Guide for

Condition Based Program for Government Vessels

June 2022

GUIDE FOR

CONDITION BASED PROGRAM FOR GOVERNMENT VESSELS
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Foreword

The ABS *Guide for Condition-Based Program for Government Vessels* has been developed to increase understanding of condition and Class compliance risks associated with a vessel's critical hull, machinery and electrical (HM&E) systems in support of maintenance planning and optimization for Government vessels. The ABS Condition-Based Program (CBP) provides a tiered set of notations that span a range of digital capabilities and supporting services. The program leverages both design and operational data by using a compliance risk model to continually update a vessel-specific CBP Survey Plan.

Recent advances in technology, such as sensor hardware, data accumulation/transmission, advanced analytics, and artificial intelligence have enabled new approaches to vessel health understanding that, when effectively implemented, will support improved system safety and reliability. ABS recognizes that operators of Government vessels require improved life-cycle management approaches to achieve high levels of operational availability and readiness while reducing total ownership costs. This Guide provides a process for a condition-based approach to survey by establishing the CBP enrollment and sustainment framework covered by the notations herein. The ABS CBP focuses on leveraging data to enable a survey to become informed, targeted, and predictive supported by a continuous data-driven process aligned with government operational and maintenance workflows. Once implemented, the CBP leverages such data-driven capabilities and insights to support a Government Technical Authority's in-service decision-making process.

This Guide applies to any Government Acquisition Program as guidance to provide support to system performance specifications during the design and development phase. The Class requirements during the acquisition phase are covered upon vessel delivery by the optional notations **CBP-Ready (S1, S2 or S3; M1, M2 or M3)**. In addition, this Guide is also intended to apply to Government Operators to enroll vessels into CBP for sustainment across the operational life-cycle phase. The optional notations **CBP (S1, S2 or S3; M1, M2 or M3)** are used for enrolled vessels that comply with the requirements in this Guide.

This Guide also incorporates by reference other mandatory or optional CBP supporting notations **(PMP, SMART, TCM, HIMP)** and vendor equipment approvals (SMART and CYBER product design assessment (PDA) endorsements) that support the CBP via incorporation into the CBP risk model. Supporting notations can provide ABS with maintenance program status, condition and health monitoring, and self-inspection program results, all of which support the vessel-specific CBP Survey Plan.

This Guide becomes effective on the first day of the month of publication.

This Guide is to be used in conjunction with the ABS Rules for *Building and Classing Marine Vessels (Marine Vessel Rules)* and other applicable ABS Rules, Guides and Statutory Regulations.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDE FOR

CONDITION BASED PROGRAM FOR GOVERNMENT VESSELS

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SECTION 1
General

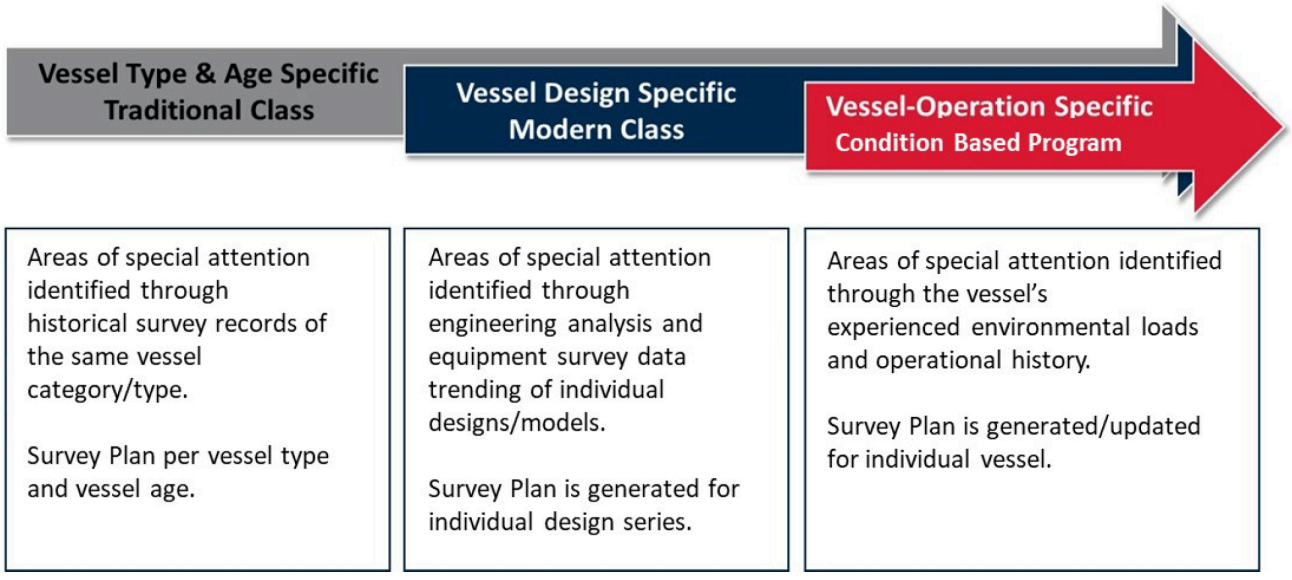
1 Introduction to the Condition Based Program

This Guide covers the scope and requirements to be applied for the development and implementation of a Condition-Based Program (CBP) for Government Vessels. The CBP provides a tiered set of notations that span a range of digital capabilities and supporting services. It leverages both design and operational data to support survey planning and execution. The CBP continually informs survey activity through the utilization of a risk informed vessel-specific CBP Survey Plan.

The CBP defines a data-driven evolution in Class survey planning and execution that is aligned with the vessel design features and vessel operational data. Traditional Class survey requirements are typically based on the historical performance of vessels of a certain type and age but share only a minimal amount of actual vessel data prior to survey commencement. This evolution is detailed in Figure 1.

- The CBP Survey Plan is kept up to date via data collection and continual re-assessment to deliver insights about the condition of a vessel's critical hull structure, machinery and components.
- CBP supports a continuous survey process and assists with decision-making.
- CBP activities are aligned with most Government vessel operational and maintenance workflows to support their maintenance availability planning and strategies.

FIGURE 1
ABS Class Survey Philosophy Evolution

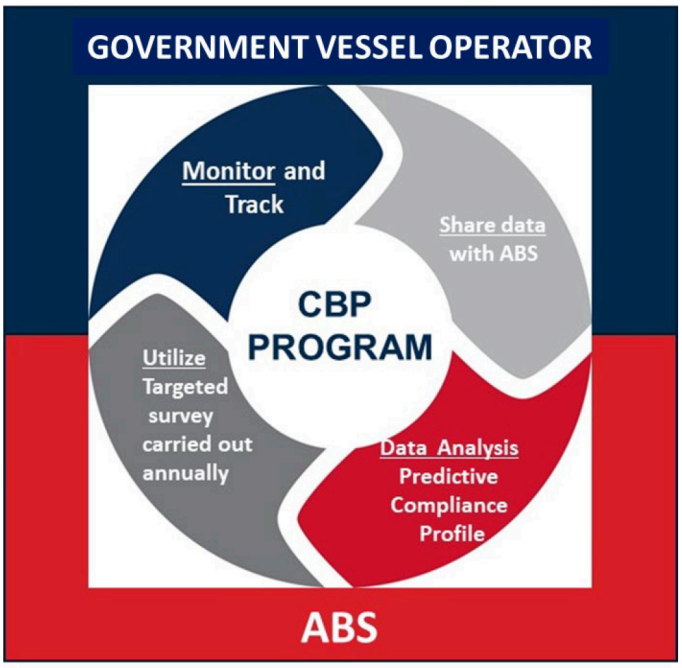


Each CBP tiered Notation expands upon the scope, fidelity, and use of vessel related data, but all tiers begin with the development of a vessel-specific CBP Survey Plan that is based upon an initial assessment of vessel structures and machinery. The requirements and activities for structures and machinery to develop the CBP Survey Plan are described below and form the basis of enrollment (see Section 4).

- Structures: The CBP utilizes Finite Element Analysis (FEA)-based strength and fatigue analysis derived from the design operational profile and previous route history (if applicable) as well as current or as-delivered baseline hull condition. The strength assessment is based on ABS Rule requirements. This information highlights structurally critical areas to be examined with specific scope and frequency, based on a risk categorization.
- Machinery: The Machinery assessment is conducted via profiling of maintenance and condition data, equipment and system criticality, along with optional reliability, availability and maintainability (RAM) maintenance data analysis and risk profiling for higher chosen tiers. The Reliability, Availability and Maintainability (RAM) assessment also identifies critical equipment that could be targeted for data analytics-based Anomaly Detection.

Upon enrollment into the program, CBP Sustainment activities (see Section 5) involve targeted and focused surveys of hull and machinery items via collaborative data sharing and a set of services depending on the tiered notation chosen. The CBP approach is to receive data prior to survey commencement to optimize the on-board survey effort or to better inform the survey process. Shared data is then processed by a composite risk profiling approach called the ABS Predictive Compliance Model (PCM) in order to maintain and update the vessel's CBP Survey Plan. The notation tiers also define the tools and services involved in the CBP. Figure 2 illustrates the data sharing process within the CBP.

FIGURE 2
CBP Sustainment / Data Sharing Concept



Enrollment and sustainment of the CBP not only supports the Class survey and crediting process, but also assists Government vessel operators with maintenance and availability planning to improve the continued readiness of their fleet. Desired outcomes of the CBP include:

1) Operational availability (A_o) planning, with a focus on planned vessel time out of service resulting from a better understanding of anomalies and condition of class prior to a repair campaign or drydocking.

2) Flexibility in prioritization of closure and dispositioning of anomalies and conditions of class while at the same time maintaining vessel mission readiness.

3) Support a shift from schedule driven maintenance strategies to a program that comprises predictive and condition-based maintenance strategies (less time-based tasks, optimal spares and consumables).

4) Detection of the initiation of structural and equipment anomalies leading to failure, before they impact longevity, to minimize unplanned HM&E conditions of class or statutory compliance.

5) Targeted and focused survey time on board an asset supported by a data-driven process covering Annual/Intermediate/Special Survey Requirements for the vessel through a continuous survey process.

6) Reduced crew and ship superintendent Survey Preparation burden.

7) Support for Class survey decisions using a predictive risk model.

2 Application and Scope

2.1 Application

This Guide is for use by Government agencies and organizations operating all types of vessels and maritime assets. The requirements in this Guide are stated in general terms to apply to a wide variety of new construction and in-service vessels, maritime assets, and their managing Government agencies. It is intended to apply to Government owned military vessels and other Government owned vessels in non-commercial service whose primary purpose is for research, safety, security, or defense.

Note that for practical purposes in this Guide, any ship or maritime asset is referred to as a "vessel." This term includes surface ships, watercraft, boats, and unmanned/autonomous vehicles as well as their associated systems and sub-systems.

The Guide applies to vessels enrolled in the CBP and their associated HM&E Class items. Class items include hull structures, compartments, tanks, spaces, machinery, equipment and components having specific survey requirements to be complied with for maintaining Class, including the respective Class notations assigned to the vessel/facility.

2.2 Classification Scope

The requirements in this Guide apply to ABS class items to be enrolled in the Condition-Based Program. Class items include hull structures, compartments, tanks, spaces, machinery, and components having specific survey requirements to be complied with for maintaining Class and the respective notations assigned to the vessel. Refer to 2/2.3 for **CBP** notation eligibility, process, and assignment approach for both **CBP Ready** and **CBP** notations.

Items that are covered by both Class and statutory requirements may be enrolled in CBP with regulatory approval from the Flag or Technical Authority, as applicable.

2.3 CBP Enrollment Eligibility

To be eligible for enrollment in CBP, the class items included in the program require:

i) Enrollment in Special Continuous Survey in accordance with 7-2-1/7 of the ABS *Rules for Survey After Construction (Part 7)* for hull, machinery, and automation as applicable to CBP enrollment coverage.

ii) Enrollment in the preventive maintenance program for machinery, equipment and components in accordance with the requirements of Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* is to be fully implemented for all eligible CBP enrolled equipment.

iii) A vessel-specific CBP Survey Plan as outlined within an ABS Structures Survey Planning Document and a Machinery Survey Planning Document. See Subsection 3/2 for CBP Survey Plan requirements and information.

3 Classification Symbols and Notations

The requirements for conditions of classification are contained in the ABS *Rules for Conditions of Classification (Part 1)*. Additional requirements specific to the Condition-Based Program and notations are contained in the following sections of this Guide.

3.1 Condition-Based Program (CBP) Notation

Vessels and facilities with their class items enrolled in the Condition-Based Program (CBP) program are eligible for the optional class notations **CBP Ready** or **CBP**. Both notations are appended by **S1, S2, or S3 (as applicable to the selected tier)** for selected hull/structural items and by **M1, M2, or M3 (by system)** for all vessel machinery selected for inclusion in the program.

Upon vessel delivery, the optional notation **CBP Ready** can be awarded to the vessel, provided the technical requirements outlined in Section 3 have been met and verified by ABS. Upon completion of the CBP enrollment process defined in Section 4 of this Guide, the optional CBP notation will be entered into the ABS *Record*. See 2/2.3 for more information about the notation minimum scope and 2/2.3 Figure 3 for notation relationships.

The selected tier number **(1, 2, or 3)** can be applicable to a single notation (i.e., the hull or one selected system), or a combination of the notations applicable to the chosen system(s) listed (multiple systems, different tiers). **CBP (S or M)** is to be listed in the Class Certificate with details on the tiers and selected machinery in the certificate's descriptive notes section.

Maintenance of the **CBP (S1, S2 or S3); (M1, M2 or M3, by system)** notations over the operational life of the vessel is subject to continued compliance as evidenced by satisfactory completion of periodic surveys conducted by ABS as part of the CBP.

3.2 Survey Status Indicator for CBP

The class items covered by the **CBP** notation will be identified with an indicator "CBP" in the ABS vessel/facility survey list and ABS Survey Reporting system. Upon satisfactory completion of the engineering review letter, plus the implementation survey as part of the enrollment process (4/4.3 of this Guide), the attending surveyor will then recommend assignment of the **CBP M and/or S** notation(s), by tier and system at the vessel/facility level, and the applicable class items enrolled in the CBP are placed in the vessel/facility asset listing with an indicator "CBP". This indicator signifies the class items will also follow a CBP Survey Plan for sustainment as defined by Section 5 this Guide.

4 Organizations

4.1 Government Agency

The owning Government Agency (referred to as "agency") initiates the application of the Guide and its associated notations and services.

4.2 Technical Authority

The Technical Authority is the organization with the ultimate responsibility for setting requirements within a Government Agency, the Technical Authority determines how ABS notations and/or certifications will be accepted against agency requirements. The Technical Authority has ultimate accountability for the safety and effectiveness of government ships, and authority for establishing engineering standards and setting

technical policy. The Technical Authority is also generally assigned the responsibility on ship acquisition programs to assess the degree of compliance with technical policies and to provide top-level design approval.

4.3 Ship Builder Integrator (SBI)

For new construction projects, the SBI is the shipyard or subcontractor. If no shipyard is involved, then SBI activities and requirements are to be performed by, or contracted for accomplishment by, the Owner or agency.

4.4 Service Supplier

A Service Supplier is any company recognized by ABS via a formalized approval process to provide services in support of the Class survey and crediting process. Recognized Service Suppliers, if used, with these skills and expertise are required to support condition based programs. Examples include Condition Monitoring firms, non-destructive examination (NDE) and gauging firms, remote inspection technology firms, and Smart Service Suppliers.

5 Exclusions

A vessel/facility with conditions of class or statutory conditions may, at the discretion of the attending surveyor, be excluded from enrollment in the CBP until such issues are resolved.

CBP enrollment of class items related to Load Line, SOLAS, MARPOL, USCG ACP programs, and other IMO requirements will require Flag administration approval, as applicable.

6 Regulatory Approval

The scope of this Guide does not cover any statutory survey requirements that may apply to the vessel/facility or facility being considered (e.g., Load Line, SOLAS, MARPOL). ABS cannot alter or waive statutory requirements when performing statutory surveys on behalf of Flag States.

The governing administration or regulatory body is the final determining body for statutory or regulatory requirements under their jurisdiction. ABS will assist the Technical Authority in requesting Coastal and Flag State for approval when developing alternative means of verification for the CBP Survey Plan.

If deviations from minimum regulations are proposed as part of CBP, ABS will support the Technical Authority to seek approval from the regulators as well as other regulatory authorities for the vessel/facility enrolled in CBP when a survey approach potentially deviates from the prescriptive requirements of these regulatory authorities.

7 CBP Cancellation

CBP for an enrolled class item may be cancelled for deviations from the approved CBP Survey Plan that remain unresolved, including:

i) Material condition or maintenance status reports for the covered class item(s) sent prior to the survey execution which do not accurately represent the general condition of the class item(s) during survey.

ii) Data transmission and/or connectivity to send data to ABS to support the CBP or its associated services is not available over a significant period of time greater than 6 months or as to negate the benefit of the vessel's compliance risk profile updating for the CBP and Survey Plan prior to survey execution.

iii) Overdue maintenance tasks and/or insufficient maintenance records.

iv) Overdue or unresolved anomalies or findings.

When there are no remaining class items enrolled in the CBP, then the program will be cancelled. CBP cancellation will also result in removal of the **CBP** notation and related system/hull indicator(s) from the ABS *Record*. This will result in the class item being surveyed and credited in accordance with standard ABS *Rules for Survey After Construction (Part 7)*.

When a vessel/facility enrolled in the CBP undergoes a sale or change of vessel/facility management, the CBP will be suspended until a new enrollment for the new Technical Authority can be implemented and executed.

When a vessel transfers out of ABS class, the CBP will be cancelled.

The Technical Authority may at any time cancel the CBP by informing ABS in writing.

8 Definitions, Abbreviations and References

8.1 Definitions

Alternate to Inspections. Examination in lieu of the traditional inspections to confirm the condition or health status of the class item (e.g., replace "Open & Examine" by "General Visual Inspection" along with "Functional Test" with health report review). See 3/5.1.

Alternative Means of Verification. Inspections/examinations and means or combinations thereof, other than traditional physical inspections, that may be conducted to verify condition of the class item, based on review of class item's health status reports.

Anomaly. A condition that deviates from what is standard, normal, or expected; outside an acceptable threshold from what is considered normal.

Baseline Assessment. The initial condition from which all subsequent examination will be measured. In the context of machinery condition-monitoring indications (e.g., vibration records on rotating equipment), established with the machine in question operating in good order when the vessel first entered the Program; or the first condition monitoring data collected following an overhaul or repair procedure that invalidated the previous baseline assessment. In the context of a structural item, the baseline is the initial condition of the item, as determined by survey, inspection and NDE upon entering the program.

Class Item. Class items include hull structure, compartment, tanks, spaces, machinery, equipment, components, and offshore industrial machinery and equipment having specific survey requirements to be complied with for maintenance of Class and the respective notations assigned to the vessel/facility.

Computerized Maintenance Management System (CMMS). Maintenance management platform of a vessel/facility that includes the inspection and maintenance plan activities. This is a system for administration and tracking of maintenance activities and collection and storage of maintenance information. See details for CMMS in Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)*

Condition Monitoring (CM). The acquisition and processing of information and data that indicate the state of a machine over time. The machine state deteriorates if faults or failures occur.

Condition-Based Maintenance (CBM). A maintenance plan, conducted on a frequent or real-time basis, which is based on the use of Condition Monitoring to determine when part replacement or other corrective action is required. This process involves establishing a baseline and operating parameters, then frequently monitoring the machine and comparing any changes in operating conditions to the baseline. See details for CMMS in Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)*. Owner/operator perform maintenance based on the condition monitoring programs which may include traditional condition monitoring techniques and/or smart functions using data analytics, with approved service providers.

Condition-Based Program (CBP). CBP is an ABS program that provides for a vessel-specific Survey Plan that is continually updated using a compliance risk model that utilizes two way data sharing between ABS and the applicable Government Technical Authority.

Continuous Survey. A survey where the individual parts of a special periodical survey are done in regular rotation over a period of five years so that all parts are covered within five years. See 7-2-1/7 of the ABS *Rules for Survey After Construction (Part 7)*.

Critical Areas. Locations which have been identified from calculations, experience, service history of the subject vessel/facility or similar sister vessels/facilities to be sensitive to cracking, buckling or corrosion that could impair the structural integrity of the ship. See 7-1-1/3.27 of the ABS *Rules for Survey After Construction (Part 7)*.

Digital Reporting. Reporting in an electronic format that can be transferred via data networks, emails, or application programming interfaces replacing hard copy reports. Also see Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)*.

Digital Twin. A digital representation of a physical asset, its related processes, systems, and information which is continually updated through the exchange of information between the physical and virtual systems.

Inspection. The act of examination, often with respect to a set of criteria.

Lagging PCM Factors. Existing or historical deficiencies in Class and Statutory criteria. See definition of Predictive Compliance Model (PCM).

Leading PCM Factors. Expected or potential future deficiencies in Class and Statutory criteria. See definition of Predictive Compliance Model (PCM).

Machinery Health Monitoring. Monitors the health state and operational conditions of onboard machinery and systems to detect anomalies that assist in the prediction of the onset of condition degradation or improper operation which may lead to functional failure.

Predictive Compliance Model (PCM). A weighted set of leading and lagging condition related factors for a class item that gives insight into the current or future compliance state of that item.

Remote Inspection Techniques (RIT). Remote Inspection Technology refers to a technology using a remote inspection vehicle (RIV) to perform an inspection.

Remote Inspection Vehicle (RIV). Remote Inspection Vehicle refers to a remotely-controlled vehicle operating in the air, underwater, or on structures, such as UAVs, ROVs, or robotic crawlers.

Remote Survey (RS). A process of verifying that a ship and its equipment are in compliance with ABS Rules where the verification is undertaken, or partially undertaken, without attendance on board by a surveyor.

Signature. Condition monitoring data (e.g., vibration data or similar) collected subsequent to the Baseline.

Smart Function (SF). Systems installed and service deployed to continuously collect, transmit, manage, analyze, and report data for enhanced health and condition awareness, operational assistance, operational optimization, and decision-making support. See Appendix 1 in the ABS *Guide for Smart Functionality for Marine and Offshore Vessels (Smart Guide)*.

Structural Health Monitoring. Monitors structural loads, responses, and health conditions to assess the structural integrity, provide structural health awareness, and help reduce the potential for structural damage.

Time Series Data. Time-stamped data collected over a specific period at a particular frequency.

Transactional Data. Discrete, time-stamped business and device data generated by maritime operations, condition and performance monitoring, inspection, repair and maintenance activities (e.g., maintenance data, spare parts data, survey reports, noon reports and event data captured by sensors).

8.2 Acronyms

ABS	American Bureau of Shipping
ACP	Alternative Compliance Program (USCG)
AI	Artificial Intelligence
A_o	Operational Availability
API	Application Program Interface
CAD	Computer Assisted Design
CBM	Condition-Based Maintenance
CBP	Condition-Based Program
CG	Center of Gravity
CM	Condition Monitoring
CMMS	Computerized Maintenance Management System
CMS	Continuous Machinery Survey
COC	Condition of Class
CPU	Computer Processing Unit
CVI	Close-up Visual Inspection
DLA	Dynamic Loading Approach
FEA	Finite Element Analysis
FMEA	Failures, Modes and Effects Analysis
FMECA	Failure, Modes, Effect and Criticality Analysis
FPSO	Floating Production, Storage and Offloading Unit
FRACAS	Failure Reporting, Analysis and Corrective Action System
FT	Functional Testing
GHS	General Hydrostatics™
GSA	Global Strength Assessment
GVI	General Visual Inspection
HAZID	Hazard Identification Analysis
HAZOP	Hazard and Operability Analysis
HM&E	Hull, Mechanical and Electrical
HMI	Human - Machine Interface
I/O	Input/Output
IMO	International Maritime Organization
LBSG	Long-Based Strain Gauges

LORA	Level of Repair Analysis
MARPOL	*International Convention for the Prevention of Pollution*
MHM	Machinery Health Monitoring
MoC	Management of Change
MRU	Motion Reference Unit
MTBR	Mean Time Between Repair(s)
MVR	*Marine Vessel Rules*
NDE	Non-Destructive Examination
NLP	Natural Language Processing
NOAA	National Oceanographic and Atmospheric Administration
O&E	Open-and-Examine
OEM	Original Equipment Manufacturer
OSR	Outstanding Survey Requirement
PCM	Predictive Compliance Model
PDA	Product Design Assessment
PM	Planned Maintenance
PMP	Preventive Maintenance Program
PMS	Planned Maintenance System
QAQC	Quality Assurance and Quality Control
RAM	Reliability, Availability and Maintainability
RBI	Risk-based Inspection
RBM	Reliability-Based Maintenance
RCM	Reliability-Centered Maintenance
RMF	Risk Management Framework
RS	Remote Survey
RTD	Resistance Temperature Detectors
RTM	Real Time Monitoring
SBI	Ship Builder Integrator
SDT	Structural Digital Twin
SF	Smart Function
SFA	Spectral Fatigue Analysis
SHM	Structural Health Monitoring
SOE	Ship Operating Envelope
SOF	Statement of Fact
SOLAS	*International Convention for the Safety of Life at Sea*
SPD	Survey Planning Document
TCM	Tailshaft Condition Monitoring

TM	Thickness Measurement
USCG	United States Coast Guard
UT	Ultrasonic Thickness Measurement

8.3 References

During the development of the Condition-Based Program, and when carrying out surveys onboard, reference should be made to the latest version of the following documents, as applicable:

- ABS *Rules for Building and Classing Marine Vessel (Marine Vessel Rules)*
- ABS *Guide for Hull Condition Monitoring Systems (HCM Guide)*
- ABS *Guide for Hull Inspection and Maintenance Program (HIMP)*
- ABS *Guide for Surveys Based on Machinery Reliability and Maintenance Techniques (MRM Guide)*
- ABS *Guide for Smart Functionality for Marine and Offshore Vessels (Smart Guide)*
- ABS *Guide for Cybersecurity Implementation for Government Vessels - CyberSafety Volume 6*
- ABS *Guide for CyberSafety for Equipment Manufacturers - CyberSafety Volume 7*
- ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries (Risk Guidance Notes)*
- ABS *Guidance Notes on the Use of Remote Inspection Technologies (RIT Guidance Notes)*
- ABS *Guidance Notes on the Application and Maintenance of Marine Coating Systems*
- ABS *Performance Standards for Corrosion Protection (PSCP Guide)*
- Inspection Grading Criteria for the ABS Hull Inspection and Maintenance Program (HIMP)
- IACS Rec. 87 – Guidelines for Coatings Maintenance and Repairs
- IACS Rec. 84 – Container Ships: Guidelines for Surveys, Assessment and Repair of Hull Structures.
- IACS Rec. 76 – Bulk Carriers: Guidelines for Surveys, Assessment and Repair of Hull Structures.
- IACS Rec. 96 - Double Hull Oil Tankers: Guidelines for Surveys, Assessment and Repair of Hull Structures
- IACS – Guidance Manual for Tanker Structures
- IACS Rec. 47– Shipbuilding and Repair Quality Standard – SARQS
- TSCF – Tanker Structure Co-operative Forum – Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures.
- TSCF – Tanker Structure Co-operative Forum – Guidance Manual for the Inspection and Condition Assessment of Tanker Structures.

SECTION 2

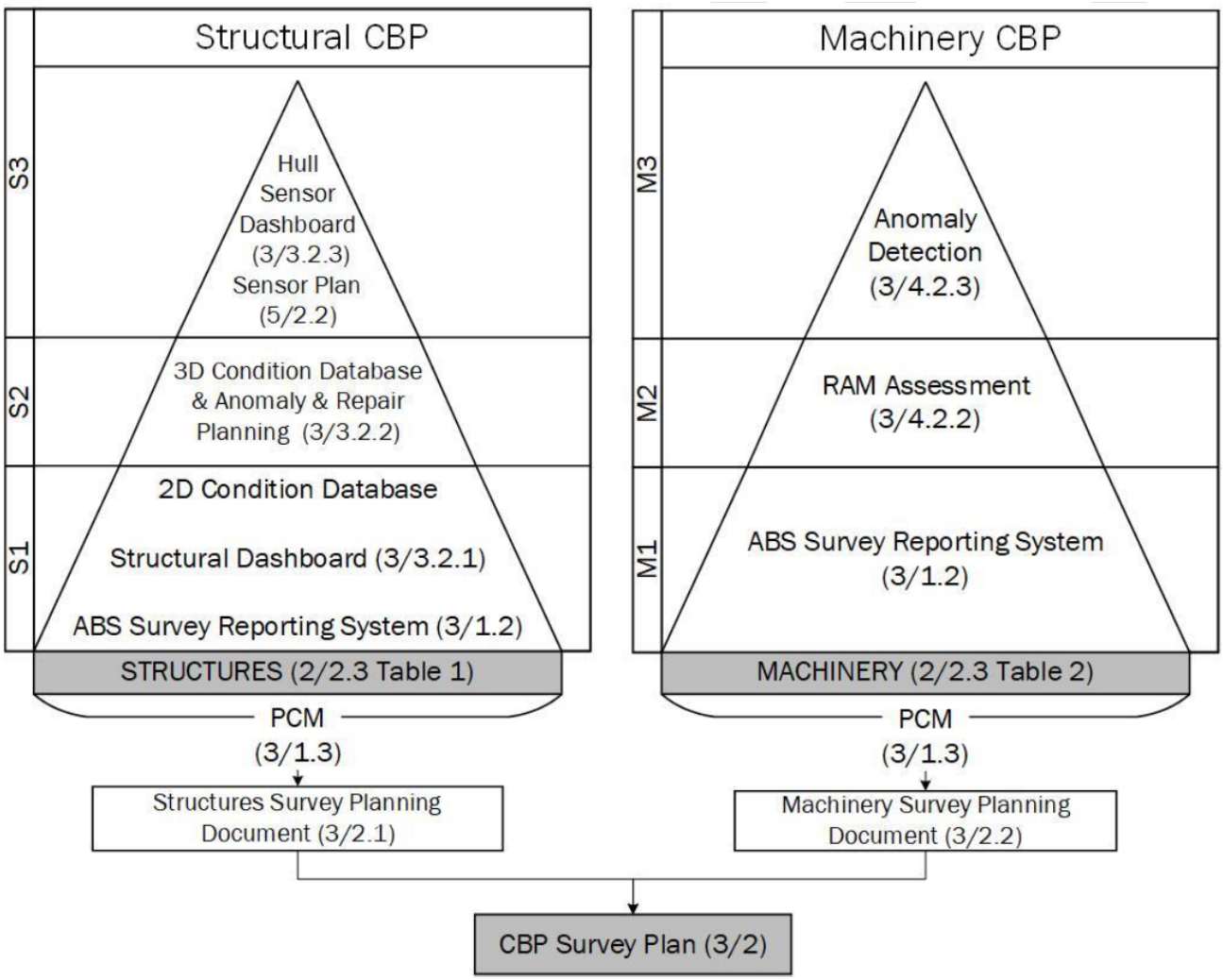
Condition Based Program

1 General

The ABS Condition-Based Program (CBP) is focused on leveraging data to support ABS surveys becoming more informed, targeted, and predictive by shifting to a continuous data driven process, while also aligned with government operational and maintenance workflows.

Three tiers of CBP notations are defined for both ship structures (S1, S2 or S3) and machinery (M1, M2 or M3, by system). These notations set the requirements for the vessel's CBP related technical capabilities, the required datasets to support the program, and the associated ABS products for CBP tier execution. Section 2/1 Figure 1 shows both the structures and machinery aspects of CBP, indicating (with references to Sections within this Guide) the tiered notations and additional CBP services contributing to higher fidelity input to the CBP Survey Plan as higher notations are chosen. The figure indicates the sequential relationships between notation tiers, as requirements for S1/M1 are foundational to achieve S2/M2 and S2/M3 tiers.

FIGURE 1
CBP Guide Structural and Machinery Components

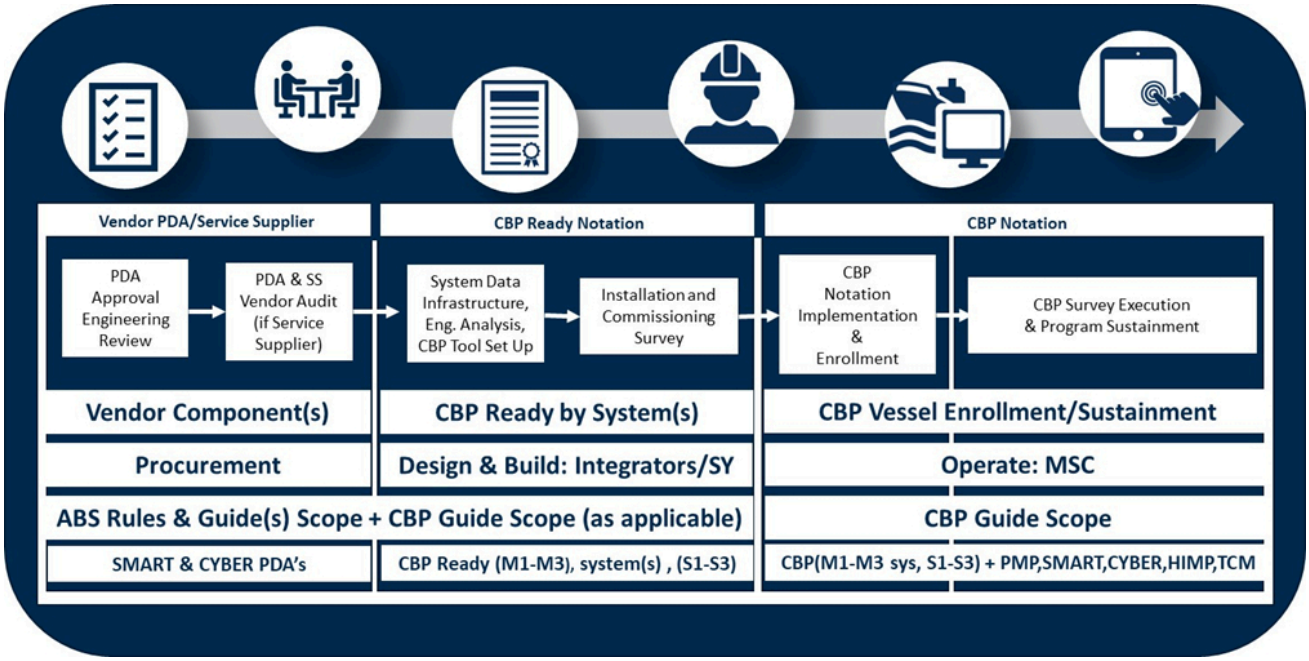


2 CBP Notations and Supporting Class Notations

2.1 CBP Vessel Lifecycle Application

This Guide provides technical and survey requirements for CBP in order to obtain a **CBP Ready** or a **CBP** notation in the vessel's various lifecycle stage (see 2/2.1 Figure 2).

FIGURE 2
Lifecycle Application of CBP and all Related Notations



The core of the CBP is the development of a CBP Survey Plan. The CBP Survey plan as described in this Guide allows for customization of scope for enrolled class item(s) by taking into account the vessel-specific design features, the compliance risk profile and the current condition of the covered items, resulting in increased clarity in the classification survey process. The guide defines the framework for the development and sustainment of the CBP Survey Plan based on the selected CBP tier.

CBP may also include any CBP supporting notation(s), specified as either mandatory (essential components of the CBP) or optional (not essential, but which may also be contributory towards CBP survey planning on-board).

2.2 CBP Relevant Product Design Assessment (PDA) Endorsements

ABS provides several optional types of product or equipment certifications and notations for Government vessels to achieve specified capabilities which support CBP implementation. The certifications and supporting notations are summarized below. These PDA endorsements are not required to receive the **CBP** notation.

Product Design Assessments (PDA) certifications are mechanisms for ABS to evaluate vendor submitted objective quality evidence against specified criteria that may contribute towards a more robust CBP for the vessel and its systems. Two ABS vendor programs of relevance include PDA endorsements and certification applications addressing equipment and subsystem level smart capabilities, and equipment level cybersecurity.

- **Smart PDA endorsement:** Covers PDA approval for smart function capability on equipment or systems with smart health or performance monitoring capability, with or without applicable Service Supplier recognition for Data Center or human-in-the-loop product support. Smart functions utilize equipment and system time-series data and such capability can augment CBP services and the survey planning process.

  This endorsement covers the approval process for original equipment manufacturer (OEM) or 3rd party expert-supplied health and performance monitoring capability for equipment that utilizes physics or artificial intelligence (AI)-based algorithms. Refer to the ABS *Guide for Smart Functionality for Marine and Offshore Vessels (Smart Guide)*.

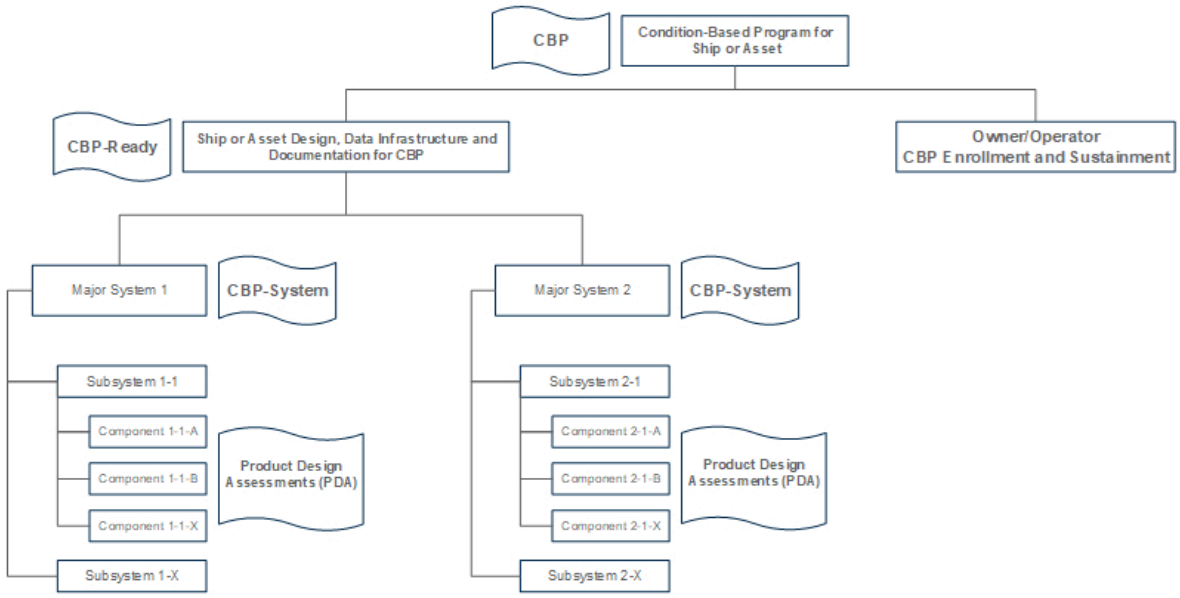
- **CyberSafety PDA:** Covers equipment-level cyber security features to support the CBP data sharing environment, in support of a machine that can send data off the vessel in support of a CBP service (streaming, batch, or otherwise). The CyberSafety Product Design Assessment (CS-PDA) is a recognized way for OEMs to work with ABS to standardize and apply cybersecurity requirements to products. CS-PDA, requires OEMs to provide documentation on settings, configurations, protocols in use, data requirements, software versions, vulnerabilities, and similar information that will help the Ship Integrator or the Owner correctly configure, operate, and maintain the systems. Documentary submittal requirements for CS-PDA products are found in the ABS *Guide for CyberSafety for Equipment Manufacturers - CyberSafety Volume 7*.

2.3 CBP Notations

The **CBP Ready** notation indicates that the vessel has been built and delivered by the Shipbuilder-Integrator (SBI) with either hull and/or machinery CBP capability (for at least one system). Chosen notations dictate the scope of capability, tools and products, and data infrastructure as defined Section 3 of this Guide, but not yet including the process of program enrollment, which is to be covered by the vessel Technical Authority when taking ownership of the vessel. See 2/1 Figure 1 and 2/2.3 Figure 3.

- **Machinery: CBP Ready M1, M2 or M3 (by system),** as applicable to one or more of the following systems:
  - Propulsion System
  - Steering/Maneuvering System
  - Power Generation/Distribution
  - Firefighting System/Equipment
  - Auxiliary Machinery
  - Cargo/Ballast Handling System
  - Hotel/Accommodations/HVAC
  - Navigation System
  - Station Keeping, Anchors, Mooring and Towing Equipment
- **Structures/Hull: CBP Ready S1, S2 or S3**

FIGURE 3
Notation Relationships



The **CBP (S1, S2 or S3) or CBP (M1, M2 or M3, by system)** notation indicates that the hull or individual system(s) have achieved CBP enrollment per Section 4 of this Guide in line with one or more of the following CBP tiers:

- **Tier 1 (S1 and/or M1):** Entry level requirements for CBP enrollment. Transactional data and route or exposure-based sea state history will be leveraged for analysis and creation of vessel-specific CBP Survey Plans. Based on the ABS survey reporting system, ABS annual survey assessments will include a focused effort on structural critical areas and machinery identified via the Predictive Compliance Model (PCM, see 3/1.3) as high or medium risk primarily through lagging indicators on the system aspects, and including some structural leading indicators via the continually reassessed hull critical areas and the structural dashboard alert system defined in 3/3.2.1.
- **Tier 2 (S2 and/or M2):** Involves a higher fidelity of transactional data analysis utilization in PCM, via the inclusion of structural condition tracking and degradation forecasting, and increased use of leading indicators for machinery reliability emergent risk identification (reliability, availability and maintainability, or RAM). The higher fidelity 3D condition model is deployed to complement the route or exposure-based sea state history tracking, and to support anomaly management, maintenance/repair, and availability planning.
- **Tier 3 (S3 and/or M3):** Introduces the use of time-series sensor data for enhanced PCM use. Alerts from either hull sensor or anomaly detection for system monitoring serve as added leading indicator inputs to the PCM, further informing survey planning. In addition, hull sensor full-scale measurements enable structural digital twin calibration for improved accuracy and reliability of the continual structural reassessments involved in the sustainability phase.

See Section 2/Tables 1 and 2 for high-level **CBP** Notation Tier definitions. Detailed information and notation differentiations are provided in 3/3.1 Table 1.

TABLE 1
CBP Structural Notations

Notation	*Technical Scope/Fidelity*
S1	• ABS Predictive Compliance Model (PCM) leveraging *transactional* data (inspection data and Critical Areas) used as methodology to calculate *lagging and leading* weighted factors to quantify asset hull condition/risk for survey scope/prioritization • Annual survey assessments driven by asset specific Critical Areas derived from Strength and Fatigue Analyses • Current gauged condition of asset used to periodically update FEA models only (as-gauged analysis) • Load exposure and fatigue damage rate estimation based on vessel operational / position history using metocean hindcast data sets • Survey grades condition using a severity scale (i.e., *ABS HIMP Grading Criteria* to grade compartments and anomalies)
S2	• **S1 plus,** • ABS Predictive Compliance Model (PCM) leveraging added fidelity condition data to calculate *lagging and leading* weighted factors to quantify asset condition/risk for survey scope/prioritization • Structural Digital Twin comprising both condition and structural analysis models • High fidelity 3D condition database model to store and maintain inspection history and prioritize anomaly management, hull ultrasonic thickness gauging planning and assessment, and repair planning and assessment to support vessel availability planning. See 3/3.2.2 • Corrosion Prediction Models
S3	• **S2 plus,** • ABS Predictive Compliance Model (PCM) leveraging hull sensor alerts used as methodology to calculate *lagging and leading* weighted factors to quantify asset condition/risk for survey scope/prioritization • Hull sensor plan, based on hull form and critical area needs. See 3/3.2.3 and 5/2.2. • Calibrated Structural Digital Twin using sensor-based measurements, for improved analysis accuracy • Near real-time alerts resulting from load events captured by the sensor dashboard • Fatigue damage accumulation trending, tied to CBP Survey Plan critical areas

TABLE 2
CPB Machinery Notations

Notation	*Technical Scope/Fidelity*
M1	• ABS Predictive Compliance Model (PCM) leveraging *transactional* data, e.g., PM, CM, failures, or outstanding survey requirements (OSRs) used as methodology to calculate *lagging* weighted factors to quantify asset condition/risk for survey prioritization Leveraging Client Computerized Maintenance Management System (CMMS) connectivity for a continuous targeted survey and a streamlined Preventative Maintenance Program (PMP) process
M2	• **M1 plus,** • ABS Predictive Compliance Model (PCM) leveraging *transactional* data (e.g., PM, CM, failures, OSR) used as methodology to calculate *leading* weighted factors to quantify asset condition/risk for survey scope/prioritization • Reliability, Availability and Maintainability (RAM) assessment on *transactional* data to identify system 'bad actors' and system performance and risk trends. See 3/4.2.2
M3	• **M2 plus,** • ABS Predictive Compliance Model (PCM) leveraging *time series* data (e.g., machinery operational sensor data), used as methodology to calculate both *lagging and leading* weighted factors to quantify asset condition/risk for survey scope/prioritization • Use of machinery sensor data for real to near real time Machinery Anomaly Detection for those critical machinery/components and bad actors identified in RAM analysis. See 3/4.2.2

2.4 CBP Supporting Notations for Health and Condition Monitoring

Other ABS notations and programs which provide contributing CBP related information in the form of transactional data or reports, can support the CBP Survey Process (Table 3). The CBP supporting notations and programs are all related to maintenance, health and condition monitoring, and is to be incorporated into the CBP either optionally or as mandatory requirements as denoted in Table 3. Table 3 covers the CBP supporting notations, and these notations can be assigned to the vessel provided the compliance to the requirements in the respective referenced Rules and Guides are met.

TABLE 3
CBP Supporting Notations

	CBP Supporting Notations	*Submittal Requirements (ABS References)*	*Required or Optional*
Machinery	**PMP (PM, CM, RTM)**	Section 7-A1-14 of the ABS *Rules for Survey after Construction (Part 7)*	Mandatory
Structures	**HIMP**	ABS *Guide for Hull Inspection and Maintenance Program (HIMP Guide)*	Optional
Structures	**SMART (SHM)**	ABS *Guide for Smart Functions for Marine Vessels and Offshore Units*	Optional
Machinery	**SMART (MHM)**	ABS *Guide for Smart Functions for Marine and Offshore Units*	Optional

	CBP Supporting Notations	*Submittal Requirements (ABS References)*	*Required or Optional*
Machinery	**TCM**	Section 4-3-2 of the ABS *Marine Vessel Rules*	Optional
All	**CS-System, CS-G**	ABS *Guide for Cybersecurity Implementation for Government Vessels – CyberSafety Volume 6*	Optional

2.4.1 Preventative Maintenance Program (PMP-PM, CM, or RTM) Notations (Mandatory)

Vessels/facilities with machinery class items enrolled in a **PMP** notation indicate compliance with Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)*. As PMP-related data on maintenance program health forms a key aspect of the CBP and the class models it employs, enrollment in the PMP is mandatory for all CBP enrolled machinery.

2.4.2 Hull Inspection and Maintenance Program (HIMP) Notation (Optional)

A vessel/facility with hull structural items enrolled in **HIMP** notation indicates compliance with the *HIMP Guide*. For assignment of the **HIMP** notation, the vessel/facility's hull inspection and maintenance scheme are required to be examined at the time of its implementation. The vessel/facility is to be enrolled into Continuous Survey of Hull. The requirements of the implementation survey and maintenance of the **HIMP** notation are listed in the ABS *Guide for Hull Inspection and Maintenance Programs*.

2.4.3 Smart Functionality Notations (SMART) (Optional)

The optional class notation **SMART (SHM, MHM)** is to be recorded for the vessel/facility with smart functions in compliance with the *Guide for Smart Functionality for Marine and Offshore Vessels*.

2.4.4 Tailshaft Condition Monitoring Notation (TCM) (Optional)

The optional class notation **TCM** may be assigned to a vessel/facility with tailshaft(s) and stern tube bearings, provided it complies with the requirements noted in Section 4-3-2 of the Marine Vessel Rules.

2.4.5 Cybersecurity Notation(s) CS-System to CS-Ready (Optional), CS-G (Optional)

CBP involves data handling and data interchange between the vessel, ABS, and Government Data Centers. Therefore, the requirements for cybersecurity can apply to all applicable CBP tiers. Building on the CyberSafety PDA, the notations referenced in this section cover optional requirements for a vessel delivering as CBP-Ready from a shipyard as the cyber protection of the capability selected for CBP.

Cybersecurity notations can be considered for supporting all CBP activities for several reasons:

- Integrity of systems is a necessary condition to provide confidence in system reporting and system capabilities within the performance assessment, analysis, and management chain.
- Integrity of data is a necessary and sufficient condition to provide data of quality and veracity that supports decisions and decision requirements within the crew's operational conditions.
- Security of data and systems supports data integrity directly, and it has a critical impact on CBP analysis and decision-making processes.
- Sensors and sensing systems are the expected operational components to provide data in the higher tiers of the CBP environment. Other infrastructure systems may also support data generation, transmission, aggregation, and storage; but all reporting systems or components will have to represent an understandable level of security prior to installation, integration, and activation.

The **CS-System** notation, leading to the **CS-Ready** notation at the vessel level, is an integrator's method for taking defined and documented systems, optionally drawing upon CS-PDA data package(s), and building them into shipboard networks. **CS-System** requires standardization of the network segment or enclave into which the installed system will provide its output functions. **CS-System** requires an annual survey to verify documented conditions remain as expected, in accordance with both the Notation and the ship's Management of Change program.

ABS requires vendors and integrators to document, configure, and record specifications for systems as installed and as networked. Connections that allow critical functions (i.e., components or systems that contribute to ship or personnel mission or safety) to communicate with other systems, or with user entities (machine or human), are to be documented. Conditions for local, network, and remote access are to be deliberately configured and documented to be included in the ship's policies and procedures.

To carry this concept further into operations, one of the fundamental principles for systems related to cybersecurity is that they be understandable and documented. Vendors' systems contribute to the networked environment in which integrators install them, under the supervision of the owning or contracting Agency operating the vessels. The key factor to unite all these players is the ship's crew, which uses the information provided about systems to improve operations, build and maintain secure conditions on the ship, and implement sustainable development for the company and the community. This is where the optional **CS-G** notation comes into play. Given the nature of the data exchange inherent in the CBP, it is recommended that an operational program for cybersecurity be instituted which follows the **CS-G** notation approach, though it remains optional. Note that if a vessel has an ISM certificate, the basic cyber IMO MSC.428[98] requirements are mandatory. See Volume 2 of the CyberSafety® Series.

CS-G is described in Volume 6 of the CyberSafety® series, and implements cybersecurity as a series of eight goals, with twenty-six objectives. This notation provides a minimum cybersecurity implementation program to bring knowledge of architecture and confidence in data integrity into the performance and analysis environment.

SECTION 3

CBP Technical Requirements

1 General

This Section describes the mandatory and optional components of the CBP process based on tier selection. See 2/1 Figure 1 for an overview of all components. For each CBP tier component of the program, the following technical requirements are covered:

1) CBP Component Technical Scope and Key Features – Applicable CBP tier for the component and its function and purpose.

2) Plans and Data to be Submitted – Data and technical information must be made available by the Technical Authority to ABS to deliver the subject CBP component.

3) Technical or Modeling Criteria –ABS Rule criteria applied in the delivery of the technical component upon deployment or as part of continuing service delivery.

4) Key Output and Services – Key contributions to CBP and its benefits.

5) CBP Ready Completion Level – Requirements for Component to achieve a CBP Ready state of completion and subsequently receive a **CBP Ready** notation for a new build at vessel delivery or for an existing vessel to have a state of CBP component completion, and therefore ready for CBP enrollment.

Section 3/1.3 also defines the role of the Predictive Compliance Model (PCM) as the means for aggregating CBP technical components into a compliance risk profile to be used to support the CBP survey process. PCM leverages the component outputs, based on the selected tiers, to calculate lagging and leading factors, to profile asset compliance risk.

Lastly, Appendix 4 covers requirements for when a CBP purpose-installed data infrastructure is needed to support the collection and processing of on-board transactional or time-series data for the chosen CBP tier.

1.1 CBP Process

The CBP's data-driven process consists of four distinct stages to assist both ABS and the Technical Authority with Class sustainment activity as well as maintenance, inspection, and availability planning insights. The process seeks to continually provide ABS and the Technical Authority with an up-to-date understanding of vessel condition and risk, resulting in a vessel-specific CBP Survey Plan. The CBP Survey Plan is a key program component and defines the scope and prioritization of all ABS survey assessments with detailed information regarding HM&E risks associated with compliance, derived from the various CBP components. For government operators, this process also provides pertinent information to maintenance personnel and vessel crew to support long-term planning for in-water or drydock-based availability periods. The four CBP Stages are described below and in 3/1.1 Figure 1.

Stage 1 – Data Acquisition

This stage involves the ingestion of data in all its forms. Transactional data (e.g., PMS records, failure events, in-situ test results, etc.) or sensor time-series data (e.g., Data Historian logs and similar) will be collected and ingested into the ABS Client Portal, either by secure application program interface (API) Gateway (structured reports) or via a secure cloud platform. Further explanations of transactional and time-series data are provided below.

- Transactional Data: Involves data coming to ABS that has been summarized and reported upon to cover a period of time or a snapshot in time as part of an ABS program, often via an ABS recognized Service Supplier. Typically, processed data comes in the form of "traffic light" status reports which summarize the maintenance status, health or condition state, as well as corrective actions taken by the Technical Authority to correct deficient states. Examples of this type of report are PMP program PM, CM, or SMART reports. The data within such reports are also utilized to inform the PCM model risk profile (see 3/1.3). In short, there is the report needed to credit the program, such as PMP, and then there is the need to inform the CBP profile.
- Time-Series Data: This type of data is utilized only for ingestion and analysis within higher-tier CBP components. These components ingest sensor data from either systems or machines (typically the operational sensors that are part of the OEM or builder package) or structures (typically in the form of a hull sensor set installed to better understand of vessel global responses to hull loading). Once analyzed, such data provides vessel compliance risk profiling to support survey planning as well as to provide ship alerts to the Technical Authority for action.
- Contextual Data includes both vessel route history in the form of vessel operational / position history as well as the corresponding metocean hindcast data sets to support the aggregation of a route and sea state load history that can be utilized to reassess the vessel based on its service history over time after every drydock.

Stage 2 – Data Processing and Analysis

Data Processing and Analysis covers the following activities, as applicable to the chosen tier:

- Ingestion and appropriate mapping of information to the CBP tier component, as applicable.
- Ingested system data processing, including data quality and verification that ingested data meets the minimum required fidelity for follow-on analytics, as referenced in 4/3.2 Table 2. Data quality will be monitored and reported to quickly identify and notify the Technical Authority of potential issues in the data collection process (e.g., failing sensors, etc.).
- Analytical models that provide predictive compliance-related forecasting abilities, which inform CBP and condition-based maintenance activities. This includes RAM or anomaly detection models used to identify reliability risks enabling prioritized survey or maintenance prioritization for the Technical Authority or a structural analysis accounting for initial design envelope and as-built configuration and all continued reassessments based on load exposure and fatigue damage rate estimation as well as any changes in condition associated with degradation or repair/restoration.

Stage 3 – Visualization and Risk Profile

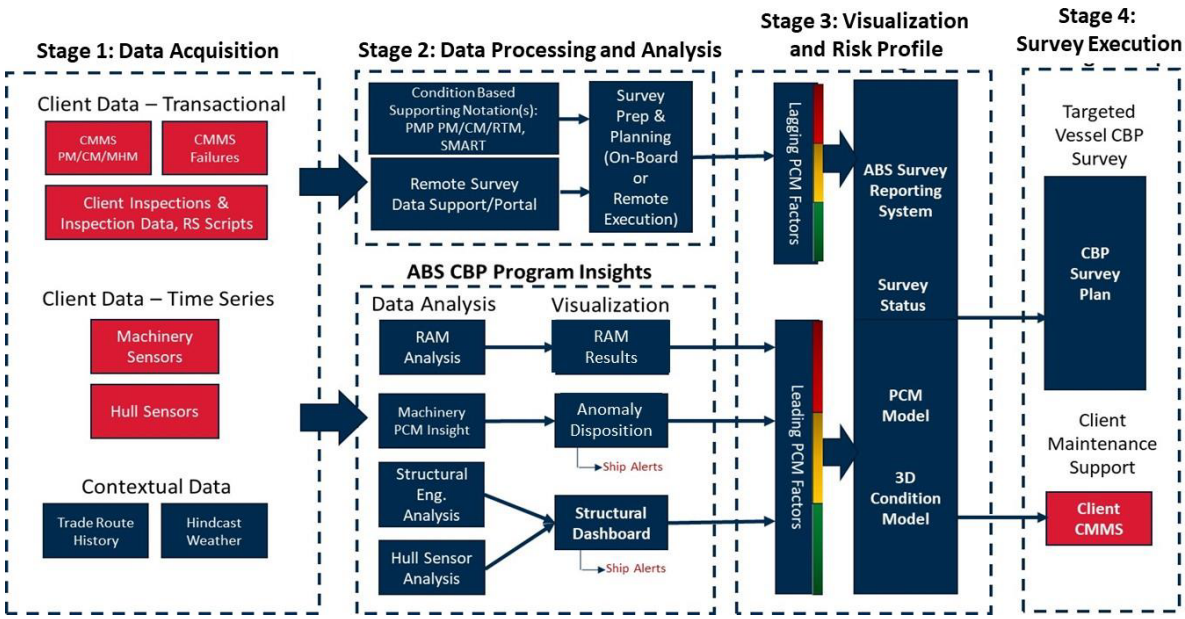
This stage covers the visualization of all inputs from tier components for CBP Survey execution including:

- A vessel-specific CBP Survey Plan as shown in ABS Survey Reporting system for structures, as informed by the structural analysis and the current/updated PCM profile. See 3/2.1.
- A vessel-specific CBP Survey Plan for machinery as shown in ABS Survey Reporting system, as informed by the CBP supporting program data, and the predictive insights from the selected tier components as well as the current/updated PCM profile. See 3/2.2.
- High-level and detailed condition data for the hull structures as shown in both the ABS Survey Reporting system and the 3D condition model to support availability and repair planning, if applicable to the selected tier.

Stage 4 – Survey Execution

Stage 4 covers the output of either the CBP survey activity itself or CBP services providing alerts to the Technical Authority's Computerized Maintenance Management System (CMMS) for their own repair, maintenance, survey, and availability planning.

FIGURE 1
Condition-Based Program (High-Level Process)



1.2 CBP Data Integration and Management with ABS Survey Reporting System

The CBP process is fully contained and controlled within the ABS Survey Reporting System and integrated with the Technical Authority's reporting systems. The ABS Survey Reporting system is the official Class system of record, and supports data aggregation, visualization of status in the ABS Client Portal, anomaly management, and CBP Survey Plan generation.

1.3 Predictive Compliance Model

The ABS Predictive Compliance Model (PCM) is used to assess and quantify a vessel's compliance risk profile based on various leading and lagging datasets received either from the client or generated from a CBP component. The model is used to determine compliance risk with respect to structural and system operational availability and Class compliance. PCM is not indicative of literal compliance or non-compliance, rather it identifies those HM&E systems and components determined to be at higher risk of being non-compliant with respect to condition degradation, the presence of anomalies, or maintenance status and is used as the means to inform annual survey scope and prioritization via the CBP Survey Plan. The PCM is deployed within the CBP to:

- Assess the current condition/readiness of the hull and machinery with respect to applicable Class and Statutory (e.g., USCG ACP) requirements via a set of lagging factors.
- Forecast the degradation of an asset's condition to evaluate via a set of leading factors and thus the future risk of the asset non-compliance.
- Identify and prioritize maintenance and survey activity with respect to availability planning, and crediting of items towards special continuous survey of hull and machinery.
- Identify opportunities for aligning Technical Authority maintenance activities with Class compliance activities to improve vessel readiness and reliability.

The PCM model is deployed within the ABS Survey Reporting system applications and plays an important role in keeping a vessel's CBP Survey Plan up to date. It provides a means to synthesize various client and ABS data sets into an easy-to-use decision-making tool for the Surveyor.

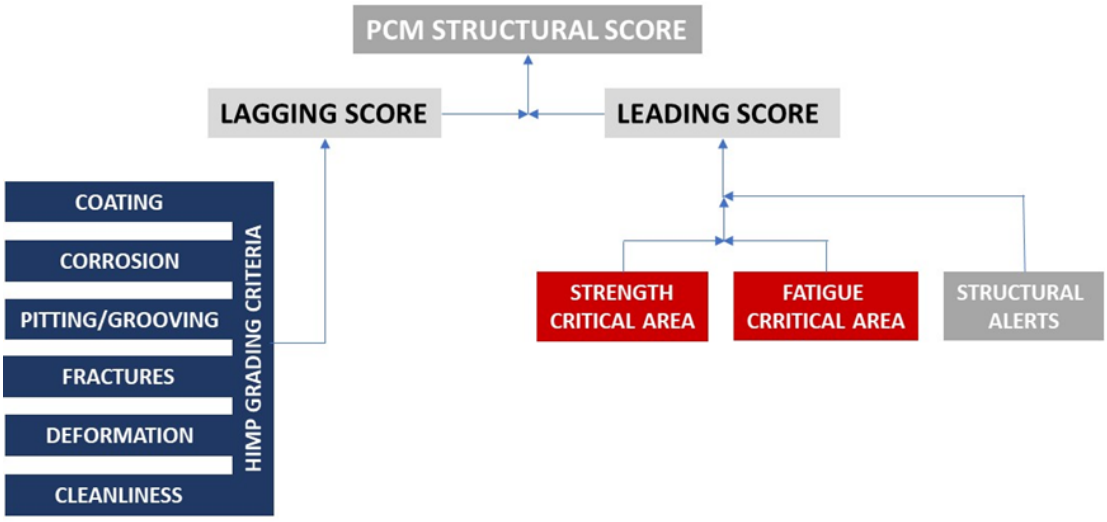
1.3.1 Predictive Compliance Model for Structures

For structures, ABS utilizes various data inputs to generate a PCM score, utilizing criteria specified in 3/2.1, as applicable.

- HIMP Criteria: Reporting is completed by ABS Surveyor as the surveys are executed.
- Strength and Fatigue Critical Areas: ABS Engineering enters data to update the critical area (CA) profiles at completion of initial and subsequent updates to the strength and fatigue analyses.
- Structural Alerts: Structural Dashboard alerts which cover load exposure and thresholding limits received from the aggregated route and metocean data correlated to vessel response, as well as sensor threshold limits for any directly monitored locations, if the vessel has such capability.

Each compartment leading and lagging score rolls up to a single PCM score for that compartment. This score is displayed in both the ABS Survey Reporting system and the Survey Planning Document. See 3/1.3.1 Figure 2.

FIGURE 2
Structural PCM Model



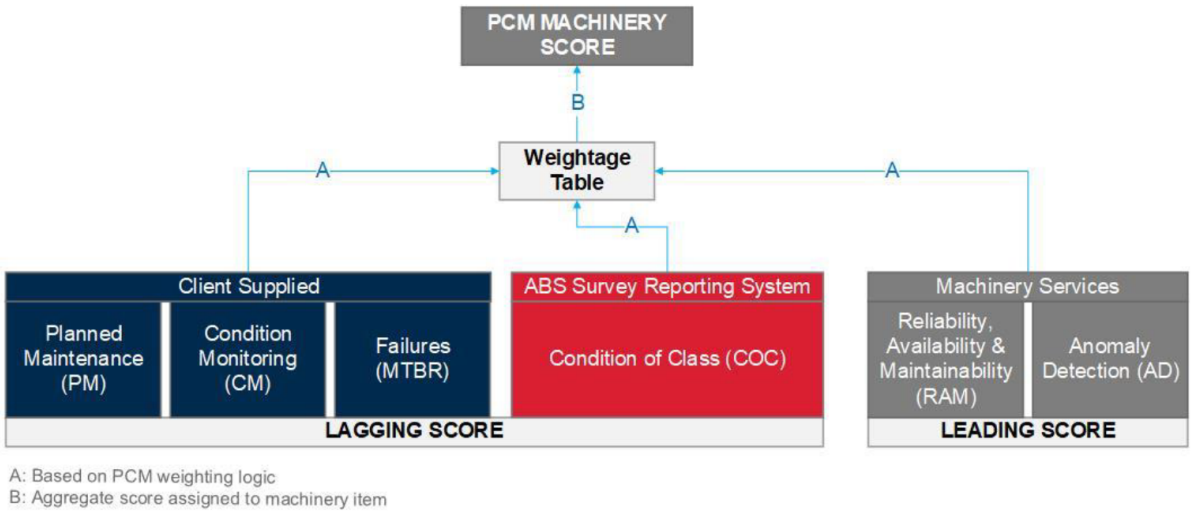
1.3.2 Predictive Compliance Model for Machinery

For Machinery, ABS utilizes various data inputs to generate a PCM score, including:

- PM and CM Data is received from the Technical Authority's CMMS system.
- MTBR: Mean Time Between Repair Data is received from the Technical Authority's CMMS system.
- COC: Conditions of Class as noted in the ABS Survey Reporting system at the time of occurrence.
- RAM: RAM Analysis scoring (Tier 2 and 3).
- System Anomaly Detection alerts and scoring (Tier 3).

Each piece of equipment possesses various combinations of inputs based on the CBP tier features available. These inputs are then synthesized in the PCM to generate a single PCM score. This score is displayed in both the ABS Survey Reporting system and the Survey Planning Document. See 3/1.3.2 Figure 3.

FIGURE 3
Machinery PCM Model



2 CBP Survey Plan

The CBP Survey Plan is a vessel-specific survey plan developed by ABS for the HM&E systems enrolled in the program. All CBP tiers are based on the development of a vessel-specific initial CBP Survey Plan that is utilized for program enrollment. That plan is based upon an initial technical assessment and profiling of vessel structures and machinery and includes the following structural and system development tasks.

The CBP Survey Plan is regularly updated as part of CBP sustainment activity via ABS Survey Reporting system and uses the PCM scoring results. Using these inputs, the CBP Survey Plan continually identifies and prioritizes the scope of the annual survey/inspection.

The CBP Survey Plan is comprised of two contributing parts, one related to Structures CBP and the other related to Machinery CBP described in 3/2.1 and 3/2.2, respectively.

2.1 Structures Survey Planning Document

In all CBP Structural tiers, the structural component of the CBP Survey Plan is derived from a rule-based scantling strength evaluation and an FEA-based strength and fatigue analyses. These analyses incorporate the as-designed or previous vessel route history and the as-built or current hull condition. The as-delivered baseline hull condition is captured within the finite element model, as applicable. That finite element model is also kept up to date with current hull conditions either by direct updating or optionally through the 3D condition model database if notation S2 or higher is selected. These evaluations are then used to produce the structural component of the initial CBP Survey Plan and the accompanying Structures Survey Planning Document (SPD) which highlights structural critical areas to be examined with specific scope and frequency, based on a critical area risk categorization for the entire vessel.

The suite of analyses and condition models and their associated degradation models comprise what ABS terms the Structural Digital Twin (SDT), which is described in further detail in 3/3.2.

2.1.1 Technical Description and Key Features

The SDT uses data from various sources to represent the current state of the vessel's scantlings in all respects throughout the vessel's lifecycle. Such sources include design documentation and as-built drawings, repair or modification history, in-service vessel ultrasonic thickness (UT) gauging measurements, operational and environmental data, results from the initial baseline assessment or sustainment survey assessments, and results from engineering analyses. Section 4/5.4 of this Guide describes the baseline assessment process for existing vessels.

At the heart of the SDT are the engineering models and their associated analyses. The structural analyses identify critical areas for survey and inspection, recommend survey inspection frequencies for the various critical areas of concern, and assist with the identification of immediate, near-term, and long-term repairs in the case of existing vessels.

The strength assessment is to be performed in a two-step process covering a Rules Scantling Evaluation and an FE-based Global Strength Assessment (GSA). The main objective of the Rules Scantling Evaluation is a scantling assessment for global and local strength requirements of applicable ABS Rules (using the corroded condition of the vessel, if applicable). The main purpose of the GSA is to confirm that the identified design scantlings in their current condition are adequate to resist the failure modes of yielding, buckling, and ultimate strength. This is accomplished using the ABS Dynamic Loading Approach (DLA) which provides an enhanced structural analyses basis to assess the capabilities and sufficiency of a structural design. Results from both the Rules Scantling Evaluation and the GSA are then used to determine inspection and repair guidelines using the set of risk matrices outlined in 3/2.1.4.

The fatigue analysis is performed to approximate the material age of the surveyed vessel and predict the remaining fatigue life based on its design profile (for a newbuild) and operational history and observed degradation (for existing vessels). The analysis is performed with the finite element model representing the as-built and/or corroded condition (if applicable) of the vessel using the spectral-based fatigue analysis (SFA) approach, accomplished via the analysis approach specified in this Guide. The calculated fatigue damage for all ship structural details are then used to determine the inspection and repair guidelines using the risk matrix outlined in 3/2.1.4.

2.1.2 Plans and Data to be Submitted

The finite element model, the Structural Analysis Report and the Structures Survey Planning Document (SPD) are based on the following information:

1) Vessel operational history or design envelope

2) General arrangements and structural drawings, including:

- General Arrangement and/or Compartment and Access
- Outboard and Inboard Profiles
- Midship Section
- Scantling-Level Structural Drawings
- Unit Drawings/Structural Assemblies
- Major Modification Drawings (as applicable for existing vessels)
- Trim and Stability Booklet
- Model Test Report (if available)
- Molded Lines and/or Table of Offsets

3) Historic and current gauging (UTM) (existing vessels)

4) Survey reports, known survey critical areas, and known repaired areas (existing vessels)

2.1.3 Technical Approach for Analysis Process

The process to develop the structural analyses and corresponding Structures SPD involves the following steps:

1) Development of a full ship finite element model(s), including the following requirements as applicable:

a) The As-Built model should reflect the provided drawings.

b) The model should represent the corroded condition using the provided gauging reports and repairs (existing vessels).

2) Performance of a Global Strength Assessment using the Dynamic Loading Approach (DLA) Analysis. The analysis considers:

a) Selection of most appropriate loading condition(s) and determination of the environmental conditions. This can take the following forms, as applicable or depending on available data:

1) Design Operational Profile (all vessels)

2) Actual Operational Profile either reflecting actual vessel route history with corresponding metocean exposure if available, or an approximate operational profile based upon a weighted exposure time and the vessel operational history from vessel logs, time spent along routes, and time at sea and a wave scatter diagram to reflect historic and/or expected conditions (existing vessels only).

b) Assess the structure for yielding and buckling. Acceptance criteria will be based on the applicable ABS rules and guides, including but not limited to: *Guidance Notes on Structural Direct Analysis for High-Speed Craft*, *Guide for 'SafeHull-Dynamic Loading Approach' for Vessels*, and *Rule for Building and Classing Light Warships, Patrol and High-Speed Naval Vessels*.

c) Define Global Strength Assessment (GSA) Critical Areas based on the risk matrices in this section

3) Performance of Spectral-Based Fatigue Analysis (SFA) using the finite element models. The analysis should consider:

a) Selection of the most appropriate loading condition(s).

b) Determination of the environmental conditions. Operational profile and exposure time are to reflect historic and/or expected conditions.

c) Define Spectral-Based Fatigue Analysis (SFA) Critical Areas based on the risk matrices in this section.

4) Performance of Rule Scantling Evaluation

a) Calculate global loads for the as built and corroded condition

b) Evaluate gauged areas for rule requirements

c) Define Rules Scantling Evaluation Critical areas based on the risk matrices in this section.

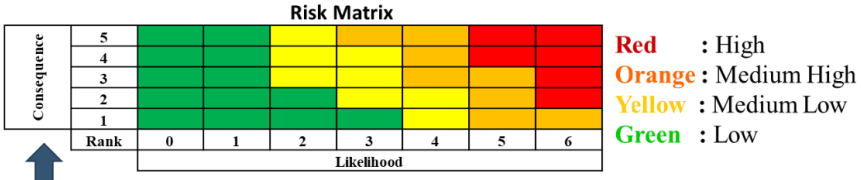
2.1.4 Technical Criteria for Critical Area Determination

ABS will determine a list of consolidated critical areas using the results of the GSA, the SFA, and the Rules Scantling Evaluation, their respective risk matrices, and the use of a consolidated risk matrix for final critical areas determination and categorization, as appropriate. These results will be compiled in the Structures SPD for the vessel. Section 3, Figure 4 through Figure 7 outline the CBP critical area determination and assessment criteria. The Structures SPD includes all Rule Based Survey Requirements as well as any additional vessel-specific Hull Survey Requirements

for CBP Survey Assessment. The Critical Areas and any additional vessel-specific items deemed important of consideration during the engineering analysis will be covered in the Structures SPD as a vessel-specific summary of the hull inspection checklists for all compartments and external hull locations of interest.

The Structures SPD provides the structures-related input to the CBP vessel-specific Survey Plan. The determined risk for each item will establish the recommended action(s) to address the risk, including the scope and frequency of examination for each consolidated critical area or repair/ modification for upload into the CBP Survey Plan and the ABS Survey Reporting system.

FIGURE 4
Global Strength Assessment Critical Area Risk Assessment



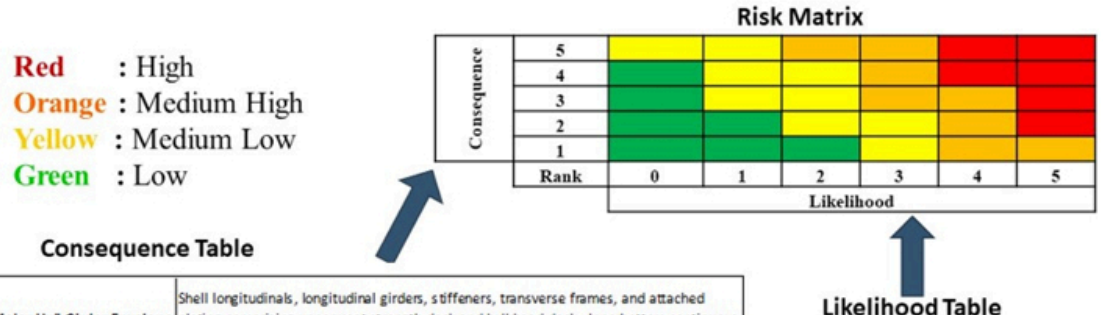
Consequences Table

5	Major Hull Girder Envelope Components	Shell longitudinals, longitudinal girders, stiffeners, transverse frames, and attached plating comprising uppermost strength deck and bulkhead deck. Innerbottom continuous longitudinal structure. Structure penetrating the watertight envelope below design waterline.
4	Continuous Longitudinal Strength Members and Subdivision Bulkheads	Longitudinal girders, stiffeners, transverse frames, and attached plating comprising other strength deck(s). Continuous longitudinal bulkheads, subdivision bulkheads below bulkhead deck, and structure penetrating watertight envelope above design waterline. Superstructure acting as a vital space boundary, exterior weathertight boundary, and superstructure decks. Also damage control deck when not the same as the bulkhead deck in accordance with the applicable build specification.
3	Other Decks, WT Structure, & Vital Spaces	Non-continuous watertight longitudinal bulkheads, intermediary transverse watertight bulkheads, breasthooks, and subdivision bulkheads above bulkhead deck acting as vital space boundaries or tank boundaries. Structure comprising other decks and/or platforms (not including superstructure decks). Tank tops.
2	Non- Vital Superstructure & Minor Members	Superstructure not acting as a vital space boundary no exterior weathertight boundary, minor members including panel breakers, brackets, small headers, etc.
1	Miscellaneous Bulkheads & Non-Primary Structure	Miscellaneous bulkheads, non-primary structure such as injection scoops, foundations, piping, etc.

Likelihood Table

Likelihood	Unity (Actual Stress / Allowable Stress)	
	Aluminum	Steel
0	1 - 1.07	0.95 – 1.00
1	1.07 - 1.14	1.00 – 1.05
2	1.14 - 1.21	1.05 – 1.10
3	1.21 - 1.28	1.10 – 1.15
4	1.28 - 1.35	1.15 – 1.20
5	1.35 - 1.42	1.20 – 1.25
6	> 1.42	>1.25

FIGURE 5
Rules Scantling Evaluation Critical Area Risk Assessment



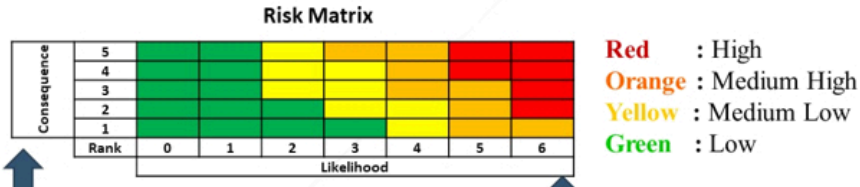
Consequence Table

5	Major Hull Girder Envelope Components	Shell longitudinals, longitudinal girders, stiffeners, transverse frames, and attached plating comprising uppermost strength deck and bulkhead deck. Innerbottom continuous longitudinal structure. Structure penetrating the watertight envelope below design waterline.
4	Continuous Longitudinal Strength Members and Subdivision Bulkheads	Longitudinal girders, stiffeners, transverse frames, and attached plating comprising other strength deck(s). Continuous longitudinal bulkheads, subdivision bulkheads below bulkhead deck, and structure penetrating watertight envelope above design waterline. Superstructure acting as a vital space boundary, exterior weathertight boundary, and superstructure decks. Also damage control deck when not the same as the bulkhead deck in accordance with the applicable build specification.
3	Other Decks, WT Structure, & Vital Spaces	Non-continuous watertight longitudinal bulkheads, intermediary transverse watertight bulkheads, breasthooks, and subdivision bulkheads above bulkhead deck acting as vital space boundaries or tank boundaries. Structure comprising other decks and/or platforms (not including superstructure decks). Tank tops.
2	Non- Vital Superstructure & Minor Members	Superstructure not acting as a vital space boundary no exterior weathertight boundary, minor members including panel breakers, brackets, small headers, etc.
1	Miscellaneous Bulkheads & Non-Primary Structure	Miscellaneous bulkheads, non-primary structure such as injection scoops, foundations, piping, etc.

Likelihood Table

Strength RSE Likelihood Table	
Likelihood	Capacity
0	1 – 1.05
1	1.05 – 1.10
2	1.10 – 1.15
3	1.15 – 1.20
4	1.20 – 1.25
5	> 1.25

FIGURE 6
Spectral-Based Fatigue Assessment Risk Assessment



Consequences Table

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1	Miscellaneous Bulkheads & Non-Primary Structure	Miscellaneous bulkheads, non-primary structure such as injection scoops, foundations, piping, etc.

Likelihood Table

Likelihood	Predicted Remaining Fatigue Life (Years)
0	>50
1	30-49
2	20-29
3	10-19
4	5-9
5	1-4
6	<1

FIGURE 7
Consolidated Critical Areas Risk Matrix for Structures SPD Incorporation

Red / Very High:	If the anomaly is still present, areas should be repaired and modified.
Pink / High:	If the anomaly is still present, areas should be repaired in kind.
Orange / Medium High:	Visual inspection with NDT of area yearly. NDT should be utilized to inspect for initiation of fractures. Areas with High or Medium High Fatigue Risk should be repaired and modified. Areas with Medium Low or Low Fatigue Risk should be repaired in kind.
Yellow / Medium:	Areas contained within Hull: Visual inspection with NDT of area yearly. NDT should be utilized to inspect for initiation of fractures. Areas contained within Superstructure: Visual inspection with NDT of area every 2.5 Years. NDT should be utilized to inspect for initiation of fractures. Structure should be repaired in kind if an anomaly is discovered.
Blue / Medium Low:	Visual inspection with NDT of area every 2.5 years. NDT should be utilized to inspect for initiation of fractures. Structure should be repaired in kind if an anomaly is discovered.
Green / Low:	Visual inspection of area every 5 years. Structure should be repaired in kind if an anomaly is discovered.

Critical Area Based on Fatigue Analysis	Contains Anomaly	Repair in Kind	Repair in Kind	Repair in Kind	Modify	Modify	Modify
	High	2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly Inspection	Yearly Inspection	Modify
	Medium High	2.5 Year Inspection	2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly Inspection	Yearly Inspection	Modify
	Medium Low	2.5 Year Inspection	2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly Inspection	Repair in Kind
	Low	5 Year Inspection	2.5 Year Inspection	2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly Inspection	Repair in Kind
	None	No Action Required	5 Year Inspection	2.5 Year Inspection	Yearly / 2.5 Year Inspection	Yearly / 2.5 Year Inspection	Repair in Kind
		None	Low	Medium Low	Medium High	High	Contains Anomaly
		Critical Area Based on Strength Analysis					

2.1.5 Key Output

The Structural Analysis Report is to include:

1) Fatigue Analysis, including Fatigue Screening and Fatigue Critical Areas.

2) Strength Analysis, including Rules Scantling Evaluation, Rules Scantling Evaluation Critical Areas, Global Strength Assessment (GSA) through Dynamic Loading Approach (DLA), and GSA Critical Areas

3) Consolidated critical areas, including location, description, and unique tracking numbers.

The Structures Survey Planning Document (SPD) is to include:

1) Rule Based Survey Requirements

2) Additional Hull Survey Requirements for CBP Survey Assessment

3) Critical Areas Identified during Engineering Analysis, including a unique number for each Critical Area for tracking purposes.

4) Hull Inspection Checklist

2.1.6 Requirements for Structural Component to Achieve CBP Ready

At minimum for a component to achieve **CBP Ready**, the structural analyses above are to be undertaken for the vessel based on the specified design operating envelope and the as-built scantlings of the vessel. For an existing vessel, please refer to Section 4, which covers enrollment requirements for existing vessels and the baseline assessment prior to commencement of the engineering structural assessment.

2.2 Machinery Survey Planning Document

The Machinery aspect of the initial CBP Survey Plan at a Machinery Survey level initially requires that the ABS vessel hierarchy used within the Machinery SPD to be tagged with respect to the Technical Authority's equipment or system criticality. This criticality tagging enables the PCM risk profiling.

2.2.1 Technical Description and Key Features

The system and machinery component of the Machinery SPD will involve compliance insights being generated via PCM profiling of maintenance and condition data for the risk "likelihood" aspect. The "consequence" aspect of this risk profile is the defined equipment and/or system

criticality (in effect, consequence) that is to be provided to ABS as part of the mandatory PMP program enrollment.

A Tier M1 approach only leverages transactional data (PM, CM, failures, COC) to calculate a lagging set of PCM risk factors for each Machinery SPD, for assessment during survey prioritization in CBP sustainment activities.

Higher M2 and M3 Tier approaches invoke the RAM maintenance data analysis and risk profiling (M2, see 3/4.2.1) and the use of data analytics for Anomaly Detection on select critical equipment (M3, see 3/4.2.2) for PCM incorporation. Reference 3/4.1Table 3 and 3/4.1 Table 4 for details of machinery notations.

2.2.2 Plans and Data to be Submitted

Documented equipment or system criticality is to be sourced from any one of the following documents and submitted for Machinery Survey Planning Document incorporation:

a) A specified Technical Authority criticality list, by system or equipment, for the vessel class.

b) Criticality information that may be sourced from design documentation supplied by the vessel designer, integrator or shipyard for the delivered machinery and equipment within the vessel. Such information may be contained within HAZID/HAZOP analyses, FMEAs/FMECAs, Fault/Event Tree analyses, System Reliability Block Diagrams, categorization in Section 4-9-4 of the *Marine Vessel Rules*, etc.

c) Criticality that is defined in documents related to reliability in system design and operation (either design for maintainability or reliability in operations) prepared by the designer, integrator, or shipyard in conjunction with the Technical Authority. Such information may be included in a level or repair analysis (LORA), reliability centered maintenance (RCM) or reliability-based maintenance (RBM) analysis, which also typically carries through and includes design basis and documented criticality information.

2.2.3 Key Output and Services

The key deliverable of the Machinery SPD includes an ABS Vessel system hierarchy annotated by criticality values aligning with the PCM. This annotated hierarchy enables the model to work continuously as the likelihood factors that comprise PCM are updated.

2.2.4 Requirements for Equipment or System to achieve CBP Ready or CBP Enrollment

For **CBP Ready** or CBP Enrollment, the assigned criticality for the equipment or system is to be provided in any form as described in 3/2.2.2 above.

3 CBP Structural Tiers Component Requirements

This section describes the technical requirements for all components of the structural S1, S2, and S3 notation tiers. The Technical Authority is to choose the desired structural tier. This section includes brief summaries of each CBP technical service or product, the data sets required, the modeling and analysis requirements, as well as the technical criteria applied for each CBP component. Information contained in this section also covers the scope applicable to **CBP Ready**.

3.1 General

The structural notation tiers are rooted in the structural components of the CBP Survey Plan which is documented in the Structures SPD. The CBP Survey Plan highlights structurally critical areas to be examined with specific scope and frequency, as determined by risk. The services and products involved in the structural tiers keep the Structural SPD up to date during CBP sustainment, and include the following as applicable to the selected tier:

- ABS Survey Reporting system as the key data aggregators and reporting tools of record.
- 3D Condition Database to track detailed condition information to support enhanced repair and availability planning as part of a structural digital twin (SDT). See Section 3/3.2.2.
- Structural Dashboard to provide tracking of load exposure for vessel level-insight into load exposure and alerts for Survey Plan and Technical Authority support. See 3/3.2.1.
- Hull Sensor Dashboard for direct insight into critical area and load exceedance monitoring and to assist in Structural Dashboard calibration from the sensor monitoring. See 3/3.2.3 and 5/2.2.

A summary of information on supporting data sets and modeling, analysis and other submitted information are provided in Tables 4 and 5. Detailed requirements for the individual services and tools that elaborate on the tables are covered in 3/3.2.

TABLE 1
CBP Structural Notation Tier Scopes, Data Sets and Products

Notation	*Technical Scope / Fidelity*	*Supporting Data Sets*	*ABS Products*
S1	• Annual survey assessments driven by asset-specific Critical Areas derived from Strength and Fatigue Analyses • Current gauged condition of asset used to periodically update the above (as-gauged analysis) • Load exposure alerts, and approximate fatigue damage rate estimation based on vessel operational/position history using metocean hindcast data sets • Survey results graded on a severity scale (i.e., HIMP criteria to grade compartments and anomalies)	• Operational Route History • Hindcast Weather corresponding to above • Inspection Data (visual, UTM, NDE)	• **ABS Survey Reporting system (see 3/1.2)** • **Structural Dashboard (see 3/3.2.1)**
S2	• S1 plus, • 3D condition database to store and maintain inspection history and prioritize anomaly tracking, thickness gauging planning and assessment, and repair planning and assessment to support vessel integrity management programs • Corrosion rate Prediction	• Same as S1, but now with UTM readings in 3D CAD format	• Same as S1, plus • **3D Condition Model (see 3/3.2.2)**
S3	• S2 plus, • Hull sensor plan, derived based on hull form and critical area needs • Sensor based alerts resulting from load events, tied to CBP Survey Plan Critical Areas • Fatigue damage accumulation trending, tied to CBP Survey Plan Critical Areas	• S2 plus, • Hull Sensor Time-Series Data	• S2 plus, • **Hull Sensor Dashboard (see 3/3.2.3 and 5/2.2)**

TABLE 2
CBP Structural Notation Modeling and Analysis Requirements

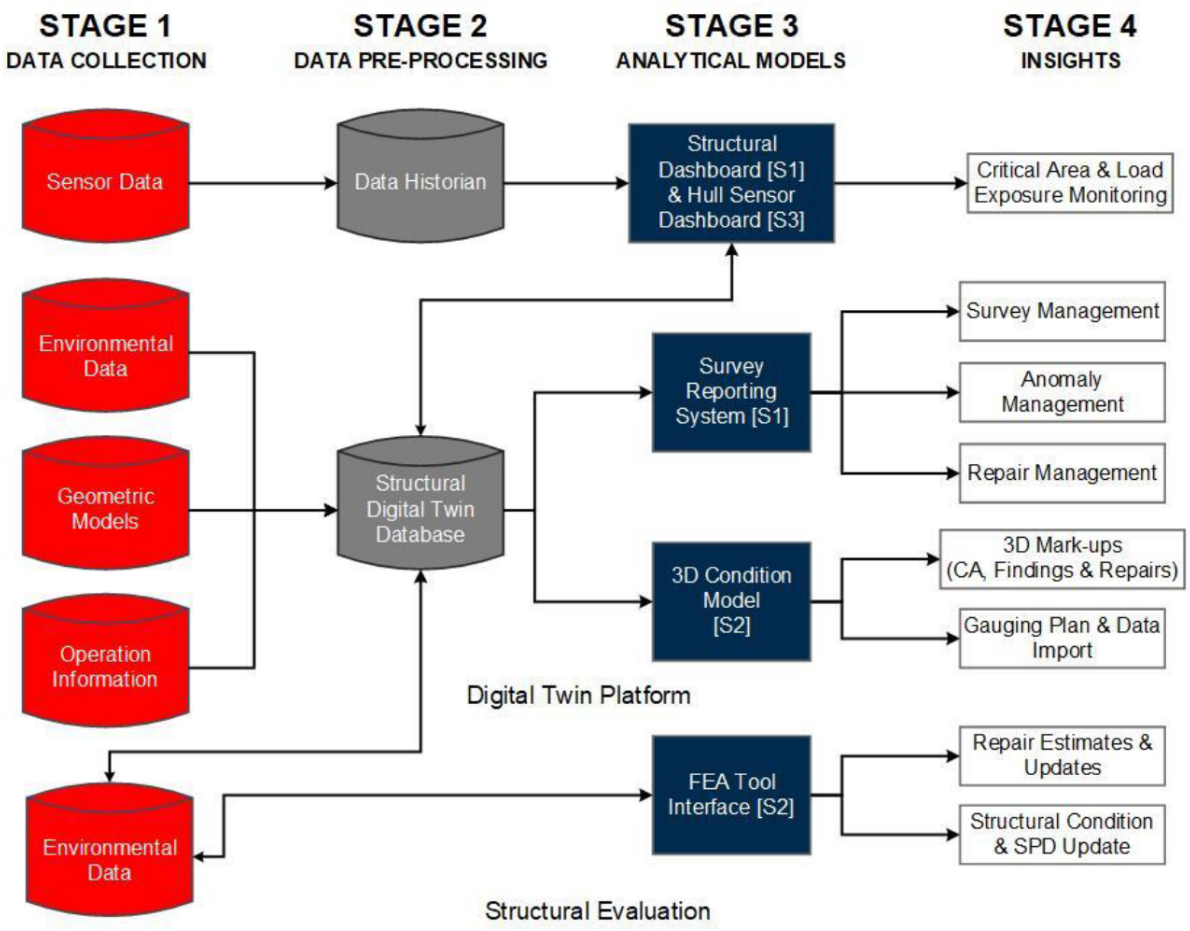
Notation	*Modeling and Analysis*	*Submitted Information*
S1	• **Structural and Fatigue Analysis** (both as-built and as-is condition) – Survey Planning Document with Critical Area prioritization – Setup of Structural Dashboard for route/load history capture • **2D Model** (as compartment navigator condition view)	• Vessel hull as-built drawing set • Historical hull UTM data to establish baseline condition • Vessel route history or prior sphere of operation
S2	• **3D CAD Model** (CAD to a Condition Model Database)	• Same as S1
S3	• **Hull Form Specific Sensor Plan** (locations/type/specification) – with operational input/known problems feeding the plans • **Setup of Sensor Dashboard** for sensor data capture and structural analysis-based threshold limits and FEA model calibration	• S2, plus • Sensor Mapping / Tagging

3.2 CBP Structural Tier Component Details

The suite of components that comprise the analysis models and CBP S1-S3 tier structural and sensor dashboards, condition models, and their visualization and decision-making support capabilities provide the Technical Authority with what comprises a CBP Structural Digital Twin (SDT). A digital twin is defined as a digital representation of a physical asset, its related processes, systems, and information. The SDT combines engineering models and analytics with asset-specific inspection and operational data to create informational models that are updated throughout the lifecycle of their physical counterparts. The SDT provides a platform for information management and collaboration, where stakeholders share a common understanding of the asset's condition. The objectives of the SDT developed for CBP are to manage and visualize data from several sources, including traditional or remote inspection techniques, thickness gauging results, analytical models, structural sensors, operational history, and predictive analytics forecasting to provide input to future inspection and maintenance planning.

The SDT platform functionality is shared between ABS Survey Reporting system, a 2D CBP client status display accessible via the Client Portal, the 3D Condition Model, and the structural and sensor dashboards as shown in 3/3.2 Figure 8.

FIGURE 8
CBP Structural Digital Twin



The following sections describe the individual CBP Tier component features and capabilities, their technical requirements if any, and requirements for the component to achieve the **CBP Ready** notation. Enrollment and sustainment requirements related to each component are covered in Sections 4 and 5.

3.2.1 Structural Dashboard (All Tiers, S1, S2, S3)

The Structural Dashboard fuses hindcast metocean data and ABS domain expertise to deliver structural condition insights. The ABS Structural Dashboard provides a view into the operational profile of enrolled CBP vessels and allows the aggregation of operational load history used to continually update the SDT and the applicable vessel's CBP Survey Plan. The Technical Authority also receives data-driven insights regarding extreme load events, accumulated fatigue damage, and potential impacts to structural critical areas as documented in the Structures SPD and CBP Survey Plan.

3.2.1(a) Technical Description and Key Features

The ABS Structural Dashboard manages environmental loading-based hull monitoring and data aggregation for the Structural Digital Twin. Route-specific wave conditions are monitored via position data and through metocean hindcast services that correlate such data. The experienced sea state conditions are converted into dominant vessel structural loads determined from seakeeping analysis. These loads are monitored in the dashboard and alerts are created when the vessel's pre-configured operational thresholds are exceeded (see 3/3.2.1(c)). Such alerts require dispositioning by both the Technical Authority and ABS.

In addition, the Structural Dashboard also collects the monitored sea state conditions which are used to estimate the fatigue damage accumulation for the vessel and selected set of representative critical areas. The total accumulated fatigue damage and fatigue damage rate can be compared against the original design assumptions.

3.2.1(b) Plans and Data to be Submitted

Vessel position information is to be sent by the Technical Authority, consisting of either periodic batch upload or streaming service into the Structural Dashboard for processing.

In addition, the design drawings as outlined in 3/2.1.2 are to be sent by the Technical Authority to ABS for pre-analysis and dashboard configuration purposes.

3.2.1(c) Technical Criteria

Structural Monitoring threshold load exceedance levels are set via engineering analysis and correlated to locations on the vessel for survey support. These pre-configured operational threshold limits are monitored and, when exceeded, alerts are triggered and sent to the Technical Authority and the ABS Survey Reporting system. Alerts are automatically generated as part of the Structural Monitoring service. All alerts are also sent to the Technical Authority in the form of a monthly Structural Monitoring Report. All alerts require dispositioning by the Technical Authority and also inform the structural survey prioritization via the ABS CBP Survey Plan.

An alert indicates a potential hull deficiency or damage may have occurred. Alerts fall into two severity categories as defined below. Additionally, an alert may also include any operation or exposure of the subject vessel to conditions exceeding its load-based or geographical design limits. As an example, for a hull structure, a restricted service vessel operating in a sea state exceeding its design sea state would constitute a structural alert. The frequency of reporting to the Technical Authority of received alerts by the dashboard function is to be based on the following severity of threshold exceedance:

- Severity Level 1 alert at or above 100% the governing structural criteria limits
- Severity Level 2 alert at or exceeding a pre-defined percentage of the governing structural criteria

Alerts are to be reviewed by ABS, validated, and uploaded into the Survey Reporting system and the PCM model for routine dispositioning action by the Technical Authority and for PCM prioritization within the Survey Plan.

However, since they may potentially involve structures that could affect the safety of the vessel and its classification status, any Severity Level 1 alerts are be sent to the Technical Authority within 72 hours of validation, in addition to being included within the monthly report. The Technical Authority is recommended to investigate such alerts and report back at the first opportunity. If upon investigation, any damage or a deficiency is discovered, ABS Surveyor attendance is to be requested.

3.2.1(d) Key Output and Services

Key outcomes from the use of the structural dashboard include the following:

- Integration with ship automatic identification systems or Technical Authority reported vessel position data and publicly available metocean hindcast data
- Notifications for extreme sea states or wave events and potential overload with highlighting of potential impact to structural critical areas
  - Reportable Events and Dashboard alert Dispositioning/Review/Analysis
  - Detailed reporting on extreme events
  - Recommendations on vessel inspections based on findings

- Summary reports for reportable events - quantity and duration

- Current and forecasted cumulative fatigue damage based on operational history
- Increased transparency into a vessel's operational profile
- Fatigue damage accumulation tracking
- Support CBP targeted surveys, based on vessel-specific operation

3.2.1(e) Requirements for Component to achieve CBP Ready

To achieve **CBP Ready** notation, the Structural Dashboard setup is to be completed and calibrated based on the as-built DLA/SFA analysis results and the vessel's design operational envelope.

3.2.2 3D Condition Model Database (Tier S2 and Higher)

ABS utilizes a 3D Condition Model software tool within the SDT designed to record anomaly and condition data from the design stage to the end of service life using a 3D structural model. The 3D condition model serves as a condition data-storing component with the SDT to visualize, manage and disposition condition data.

3.2.2(a) Technical Description and Key Features

The condition database is designed to facilitate and capture the structural condition data as well as to assist in managing hull inspection and survey results. The 2D viewer, provides an interactive traffic light status of condition in vessel compartments for the various condition criteria as well as housing the vessel-specific Structures SPD information and critical areas derived from the Structures SPD.

The criteria that are applied as part of the hull condition score used in the database can be found in the ABS publication*; Inspection Grading Criteria for the ABS Hull Inspection and Maintenance Program (HIMP)*, the program requirements for which the Technical Authority use are documented in the ABS Guide of the same name.

The 3D database also supports inspection and repair such as gauging planning and execution and repairs during vessel availabilities. The 3D model allows for interactive 3D hull visualization, condition tracking and links to FEA analysis software solutions that assist users in organizing and managing structural condition information. The 3D model provides a higher degree of visualization for the vessel's condition and allows the relevant condition information to be tracked within the model in a historical timeline.

3.2.2(b) Plans and Data to be Submitted

In addition to the structural submittal items identified in 3/2.1.2, vessel as-built or as-modified structural information, plus any available condition data are required to prepare and populate the database models. The following drawings (as applicable) are generally required to prepare a Structural 3D condition model of a vessel:

- General Arrangement
- Capacity Plan
- Midship Section
- Construction Profile and Deck Plans
- Transverse Bulkheads and Sections
- Aft End Construction
- Fore End Construction
- Cargo Hold / Tank Construction
- Shell Expansion

- Engine Room Construction
- Hatch Covers (if applicable)
- Upper Structure/Superstructure Construction
- Structural Details Document
- Bill of Materials/List of Materials
- GHS™ (General Hydrostatics) software file, Lines Plan, and / or a Frame Offset table (for hull form geometry definition), all if available
- Modification and/ or repair drawings to original or existing structures

In general, all structural engineering drawings pertaining to the construction of the vessel may need to be made available to ABS. Original soft copies are preferred since the data, dimensions, and special geometries can be taken directly for more precise modeling and time savings benefits. This could include but is not limited to drawing files, 3D CAD models, or PLM generated Project files, as well as any tabulated files with offset points tables, drawings, and materials list, etc.

For existing vessels, condition data and UTM readings and results, if available, are to also be used to populate the completed 3D condition model, to best represent the vessel in its current condition. The level and amount of detail to be entered in this regard should be as agreed between ABS and the vessel Technical Authority. Refer to 4/2.2 for additional information on this process.

ABS can also accept CAD model information to assist in accelerating the modeling time and efficiency in the generation of a 3D condition model. ABS can ingest and accept a variety of CAD models as a starting point to assist in model creation. Any of the following model types can be used to support the modeling process:

- Any CAD model which can be utilized for conversion into the 3D CAD schema.
- Any PLM generated project file.

3.2.2(c) Technical Criteria for Modeling Guidelines

The following guidelines are to be followed for submitted 3D models, in general unless otherwise agreed:

- Each structure / hull part is to be modeled as per the dimensions noted in the drawings.
- Modelling of all plate seams, even if thickness is the same as adjacent plate
- Model all Holes/openings ≥ 200 x 200 mm
- No modelling rat holes / scallops / cutouts (openings < 200 mm max dimension in any direction) in a web frame / bulkhead plating for stiffeners
- Plates ≤150 x 150 mm not modeled (merge area with an adjacent plate if on same surface)
- Model bracket break at weld seams
- End connection details are not modeled (e.g., snipe and cut-back).
- Stiffeners modeled from a stiffener library.

Built up Members modeled as Plates with Coaming

3.2.2(d) Key Output and Services

Key outcomes from the use of the 3D Condition Model Database include the following:

- 3D CAD models visualization of structural components such as compartments, plates, brackets, stiffeners, and other structural components in their present condition.

- Tracked anomalies and repairs including hull gauging information, anomaly mark-up, critical area mark-up, anode states and others.
- A provided range of analytical model and trending capabilities involving the use of thickness gauging information that can be used for corrosion modelling and further engineering analysis.

3.2.2(e) Requirements for Component to achieve **CBP-Ready**

Details in 3.2.2 are to be provided by the shipyard representing the as-built vessel configuration, and the 2D and 3D models are to be developed.

3.2.3 Hull Sensor Dashboard (Tier S3)

The ABS Sensor Dashboard collects time-series data from installed hull sensors as prescribed by an approved ABS Sensor Installation Plan (refer to 5/2.2) to continuously update the knowledge on the loading and structural responses of the asset. Operational sensor thresholds are set to generate alerts in the ABS Survey CBP Reporting system when sensor data exceeds a pre-determined set of values.

3.2.3(a) Technical Description and Key Features

Sensors are placed for both vessel global response calibration and optionally at locations of critical structures as determined by the Structures SPD. As outlined in 5/2.2, a vessel-specific structural sensor plan supports enhanced understanding of both vessel responses as well as insight into locations where sensors are placed for direct monitoring to support structural integrity understanding and enhanced survey, inspection and repair planning. Such data can identify integrity-related issues and guide future inspection planning and scope changes.

The dashboard also enables visualizations of the sensor data, including overlaying multiple sensor types to help provide sensor-based insights that can help reduce uncertainty and provide increased confidence in the structural integrity risk profile to better inform and target future structural inspections.

Vessel sensor time series data, are to be sent by the Technical Authority in the required fidelity related to that sensor's purpose, consisting of either periodic or batch upload into the Sensor Dashboard for processing.

3.2.3(b) Plans and Data to be Submitted

Hull Sensor Calibration and Set Up Process: ABS will support the process of performing hull sensor calibration and set up activities. The objective of the calibration process is to predict sensor readings for a specific vessel loading condition when the data acquisition system comes online. This is expected to be done with a vessel steady state such as in dry dock or still water under calm conditions.

Hull Sensor Installation, Calibration and Data: Sensor plan and installation process are to be reviewed by ABS Engineering, and the recommendations in Appendix 4/ 1.2 to 1.4 and Appendix 4/ 2 of this Guide are to be verified by the Surveyor to confirm installation suitability, adequacy of the hardware and software, and functionality.

Calibration will be performed via the SDT. Specific loading conditions at the time of the calibration are to be provided by the client such as:

- Weight distribution
- Draft and trim data
- Docking plan

3.2.3(c) Technical Criteria

Sensor Monitoring threshold load exceedance levels are set via engineering analysis and correlated to locations on the vessel for survey support. These pre-configured operational threshold limits are monitored and, when exceeded, alerts are triggered and sent to the Technical Authority and the ABS Survey Reporting system. Alerts are automatically generated as part of the Sensor Monitoring service and sent to the Technical Authority in the form of a monthly Sensor Monitoring Report. All alerts require disposition by the Technical Authority and result in structural survey prioritization via the ABS CBP Survey Plan.

An alert indicates a potential hull deficiency or damage may have occurred. Alerts fall into two severity categories as defined below. The frequency of reporting to the Technical Authority of received alerts by the dashboard function is to be based on the following severity of threshold exceedance:

- Severity Level 1 alert at or above 100% the governing structural criteria limits
- Severity Level 2 alert at or exceeding a pre-defined percentage of the governing structural criteria

Alerts are to be reviewed by ABS, validated, and uploaded into the Survey Reporting system and the PCM model for routine dispositioning action by the Technical Authority and for PCM prioritization within the Survey Plan.

However, since they may potentially involve structures that could affect the safety of the vessel and its classification status, any Severity Level 1 alerts are to be sent to the Technical Authority within 72 hours of validation, in addition to being included within the monthly report. The Technical Authority is recommended to investigate such alerts and report back at the first opportunity. If upon investigation, any damage or a deficiency is discovered, ABS Surveyor attendance is to be requested.

3.2.3(d) Key Output and Services

Hull sensor data is to be collected and transferred to ABS at established intervals (e.g., weekly, after key missions/voyages, etc.) to actively monitor the condition status of the sensors and the hull structure. The active monitoring consists of the following:

- Sensor verification and data quality checks performed to confirm that the sensors are operating as intended so that the resulting data can continue to be dependable for use in data analysis and the resulting ABS class decisions. The results of these data quality checks are to be continually updated in the Sensor Dashboard.

Key outcomes from the use of the sensor dashboard include the following:

- Notifications for extreme sea state or wave events highlighting potential impact to structural critical areas including Hull Sensor Alerts Dispositioning/Review/Analysis.
- Detailed reporting on extreme events. Extreme events are to be identified via periodic evaluations of structural monitoring system sensor data and a summary of out-of-threshold alarms.
- Identified extreme events are to be reviewed by ABS engineering to categorize the alerts and to determine alerts requiring immediate Technical Authority attention and other alerts requiring additional analysis as part of the periodic SDT updates. See threshold criteria in 3/2.3.3 above.
- Recommendations on vessel inspections based on findings
- Cumulative fatigue damage based on operational history
- Support for CBP targeted surveys, based on vessel-specific operation

- After a sufficient period of hull data collection, extreme event identification and analysis, opportunities to recalibrate the hull sensor thresholds, are to be identified, and implemented.

In addition, the Technical Authority is to have a sensor maintenance and calibration procedure in place (ref. Section 3 of the ABS *Guide for Hull Condition Monitoring Systems*).

3.2.3(e) Requirements for Component to achieve **CBP Ready**

To achieve **CBP Ready** notation, the Sensor Dashboard setup including the pre-defined alert thresholds is to be completed based on the approved sensor plan.

4 CBP Tier System and Machinery Component Requirements

This section describes the technical requirements for all components within the system CBP M1, M2, and M3 notation tiers. It includes brief summaries of each CBP component covering the technical service or product, the data sets required, the modeling, analysis requirements, as well as the technical criteria applied, if any. Information contained in this section also covers scope applicable to CBP Ready.

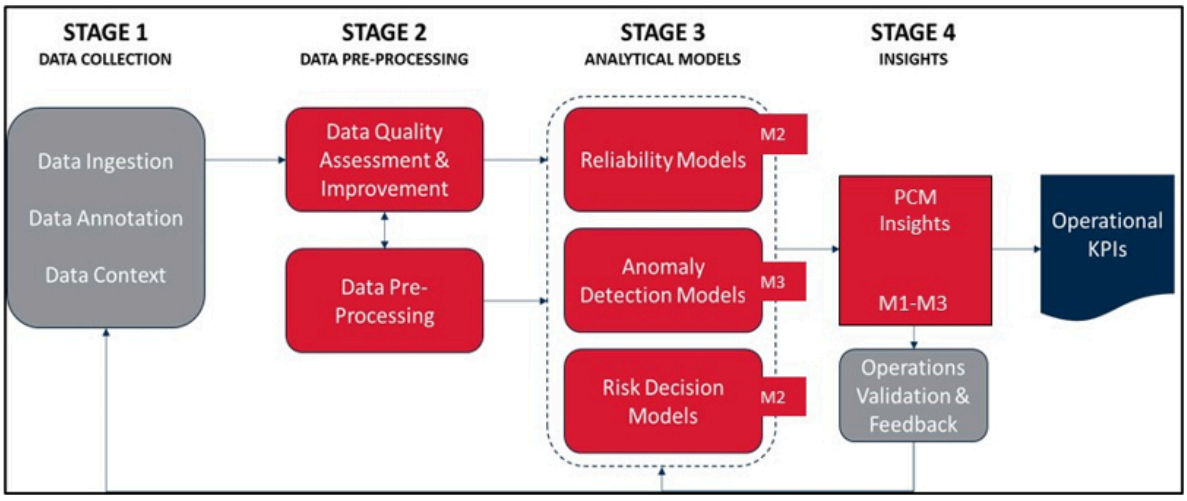
4.1 General

The CBP system notation tiers are rooted in a criticality based and targeted approach to annual and special continuous machinery surveys with a foundation rooted in the traditional ABS Preventative Maintenance Program (PMP), but also involving PCM profiling of such data and reports. The leading indicator insights are derived from the analytics-based profiling of maintenance and condition data as well as equipment and system criticality, with higher tier and optional RAM maintenance data analysis, and the use of data analytics for Anomaly Detection on identified and select critical equipment. The CBM Tiered services and tools are managed within an ABS Machinery Digital Asset Framework as depicted in 3 /4.1 Figure 9.

Key ABS services and products involved in the tiers include:

- ABS Survey Reporting system as the key data aggregator, **PMP** notation credit facilitation, and reporting tools of record.
- RAM Analysis capability to provide “Leading” and/or ‘Lagging’ factors as additional inputs to PCM (Reliability & Emergent Risk)
- Anomaly Detection to provide alerts on anomalous conditions that could potentially lead to increased potential for failure and degradation, as well as to provide compliance risk predictive capabilities as Leading factors to for the PCM Model.

FIGURE 9
CBP Digital Asset Framework for Machinery



Summary information for supporting data sets that correspond to the service tiers, as well as modeling, analysis and submitted information to support are provided in 3/4.1Table 3 and 3/4.1 Table 4. Detailed requirements for the individual services and tools are covered in 3/4.2.

TABLE 3
CBP Machinery Notation Tier Scopes, Data Sets and Products

Notation	Technical Scope / Fidelity	Supporting Data Sets	ABS Products
M1	• Annual survey assessments for annual and Special Periodic Survey - Machinery Survey (SSM) scope leveraging CMMS data for a targeted survey and a streamlined Preventative Maintenance Program (PMP) process	• CMMS PM, CM, RTM in Standard Report Format • CMMS Failure Data Sets in standard format • Tech. Authority self-test or inspection reports in Standard Report Format (optional)	• **ABS Survey Reporting system**
M2	• M1 plus, • Reliability, Availability and Maintainability (RAM) assessment on transactional data to identify reliability risk trends	• Same as M1	• M1 plus, • **RAM Service (see 3/4.2.1)**
M3	• M2 plus, • Use of OEM supplied machinery sensor data for real to near real time Machinery Anomaly Detection) for critical machinery/components identified in RAM	• M2 plus, • Machinery Time-series data for selected machinery scope • Anomaly Inspection and Disposition assessment Data via Tech. Authority's CMMS	• M2 plus, • **Anomaly Detection service (see 3/4.2.2)**

TABLE 4
CBP Machinery Notation Modeling and Analysis Requirements

Notation	*Modeling and Analysis*	*Client Submitted Information*
M1	• Reports sent to ABS Survey Reporting system and data mapped to ABS Vessel Hierarchy to enable PCM aggregation	• Program Reports in ABS requested Format sent to ABS Survey Reporting system (see Appendices 1,2, and 3.
M2	• **RAM System Modeling covering:** – Annotation of CMMS data – Model Building: Using the annotated data, build reliability models.	• M1 plus, • CMMS Data • System Modeling: RBDs as starting point (via integrator, shipyard, or MSC)
M3	• M2 plus, • Targeted Equipment for Anomaly Detection Algorithm Development for selected equipment including: – Data Pre-Processing is to include: · Algorithm Development · Algorithm Deployment	• M2 plus, • Sensor availability and mapping arrangement for all selected equipment

4.2 CBP Tier Machinery Component Details

The suite of components that comprise the analysis models and the CBP M1-M3 tiered system approach covering analytics models, visualization, and decision-making support capabilities collectively provide the Technical Authority with the CBP System Digital Asset Framework. The asset framework approach consists of the utilization of the ABS Client Portal and the secure cloud environment to provide a base platform for data ingestion.

Compliance insights within the RAM and Anomaly Detection service components provide leading PCM indicators for potential class compliance issues as well as system or equipment reliability insights related to potential unplanned maintenance and parts consumption.

4.2.1 PMP and Class Profile (Tier M1)

The CBP system and machinery M1 tier is based on the criticality and a PCM profile based on the ABS Preventative Maintenance Program (PMP), covering status of PM, CM or Smart, failure history, and the presence of Conditions of Class.

4.2.2 RAM and Risk Profile (Tier M2 and higher)

The RAM analysis analyzes transactional CMMS data sets to provide insights for key performance indicators on emerging system compliance operational related risks, provide benchmark reliability estimates for critical components, and provide a vessel-level reliability risk score for unplanned maintenance. Data analytics and modelling is combined with the domain expertise to generate insights from CMMS data with the outcome of increasing Reliability, Availability and Maintainability (RAM) of vessel systems.

4.2.2(a) Technical Description and Key Features

A RAM analysis is performed to assess critical machinery assets and to identify critical areas that can potentially impact overall operational availability and reliability. For this purpose, ABS utilizes historical CMMS data supplied by the Technical Authority to perform an independent

assessment to benchmark the current reliability of major machinery systems. The analysis provides insight into reliability issues affecting enrolled CBP vessels and identifies emergent compliance risks for major machinery systems, and for cases where sufficient data is available, also analyses the sub-systems under the systems. Ultimately, this approach can assist the Technical Authority with targeted areas for improvement to increase operational availability.

The RAM analysis is also used to evaluate Systems reliability, using a 'System-of-Systems' approach, utilizing Reliability Block Diagrams (RBDs) and other related methodologies. The RBD includes individual systems and their sub-systems covering all operating conditions of the vessel. In addition, RAM guides the identification of machinery systems (or their sub-systems) as a starting point for the use of the M3 tier Anomaly Detection service.

Sensor data can be used to perform predictive data analysis for potential compliance issues or equipment and system degradation and failure risks, with ABS and the Technical authority taking mitigating responses to minimize those risks.

4.2.2(b) Plans and Data to Be Submitted

The following information is to be submitted to initiate the RAM process:

a) Identify the systems and equipment to be covered for the RAM analysis – this can be identified from any exploratory data analysis shared with ABS or recommended systems requested to be reviewed.

b) Data Assembly: The maintenance data required is the computerized maintenance management system (CMMS). The time period over which RAM analysis needs to be performed is to be agreed upon by ABS and the Technical Authority. It is typically recommended to use a minimum four-year rolling time window for the equipment item or system in question, however, utilized data at a minimum is to comprise no less than 6 months of data. This data normally comprises individual line items each pertaining to a maintenance event. For new equipment, where data for four years or more may not be available, RAM analysis can still be performed, but the results will have higher variation (and lower confidence). Data utilization priority is to be in the following order of preference:

- ***1)*** Data from the machine or system coming from the vessel itself (existing vessels only)
- ***2)*** Vessel Class data for similar equipment or system service (existing class but a new vessel)
- ***3)*** Equipment or systems type, but no specifics on vessel or class (new vessel, new vessel class)

c) The above should be noted in the RAM report when drawing inferences from the analysis.

4.2.2(c) Technical Criteria

Utilizing the data from the CMMS, a benchmark of the current reliability of major systems is performed, system-of-system reliability estimates made, and recommendations on potential compliance and reliability risks reported upon. These initial RAM models are used to develop future reliability trend estimates to help identify emergent risks that might impact future availability. Historical maintenance data is used to identify key risks and their contributing sources. This data is then used to support CBP Survey execution. Using CBP engineering and data science, ABS will perform the RAM assessment of the historical transactional data defined above utilizing the following process:

a) Data Annotation: Determination and profiling of maintenance data into planned or unplanned maintenance events as well as the vessel systems hierarchical structure.

b) Maintenance Case Analysis: Determination of the most likely root causes (damage descriptors and description) and location of the system or sub-system where maintenance was performed.

c) Model Building: utilization of the annotated data from step (a), ABS will build reliability models that best describe the failure mechanism for each system and its sub-systems. This is an iterative step and therefore multiple models may be built before selecting the best fit. Standard statistical hypothesis test methods are used for model selection.

d) Recommendation: Analysis and review of models built to develop recommendations for decision making.

4.2.2(d) Key Output and Services

RAM Analysis Assessment service covering the following:

a) Reliability Baselining: Used to identify system and machinery items that negatively contribute to vessel readiness and operational availability (A_0).

b) Emergent Risks: Analysis to identify systems and machinery where reliability progression is trending negatively, and which may impact future vessel readiness.

c) Vessel Comparison: analysis to determine if the system reliability trends determined using data provided for a specific vessel are similar or different when compared with similar metrics on system reliability for the same system and from different vessels in the fleet.

d) Summary results will be incorporated into PCM and the Machinery SPD.

Periodic (6 monthly) RAM Analysis Report covering the following:

a) Summary of data provided by the Technical Authority (Vessel Data, Event Time and Event Records)

b) All ABS assumptions

c) Analysis & Results

- Data Annotation
- Identified negative contributors to reliability
- Reliability Benchmarks
- Emergent Risk Identification
- Vessel to Vessel Comparison
- Damage Type and Damage Descriptor
- Vessel Level Reliability
- Opportunities for improvement

d) Summary of Findings

e) ABS Recommendations

4.2.2(e) Requirements for Component to achieve CBP Ready

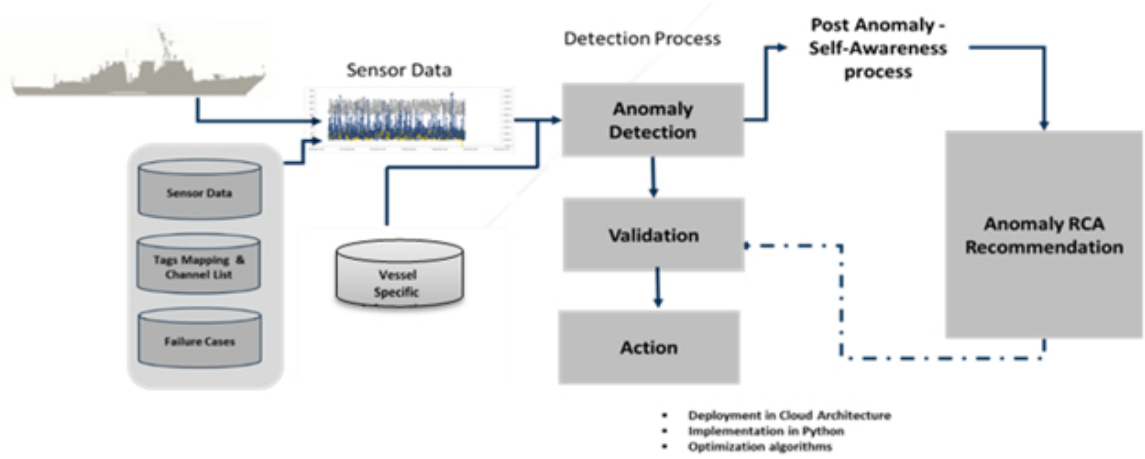
The initial RAM report, aligned with the delivered ship system hierarchy and aligned to the ABS vessel hierarchy covering the data processing and analyses defined in both 4.2.2(c) and 4.2.2(d) will enable this component tier.

4.2.3 Anomaly Detection (AD) (Tier M3)

The Anomaly Detection service consists of algorithms to detect early indications of potential failures using anomaly detection, by combining knowledge of physical understanding of assets with statistical patterns derived from data. The identification of potential failure events for

selected specific systems, sub-systems or components covered is performed by using the continuous stream (or batch mode) of OEM installed sensor data from the covered systems, and by combining domain knowledge and operations with advanced artificial intelligence and machine learning. See 3/4.2.3 Figure 10.

FIGURE 10
Anomaly Detection Process



4.2.3(a) Technical Description and Key Features

Anomaly Detection involves a suite of algorithms to monitor the operational state of select critical equipment, often driven by the RAM service identification of negative reliability contributors defined in 4.2.2, to detect early indications of compliance issues or potential failures. The approach combines domain knowledge and physical understanding of assets with statistical patterns derived from data. Using machine learning methods, adaptable representations of such anomalies are built into a series of algorithms that are used to detect any anomalous data patterns correlated to the onset of condition degradation or improper operation which may lead to functional failure. The methods are also capable of capturing signatures which might not have historical precedence but have a strong likelihood of developing into compliance issues. ABS will perform data pre-processing, algorithm development and algorithm deployment. The process for deployment of the anomaly detection algorithms involves the following steps:

a) Data Pre-Processing covering sensor mapping and location analysis with algorithms mapping.

b) Algorithm Development covering failure and signature analysis and validation and testing.

c) Algorithm Deployment covering sensor mapping, validation and deployment into production.

4.2.3(b) Plans and Data to Be Submitted

For both new and existing vessels, the following data is required for Anomaly Detection development and deployment:

a) Continuous Time series Sensor data for the major systems and sub-systems

b) Sensor tag map identifying differences in the sensors and their placement, units of measurement, physical quantity being measured, etc.

c) Historical Failure Event Occurrence & Repair Dates for known failure events

d) The Client's understanding of the root causes for the failure events ((FMEA, Fish Bone, etc.)

For a newbuild, the starting point would be generic equipment item type with available algorithms (not attuned to the specific equipment item itself). Sustainment activity will then be used to refine and calibrate the algorithms to the actual equipment and systems to which they are applied.

4.2.3(c) Technical Criteria

Anomaly alert levels for Machinery are defined within the review and dispositioning process under three severity levels:

- **Severity Level 1:** Machine operating at or around full speed and/or generating power with high amount of anomaly alerts in proximity over the time scale. Such anomalies require closer monitoring by the Technical Authority and should be tagged for examination at next available opportunity by ABS.
- **Severity Level 2:** Machine operating at or around full speed and/or generating power, but not a high number of anomaly alerts in proximity over the time scale. Requires monitoring and/or inspection by the Technical Authority and examination by ABS at next available opportunity or if repeated events occur.
- **Severity Level 3:** Machine operating at lower speed and/or generated power below full rating, low number of anomaly alerts in proximity over the time scale. No imminent action required but recommend monitoring and/or inspection if the severity level changes over time or if repeat events start to occur.

Alerts are generated as part of the Anomaly Detection service. Once qualified by the disposition team, all alerts are sent to the Technical Authority in the form of a monthly Anomaly Report and also to the Survey Reporting system. All alerts inform the PCM as part of the machinery survey prioritization via the CBP Survey Plan.

The anomaly alert detection process captures data-driven anomalies, to detect potentially incipient equipment issues. However, since these alerts may potentially involve vessel equipment or systems that could affect the safety of the vessel and its classification status, any Severity Level 1 alert will be sent to the Technical Authority within 72 hours of internal validation, in addition to being included within the monthly report. The Technical Authority is recommended to investigate such alerts and report back at the first opportunity. If upon investigation, any damage or a deficiency is discovered, ABS Surveyor attendance is to be requested.

4.2.3(d) Key Output and Services

For the Anomaly dispositioning service, ABS will provide dispositioning of anomaly alerts received from deployed algorithms. The anomaly assessment involves the following activity:

1) Anomaly alarm disposition is performed before detected alarms are sent to the field personnel. Alerts received are reviewed by analyzing the output parameter values, compared to anomaly alert history accumulated for same equipment over time.

2) Disposition process involves review of detected anomalies by ABS. This is to correct interpretation and diagnosis of the alerts.

3) Examination of additional data within time proximity of detected anomaly times such as recent CMMS maintenance logs and ABS findings, based on data availability, to see if any anomalies can be further explained.

4) Anomalies which were determined to be valid are marked to be sent to field personnel.

5) Match feedback on actions taken by customer/field engineer against historical anomalies and use for algorithm enhancement.

4.2.3(e) Requirements for Component to achieve **CBP Ready**

The initial Anomaly Detection capability based on the vessel's RAM report and aligned with both the delivered ship system hierarchy and the ABS vessel hierarchy, along with the sensor mapping required to enable the services for data processing and analyses outlined in 4.2.3(a) and 4.2.3(c), will enable this component tier.

5 Remote Survey

One of the key benefits of the CBP is that the collaborative data sharing effort between ABS and the Technical Authority can also help facilitate the ABS Remote Survey (RS) Process. Remote survey can increase operational flexibility to support mission readiness and optimize survey scheduling and planning while minimizing disruptions due to verification activity. Integration of remote survey within the CBP allows for further leveraging of data and technology driven surveys.

SECTION 4

CBP Enrollment

1 General

The requirements in this section cover the CBP enrollment process for both existing vessels and newbuild vessels delivered with the **CBP Ready** notation. There are two paths to CBP enrollment; one for new construction vessels complying with the requirements for the CBP tier selected within Section 3 and assigned the **CBP Ready** notation, and the other for existing in-service vessels without the **CBP Ready** notation and entering CBP as existing vessels with prior service history and condition and health state already established under a current Class program. This section covers requirements for both paths of enrollment activity for the following main activities:

- All Engineering activity needed for enrollment prior to Implementation Survey
- All required Data Integration Activities to enable the selected CBP Tier
- All Implementation Survey activity for enrollment of both vessel states covering CBP Implementation Survey activity as well as CBP and CBP Supporting Notation Implementation survey activity

Additional requirements for existing vessels from a survey perspective as well as the additional engineering activities that must be conducted with respect to existing vessels are also covered within this section. CBP Structural and System and Machinery workflow summaries by lifecycle stage through enrollment and sustainment for both newbuild or existing vessels are outlined in 4/1 Figure 1 and 4/1 Figure 2.

FIGURE 1
Structural CBP Workflow

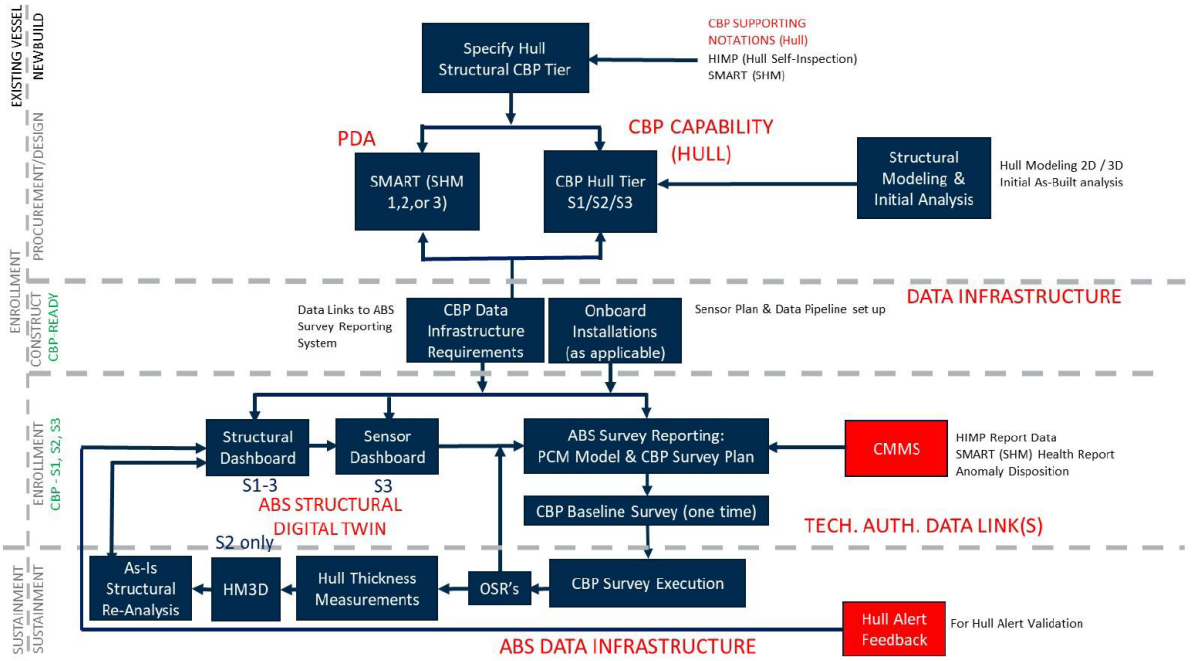
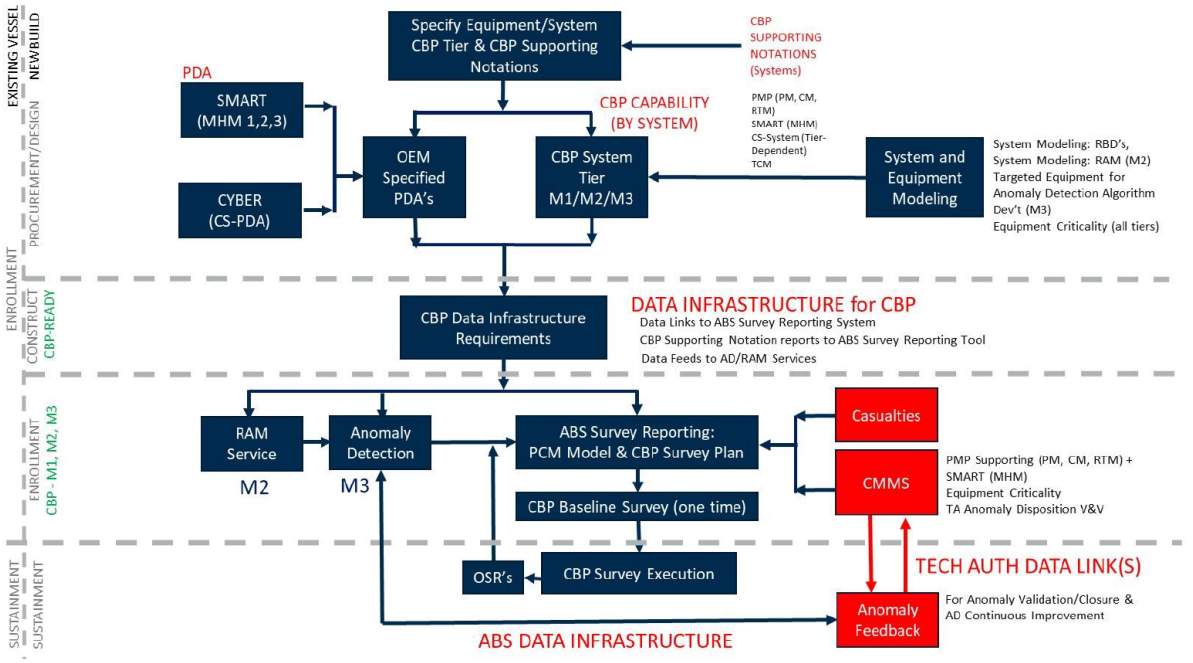


FIGURE 2
System and Machinery CBP Workflow



2 CBP Engineering Criteria for Enrollment

Based on the selected CBP tier, the CBP Component analyses and services defined in Section 3 of this Guide are to be completed to facilitate the enrollment activity. For existing vessels, the following additional subsection requirements also apply. Section 4/2 Table 1 summarizes the required additional data

sets and engineering analyses required for incorporation into the CBP for existing vessel enrollment when the identified tier is indicated.

TABLE 1
Existing Vessel Engineering Data Incorporation

CBP Component	*CBP Ready Section 3 Reference*	*Additional Data to be Incorporated into Engineering Activity for CBP Enrollment Phase - Existing Vessels*
Strength and Fatigue Assessments (all tiers S1-S3)	2.1	• Actual vessel operational route history, or at minimum, information related to the vessel deployed sphere of operation so an approximation of the historical damage accumulation from fatigue can be performed as part of the analysis. • Gauging information from the baseline assessment activity is to be used to perform a separate structural analysis covering the current as-is condition. This analysis should be conducted and incorporated into the vessel Structures SPD as well as the ABS Survey Reporting system, preferably prior to Implementation Survey activity. • If the baseline assessment is being done in conjunction to the Implementation survey as part of CBP enrollment, the as-is analysis is to be completed prior to the upcoming first Sustainment Survey • Historical Structural Failure Event Occurrence & Repair Dates for known failure events for the vessel itself. • The Client's understanding of the root causes for failure events, e.g., FMEA Fish Bone, failure reporting, analysis, and corrective action system (FRACAS).
3D CONDITION DATABASE (S2 and higher)	3.2.2	• Current as-is condition as captured by the baseline assessment, represented by current baseline gauging thickness measurement information and any gauging data not older than 15 months from the date of analysis. Special consideration is given to thickness gauging measurements older than 15 months (via the use of corrosion rate aging algorithms and the like) • Known open structural anomalous conditions are to be entered and added to the current anomaly register in the 2D/3D condition model database and marked up accordingly in the 3D condition model.
SURVEY PLANNING DOCUMENT (all tiers S1-S3, M1-M3)	2.1 & 2.2	• Historical Structural Failure Event Occurrence for known failure events for the vessel itself. This anecdotal information is added to the Structures and Machinery SPDs based on service experience of the vessel (or vessel class) • The Client's understanding of the root causes for failure events. (e.g., FMEA Fish Bone, FRACAS, etc.)
STRUCTURAL DASHBOARD (S1 and higher)	3.2.1	None
HULL SENSOR DASHBOARD (S3)	3.2.3	• Historical Structural Failure Event Occurrence & Repair Dates for known failure events for the vessel itself or the vessel class. • The Client's understanding of the root causes for failure events, e.g., FMEA Fish Bone, FRACAS

CBP Component	*CBP Ready Section 3 Reference*	*Additional Data to be Incorporated into Engineering Activity for CBP Enrollment Phase - Existing Vessels*
RAM SERVICE (M2 and higher)	4.2.2	• Historical Failure Event Occurrence & Repair Dates for known failure events • Where available the resolutions that were implemented to address the failure events • The Client's understanding of the root causes for failure events, e.g., FMEA Fish Bone, FRACAS
ANOMALY DETECTION SERVICE (M3)	4.2.3	• Actual Vessel Time series Sensor data for the major systems and sub-systems • Historical Failure Event Occurrence & Repair Dates for known failure events • The Client's understanding of the root causes for failure events, e.g., FMEA Fish Bone, FRACAS

2.1 Strength and Fatigue Assessments and Structures SPD Preparation

For existing vessels, upon completion of the Baseline Assessment, an updated structural analysis is to be completed. However, if the baseline assessment activity is being done in conjunction with the initial CBP survey as part of CBP enrollment, the updated current condition analysis is to be completed prior to the first Sustainment Survey. The Structures SPD is to be updated to reflect the current condition at that time, and also incorporate any new condition, anomaly, or outstanding survey recommendations changes that may have been documented during the Implementation Survey.

2.2 3D Condition Model

Current as-is condition as captured by the baseline assessment, represented by current baseline gauging thickness measurement information and any gauging data not older than 15 months from the date of analysis is to be entered into the model.

Known open structural anomalous conditions are to be entered and added to the current anomaly register in within the 2D/3D database and marked up accordingly in the 3D condition model.

Historical structural failure event occurrence for known failure events for the vessel itself. This anecdotal information will be added to the Structures SPD based on service experience of the vessel (or vessel class).

2.3 RAM Baseline

a) Historical failure event occurrence & repair dates for known failure events are to be utilized in the Reliability, Availability and Maintainability (RAM) analysis. See 3/4.2.2(b).

b) The Client's understanding of the root causes for the above failure events is to be used to inform the reliability analysis.

2.4 Initial Anomaly Detection Algorithm Deployment

a) Actual vessel time-series Sensor data for the major systems and sub-systems is to be incorporated into the algorithms and models.

b) Historical failure event occurrence & repair dates for known failure events are to be utilized to support anomaly detection algorithm development defined in item a above.

c) Additional weight will be given to the aligned time-series data in a and b above if the Technical Authority has performed root cause analysis for the failure events defined in item b.

2.5 Hull Sensor Dashboard

Historical structural failure event occurrence & repair dates for known failure events for the vessel itself or the vessel class and any Technical Authority understanding of the root causes for failure events are to be utilized in determining the Hull Sensor plan. This data is related to direct measure of critical areas and from a global response perspective, the capturing of hull response phenomena that have contributed to the known failures. As such, this information has a direct bearing on accuracy and relevance of the data displayed on the dashboard.

3 Technical Authority Data Integration with ABS Client Portal and Survey Reporting System

The main principle of CBP is data sharing and the automation of that process via the ABS Client Portal and into the ABS Survey Reporting System. This production environment covers both CBP survey execution and the CBP Component Services that support it. The data sharing related tasks that are to be carried out as part of CBP enrollment activities are defined in 3.1 and 3.2 below.

3.1 Data Infrastructure

The data infrastructure of the vessel is to be connected to the ABS Services where applicable via the ABS Client Portal and the secure cloud environment.

a) Tier 1 Structural Dashboard is to be set up to receive vessel position and route summaries.

b) Data acquisition systems for sensors are to be mapped and tagged with appropriate data pipelines for ingestion into Tier 3 service enablement (S3 or M3).

3.2 Data Integration

Data integration from either the enrolled vessel directly or the Technical Authority enterprise systems is to be completed for enrollment, covering the following, as applicable to the chosen tier(s):

a) Technical Authority CMMS and ABS Vessel hierarchy alignment

b) CBP tags for appropriate tier applied in Survey Reporting system to all covered Special Machinery and Hull Survey Parts to denote they are part of the program

c) Correct tags in Survey Reporting system also present for all required and optionally selected CBP Supporting Notations

d) ABS Survey Reporting system and 2D/3D Condition database aligned with both Technical Authority and ABS Vessel hierarchies

e) RAM, Anomaly Detection, and structural dashboard service enablement and output for PCM factor ingestion

f) ABS Client Portal set up for all reports related to CBP supporting Notations

The Integration requirements along with their frequency of update and report format data integration methodology are denoted in 4/3.2 Table 2.

TABLE 2
CBP Data Integration Reporting and Updating Approaches and Frequencies

CBP Supporting Program	*Survey Reporting system Tag*	*Minimum Rule/Guide Reporting Frequency*	*Frequency of Send to ABS*	*Report Time Max Suggested Interval*	*Method of Data Send / Uses*	*Tech. Auth. (TA) or ABS*
PMP	PM	Annual	30 days prior to due date or on demand	Quarterly	API for data share into virtual vessel asset and PCM	TA
PMP	CM or RTM	Annual, or as per 7-A1-14 depending on method of measurement	30 days prior to due date or on demand	Equipment dependent on trend R/Y/G frequency, maximum quarterly	API for data share into virtual vessel asset and PCM	TA
PMP / SMART	MHM	Annual	30 days prior to due date or on demand	Equipment dependent on trend R/Y/G frequency, maximum quarterly	API for data share into virtual vessel asset and PCM	TA
PMP / SMART	SHM	Annual	30 days prior to due date or on demand	Maximum quarterly	API for data share into virtual vessel asset and PCM	TA
Structural Dashboard	CBP S1	Monthly for Routine Alerts, Critical Area reassessment as per contract	Upon Completion of Service Update, including disposition and follow up on alerts	Monthly summary, Severity Level 1 Alerts as soon as identified in 3/3.2.1(c) Critical Area reassessment as per Technical Authority request, but not be less than 1 year or greater than 5 years	Raw Data to Secure Cloud (stream or batch) for Service Alerts via API to PCM, including client CMMS follow up Report on route/ load history via secure file or via API through Client Portal	ABS

CBP Supporting Program	*Survey Reporting system Tag*	*Minimum Rule/Guide Reporting Frequency*	*Frequency of Send to ABS*	*Report Time Max Suggested Interval*	*Method of Data Send / Uses*	*Tech. Auth. (TA) or ABS*
Hull Sensor Dashboard	CBP S3	Monthly for Routine Alerts, Critical Area reassessment as per contract	Upon Completion of Service Update, including disposition and follow up on alerts	Monthly for Routine Alerts, Critical Area reassessment as per Technical Authority request, but not less than 1 year or greater than 5 years Monthly summary, Severity Level 1 Alerts, as directed by criteria in 3/3.2.3(c)	Raw or Statistical Data to Secure Cloud (stream or batch) for Service Alerts via API to PCM, including client CMMS follow up Report on route/ load history via secure file or via API through Client Portal	ABS
RAM Service	CBP M2	Bi-Annually	Upon Completion of Service Update	Bi-annually	API for client CMMS data	ABS
Anomaly Detection	CBP M3	Monthly	Upon Completion of Service Update, including disposition and follow up on alerts	Monthly summary, Severity Level 1 Alerts as soon as identified, per 3/4.2.2(c)	Raw Data to Secure Cloud (stream or batch) for Service enabler Alerts via API to PCM, including client CMMS follow up	ABS

4 CBP Enrollment Implementation Survey Activity

The implementation survey for the CBP is to be conducted after completion of the CBP Survey Plan and the data integration activity defined in Section 4/3.

For existing vessels, all baseline assessment and engineering activity defined in Subsections 4/3 and 4/4 above are also to be completed. This is required so the implementation survey is conducted after the initial CBP tier service enablement and the output from such services has populated the initial PCM risk prioritization. Following this step, ABS Survey can utilize the ABS Survey Reporting system to generate the prioritized CBP Survey Plan.

Prior to commencement of the Implementation Survey, a survey kick-off meeting is to be carried out.

This process is not intended to replace in any way the requirements and intent of the Rules nor to substitute in any degree the technical judgement that the Surveyor must use while carrying out the survey.

4.1 CBP Implementation Machinery Survey

The machinery related scope of CBP Implementation Survey encompasses all CBP tagged machinery parts.

CBP implementation survey scope is defined by the generated CBP Survey Plan. The Survey Plan is to be available to the Technical Authority prior to the kick-off meeting and for Surveyor use prior to commencing the Survey.

a) The CBP Survey Plan will include a traffic light prioritization for machinery items enabled by the service tier components after the data integration is completed via the PCM model. The reason(s) for the high and medium risk CBP parts will be discernable from the Survey Plan.

b) The above information will be provided to support simultaneous crediting of both annual and special survey for CBP items within the ABS Survey Reporting system on a continuous annual basis, provided no COC's exist. Any machinery due for crediting at the time of the Implementation Survey is to be credited based on current ABS *Rules for Survey After Construction (Part 7)* requirements prior to enrollment in CBP.

c) All CBP items are evaluated within the ABS Survey Reporting system and a PCM score will be generated. For the initial survey score, if Tier 3 is enabled, the PCM factors related to Anomaly Detection will not affect the score as there is no time series data yet available. The PCM score for the implementation Survey will only include lagging factor data related to PM, CM, COCs and Failures as defined in the PCM Model.

d) Baseline Condition Assessment for Existing Vessels, see 4/4.4 for further details.

4.2 CBP Implementation Hull Survey

CBP Hull Implementation Survey scope is defined by the generated CBP Survey Plan. The Survey Plan is to be available to the Technical Authority prior to the kick-off meeting and for Surveyor use prior to commencing the Survey.

a) The survey status of the vessel and the CBP Survey Plan is to be reviewed by the Surveyor prior to the kick-off meeting with the vessel crew/representatives.

b) Examination and grading of hull items per the CBP Survey Plan.

c) Baseline Condition Assessment for existing vessels, see 4/5.4 for further details.

d) For S3 sensor installation, when applicable, the recommendations in Appendix 4/ 1.2 to 1.4 and Appendix 4/ 2 of this Guide are to be verified by the Surveyor to confirm installation suitability, adequacy of the hardware and software, and functionality including:

- ***i)*** Interfaces to onboard systems
- ***ii)*** Data network and communication
- ***iii)*** Data management
- ***iv)*** Data infrastructure technical guidance

Notes:

1 The Inspection Grading Criteria for the ABS Hull Inspection and Maintenance Program (HIMP) will be used for grading hull items within the ABS Survey Reporting system. All items enrolled in CBP are to be fully graded using the criteria.

2 An anomaly found will be created in the ABS Survey Reporting system for each deficient condition (scores indicating a yellow or red grade) found onboard. Corresponding COCs will be generated for red graded items as they also represent Class deficiencies.

4.3 Implementation Surveys for CBP Supporting Notations

The implementation survey for class items enrolled in CBP supporting notations (PMP, etc.) covered under the program per 2/2.4 is to also involve an onboard implementation survey.

The implementation survey for the class items enrolled in CBP Supporting notations is carried out to verify the program has been properly implemented and that CBP related arrangements for maintenance, condition and health status determination reporting and data sharing arrangements have been completed. The condition and health status of the class items enrolled in CBP supporting notation programs will be verified by the surveyor as per the health status determined during the engineering review. The implementation survey will include the verification of the following:

i) Functional CMMS onboard for managing the vessel's maintenance plan.

ii) Overall examination of the class item(s).

iii) Baseline Condition Assessment health verification to compare class item conditions with the health status provided by owner/operator, as applicable.

iv) Condition and Health monitoring reports from service suppliers including initial Condition Monitoring (CM) Program baseline readings, as applicable.

v) Vessel enrollment in Special Continuous Machinery Survey.

Upon satisfactory completion of the implementation survey, the surveyor may recommend assignment of the CBP Supporting notation(s) for the vessel, and the class items enrolled in the supporting program be tagged with an appropriate indicator (PM, CM, RTM, MHM, SHM, etc.) in the ABS Survey Reporting System signifying the class items also have an approved CBP supporting notation(s).

4.4 Baseline Condition Assessment for Existing Vessels

When CBP enrollment for notation achievement is requested, a Baseline Condition Assessment and health determination is to be performed to establish the current condition of hull structures and machinery class items to be covered under the CBP. This effort will be achieved via a combination of data gathering and inspection as part of a baseline assessment process alone preceding the enrollment activity defined in this section, or in tandem with the CBP Implementation Survey activity.

For all existing vessels requiring enrollment into the CBP, a Baseline Condition Assessment is mandatory. Consideration may be given to utilize existing baseline health and condition monitoring data for machinery already enrolled in a related Class program such as PMP for the respective class items to be enrolled into the CBP. Current condition and health monitoring utilized for class items will also contribute to benchmarking current health and condition status. This helps identify future anomalies, exceedances, and outliers during CBP sustainment.

Prior to the Implementation Survey in 4/4.1 and 4/4.2, the following types of data are to be collected and reviewed for the components within the scope of a Baseline Condition Assessment include the following:

- *Original Design and As-Built Information.* Covers the initial data point against which all subsequent information can be compared. This includes data on original materials of construction, initial thickness, degree of NDT used during fabrication, initially assumed design and operating envelope, and design analysis reports, if available. Modifications should also be noted, if performed.
- *Operational history.* Covers knowledge of how the vessel, machinery and components were operated from the time of deliverable. Information on experienced loading versus design intent or extent of fatigue related loading can be ascertained from this information.
- *Maintenance history.* Covers historical data pertaining to past maintenance events, their origination and resolution. This can include maintenance data from a CMMS and other major maintenance events performed during overhaul periods or otherwise.

- *Inspection records and inspection methods/frequencies.* Enables identification of prevalent damage and trending of that damage versus the initial as-built condition. Includes hull gauging and NDT that may be available. Refer to 4/2.2 above on the validity of condition data for CBP use.

4.4.1 Hull/Structures

The information for Baseline Condition Assessment health determination of the hull survey items to be enrolled in CBP include:

Current condition report of all Special Survey items such as spaces, tanks, compartments and/or structural members from the existing vessel survey status.

a) The condition is to be established via a grading system for criteria such as coating, corrosion, deformation, and fractures as well as available NDE, gauging and anomaly information. The baseline assessment is to utilize the grading system in accordance with the ABS *Inspection Grading Criteria for the ABS Hull Inspection and Maintenance Program (HIMP)*. Special consideration may be given to acceptance of a Technical Authority HIMP program upon submission of full program details and notation assignment.

b) Identified structural critical areas to be provided by the structural analysis as defined in Section 3 of this Guide.

c) Current thickness measurements, as applicable, to ascertain the diminution of the structural members.

4.4.2 Machinery

The information for Baseline Condition Assessment health determination for machinery class items to be enrolled in the CBP include the following:

i) Normal working condition of equipment with details of operating parameters ranges as per OEM.

ii) Details of any condition monitoring including results to determine the baseline condition status, being conducted by recognized service supplier, as applicable. Refer to Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)*.

iii) Details of smart functions health monitoring including results to determine the baseline condition status, being conducted by approved Smart service supplier, as applicable. Refer to the ABS *Smart Guide.*

iv) Current health report for class items to be enrolled in CBP from such service suppliers are shown in the format similar to the samples provided within the Appendices of this Guide.

5 CBP Notation Assignment

Upon satisfactory completion of the engineering, data integration, and Implementation Survey as defined in subsections 2 through 4 above, for all enrolled structures and machinery, the attending surveyor may recommend assignment of program enrollment level CBP notations, according to 2/2.3 Table 1 for structures and 2/2.3 Table 2 for machinery, replacing the CBP Ready notations in the Record, if previously assigned.

SECTION 5
CBP Sustainment

1 General Requirements

After the enrollment Implementation Survey has been completed and the CBP notation(s) are assigned, the CBP will be maintained in effect by carrying out CBP sustainment activities. Sustainment Activity covers:

1) Engineering Service Sustainment covering reassessment, services updates

2) Continued Data integration validation

3) Annual Sustainment surveys

Annual Sustainment survey also supports the Technical Authority's availability planning.

2 Engineering Service Sustainment

2.1 Structural Reassessment

ABS will utilize updated data that is stored in the Structural Digital Twin (SDT) such as thickness gauging and anomaly data gathered during the initial and subsequent sustainment surveys to perform reassessments of the hull structure. As seen in 5/2.1 Figure 1, this activity will cover:

a) An update of the initial engineering assessments (Rules Scantling Evaluation, GSA, and Fatigue analysis) using:

- Additional operational history gathered within the Structural Dashboard
- New gauging reports to update the FEA models and Rules Scantling Evaluation to reflect the current state of the vessel's scantlings
- Shipyard repairs or modifications also reflected in the FEA models and Rules Scantling Evaluation.

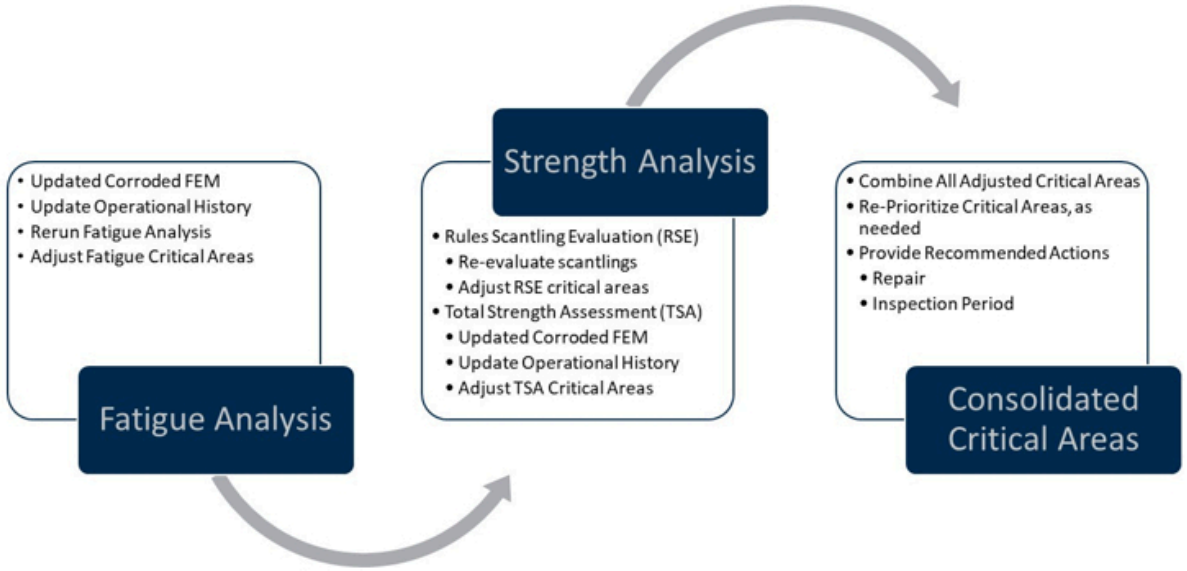
b) Use of the above analysis to update the critical areas and risk profile for the CA's in the 2D/3D condition databases.

c) Regenerate a new CBP Survey Plan covering the above changes for use in the current Sustainment survey.

d) Document and prioritize further action required by the Technical Authority including necessary repair or monitoring of open anomalies.

The frequency of reassessment is dependent on vessel class and is to be as agreed between ABS and the Technical Authority. However, the reassessment period is not to be less than 1 year or greater than 5 years from the initial enrollment, previous reassessment, and/or CBP Ready analysis.

FIGURE 1
Engineering Sustainment Process



2.2 Structural and Sensor Dashboard

ABS will perform monthly monitoring of the route history and sensor data being processed within the structural (all tiers) and sensor dashboards (S3 only). The hull structural route and sensor analysis will consist of:

a) Sensor verification and data quality checks to confirm that the sensors are operating as intended and the resulting data is dependable and can be utilized for both hull monitoring and finite element model calibration.

b) Threshold exceedance alerts from both the structural dashboard and the sensor dashboard will be monitored and a summary of out-of-threshold alarms will be generated based on two severity levels. Identified Severity Level 1 events will also be reviewed by ABS SMEs and brought to the attention of the Technical Authority for both disposition and any subsequent engineering and survey action that would be required. Refer to 3/3.2.1(c) and 3/3.2.3(c) for criteria on alert levels and alert actions and frequencies.

c) Summaries of the above will be used to update the PCM Models and the CBP Survey Plan.

The typical reports produced in support of the Structural and Sensor Dashboards as part of Sustainment activity includes the following:

Monthly and Ad-Hoc Hull Sensor Alert Dispositioning/Review/Analysis

1) Monthly Detailed reporting on threshold exceedance events

2) Monthly Summary reports of sensor alerts - quantity, severity, and durations

3) Recommendations on vessel inspections based on findings for all threshold exceedances and overall sensor based FEA model calibration

4) Threshold 1 sensor exceedance alerts and following on actions, including potential recreation of extreme events using the SDT as deemed necessary (based on wave data, acceleration, speed, etc.) to identify the impact of events on other structure. Refer to 3/3.2.3.

Hull Sensor Monthly Report

ABS will review and analyze the hull sensor data monthly and prepare summary reports that document all findings. The objective of the periodic reports is to highlight the overall vessel operational details, summarize all sensor warnings or exceedances that occurred, and document key findings related to specific vessel events or sensor data irregularities that occurred during the reporting period.

Typical sensor report contents as applicable:

1) Vessel operational summary – days at sea, speeds, wave conditions

2) System status report summary and documentation of any time intervals where individual sensors or the entire system were offline

3) Document alarm thresholds:

- No alarms – No warnings or exceedances found
- Warnings – Severity Level 2 Thresholds reached for sensor readings that approach the class specified limit (e.g. typically 85% of limit)
- Reportable Events – Severity Level 1 exceedances from sensor readings that will result in the load and/or structural response exceeding the Class limit

4) Summary reports of sensor alarms

- Overall sensor status during reporting period
- Number of operation hours in reporting period where senor readings exceeded the warning threshold
- Number of operating hours the vessel spent above the exceedance limits

5) Summary of vessel operation relative to applicable operating envelopes

6) Detailed reporting on key events

- Provide detailed observations for key events
- Present data plots for key events to support observations
- Investigation of other sensor readings during key events to understand event scope and vessel impact

7) Detailed sensor event logs

8) Specific sensor time history plots

2.3 RAM Service Sustainment

Sustainment activity for the Reliability, Availability and Maintainability (RAM) service consists of the following process:

a) Identify the latest data available from the Technical Authority Computerized Maintenance Management System (CMMS) over which the RAM analysis is to be performed. The most recent data are to be received via the ABS Client Portal and appended to the data used for the previous analysis. Data from the earliest time period can be removed (rolling-window) to maintain data recency. If, however, the data in the previous analysis was less than the minimum four year period or had less numbers of cases for analysis, the removal of the earliest data can be omitted, until an adequate operational history is achieved with sufficient number of cases for significant model building.

b) Perform RAM assessment as defined in 3/4.2.2 for the same systems as covered in the previous analysis. If data availability supports analysis of additional systems or sub-systems due to increased data, the same analysis is to be performed and reported as such.

2.4 Machinery Anomaly Detection Services Sustainment and Model Maintenance/ Redeployment

Sustainment activity for the Anomaly Detection service consists of the following process:

a) Process for the maintenance of anomaly detection algorithms:

1) Periodic updates to the algorithms as required depending upon algorithm performance metrics and algorithm enhancements to cover any new signatures, or new emerging operational profiles.

2) Identify historical test data for validation of updated algorithms.

b) Process for anomaly disposition services:

1) Anomaly alert disposition should be performed before detected alerts are sent to the Technical Authority's field personnel.

2) Disposition process to involve review of detected anomalies by ABS. This is to provide correct interpretation and diagnosis of the alerts. The disposition process is to follow based on alert severity index being applied by the dispositioning team. See 3/4.2.3 for guidance.

3) Examine any additional data near detected anomaly occurrences such as recent CMMS maintenance logs and ABS findings, based on data availability.

4) Mark anomalies which were determined to be indicating validated equipment or system anomalies. Anomalies seeming to be caused by sensor or data quality issues should not be marked as equipment or system anomalies related to condition or health and therefore are not marked for correction by the Technical Authority.

5) Match feedback on actions taken by Technical Authority / field engineer against historical anomalies.

6) Use item 5 for algorithm refinement and enhancement.

3 CBP Data Custodianship and Integration Validation

The following activity is to be carried out by ABS upon completion of all annual sustainment activity:

- Mark up of anomalies reported by the Surveyors in the 2D/3D condition database. This mark-up will link the anomaly and any associated pictures, video or sketches to the 3D condition model to enable detailed repair planning to be done within the 3D condition model.
- Upload gauging campaign results back into the 3D condition model to assess results graphically. Create additional anomalies where needed and update the ABS Survey Reporting system with CoC's as required.

In addition, ABS will confirm that all transactional report and time series data feeds remain functional, aligned with the respective vessel hierarchies, and are populating the reporting tools, services, and data models as needed to facilitate the CBP process, or action is taken to update or take corrective action as needed.

4 Sustainment Surveys

After the Implementation Survey has been completed and the CBP notation(s) are assigned, the condition-based program will be maintained in effect by carrying out an Annual CBP Survey for all enrolled items through continuous structural and machinery survey program effectively replacing the traditional special survey approach. The CBP Survey scope will be carried out according to the approved CBP Survey Plan in conjunction with the Annual Survey of Machinery and Hull.

The Technical Authority is also to provide via the CBP data integration process, the CBP Supporting notation reports documenting the vessel maintenance, condition or health status of the class items enrolled in CBP and the respective supporting programs. These will be utilized for ABS review and individual program crediting, as well as for incorporation into PCM weight incorporation for CBP Survey Plan generation prior to commencing any sustainment surveys.

The attending Surveyor will follow the approved CBP Survey Plan for the class items tagged and enrolled in CBP.

The survey of class items not enrolled in CBP will be conducted in accordance with the ABS *Rules for Survey After Construction (Part 7)*.

4.1 Survey Preparation

Prior to the sustainment survey, a survey planning meeting is to be held between the Technical Authority and ABS. This meeting is to communicate the ABS CBP survey requirements as noted in the CBP Survey Plan and detail the assessment scope of work.

4.2 CBP Annual Survey Execution

4.2.1 Hull Structure Surveys

The CBP Hull Survey approach will follow the CBP Survey Plan which is provided to target annual survey of critical areas and compartments. The CBP Survey plan is updated by the engineering sustainment activity to regenerate and refocus the sequential CBP Survey Plan. This approach provides for more vessel-specific surveys such that the CBP Survey Plan augments the standard Hull Survey. While all hull items are surveyed per current prescriptive rules over a Special Continuous Hull Survey cycle, the CBP Survey Plan tags traffic light PCM risk prioritization on an annual basis to inform Surveyor where to focus onboard activities:

- Green score – follow current Class Survey per CBP Survey Plan
- Yellow or Red – Increase Survey Scope by reviewing reason for higher score in the CBP Survey Plan

4.2.1(a) Tier 3 Sensor Plans for Hull Structures

Hull sensor calibration/re-calibration records are to be checked by the ABS Surveyor in accordance with Section 6 of the ABS *Guide for Hull Condition Monitoring Systems*.

4.2.1(b) CBP Annual Survey for Hull

In addition to annual hull survey requirements noted in Section 7-3-2 of the ABS *Rules for Survey After Construction (Part 7)*, the Surveyor is to examine/verify the following items per the CBP Survey Plan:

1) Identified structural critical areas requiring a CVI (close visual inspection, per risk matrix determined schedule). Critical Area examination is to be carried out at a 1, 2.5, or 5 year frequency as per engineering assessment.

2) NDT of suspect areas based on critical area criticality. See 3/2.1.4 Figure 7.

3) Structural compartment GVI (general visual inspection).

4) Review and confirm gauging survey results, as applicable.

- Note: Gauging Reports are to be uploaded into the 3D condition model

5) Dispositioning of any anomalies or conditions of class requiring actions per review by ABS Engineering, including immediate or temporary repairs, modifications, or recording and monitoring activities.

6) Hull sensor calibration/re-calibration records per 5/4.2.1(a), if applicable.

Notes:

1 Anomalies (e.g., fractures, cracks, corrosion, etc.) are identified and recorded via ABS Survey Reporting system and the 2D/3D condition database using the ABS *Inspection Grading Criteria for the ABS Hull Inspection and Maintenance Program (HIMP).*

2 Gauging Survey still carried out twice in five years, as per the applicable Rules. See Section 7-3-2 of the ABS *Rules for Survey After Construction (Part 7)* for details.

3 Tank hydrostatic testing still carried out once in five years, as per Section 7-3-2 of the ABS *Rules for Survey After Construction (Part 7)*.

4.2.2 CBP Annual Survey for Machinery

The approach for CBP System/Machinery Survey will follow the CBP Survey Plan which is provided to support Survey crediting of continuous machinery survey (CMS) items on a continual annual basis and in conjunction with each annual machinery survey.

The CBP Survey Plan for machinery is based on the risk prioritization from items identified the PCM model. The CBP Survey Plan is tagged with traffic light identifiers to inform Surveyors where to focus onboard activities specific to machinery compliance risks.

- Green score – follow current Class Survey per Survey Plan
- Yellow or Red – Increase Survey Scope by reviewing reason for higher score identified in the Survey Plan

In addition to annual machinery survey requirements noted in Section 7-6-2 of the ABS *Rules for Survey After Construction (Part 7)*, the Surveyor is to examine and verify that the following items identified in the CBP Survey Plan have been addressed to the satisfaction of the attending surveyor:

1) CBP Supporting Notation PMP surveys are completed; see 5/4.2.3 of this Guide for reporting on PM, CM, SMART, or combinations thereof.

2) Existing Machinery Anomalies (in the ABS Survey Reporting system)

3) Existing Machinery Conditions of Class (in ABS Survey Reporting system)

4) Items with “Yellow” or “Red” Individual Scores within the PCM score driven by M2 or M3 services have been satisfactorily resolved.

5) System and Machinery Alerts (Tier 3 notation only) have been dispositioned per 5/2.4 above.

4.2.3 CBP Supporting Notation Surveys

In addition to the above CBP Survey Plan, the Annual Survey – Preventative Maintenance is to be carried out to cover this mandatory CBP Supporting Notation program sustainment crediting. The intent of the CBP Supporting Notation Sustainment survey activity is to annually verify the maintenance status and condition of machinery and equipment for Classification purposes by maintenance completion validation, as well as condition monitoring such as temperature, pressure and power indications; vibration instrumentation, or other metrology, with a minimum of disassembly except where the condition monitoring indications warrant otherwise.

The Surveyor will base this determination primarily on the receipt of reports (see 4/3.2 Table 2 for CBP required frequencies of submittal) summarizing the status of the vessel's maintenance and condition monitoring records, together with an annual external examination of the equipment and performance testing as appropriate at the time of the annual survey.

Refer to Section 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* for survey requirements.

5 Survey Crediting

Upon satisfactory verification by the ABS Surveyor, the class items enrolled in CBP will be credited towards the survey for both annual and special survey requirements.

6 Special Instructions

6.1 Damage, Failure and Repair

Damage, failure, or deterioration detected by the implemented supporting notation condition or health monitoring techniques to hull, machinery or electrical equipment which affects or may affect classification, is to be submitted by the Technical Authority for examination by a Surveyor at first opportunity. All repairs found necessary by the Surveyor are to be carried out to the Surveyor's satisfaction. Refer to 1-1-8/1 of ABS *Rules for Conditions of Classification (Part 1)*.

For Damage Surveys that are related to dispositioned alerts and anomalies, please refer to 3/3.2.1(c) and 3/3.2.3(c) for hull alerts and to 3/4.2.3(c) for machinery alerts and their respective Technical Authority notification actions and frequencies.

APPENDIX 1

MACHINERY HEALTH REPORT TEMPLATE PMP Annual Planned Maintenance

Complete requirements:

Survey After Construction (Part 7) 7-A1-14 reference	*App 14 Description/Explanation*	*What is required from CMMS systems?*	*PM*
13.1.1 List of Machinery Enrolled in	A summary list of all machinery enrolled in PMP.	Machinery Hierarchy export from CMMS with items enrolled in each program. Preferably these are items tagged as part of PMP PM program on the owner's hierarchy.	x
13.1.2 Equipment Item Changes:	Item deletions, replacements and additions occurring after the previous annual report are to be stated in the subsequent report	identification of items (from above Hierarchical list) that have changed (added new, new serial item of the same item, or removed/deleted from the vessel and corresponding hierarchy)	x
13.1.3 Maintenance Records:	Records are to provide a complete description of work completed on each machine since the last submitted report	CMMS export of completed work orders for each equipment (annual), since the last report. Covers a summary of completion rate (scheduled vs. completed), as well as a detailed description of each task completed (summary of maintenance actions with accompanying photos if available).	x
13.1.4 Report Exceptions:	The Owner is to report to the attending Surveyor all machinery for which: i) Maintenance is not indicated, ii) Maintenance is incomplete	Any maintenance that was not conducted or deferred (with reason for deferral), incomplete.	x
13.1.5 Reporting Failures:	The report is to list items that failed prior to scheduled maintenance, servicing, or monitoring and analysis and related record of corrective actions taken.	Corrective maintenance actions as a result of a failure, when necessary are to be highlighted for additional attention.	x
13.1.6 Maintenance Plan Changes:	Modifications with justifications to the schedule, such as might be recommended/permitted by a machinery manufacturer's technical bulletin.	CMMS schedule changes based on OEM recommendations, CM or Smart MHM results, or owner corporate policy (with suitable justification)	x

13.1.1 List of Machinery Enrolled: A summary list of all machinery enrolled in PMP.

13.1.2 Equipment Item Changes: Item deletions, replacements and additions occurring after the previous annual report are to be stated in the subsequent report. Items added or deleted are to be annotated with notes of the changes.

13.1.4 Report Exceptions: The Owner is to report to the attending Surveyor all machinery for which:

i) Maintenance is not indicated,

ii) Maintenance is incomplete

13.1.1

System Summary (Previous 12 months as of report date)	13.1.4 SJ's Scheduled	SJ's Completed	Unsched WO's	Failure WO's
Anchor Mooring System	7	5	1	0
Ballast System	9	9	2	1
Bilge system	4	4	0	0
Boiler Feed Water System	3	3	4	0
Boiler Fuel Oil Service Piping System	9	8	0	0
Cargo Area Foam System	2	2	1	1
Cargo Piping System (see note 1)	7	7	0	0

13.1.2

Note 1: Cargo Piping System was added to PM

13.1.3 Maintenance Records: Records are to provide a complete description of work completed on each machine since the last submitted report.

13.1.5 Reporting Failures: The report is to list items that failed prior to scheduled maintenance, servicing, or monitoring and analysis and related record of corrective actions taken.

13.1.6 Maintenance Plan Changes: Modifications with justifications to the schedule, such as might be recommended by a machinery manufacturer's technical bulletin.

Anchor and Chain Port

Maintenance History	Document No 13.1.3	Date Completed	Title	
Standard Jobs	WO 0604929	2/7/2021	Rinse and Flush Chain Lockers	
	Description: Clean both chain lockers. Pump dry with eductor.			Findings: Filled both lockers to four feet and educted mud overboard. Very muddy. Attachments:
	WO 0601118	2/15/2021	Deck Machinery Lubrication	
	Task Description (as per CMMS description): Inspect and Lubricate Mooring Winches and Anchor Windlasses: - Check gear oil levels and top off as necessary. - Grease moving parts with machinery turning. - Grease all drum and wild-cat grease points, engaging devices and joints on brake band spindles. - Clean all threads of the brake band spindles and coat with grease. - Mobilith SHC-460 grease (red color.) Lubricate Fair-leads and Roller Chocks: - Grease rollers while turning. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Anchor Chain Rollers: - Grease all grease points and inspect for proper movement of rollers. - The spindle of the lashing devices must be provided with water repellant grease. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Accommodation Ladder Sheaves and Pivot Points: - Grease all sheaves and davit pivot points. - Mobilith SHC-460 grease (red color.)			Work Completed & Anomalies Observed / Findings: All deck winches and windlasses greased. roller chocks freed and greased. accom ladders rolled out and greased. Attachments JobPhoto1.jpg Reason for Maintenance Variation /Job Comments: Schedule of job changed based on OEM letter dated 12/10/2020 13.1.6
Unscheduled Failures	None None	13.1.5		

APPENDIX 2

MACHINERY HEALTH REPORT TEMPLATE PMP Annual Condition Monitoring

Survey After Construction (Part 7) 7-A1-14 reference	*App 14 Description/Explanation*	*What is required from CMMS systems?*	*CBM (CM or RTM approaches)*
13.1.1 List of Machinery Enrolled in	A summary list of all machinery enrolled in PMP.	Machinery Hierarchy export from CMMS with items enrolled in each program. Preferably these are items tagged as part of PMP CM program on the owner's hierarchy.	x
13.1.2 Equipment Item Changes:	Item deletions, replacements and additions occurring after the previous annual report are to be stated in the subsequent report	Identification of items (from above Hierarchical list) that have changed (added new, new serial item of the same item, or removed/deleted from the vessel and corresponding hierarchy) Note: Any additions to the CM program engineering approval prior to addition.	x
13.1.3 Maintenance Records:	Records are to provide a complete description of work completed on each machine since the last submitted report	CMMS export of completed work orders and reports for each equipment item (annual)	x
13.1.3(b) CM Overall Condition	When applying CM techniques for items, the report is to include the overall condition of the item based on the most recent CM measurement data, which must have been collected within three months of the submission date of the report by an ABS recognized Service Supplier. This report is to be provided to the attending Surveyor	Service Supplier Report: list of equipment and current CM reading "health" () based on most recent results. History of results/trends (at least previous reading or 2) are required.	x

Survey After Construction (Part 7) 7-A1-14 reference	*App 14 Description/Explanation*	*What is required from CMMS systems?*	*CBM (CM or RTM approaches)*
13.1.3(c)	The report should be organized by item or system with the assigned Condition Monitoring techniques result summaries listed	For above source of satisfactory, marginal, or unsatisfactory is to be identified, for each CM type applied. Traffic light status ("Green-Yellow-Red") Type reporting is preferred for ease of reading.	x
13.1.3(d)	The results of trend reports that evidence the health state of items should be simplified as indicated (e.g., good, marginal, unacceptable or failure occurred) on the approved periodic basis	Service Supplier Report: list of equipment and current "health" (satisfactory, marginal, or unsatisfactory) based on most recent results. History of results are valuable if available. "GAR" Type reporting is preferred for ease of reading.	x
13.1.3(d)i	i) CM trending results; description of anomalies observed, and corrective action taken.	Corrective action could be adjustment, or non-intrusive to intrusive maintenance activity.	x
13.1.3(d)ii	ii) Planned maintenance tasks performed as a result of trending and any routine planned maintenance tasks performed.	This would include a link and description of the unscheduled corrective maintenance task performed to restore the machine to satisfactory condition.	x
13.1.3(d)iii	iii) CM tasks confirming satisfactory functionality of items and alarm/trip functionality.	If CM is done, following the maintenance task, to confirm the machine is in satisfactory working order, that task should be documented, and new baseline readings established upon which to base subsequent CM measurements. Confirmation of CM/RTM alarm functionality should be confirmed	x
13.1.4 Report Exceptions:	The Owner is to report to the attending Surveyor all machinery for which: i) Maintenance is not indicated, ii) Maintenance is incomplete, or iii) More frequent monitoring of the machinery is needed based on CM results near or exceeding a pre-established threshold.	Any maintenance that was not conducted or deferred (with reason for deferral), incomplete or if corrective action was necessary based on CM/Smart (MHM) results are to be highlighted for additional attention.	x
13.1.5 Reporting Failures:	The report is to list items that failed prior to scheduled maintenance, servicing, or monitoring and analysis and related record of corrective actions taken.	Failure corrective action was necessary based on CM/Smart (MHM) results are to be highlighted for additional attention.	x

Survey After Construction (Part 7) 7-A1-14 reference	*App 14 Description/Explanation*	*What is required from CMMS systems?*	*CBM (CM or RTM approaches)*
13.1.6 Maintenance Plan Changes:	Modifications with justifications to the schedule, such as might be recommended by a machinery manufacturer's technical bulletin.	CMMS schedule changes based on OEM recommendations, CM or Smart MHM results	x
13.1.7 Service Supplier Records:	When recognized Service Suppliers are used, the company name and contact details, including a list of their approved CM categories and specialties, are to be indicated in the annual report	Include the CM vendor(s) service supplier ABS certification detail (Certificate Number and validity date).	x
13.1.8 Crew Training Records:	a) Where the crew is taking condition monitoring measurements, then training records for the designated crew members and a description of the training is to be included. b) The attending Surveyor may request a trained crew member to demonstrate proficiency in collection and related management of the obtained data.		x
13.1.9 Data collection methods, recording and calibration:	The type of recording device, method of data collection and calibration of the data collector is to be provided.		x

13.1.1 List of Machinery Enrolled: A summary list of all machinery enrolled in PMP.

13.1.2 Equipment Item Changes: Item deletions, replacements and additions occurring after the previous annual report are to be stated in the subsequent report.

13.1.3(d) The results of trend reports that evidence the health state of items should be simplified as indicated (e.g., good, marginal, unacceptable or failure occurred) on the approved periodic basis.

13.1.1

Summary

13.1.3(d)

Equipment Condition Summary	
Unsatisfactory	1
Marginal	24
Satisfactory	147

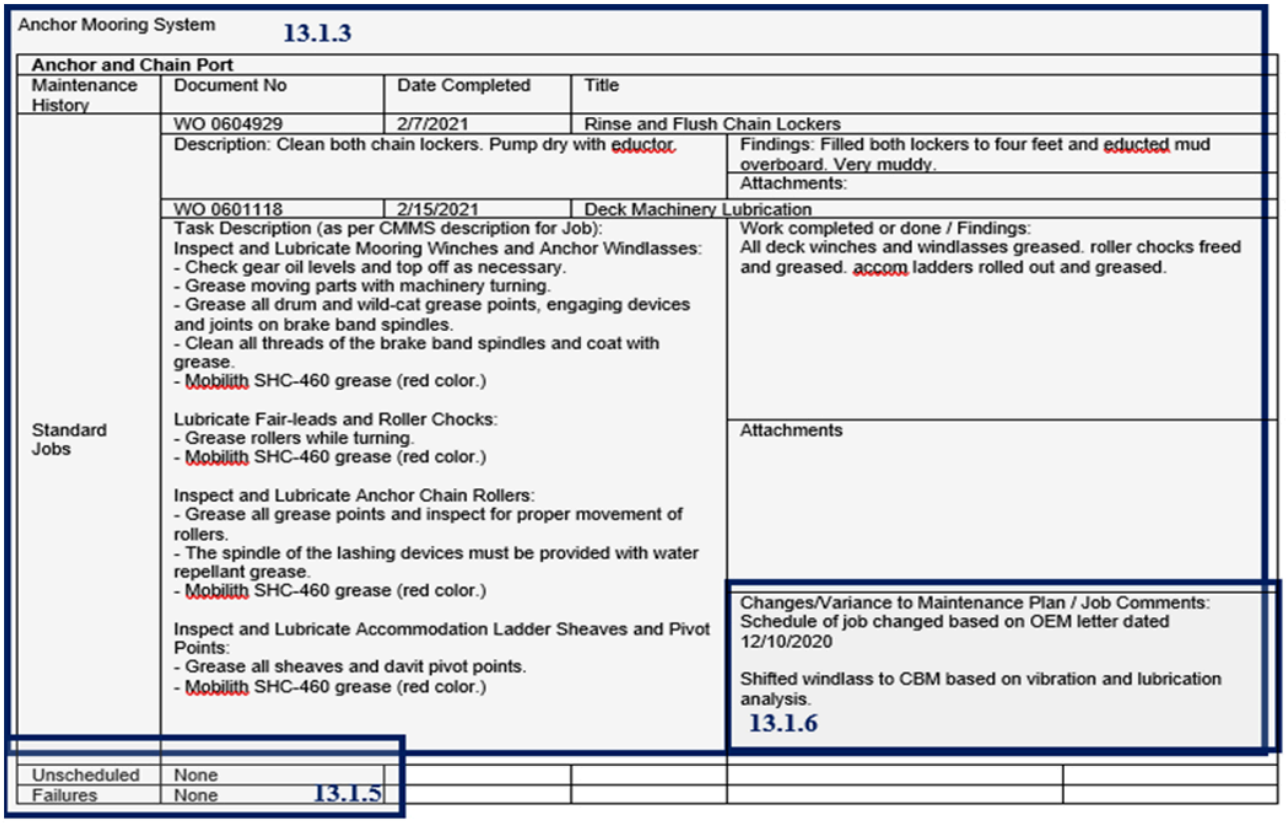
Equipment	Machinery Tag (CM/RTM	Condition Monitoring Types: Vibration	Thermography	Tribology	Other (Add CM techniques)
#1 AUX. D/G TURBOCHARGER	RTM	Satisfactory			
#1 AUX. DIESEL GENERATOR	RTM	Satisfactory			
#1 S.S. REEFER COMPRESSOR	CM	Marginal			
#2 AUX. D/G TURBOCHARGER	RTM	Satisfactory			
#2 AUX. DIESEL GENERATOR	RTM	Satisfactory			
#2 S.S. REEFER COMPRESSOR	CM	Marginal			
ACCOMODATION A/C PLANT #1	CM	Satisfactory			
ACCOMODATION A/C PLANT #2	CM	Satisfactory			
AIR SEAL FAN (see note 1)	PM/CM	Satisfactory			
BALLAST PUMP #1 MOTOR	CM	Marginal			
BALLAST PUMP #1 PUMP END	CM	Satisfactory			
BALLAST PUMP #2 MOTOR	CM	Satisfactory			
BALLAST PUMP #2 PUMP END	CM	Satisfactory			
BOILER FEED PUMP 1P AFT	CM	Satisfactory			
BOILER FEED PUMP 1S FWD	CM	Satisfactory			
BOILER FEED PUMP STBY (CENTER)	CM	Satisfactory			
BOW THRUSTER	RTM	Satisfactory			

Notes:
1 – Air seal fan switched from PM to CM

13.1.3 Maintenance Records: Records are to provide a complete description of work completed on each machine since the last submitted report.

13.1.5 Reporting Failures: The report is to list items that failed prior to scheduled maintenance, servicing, or monitoring and analysis and related record of corrective actions taken.

13.1.6 Maintenance Plan Changes: Modifications with justifications to the schedule, such as might be recommended by a machinery manufacturer's technical bulletin.

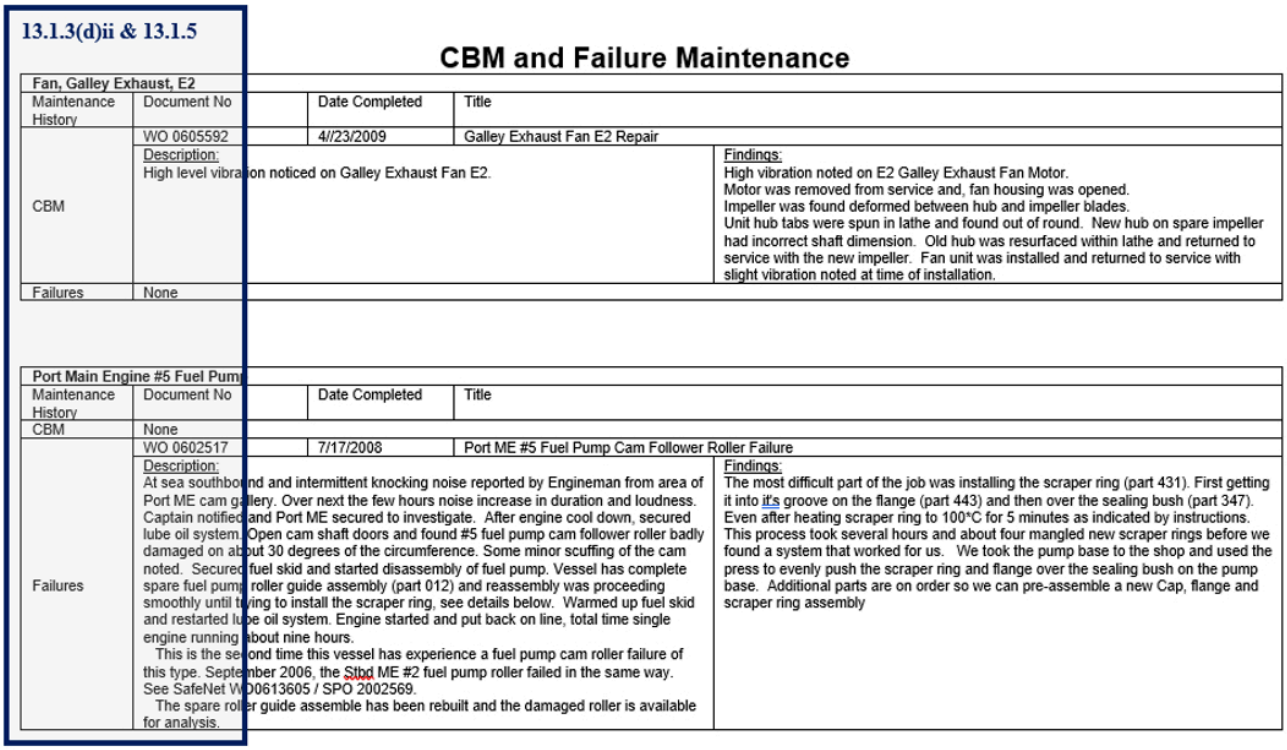


Anchor Mooring System 13.1.3

Anchor and Chain Port					
Maintenance History	Document No	Date Completed	Title		
Standard Jobs	WO 0604929	2/7/2021	Rinse and Flush Chain Lockers		
	Description: Clean both chain lockers. Pump dry with eductor.			Findings: Filled both lockers to four feet and educted mud overboard. Very muddy. Attachments:	
	WO 0601118	2/15/2021	Deck Machinery Lubrication		
	Task Description (as per CMMS description for Job): Inspect and Lubricate Mooring Winches and Anchor Windlasses: - Check gear oil levels and top off as necessary. - Grease moving parts with machinery turning. - Grease all drum and wild-cat grease points, engaging devices and joints on brake band spindles. - Clean all threads of the brake band spindles and coat with grease. - Mobilith SHC-460 grease (red color.) Lubricate Fair-leads and Roller Chocks: - Grease rollers while turning. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Anchor Chain Rollers: - Grease all grease points and inspect for proper movement of rollers. - The spindle of the lashing devices must be provided with water repellant grease. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Accommodation Ladder Sheaves and Pivot Points: - Grease all sheaves and davit pivot points. - Mobilith SHC-460 grease (red color.)			Work completed or done / Findings: All deck winches and windlasses greased. roller chocks freed and greased. accom ladders rolled out and greased. Attachments Changes/Variance to Maintenance Plan / Job Comments: Schedule of job changed based on OEM letter dated 12/10/2020 Shifted windlass to CBM based on vibration and lubrication analysis. 13.1.6	
Unscheduled Failures	None None 13.1.5				

13.1.3(d)ii Planned maintenance tasks performed as a result of trending and any routine planned maintenance tasks performed.

13.1.5 Reporting Failures: The report is to list items that failed prior to scheduled maintenance, servicing, or monitoring and analysis and related record of corrective actions taken.



13.1.3(d)ii & 13.1.5

CBM and Failure Maintenance

Fan, Galley Exhaust, E2			
Maintenance History	Document No	Date Completed	Title
	WO 0605592	4//23/2009	Galley Exhaust Fan E2 Repair
CBM	Description: High level vibration noticed on Galley Exhaust Fan E2.		Findings: High vibration noted on E2 Galley Exhaust Fan Motor. Motor was removed from service and, fan housing was opened. Impeller was found deformed between hub and impeller blades. Unit hub tabs were spun in lathe and found out of round. New hub on spare impeller had incorrect shaft dimension. Old hub was resurfaced within lathe and returned to service with the new impeller. Fan unit was installed and returned to service with slight vibration noted at time of installation.
Failures	None		

Port Main Engine #5 Fuel Pump			
Maintenance History	Document No	Date Completed	Title
CBM	None		
	WO 0602517	7/17/2008	Port ME #5 Fuel Pump Cam Follower Roller Failure
Failures	Description: At sea southbound and intermittent knocking noise reported by Engineman from area of Port ME cam gallery. Over next the few hours noise increase in duration and loudness. Captain notified and Port ME secured to investigate. After engine cool down, secured lube oil system. Open cam shaft doors and found #5 fuel pump cam follower roller badly damaged on about 30 degrees of the circumference. Some minor scuffing of the cam noted. Secured fuel skid and started disassembly of fuel pump. Vessel has complete spare fuel pump roller guide assembly (part 012) and reassembly was proceeding smoothly until trying to install the scraper ring, see details below. Warmed up fuel skid and restarted lube oil system. Engine started and put back on line, total time single engine running about nine hours. This is the second time this vessel has experience a fuel pump cam roller failure of this type. September 2006, the Stbd ME #2 fuel pump roller failed in the same way. See SafeNet WO0613605 / SPO 2002569. The spare roller guide assemble has been rebuilt and the damaged roller is available for analysis.		Findings: The most difficult part of the job was installing the scraper ring (part 431). First getting it into it's groove on the flange (part 443) and then over the sealing bush (part 347). Even after heating scraper ring to 100*C for 5 minutes as indicated by instructions. This process took several hours and about four mangled new scraper rings before we found a system that worked for us. We took the pump base to the shop and used the press to evenly push the scraper ring and flange over the sealing bush on the pump base. Additional parts are on order so we can pre-assemble a new Cap, flange and scraper ring assembly

13.1.3(b) CM Overall Condition; When applying CM techniques for items, the report is to include the overall condition of the item based on the most recent CM measurement data, which must have been collected within three months of the submission date of the report by an ABS recognized Service Supplier. This report is to be provided to the attending Surveyor.

13.1.3(d) The results of trend reports that evidence the health state of items should be simplified as indicated (e.g., good, marginal, unacceptable or failure occurred) on the approved periodic basis.

13.1.3(d)i CM trending results; description of anomalies observed, and corrective action taken.

13.1.3(d)ii Planned maintenance tasks performed as a result of trending and any routine planned maintenance tasks performed.

13.1.3(d)iii CM tasks confirming satisfactory functionality of items and alarm/trip functionality.

13.1.3 (b) **EQUIPMENT DETAILS** 13.1.3 (d)i 13.1.3 (d)ii

UNSATISFACTORY READINGS

Equipment	CM Type	Date	Current	Previous	Problem	Recommendation	WO's
E2 GALLEY EXHAUST FAN	Vibration	4/14/2020	Unsatisfactory	Satisfactory	Imbalance, flexibility, wear.	Verify foundation security. Renew the motor bearings. Balance the fan.	0605592

MARGINAL READINGS

Equipment	CM Type	Date	Status	Previous	Problem	Recommendation	WO's
#1 S.S. REEFER COMPRESSOR	Vibration	11/14/2020	Marginal	Satisfactory	Compressor vibration.	Verify rated pressures and flow. Observe under different load. Check for a common factor between the two compressors. Service the compressor.	
#2 S.S. REEFER COMPRESSOR	Vibration	4/14/2020	Marginal	Satisfactory	Compressor vibration.	Verify rated pressures and flow. Observe under different load. Service the compressor.	
BALLAST PUMP #1 MOTOR	Vibration	11/14/2020	Marginal	Satisfactory	Imbalance/flexibility/wear.	Verify foundation security. Ensure the motor bearings are good. Service the motor.	
CARGO PUMP #1 - PUMP END	Vibration	4/14/2020	Marginal	Satisfactory	Upper shaft bearing wear.	Check/renew the upper bearings.	
CARGO PUMP #2 - PUMP END	Vibration	4/14/2020	Marginal	Satisfactory	Imbalance at upper shaft bearing (reduced).	Check/renew the upper bearings.	
CARGO PUMP #4 - PUMP END	Vibration	4/14/2020	Marginal	Satisfactory	Upper shaft bearing wear.	Check/renew the upper bearings.	
CARGO RES. STRIP PUMP PUMP - CAR	Vibration	11/14/2020	Marginal	Satisfactory	Imbalance/wear in upper shaft.	Renew the upper shaft/bearings.	
PORT #2 LUBE OIL SERVICE PUMP	Vibration	4/14/2009	Marginal	Satisfactory	Check motor windings.	Check for resonance in the motor casing. Service the motor windings.	

13.1.3 (d)iii

SATISFACTORY READINGS

Equipment	CM Type	Date	Status	Previous	Problem	Recommendation	WO's
PORT IGS SCRUBBER & S/W PUMP	Vibration	4/14/2009	Satisfactory	Satisfactory			
PORT M/E #1 AUX. BLOWER UPPER	Vibration	4/14/2009	Satisfactory	Satisfactory			

13.1.7 Service Supplier Records: When recognized Service Suppliers are used, the company name and contact details, including a list of their specialties, are to be indicated in the annual report.

13.1.9 Data collection methods, recording and calibration: The type of recording device, method of data collection and calibration of the data collector is to be provided.

13.1.7 **Condition Monitoring Vendor Details** 13.1.9

Company Name	Point of Contact	CM Type	Last Visit	Next Visit	Collection Details
Condition Analyzing Corporation		Vibration	4/14/09	10/14/09	Visit Based. See current vendor report for Sensor/Calibration results
Heatseeker		Thermography	6/18/09	12/12/09	RTM – Sensor ID 123-234-TH, Calibrated 6/12/20
Exxon-Mobil		Lube Oil Analysis	8/5/09	10/2/09	Lab – See Service Supplier Audit details for calibration

13.1.8 Crew Training Records:

a) Where the crew is taking condition monitoring measurements, then training records for the designated crew members and a description of the training is to be included.

b) The attending Surveyor may request a trained crew member to demonstrate proficiency in collection and related management of the obtained data.

Crew Training Records

Crew Name	#	Training Certification	Last Certification Date	Attachments
John Smith	12345	Vibration	4/12/21	Certificate.pdf
Bill Watson	12346	Thermography	6/18/20	Certificate.pdf

APPENDIX 3

MACHINERY HEALTH REPORT TEMPLATE PMP Annual Smart MHM

General Description	***Smart Guide 8/4.2 Health Report Contents***
Summary report of Machinery Covered with Condition	i) A summary report listing all machinery covered under MHM, clearly stating the overall condition of the machinery (i.e., Satisfactory, Marginal, or Unacceptable).
Trend Reports	ii) Trend reports that evidence the health state of the machines (see Note 1). The results are to be simplified as indicated (e.g., good, degrading, unacceptable, or failure occurred) on the approved periodic basis.
Trend Reports (sub)	• MHM trending results: description of anomalies, diagnostics, or prognostics observed and corrective action taken. See Notes 2 and 3 below for clarification
Trend Reports (sub)	• Planned maintenance tasks performed as a result of trending and any routine planned maintenance tasks performed.
Trend Reports (sub)	• MHM capabilities and reporting specific to each machine confirming functionality of machine and alarm/trip functionality.
Changes to MHM Coverage	iii) Changes to the list of machinery covered under MHM with any additions or deletions from the previous report and any replacements performed
Maintenance Records	iv) Description of maintenance completed on each machine since the last submitted report with reference to related tracking numbers for details.
Maintenance Records	v) Modifications (with justifications) to planned maintenance schedules or intervals (e.g., recommended by an OEM technical bulletin).
Maintenance Records	vi) Next scheduled overhaul of equipment, if known.
Real Time Data	vii) Data trends, statistics, or evidence of testing and/or shutdowns that support alternative methods for survey, if applicable

i) A summary report listing all machinery covered under MHM, clearly stating the overall condition of the machinery (i.e., Satisfactory, Marginal, or Unacceptable).

This summary reporting should reflect a quick and easy to understand view by a reviewing or attending Surveyor. This type of traffic light condition should reflect the status of heath state with respect to the various failure modes being monitored by the algorithms employed withing the MHM capability.

ii) Trend reports that evidence the health state of the machines (see Note 1). The results are to be simplified as indicated (e.g., good, degrading, unacceptable, or failure occurred) on the approved periodic basis.

An annotation and link of each health/condition trend line to both its covered failure modes and linked maintenance tasks should also be easy to discern from the report.

iii) Changes to the list of machinery covered under MHM with any additions or deletions from the previous report and any replacements performed.

8/4.2 i

Summary

Machinery - MHM Summary for Period	Total Items Monitored	4	Restored Health after Corrective Actions
Period Covered:	Unsatisfactory	2	0
DD/MM/YY - DD/MM/YY	Marginal	1	0
	Satisfactory	1	4

Note:
1 – Cargo pump #1 switched from PM to CBM

8/4.2 iii

- MHM trending results: description of anomalies, diagnostics, or prognostics observed, and corrective action taken.

See Notes 2 and 3 below for clarification.

This would cover the maintenance task links described in the previous section as being corrective actions that were triggered, performed, and restored the item to satisfactory working order.

8/4.2 i & ii

Item No.	ABS Virtual Vessel Asset Name/ID	Algorithm or Failure Mode Tracked	Algorithm Type	Freedom TAG	Current Report	Previous QTR	Previous QTR	Previous QTR	Linked PM's for CBM or Corrective Action	Actions taken in this Period (See report details for action info)
1	Cargo Pump #1									
		Failure Mode X	Diagnostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Cargo Pump Maint. Task 1	
		Failure Mode Y	Diagnostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Cargo Pump Maint. Task 8	
2	Bow Thruster #1									
		Failure Mode AAA	Prognostic	MHM	Unsatisfactory	Satisfactory	Satisfactory	Satisfactory	BT Maint Task 1	BT Maint. Task Completed XX/YY/ZZZZ. See Report Detail Page X for corrective action and post-repair data trend.
		Failure Mode BBB	Prognostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	BT Maint Task 2	
3	#1 Auxiliary Diesel Generator									
		Ops. Data ML Profiling	Anomaly Detection	MHM	Marginal	Satisfactory	Satisfactory	Satisfactory	Anomaly Investigative Task	Investigation revealed temperature sensor was malfunctioning, see report detail page y.
4	Main Engine									
		Failure Mode 1	Diagnostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Engine Maint. Task A	
		Failure Mode 2	Diagnostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Engine Maint. Task B	
		Failure Mode 3	Prognostic	MHM	Unsatisfactory	Marginal	Satisfactory	Satisfactory	Engine Maint. Task A	ME Maint. Task Completed XX/YY/ZZZZ as per MHM prognostics. See Report Detail Page Z, and post-repair data trend.
		Failure Mode 4	Prognostic	MHM	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Engine Maint. Task C	
		Ops. Data ML Profiling	Anomaly Detection	MHM	Unsatisfactory	Satisfactory	Satisfactory	Satisfactory	Anomaly Investigative Task	Ops Data Anomaly tied to FM3 issue, see post maintenance trend.

- Planned maintenance tasks performed as a result of trending and any routine planned maintenance tasks performed.

(Note this is just an example and not directly correlated to the above report sections)

8/4.2 ii

MHM Derived and Failure Maintenance

Fan, Galley Exhaust, E2			
Maintenance History	Document No	Date Completed	Title
	WO 0605592	4//23/2009	Galley Exhaust Fan E2 Repair
MHM	Description: Anomaly indication on Galley Exhaust Fan E2.		Findings: High vibration noted on E2 Galley Exhaust Fan Motor. Motor was removed from service and, fan housing was opened. Impeller was found deformed between hub and impeller blades. Unit hub tabs were spun in lathe and found out of round. New hub on spare impeller had incorrect shaft dimension. Old hub was resurfaced within lathe and returned to service with the new impeller. Fan unit was installed and returned to service with slight vibration noted at time of installation.
Failures	None		

Port Main Engine #5 Fuel Pump			
Maintenance History	Document No	Date Completed	Title
CBM	None		
	WO 0602517	7/17/2008	Port ME #5 Fuel Pump Cam Follower Roller Failure
Failures	Description: At sea southbound and intermittent knocking noise reported by Engineman from area of Port ME cam gallery. Over next the few hours noise increase in duration and loudness. Captain notified and Port ME secured to investigate. After engine cool down, secured lube oil system. Open cam shaft doors and found #5 fuel pump cam follower roller badly damaged on about 30 degrees of the circumference. Some minor scuffing of the cam noted. Secured fuel skid and started disassembly of fuel pump. Vessel has complete spare fuel pump roller guide assembly (part 012) and reassembly was proceeding smoothly until trying to install the scraper ring, see details below. Warmed up fuel skid and restarted lube oil system. Engine started and put back on line, total time single engine running about nine hours. This is the second time this vessel has experience a fuel pump cam roller failure of this type. September 2006, the Stbd ME #2 fuel pump roller failed in the same way. See SafeNet WO0613605 / SPO 2002569. The spare roller guide assemble has been rebuilt and the damaged roller is available for analysis.		Findings: The most difficult part of the job was installing the scraper ring (part 431). First getting it into it's groove on the flange (part 443) and then over the sealing bush (part 347). Even after heating scraper ring to 100*C for 5 minutes as indicated by instructions. This process took several hours and about four mangled new scraper rings before we found a system that worked for us. We took the pump base to the shop and used the press to evenly push the scraper ring and flange over the sealing bush on the pump base. Additional parts are on order so we can pre-assemble a new Cap, flange and scraper ring assembly

iv) Description of maintenance completed on each machine since the last submitted report with reference to related tracking numbers for details.

v) Modifications (with justifications) to planned maintenance schedules or intervals (e.g., recommended by an OEM technical bulletin). *Covering either extended out or brought forward.*

vi) Next scheduled overhaul of equipment, if known. *Tied to item v) above.*

Anchor Mooring System					8/4.2 iv
Anchor and Chain Port					
Maintenance History	Document No	Date Completed	Title		
Standard Jobs	WO 0604929	2/7/2021	Rinse and Flush Chain Lockers		
	Description: Clean both chain lockers. Pump dry with eductor.			Findings: Filled both lockers to four feet and educted mud overboard. Very muddy. Attachments:	
	WO 0601118	2/15/2021	Deck Machinery Lubrication		
	Task Description (as per CMMS description for Job): Inspect and Lubricate Mooring Winches and Anchor Windlasses: - Check gear oil levels and top off as necessary. - Grease moving parts with machinery turning. - Grease all drum and wild-cat grease points, engaging devices and joints on brake band spindles. - Clean all threads of the brake band spindles and coat with grease. - Mobilith SHC-460 grease (red color.) Lubricate Fair-leads and Roller Chocks: - Grease rollers while turning. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Anchor Chain Rollers: - Grease all grease points and inspect for proper movement of rollers. - The spindle of the lashing devices must be provided with water repellant grease. - Mobilith SHC-460 grease (red color.) Inspect and Lubricate Accommodation Ladder Sheaves and Pivot Points: - Grease all sheaves and davit pivot points. - Mobilith SHC-460 grease (red color.)			Work completed or done / Findings: All deck winches and windlasses greased. roller chocks freed and greased. accom ladders rolled out and greased. Attachments Changes/Variance to Maintenance Plan / Job Comments: Schedule of job changed based on OEM letter dated 12/10/2020 Shifted windlass to CBM based on vibration and lubrication analysis. 8/4.2 v	
Overhaul Schedule	1200 hours	8/4.2 vi			

(Note this is just an example and not directly correlated to the above report sections)

Service Supplier Records: - Smart When recognized Service Suppliers are used, the company name and contact details, including a list of their specialties, are to be indicated in the annual report.

Condition Monitoring Vendor Details

Company Name	Point of Contact	CM Type	Last Visit/Report	Next Visit/Report	Collection Details
Smart MHM Company		MHM	xx	xx	
Condition Analyzing Corporation		Vibration	4/14/09	10/14/09	Visit Based. See current vendor report for Sensor/Calibration results
Heatseeker		Thermography	6/18/09	12/12/09	RTM – Sensor ID 123-234-TH, Calibrated 6/12/20
Company A		Lube Oil Analysis	8/5/09	10/2/09	Lab – See Service Supplier Audit details for calibration

APPENDIX 4

Guidelines for Data Infrastructure Supporting CBP Tiers

For a CBP Tier S3 or M3 installation involving the handling of time-series data, the following data handling functions are typically involved to manage and maintain the required data flows:

- Hull Sensor Plan (S3 only)
- Purposely Installed Sensor Interface
- Interface(s) to Onboard System
- Data Network and Communication
- Data Management
- Data Processing and Analytics

1 Functional Data Infrastructure

Given the opportunity to create a robust specification for a new construction vessel, the following is guidance provided to Shipyards and the Technical Authority for basic data infrastructure robustness to be built into the vessel at delivery or in modification and retrofit for existing vessels. The following capabilities are provided as minimum set of requirements for an optional **CBP Ready** Tier 3 data infrastructure.

1.1 Hull Sensor Plan Development (S3 Enablement only)

1.1.1 Purpose

The main purpose of a hull sensor system is to provide motion, loads and structural response monitoring and assist with safe operational decision making over the life of a vessel. To fulfill this purpose, a hull sensor package is installed to directly monitor the vessel's motion, main hull girder stress, slamming events, whipping, vibration, and local structural responses at critical structural locations through an onboard data processing and user interface. The monitored data is visualized in real-time within a onboard human-machine interface (HMI) and sensor alarms triggered in the events of exceeding the preconfigured thresholds set by the engineering analysis.

In addition to the motion, stress and vibration monitoring, sea state measurements can also be augmented by installed wave radar and data processing software to provide real-time wave conditions and assist the crew to keep the vessel within the Ship Operating Envelope (SOE).

In addition to real-time onboard data processing and visualization, the hull instrumentation system can provide valuable full-scale data to support post-voyage operation and condition analysis and assessment through a structural digital twin implementation, which may provide further insights on the ship's structural condition, potential damage and remaining fatigue life for condition-based maintenance and improved ship readiness.

While the exact sensor plan cannot be specified without knowledge of a specific vessel design, configuration specific to the vessel class, and required response phenomena monitoring, a typical hull instrumentation system consists of the following components:

- Sensors
- Supplementary information characterizing the operational environment, through dedicated sensors or interface to ship's existing sensors and system
- Fiber Optic Analyzer (for fiber optic sensors)
- PC(s)
- UPS
- Keyboard/Mouse
- Fiber Termination Tray (for fiber optic sensors)
- Local Service Monitor
- Remote Monitor (Pilothouse)
- Software

1.1.2 Hull Sensor Plan Descriptions

See the ABS *Guide for Hull Condition Monitoring System* and the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches* for guidance on sensor applications on board ships. Typically, sensors and other hardware and software constituting the hull instrumentation system cover:

a) To monitor the ship motion and hull girder stresses, motion reference unit(s) (MRU) at or close to the vessel's center of gravity (CG) and strain gauges at various longitudinal and transverse sections are installed. Typically, for monohulls, vertical and horizontal bending moments are the dominant global loads, and correspondingly, two sensors are installed at each longitudinal station at portside and starboard side, respectively. Additional sensors at each section can be considered for vessels where torsional bending moments are of concern.

b) For global loads measurements, Long-Based Strain Gauges (LBSGs) are typically installed to smear the local stress effect.

c) In addition to the direct monitoring of motion and global loads, the experienced wave condition is an important parameter that can assist to better understand the experienced sea states and keep the vessel within its operating envelope. In the case of extreme events, sea state measurements can also provide more insights on the environment and assist with operational envelope-related decision making. For post-voyage analysis and life-cycle structural monitoring and assessment, the experienced wave condition is an important parameter that can be used to derive the remaining fatigue life and other structural insights. Therefore, it is recommended by ABS to have the wave condition directly measured for hull instrumentation systems.

d) For slamming event detection, accelerometers at bow and stern locations are proposed to monitor the vertical accelerations, which can indicate slamming events. When slamming pressure measurement is deemed significant for the vessel type, pressure transducers can provide direct slamming pressure measurement. Guidance on pressure transducer installation and the considerations necessary when penetrating hull boundary can be found in the ABS *Guide for Hull Condition Monitoring Systems*

The following tables summarize a typical Hull Sensor Plan. Commercial Off the Shelf (COTS) sensor types are recommended by ABS.

TABLE 1
Recommended Sensors for Hull Monitoring[1]

Purpose	*Type of Sensors*	*# of Sensors*	*Note*
Ship motion	MRU (Motion Reference Unit)	1	Close to CG location
Wave condition	Sea State Monitor / Wave radar	1	
Hull girder loads	Strain gauges	10	At five stations
Slamming detection	Accelerometer	2	At bow and stern
Vibration	Accelerometer	2	At midship and bridge
Local Stress monitoring[2]	Strain gauges / rosettes (fiber optic)	10	Number and locations subject to detail design and analysis
Slamming pressure	Strain gauge rosettes	16	Number of sensors subject to detailed design and analysis

1) Recommended sensor arrangements for different hull forms can be found in the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches*

2) Local stress monitoring at identified critical location and structural discontinuities should be determined by direct structural analysis.

The following sensor specifications can be used as guidelines but must be tuned and calibrated according to the measurement purpose, the vessel's characteristics, actual vessel's expected optional and environmental conditions.

TABLE 2
Minimum Recommended Sensor Specifications

Sensors	*Range*	*Operating Temperature*	*Bandwidth*	*Accuracy*
Accelerometer	± 3 G	-25°C to 60°C	0 – 20 Hz	2% measured value or 0.10 m/s^2
MRU (6-DoF)	± G (tri-axial) Roll: +/- 90 deg Pitch: +/- 45 deg Yaw: +/- 180 deg	-25°C to 60°C	0 – 5 Hz	2% measured value or 0.10 m/s^2 and 0.5 deg
Strain gauge / rosette	± 2000 µm/m	-25°C to 60°C	0 – 5 Hz	± 5 micro strain

The bandwidth in the above table is mainly for measuring wave-induced response, such as dynamic wave loads. When vibration such as whipping and springing is of interest, the bandwidth should be determined through a finite element-based vibration analysis or experience with similar design or operations covering the interested vibration frequencies and modes. When transit loads such as slamming pressure (direct or indirect measurements) are of the interest, a much higher sensor bandwidth range is typically used. The sensor specification may be discussed with ABS and the ABS *Advisory on Structural Health Monitoring - Sensor-Based Approach* can be referenced.

1.1.3 Installation Guidelines Specific to Hull Sensor Plans

Typical hull stress sensor arrangements for global hull girder loads place sensors on loadbearing structures (longitudinal) under the main deck. If the main deck is close to the neutral plane for

sagging/hogging moment, a different deck away from the neutral plane may be more appropriate for instrumentation. However, it is recommended that a deck be chosen that is continuous along all or most of the overall length of the hull.

The primary hull girder load sensor positions are port and starboard amidships. The midships instrumentation is the preferred recommended configuration. Secondary positions for global loads would be the forward and aft quarter lengths, and/or at the forward and aft limit of the superstructure where hull bending is concentrated due to discontinuity. Some sensor package designs include sensors on bottom longitudinal below neutral plane in the same cross sections to catch more global loads than sagging and hogging bending moment, such as torsional bending when large opening presents and hull torsional stiffness is a concern.

Sensor positions for local hull stresses, typically with the intent of monitoring material yielding and fatigue accumulation, should be chosen based on the results of structural analyses.

The following summarizes the ABS guidelines for determining the sensor installation locations. Detailed installation locations are determined when the specific vessel is identified, and the relevant structural analyses becomes available:

- MRU: close to the vessel CG at strong structural supported location
- Wave Radar: on the main mast
- Strain gauge for global loads: main deck (or upper deck) on the deck longitudinal, at midship, and fore and aft of superstructure at the connection to main deck, portside and starboard side. Two additional stations fore and aft of the midship of the superstructure, in way of the deck steps or openings
- Accelerometer for slamming detection: bow and stern with strong structural support
- Accelerometer for vibration: at midship and bridge with strong structural support
- Strain gauge/rosette for local stress monitoring: to determine by direct structural analysis (out of the hot spot zone)
- Rosette for slamming pressure (optional): back supporting structure at bow and stern in way of mean water line
- The installation locations should consider avoiding unwanted interference, such as foot traffic, and tripping or other hazards.
- The installed sensors should be properly protected from green seas, weather, cargo operations, dropped objects, and human traffic

1.1.4 Purposely Installed Sensor Interfaces (applicable to M3/S3)

The interface receives data from the external environment and physical process/structures through sensors and measurement instruments.

The following capabilities are recommended to be presented and supported by the installed hardware and software:

i) Predefined data interface to support certain number and type of input/output (I/O) channels

ii) Connection to the Data Network and Communication function when such function is implemented

iii) Time stamping and time synchronization for the data collected through the interface

iv) Monitoring and alarming for signal/data stream interruption and lost

1.2 Interfaces to Onboard Systems (applicable to M3/S3)

The interface to onboard system accesses and receives data from other onboard systems, such as automation and control and monitoring systems, in passive or active means.

The following capabilities are recommended to be presented and supported by the installed hardware and software:

i) Predefined data interface to support certain number and type of input/output (I/O) channels

ii) Connection to the Sensor Interface directly or through Onboard Network and Communication function when such function is implemented

iii) Time stamping and time synchronization for the received data from various sources through the interface

iv) Monitoring and alarming for signal and data stream interruption and loss

v) Safeguard for potential error propagation or request flooding to the interfaced onboard systems

1.3 Data Network and Communication (applicable to M3/S3)

The network should provide data transfer among data handling functions.

The following capabilities are recommended to be presented and supported by the installed hardware and software:

i) Prewired or wireless onboard data network to access specific data interface locations, such as navigation bridge, engine control room, and cargo control room

ii) Two-way communication channels between the vessel and onshore facilities, when applicable to service deployment

iii) Managed data communication through recognized data communication protocols

iv) Centralized communication volume and network load monitoring

v) Established cybersecurity and data integrity control for the communication. See Section 2/2.4.5

1.4 Data Management (applicable to M3/S3)

The data management should manage the collected data by providing data governance, data storage, and data synchronization.

2 Data Infrastructure Technical Guidance (applicable to M3/S3)

When installed onboard, the Tier 3 hardware and software components should meet the applicable technical requirements as listed in this Appendix Section, as applicable.

2.1 Cables (Power and Data)

The following requirements on cables (power and data) are applicable for all functions handling data.

i) Power and data cables are to comply with the cable requirements in 4-8-3/9 of the *Marine Vessel Rules*, as applicable.

ii) Power and data cables are to comply with the cable installation requirements in 4-8-4/21 of the *Marine Vessel Rules*, as applicable.

iii) Power cables are to comply with the cable sizing requirements in 4-8-2/7.7 of the *Marine Vessel Rules*.

iv) Data Cables are to comply with the physical layer of the selected communication protocol.

v) Data cables occupying the same cable tray, trunk or conduit with power cables are to be effectively shielded as per 4-9-10/3.7 of the *Marine Vessel Rules*.

2.2 Power Supplies

The requirements on power supplies are applicable to all data handling functions and are to comply with 4-8-3/1.9 of the *Marine Vessel Rules*.

2.3 Electronic Hardware and Sensors

The requirements for electronic hardware and sensors applies to the corresponding data handling functions.

i) The specification of the hardware modules and sensors, such as range, accuracy, resolution, repeatability, and response time, are to be suitable for the intended measurements.

ii) The hardware modules and sensors are to be designed such that they will withstand the test conditions stipulated in 4-9-9/Table 1, items 17 and 18 of the *Marine Vessel Rules*, as applicable.

iii) When the hardware modules and sensors are to be installed in a physical location where ambient conditions may affect the system dependability and performance, the module and sensors are to be properly protected, and the protection is to satisfy the requirements in 4-8-3/1.11 of the *Marine Vessel Rules*.

iv) When the hardware modules and sensors are to be installed in a physical location with accessibility limitations, provisions are to be provided for inspection, maintenance and calibration activities, as applicable.

v) When the hardware modules and sensors are to be installed in hazardous areas where flammable or explosive gases, vapors, or dust are normally or likely to be present, they are to comply with the in 4-8-3/13 of the *Marine Vessel Rules*.

vi) The hardware modules and sensors are to be calibrated, recalibrated, and maintained according to the manufacture's recommendation. Calibration and maintenance records are to be maintained on board the vessel.

2.4 Onboard Network and Communication

i) The communication protocols are to allow for response times less than the sample time of data being gathered from Sensors and Onboard System interfacing.

ii) The onshore communication is to provide mitigations for failures or underperformance of the onshore communication channels.

iii) The communication protocol(s) are to allow a time synchronization protocol or alternative time synchronization means to be implemented.

iv) Data cable connectors are to be applicable to the vibration levels of the intended installation location.

v) When utilizing wireless communications, the requirements in 4-9-3/13.3.3(a-f) of the *Marine Vessel Rules* are applicable.

vi) Integrity checks on the messages (e.g., error correcting codes, timeouts on communications, status bits associated with measured value) are to be implemented.

2.5 Purposely Installed Sensors Interface

i) When utilizing wireless sensors interface functions, the requirements in 4-9-3/13.3.3(a-f) of the *Marine Vessel Rules* are applicable.

ii) When the system is designed with analog inputs (i.e., thermo-couple, RTD (2-3-4 wires), 4 mA to 20 mA), the analog inputs are to provide for inverse polarity protection.

iii) When the system is designed with analog inputs (i.e., thermo-couple, RTD (2-3-4 wires), 4 mA to 20 mA), proper earth connections are to be provided.

iv) When the system is designed with analog inputs, analog signals out of range input is to be prevented.

v) When the system is designed with analog inputs, analog signals rate of change out of predefined limits is to be prevented.

vi) When the system is designed with digital inputs, inappropriate combinations of digital inputs are to be prevented.

vii) The analog to digital conversion is to maintain appropriate resolution for the maximum required signal frequency, to avoid both quantization errors and unnecessary oversampling.

2.6 Data Management

i) All data collected over the measurement period is to be stored with time stamps indicting the point in time the data is collected or generated.

ii) Data collected from various sources is to be time synchronized in the storage.

iii) The data storage device is to have the capacity to record all the collected and processed data from the connected sensors and data analytics outputs.

2.7 Data Processing

i) Data consistency mitigation (e.g., confirmation that no “bad” data can be sent to analysis and the HMI in the event of failure of the primary central processing units (CPUs)) is to be in place.

ii) When statistics are generated and used for data analytics and models, the statistical parameters and statistical period are to be adequate so that no main data features are lost.

iii) Data from various data sources are to be time synchronized.

iv) Sensor configuration and mapping is to be documented and described in a System Specification Document