

ETS 2006 - *Engineering Ships for an Affordable, Integrated Force*
Reverse Distance Support: Fleet Experience for At Sea Operations

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ABSTRACT

Increased ship operation tempos and longer deployments have forced the shore side maintenance planners to become innovative in how they plan and execute ship maintenance efforts. COMNAVSURFLANT has been specifically searching for a cost effective and technically feasible process to continuously monitor shipboard machinery maintenance needs while ships are pier side or deployed. This would allow for planning efforts to occur real time and always be up to date with respect to actual machinery condition, support the deployment resulting in reduced machinery failures during deployment and reduce onsite troubleshooting and assessment efforts and the associated costs. Working together toward these goals, Naval Surface Warfare Center (NSWCCD), Mid-Atlantic Regional Maintenance Center (MARMC), and COMNAVSURFLANT were able to develop and deploy a process to conduct HM&ERA assessments procedures remotely utilizing actual machinery data and failure algorithms. This eliminated the need to have a MARMC team come onboard the ship and have the crew operate machinery to conduct assessment procedures. This process was first applied successfully to pier side HM&ERA machinery assessments. COMNAVSURFLANT then requested MARMC and NSWCCD apply the process to remotely monitor gas turbines on selected ships of the GEORGE WASHINGTON STRIKE GROUP (GWSG) during deployment. The process developed is the reverse of Distance Support, where the deployed ship requests support, instead providing proactive maintenance recommendations to the deployed ship based on actual and projected machinery operating conditions, hence the term Reverse Distance Support (RDS). The goals were to eliminate all gas turbine CASREPS, reduce on site tech assists and understand the practicalities involved with providing remote monitoring capability. This paper will report out on the results and lessons learned of the GWSG RDS experiment as well as provide a look into the future in how this process is being further implemented at MARMC and SWRMC and will meet the requirements for future sea-basing operational requirements. Cost and return-on-investment projections will be presented and discussed.

INTRODUCTION

The current maintenance philosophy is to reduce Total Ownership Cost (TOC) of ships. There are a number of initiatives to reduce TOC. Some of them include: OEM partnering, design improvements, reduced crew size and remote monitoring. The maintenance community has embraced the remote monitoring technology initiative to try and solve some of the issues in today's Navy. The Navy has adopted Integrated Condition Assessment System, ICAS, as a program of record for Condition based maintenance. Leveraging ICAS data can result in maintenance savings. ICAS is being used to collect and trend performance data, and provide automated log sheets, etc. A new use, remote monitoring, is used to send data to a shore infrastructure and provide near real time evaluation of monitored systems. This process is called Reverse Distance Support (RDS). In the RDS process, the shore Subject Matter Experts (SME's) provides feedback to the ship on problems identified or trends they need to investigate or more closely monitor. RDS has matured from a proof-of-concept project back in 2001, handling remote assessments of air conditioning plants on six ships, to a production level program with the ability to continuously monitor 100 ICAS ships with near real-time monitoring on DDG Class ships. This program provides critical decision support data to optimize: direct fleet support issues, pre-deployment assessment agendas (HMERAs), and life cycle management of equipment.

REVERSE DISTANCE SUPPORT

RDS is currently being implemented in three major areas:

- 1 Continuous remote assessments (Deployed & non-deployed ships)
- 2 HMERAs Assessments
- 3 Enterprise Remote Monitoring

Currently ten systems are being monitored remotely on nine classes of ships. The data is periodically sent from ship to shore for analysis with a goal of the data being fed into the system on a bi-weekly basis. Data analysis results and recommendations are sent back to the ship and maintenance team (port engineer, project manager) to ensure all required maintenance is being performed at the optimal time in the ships deployment cycle. While ships are away from homeports, subject matter experts (SME's) are reviewing ships logs and operating parameters and providing feedback on system problems and trends. When maintenance actions are required, the ship and maintenance team can decide when to best accomplish maintenance actions based on ships mission, upcoming commitments and allowable funding. When recommendations can be completed by the ship, the adjustments are made and the SME's can verify during the next cycle of data analysis. This can help reduce and possibly prevent catastrophic equipment failures and reduce the costs of technical assists by providing critical system information with out traveling to the ship in remote locations.

MAINTENANCE ENGINEERING LIBRARY SERVER (MELS) PROCESS

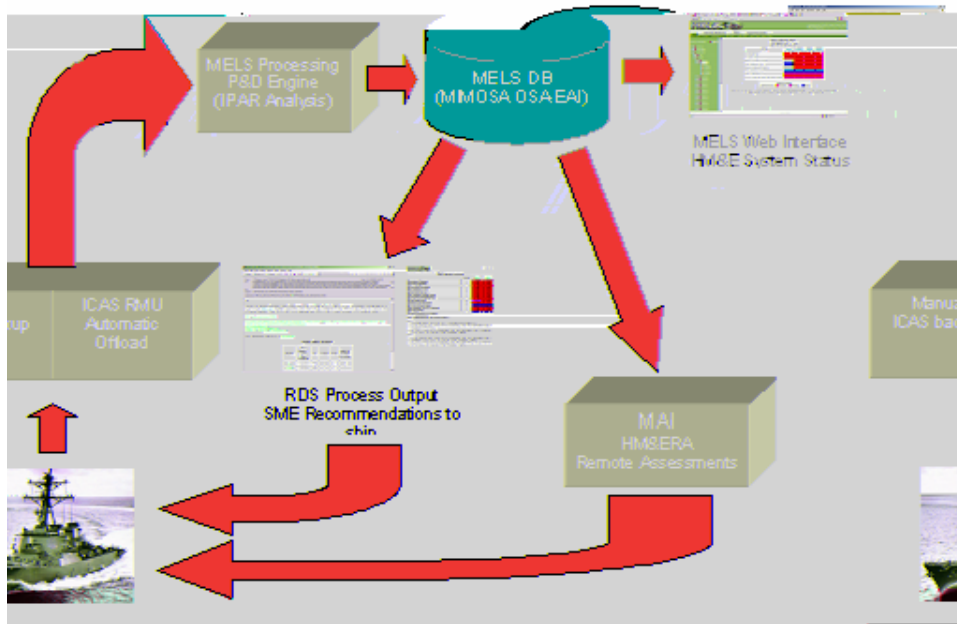


Figure 1: MELS Process Overview

The enabling technology used for remote monitoring efforts is centered around the Maintenance Engineering Library Server (MELS). This Web application provides the framework for enterprise level analysis. In addition to an open standard architecture, it incorporates two modules that allow for standard analysis: Integrated performance analysis report (IPAR) and the enterprise performance analysis report (EPAR). Due to the volume of data being presented it is essential to present the performance data in a concise, standard, repeatable method to minimize SME analysis time. Any SME with a Web browser can logon the system and determine how an individual machine is performing via the IPAR and/or compare that same machine from a fleet perspective by comparing performance with other similar equipment via the EPAR. In addition to storing the raw ICAS data, MELS processing performs the following functions to ensure accurate analysis of equipment performance:

- Data validation
- Standard / Enterprise algorithm processing
- Web presentation of data
 - Individual equipment diagnostics (iPAR)
 - Fleet comparison diagnostics (ePAR)
- SME review of iPAR / ePAR
- Distribute RDS reports to ship and maintenance community

HMERA REMOTE ASSESSMENTS

Initially, remote assessments for the HMERA visits were conducted outside of the formal agenda building process. This initial study consisted of the remote analysis of 25 air conditioning plants. A Mid-Atlantic Regional Maintenance Center (MARMC) technician conducted the physical assessments. The remote analysis was completed via MELS. The two independent assessments were then compared for correlation. The result was that over 16 assessments (per plant) had a 95% or greater correlation. By performing these remote assessments, the overall assessment visit for air conditioning plants on each ship could be reduced by 62%. When the data indicates a system is performing satisfactorily, an SME does not have to be sent to perform system assessments during the regularly scheduled assessment. If problems are identified, they will be sent to investigate the identified problems. This reduces the time required for the total assessment. Extrapolating the results of the AC plant remote monitoring project to all ICAS monitored systems resulted in a projected return on investment of over 300%.

STRIKE GROUP: RDS EXPERIMENT

Based on the initial success of the HMERA remote assessment project, the USS GEORGE WASHINGTON (CVN-73) strike group was selected as the target deployment group in an effort to expand the initial feasibility study that was limited to air conditioning plants. This meant that five DDG-51s, one CG-47, and one FFG-7 class hulls would be monitored. In addition, the USS McFAUL (DDG-74) was monitored with this process, although deployed with an amphibious battle group. The process utilized to facilitate the data analysis is described below:

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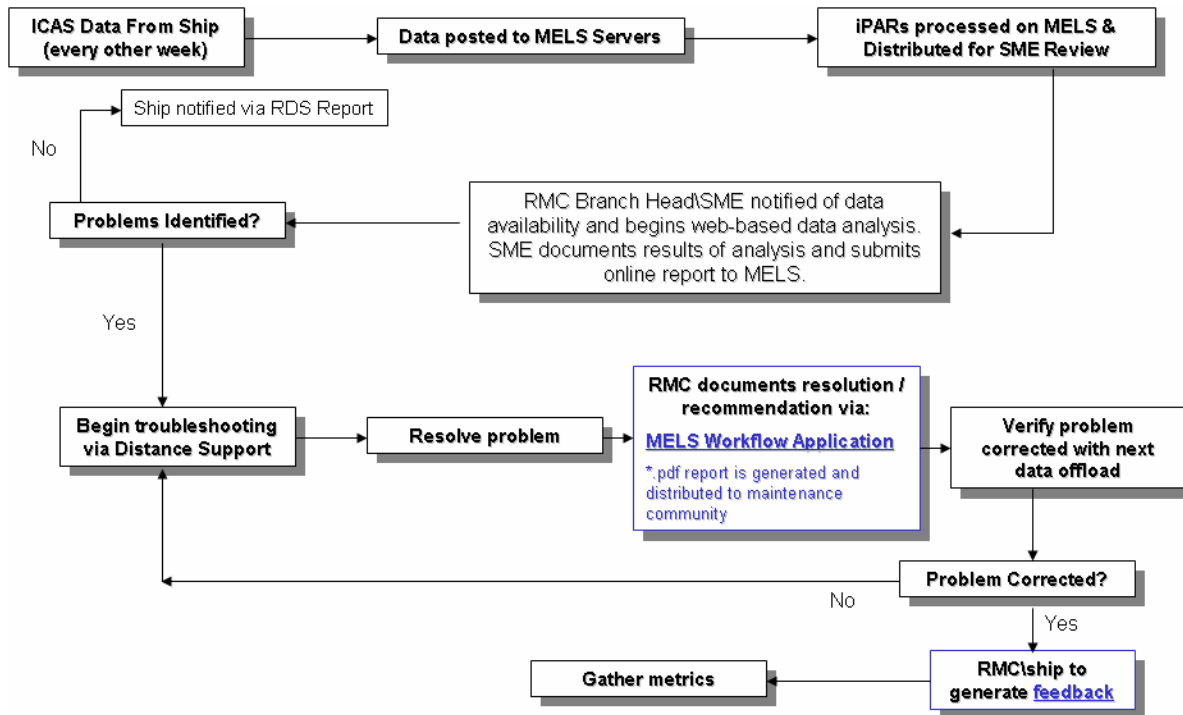


Figure 2: RDS Process

RESULTS OF STRIKE GROUP EXPERIMENT

Throughout this period, over 3,800 remote assessments were conducted across eight ships and eight systems.

- Gas Turbine Generators
- Gas Turbine Mains
- AC Plants
- Refrigeration Plants
- Reverse Osmosis
- Low Pressure Air Compressors
- High Pressure Air Compressors
- Distilling Units

Ultimately, the demonstration was deemed a success even though there was one gas turbine CASREP due to Foreign Object Debris (FOD). This could not have been detected or prevented with any monitoring technology.

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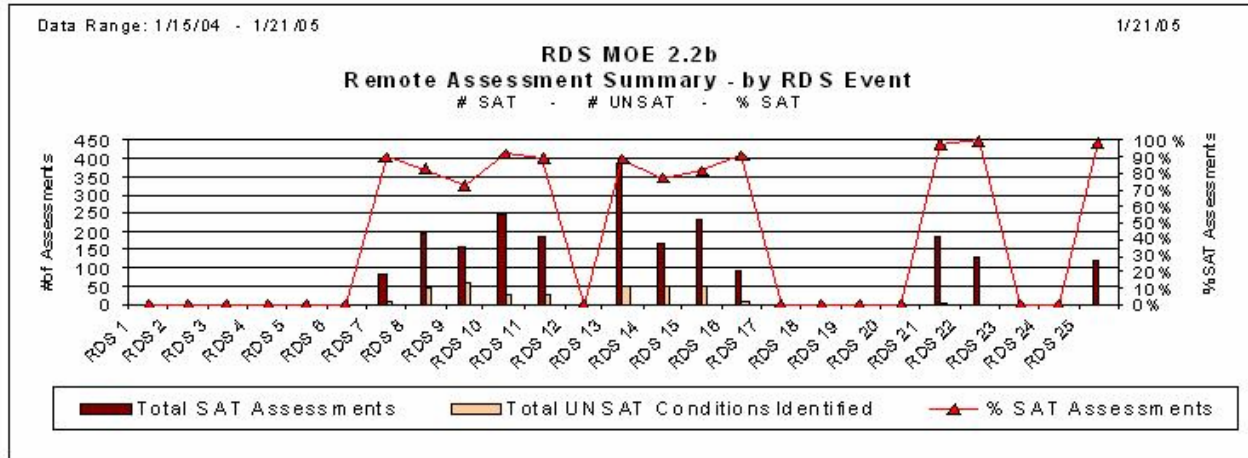


Figure 3: RDS Efforts Reduce UNSAT Assessments

The graph above summarizes the number of Remote Assessments conducted on the strike group. These RDS Events were scheduled every two weeks. The decreasing number of UNSAT assessments throughout the strike group's deployment periods illustrates the effectiveness of remote monitoring. The end result was an increased condition awareness of the engineering plant as illustrated in the DDG66 case study that follows.

MAINTENANCE ASSESSMENT INDEX (MAI)

As budgets have gotten tighter, CNSL was looking for systematic methods to reduce assessment costs while still identifying all major work candidates. A process was developed called Maintenance Assessment Index (MAI). This process uses 3M history to determine what components are most likely to fail over the ship's IDTC. By using existing 3M data for all maintenance completed on a component, the program can determine the likelihood (Risk Priority Number-RPN) of a component to fail. To reduce the cost of assessments, CNSL is willing to take some risk. They have used 80% likelihood of making it through the IDTC. Any item with a RPN number of five or greater is assessed during the scheduled assessment visit. This systematic approach has reduced assessments without increasing the likelihood for CASREPS during the deployment.

By integrating remote assessments into MAI, a focused and streamlined physical assessment can be planned. If the remote assessment determines there is a problem on a component/performance element, the SME will assess. If the remote assessment determines the systems are performing satisfactorily through trend and event analysis, then local assessments are not required, thus saving man-hours and targeting the SME's efforts where needed most.

ENTERPRISE REMOTE MONITORING

The deployment and life cycle management of enterprise remote monitoring technologies is defined in five levels. Each level enables the next to be deployed and managed at a minimized cost and effort. The enterprise remote monitoring infrastructure requires that a standard diagnostic analysis is conducted across all like equipment. Equipment

Reverse Distance Support: Fleet Experience for At Sea Operations

configurations differing from the standard analysis are handled via an exception database. This structure allows for an enterprise configuration management strategy, which reduces overall costs to maintain and upgrade the system.

With the enterprise framework implemented in a Web environment, machinery diagnostic and health assessments can be economically developed and deployed to meet the specific requirements of the system users. At this level, the capability exists to provide remote users with a common operational picture by equipment type across the fleet. The information is presented at a high enough level to focus the user to the problem areas only. Therefore, minimizing the raw data mining required to understand and correct an issue. By designing and deploying the Enterprise Remote Monitoring system with open system architectures, information becomes available for other condition based maintenance and operations technologies. Implementing technologies based on these open standards eliminates the requirement for third party applications. These technologies include machinery reliability systems, enterprise resource planning systems, maintenance management systems, health assessment systems, and prognostic and diagnostic systems. The integration of these systems enables the automation of many of the asset management processes. Using the knowledge and information within the system and continually building on that knowledge, advanced analysis technologies can be implemented and validated to reduce the manual tasks associated with maintenance and operations.

Level 1: Infrastructure

- Implementation of local information systems and processes

Level 2: Configuration Management

- Standardized configuration management for like systems

Level 3: Diagnostic Analyses

- Fleet wide assessment of like equipment
- Common set of analysis for like equipment

Level 4: Conditioned based maintenance and operations technology integration

- Prognostic analysis development
- Integration of machinery management systems
- Identification of system upgrades and changes that affect the enterprise remote monitoring system

Level 5 Process automation - automated reasoning, artificial intelligence

- Automatic work package generation
- Automatic equipment assessment and notification
- Automated root cause analysis
- Automated configuration management

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The Information is available to anyone with Internet access and a systems account. Information and visualization is tailored to meet a specific requirement. Like equipment are analyzed together to define common fleet issues. The fleet analysis can be used to drive design changes to improve reliability and maintainability. Subject matter expert training time is reduced through the review of actual operational conditions and past failure history information. Costly site visits can be minimized. Distance support processes are more effective with the capability to review actual operational conditions. Through the implementation of a remote monitoring system and progressively building and refining the systems knowledge base and capability, incremental maintenance and operational process improvements can be realized.

DDG66 Case Study:

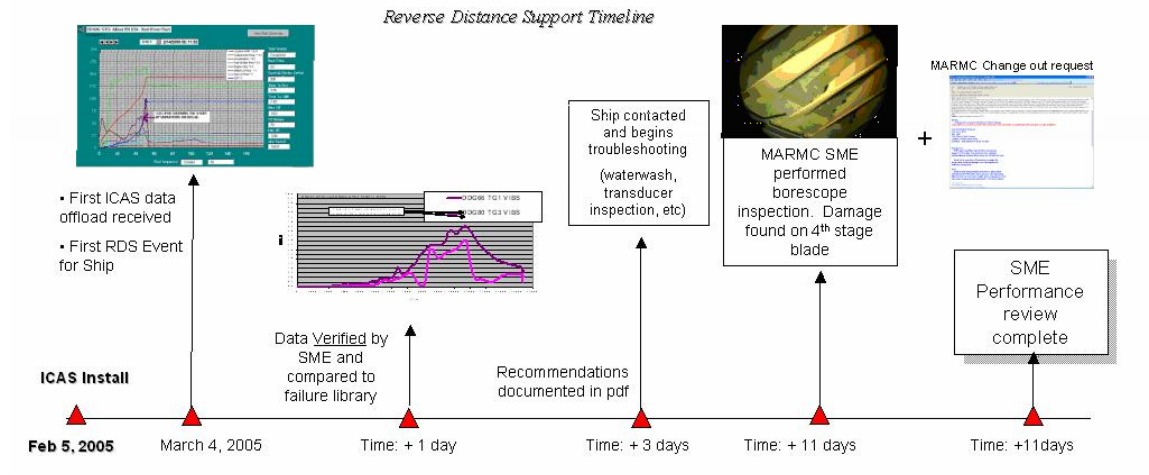


Figure 4: DDG66 Case Study

Problem Description

- High Startup Vibes on GTG#1
- Identified During RDS Event #4 - March 2005
- This is the first data offload and first RDS event for ship

Analysis performed

- High vibes compared to a Mayport, FL GTG high vibe problem that resulted in engine replacement due to 4th Stage turbine blade damage
- Vibe signature matched and suspected 4th stage turbine damage on GTG#1 – diagnosis was performed remotely

Action Taken

- Ship notified (in POM period) and begins troubleshooting
- MARMC visits ship after water wash and troubleshooting complete
- MARMC performs borescope inspection during connection of independent vibration gear

Results/Benefits

- Borescope revealed, (as suspected), 4th stage turbine blade damage
- MARMC recommended engine replacement based on damage and ship schedule
- Change out = March 21, 2005 (days before 18 month deployment)

The engine was borescoped and within eleven days the determination was made to change out the engine (GTG #1). The SMEs concur that the GONZALEZ would have experienced an (overseas) casualty on that engine during her deployment period. By detecting the problem prior to failure, the ship was not impacted during her deployment; thus increasing ship, system, and mission readiness (not to mention cost savings).

ANALYZING THE FLEET

This vibration problem is being looked at on a fleet wide, enterprise level. The vibration indication from the DDG66 and DDG80 was modeled and the MELS database mined for other ships that may have a similar performance issue. The graph below is a fleet level view of GTGs with a similar vibration problem. Any vibration over 3 mils was considered to be in a fault status. Additionally the data was filtered cold start and hot starts to look for a pattern. The result was that most of vibration peaks occur during the startup period when the engine is cold. Very few hot starts had the same vibration signature as the two DDGs. The Enterprise Performance Assessment Report (ePAR) has resulted in six engine change outs on various surface combatant hulls. The Navy’s Life Cycle Manager for this system is actively analyzing the root cause of the problem. When this is known the information can be fed back into ICAS and further enhance IPARs.

Enterprise Analysis Results

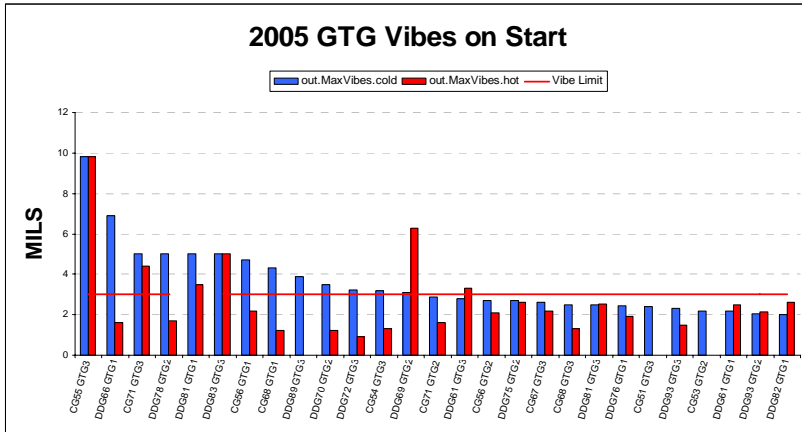


Figure 5: GTG Enterprise Analysis

Ship	GTG	Date	Status	RDS
DDG-66	1	Mar-05	C/O	X
DDG-88	3	Mar-05	VP	X
CG-54	3	Apr-05	VP	X
CG-71	3	Apr-05	VP	X
DDG-76	2	Apr-05	C/O	
CG-56	1	May-05	VP	X
DDG-65	1	May-05	C/O	
DDG-83	3	Jun-05	C/O	X
DDG-91	1	Jul-05	C/O	X
DDG-70	2	Aug-05	VP	X
DDG-78	2	Aug-05	VP	X
DDG-89	3	Aug-05	VP	X
DDG-69	2	Sep-05	VP	X
CG-60	1	Sep-05	VP	

Figure 6: Vibration Casualty Summary

CONCLUSIONS

As the remote monitoring processes mature and integration between programs increases, it is essential that policies be established in order for the Navy to take full advantage of this new access to information. The initial proof of concept for RDS has now matured to a full program that supports the remote monitoring of 100 ships on a near real-time basis. The continued success of remote monitoring and assessments will be dependent on the ability to adapt maintenance business policies and procedures to incorporate and utilize the information obtained through remote monitoring.

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Eric Pool - ESRG, LLC

CONTACTS

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Ken Krooner

Mr. Krooner, President ESRG, LLC, is a graduate of Old Dominion University (BS Engineering Technology). He has over ten years of experience in operations, planning, and program management in the marine engineering field. He has over seven years experience with designing, developing, and implementing condition based maintenance (CBM) and condition based operations (CBO) strategies within the Navy and commercial industry, using the Integrated Condition Assessment System (ICAS) and the Maintenance Engineering Library Server (MELS) as the primary enabling technology.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

ICAS: Integrated Condition Assessment System

CBM: Condition Based Maintenance

DS: Distance Support

EPAR: Enterprise Performance Analysis Report

MELS: Maintenance Engineering Library Server

HMERA: Hull Mechanical and Electrical Readiness Assessment

IPAR: Integrated Performance Analysis Report

MAI: Master Assessment Index

RM: Remote Monitoring

Reverse Distance Support: Fleet Experience for At Sea Operations

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