THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
and
THE SHIP STRUCTURE COMMITTEE

Paper presented at the Ship Structure Symposium '96
Sheraton National Hotel, Arlington, Virginia, November 18-20, 1996

The Application of Hull Monitoring and ISIT Technology to Ship Safety Operation

G. Lewis[1], R. A. May[1] and E. D. Story[2]

[1]BMT SeaTech Ltd. UK.
[2]Marine Management Systems, Inc., Stamford, Connecticut

1. Introduction

The safe operation of ships is a complex affair affected by a great number of factors, including design, construction, maintenance, crew capability and training, management philosophy, route and type of cargo. One of the features of operation which can contribute to failure of the hull is over-stressing, either through overloading or because the vessel is damaged or corroded and cannot withstand normal working loads.

During the years 1990 and 1991 a large number of casualties were reported for vessels carrying dry bulk cargoes where structural failure is believed to have been a contributing factor. In addition to specific reasons for individual failures (which have been the subject of many recent papers and articles) this highlighted the overall need for a shift towards a quality culture which emphasizes effective monitoring and maintenance.

Following the spate of bulk carrier losses in 1990/1991, the International Association of Classification Societies, (IACS), introduced enhanced survey procedures for older bulk carriers, which addressed those problems which arose due to the lack of an adequate maintenance, inspection and repair regime. As a further means of protecting the structural integrity of these vessels the Flag States, through I.M.O., introduced a recommendation covering the adoption of real-time hull strength monitoring systems, (HSMS), as a means to limit stresses and motions in heavy weather. The recommendation in I.M.O. MSC/Circ.646 covered the adoption of one long-base sensor, sited over each hold, to measure hull girder strains, coupled with accelerometers to monitor vessel motions.

This paper describes the systems presently being fitted to meet the Classification Society guidelines. It then goes on to discuss current research into a more sophisticated system making use of extensive monitoring and using Artificial Intelligence techniques to process the data. The aim is only to give an introduction to the systems; for more detailed descriptions the reader is referred to [Thompson et al. 1995] or to papers on individual topics listed in the references.

2. Classification Society Guidelines

In line with IMO recommendations, notations have been introduced by Classification Societies; Lloyds SEA(R), ABS HM2+R, DnV HULL-MON. These all provide roughly similar specifications in terms of the minimum parameters to be monitored and recognize, through notations, enhanced and more comprehensive monitoring systems. For bulk carriers and tankers Classification Society notation necessitates the following minimum provisions for monitoring.

2.1 Hull Girder Stress

A HSM system should incorporate a global hull girder response indicator to warn ship staff that the hull girder stresses are approaching a level at which corrective actions are advisable. The hull girder response indicator should present the still water bending moment and wave bending moment and how they vary with time along the length of the vessel, and should include preset warning levels. For still water loads this ensures prevention of overloading, buckling and collapse of the hull during cargo and ballast operations and ensures that the required strength for wave loading remains in the girder when at sea. Still water hull girder stress warning levels should reflect both “at sea” and “in harbor” criteria. For wave loads, the response indicator is required to display and warn of limiting values, thus allowing timely corrective action to be taken by changing heading and/or speed.

The measurement of hull girder stresses necessitates using a minimum number of long base strain gauges distributed along the length of the vessel. Such gauges are required to be located as close as possible to locations at which the loading instrumentation provides bending moment output. For tankers and bulk carriers, the minimum number and position of strain gauges are:

2 at midships (one port, one starboard on deck)
1 at 25% of the length from the bow on deck*
1 at 25% of the length from the stern on deck*
* DnV HULL-MON, ABS HM2 only

Many systems also include a facility for counting stress cycles (typically using a rainflow counting algorithm). These enable calculations of nominal fatigue damage to be performed, and comparisons to be made of the relative severity of different routes, load conditions, etc.

2.2 Slam Indicator

A slam warning monitor is required to warn the vessel's operating personnel in advance that the vessel is in a sea-state or operating condition approaching those that could induce wave slams that could lead to either local or hull girder structural damage. Here, Class normally require the use of accelerometers measuring the vertical bow motion. A slam event can be recorded by recognizing a decaying vibratory shape of the 2 node mode of vibration, the magnitude of which is indicated by the amplitude of the vibration.

3. Benefits and Limitations of Current Systems

3.1 Benefits

Despite the simplicity of the systems, a few strain gauges and an accelerometer give some very useful information on the behavior of the ship.

- Comparison of measured stresses with calculated values can aid in control of loading and ballasting operations, indicating when departures from the loading plan may have occurred.
- Slam warnings can help the master to take decisions which reduce the probability of bottom damage, such as changing course or speed. (The experience of one operator is that bottom damage has been reduced significantly).
- The very fact of having a direct read-out of stress should not be under-estimated. Although masters and officers are of course well aware that ships experience stresses under load, and that these can sometimes be quite high, they have not in the past had any information on the stresses at any particular time. In addition the system will warn of high stresses at any time, although if the limits have been observed during loading it is unlikely that a ship will experience dangerously high hull girder stresses at sea.
- There is a possibility of post-processing the recorded data to obtain information on fatigue damage to the hull and to reveal any changes in the hull behavior such as an increase in stress due to corrosion. However this has to be a long-term exercise based on statistical analysis of a considerable amount of data, because of the inevitable variations caused by different load conditions and weather during individual voyages.

3.2 Limitations

Current systems, as described in the previous sections, also suffer from several limitations, the main one of which is that stresses measured are hull girder bending stresses away from any structural discontinuities. Structural failure due to hull girder collapse is rare, with most structural problems caused by local stresses which are not measured by HSM systems (e.g. at hatch corners, sideshell, stiffener connections). This means that fatigue calculations will be extremely optimistic, and the system may well not notice a problem which begins near the hull girder neutral axis or in the fore part of the vessel where hull girder stresses tend to be low.

4. The S.H.I.P. Project

There has been a growing recognition of the much wider benefits possible from the integration of monitoring and management strategies in long-term asset management and maintenance scheduling. This has prompted programs of development towards such integrated systems, [Mutton, 1994].

Using on-board monitoring experience gathered over several decades and, more recently, in providing commercial systems complying with the aforementioned Class notations, British Maritime Technology, (BMT), is now managing and leading a US$3.3 million European Commission- funded Ship Hull Integrity Program (S.H.I.P.). The S.H.I.P. partnership of BMT, British Steel, Kelvin Hughes and Bureau Veritas has been tasked with integrating, extending and exploiting current on-board monitoring technologies. Specifically, S.H.I.P. aims to develop a system combining comprehensive physical sensor and radar-based monitoring with innovative, on-board, data mining methods. The latter utilizes on-board genetic algorithms and conceptual clustering techniques as an aid to pattern recognition in stress, fatigue, motion and sea state data clusters. The system can then generate effective guidance to minimize the risk of structural damage during operation. It can also facilitate shore-based predictions of long-term reliability and, ultimately, planning for maintenance intervention.

The experimental S.H.I.P. system has been installed on board the 173,000 tonne dwt, nine-hold, bulk carrier *M.V. British Steel*.

5. S.H.I.P. System Architecture

The S.H.I.P. system integrates conventional and other, more innovative, monitoring techniques with incremental data mining as an aid to pattern recognition and to generate useful advice based on the accumulating data sets. The system architecture on board the M.V. British Steel is shown in Figure 1.

Data is taken from the S.H.I.P. stress and motion monitoring system, and separately from the existing sensors on the ship. The latter readings are displayed on a commercial bridge monitoring system and are also fed into the S.H.I.P. data mining algorithms. Physically, two computers are used which are networked together. One is responsible for interfacing the stress and motion monitoring hardware, the filtering of the associated data, and the cargo control room Human Computer Interface (HCI) for monitoring loading and discharging operations.

The second is placed on the bridge and covers the remaining tasks including the seagoing HCI.

The S.H.I.P. system is augmented by shore-based predictions of the long-term deterioration of the hull structure. These predictions, which utilize on-board data clusters and focused hull inspection records, include sensitivity studies which examine the effects of relevant parameters on the long-term structural failure probabilities. This aspect is discussed in later Sections.

6. S.H.I.P. Instrumentation

6.1 Monitoring During Navigation

A major component of S.H.I.P. is a monitoring system comprising various sensor types to automatically monitor, at strategic locations, stress and fatigue together with motions and sea states. The arrangement of sensors on board the M.V. British Steel is shown in Figure 2.

In addition to hull girder monitoring the system includes two rosette gauges fitted in line with selected transverse bulkheads to monitor shear stresses due to hull shear forces and torsional moments. A further two gauges are fitted just beneath the wing tank and at frame mid-height in a ballast hold to monitor side shell stress and associated fatigue.

6.2 Fatigue Monitoring

The system incorporates stress range monitoring to assess design fatigue life utilization and for usage within the data mining algorithms. The processing of extreme frequency counting for this purpose is based on simple 'rainflow counting'. Sensor data from deck and inner bottom longitudinals provides information on hull girder loading fatigue damage to welded connections. Rosette sensors on side shell frames also produce information on wave-induced lateral pressure loading damage.

6.3 Monitoring during Loading and Discharging

An important feature of the S.H.I.P. system is the capability to automatically monitor departures from the load plan and associated hull girder and localized stresses. Hull girder still water stress information is useful for the prevention of overstressing during cargo loading and de-ballasting processes. The S.H.I.P. system includes an automatic interface with the loading instrument, which allows the system to highlight any significant departures from the loading plan by constantly interrogating actual hull girder loads during the loading or discharging sequence. S.H.I.P. augments global monitoring during loading and discharge operations by the additional monitoring of local stresses in cross- deck strip and double bottom structure.

6.4 Radar-based Sea State Monitoring

Direct monitoring of sea state has a reputation as an intractable problem. Some progress has been made in previous work using downward looking radars mounted on the side of the ship, but these only measure sea state in the immediate vicinity and are not robust enough for North Atlantic operation. The S.H.I.P. system on the M.V. British Steel will eventually incorporate a radar system which will process back scatter data in such a way that permits sea state information to be collected. With additional signal analysis it will be possible to determine wave direction as well, by calculating Doppler shifts, [Lynn, 1987], [MIROS Ltd]. Another advantage of a radar-based approach is that it can generate the full directional spectrum that is of most use in an on-line advice situation.

Computations of wave size will be done through an analysis of the raw video signal alone without interfering with the normal operation of the radar, although certain commercial systems, e.g., MIROS Ltd., require a specific adjustment of the radar system. As mentioned earlier, for calculating wave speed and direction, the vessel's speed through water, heading, speed over ground and course over ground are needed also.

Within S.H.I.P. there is still a considerable amount of work to complete radar sea state monitoring, but previous work clearly indicates a correlation between radar clutter and local sea state. At present the system is based on the X-band radar, but it is intended to extend this to the S-band radar in due course. Work by other researchers [Skolnik, 1970], [Barton et al, 1991], has also indicated that both X- and S- band radar can produce useful information.

7. S.H.I.P. Data Mining

7.1 Background

Having developed a system which can give detailed information on current stresses, motions and, eventually, sea states, an obvious question is whether the system can be extended to generate useful advice for the user, based on this data. Within S.H.I.P., applications of data mining to on-board monitoring will be explored. As a first step this will be achieved by continually comparing past data entries in the database to the present situation. This entails building a system which learns from experience since its installation. The system will be advisory in nature and there may be operational reasons why the advice cannot be followed. This paper will offer only a brief reference to data mining principles and its specific applications within S.H.I.P. For a useful introduction the reader is encouraged to refer to selected texts in this field, such as Everitt [1980], Michalski [1980] and Michalski & Stepp [1983].

7.2. S.H.I.P. Pattern Recognition

Data mining is a set of techniques aimed at the discovery of hidden relationships within large bodies of data. Often a human expert would be able to verify a hypothesis quite easily, but is unable to form any such hypothesis because of the mass of the data. In the case of the S.H.I.P. project, a large body of data is generated relating to sea states, loading patterns, stress and fatigue measurements, wave impacts, speed through the water, etc. The S.H.I.P. system is mainly interested in predicting measured stresses and fatigue as a function of all other parameters. This is a continuous function, but reliable interpolation is needed between known data points.

It is very important for the S.H.I.P. system to know when to refrain from giving advice rather than giving bad advice. Therefore, the results of the data mining will be presented as a series of "fuzzy rules". These can be expressed in English so that users can check them for plausibility and will be probabilistic in output.

Fuzzy rules are not in themselves data mining and in most applications they are generated by hand. In S.H.I.P. they will be used to represent the results of the data mining, [Thornton, 1992]. The mining itself will be done by using genetic algorithms, which are more commonly used as an optimization technique, and conceptual clustering, such as the well known COBWEB algorithm, [Fisher, 1987].

7.3 S.H.I.P. Real-Time Guidance

The most important application is to allow the user to evaluate "what-if" scenarios based on weather forecasts. For example, "There is a weather system ahead with force 7 winds at 50 0 to our course - can the vessel proceed through it without an alteration in heading or speed ?". By predicting the likely effect on the structure the user can evaluate alternative plans. It would not be expected that the results of the predictions would be entirely accurate, any more so than the weather forecasts which form part of their basis.

However, its advice will be the best available from the on-board historical data base which is made up of actual ship structural performance and parallel environmental parameters.

A second application will not require the user to ask questions of the system. If the vessel is already in a situation where the stress is near the limiting values, the system will look for similar circumstances in the past, matching or interpolating details of the sea state, loadings, etc. It will search for cases where stresses and motions were acceptable and could give advice of the form " reduce speed 2 knots and head 200 further into the wind, because the user limits on the forward long-base gauges are being exceeded".

A third application also does not require user intervention. In essence, the S.H.I.P. system will learn the usual patterns that the sensors adopt and will continually search for anything "unusual" in the patterns of sensor data. When a new situation is observed, the information will be presented to the user, who will be invited to judge whether it is actually a problem, or just a new mode of operation.

8. S.H.I.P. Maintenance Tools

The S.H.I.P. system is augmented by shore-based predictions of the long-term deterioration of the hull structure. This off-line analysis of the hull deterioration processes is undertaken using a probabilistic approach, known as time-variant reliability analysis, to account for variabilities in strength and applied loads. Variabilities which are time-dependent are due to such factors as fatigue, corrosion and wave-induced stresses. The techniques adopted in S.H.I.P. have been described in considerable detail elsewhere, [Shi, 1991], [Shi, 1993].

S.H.I.P. monitoring provides data clusters to improve the analysis model, both by evaluating demand (thus improving the assessment of ductile collapse modes) and by including fatigue in the assessment of capability. S.H.I.P. makes use of this, in conjunction with focused inspection data and conventional reliability techniques, to generate advice on the state of the structure at a particular time and what the risk- the nominal risk- will be associated with it. The primary use of this tool lies in its long-term planning for maintenance intervention, i.e., the examination of the extent to which future ship operations may fall below an acceptable risk level and when the ship would require additional inspection and a revised maintenance plan.

9. User Feedback

At the time of preparing this paper the M.V. British Steel has been operating for some time with all long-base sensors, rosettes and accelerometers. Prototype radar-based sea state monitor and data mining modules have been installed although they are not yet fully integrated. Nevertheless several benefits have already been realized in fitting the S.H.I.P. monitoring system.

The greatest advantage so far is the awareness that the system has generated with officers concerning the loading of the structure under various conditions whether at sea or in port. Certainly great value is now placed on the automatic interrogation of significant deviations of loading computer predictions from actual stress levels during loading and discharging operations and stress levels in areas sensitive to individual hold overloading.

So far, at sea, damage to internals within the fore part of the vessel has all but been eradicated. This is due to the system warning of conditions where bow wave impacts and possible structural damage may occur. This has proved to be particularly significant on North Atlantic westward ballast passages in deteriorating weather, with the system prompting increasing ballast or implementing speed and heading changes. British Steel have also recorded considerable interest from the users of the present system concerning the future integration and testing of data mining and radar-based sea state monitoring to advise of any unusual circumstances which might precipitate damage and to provide alternatives for vessel maneuvers to reduce the risk in such circumstances. [Thompson et al. 1995]

10. Future Developments

In the S.H.I.P. project data from a relatively large number of sensors is obtained, from which deductions can be made about the state of the structure. However, there is little monitoring of local stresses or direct evidence of structural degradation, such as corrosion or widespread cracking, and this means that predictions of future reliability must necessarily be based on conservative assumptions. In this section some possibilities for the not-too-far distant future are discussed. If the S.H.I.P. project is successful, most of these will be realistically attainable.

10.1 Fatigue Calculation

Part of the work in the S.H.I.P. project aims to find relationships between local stresses, say at the sideshell, and global stresses at the measurement points. If this is successful it will enable realistic fatigue calculations to be performed based on data from reliable deck-mounted sensors, rather than inaccessible rosettes mounted in hostile environments such as holds or ballast tanks.

10.2 Corrosion Monitoring

It is well known that many problems in ships stem from excessive corrosion, in areas which are often difficult to inspect. With the change to double hull tankers there is a possibility that this will be an increasing problem in these vessels, which have a more onerous inspection requirement. In the quest to provide more information on the behavior and condition of the vessel the next stage is perhaps continuous corrosion monitoring. Techniques for automated corrosion monitoring have been developed in other industries for applications such as storage tanks although development work is required to adapt these methods for shipboard use.

10.3 Maintenance Scheduling

Although the concept of inspection and maintenance at fixed intervals is unlikely to be abandoned completely the Classification Societies may one day allow as an alternative (for vessels with appropriate systems) the adoption of criteria based on some measure of usage. This would take into account environment, days at sea, load conditions, structural condition, structural design etc., and would have to be supported by well directed inspection. This may allow well run operators to revise maintenance schedules to take account of commercial realities, without increasing risks to people or the environment.

10.4 Weather Routing

Once data mining has established relationships between sea state and hull stress, it should be possible to make use of this information in weather routing, to provide advice which is more closely tailored to the capabilities of an individual ship.

11. Application of ISIT Technology

The application of shipboard monitoring systems such as the Ship Hull Integrity Program (S.H.I.P.) can add significantly to the safety of a ship, particularly when it is subjected to hazardous conditions. While these systems are installed to give assistance to the ships crew in operating the ship, the ability to monitor and analyze the data remotely can add to its effectiveness. Stand alone shipboard systems are always dependent on the monitoring and actions of the shipboard operators. The S.H.I.P. makes use of special shipboard sensors such as strain gauges and accelerometers as well as input from other ships instrumentation such as radar. It is also important to have as much information as possible relating to the condition of the ship in order to determine causes of high stress readings. In order to make such monitoring systems available on a standard basis it will be necessary to provide an Information Technology (IT) environment that can readily support such systems with minimum added workload on the crew.

There is a project underway in the industry called the Integrated Shipboard Information Technology (ISIT)

Platform, being co-funded by a team of eight companies from the U.S., Canada, and Norway, and the U.S. Government through the DARPA/Maritech program. ISIT addresses the three IT requirements to operate a standard shipboard monitoring system. (Figure 3) The first system is scheduled for installation on a tanker mid 1997.

11.1 Shipboard Data Collection

The first requirement is to provide a standard method of collecting the required sensor data in a common database for access by the particular monitoring system but also available to other shipboard systems. ISIT provides gateways into various shipboard control and monitoring systems and converts the data to a standard format that can then be accessed and used by any shipboard system.

11.2 Secure IT Platform

A second IT requirement is to have the monitoring system run on a standard secure IT platform that can be supported by an IT manager ashore. The ISIT platform provides this platform which is a layer of software services currently being built on a Windows NT operating system. By having the shipboard applications program, such as hull monitoring, use these services through APIs (Application Program Interfaces), there is a common way to support the software from a shore facility.

These services provide both local and remote alarm system monitoring, hardware and software testing, alarm reporting, and other services required to monitor the condition of the system itself.

11.3 Communications Link

The third requirement concerns the ability to link the shipboard system to the shore system in a standard manner regardless of the communications service used. This requires special software on the ship because of the lack of any standard interface between the new digital satellite services and the public networks. The ISIT Communications Manager insulates the application program from the problem and provides a common communications interface regardless of the system used.

11.4 Standards

While the necessity for such a standard IT platform is needed to effectively support mission critical applications, which today include all systems relating to the safety of the ship, it is also recognized that the platform must meet international standards to be widely accepted. These standards are currently under development, first by way of the U.S. National standards (ASTM) and then through the International Standards Organization (ISO). There is a standards committee represented by over 50 organizations from 10 countries.

11.5 Future

BMT SeaTech and MMS are working together to make S.H.I.P. work in the ISIT environment in the future. This should reduce the cost of installations and make them remotely supportable from a shore office. It will also allow the collection of data from many shipboard installations for further analysis by both classification societies and other support organizations.

Acknowledgments

The authors would like to thank the European Commission and British Steel plc. for their kind permission to publish this paper.

References

1 Barton, D.K. et al, 1991, **Radar Evaluation Handbook**, Artech House

2 Brook, A.K. and Robinson, D.W., 1992, Analysis of Strain Gauge Measurements and Reliability of Theoretical Load Prediction Methods, Lloyds Register Report No. TPDD 92/18.

3 Brown, J.C. and Clarke J.D., 1992, "Recent Progress on Wave Induced Loading Measurements in Warships", *Charles Smith Memorial Conference, Recent Developments in Structural Research.*

4 Everitt, B., 1980, *Cluster Analysis*. Heinemann, New York

5 Fisher, D. & P. Langley, 1986. " Methods of Conceptual Clustering and their Relation to Numerical Taxonomy," *Artificial Intelligence and Statistics*, W Gale ed. Addison-Wesley, Reading, Ma.

6 Fisher, D., 1987, "Knowledge Acquisition via Incremental Conceptual Clustering," *Machine Learning*, Vol 2, pp139 - 172, Kluwer Academic.

7 Gennari, J., Langley P. & Fisher D., 1989 " Models of Incremental Concept Formulation," *Artificial Intelligence,* 40, 11

8 Janssen, F.A.J. and Huysmans, R.H.M., 1993, "Installation of Measuring Equipment on Board M V "Nedlloyd Africa," Final Report, MARIN Report No. 410777-2-SE

9 Kohonen, T. 1988, "Associative Memory: A Systems Theoretical Approach," New York, Springer

10 Lloyds Register, 1991, Provisional Rules for the Classification of Hull Surveillance Systems

11 Lynn C and Shin, D.G., 1994, **Radar Systems**, Macmillan

12 Melitz, D.T., Robertson, E.J. and Davison, N.J., 1992, “Structural Performance Management of VLCCs - An Owners Approach,” SNAME, New York Metropolitan Section.

13 Michalski, R.S., 1980, “Knowledge Acquisition Through Conceptual Clustering: A Theoretical Framework and an Algorithm for Partitioning Data into Conjunctive Concepts,” *International Journal of Policy Analysis and Information Syst*ems, 4, 220

14 Michalski, R.S & Stepp, R.E., 1983 “Automated Construction of Classifications: Conceptual Clustering Versus Numerical Taxonomy,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **5,** 396

15 Michalski, R.S, Stepp, R.E. & Diday, E., 1981. “A Recent Advance in Data Analysis: Clustering Objects into Classes Characterised by Conjunctive Concepts,” *Progress in Pattern recognition,* L.N. Kanal & A. Rosenfeld eds. North-Holland

16 MIROS Ltd. Operation Manual for WAVEX Radar Data Capture System

17 Mutton, P.J., 1994. “The Integrated Hull Condition Monitoring System (IHCMS): Concept and Applications,” *Ship Shape for the 21st Century Conference,* Sydney.

18 Robinson, D.W., 1990, “Data Recorders - Operating with Safety and Efficiency,” *IMAS90*

19 Skolnik, M.I., 1970, **Radar Handbook**, McGraw-Hill

20 Shi, W.B. & P.A. Frieze, 1993, “Time Variant Reliability of a Mobile Offshore Unit”.

21 Shi, W.B., 1991, “Maintaining Marine Structures: A Probabilistic Approach,” ISMS’91, Shanghai, China, 1991.

22 Thornton, C.J., 1992 “Techniques in Computational Learning,” Chapman & Hall.

23 Ward, G. & Katory, M., 1975, “Data on Midship Bending Stresses from Four Ships,” *International Symposium on Dynamics of Marine Vehicles and Structures in Waves.*

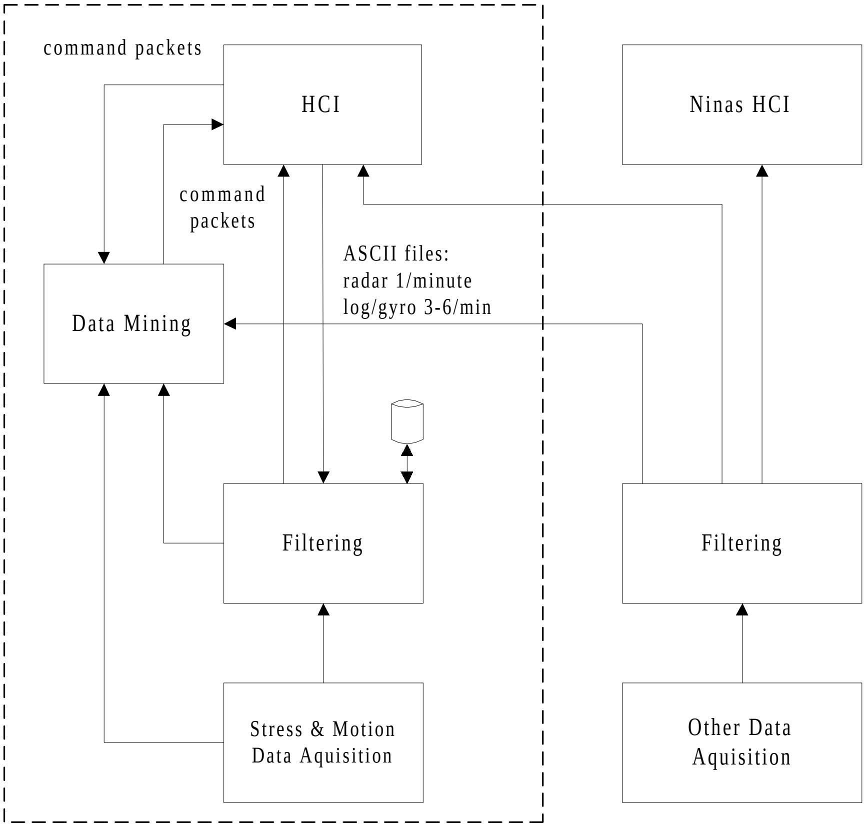

Figure 1
S.H.I.P. System Architecture

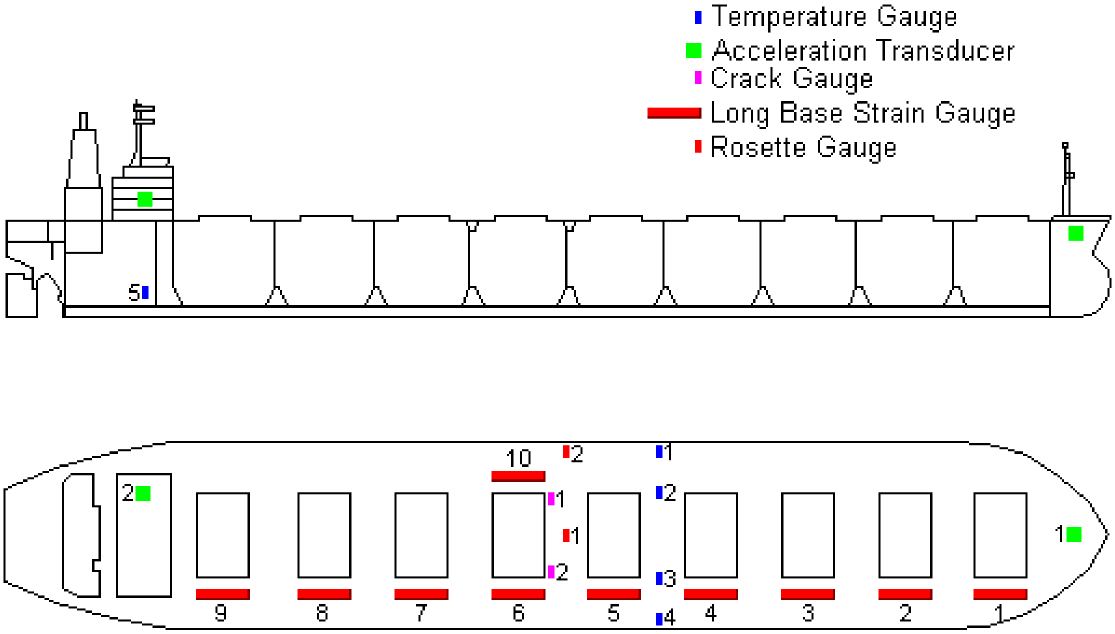

Figure 2
S.H.I.P. Sensor Arrangements

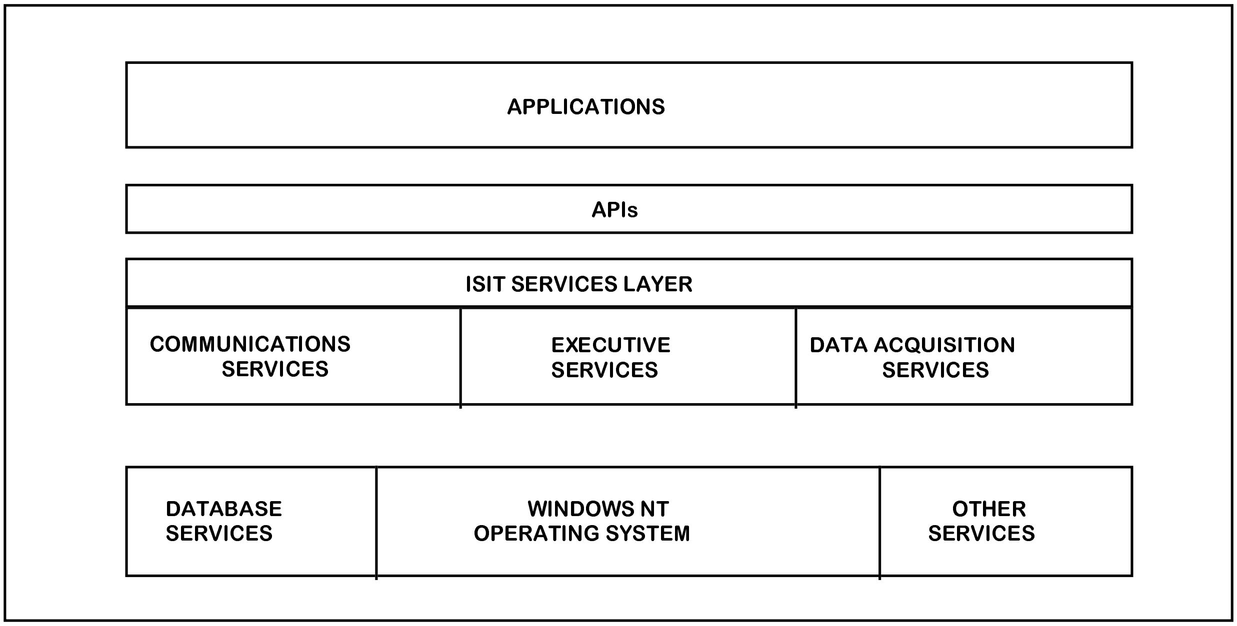

Figure 3
ISIT Structure

Discussion

by Steve Sharpe
Executive Director, Ship Structure Committee, USCG

I congratulate the author on a very interesting paper and the ISIT team on doing a very valuable effort for the marine industry. I was able to attend a briefing by Mr. Story and the ISIT team last year as this program was being developed. The parallel that struck me most was the comparison of ISIT to Windows. The ISIT system is foremost an architecture for other systems to exist within. This system can become a great tool.

There are several efforts being completed consecutively which relate to ISIT. The Gulf Coast Maritime Transportation Consortium is preparing a RAM database system to gather together the information from the systems and organize it for the customer. I understand the ISIT team is working with them in this effort. This system will enable that data to be sent to the home office to allow them to make real time decisions on systems while they are still at sea.

The University of Berkeley, under the leadership of Bob Bea, is doing a similar effort to develop a database to record and correlate data on hull failures. One thing recently learned by the team there is that merely recording the failure of hull members does not assist the user very much. The analyst must also have available environmental and operational characteristics. Recently two cases of correlated hull failures between several ships were found to be attributable to environment (waves impacting on one side of the ship in transit) and operating conditions (tank levels, course headings). This required a detailed manual search of the ships logs, something not normally undertaken. Such correlations are only routinely possible if all the data is brought together in a common format to be analyzed. Phase one of that study was printed as SSC-380 Ship Structural Integrity Information System and phase two as SSC-388 Ship Structural Integrity Information System; Phase II.

by Dr. Marc Mandler
Waterways and Marine Safety, USCG R&D Center and Co-chair, National Science and Technology Council, Subcommittee on Human-Centered Transportation Safety

The authors discuss the development of a sophisticated information management system onboard ships to provide crew with knowledge about the status of a variety of shipboard monitoring systems. My understanding from the paper is that some parts of this system are being tested today, and other parts are merely a conceptual description of what is technically feasible in today's information age. The proposed system integrates information from a tremendous number of systems and subsystems both onboard the vessel and from land-based information sources. The challenge that this system poses is developing the human interfaces for these information sources in such a way that they are performance enhancers rather than performance detractors.

Several years ago President Clinton's National Science and Technology Council (NSTC) formed a Transportation Committee to look for opportunities in our nation's transportation system where investments in science and technology could be of benefit to safety and competitiveness. A subcommittee was formed to look at opportunities to improve our transportation system by considering human factors. This subcommittee, of which I am a co-chair, has had active participation from experts in DoD and NASA, as well as from the various modes in DOT.

We have found that transportation safety and competitiveness can be enhanced through consideration of human-centered principles in the design and operation of transportation systems. The greatest need is in automation system design, understanding the proper role for an operator in an automated system, and effectively managing the flow of information between automated systems and humans. The ideas proposed in this paper embody many of the challenges we face in this information age. The concept is founded on sound principles of providing information to ship crew that will enhance their performance and reduce the risk of a system failure. This concept is achievable if the designers take an approach that puts the human at the center of the design decisions. Success requires a clear focus on the human interface, and properly identifying the function that should be allocated to the computer and those that are reserved for the human, and ensuring that the right information is distributed to the right person at the right time.

by Walter M. Maclean
U.S. Merchant Marine Academy, Kings Point

I want to thank Mr. Story and his co-authors for telling us of their work in integrating hull monitoring and ISIT. I am also pleased to hear the developments reported in this paper are going to be operational in some new construction. It is good to know that we have more and more operators recognizing the value this technology has to offer for improving their operating performance. A number of U.S. Flag operators have retrofitted their ships with hull monitoring systems, but this is the first I have heard of efforts to fit new ships with this combined technology. That **is** most encouraging and certainly a big step in the right direction.

The Maritime Administration, SNAME, U.S. Coast Guard, Ship Structure Committee, several U.S. Flag steamship companies and the Military Sealift Command have all provided support in this country for development of this technology over a period of some twenty years. These efforts have been reported in numerous papers and technical reports, none of which are cited in the list of references. There is a question then as to whether the application developments reported here are independent of the earlier work in this country, or do they build upon this work. Could the authors tell us how they are related?

One of the problems faced in the U.S. work has been the need to retrofit ships due to the lack of new construction in the recent years. Operating budgets have been typically tight and justifying the cost of retrofit has often been hard to come by except where clear benefit is seen. On the other hand, installation on newbuildings is easier to come by due to the capital budget being more supportive of instrumentation installation costs, which are generally less. To more easily promote this technology, it is necessary to have reliable installation cost data. Do the authors have information on the installation cost of the system discussed?

Thanks again for an interesting and well made presentation.