

TAKING THE INTEGRATED CONDITION ASSESSMENT SYSTEM TO THE YEAR 2010

Michael DiUlio, NAVSEA, USA
Chris Savage, Brian Finley, NAVSEA Phila., USA
Eric Schneider, AMSEC LLC., USA

ABSTRACT

Since the early 1990's, the United States Navy has been augmenting control systems by installing the Integrated Condition Assessment System (ICAS) to enable automated Monitoring, Trending, and Condition Based Maintenance (CBM). The Navy, capitalizing on Commercial Off the Shelf (COTS) software, has successfully deployed ICAS on 95 surface ships.

ICAS is the Navy's CBM Program of Record and is the shipboard system for machinery monitoring and analysis, supporting various levels of condition-based maintenance. For ICAS to realize its full potential, enhancements must continue and be deployed in the fleet. Examples of such enhancements would include a seamless integration with the shipboard control system and a Computer Maintenance Management Systems (CMMS) such as an Enterprise Resource Planning (ERP) system.

This paper will trace the history of the ICAS software product in the Navy and detail the enhancements required to bring it to a seamless integration with the control systems of 2010.

KEY WORDS

Integrated Condition Assessment System (ICAS), Condition Based Maintenance (CBM), Machinery Control System (MCS)

INTRODUCTION

The authors of this paper foresee a maintenance and operation vision in 2010 that fully integrates ICAS with the control and logistical support systems, as depicted in Figure 1. ICAS will have the ability to predict a fault on a particular machine and, at the appropriate time, alert the control system to secure the unit and bring an alternate on line. At the same time, ICAS will alert the integrated logistic system of the required maintenance to be accomplished in order to prevent the impending casualty. This will allow the ILS to ensure necessary parts and specialized labor are available at the optimal time, thus maximizing readiness while reducing maintenance costs.

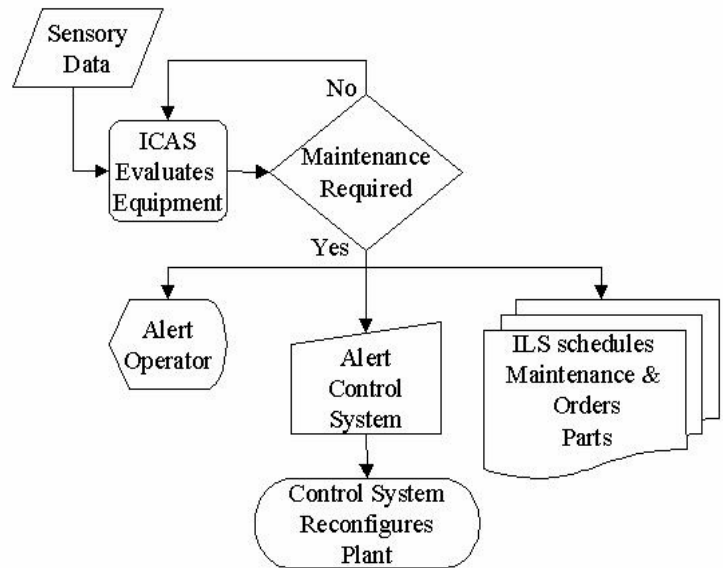


Figure 1. Process of 2010

ICAS OF TODAY

The Integrated Condition Assessment System (ICAS)¹ is a Commercial Off the Shelf (COTS) software product for which the U.S. Navy holds Government Purpose License Rights (GPLR). It is developed in a shell type architecture to allow for varied implementation of machinery monitoring and CBM. Presently, ICAS is installed on 95 U.S. Navy ships. Figure 2 depicts the ICAS Desktop Shell. This shell is identical on all 95 ships. The Configuration Data Set (CDS), which contains the engineering knowledge base, varies based on the ship system configurations.

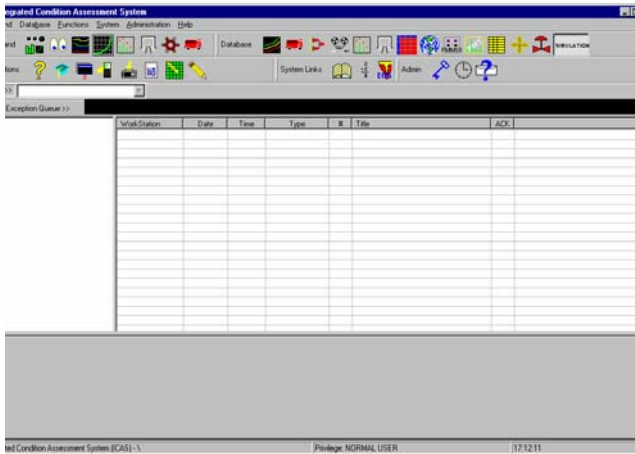


FIGURE 2. ICAS Shell Top

A typical U.S. Navy ICAS installation consists of four to five workstations, one in each major machinery compartment as depicted in Figure 3, connected by an active Local Area Network (LAN).

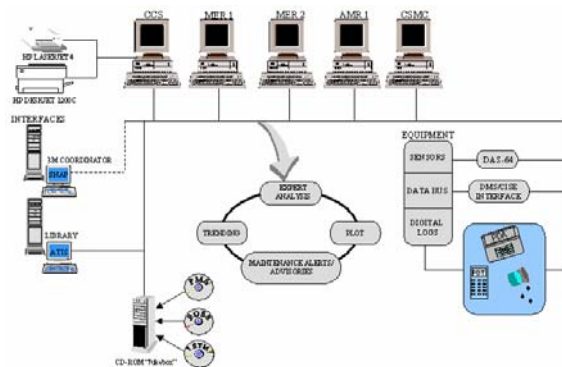


FIGURE 3. Typical ICAS Installation

Each workstation accommodates a unique Configuration Data Set (CDS), which contains the engineering information. ICAS converts uploaded data into useful information. Data is trended, evaluated, and fused to allow

for maintenance to be accomplished based on evidence of need. Typically ICAS will interface to an existing machinery control data bus to receive pertinent information without duplicating sensor or processing hardware. For additional data points, ship's force utilizes a portable data collector to upload data, via a serial interface, to the workstations.

An ICAS installation on a CG-47 class hull monitors the following machines/systems:

- Main Propulsion
- Reduction Gear
- Line Shaft Bearings
- Controllable Pitch Propeller
- Ship Service Gas Turbine Generator
- Fuel Oil Service
- Main Propulsion Lube Oil
- Lube Oil Fill, Transfer, and Purification
- Air Conditioning
- Refrigeration
- Distilling Plant
- Auxiliary Boiler
- Firemain
- Seawater Pumps
- Fuel Oil Fill and Transfer
- High Pressure Compressed Air
- Low Pressure Compressed Air

ICAS also contains links to digital Navy logistic products such as the Engineering Operational Sequencing System (EOSS), Planned Maintenance System (PMS), and Integrated Electronic Technical Manuals (IETMs). These link directly to the appropriate section or card as well as enabling browsing of the entire books.

Data automatically collected on these ships has annually saved thousands of man-hours through the automation of performance monitoring as well as time saved through the software's automated diagnostic features.

An effort has been made to gather this data in a common database, Maintenance Engineering Library Server (MELS)², so that statistical analysis can be accomplished to gain a better knowledge of equipment operation in a marine environment and to further maintenance savings. As more data is gathered, the failure rates and causes of the failures are better understood and thereby more predictable. This knowledge is used to effect maintenance periodicities, design changes, and operational practices.³

Figure 4 is a graphical plot of a Gas Turbine Generator Start on a CG-47 Class hull; the data was retrieved from the MELS database. The plot can be used to determine if the specific start was successful and further used in determining the overall start reliability of the engine.

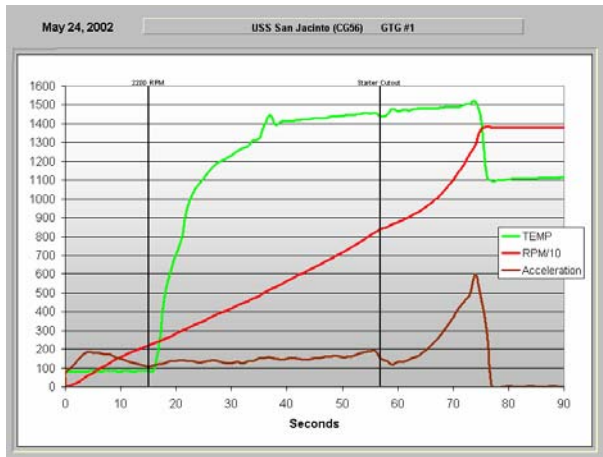


FIGURE 4. GTG Start

Technicians can use this type of information, processed data, in pre-screening systems for review by maintenance visit assessment teams⁴. These teams visit the ship prior to deployment to identify issues and perform needed maintenance. Figure 5 represents a trend of the three Gas Turbine Generators (GTG) start reliabilities over a ten-month period.⁵ By reviewing this trend, the technician gains immediate knowledge of the operational capability of all three units. Trending this type of processed data (start reliability in percentage format vice parametric) has allowed maintainers to not only identify maintenance, but also capture a system's operational capability.

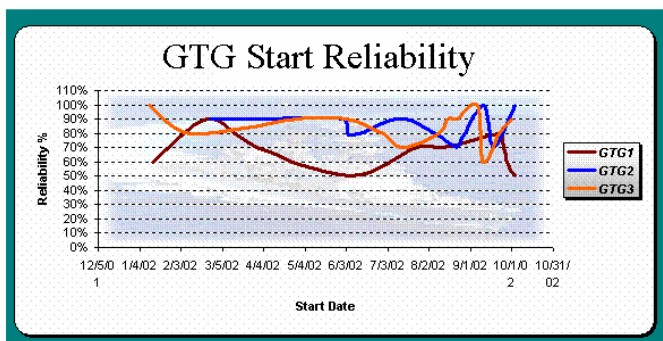


FIGURE 5. GTG Start Reliability

ICAS OF TOMMORROW

The ICAS of 2010 will be a continuous evolution of the "ICAS of today" with new technologies and best business practices implemented. It will leverage off commercially available Electronic (E) business applications, wireless networks and devices, while integrating with specific military control systems and integrated logistic products in

a secure environment. The following paragraphs detail the evolution of the hardware and software needed to achieve the "ICAS of Tomorrow." The author's view of this evolution is depicted in Figure 6.

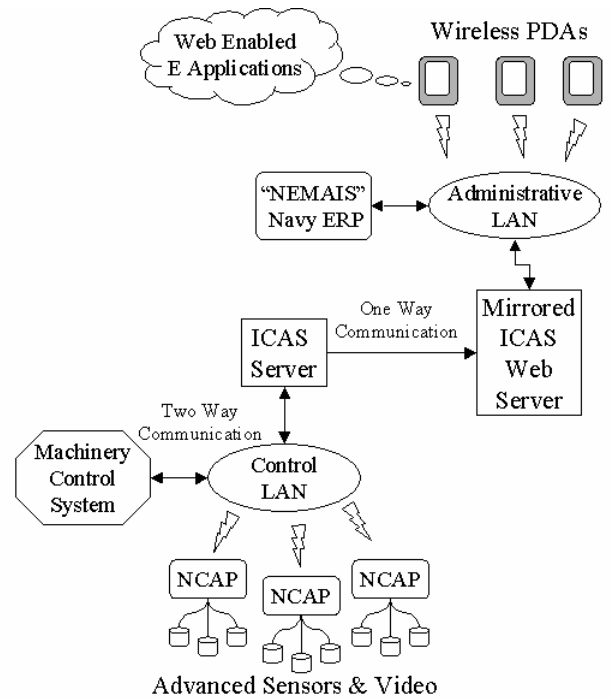


FIGURE 6. ICAS of Tomorrow

SOFTWARE

Open Systems Architecture

An Open Systems Architecture will be achieved on different levels at varying resolution. Presently, ICAS allows for open exchange of information at certain levels, data processing and presentation. ICAS will also need to provide for open exchanges at the diagnostic and prognostic levels to meet the challenges of distributed systems. Figure 7 depicts these levels overlaid on the Open Systems Architecture for Condition Based Maintenance (OSA-CBMTM).⁶ The OSA-CBM model was developed under a Dual Use Science and Technology (DUST) program between the Office of Naval Research (ONR) and industrial partners.

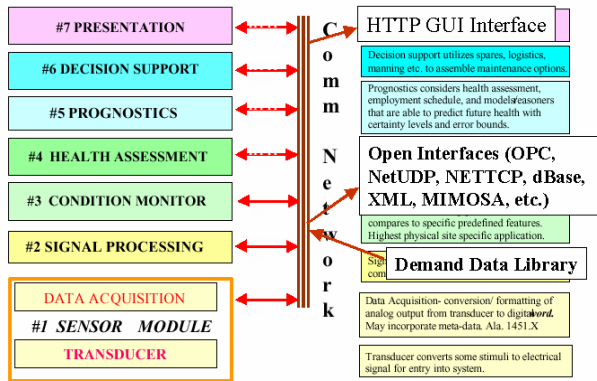


FIGURE 7. OSA-CBM

Open System Architecture allows many benefits in the system's life cycle; from system development through deployment. The Navy can leverage off of other installed open systems to share data and/or information without costly hardware and software development, testing, and installation. This architecture reduces In Service costs by replacing obsolete hardware and software with those of a "plug and play" philosophy. These savings are realized when the new piece of hardware or software seamlessly is integrated with the legacy system.

Electronic Applications

ICAS will evolve into a server application allowing for connectivity through electronic (E) applications. The architecture will allow a single application of ICAS to operate fully integrated with the control system, while providing all of the data processing, collection, storage, and reasoning. This server would then be mirrored allowing it to act as a pseudo web server for various E applications. It is envisioned that all data/information viewing and processing will be provided via these E applications.

E applications will be the heart of the shipboard machinery information distribution and display. They will operate on both workstations and handheld PCs. It is believed the hand held PC will be the sailor's viewport into the operation and status of the machinery plant. They will allow shipboard operators the ability to view real time plant and machinery status via web browser technologies. In addition, when a problem is detected, alerts can be sent via these units to indicate a problem and provide access to the necessary data and logistics information for troubleshooting. Thus the operator will be in constant contact with the required operation and logistic information.

Enhanced Diagnostics & Prognostics

Since the inception of ICAS, an emphasis has been placed on improving and evolving the automated expert diagnostic system. The original software version included

a Boolean Logic expert system. The system allowed ICAS to be deployed on a wide range of equipment and systems while meeting its return on investment thresholds. Follow on versions of ICAS will include Fuzzy Logic in the expert system and the ability to use third party plug-in diagnostic modules.

However, to meet the ongoing challenges of reduced manning, increased readiness, and reduced maintenance costs, these enhancements must be built upon to allow for the development and utilization of prognostic and enhanced diagnostic algorithms. The future model is based on automated prognostic algorithms' ability to identify impending faults and predict the remaining useful life of the machine. This will allow the system maintainers and operators to take appropriate action at the optimal time.

The ICAS program is currently involved with several prognostic enhancement projects. These projects use different types of analysis engines (i.e. model based, neural networks, etc.) to perform diagnostic and prognostic capabilities. One focus is on predictive algorithms for Gas Turbines Modules (GTM). The GTM algorithm relies on comparing operational data with engine models to determine its remaining life.⁷

A second project centered on using a COTS product, MACSEA Limited's *Diagnostic EXPert Test Engineering Reasoner* (DEXTER™), which utilizes a Bayesian probabilistic neural network to provide both prognostic and diagnostic capabilities.⁸ A version of the product was installed on an LSD-41 class hull to monitor the main propulsion diesel engines.⁹ The software product utilized all sensory information provided via the ICAS infrastructure.

HARDWARE

VIDEO AND ADVANCE SENSOR INTEGRATION

The ICAS of tomorrow will include the integration of video and advanced sensors. ICAS information is used for machinery assessment and to decrease the need for manual inspections by visit teams or ship's force. However, at this point certain inspections are still required due to the fact that these failure modes cannot, or are too costly to, be monitored by sensors and instrumentation. Integrating video into ICAS will remove certain requirements for manual visual inspections (i.e. leaking pump seal) and thus further support reduced manning initiatives.¹⁰ The ICAS of today has already established itself as a tool for implementing reduced manning, however the effectiveness can be multiplied by integrating video monitoring. This integration will allow video to be triggered by alarm and

maintenance indicators. Thus watch standers will not continuously monitor all video channels; triggered channels will be proactively presented.

Also as new types of sensors are developed, they can be used to automatically monitor and detect failure modes that previously could only be identified through manual inspections. An example of this would be automatic corrosion detection sensors.

WIRELESS DEVICES

In addition to hardware and software changes, the authors foresee a breakthrough in the development and deployment of wireless devices.

Wireless I/O Devices

One such area of these devices would be Network Capable Access Points (NCAPS). NCAPS allow sensory data to be collected and transmitted via a wireless Local Area Network (LAN) to the control and monitoring system. These units greatly decrease installation and life cycle costs. 3eTI's Wireless Input/Output Node (W-LION™) is an example of an NCAP, depicted in figure 8. It allows up to eight sensor inputs to be processed and sent wirelessly to ICAS workstations.¹¹



FIGURE 8. NCAP

Wireless PDA's

The ICAS of 2010 will include the use of wireless Portable Digital Assistants (PDAs). These PDAs will be used to upload and view information in conjunction with ICAS, as well as provide an interface into the integrated logistics system. They will evolve to be the personal tool for both the operator and maintainer, allowing them to view

anything from the plant status to the status of a parts requisition while going about their daily routine.

FULLY INTEGRATED WITH CONTROL SYSTEM

In most installations of today, ICAS is partially integrated with the control system. This partial integration provides ICAS the ability to access sensory data, alarms, and control system configuration. This integration needs to be advanced to allow for ICAS to send information back to the control system. This information will include recommendations of which equipment to operate. An example is the following scenario: Fire Pump #1 has been experiencing high vibration. ICAS has been automatically monitoring the unit and detects that the unit is not operating within specification. ICAS will send a message to the Machinery Control System to automatically shut down Fire Pump #1 and bring Fire Pump #2 on-line. This information maybe no more than a health indication number. The following is a simplistic example of a five number system:

- ONE - Unit available for full operation, no restrictions.
- TWO - Unit available for operation, however maintenance is scheduled.
- THREE - Unit available for operation with restrictions, maintenance is scheduled.
- FOUR - Unit has significant degradation and should be operated in an emergency situation only. Maintenance is scheduled.
- FIVE - Unit has failed and cannot be operated. Maintenance is scheduled.

The control system, aware of each unit's health, can select the appropriate unit to operate. This additional "feedback loop" will also allow for the prevention of cascading and catastrophic failures. For example, if ICAS detects an engine problem, it can order the engine to de-rate or slow down to prevent a catastrophic failure. This process is depicted in Figure 9. Prevention of such failures is the difference between a small repair and a complete overhaul; a significant cost savings.

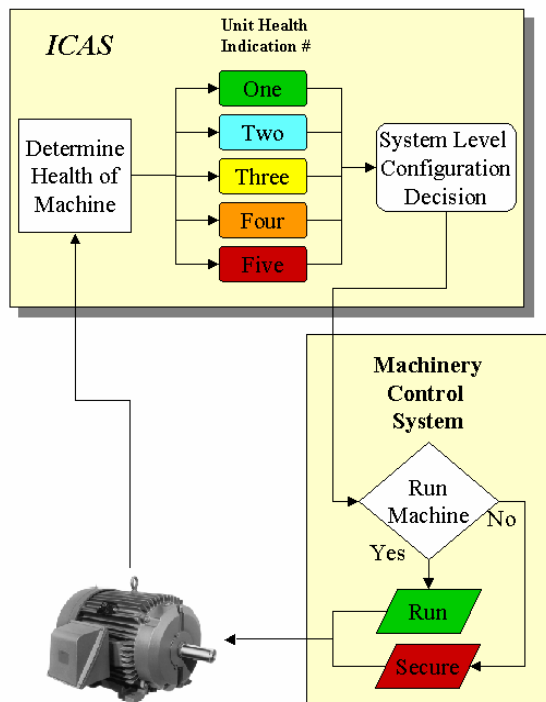


FIGURE 9. Automated Control Process

It is believed by the authors that a natural progression of this interface would have some manual user intervention.

FULLY INTEGRATED WITH NAVY'S ENTERPRISE RESOURCE PLANNING (ERP) SYSTEM

ICAS should be fully integrated with the Navy's Enterprise Maintenance Automated Information Service (NEMAIS). The NEMAIS program is a joint NAVSEA and Fleet initiative to implement an Enterprise Resource Planning (ERP) solution improving maintenance and modernization processes aboard ship and in shore based industrial activities.¹²

ICAS will provide maintenance information and recommendations to NEMAIS so the work order can be scheduled, parts can be ordered, technical documents can be provided, and resources assigned. The information from ICAS will allow for the scheduling of work on the condition of the equipment thus helping to streamline the process and reduce maintenance costs.

With ICAS receiving information from the logistics management software, it can further provide information to the operators on what maintenance is planned and

inform the control system to shift equipment to allow for the planned maintenance.

WHAT IS NEEDED TO GET THERE

Some of the hardware and software enhancements required to fulfill the "ICAS of 2010" are presently being explored by various programs. These include enhanced prognostic and diagnostics, integration with the machinery control system and NEMAIS. Increased bandwidth and data compression algorithms are required to allow the flow of information between the ship and shore based technical representatives. These representatives will be able to assist in the complex troubleshooting, maintenance, as well as maintenance planning, thereby supporting reduced manning.

CONCLUSION

By implementing the improvements cited in this paper, ICAS will evolve into the Navy's maintenance and monitoring system of the year 2010. The successful integration of ICAS with the control systems and NEMAIS will provide the future Navy a complete Asset Management Solution for any given system.

REFERENCES

- [1] Integrated Condition Assessment System (ICAS) is developed by IDAX Inc (now GE Power Systems), Jan 1992.
- [2] Maintenance Engineering Library Server (MELS); Savage and Albright; American Society of Naval Engineers (ASNE) Maintenance Symposium, Oct 2001.
- [3] Data utilization for Maintenance Decisions; Savage and Ferrese; American Society of Naval Engineers (ASNE) Smart Ship Symposium, June 1999.
- [4] Revolutionizing Maintenance Through Remote Monitoring via ICAS & Distance Support; DiUlio, Finley, Savage and Krooner; DOD Maintenance Symposium, Oct 2002.
- [5] Allison 501k17 Scoreboard; Krooner, December 2002
- [6] Prognostic Enhancements to Diagnostic Systems (PEDS) Development for Power Generation Systems; Byington, Roemer, Galie, McGroarty, Savage, April 1997.
- [7] A Practical Application of Probabilistic Neural Networks and Bayes Theorem to Machinery Failure Prevention; Logan, Savage, and Galie; 51st Meeting of the Society for Machinery Failure Prevention Technology (MFPT), April 1997.
- [8] DEXTERTM User's Manual for the USS COMSTOCK (LSD-45), Oct 1999
- [9] Open Systems Architecture Enables Health Management for Next Generation System Monitoring

and Maintenance; Discenzo, Nickelson, Mitchell, and Keller, OSA-CBM™ Development Program White Paper, <http://www.osacbm.org>.

[10] Integrated Condition Assessment System - Video Monitoring (ICAS-VM); McLean, November 2002

[11] Wireless Expansion and Enhancements of ICAS; Hogan and Savage, 13th Ships Control Symposium, April 2003

[12] Navy ERP Project Overview; Association for Enterprise Integration Conference, 2002.

BIOGRAPHY AND CONTACT INFORMATION



Michael DiUlio, MSES, BSEE

Mr. DiUlio is the ICAS Program Manager for the US Navy. He has a Masters in Engineering Science Emphasis in Computer Design from The Pennsylvania State University (1991) and a Bachelors of Science Degree in Electrical Engineering from Villanova University (1985). He has over 17 years of experience with machinery control systems, with the last 18 months working ICAS programmatic, budgetary and technical program issues.

Michael DiUlio can be reached at diuliomr@navsea.navy.mil



Brian Finley, BSEE, MCSE

Mr. Finley is the ICAS Deputy Program Manager for the US Navy. He has a Bachelors of Science Degree in Electrical Engineering from The Pennsylvania State University. He has over 15 years of experience with ship electrical systems and networks, the last 7 years with ICAS. For the last 4 years, Mr. Finley has assisted the ICAS Program Office at NAVSEA with budgetary, scheduling and various programmatic and technical issues for the program. Mr. Finley is also a registered Microsoft Certified Systems Engineer.

Brian Finley can be reached at finleybk@nswccd.navy.mil



Christopher Savage, BSEE

Mr. Christopher Savage is the head of the Maintenance, Monitoring, and Information section at NAVSEA Philadelphia. He holds a Bachelors of Science in Electrical Engineering from The Pennsylvania State University. His last 10 years were focused on Condition Based Maintenance (CBM) and automation. His group is the Software Support Activity (SSA) and In Service Engineer Agent (ISEA) for ICAS.

Chris Savage can be reached at savagecj@nswccd.navy.mil



Eric Schneider, BSME, PE

Mr. Eric Schneider is the program manager for Monitoring and Control Systems for AMSEC, LLC. He holds a Bachelors of Science Degree in Mechanical Engineering from Old Dominion University. He has over 11 years of experience in design and repair of ship main propulsion and auxiliary systems, focusing the last 6 years on condition monitoring / RCM for ship systems. He is a registered Professional Engineer in the Commonwealth of Virginia, and is an Engineering Duty Officer in the Naval Reserve.

Eric Schneider can be reached at eric_schneider@amsec.com

Presented at the Thirteenth International Ship Control Systems Symposium (SCSS) in Orlando, Florida, on 7-9 April 2003.