total replacement, repair and overhaul (R&O) requirement, two additional significant effects must be factored in. First, an estimate of the numbers of modules which may be lost or damaged through accident. This has been set at 40 modules per year. Second, the refit policy for towed array ships has been omitted in the usage rate calculations. We aren't placing any bets at this point, but in any event the arithmetic is easy — about one module "saved" per ship-month in refit. However, it is most likely that a refitting ship would land its array and spares for a complete testing and overhaul, thus causing a

Glossary

Mean Time To Failure (MTTF): This is the expected value of a failure density function. In other words if a study determined how much time it would take for a type of component to fail, and then averaged this data over the number of components involved, one could ascertain an expected lifetime of the component. (*Billinton, p. 155.*)

Mean Time Between Failures (MTBF): Whereas MTTF applies to items that have never been repaired, *MTBF* applies to items which have been repaired. MTBF excludes down-time, and can therefore be defined as "up-time" between failures.

Hazard Rate: A measure of the rate at which failures occur. (*Billinton, p. 127.*) It is designated as λ (t) where:

$$\lambda (t) = \frac{\text{number of failures per unit time}}{\text{number of components exposed to failure}}$$

Multiply Censored Data: Incomplete failure data consisting of times to failure on failed units and differing running times on unfailed units. (*Nelson, p. 120.*)

Confidence Interval: Suppose that a 95-percent confidence interval is to be computed. This implies that in the long run 95 percent of the limits so computed can be expected to include the true lifetime of the module. This *does not* mean, however, that in any one instance the probability is .95 that the true module lifetime falls within the limits computed in this case. (*Bowker and Lieberman, p. 294.*)

Censored Item: An item which still functioned at the end of a time-limited test.

Censored Time: The length of time a censored item had been working when the test was halted.

Proportion of Failed Modules	Minimum Repair Work Probably Required	Module Types
32%	Rehose	mostly VIM, Ac
28%	Replace some electronics	mostly TDM,HDTM
11%	Replace hydrophone and/or amp and/or wiring harness	Acoustic
11%	Replace pin connectors	mostly Acoustic
7%	Rehose and replace wiring harness and/or electronics	Any
7%	Replace mechanical coupling	Any
4%	Replace pins and electronics	mostly Acoustic

Fig. 10. Repair and Overhaul Summary

net increase on the R&O facility to the tune of up to 30 modules (depending on the condition of the landed array and spares), less one module for each month of the refit duration. Perhaps a zero balance will ensue!

Concluding Material

During the summer of 1989 CANTASS and CPF project staffs commenced groundwork in support of establishing a Canadian navy AN/SQR-19 R&0 facility. Information from the manufacturer indicated that a single facility in a normal configuration has a capacity to handle approximately two modules per week. It is therefore apparent that a capacity approaching that of two facilities will be required. The logistics of transportation and availability seem to support the placement of one facility on each coast vice a double capacity on only one coast.

Spare modules have to date been procured in groups of ten, consisting of two each of LFM and VLFM and one each of all the rest. The data indicates that continuance of these ratios will result in continued shortages of TDMs and a growing stockpile of LFMs; or, if TDM demands are kept up with, large numbers of everything else. One LFM should be replaced by one TDM in each group of ten spares to achieve a balance. HFMs may pile up, but the MTBF of this module is not yet certain.

Our study falls short of making recommendations on required stock levels for module components. We would need the results of the R&O effort on these modules to undertake this logical follow-up, and a much larger database would be required because of the numbers of different components involved. Our observations in this regard are limited to the summary shown in *Figure 10.*

Although the previously mentioned weighted average of MTBFs exceeds the manufacturer's 2000-hour estimate, it is clear there is a reliability (or hard usage) problem with non-acoustic module types (although the jury is still out on HDTMs!) which is deserving of an engineering study. A study of TDM problems will by necessity have to be undertaken by the manufacturer (at least until our own R&0 facility is in place), and should be initiated soonest because of the criticality of this module to an operational array. The problem with the VIMs is manifest in a loss of elasticity of the hose, and has been under study by DREA and the CANTASS project staff since December 1988. Delays in receipt of materials for destructive testing, however, suspended progress until last autumn.

For the operational user it is relevant that, for a weighted average module MTBF of 3081 hours, 20 individual failures can be expected during this interval. Some module failures may not require immediate retrieval of the array and some failures will be noted at the same time as others or while the array is on board. Ships may therefore have to interrupt operations to carry out module replacement every 300 to 400 hours on average, at a cost of one to three hours "out of action."

The expected dependence of MTBF on the number of channels in acoustic modules is not apparent in the data at present. Similarly, we have not at this point made any correlation between a module's position in the array and its MTBF. There is no obvious trend when comparing module type MTBFs with their positional groupings. Positional information is logged and available for analysis, but as it is not presently supported in the electronic database a manual records-crawl (everybody's favourite occupation!) and probably more usage data will be required.

We have also been unable to make any more useful correlation of MTBF as a function of deploy/retrieve cycles for mechanical failures as compared with the preceding analysis.

In due course the Supply System will be equipped to handle the issue and return of modules. There will be a pool of spares sufficient to allow replacement of degraded modules, module repair will become an integral part of their support, and SMMIS will be capturing the reliability data. Until then, and perhaps even after, it is important for engineering support personnel to maintain the database (in whatever form) and keep on top of module reliability developments as they evolve. In any event, this has been an instructive example in the crucial role of the engineering community in ILS in the very early days of a project using off-the-shelf equipment.

Acknowledgment

The authors extend their appreciation to the NW Techs, NE Techs (Acoustic) and CSEs formerly of HMCS *Annapolis* and HMCS *Fraser* for their diligence in keeping the records upon which this study is based.

References

1. Roy Billinton and Ronald N. Allan, *Reliability Evaluation of Engineering Systems: Concepts and Techniques* (New York: Plenum Press, 1983), p. 2.

2. Billinton, p. 135.

3. Billinton, p. 150.

4. Wayne Nelson, "Hazard Plotting for Incomplete Failure Data," *Journal of Quality Technology*, (January 1969).

5. Albert H. Bowker and Gerald J. Lieberman, *Engineering Statistics*, 2nd ed. (Englewood Cliffs, N.J.: Prentice-Hall Inc., 1972), p. 459.

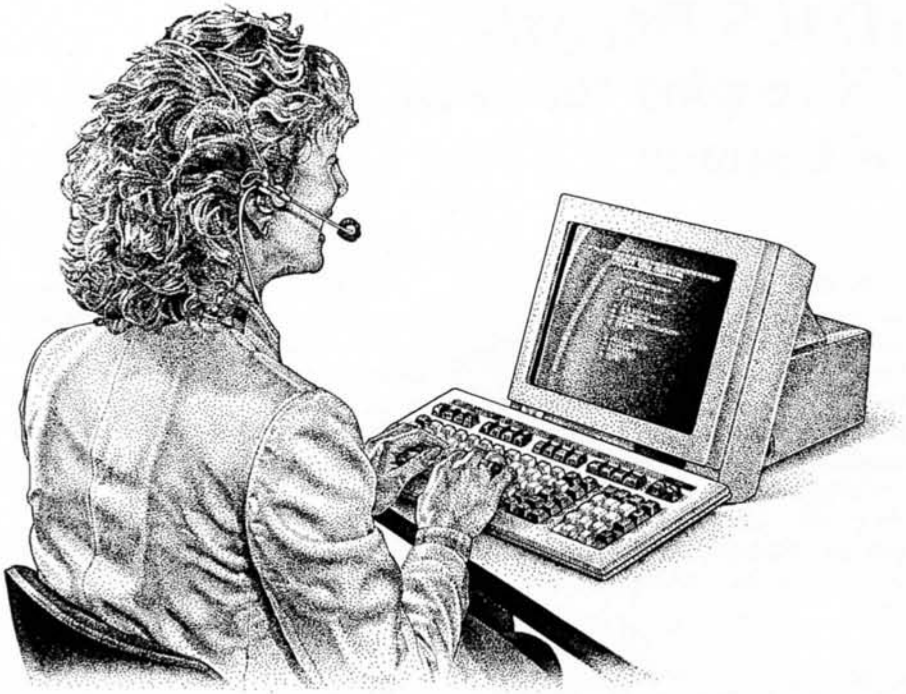
6. K.C. Kapur and L.R. Lamberson, *Reliability in Engineering Design* (New York: John Wiley and Sons, 1977), p. 239.

7. Bowker and Lieberman, p. 454.

LCdr Smit was the CANTASS Trials and Installations Officer from 1986 until 1989, and continued to work on the CANTASS trials analysis until April 1990. He retired from the navy last summer.

Lt(N) Putney is an administration officer at NOTC Esquimalt. He became involved with this CANTASS study while on CSE Applications Course 8901 in Fleet School Halifax.

Information — Your Key to Success



By Janet Cathcart

Have you recently been posted and need background information on your new responsibilities? Do you want to be alerted to recent papers and reports in your area of expertise? Do you have to write a paper, a speech or prepare a presentation and need help with your research? Need to see scientific or technical documents published by the defence community in Canada, the U.S., NATO countries, or elsewhere? For all of this and more the Directorate of Scientific Information Services (DSIS) is your answer.

DSIS supports the research and development activities of the Canadian defence community by providing defence-related scientific and technical documents and information. Specific subject fields are covered by specialists like Information Scientist Cheryl MacLennan, the naval information expert in DSIS. Some of the more popular topics which she has been asked for recently include: shipboard computer technology, marine propulsion, ASW and underwater acoustics.

The DSIS document collection consists primarily of classified and unclassified technical reports from Canadian, U.S., U.K. and other international and foreign defence organizations. This unique collection of defence-related scientific and technical documentation covers a wide variety of subjects in addition to marine engineering and naval warfare: aeronautics, applied sciences, communications, computer science, engineering, medical and biological sciences, military sciences, physical sciences, social and behaviourial sciences.

Since 1969, information on all our documents has been entered into our computerized database. Your information scientist at DSIS can search the database for you and provide you with a list of documents relevant to your needs. Of course, DSIS can also provide you with any document on the list.

Our current awareness service, Selective Dissemination of Information, or "SDI," is extremely useful in that it automatically alerts you, monthly, to new documents in your specific field of interest. A client profile, composed of key words in your subject area, is matched against records which represent the recent additions to the DSIS collection. This search produces a list of recent relevant documents from which you can select and order documents from DSIS. In addition DSIS provides an SDI listing based on American DoD documents (twice a month) and on British MoD documents (semi-annually).

Our exchange agreement with the U.S. Defense Technical Information Center (DTIC) also provides DSIS with dial-up online access to the DTIC database, covering defence-related technical reports from the early 1950s to the present. Literature searches on this database provide listings of relevant reports from American and other foreign defence sources.

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Literature searches of the various defence databases can be performed at sophisticated levels to provide you with current and retrospective information to support your specific tasks. In addition DSIS has access to many commercial online databases such as COMPENDEX (Engineering Index), NTIS (U.S. National Technical Information Service), and Oceanic Abstracts.

Many of you are already established DSIS clients and DSIS appreciates the opportunity to support your work. If you have never used our services, call (613) 992-0105 and we can discuss your information needs.

Janet Cathcart is the head of information services in DSIS.

Looking Back: 1938-1945

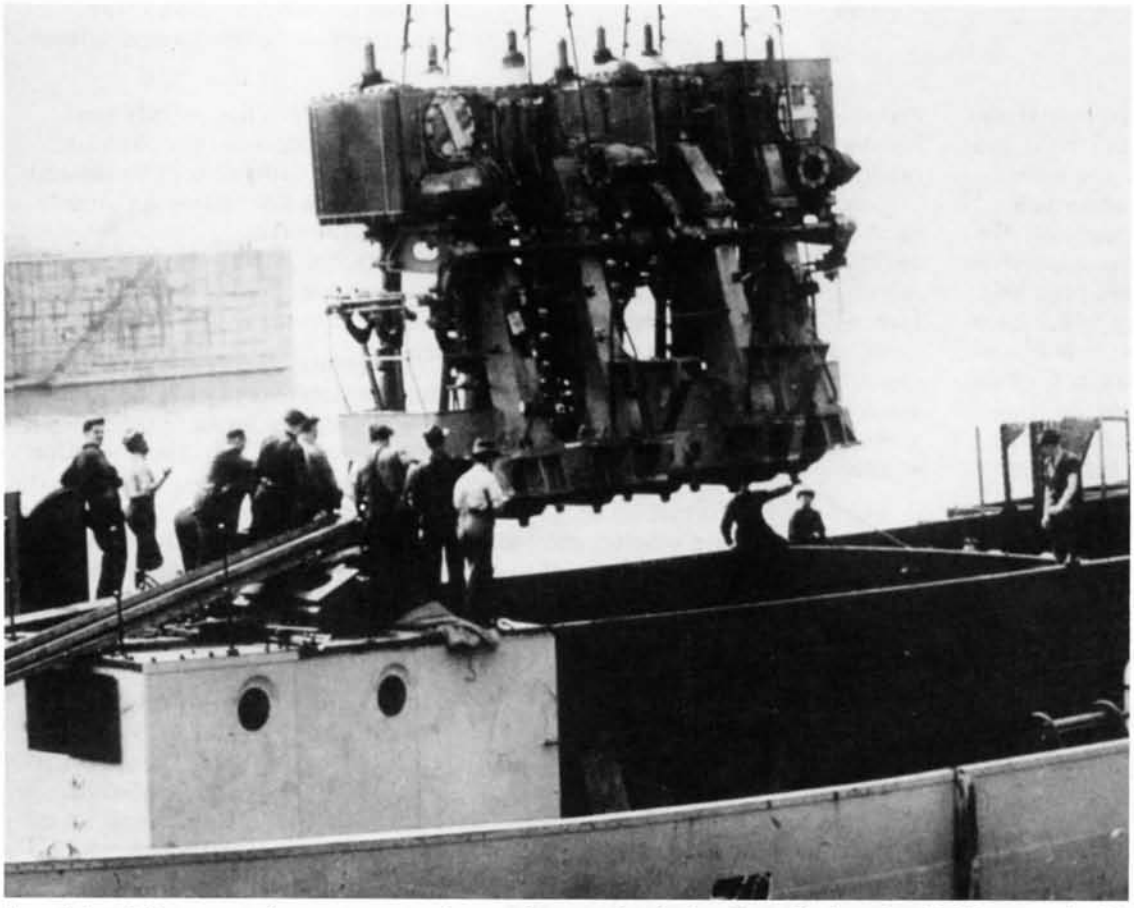
HMCS *Fundy(I)* — "Sweeping the deep" in defence of Canada

By LCdr Brian McCullough and CPO1 Jim Dean

When Canada went to war on September 10th, 1939 the RCN had only 13 vessels in commission: six destroyers, five minesweepers, a training schooner and one motor vessel. Four of the sweepers, including *Fundy*, were Basset-class trawler types that had been laid down in January and February of 1938 and commissioned later the same year.

By the end of the first month of the war *Fundy* and her sister ship *Gaspé* were assigned to the Halifax Local Defence Force, responsible for maintaining the swept channel at Halifax. *Fundy*'s entire war service entailed local minesweeping duties — her motto: *verimus altum* (We sweep the deep) — except in July 1942 when she escorted one convoy to Boston and another back to Halifax.

In 1943 *Fundy* underwent some level of refit, becoming the first ship to be docked at the naval base in Shelburne, NS following completion of the 3000-ton haul-out system there in June. (This marine railway is still in use today.) On January 15th 1945, *Fundy* along with another sister ship *Comox* rescued survivors of the torpedoed *Martin van Buren*. *Fundy* was paid off at the end of the war and sold to Marine Industries Ltd. in 1947.



***Fundy*'s triple-expansion, steam reciprocating engine being installed at the Collingwood shipyard in 1938. The two large circular LP steam exhausts visible at each end of the engine have been covered for protection during installation. Note the absence of hardhats on the yard crew.**

HMCS Fundy(I)

Trawler Minesweeper

Modified Basset Class (Fundy Class)

Pennant: J88

Complement: 33

Sister Ships: *Comox* (Burrard Dry Dock Co., Vancouver); *Gaspé* (Morton Engineering & Dry Dock Co., Quebec); *Nootka** (Yarrows, Victoria)

(*Later renamed *Nanoose* so that the name could be used for a new Tribal-class destroyer launched in 1944.)

Displacement: 460 tons (696 tons full load)

Length Overall: 167′

Breadth: 27′ 7″

Draft: 10′

Machinery: Triple expansion, steam reciprocating (coal: 180 tons), single screw

Speed: 12.5 kts (950 I.H.P.)

Hull: Strengthened for ice

Armament/Equipment: (1) 4-inch gun; minesweeping gear

Builder: Collingwood Shipyards Ltd.

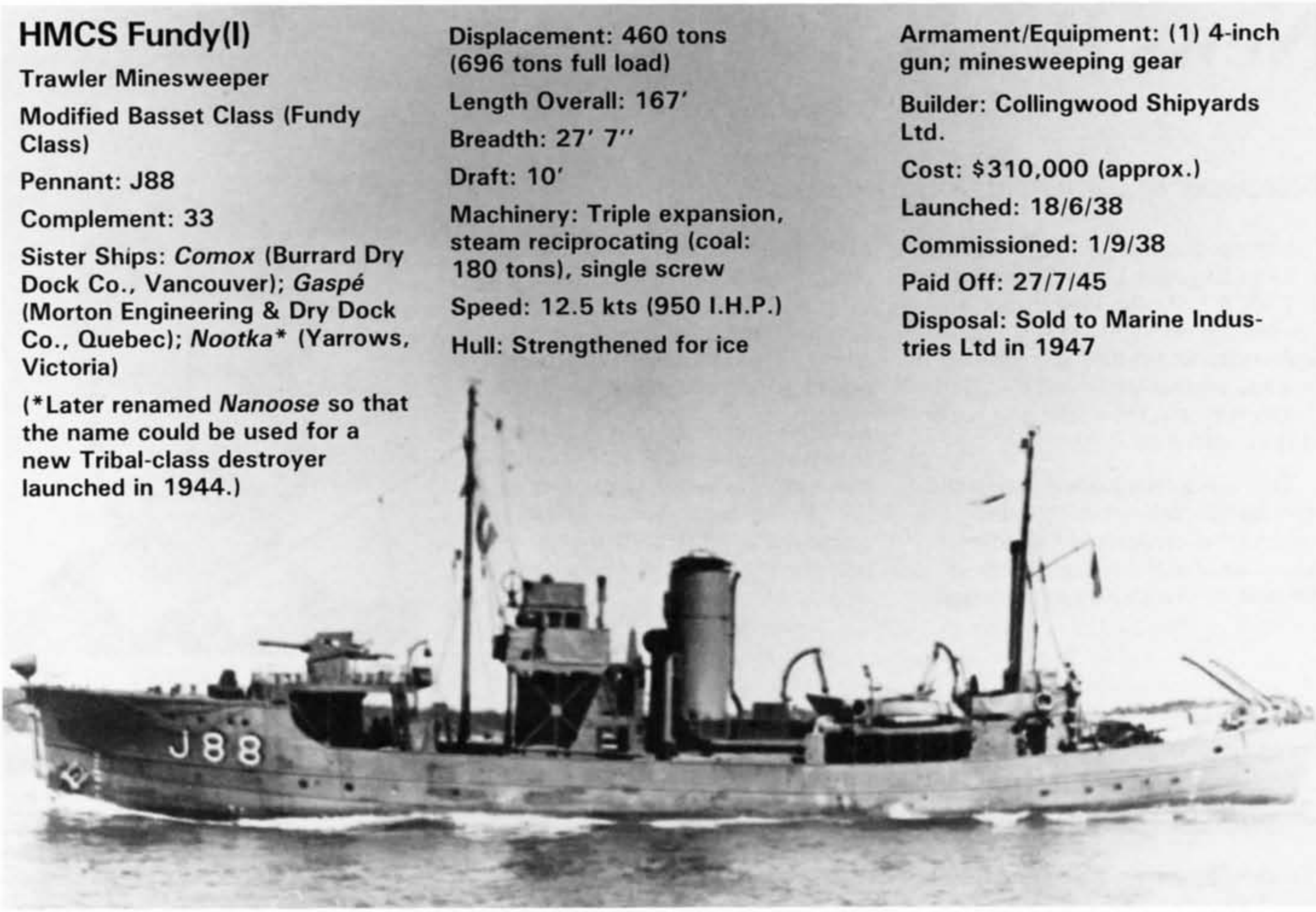
Cost: $310,000 (approx.)

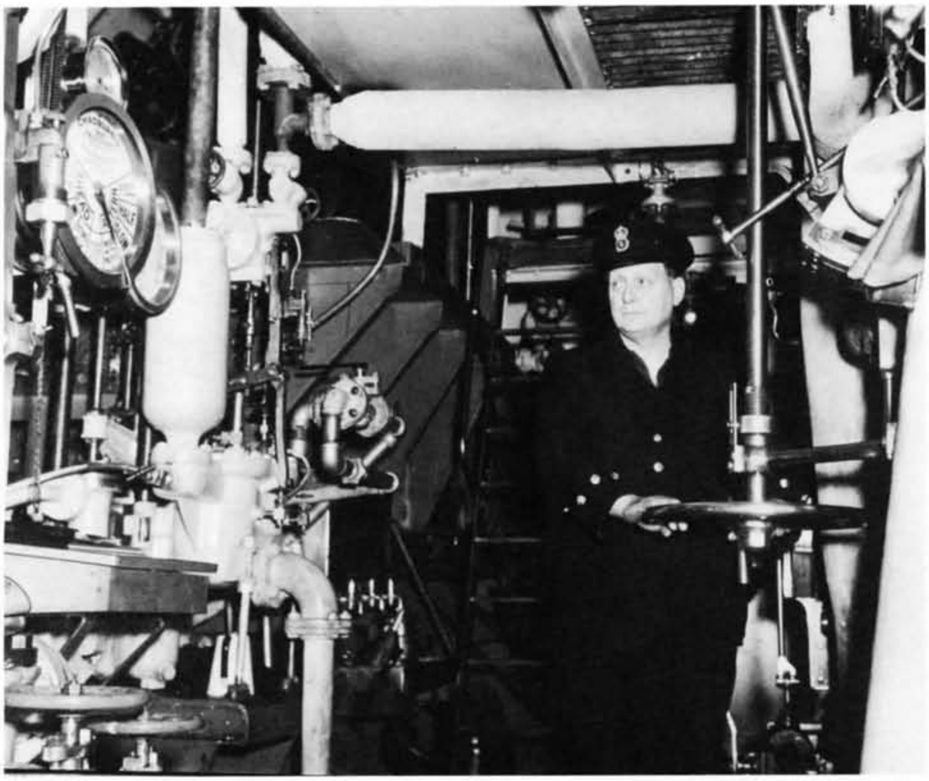
Launched: 18/6/38

Commissioned: 1/9/38

Paid Off: 27/7/45

Disposal: Sold to Marine Industries Ltd in 1947





The telegraph indicates "Finished with Engines" in this 1938 photo likely taken during *Fundy*'s acceptance trials. Note the lagging is still incomplete around some of the piping in the engine-room. In those days it was not at all unusual for the chief of the watch to steam in full uniform.

News Briefs

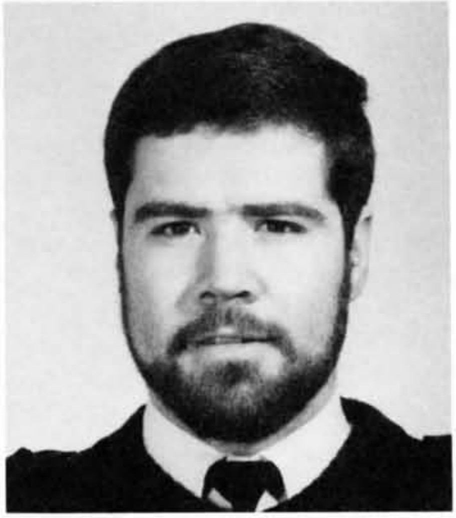
Best paper of conference awarded to CSE

Congratulations go out to Combat Systems Engineer Lt(N) Tudor Davies of DMCS 3. At the 1990 Canadian Conference on VLSI (Very Large Scale Integration) held last October in Ottawa, a paper presented by Lt(N) Davies was selected as the best paper of the conference.

This was a tremendous accomplishment as the conference included papers from recognized Canadian, American and European experts in the field of integrated circuit design.

Lt(N) Davies' paper, "A Floating-Point Systolic Array Processing Element with Built-in Self Test," was deemed the best of the 46 papers (chosen from 86 submissions) presented at the conference.

Lt(N) Davies completed postgraduate training at RMC last year and his paper was largely a product of his research work. He is currently employed as a DMCS 3 project engineer for the AN/SQS-510 sonar.



Lt(N) Davies: best paper of conference

CF units in Persian Gulf receive commendation

Canadian Forces Unit Commendations have been awarded to the first CF units to deploy to the Persian Gulf.

The Chief of the Defence Staff, General John de Chastelain, approved the awards last January for HMCS *Protecteur*, HMCS *Athabaskan*, HMCS *Terra Nova*, 409 Tactical Fighter Squadron and "M" Company, 3rd Battalion, The Royal Canadian Regiment.

"Each unit was cited for their determination and professionalism in conducting their activities under harsh climatic conditions in an unfamiliar region," said General de Chastelain. "Our units have achieved unqualified success in their operations to date and have earned the respect of their peers in other allied forces in the region."

The Canadian Forces Unit Commendation was awarded on three occasions in 1990: to HMCS *Provider* for its role in the rescue of 90 boat people in the South China Sea in June; to the CF aerial demonstration team, the Snowbirds, on the occasion of their 25th anniversary; and to 5e Brigade mécanisée du Canada for its support during the Oka Crisis in the summer.

1991 senior promotions and appointments announced

The list of senior officer promotions and appointments for 1991 was released in early January. While other changes had yet to be confirmed, the following were among those approved by the minister of national defence and announced in January:

Capt(N) R.L. Preston, commanding officer of Ship Repair Unit Pacific, will be appointed Chief of Staff (Materiel) for Maritime Command on his promotion to commodore. He relieves Cmdre Green who retires this summer.

RAdm J.R. Anderson will be promoted vice-admiral and appointed Commander Maritime Command, relieving VAdm R.E. George who has been appointed Deputy Chief of the Defence Staff, NDHQ.

Capt(N) Preston: appointed COS MAT

RAdm Anderson: appointed Commander Maritime Command

Journal editor wins writing award

Journal Production Editor LCdr(R) Brian McCullough has been presented with the "Article of the Year" award for 1990 by the Ottawa Centre of the Royal Astronomical Society of Canada. His article, "*EYE-MAX Theatre Presents: Planets in the Palm of your Hand*," was published in the July issue of *Ottawa Centre AstroNotes*.

LCdr McCullough is an avid amateur astronomer and regular contributor to the monthly *AstroNotes*. A number of his articles have been reprinted in other astronomical society newsletters in Canada and the U.S.

Naval reserve ROUTP 1972 reunion

A 20th-anniversary reunion of the naval reserve ROUTP class of 1972 will take place in Ottawa from 3 to 5 July 1992. For more information, contact Cdr Hugues Létourneau at HMCS *Donnacona*, 2055 Drummond St., Montreal, Quebec H3G 1W6; tel. **(514) 283-6517**, FAX (514) 283-6868.

Pack it up and bring it back

If you are planning to be on or around Canada's waterways this year, whether for work or recreation, keep your garbage *out* of the water!

That's the message from the folks at the Environment and Plastics Institute of Canada (EPIC) and the Department of Fisheries and Oceans. The two agencies have co-published a marine environmental awareness brochure aimed at protecting marine life and the natural beauty of Canadian shorelines.

— Coming up in July