



GUIDE FOR

SMART FUNCTIONS FOR MARINE VESSELS AND OFFSHORE UNITS

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**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

Smart Functions, which provide crew and support personnel with key information to aid in decision-making, are becoming increasingly common on board marine vessels and offshore units. Common Smart Functions include structural and machinery health monitoring, asset efficiency monitoring, operational performance management, and crew assistance and augmentation to support vessel operations.

Smart Functions are enabled via a data infrastructure and supported by robust software integrity and cybersecurity that facilitate the use of aggregated data from sensors and other sources, data analytics, and data synthesis for reporting, decision making and actions.

ABS is introducing this *Guide for Smart Functions for Marine Vessels and Offshore Units* to provide the industry with technical and survey requirements for vessels fitted with Smart Functions. Compliance with the requirements given in this Guide may result in the granting of optional class notations **SMART (INF)** covering the data infrastructure, as well as **SMART (SHM)** and/or **SMART (MHM)** covering the Smart Functions for health monitoring of structures or machinery of marine vessels or offshore units.

This Guide further describes the ABS process to approve technology and services offered in support of Smart Function implementation. Approval by ABS of external service providers includes third party organizations that support Smart Function implementation, Original Equipment Manufacturers (OEMs), shipyards, owners, and operators. The Product Design Assessment (PDA) option may also be offered to any party providing hardware and software meeting the requirements within this Guide.

This Guide allows for the use of the data and decision-making support provided by the Smart Functions to assist Surveyors in performing onboard activities. Onboard equipment or systems having Smart Function capability can be considered for implementation within Condition Based Class (CBC).

This Guide is meant to be used together with the ABS *Guidance Notes on Smart Function Implementation*, which provides ABS clients with the procedures for setting goals and deciding on the Smart Functions needed to achieve these goals, as well as the Rules and Guides issued by ABS and other recognized International, National, and Industry Regulations and Standards.

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

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

SMART FUNCTIONS FOR MARINE VESSELS AND OFFSHORE UNITS

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SECTION 1 General

1 Introduction

1.1 Purpose

The purpose of this Guide is to:

- i) Establish a goal-based framework for Smart Function (SF) implementation;
- ii) Establish a risk informed approach and requirements for Smart Function assessment;
- iii) Offer optional Smart Function class notations;
- iv) Provide approval to Service Providers (SPs) offering Smart Function services;
- v) Issue Product Design Assessments (PDAs) to Smart Function system hardware and software;
- vi) Extend equipment PDA documents with attachment for manufacturers equipment to recognize Smart Functions for alternative survey approach;
- vii) Establish an alternate approach to credit survey after construction requirements within Condition Based Class (CBC).

1.2 Audience

This Guide is intended for use by marine vessel and offshore unit owners, operators, designers, shipyards, equipment and system manufacturers, as well as Smart Function product and service providers, vendors, and integrators.

2 Smart-to-Autonomy Levels

Smart is defined in this Guide on the scale of Smart-to-Autonomy levels based on the human-system level of interaction in the processes of data handling, decision-making and execution.

The Smart-to-Autonomy levels are defined as follows:

- i) *Manual*: No system augmentation of human functions. The system offers no or limited assistance, and a human must make all decisions and take all actions.
- ii) *Smart*: System augmentation of human functions. The system provides passive decision support, in the form of health and condition anomaly detection, diagnostics, prognostics, decision/action alternatives, and/or recommendation.
- iii) *Semi-Autonomy*: Human augmentation of system functions. The system takes a decision-making role and performs action selection. A human is in the loop for approval and possible override of system-selected actions.
- iv) *Full Autonomy*: No human involvement in system functions. The system makes decisions and takes actions autonomously. Humans are out of the loop and the system may provide notifications.

The role of human and system for the levels described above is summarized and detailed in Section 1, Table 1.

TABLE 1
Smart-to-Autonomy Levels

<i>Level</i>	<i>Features</i>	<i>Data Handling</i>	<i>Decision Making</i>	<i>Execution of Action</i>
Manual	No system augmentation	System and Human	Human	Human
Smart	System augmentation of human functions	System and Human	Human with System support	Human
Semi-Autonomy	Human augmentation of system functions	System	System with Human supervision	System with Human supervision
Full Autonomy	No human augmentation	System	System	System

3 Smart Function

3.1 Definition

The Smart Function described in this Guide refers to systems installed and services deployed to continuously collect, transmit, manage, analyze, and report data for enhanced health and condition awareness, operational assistance, operational optimization, and decision-making support.

3.2 Features

The Smart Function described in this Guide has the following features:

- i) Is categorized at the Smart level as defined in Subsection 1/2
- ii) Can be implemented for individual onboard equipment, across functional systems, or holistically across the entire vessel
- iii) Can be implemented as a standalone system or through integration/interaction with other onboard systems
- iv) Can be centralized at one physical location or decentralized across several onboard locations, with or without onshore support facilities that are interlinked for continuous or periodic data exchange
- v) Provides passive decision support and typically requires services from SPs to close the decision-making loop

3.3 Smart Function Categories

The following Smart Function (SF) categories are typically implemented:

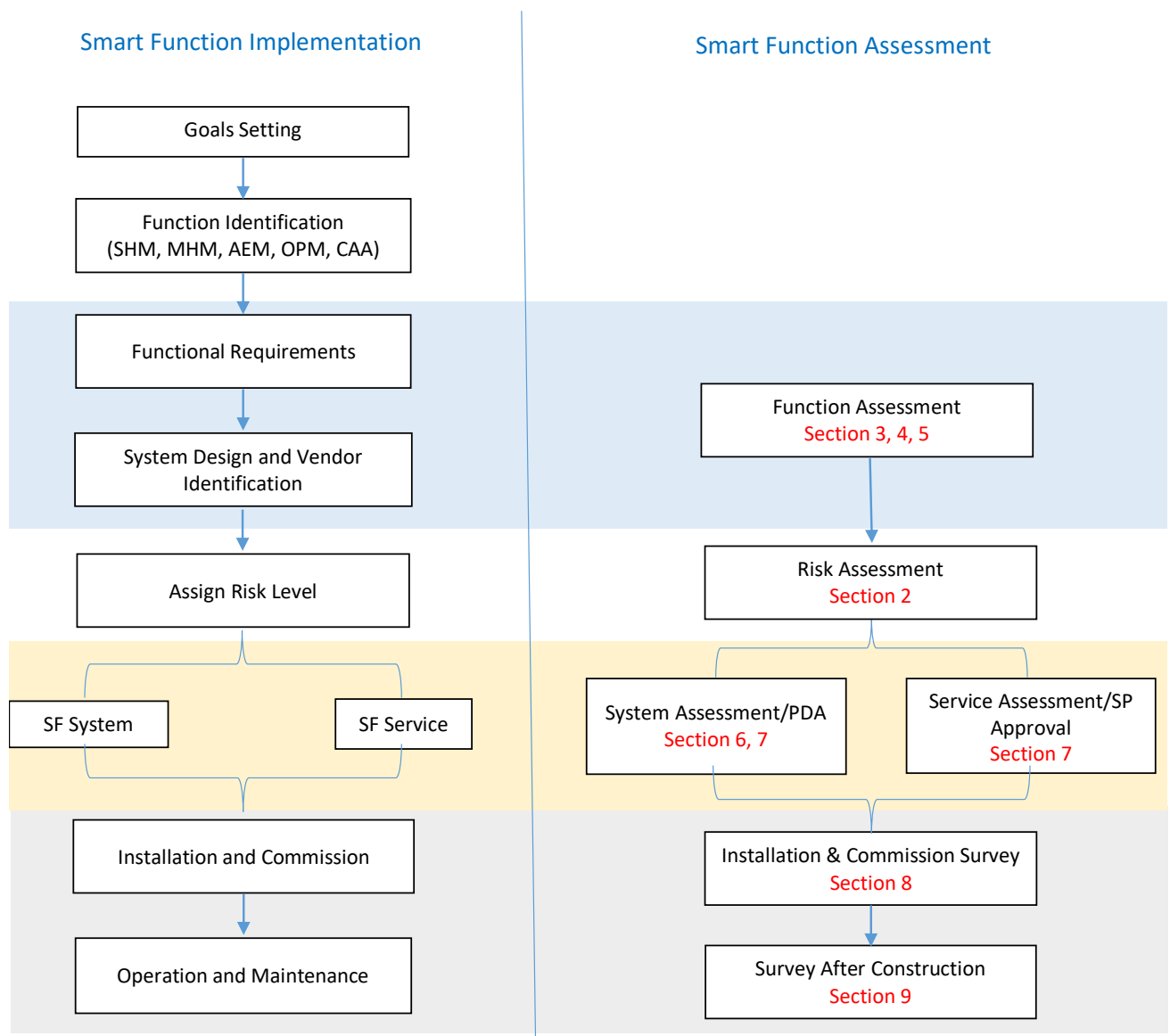
- i) *Structural Health Monitoring (SHM)*: Monitors structural loads, responses, and health conditions to assess the structural integrity, provide structural health awareness, and help reduce the potential for structural damage.
- ii) *Machinery Health Monitoring (MHM)*: Monitors the health state and operational conditions of onboard machinery and systems to detect anomalies that assist to predict the onset of condition degradation or improper operation which may lead to functional failure.
- iii) *Asset Efficiency Monitoring (AEM)*: Assesses equipment, system, or vessel efficiency and provides maintenance and tune-up activity triggers to maintain or improve efficiency levels. Examples of asset efficiency include hull resistance and engine efficiency. AEM is often used in tandem with a health monitoring function, as it usually monitors efficiency.
- iv) *Operational Performance Management (OPM)*: Monitors, manages, and analyzes equipment, systems, or vessel operational parameters and performance data. The results provide guidance and recommendations for operators and onboard crew to optimize the way the equipment, system, or vessel is operated and managed. Examples of OPM functions include voyage optimization, route planning and power plant balancing.

- v) *Crew Assistance and Augmentation (CAA)*: Assists crew reporting and other onboard activities through automatic data collection, electronic logging, data processing, analysis, and report generation. CAA-related Smart Functions can be either a standalone function or integrated with the health monitoring and performance management functions. For example, auto-logging and reporting are a common feature often incorporated within an OPM function. Enhanced situational awareness can also come from increased sensing and analytics capacity that augments the crew in vessel operations, such as night vision, obstacle detection, and collision avoidance.

4 Goal-Based Framework

Section 1, Figure 1 shows the goal-based framework for Smart Function implementation in the left-hand column outlined in the *ABS Guidance Notes for Smart Function Implementation* with parallel requirements for assessment as described in the indicated Sections of this Guide shown in the right-hand column.

FIGURE 1
Smart Function Implementation and Assessment



4.1 Smart Function Implementation

This paragraph provides guidance on the general process that the SF implementation is to cover. The *ABS Guidance Notes for Smart Function Implementation* may be used as a reference. This general process is to be assessed by ABS following the methodology of 1/4.2.

4.1.1 Goal Setting

Smart Function implementation may achieve the following goals:

- i) Increase health state awareness in order to enhance safety and asset integrity and to minimize downtime associated with failures and maintenance;
- ii) Improve asset efficiency and operational performance in order to reduce fuel consumption, emissions and Operational Expenses (OPEX);
- iii) Assist and augment crew with vessel operations related to navigation bridge management, practices, and compliance reporting in order to enhance vessel situational awareness and navigation safety, reduce crew workload, and minimize potential human error.

As classification requirements incorporate more vessel-specific and condition-based approaches, properly implemented Smart Functions may augment the Surveyor's understanding of the vessel's health state for more condition-based and less intrusive survey scopes.

4.1.2 Smart Function Identification

To achieve the goals described in 1/4.1.1, the appropriate SF categories as defined in 1/3.3 are to be identified.

The following table aligns SF categories with common vessel functions, structures, and systems, as applicable to marine vessels and offshore units. Similar categorization may apply to systems for other vessel types, not explicitly referenced in Section 1, Table 2.

TABLE 2
Map of Smart Function Category to Vessel Function, Structure and System

<i>Vessel Function/Structure/System</i>	<i>Health State Awareness</i>		<i>Asset Efficiency & Operational Performance</i>		<i>Crew Assistance & Augmentation</i>
	<i>SHM</i>	<i>MHM</i>	<i>AEM</i>	<i>OPM</i>	<i>CAA</i>
Propulsion System		X	X	X	
Steering/Maneuvering System	X	X	X		
Power Generation/Distribution		X	X	X	
Firefighting System/Equipment		X			
Auxiliary Machinery		X	X	X	
Drilling and Production		X	X	X	
Cargo/Ballast Handling System		X	X	X	X
Hotel/Accommodation/HVAC		X	X	X	
Global Hull	X				
Local Structures	X				
Shafting/Propeller		X			
Navigation		X		X	X
Station Keeping/Mooring	X	X		X	X
Hull & Propeller Performance			X	X	X
Compliance Reporting					X

4.1.3 Functional Requirement

Functional requirements define a set of Smart Function tasks necessary to accomplish the specified goals.

Functional requirements for individual SF categories eligible for notations are listed in Sections 3, 4, and 5 of this Guide.

4.1.4 System Design and Vendor identification

To realize the functional requirements set per 1/4.1.3, the SF system design and vendor(s) are to be identified.

4.1.5 Risk Level Assignment

A risk level is to be assigned based on the procedure outlined in Section 2 by evaluating the various risk factors associated with the Smart Function implementation.

The system technical requirements presented in Section 6 of this Guide are based on the assigned risk level.

4.1.6 Smart Function System

The Smart Function system (or SF system in this Guide) is a combination of hardware and software, including data source, data analytics algorithms, and models that realize the identified Smart Functions and satisfy the functional requirements.

The hardware and software of the SF system can be centralized at one physical location or decentralized across several locations onboard the vessel with or without onshore facility support.

4.1.7 Smart Function Service

The Smart Function service (or SF service in this Guide) is a human-in-the-loop process that facilitates decision making for the SF system including actions related to anomaly detection, structural and machinery health diagnostics and/or prognostics.

SF service delivery is to follow established and quality-controlled procedures by qualified and competent staff. The SF service typically involves interaction and data exchanges with SF systems.

The service delivery component of SF implementation is covered under Section 7.

4.2 Smart Function Assessment

The Smart Function implementation described in 1/4.1 and Section 1, Figure 1, is to be independently assessed by ABS as outlined in 1/4.2.1 to 4.2.3 and summarized in Section 1, Table 3.

4.2.1 Function Assessment

Function assessment is the verification and validation procedure to confirm the capability and scope of the Smart Function satisfy the implementation goals.

The function assessment requires verification through engineering review and Surveyor validation through representative witnessing of functional achievement either at vendor site or on board the vessel and is covered by the technical requirements of Subsections 3/6, 4/6 and 5/7.

4.2.2 System Assessment

System assessment is the verification and validation procedure to confirm that the SF system hardware and software and its interaction and integration with onboard system(s) satisfies the system technical requirements of the appropriate risk level. The system assessment covers the following system properties:

- i) Suitability for marine environment
- ii) System integration and potential error propagation
- iii) System reliability, maintenance, integrity and security
- iv) Algorithm and model accuracy, system response time and capacity

The system assessment requires verification through engineering review and Surveyor validation via onboard installation survey and onsite manufacture survey.

Detailed technical requirements for system assessment on hardware, software, data, data analytics and model are summarized in Section 6 of this Guide.

4.2.3 Service Assessment

Service assessment is the verification and validation procedure to confirm the SF service supported by Quality Assurance/Quality Control (QA/QC) procedures and practices, personnel qualifications and competencies, to confirm that the service can be delivered consistently and reliably for its intended purpose.

Service assessment requires verification through engineering review and Surveyor validation via onsite audit. Detailed service assessment procedures and requirements are defined in Section 7 of this Guide.

TABLE 3
Smart Function Assessment

	<i>Intention</i>	<i>Applicable to</i>	<i>Assessment Method</i>	
			<i>Verification</i>	<i>Validation</i>
Function Assessment	Smart Function capability is defined and understood	SF capability and scope	Engineering review	Representative demonstration and/or functional test
System Assessment	System satisfies the technical requirements	SF system hardware, software (platform), algorithm, model, and data source	Engineering review	Onboard (onsite) Survey
Service Assessment	Service can be delivered consistently and reliably	Procedure, process, staff qualification and competency, QA/QC	Engineering review	Onsite audit, site/vessel validation by Surveyor

5 Guide Scope

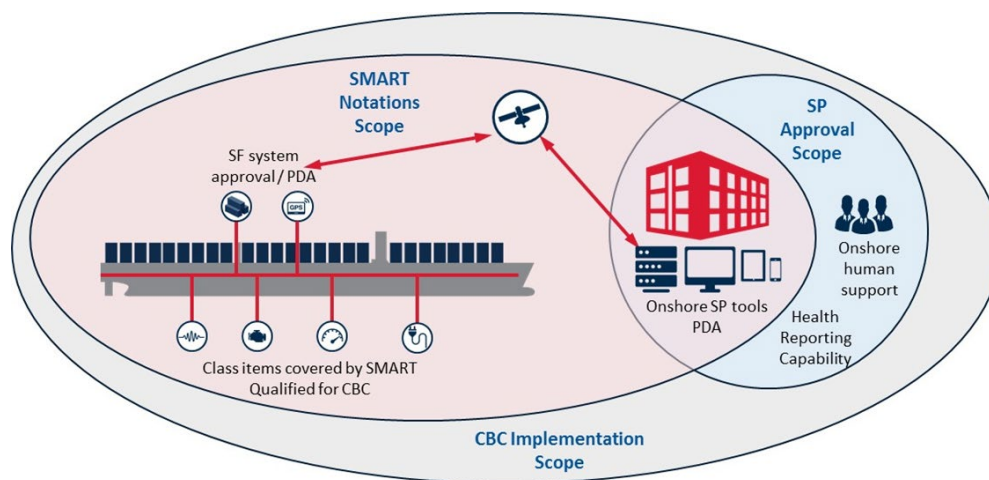
This Guide is applicable to all marine vessels and offshore units, herein referred to as vessels.

This Guide covers the SF categories SHM and MHM as defined in 1/3.3, within the scope of optional Smart Function class notations, **SMART (INF)**, **SMART (SHM)** and/or **SMART (MHM)**, SP approval, and PDA as described in Subsections 1/6, 1/7 and 1/8.

In order to keep this Guide concise, references in this Guide are made to requirements in the *ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* and *ABS Rules for Building and Classing Mobile Offshore Units (MOU Rules)*. Where the requirements are not stated for other vessel types, similar requirements will be applied. We recommend contacting ABS for clarification on applying these requirements to vessels not covered by the *Marine Vessel Rules* and the *MOU Rules*.

Section 1, Figure 2 demonstrates the relationship of hardware and software approval to notation achievement as well as the approval scope for Service Providers, and further illustrates the relationship of both these scopes to CBC implementation to support Survey after construction.

FIGURE 2
Class Scope for Smart Functions



5.1 AEM, OPM and CAA Functions

Smart Functions for AEM, OPM, and CAA as defined in 1/3.3 may be enabled by the optional Smart Function Notation **SMART (INF)**.

ABS may recognize these Smart Functions via the verification and validation process defined in the *ABS Guidance Notes for Qualifying New Technologies* while also considering the applicable requirements of this Guide, the *ABS Guidance Notes on Smart Function Implementation*, and other relevant ABS and industry standards.

Class Record Comments may be recorded as SMART (AEM), SMART (OPM), and/or SMART (CAA) to recognize that the corresponding function has been reviewed by ABS, approved for “System Integration” maturity, and installed on an ABS Classed vessel.

5.2 Semi-Autonomy and Full Autonomy

Functions operating at semi-autonomous or fully autonomous levels as defined in Subsection 1/2 are outside of the scope of this Guide. For such applications, use of the goal-based framework defined in Subsection 1/4 of this Guide is considered appropriate. ABS qualification of autonomous applications may require use of additional risk assessment via the New Technology Qualification (NTQ) as defined in the *ABS Guidance Notes on Qualifying New Technologies*.

Review and approval of semi-autonomous and autonomous functions are to be carried out on a case-by-case basis.

6 Class Notations

6.1 Smart Function Notations

The optional class notation **SMART (xx, yy, etc.)** is to be assigned to a vessel possessing a permanently installed SF system. The implementation is to satisfy the function assessment and system assessment as described in Section 1, Table 4.

The SF system can be installed during vessel construction or by retrofit.

The descriptive notation “**xx, yy, etc.**” can be any of the single notation, or a combination of the notations listed here.

INF:	Data INF rastructure for Smart Function implementation
SHM:	Structural H ealth M onitoring
MHM:	M achinery H ealth M onitoring

For example, **SMART (INF, MHM)** indicates a vessel with pre-installed data infrastructure and a machinery health monitoring Smart Function system.

The SF covered vessel structure/system/equipment (see Section 1, Table 2 for examples) and their corresponding Tiers (see Sections 4 and 5) are to be recorded in the vessel record notes.

TABLE 4
Requirements for Obtaining Smart Function Notations

<i>Notation</i>	<i>Applicable to</i>	<i>Task</i>	<i>Function Assessment</i>	<i>System Assessment</i>
INF, SHM, MHM	Smart Function system(s)	Verification	Functional requirements (Sections 3, 4, 5)	Technical requirements (Section 6)
		Validation	Onboard function test (Sections 8, 9)	Installation survey and Surveys after Construction (SAC) (Sections 8, 9)

6.2 Maintenance of Smart Function Notations

To maintain the optional Smart Function notations of 1/6.1:

- The SF system is to be kept properly maintained and operational. The survey after construction requirements described in Section 9 are to be met and the survey is to be conducted to the satisfaction of the attending Surveyor;
- Records of modifications, upgrades, and retrofits to the SF system, including both hardware and software, are to be kept onboard and made available to the attending Surveyor.

6.3 Change of Vessel Ownership

Sale, change of vessel management, or transfer of class will result in reconsideration by ABS of SF system approval, notations and class survey use.

7 Service Providers

ABS is to issue a certificate to approved Service Providers (SPs). SPs approved by ABS are listed on the ABS website so that the information is verifiable and available to the industry.

The SP approval covers SHM and/or MHM functions. The requirements for obtaining a SP approval are summarized in Section 1, Table 5. Refer to Section 7 of this Guide for the detailed procedure and requirements for SP approval.

TABLE 5
Requirements for Obtaining SP Approval

<i>SP Approval</i>	<i>Applicability</i>	<i>Task</i>	<i>Function Assessment</i>	<i>System Assessment</i>	<i>Service Assessment</i>
SHM, MHM	OEM, Third Party Service Companies, Shipyard, Owners and Operators that conduct Smart Function Operations	Verification	Functional requirements (Sections 4, 5)	PDA for hardware and software tools (Section 7)	Procedure/staff/quality requirements (Section 7)
		Validation	Representative service demonstration (Section 7)	Tool deployment onsite survey (Section 7)	Onsite audit (Section 7)

8 Type Approval Program

8.1 Product Design Assessment

ABS may issue a Product Design Assessment (PDA) for the below systems reviewed under the Type Approval program:

- System/equipment to deliver the Smart Function;
- Hardware and software that the SP uses for data handling, data analytics, and service delivery. The tool and platform can be designed and developed by the SP or by a third-party.

The PDA is to follow the ABS Type Approval Program; refer to Appendices 1-1-A3 and 1-1-A4 of the *ABS Rules for Conditions of Classification (Part 1)*.

8.2 Product Design Assessment Attachment

When the Smart Function product is provided by OEMs as part of their system/equipment, ABS may issue a PDA as an attachment to the approved system/equipment PDA. The approved Smart Function capability, scope, applicable risk level, and alternate survey approach are to be recorded in the PDA Attachment.

The PDA attachment to be issued is unique for individual system/equipment types.

9 Alternate Approach to Crediting Survey Requirements

Condition Based Class (CBC) is an ABS program that enables less intrusive surveys of hull and machinery systems through alternative means of verification of compliance to specific survey requirements. Alternative means of verification involves determining the vessel's health and maintenance status by leveraging data and digital capabilities such as but not limited to, Smart Functions, system automated and self-verification testing, remote inspection technologies, and remote verification and attendance through the ABS Remote Survey program.

Class items covered by Smart Function SHM and MHM may qualify for alternate means of crediting the required survey scope under Condition Based Class (CBC). This approach requires a Planned Maintenance System in accordance with the requirements of 7-A1-14 of the *ABS Rules for Survey After Construction (Part 7)*.

10 Submittal Requirements

Section 1, Table 6 below summarizes the documents to be submitted to ABS for the optional Smart Function class notations, Service Providers approval as well as PDA. Detailed description and requirements on these submittals are listed in Appendix 3. ABS may request additional submittals.

TABLE 6
Submittal Requirements

<i>Submittal Requirements</i>	<i>For SF Notation</i>	<i>For SP Approval</i>	<i>For PDA</i>	<i>Assessment Requirements</i>
<i>For Function Assessment</i>				
1. Concept of Operations	X	X	X	Sec. 3/4, INF Function Assessment Sec. 4/6, SHM Function Assessment Sec. 5/7, MHM Function Assessment Sec. 7/7, SP Approval
2. Smart Function Risk Level	X	X		
3. Smart Function Description	X	X	X	
4. Stakeholder Role Matrix for Implementation	X	X		
<i>For System Assessment</i>				
5. SF System Architecture	X	X*	X	Sec. 6, System Assessment (*) submittals to include system specification to cover applicable requirements of Sec 6
6. SF System Specification	X	X*	X	
7. Additional Specification for Medium and High Risk Levels	X	X*	X	
8. Installation and Commissioning Plan	X			Sec. 8, Installation and Commissioning Survey
<i>For Service Assessment</i>				
9. Organizational Capability		X		Sec. 7/7, SP Approval Sec. 8, Installation and deployment
10. Tool Development and Deployment Process		X		
11. Data Center Support		X		

11 Application of New Technologies

Smart Functions in marine and offshore applications are built upon information technology, data science, software, and cybersecurity. It is foreseen that as these evolve, new and alternative capabilities and technologies not yet described within this Guide may be implemented on board ABS Classed vessels.

ABS will accept new capabilities and technologies on a case-by-case basis following the goal-based framework and risk-informed approach established in this Guide, the *ABS Guidance Notes on Smart Function Implementation*, the *ABS Guidance Notes on Review and Approval of Novel Concepts* and the *ABS Guidance Notes on Qualifying New Technologies*.



SECTION 2 Risk Categorization

1 General

This Guide uses a risk-informed approach to set the prescriptive requirements for ABS verification and validation activities. The risk level is to be assigned by the submitter with consideration of the safety related risk factors and the potential consequences of the Smart Function failure or under-performance on the vessel's safety and operations.

Consideration of commercial risk is an important concept during a Smart Function implementation. However, a commercial risk assessment is not required to obtain optional Smart Function notations, SP approval, or PDA attachment, and thus is not within the scope of this Guide.

The requirements for system assessment as described in Section 6, are based on the Smart Function's risk level assigned by the process described in Subsection 2/2.

2 Assignment of Risk Level

Each Smart Function submitted to ABS for approval is to be assigned a risk level by the submitter based on the approach described below.

2.1 Likelihood of Failure

The likelihood of a Smart Function failure or under-performance is to be determined by:

- i) The complexity level of Smart Function system, service, and their integration and interaction (denoted as *SFN*)
- ii) The highest sophistication level of the data analytics and model employed (denoted as *SDA*)

The characteristics levels for the complexity level of Smart Function Network (*SFN*) and highest Sophistication level of Data Analysis method employed (*SDA*) are defined in Section 2, Table 1.

TABLE 1
Smart Function Likelihood Characteristics Levels

<i>Complexity Level of Smart Function System and Service (SFN)</i>	
0	Simple (Standalone system)
1	Simple Network (Partial integration with other systems, not all systems networked)
2	Complex Network (All networked and fully integrated, onboard access only)
3	Multi-Attribute Connected (Remote and onshore accesses, onboard function relies on onshore support and continuous and reliable vessel-onshore communication)
<i>Highest Sophistication Level of Data Analysis Employed (SDA)</i>	
0	Basic (Parameter monitoring, statistics and trending)
1	Physics Based Models and Traditional Condition Monitoring Techniques with Analytics Support
2	Data Driven Models (Machine learning and Artificial Intelligence (AI) models, with or without use of physics-based models)

The likelihood of Smart Function under-performance or failure is defined as the summation of the assigned levels of above key likelihood characteristics ($SFN + SDA$) and is represented by the three likelihood levels defined in Section 2, Table 2.

TABLE 2
Likelihood Levels of Failure or Under-Performance

<i>Likelihood Level</i>	<i>SFN+SDA</i>	<i>Example</i>
L (Low)	0, 1	Hull girder bending moment and slamming monitoring with strain gauges and accelerometers
M (Medium)	2, 3	Engine cylinder temperature and pressure monitoring with integrated thermal and pressure sensors
H (High)	4, 5	Voyage optimization (periodical weather forecast feeding, operational parameters collected from relevant onboard systems, data-driven fuel consumption model)

2.2 Consequence of Failure

The consequence level denotes the potential impact of the Smart Function failure or underperformance on the vessel safety and operation. The consequence level is influenced by the following three factors:

- i) The Smart Function level of Decision-making support (denoted as SFD)
- ii) The Smart Function Integration level with the onboard systems (denoted as SFI)
- iii) The System Category that the Smart Function integrates with (denoted as SC)

The decision-making support (SFD) and integration level (SFI) are defined in Section 2, Table 3.

TABLE 3
Smart Function Decision-Making Support and Integration Level

<i>Smart Function Level of Decision-Making (SFD)</i>	
0	Dashboard and Auto Reporting of Health, Performance, and Situational Awareness State
1	Decision Recommendations (Human take action)
2	Auto-Initiated Actions with Human's Supervision (Human in-the-loop)
<i>Smart Function Integration Level (SFI)</i>	
0	Standalone (Isolated from other systems, or passive listening only for data collection when integrated with onboard systems. No potential impact on the integrated system's safety and performance)
1	Partial (one-way data communication to the Smart Function with active data request. May cause performance degradation but there is no safety impact on the integrated onboard system)
2*	Fully Integrated (two-way communication with onboard systems with the potential sending commands to the systems for operational adjustment or optimization)

* Note: Auto-initiated actions ($SFD = 2$) typically require full integration level ($SFI = 2$).

When Smart Functions are integrated with vessel systems (usually via an interface to the computer-based systems for control and alarming), a failure of the Smart Function may propagate to the integrated computer-based system and therefore expose the vessel to risk.

System Category (SC) is defined in 4-9-3/Table 1 of the *Marine Vessel Rules* according to the potential extent of the damage that may be caused by a single failure within the computer-based system. This categorization, implemented in this Guide for marine vessels and offshore units, is shown in Section 2, Table 4.

TABLE 4
System Categories (SC)

<i>System Category</i>	<i>Effects of Failure</i>	<i>Typical System Functionality</i>
I	Failure will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment	Monitoring function for informational/administrative tasks
II	Failure could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	Alarm and monitoring functions Control functions which are necessary to maintain the ship in its normal operational and habitable conditions
III	Failure could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	Control functions for maintaining the vessel's propulsion and steering Vessel safety functions

Examples of assignment to system categories are shown in 4-9-3A2/5 of the *Marine Vessel Rules* and listed below. For similar system categories for other vessel types not listed below, refer to the applicable ABS Rules and Guides

i) Systems Typically Belonging to Category I:

- Maintenance support systems
- Information systems

ii) Systems Typically Belonging to Category II:

- Liquid cargo transfer control system
- Bilge level detection and associated control of pumps
- Fuel oil treatment system
- Ballast transfer valve remote control system
- Stabilization and ride control systems
- Alarm and monitoring systems for propulsion systems

iii) Systems Typically Belonging to Category III:

- Propulsion system of a ship, meaning the means to generate and control mechanical thrust in order to move the ship (devices used only during maneuvering, such as bow tunnel thrusters, are not in this scope)
- Steering system control system
- Electric power system (including power management system)
- Ship safety systems covering fire detection and fighting, flooding detection and fighting, internal communication systems involved in evacuation phases, and ship systems involved in operating lifesaving appliances
- Dynamic positioning system of equipment classes 2 and 3 according to IMO MSC/Circ.645 or MSC.1/Circ.1580
- Drilling systems

The consequence of a Smart Function failure or under-performance is defined by the below formula and represented by the three levels defined in Section 2, Table 5.

$$SFD + (SFI \times SC)$$

TABLE 5
Smart Function Failure – Consequence Levels

<i>Consequence Level</i>	<i>SFD + (SFI x SC)</i>	<i>Example</i>
L (Low)	0, 1	Hull girder condition monitoring (dashboard with installed strain gauges)
M (Medium)	2, 3, 4	Weather routing (route recommendations and passive data collection from relevant systems)
H (High)	5 and above	Power management and optimization (auto-adjusting engine operational parameters with certain range for best performance)

2.3 Risk Matrix

A risk matrix is to be utilized based on the level of likelihood and consequence described in 2/2.1 and 2/2.2, respectively, and as shown in Section 2, Table 6.

The risk matrix is to be utilized to assign a risk level (L: Low, M: Medium, H: High) to each of the Smart Functions implemented on each vessel.

TABLE 6
Risk Matrix

<i>Consequence Level</i>	<i>Likelihood Level</i>		
	L	M	H
L	L	L	M
M	M	M	H
H	M	H	H

3 Risk Assessment

For the Smart Functions that are assigned a high-risk level, a Functional Failure Modes, Effects and Criticality Analysis (FMECA) approach and Management of Change (MoC) process to address potential new risks to the vessel or unit are to be performed by the submitter. Based on the results of the functional FMECA, a component level FMECA is to be conducted when deemed necessary by ABS when:

- A particularly critical subsystem, hardware and software component, data source, algorithm and analytics model are identified during the functional FMECA;
- Critical functions with a risk level high are identified during the functional FMECA;

Standard engineering evaluation can be used to demonstrate compliance with the stated design philosophy in lieu of the component FMECA assessment for simple system and physics-based models. Use of a Standard engineering evaluation to replace the component FMECA assessment may be accepted upon approval by ABS.

3.1 Functional FMECA for Smart Functions

A Functional FMECA can be used to systematically identify and assess the potential risks to the vessel's safety and operation relevant to the Smart Function implementation.

3.1.1 Scope

The scope of the Functional FMECA is to include the risks associated with the Smart Function, including its hardware, software, data analytics and models, data integrity, cybersecurity, communication and interaction as well as its integration with onboard control and automation systems.

3.1.2 Objective

The objectives of the risk assessment are to at least include the following:

- i) Assess the impact of functional failure of the Smart Functions to the vessel's safety and operability by conducting criticality analyses;
- ii) Identify the failure modes and fail-safe state for the Smart Function system and actions required to reach the state under various operational modes;
- iii) Identify any hazardous situations originating from the Smart Function and the potential impact on other vessel systems through integration or interactions;
- iv) Evaluate if the existing safeguards are adequate and identify if additional safeguards are required to mitigate the risks for the design and operation of the Smart Function, when necessary.

3.1.3 Risk Factor

During the risk assessment, the following Smart Function risk factors are to be considered, as a minimum:

- i) The role of the Smart Function, in terms of decision support and decision making;
- ii) The complexity of the hardware, software, data analytics, algorithm and model;
- iii) The reliability of the hardware, software, network and data communication;
- iv) The redundancy of the onboard automation and control systems;
- v) Loss of power supply;
- vi) The uncertainty of analytics models, data, and data quality;
- vii) The accuracy and robustness of the algorithm and analytics models;
- viii) Data integrity, software quality and cybersecurity;
- ix) Operation errors and human factors;
- x) Potential integrity impacts on data;
- xi) Potential corruption from integration and interoperability issues (i.e., from software and system interface incompatibilities).

3.1.4 Risk Assessment Plan

A risk assessment plan is to be developed and submitted to ABS prior to conducting the Functional FMECA study. The risk assessment criteria for evaluation (i.e., risk matrix) is to be included within the risk assessment plan. ABS will review the risk assessment plan and confirm if the proposed study approach is satisfactory. Further guidance on the development of risk assessment plan can be found in the *ABS Guide for Risk Evaluations for the Classification of Marine-Related Facilities*.

3.2 Component Level FMECA

When required, the component level FMECA is to demonstrate that the Smart Function subsystems, hardware and software component, data source, algorithm and analytics model are designed so that no single failure will lead to an unsafe situation for the vessel and the vessel's primary functions in operation will not be lost or degraded.