BUREAU VERITAS
MARINE & OFFSHORE

NI 641 – Guidelines for Autonomous Shipping
Revision 01 – October 2019

INAS WORKSHOP – TRONDHEIM

JÉRÔME FAIVRE – NOVEMBER 12TH 2019

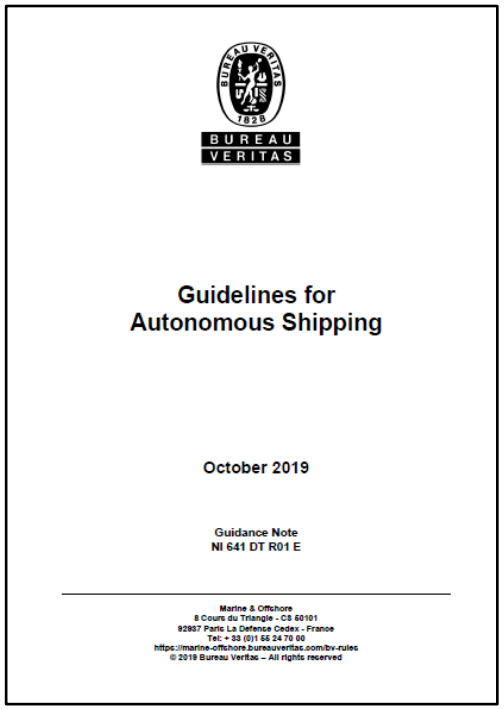
NI 641 – REVISION 01 – OCTOBER 2019

Guideline for Autonomous Shipping
NI 641 – December 2017

→ **More than 140 comments received**
from clients, manufacturers, flags, BV network

Draft April 2019

shared internally and externally on 04/2019
→ **More than 100 new comments considered**



NI 641 – Revision 01
October 2019

http://erules.veristar.com/dy/data/bv/pdf/641-NI_2019-10.pdf

NI 641 – BV APPROACH

General

Scope & definitions
General requirements about Safety & Security
Rules & Regulations

Risk and technology assessment

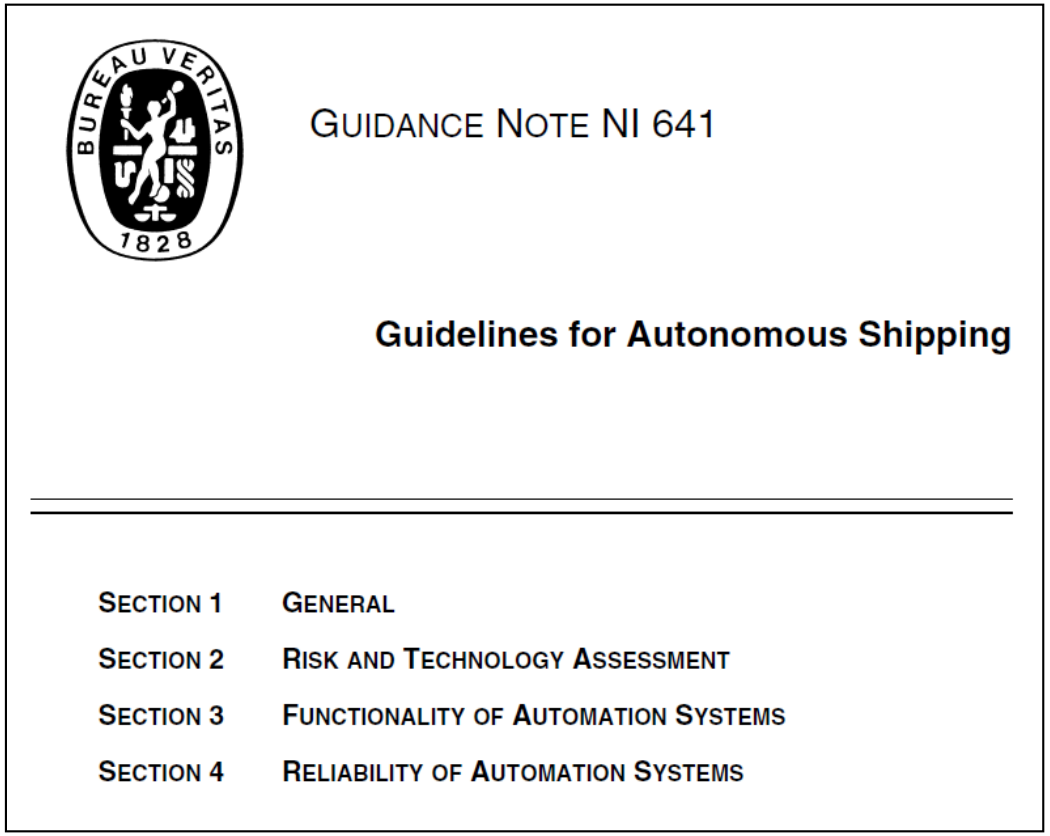
Risk identification and mitigation for autonomous ships

Functionality of autonomous systems

Minimum level of functionality for essential systems
Goal based recommendations

Reliability of autonomous systems

Recommendations on design and **level of performance**
Quality assurance methodology



GUIDANCE NOTE NI 641

Guidelines for Autonomous Shipping

NI 641 – SCOPE

INCLUDED

- **Design and operations of ships equipped with automation systems** and their associated **remote control centres** (if any)
- Applicable to a **specific automation system** or to a **ship** as a whole
- **small units** not more excluded

EXCLUDED

- exclusion limited to **underwater vehicles** and **non-manoeuvring units**, such as drifting buoys used for scientific researches

1.2.2 The recommendations of this Guidance Note are related to the design and operations of ships equipped with automation systems capable, to varying degrees, of making decisions and performing actions with or without human interaction, and their associated remote control centres if any.

1.2.3 This Guidance Note could be applied to a specific automation system, such as for example a navigating automation system or a remote engine control system, or to a ship as a whole.

1.2.4 This Guidance Note is mainly focused on surface propelled units. This excludes underwater vehicles and non-manoeuvring units, such as drifting buoys used for scientific research.

NI 641 – STATUTORY FRAMEWORK

- **Statutory framework**
  addition of a specific paragraph

1.2.5 This Guidance Note provides also recommendations on the statutory requirements deemed applicable for ships covered by this Guidance Note, see in particular [3].

These recommendations are intended as a reference for designers, shipyards, manufacturers, shipowners and Administrations in order to help in the definition of the statutory framework applicable to these ships.

The application of this Guidance Note does not relieve the Interested Party from compliance with any requirements issued by Administrations.

NI 641 – WORDING

- **“Remote Control Centre (RCC)”**
  - the Remote Control Centre (RCC) is outside the ship and can be onshore or on another ship or offshore unit
- **“Crew”** --> aboard
- **“Operators”** --> in the RCC

Remote Control: control of an operation at a point distant from the controlled device, using the transmission of information by telecommunications techniques.

Remote Control Centre: area located onshore or on another ship (conventional ships included) or on an offshore unit from which the monitoring and control the ship is exercised.

Crew: all persons carried aboard the ship to provide navigation and maintenance of the ship, its machinery, systems and arrangements essential for propulsion and safe navigation or to provide services for other persons aboard (IMO Resolution MSC.266(84)).

Operators: all persons in the remote control centre to provide remotely navigation and maintenance of the ship, its machinery, systems and arrangements essential for propulsion and safe navigation or to provide remotely services for other persons aboard.

NI 641 – DOCUMENTS TO BE SUBMITTED

- **Addition of documents to be submitted**

1.11.1 At the request of the designer, shipyard, manufacturer and/or owner, the Society may review the design of a ship according to the content of this Guidance Note.

1.11.2 For this purpose, the documents that should be submitted in the scope of this review are listed in Tab 3.

Topic	Plans and documents to be submitted
Classification	Plans and documents to be submitted according to Society Rules in the scope of the classification of the ship and relevant to the service notation applied for
Additional class notations	Plans and documents to be submitted according to Society Rules in the scope of the additional class notations as specified in this Guidance Note, see Sec 3, [2.3.1], Sec 3, [4.3.1], Sec 3, [5.3.1] and Sec 4, [7.1.1]
Operational limitations	Details of parameters to which the crew or operators must refer for the control of the ship, see [2.3]
Identification	Details of provisions for identification, see [2.4]
Interactions	Details of provisions for interactions, see [2.5]
Automation systems	Detailed specification of all automation systems, including: • Specification of the Navigation system, see Sec 3, [2] • Specification of the Communication network and system, see Sec 3, [3] • Specification of the Machinery system, see Sec 3, [4] • Specification of the Cargo management system, see Sec 3, [5] • Specification of the Passenger management system, see Sec 3, [6] • Specification of the Remote Control Centre, see Sec 3, [7] These specifications should clearly specify for each function the distribution of roles and responsibilities between the human and the system, see [2.6] and [1.8.2]
Risk assessment	Detailed risk assessment report including: • Groups of functions considered, see Sec 2, [2.2] • List of hazards considered, see Sec 2, [2.3] • Risk analysis outcome, see Sec 2, [2.4] • Risk Control Options considered, see Sec 2, [2.6]
Technology assessment	Detailed technology assessment report, if applicable, see Sec 2, [3]
Reliability	Details of provisions for improving the reliability of systems including: • General system design, see Sec 4, [2] • Human machine interface, see Sec 4, [3] • Network and communication, see Sec 4, [4] • Software quality assurance, see Sec 4, [5] • Data quality assurance, see Sec 4, [6] • Cybersecurity, see Sec 4, [7]
Testing	Detailed tests specifications and reports, including: • Software tests, see Sec 4, [8.1] • Simulation tests, see Sec 4, [8.2] • Full scale tests, see Sec 4, [8.3] All tests reports should include the targeted objective, the followed procedure, the expected results and the outcome achieved
Pollution	Details of provisions for preventing pollution, see [3.4]
Recycling	Details of provisions for recycling, see [3.10]

NI 641 – DEGREES OF AUTOMATION

- **Degrees of automation**
  addition of a specific subarticle

1.8.1 The degree of automation represents the degree of decision making (authority) deferred from the human to the system.

1.8.3 A degree of automation Ax (x from 0 to 4) should be defined for each automation system.

1.8.4 Several different degrees of automation could be considered for the duration of a single voyage.

1.8.6 A global degree of automation GAx (x from 0 to 4) of a ship should be defined considering the lowest degree of automation of main systems covering essential services (see Sec 2, [2.2.1] and Sec 3).

NI 641 – DEGREES OF AUTOMATION

Degree of automation		Manned	Definition	Information Acquisition	Information Analysis	Authority to make decisions	Action initiated by
A0	Human operated	Yes	Automated or manual operations are under human control. Human makes all decisions and controls all functions.	System Human	Human	Human	Human
A1	Human directed	Yes/No	Decision support: system suggests actions. Human makes decisions and actions.	System	System Human	Human	Human
A2	Human delegated	Yes/No	System invokes functions. Human must confirm decisions. Human can reject decisions.	System	System	Human	System
A3	Human supervised	Yes/No	System invokes functions without waiting for human reaction. System is not expecting confirmation. Human is always informed of the decisions and actions.	System	System	System	System
A4	Full automation	Yes/No	System invokes functions without informing the human, except in case of emergency. System is not expecting confirmation. Human is informed only in case of emergency	System	System	System	System

NI 641 – DEGREES OF CONTROL

- **Degrees of control**
  definition of degree of availability of crew or operators operating the ship aboard or remotely

1.9.1 The degree of control represents the degree of availability of human operating the ship aboard (crew) or remotely outside the ship from a remote control centre (operators).

1.9.2 A degree of direct control DCy (y from 0 to 3) and remote control RCz (z from 0 to 3) should be defined for each automation system.

1.9.3 Several different degrees of control could be considered for the duration of a single voyage.

1.9.5 A global degree of direct control GDCy (y from 0 to 3) and remote control GRCz (z from 0 to 3) of a ship be defined according to the lowest degrees of direct control and remote control of main functions covering essential services (see Sec 2, [2.2.1] and Sec 3).

NI 641 – DEGREES OF CONTROL

Degree of control			Human presence	Location of control station
Direct control	DC0	No direct control	No crew available to monitor and control the system, nor to take control in case of warning or alert.	(1)
	DC1	Available direct control	Crew available aboard, ready to take control in case of warning or alert But they may be not at the control station	Aboard
	DC2	Discontinuous direct control	Monitoring may be discontinuous during a short period Crew always available at the control station, ready to take control	Aboard
	DC3	Full direct control	System is actively monitored and controlled at any time	Aboard
Remote control	RC0	No remote control	No operator available to monitor and control remotely the system, nor to take control in case of warning or alert.	(1)
	RC1	Available remote control	Operators available in the RCC, ready to take control in case of warning or alert But they may be not at the remote control station	RCC
	RC2	Discontinuous remote control	Remote monitoring may be discontinuous during a short period Operators always available at the remote control station, ready to take control	RCC
	RC3	Full remote control	System is actively monitored and controlled remotely at any time	RCC
(1) See also [2.8.3]: there may not be any integrated control station				

NI 641 – SYSTEM CHARACTERISATION

- **Characterisation**
  addition of a specific subarticle

  Any **system** should be characterised by:

  - a **degree of automation Ax**
    (x from 0 to 4)
  - a **degree of direct control DCy**
    (y from 0 to 3)
  - a **degree of remote control RCz**
    (z from 0 to 3)

1.10.1 Any system covered by the present Guidance Note should be characterised by:

- a degree of automation Ax
  (x from 0 to 4), see [1.8]
- a degree of direct control DCy
  (y from 0 to 3), see [1.9]
- a degree of remote control RCz
  (z from 0 to 3), see [1.9]

1.10.2 For example, a "human supervised" Navigating Automation System (see [1.8.5]) with available direct control and no remote control (see [1.9.4]) would be characterized by the following terminology:

A3 DC1 RC0

NI 641 – SHIP CHARACTERISATION

- **Characterisation**
  addition of a specific subarticle

  Any **ship** should be characterised by:
  - a **global degree of automation GAx** (x from 0 to 4)
  - a **global degree of direct control GDCy** (y from 0 to 3)
  - a **global degree of remote control GRCz** (z from 0 to 3)
  - a **navigation notation**

1.10.3 Any ship covered by the present Guidance Note should be characterised by:

- a global degree of automation GAx (x from 0 to 4), see [1.8]
- a global degree of direct control GDCy (y from 0 to 3), see [1.9]
- a global degree of remote control GRCz (z from 0 to 3), see [1.9]
- a navigation notation, see [1.7]

1.10.4 For example, a "human delegated" unmanned ship (see [1.8.5]) with no direct control and discontinuous remote control (see [1.9.4]) and intended to operate in any area and any period of the year would be characterized by the following terminology:

GA2 GDC0 GRC2 unrestricted navigation

NI 641 – OPERATIONAL LIMITATIONS

- **Addition of operational limitations**
  - to which the crew or operators **must refer for the control** of the ship
  - **to be specified by the designer, shipyard and/or manufacturer**

2.3.1 The operational limitations of a ship are parameters to which the crew or operators must refer for the monitoring and control of the ship.

2.3.2 It is the designer, shipyard, manufacturer and/or ship-owner responsibility to specify these limitations in order to define the conditions under which the ship is to be operated.

2.3.3 The operational limitations should at least refer to the following parameters:

- degree of automation
- degree of control
- navigation notation
- Administration's national regulations, if any
- local legislation, if any
- traffic conditions, if any
- deadweight and assigned freeboard
- minimum ballast draught
- maximum service speed
- design loads on decks, hatch covers and double bottom
- density of cargoes
- situational awareness system characteristics
- navigation system characteristics
- communication system characteristics
- machinery system characteristics
- cargo management system characteristics
- passenger management system characteristics
- distributions of roles and responsibilities.

NI 641 – TESTING

- **Testing:** requirements about
  - **Software** testing
  - **Simulation** testing
  - **Full scale** testing

8.1 Software testing

8.1.1 The software modules of the application software should be tested individually and subsequently subjected to an integration test. It should be checked that:

- the development work has been carried out in accordance with the quality plan
- the documentation includes the method of testing, the test programs producing, the simulation, the acceptance criteria and the results.

8.1.2 Software module tests should provide evidence that each module performs its intended function and does not perform unintended functions.

8.1.3 The behaviour of a machine-learning system is dependent on the training set used during the learning phase of the system. It is recommended to use an extensive training set in order to cover a maximum number of potential situations.

The consistency of the behaviour of a machine-learning system should be tested (repeatability). In particular to be sure that after a long period, the behaviour of the system is not modified and is always responding in the same way.

When testing a machine-learning system, the test data should include some exceptional conditions, in order to validate the behaviour of the system and to detect any deviation from the expected behaviour.

8.1.4 System or subsystem testing should verify that modules interact correctly to perform the functions in accordance with specified requirements and do not perform unintended functions.

8.1.5 Repetition tests should be required to verify the consistency of test results.

8.1.6 Faults should be simulated as realistically as possible to demonstrate appropriate software fault detection and software response.

8.2 Simulation testing

8.2.1 The aim of the simulation tests is to demonstrate by virtual means (simulation) the safe operations of any ship covered by this Guidance Note and associated RCC if any.

8.2.2 Tests should be defined in order to cover all expected operating scenarios and should address the following topics:

- Functionality:

  All functionalities of systems associated to essential services should be tested.
- Performance:

  Performance assessment criteria should be defined beforehand.
- Failure resiliency:

  All hazards identified in the risk assessment (see Sec 2, [2]) should be simulated in order to confirm the resiliency of systems associated to essential services.

8.2.3 Hardware-in-the-loop (HWIL) testing could be considered for checking proper working of any embedded control systems: refer to the requirements of Society Rule Note NR632, Hardware-in-the-loop Testing.

8.3 Full scale testing

8.3.1 The results of all simulation tests as specified in [8.2] are to be verified as far as feasible by full scale testing during sea trials.

8.3.2 Full scale testing should be done in a specific tests area approved by the Administration.

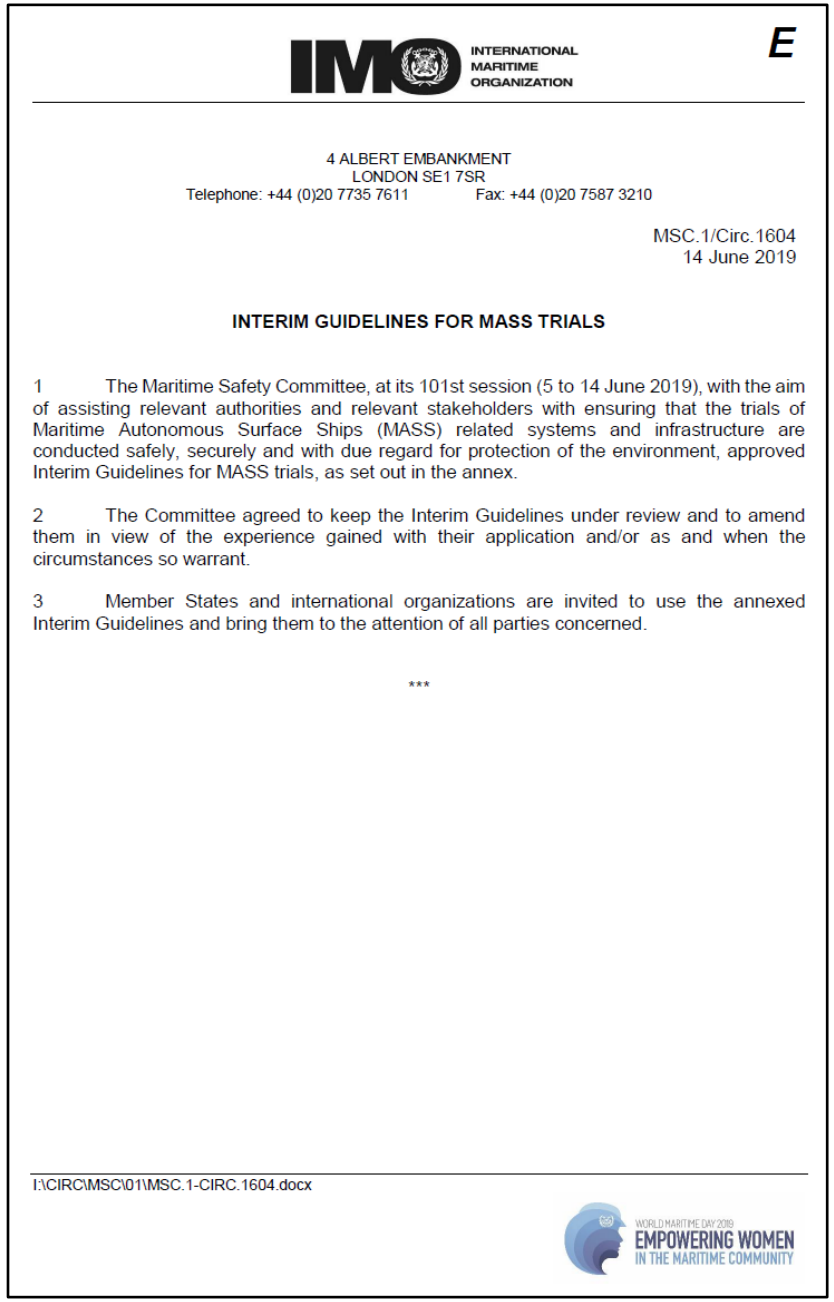
8.3.3 See also Sec 1, [3.3.3] about the IMO Interim Guidelines for MASS trials MSC.1/Circ.1604.

NI 641 – TRIALS

- **Trials:**
  - Reference to the IMO Interim Guidelines for MASS trials

3.2.3 Interim Guidelines for MASS trials

IMO Maritime Safety Committee MSC 101 (06/2019) approved the "Interim Guidelines for MASS trials", with the aim of assisting relevant authorities and relevant stakeholders with ensuring that the trials of Maritime Autonomous Surface Ships (MASS) related systems and infrastructure are conducted safely, securely, and with due regard for protection of the environment.



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MSC.1/Circ.1604
14 June 2019

INTERIM GUIDELINES FOR MASS TRIALS

1 The Maritime Safety Committee, at its 101st session (5 to 14 June 2019), with the aim of assisting relevant authorities and relevant stakeholders with ensuring that the trials of Maritime Autonomous Surface Ships (MASS) related systems and infrastructure are conducted safely, securely and with due regard for protection of the environment, approved Interim Guidelines for MASS trials, as set out in the annex.

2 The Committee agreed to keep the Interim Guidelines under review and to amend them in view of the experience gained with their application and/or as and when the circumstances so warrant.

3 Member States and international organizations are invited to use the annexed Interim Guidelines and bring them to the attention of all parties concerned.

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