RULES FOR
CLASSIFICATION OF

SHIPS

NEWBUILDINGS

SPECIAL EQUIPMENT AND SYSTEMS
ADDITIONAL CLASS

PART 6 CHAPTER 22

ENHANCED SYSTEM VERIFICATION (ESV)

JULY 2009

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DET NORSKE VERITAS

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INTRODUCTION

General

The Board approved this new chapter in June 2009.

The rules come into force on 1 January 2010.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

CONTENTS

SECTION 1
GENERAL

A. Classification

A 100   Rule application

101   The requirements of this chapter apply to vessels where specified onboard systems have undergone enhanced system verification (ESV). A class notation as specified in these rules can be assigned when one or more methods as addressed in these rules have been used for enhanced system verification on systems as specified in Table A1 of these rules.

> **Guidance note:**
>
> The requirements in this chapter apply to marine and offshore systems and cover test and verification methods that may be utilized to assist in verification of functionality and performance of such systems. The verification methods are aligned to be applied in conjunction with classification activities of systems at e.g. type approval, manufacturing survey, onboard testing, and on sea trial in order to provide additional evidence of expected and required functionality.
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102   The rules address specific test and verification methods as described in the following sections. Application of such methods shall provide additional objective evidence of functionality and quality during normal, abnormal and degraded condition in accordance with the relevant requirements.

> **Guidance note:**
>
> The objective is to analyse the specified target system by use of one or more verification methods as described in these rules in order to provide objective evidence of acceptable functionality and quality according to stated requirements. Application of any ESV verification or test method should provide an additional broader and/or deeper and/or earlier verification of the applicable requirements when compared to normal classification test activities required for the target system(s).
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103   In addition to the generic requirements given in these rules, functional requirements and any quality requirements for the stated system(s) shall be specified. In this context all main and additional class requirements applicable for the target system applies.

> **Guidance note:**
>
> Upon special agreement other rules and requirements may be made applicable if relevant. In the case that rules and requirements have conflicting requirements, such conflicts shall be clarified, concluded, and documented in each case.
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A 200   Class notations

201   Vessels built and tested in compliance with the requirements of these rules may be assigned the class notations for enhanced system verification shown in Table A1.

Table A1 Class notations	
ESV-DP[....]	vessels having undergone enhanced verification of dynamic positioning (DP) systems (Ch.7)
ESV-TAM[....]	vessels having undergone enhanced verification of thruster assisted mooring or automatic thruster assisted mooring (TAM) systems (DNV-OS-E301)
[....]	contain the verification method signifying the method of verification
HIL	= "Hardware-In-the-Loop" testing

> **Guidance note:**
>
> Example of the class notations is **ESV-DP[HIL]**.
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A 300   Alterations and additions

301   In case of alterations during the life cycle of the target system, it is the owner's obligation to inform the Society about changes made to the software and/or the hardware. The Society will consider the need for retesting and/or survey in connection with such alterations. Also refer to Pt.4 Ch.9 and Ch.7.

B. Definitions

B 100   Definitions

> **Guidance note:**
>
> General definitions can be found in the rules. Specific definitions can be found for control systems in Pt.4 Ch.9 and dynamic positioning systems in Ch.7.

101   *Control computer system:* A system consisting of at least one computer or processor with CPU processing and I/O capacity, and one or several operator stations. The control computer system includes also network, interface, and cabling for signal communication, and the HW/SW platform with the controllers containing both basis software and application specific software.

> **Guidance note 1:**
>
> The control computer system also includes control and management networks and interface used for integration with other control systems and decentralized command and/monitoring terminals.
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> **Guidance note 2:**
>
> The operator stations constitute the command and monitoring functionality of the control system, consisting usually of human-machine interfaces (HMI's), Visual Display Unit's (VDU's), alarm panels, joysticks, switches, printers, etc.
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102   *ESV:* Enhanced System Verification.

103   *Failure:* [IEEE610.12-1990] The inability of a system or component to perform its required functions within specified performance requirements.

104   *Failure mode:* [IEEE 610.12-1990] The physical or functional manifestation of a failure. For example, a system in failure mode may be characterized by slow operation, incorrect outputs, or complete termination of execution.

105   *Failure testing:* To test the functions of a target system by inducing relevant failures in the system in order to verify compliance with the stated requirements.

> **Guidance note:**
>
> This may be done by inducing relevant failures in the system or components connected to it, either simulated or real, and observing and reporting the effects of these failures on the behaviour of the target system.
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106   *Function:* [IEEE 610.12-1990] A defined objective or characteristic action of a system or component.

107   *Functional testing:* Testing functions of a system to ver-

ify compliance with the stated functional specification and requirements. The main objective is to reveal failures occurring in design, implementation, integration, and configuration.

108 *HIL:* Testing by "Hardware-In-the-Loop" simulation.

109 *HIL simulator:* A real-time simulator constructed by hardware and software, which is configured for the control system under consideration and interfaced to the target system or component through appropriate I/O. During testing with an HIL simulator the target system or component will not experience significant difference from being connected to the real system.

110 *HW:* Hardware (computer hardware).

111 *SW:* Software (computer software).

112 *Repeatability:* A test case is *repeatable* if the outcome of the specified test case for several test runs is unchanged.

113 *Target system:* An identified set of equipment with hardware and software that is subject to analysis, testing and verification.

114 *Testability:* The extent to which a test objective and feasible test can be designed to determine whether a requirement is met. Testability of a function in a system requires *controllability* and *observability* of that function:

— *Controllability:* A function in a system is controllable if for each possible behaviour of the function, i.e. each possible output data value, condition, or state, there exists a set of actions that can be applied to the inputs of the system such that the corresponding behaviour is achieved.
— *Observability:* A function in a system is observable if any arbitrary behaviour of the function can be determined from the outputs of the system.

115 *Test activity:* An activity for testing a specified target system according to a defined test scope and test program in order to partly or fully meet the overall objective of ESV. Test activities may range from testing of isolated modules or subsystems in laboratory conditions, testing of integrated modules, integration testing of complex systems consisting of equipment from many makers, to full-scale testing of an inte-grated control system.

Guidance note:
A test activity may be divided into one or several test sessions due to practical considerations of the availability of the target system. Typically, each test activity has a documented Test Program to be carried out in one or several test sessions.

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116 *Test package:* A test package normally consists of the following elements:

— one or several tool(s) for the specific testing or analysis to be carried out
— all documentation required for planning and approval of the specified testing to be carried out
— all documentation required for execution and reporting
— all analysis and test results including findings and conclusions.

Guidance note:
An HIL simulator may be the testing tool referred above.

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117 *Validation:* [ISO 9000:2000] Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

118 *Verification:* [ISO 9000:2000] Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled.

C. Documentation

C 100 General documentation related to Enhanced System Verification (ESV)

101 Systems subject to Enhanced System Verification shall be documented as for main class, relevant optional class notations and standards.

SECTION 2
HARDWARE-IN-THE-LOOP TESTING

A. General

A 100 Objectives

101 The objective of a Hardware-In-the-Loop (HIL) test is to test the specified target system by means of a Hardware-In-the-Loop simulator in order to provide objective evidence of acceptable functionality (during normal, abnormal and degraded condition) according to stated or implied requirements.

A 200 HIL test requirements

201 Functional requirements for the target system shall be referred and form the basis for the tests in the HIL test package. Reference is made to Sec.1 A201.

202 In order to obtain an **ESV** notation based on HIL testing, the tests shall comprise a minimum set of specified hardware components, software programs, and system functions. Typically, this shall include, but not be limited to the functions as specified below:

Table A2 Scope of verification	
Class notation	*Scope of verification*
ESV-DP[HIL]	All functions in computer hardware and software implemented in the dynamic positioning control system. Reference is made to rules for dynamic positioning systems.
	(Parts of the dynamic positioning control system as defined by the DNV rules, may not be included in the target system, E.g. reference systems and sensors.)
ESV-TAM[HIL]	All functions in computer hardware and software implemented in the system for thruster control. Reference is made to rules for position mooring.
	(Parts of the thruster assisted mooring control system as defined by the DNV rules, may not be included in the target system, E.g. reference systems and sensors.)

A 300 Class notation

301 Ships which have undergone HIL testing in compliance with requirements in this section, can be assigned the class notation as described in Sec.1 A201.

A 400 Requirements for the maker of the HIL test packages

401 The company which makes the HIL test packages shall be independent from the other involved parties.

Guidance note:
In general the following issues should be addressed, in order to verify the organisational independency of the HIL test package maker:

- the company should have testing and verification as one of its main activities
- involvement in the design and development process, in terms of delivering design propositions and solutions for the target system to be HIL tested
- independency with respect to personnel and technology
- ownership and other business relationships.

402 The HIL test simulator technology shall be based on other (diverse) technology than the target system technology. This means that:

— the HIL simulator shall be implemented by means of a separate hardware unit

— the HIL simulator application software shall be sufficiently diverse from the target system application software, and testing tools used in design and development of the target system.

403 The maker of HIL test packages shall have a documented quality management system.

Guidance note:
This may be a recognized system such as e.g. ISO 9001 or equivalent.

404 The quality management system of the HIL test package maker, shall have documented procedures for:

— operation as an independent maker of HIL test packages
— verification and validation
— preparation of HIL test packages including a statement of the intended use of the test packages
— preparation of the HIL test interface to the target system
— software development and software quality assurance
— maintaining special competence in the target system domain
— identification of hazards and risks related to HIL testing
— preparation of instructions for risk control measures to other involved parties
— preparation of reports, results evaluation, and retesting
— archiving of HIL test packages including reports with version control of tests carried out for specific vessels and systems during the system life cycle
— competence requirements and training for personnel involved in all phases of HIL testing
— requirements verification
— design and version control.

405 Upon request the maker of the HIL test package shall demonstrate and document that the procedures in the quality management system are applied in its HIL test package deliveries.

406 The Society shall be informed about organisational and technical dependencies. The Society may request documentation to verify independency.

B. Documentation

B 100 General

101 Documentation as listed in Tables B1 and B2 must be submitted for Enhanced System Verification by use of HIL testing.

102 Upon finalisation of the project, all the documentation in the HIL test package for the specific project shall be compiled in a complete HIL documentation report. This documentation report shall be submitted to the Society for information and filing.

Guidance note:
Normally the target system documentation received from the system vendor, is not required to be included in the complete HIL documentation report.

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103 A stamped copy of the complete HIL documentation report shall be stored onboard the ship.

Guidance note:
Generic technical documentation of the HIL test simulator tool as required by the Society may be excluded from the onboard documentation.

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Table B1 HIL package documentation required before HIL test activities			
Applicable system	Documentation type	Additional description	Documentation submitted for information (FI) or Approval (AP)
Vessel	Z040 - Vessel specification	Vessel system design intention and philosophy (e.g. redundant thrusters, power generation, and control systems)	AP
Control system	Z160 - Operation manual	Operational vessel system intention and philosophy (e.g. related to operational modes, redundancy, operational boundaries, and limitations)	AP
Control system	Z320 - Document register Z060 - Functional description Z120 - Test procedure at manufacturer Z140 - Test procedure for quay and sea trial	Test Plan. Test project overview. Test Package objective, and intended use. Overview of target system hardware, software and functions to be tested. Listing of target system functions to be tested. Specification or reference to functional requirements (e.g. reference to classification rules, configuration and technical specifications for the given ship, end user requirements, etc.). Test activity schedule (Typically a manufacturer survey and sea trials or other onboard testing). Risk assessment of planned testing. Emergency procedures for handling critical situations during testing. Responsibilities, resources, and approvals: — List of involved companies, name of contact person/title, contact information — Identification of test package and phase, (manufacturing survey, sea trials, or other onboard testing) — References to other test plans and reports. Procedures for the testing, verification, validation, and for handling of findings.	AP
HIL simulator	Z100 - Specification	HIL simulator configuration report (one for each HIL simulator to be used). Identification of HIL simulator hardware and software versions. Specification of the HIL simulator functionality. HIL simulator configuration. HIL simulator verification results.	AP
HIL simulator	Z250 - Procedure	HIL simulator operator manual (one for each HIL simulator to be used). Description of HIL simulator operation, providing information on: — user interface functionality — operation modes — operating instructions, and — presentation of trends and test log-files.	FI
HIL simulator	Z170 - Installation manual	Procedures for HIL simulator interfacing, test start-up, and test closure (one for each test activity e.g. manufacturing survey and sea trial). Description of test system configuration and test simulation methods. Specification of test interface of HIL simulator. Identification of HIL simulator hardware components and software versions. Identification of target system hardware components and software versions. Procedure and checklist for the interfacing process, test system start-up, verification of all interfaced IO signals, and verification of closed loop performance with HIL simulator. Procedure and checklist for disconnecting the HIL simulator and verification of correct re-instatement of normal target system functionality.	AP
Control system	Z120 - Test procedure at manufacturer Z140 - Test procedure for quay and sea trial	Test programs (one for each test activity e.g. manufacturing survey and sea trial). Listing of functions and failure modes to be tested and corresponding test cases. Based upon the functional description, each test case shall be described specifying: — test purpose — test setup — test method — expected results and acceptance criteria — space for notes and conclusions — signature from the tester — space for additional signature(s).	AP

Table B2 HIL package documentation required to be completed during and after the HIL test			
Applicable system, function or component	*Documentation type*	*Detailed description*	*Documentation submitted for information (FI) or Approval (AP)*
Control system	Z130 - Report from test at manufacturer Z150 - Report from quay and sea trial	Test reports (one for each test activity e.g. manufacturing survey and sea trial). Recorded results of each test case with signatures by tester and attending Society surveyor. Description of each finding from functional requirements as observed in any test case. These findings shall be recorded with sufficient detail to be followed up further. Any functions incomplete or not available for testing shall be recorded as a finding. After the HIL test activity, the test findings shall be reviewed and responsibilities for follow up shall be agreed. A due date for follow up by the nominated responsible shall be set.	FI
Control system	Z130 - Report from test at manufacturer Z150 - Report from quay and sea trial	Test summary report A summary of test activities, test results, and findings shall be compiled into a test summary report. Validation results of test package with respect to intended use of the test package. Each finding shall be described in a template containing the following information elements: — reference to the approved test package/plan and specific item (system, ship, version, date, test activity) — description of the finding, including an explanation of why it is a finding — recommended action or follow up — responsible party for following up corrective action — due date for completion of the action — conclusions and actions taken.	FI
Control system	Z290 - Record	HIL test notation document. When testing is completed and all findings are concluded an HIL test notation document shall be prepared. This shall contain a specification of: — the target system identification (hardware and software components, parts, serial numbers and software versions), and — reference to the functional requirements applied.	AP

C. Tests

C 100   General

101   HIL testing shall be carried out at the manufacturers works, and onboard the vessel. The HIL testing shall assure that the target system has been configured, and completed according to relevant functional specifications and requirements.

Guidance note:

HIL testing at the manufacturers works or onboard the vessel are the main sites where witnessing of the tests are assumed in the rules. However, upon agreement, other sites may be accepted. This also implies that e.g. tests planned at the manufacturers works could upon agreement be carried out at the dock or at a dedicated test laboratory. Parts of the on board testing may be accepted carried out during dock and/or quay trials

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102   All tests shall be according to test programs approved by the Society upfront the HIL test sessions. The Manufacturing Survey test program shall be prepared for testing of the target system at the manufacturers works. The onboard testing test programme shall be prepared for testing of the onboard installed target system. When deemed necessary by the attending surveyor, tests additional to those specified by the test program will be required.

103   Before the HIL test session and survey commences, an opening meeting should be arranged between the responsible parties. The following items should be clarified:

— responsibilities related to the HIL test session
— emergency procedures and responsibilities for potential hazardous situations during the HIL test session
— the test setup and objectives of the HIL tests to be carried out
— the schedule and sequence for carrying out the HIL testing.

104   The tests shall be performed according to the approved test programs in the HIL test package. The test results for each test shall be recorded. The conclusion of each single test shall be documented into the HIL test report.

105   Testing as described in 104, shall be carried out in the presence of a DNV surveyor. Upon special agreement, parts of the testing may be carried out without the presence of the surveyor. Each single test outcome shall be presented to the surveyor, if requested. The surveyor may request any test to be repeated. Due to this, the HIL test simulator shall not be disconnected before the surveyor has confirmed that no more testing will be requested to be witnessed in the current test session.

106   After an HIL test activity is completed, the complete set of results shall be compiled into an HIL test report. Each test or conclusion shall be documented and signed. In the case that some tests have become not applicable or is not possible to carry out or it is decided to postpone the tests to a later HIL test activity, such conclusions shall also be documented.

107   After the HIL test activity, a closing meeting shall be arranged between the responsible parties. The purpose of the meeting is to agree upon the findings from the testing. For each finding a responsible party for follow up within a set due date shall be agreed, documented, and signed as applicable.

108   The finding shall be categorised into class-related and non-class related. This categorization shall be approved by the Society.

Guidance note 1:
The class-related findings will be followed up by the Society as e.g. comments, conditions of class in the normal manner.

The non-class-related findings may be categorised by additional codes by the HIL test package maker. However, such findings will be required by the Society to be finally concluded before the **ESV** notation is issued.

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Guidance note 2:

Class-related findings will be given as comments and/or conditions as found necessary.

Non-class-related findings will be required to be finally concluded before the **ESV** notation is issued. These conclusions may e.g. be void, or no action. However, in case the conclusions imply changes to the system, these changes shall be approved.

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109 The conclusions from the closing meeting shall be documented in an HIL test summary report as described in Table B1. The HIL test summary report shall be distributed to all parties and the agreed actions shall be followed up.

110 After completion of an HIL test activity, the HIL test report shall be prepared. The HIL test report shall be submitted to the Society.

111 The personnel responsible for performing the HIL testing shall be qualified according to the quality requirements in A404. Documentation of completed training shall be available on the Society's request.

Guidance note:

The HIL testing may be carried out by personnel from e.g. the maker of the HIL test package, the system manufacturer, the yard, the vessel owner, or a marine consultant.

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C 200   Manufacturing survey

201 HIL testing at the manufacturer works shall be carried out based on an approved HIL test package.

202 The HIL testing at the manufacturing survey shall verify closed loop functionality and response of the target system when connected to the HIL simulator. Both normal, degraded and abnormal operation shall be simulated.

203 After successful HIL testing at the manufacturer works, an HIL test certificate can be issued to the target system.

Guidance note:

The HIL testing at the manufacturers works may, upon agreement, be combined with other certification activities.

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204 The HIL Test Certificate must specifically identify the target systems that have been tested, by listing of specific HW type, serial numbers, and specific SW version identification. References to the specific HIL test package and HIL test report shall also be provided.

Guidance note:

The HIL testing at the manufacturers works may, upon special agreement, be carried out on replica hardware.

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205 The HIL testing at the manufacturer works may be limited in test scope or omitted when the target system is HIL Type Approved.

Guidance note 1:

The requirement to the scope of the HIL testing at the manufacturer works will be based on the total system functionality and the degree of configuration and customisation for the specific target system delivery.

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Guidance note 2:

The certification requirements according to main class require-

ments and other optional class notations will not be omitted based on HIL Type Approval.

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206 For an HIL Type Approval to be valid, the delivered hardware and software must be covered by the HIL Type Approval Certificate.

Guidance note:

This means that the HIL Type Approval certificate will specify the hardware components and the software versions. Note that the HIL Type Approval certificate, does not imply that the hardware in itself is type approved and tested according to the DNV Standard for Certification of 2.4 or other standards stating environmental requirements. However, relevant environmental requirements will always apply.

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C 300   Onboard testing

301 HIL testing of the installed target systems onboard the vessel shall be carried out based on an approved HIL test package in order to assure that the target system has been configured, and installed according to relevant functional specifications and requirements for the vessel.

302 The HIL testing shall verify normal closed loop functionality and response of the total system upon normal, degraded and abnormal operation.

Guidance note:

The requirement for normal closed loop functional testing, may in some cases give situations which are harmful to the equipment under test. The requirement for closed loop functionality may upon special consideration be omitted and/or replaced by other types of testing.

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303 The target system and other possible influenced systems, shall be re-instated and set back to normal operational mode after completion of the HIL testing.

D. HIL Test-packages

D 100   General

101 An HIL test-package is a test-package including HIL simulator(s) as testing tools and all documentation required for description and reporting of the HIL testing.

102 The HIL test-package shall refer to the specific functional requirements to the target system which has formed the basis for the HIL test scope. Reference to these functional requirements shall be stated in the HIL test notation document.

103 The applicable parts of the HIL test-package documentation shall be prepared for serving as working documents during the HIL tests.

104 The intended use of the HIL test-package shall also be stated. The intended use statement shall give directions for the HIL test scope.

Guidance note:

The intended use of the HIL test-package may be to verify specific functional requirements for a specified type of future vessel operation. The intended use may also include statements of methods for selection of the verification and test scope.

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105 The HIL test-package shall describe the target system and possible interfaced systems as necessary.

Guidance note:

The required documentation for the HIL test-package can be found in Table B1 and Table B2.

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106 The HIL test-package shall contain test cases related to the normal, degraded and abnormal operation of the target and simulated systems. Normally single and common failure modes and common components should be extensively analysed and tested. Multiple failures should be tested if found relevant.

Guidance note 1:

Operation in all normal modes and transfer between operational modes and the corresponding functional requirements, should be the basis for establishing the HIL test scope. In addition, failure testing is also to be included in the test scope. General types of failures to be simulated could be, but not limited to:

- sensors or input devices failure modes (dropout, noise, calibration errors, drift, bias, signal freeze, wild point,…)
- failure mode of actuators, drives, power system components or other electro-mechanical components
- feedback from sensors on actuator failure modes
- failure modes in computer networks
- failure modes related to overload of networks
- failures affecting weighting and voting mechanisms
- failures affecting protective safety functions
- failures affecting alarms, monitoring, and analysis functions
- failures causing and/or otherwise affecting switch-over in redundant systems
- common mode failures affecting several components and/or signals
- emergency handling (special emergency functions required during emergency handling could be tested)
- reconstruction of relevant reported failures/incidents related to the system and/or operations.

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Guidance note 2:

When establishing the HIL test scope, verification planned to be carried out by other methods (e.g. FMEA), should be considered. The purpose should be to give input to the HIL test scope and to align the execution of the tests in an efficient manner.

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107 Testing shall be performed for all relevant operational modes of the target system. The need for testing in different operational modes of relevant equipment and systems connected to the target systems shall also be evaluated.

108 The Society shall approve the relevant parts of the HIL test-package upfront each HIL test activity. The approval will in addition to these rules also be based on the specified functional requirements for the target system.

D 200 Risk assessment

201 A risk assessment for each test activity shall be a part of the HIL test-package.

Guidance note:

The intention is to ensure that the responsible parties have addressed that there may exist possible hazards and risks related to HIL testing and that sufficient overall actions for emergency handling have been planned and agreed. Items which typically should be considered if appropriate:

- specification of equipment to be tested
- specification of personnel required for the HIL testing
- specification of required environmental conditions during the HIL test
- hazard identification for the equipment during the HIL test operation
- hazard identification (personnel safety) for the personnel during HIL testing
- hazard identification for the ship and the ship environment
- availability of an emergency procedure for handling possible hazardous situations.

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D 300 Verification and validation

301 The HIL test-package shall contain procedures for verification and validation of the configured HIL simulator. The scope of verification and validation shall be based on the specific intended use of the HIL testing.

302 Functional suitability and accuracy of the simulator shall be documented according to procedures (ref. 301) in order to ensure sufficiently accurate and valid test results. This must as a minimum include:

— verification tests to document that the simulator functions are correct and sufficiently accurate
— validation tests to document that the functional suitability of the simulator is according to the intended use of the HIL testing.

Verification and validation activities and/or assessments shall be documented in the HIL test summary report as required in subsection B.

Guidance note:

The key element for planning the validation activities is to analyse the intended use statement and identify possible critical factors/elements in the simulator/test package which may leave the test results not representative. A set of relevant validation activities for the HIL simulator and HIL test package should be identified and measures for limiting possible inaccuracies and uncertainties should be described.

In case the objective of the HIL testing is to test the qualitative behaviour of functions and failure handling, it must be validated that the accuracy of the simulator is sufficient to obtain testability of the target functions.

If, on the other hand, the objective of the HIL testing is to test both the qualitative and quantitative behaviour of functions in the target system, it must be validated that the performance of the simulator is sufficiently accurate and realistic to assess the target system performance. It is recognized that some validation tests can only be carried out by full-scale trials. In order to collect information supporting the correctness of the simulator such validation tests are advised.

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