

# Centralized Analysis for CBM Enabling Technologies

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**Ken Krooner and Eric Pool**

*Engineering - Software - Reliability* Group

## ABSTRACT

Engineering • Software • Reliability Group (ESRG) has been assisting the U.S. Navy in utilizing a maintenance process that is enhancing condition assessment processes for HM&E operations and maintenance. This process began by equipping ships to continuously collect engineering plant performance data for use in a Condition-Based Maintenance environment. Today, the digitized performance data is accessible in real-time to shipboard operators and on the world-wide-web for shore-based personnel. Access to this data is enabling the U.S. Navy to obtain unprecedented situation awareness of the health of their propulsion plants and auxiliary equipment. Furthermore, the quality and accessibility of this data will eliminate the critical delay of detailed engineering performance analysis. All performance analysis evaluations will be provided on a continuous basis, which will have a direct impact on maintenance scheduling, remote troubleshooting, life cycle management and more.

It is the vision of ESRG to provide operational and maintenance organizations with a common and repeatable method of interpreting and communicating engineering performance data. Having access to centralized equipment performance data, combined with the real-time performance analysis of fleet wide conditions, will enable operation and maintenance communities to take advantage of real-time actionable performance information to make critical operational and maintenance decisions.

## Current Functional Requirements for Navy CBM Systems

The following pages contain several case studies that outline the current processes and uses of equipment performance data. A transition to a centrally managed CBM system will provide the architecture and infrastructure to support enterprise based performance assessments of distributed assets.

### Reduced Manning Requirements

In the US Navy, the use of machinery performance data is currently being institutionalized through several programs. The Maintenance Assessment Index (MAI) approach to the equipment assessment visits is one of those programs. The MAI process combines historical performance results, as accumulated from SCLSIS and 3-M system, to develop a Risk Priority Number (RPN). The RPN is calculated for each equipment component and provides maintenance agenda building teams the flexibility of adding and removing assessments based on statistical probabilities of the respective component failing during the next deployment.

Machinery performance data adds value to the process by analyzing actual equipment performance. This is independent of the RPN assessment and historical performance. Performance data provides a “real time” look at equipment. The business rules allow for an item to be removed from the agenda based on RPN but then added back to the agenda should the performance data analysis determine the system/component performance has degraded. The MAI process, combined with performance data utilization, allows for a scalable equipment assessment visit.

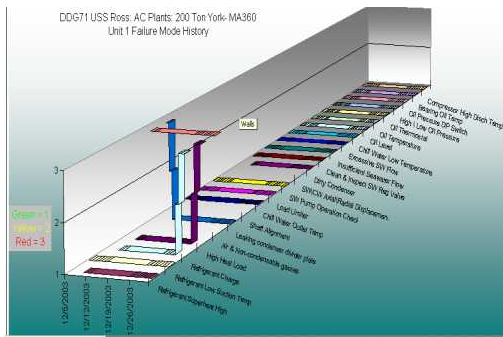


Figure 1 - AC Unit Performance Review

### Remote Assessment

The iPAR™ is a tool that uses performance data to present results in an intuitive view that can be utilized for quick analysis. In figure 1, all failure modes are summarized for a single AC unit. In this single view, technicians can gain immediate performance awareness for the entire AC unit for the previous month of operation. There are three levels of status: green (floor level), Yellow (mid-level), and red (ceiling). In this example it is clear that this AC unit as had four faults occur in the past month: one fault that has been constant for the past month, two that have recently surfaced and one that was corrected at the beginning of the time period.

These reports are the standard to which performance reporting will evolve. The user interface is intuitive with all the complex algorithms being processed in the background. The end result is that performance data is turned into actionable information in a web environment.

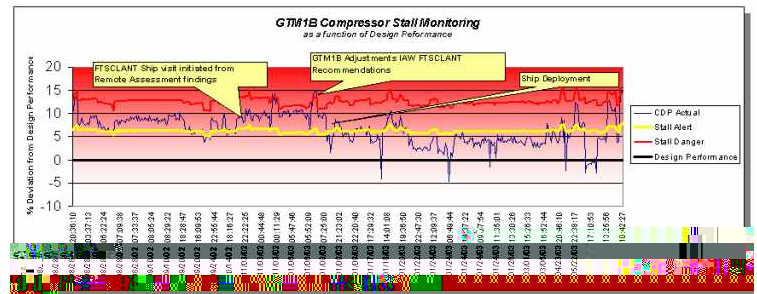


Figure 2 - Gas Turbine Compressor Performance

### Optimized maintenance planning

Performing the right maintenance at the right time is the foundation of CBM programs. Figure 2 above demonstrates this concept. A deploying ship’s gas turbine engines were assessed based on alerts provided by performance data prior to a deployment. It was determined that control adjustments were needed in order to prevent a catastrophic failure of the gas turbine compressor during the deployment. After the ship deployed, the affects of the control adjustment can be seen in the blue performance line drop. The ship made the entire deployment below the red alert limits. Once the ship returned, the performance began to degrade again as seen by the blue performance line approaching the red limit at the far right side of the graph.

Although a failure was averted during deployment, there was no action taken based on this data once the ship returned. This resulted in several compressor stalls which ultimately required a complete engine replacement. The cost to the Navy was approximately \$800,000 to replace the engine. If the Navy experiences five compressor stalls per year, it can be seen that an effort to centrally assess performance data would provide significant savings to the Navy for gas turbines alone.

### Technology to support Functional Requirements

To continuously support the requirements mentioned above, on a broad scale, the next generation of the navy's CBM system should include a centralized model for engineering analysis and configuration management. A database model and user interface concept must be open and flexible to meet the current and future needs of integrating new, and existing, CBM systems. Moving to an open architecture such as the OSA-CBM (MIMOSA) standard will meet these requirements.

#### Database architecture

To support information analysis at all levels of the Navy's hierarchy, standard database architecture is required. This architecture must support all the local and central needs of the organization for data storage and data integration. Three types of information are required to be stored in a centralized CBM database. They are raw data, calculated data and results information. Raw data can be of two types: either continuous (Trend or historian information) or event type information. Calculated data is directly calculated from raw data and results information are calculations that meet a particular need or requirement of the organization. The OSA-CBM (MIMOSA) database architecture supports these needs and is an open standard for the integration of all systems related to equipment health assessment. Each ship will collect sensor information and perform a first level of analysis that will include basic alarming and data qualification. The information will then be sent to a central repository for higher level analysis. For example, fleet wide component degradation analysis. A central system is required to efficiently and correctly analyze and manage information.

#### Configuration Management

Management of this system should be centralized with standard configurations based at the ship component/system level. Ship to ship variation will be handled within the component configuration itself. Once libraries of component analysis have been developed, the modules can be combined to make up the configuration for a specific ship. The component analysis can be combined to develop higher level analysis at the system, ship, class, battle group and fleet levels.

#### Presentation Layer \ User Interfaces

In order to ensure the correct information is in the correct hands, a flexible user interface has to be deployed. The user interfaces must support every level of the organization from the deck plate sailor requiring real-time operating information to the Battle group commander needing a combined readiness display of all ships in the battle group. This is accomplished by applying the technologies of a subscription based web enabled display model (i.e. MyMSN, MyYahoo functionality) that provides customized views, based on user preferences and monitoring responsibilities, of information available within the system data store.

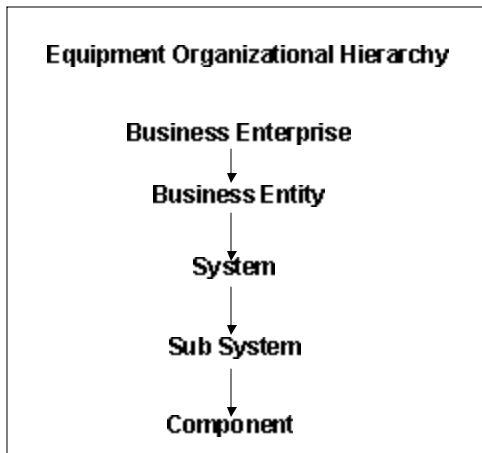
#### Engineering analysis

Any system that is deployed to perform condition based monitoring is deployed for economic reasons. There will always be a cost benefit struggle between information that is required and information that is readily available. In order to make the most of limited information an infrastructure must be in place to ensure the information arrives on schedule and the data is in a form that promotes advanced analysis.

	Fuzzy Logic ("reasoning")	Neural nets ("associative")	Physics/First Principles	Statistical Change Detection (SCD)	Least Squares Fit	State-Based Feature Recognition	Case-Based Reasoning	Rule-Based Expert Systems	ARMA/ARIMA	Wellbore Modeling	Dynamic Neural Nets
Problem Parameters											
Amount and nature of required data	Green	Red	Red	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Time required to generate a solution	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Relative Cost of the solution	Yellow	Red	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Reliability (robustness) of the solution	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Stability of the solution	Green	Red	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Effort Required to modify the model if the system changes	Green	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

Figure 3 - Diagnostic\Prognostic Technologies

Figure 3 displays potential modeling technologies performed in support of diagnostics and prognostics. Each one of these technologies requires different types of data to support the analysis. For example, a neural network requires a great deal of continuous data to train the model where fuzzy logic systems can be deployed with very little continuous sensor data but it requires good expert information. A centralized CBM system needs to support both the development and implementation needs of both analysis implementations. This can only be accomplished through a standard architecture that supports 3<sup>rd</sup> party development of advanced algorithms as plug in modules. By providing this standard interface, the correct analysis for the specific process, or function, can be implemented with a minimum amount of effort as well as implemented in a way to support easy configuration and updating.



**Figure 4 - Reporting Hierarchy**

### Conclusion

The ultimate mission of a centrally based CBM system is to provide the necessary infrastructure to support the rollup of equipment performance analysis from the deck plate level all the way through the battle group commander and shore based maintenance support teams, Figure 4. Customizable views of performance analysis reports will optimize the efficiency and availability of performance data such that actionable performance information is returned for every user session. It is through this centralization and focus on the presentation layer of the performance data that like systems can be compared with a standard set of measurements across an entire fleet to determine performance leaders and laggards. Once an Enterprise view of

equipment performance is achieved, the true value of a CBM approach will be realized through optimization of equipment operation and optimization of available maintenance resources.

### ESRG Corporate Overview

ESRG was established in 2000 with a background in Hull, Mechanical & Electrical maintenance and operations. The mission of ESRG is to implement proven Reliability Centered Maintenance strategies using Condition-Based Maintenance solutions in order to improve conditional awareness of distributed power producing assets. This is accomplished by utilizing industry best practices in performance monitoring and utilizing the latest technologies that support rapid development solutions. Our analysis and products are designed to provide all maintenance levels with a common, repeatable method of reviewing and communicating condition assessment performance information. The result is an integrated, streamlined, and accurate enterprise picture of the overall health of distributed assets.

Performance information is made available utilizing the latest technologies in web presentation solutions. Each view of information is tailored to meet the needs of a particular user. A management level view consists of overall equipment performance and maintenance status with pending and current issues flagged as potential problems. An operational and maintenance level view consists of specific equipment performance and condition attributes with pending and current failures flagged for action. All of this information is made available with the customer's operational and maintenance requirements in mind in accordance with industry standard Reliability Centered Maintenance (RCM) and Condition based Maintenance (CBM) strategies.

### Products and Services

Since January of 2001, ESRG Inc. has provided products and services for bringing together information and providing automated analysis in support of our customer's business strategies. This has been accomplished by providing services for data integration, system engineering, maintenance engineering, software and database design engineering, and software development using the latest processes and rapid development tools.

## Corporate Experience

- ESRG Application Engineers have experience in applying Condition-Based Maintenance (CBM) strategies in the following industries:
  - U.S. Navy conventional and nuclear HM&E systems
  - Commercial power equipment
  - U.S. Navy /Commercial Steam & gas turbine applications
- Computer Engineers at ESRG have experience in the following areas:
  - Design, implement, and maintain software components of the Integrated Condition Assessment System (ICAS). Areas of emphasis include:
    - Multithreaded application programming
    - Win32 applications
    - Borland C++ 5.02 Suite, Borland C++ Builder 3,4,5 and MSVC5,6
    - Relational database design and usage (MSSQL and Oracle)
    - Object-oriented programming methodologies and design patterns
  - Significant experience with the following portions of ICAS:
    - Type II logs (original developer)
    - Quick Status Pages (complete rewrite for version 5.0)
    - Analysis Engine
    - Router
    - All demand applications
    - CDS Developer
  - Integrating multiple applications and new modules using the following technologies
    - BEA Weblogic Server
    - Java 1.4.1
    - J2EE (Servlets, EJB's, JSP, Java Messaging)
    - XML (Xerces Parser)
    - SQL (Oracle and SQL Server Extensions)