DYNAMIC POSITIONING CONFERENCE
October 09 - 10, 2018

REGULATORY SESSION

D-Class

Data smart Classification

By Aleks Karlsen

DNV GL

Abstract

The industry has throughout the years developed the current practices for verification of DP systems. For operational vessels, this traditional way of doing verification can represent a significant verification burden.

With the increasing digital capabilities, new methods for doing verification can be developed. These methods are expected to be able to support a more flexible and less invasive survey scheme. The goal is to provide increased safety, in a more efficient verification scheme.

It is also anticipated that new verification technology can be incorporated as more integral parts of DP systems. When such functions can be accepted to provide, genuine and tamper-proof verification information, the verifier may use this information to be able to perform objective considerations towards the specified acceptance criteria, in a more effective manner.

The objective with the D-Class project is to set requirements for, verification of DP systems based on modern digital technology, enabling an improved and less invasive classification scheme. Pilot testing of new technology is a part of the project.

The objective builds upon the principles of ensuring that systems are designed to be verified, and on incorporation of verify-on-demand capabilities. When in place, such capabilities can assist in ensuring that systems and vessels are safe to operate.

Content

Abbreviations and Definitions

term	*description*
AI	Artificial Intelligence
Algorithm-based Verification Agent (AVA)	An algorithm with a dedicated role, purpose, function, and responsibility (i.e. agent) in conducting verification (i.e. generating evidence) by interacting with the target system through an interface.
Assurance	grounds for justified confidence that a claim (requirement) has been achieved
Assessment	validation of evidence properties such as correctness, relevance, capability, quality, integrity
Cyber security	Practices, tools and concepts that protect: • the operational technology against the unintended consequences of a cyber incident; • information and communications systems and the information contained therein from damage, unauthorised use or modification, or exploitation, and/or • against interception of information when communicating and using internet
Data	Symbolic representation of something that depends, in part, on its metadata for its meaning, ref.ISO 8000-2
Data accuracy	Composite of trueness and precision, ref. ISO 5725-1
Data completeness	Quality of having all data that existed in the possession of the sender at time the data message was created, ref.ISO 8000-2 *Alt*: Completeness of data is the extent to which (i) the relevant data sets, (ii) the expected records of a data set, and (iii) data elements, attributes, and values in a data set are provided and reflect the scope and the real world.
Data precision	The closeness of agreement between independent test results obtained under stipulated conditions, ref. ISO 5725-1
Data set	Logically meaningful grouping of data, ref. ISO 8000-2.
Data trueness	The closeness of agreement between the average value obtained from a large series of test results and an accepted reference value, ref. ISO 5725-1
Data quality management	Coordinated activities to direct and control an organisation with regards to data quality, ref. ISO 8000-2
Deficiency	A failing or shortcoming with respect to applicable requirements.
DP verification program	A program encompassing all DP verification activities. The system shall organize and keep track of all DP verification activities, including when, what and how to test and keep an historic record of all results. The program may be built up of smaller blocks/methods, but shall be organized so that it is keeps track of the verification activities for the complete DP system.
Evidence	Information elements, such as test results, used in the assessment supporting that the system complies to the requirements
FMEA	Failure Mode and Effect Analysis
Metadata	Data that describes and defines other data, ref. ISO 8000-2
Self-verifying-system	A system which has built in functionality which can provide evidence that a specified set of requirements are complied with
Validation	The process of providing evidence that the system, software, or hardware and its associated products satisfy requirements allocated to it at the end of each life cycle activity, solve the right problem, and satisfy intended use and user needs
Verification	The process of providing objective evidence that the system, software, or hardware and its associated products conform to requirements

Verification activity responsible	The company responsible for carrying out the verification and delivering the verification information to the society
Verification method	The method used to gather information (e.g. data) which are used for the assessment of system towards stated or implied requirements
Verification method design responsible	The company responsible for design of the verification method and/or functionality

Introduction

Dynamic positioning systems are designed with varying degrees of robustness towards loss of position in case of failures. This built-in robustness is typically guided by rules and industry standards, and on top of this, vessel specific design properties. Generally, operators aim to choose a design with a built-in robustness that matches the risk involved in the industrial mission being carried out. For this approach to be successful, it is instrumental that the intended robustness is in place at the anticipated level.

The maritime industry has throughout the years developed practices for how to verify and document that the intended robustness is achieved during the design and building phase, and that it is maintained during a vessels operational life span. An important part of this is classification rules, both the new building design rules and the rules for verification of vessels in service. Until today the methods used for this verification have normally required class to be present at pre-determined calendar based intervals to witness that the required verification activates are being performed in the correct manner and to observe the results of these activities.

This is typically the case for operational vessels, where the traditional way of doing assurance requires that the class surveyor, often in addition to other experts, like DP FMEA consultants and equipment vendor experts, are visiting the vessel in order to witness verification activities within predefined time windows. Normally this requires that the vessel is taken out of its normal operations to perform verification trials. For a vessel with redundant DP class notations such trials may take several days and can represent a significant burden.

Digitalization has been ongoing in the maritime industry for many years, and this process has from its early beginning been and is still accelerating. This development provides increasing digital capabilities designed into equipment and systems. and in conjunction with increasing connectivity between vessel and shore, it is understood that new methods for doing verification can be developed. Such new methods are expected to be able to support more flexible and efficient classification schemes. It is anticipated that the new technologies can be used to develop effective verification and test functionalities which can be incorporated as integral parts of the DP system. When such functions can be accepted to provide a genuine and trustworthy body of evidence, it is the intention that the class society may include this evidences as part of its assessment towards the specified acceptance criteria. In the future a switch from traditional methods in to more data-based and automated verification methods is anticipated.

The D-Class project

As part of a much bigger digital initiative DNV GL imitated the D-Class project in 2017, with the aim to establish a requirements document that could be used to evaluate and accept new methods of doing verification of DP systems. As a central part of the project industry players were invited to join a project work group. The purpose with the workgroup is to enable the industry to comment on, discuss and propose changes during the requirements development process. Up until October 2018 four workshops have been arranged. Three in 2017 and one in 2018. In these workshops DNV GL has presented proposals and received very useful feedback from fruitful discussions in the group. Several of the participants have also contributed with presentations, ideas and participation/proposals for piloting of verification methods.

The project pilots are intended to test potential new verification methods and to provide input to the requirements development process. At the time of writing one pilot project is ongoing. This pilot involves three of the D-Class participants in addition to DNV GL, and is looking in to using new technology to gain better and more efficient verification of switchboard protection system. Results so far shows promising results on the technology. Several other pilots are discussed and about to be initiated, some of these will probably be continued also after the D-Class project has ended.

The D-Class project is intended to run for 2 years, 2017 and 2018. The deliverables, the draft requirements document and the pilots, will however be taken forward and continued. The draft requirements document is planned to be sent on external industry hearing in spring 2019 with the aim to be released 1st July 2019.

Scope

The intention is to provide a framework for acceptance of new verification methods for DP systems, which the industry can use when designing, and requesting acceptance, of such methods. The document will therefore set requirements for how to document and demonstrate the effectiveness and capabilities of the new methods. The high-level intention is for new methods to be accepted when the new methods can perform equal or better than existing methods in terms of ensuring adequate safety levels. To accommodate this, the new standard will set requirements to how verification results (e.g. data, recordings, etc.) are generated, manged and how results are delivered in order to ensure that data is tamper free, genuine, and of sufficient quality to be used as basis for verification.

A wide range of methods are expected to emerge from the vast development within digitalization, data analytics and data connectivity. Typical examples on such methods are:

- self-verifying-systems, i.e. verification functionality built in to systems
- performance monitoring of active functions
- condition monitoring of active functions
- on-demand testing of on demand functions
- on-demand testing of the availability of redundant functions
- use of simulation tools
- remote witnessing

The main focus in the project is at verification during the operational phase, but the methods developed are anticipated to be useful also during classification of new vessels. It is expected that the methods will influence the design and verification of new equipment, to prepare the equipment for a different verification scheme during the system operational life.

Other areas which is anticipated to need an increased focus in order to prepare for more data and software driven verification schemes are management of change processes/functionality, software development and cyber security. The requirements related to some of these areas is not developed within the D-Class project, but within other projects in DNV GL. Examples of these are the class notation for Cyber Security [16] and the classification programme for approval of Manufacturers System and Software Engineering [17].

Objectives

The D-Class objective has been defined as: "*Provide requirements for "DP system verification methods" which are based on modern technology, enabling an improved and less intrusive classification scheme for verification of DP systems*". As mentioned, new methods to support this are expected to emerge from the increased digital capabilities and improved vessel to shore connectivity.

These objectives include setting requirements to:

- Built-in test equipment and functionality
- Performance and condition monitoring systems
- Gathering, treatment and delivery of collected data to ensure the truthfulness, correctness and quality of data used for class assessment
- Remote witness equipment and procedures for conducting such witnessing

The project goals include reducing:

- Exposure to non-productive time associated with taking DP vessel's out of service for trials
- The costs associated with surveyors from several organisations attending the vessel
- redundant verification activities
- The cognitive burden imposed upon vessel crews carrying out testing.

The means to achieve this include:

- Acceptance of class approved built-in verification functionality to deliver information (evidence) as basis for assessment
- Allow data analytics to be used for performance monitoring and predictive maintenance
- Allow the use of condition based monitoring and on-demand testing as means to increase confidence in DP system integrity
- Provide requirements suitable for efficient assessment of autonomous systems and vessels
- Permit a risk-based verification scope to be carried out

The objective builds upon the two important principles of:

- Ensuring that systems are designed to be verified
- Incorporate verify-on-demand capabilities

It is the intention that, when in place, such capabilities will assist in ensuring that systems and vessels are healthy and safe to operate.

It is anticipated that the new technologies can assist in reducing the need for class on board attendance. However, it is expected that some on-board attendance will still be required, e.g. in order to ensure proper visual inspections of system and equipment condition, not suitable for remote witnessing. On board inspections is also anticipated to be necessary to perform verification and validation of new verification methods when these are taken in to use, and when new methods are piloted and tested.

The focus for the D-Class project is on verification of DP systems. It is however assumed that the methods developed can be used also for verification of systems not being part of DP, and in relation to systems governed by other class notations. The evaluation of the extent of such synergies are not part of the project scope.

Classification in a digital transformation

It is not within the project objectives to change the role of the class society. The role as a competent independent assessor shall be maintained also when new verification methods are taken in to use. This means, that for a verification method to be accepted, the method must be able to deliver trustworthy data in such a format and of such a quality that the society can perform objective evaluations towards the stated or implied requirements in the same way as it does in the current verification schemes (or potentially even better). For this to be possible the body of evidence which represents the basis for issuance and maintenance of a class notation must be generated and delivered in so that the society can assess that the data has been generated in the right manner and that the evidence is complete and genuine.

The initiative originates from a realization of the improvement potential and capabilities made possible by modern technology. New and potentially more effective verification methods can in general be accepted when they are demonstrated to be able to provide the same, or higher, level of assurance when compared to the traditional methods. The development of the new verification methods is expected to build on evolution of current industry practice and in addition to seek to use both established and emerging technologies to address some of the limitations and disadvantages of traditional methods. The traditional way of achieving the required level of verification has typically been characterized by physical presence on site by competent surveyors witnessing “manual” testing and simulation activities. This witnessing, typically in combination with other activities like e.g. approval of documentation, has been considered necessary for the class to be able to collect sufficiently trustworthy data to fulfil its role as an independent assessor. This way of working often cause interruption of operations, downtime and delay. In addition is also experienced that the traditional verification methods provide varying levels of verification. Typically, low verification efficiency can sometimes be experienced in relation to modern software intensive (and often highly integrated) systems. It is anticipated that new verification methods can improve the situation in relation to both interruption of operations causing downtime and delays, and with respect to providing better verification of software based systems. Evidence generated by approved new methods can as found relevant be accepted as additional to, or maybe even fully replacing, evidence generated by traditional verification activities. When the new methods will not be able to fully generate a body of evidence, it is anticipated that the new methods can be used in combination with traditional methods to provide sufficiently complete verification coverage. Automated functions, able to deliver tamper free data with sufficient quality at requested intervals, it is anticipated that the assessments done by class can be moved both in time and space from where and when the actual data generation/gathering takes place (i.e. the body of evidence is generated).

For class to be able to accept new methods as basis for class services (e.g. issuance and maintenance of a DP class notation) the data produced as evidence must be trustworthy and with sufficient quality. When these capabilities can be documented and demonstrated as required by the D-Class standard requirements the methods may be accepted as replacing, partly or fully, the existing verification schemes and methods.

When enabling class to maintain its independent assessor role, some of the benefits potentially supported by introduction of new methods can be:

- Reduced need for physical presence of the assessor
- Automated verification functionality, more efficient and less dependent on personnel
- Verification “during” operations (i.e. based on data gathered during normal operations)
- More flexible schemes, e.g. by moving away from the present calendar based schemes
- Improved level of verification, e.g. for software intensive and highly integrated systems
- Reduced down-time due to survey and verification activities
- Methods fit for autonomous vessels and digital twins
- Improved safety levels

For further reading on properties of evidence and evidence generation, see [18].

New methods should influence schemes and scope

One big discussions items in the DP industry over the past several years have been the scope and frequency of DP verification, and this is still being heavily debated. The existing test schemes are guided by different requirement documents, like e.g. the IMO DP guidelines [1] and [2] and the classification rules [22], and are normally implemented in fixed calendar based schemes. Typically, annual verification trials and 5-yearly renewal trial has been widely used in the DP industry. Both annual trials and 5-yearly trials are normally based on pre-approved programs consisting of a fixed set of tests performed during one consecutive test session.

When analysing the typical trials programs (i.e. by studying traditional DP FMEA trial programs) it is quite clear that that the existing scope and frequency is heavily influenced by the historically available verification methods. As previously discussed, it is believed that these methods can be improved with respect to operational disturbance, and it can also be debated if the existing methods are suitable for providing sufficient verification of today’s heavily software dependent and highly integrated systems. These potential shortcomings of existing verification methods would, if kept unchanged, become even more visible as systems become even more and more integrated, software based and data driven. Undoubtedly with increasingly autonomous functionality and potentially also with build in AI.

Based on this the D-Class project do not want to take an approach of simply digitalizing the existing DP verification scope(s). To achieve the goals of providing at least the same or preferably higher safety standards, a new approached is needed where the scope and frequency is tuned to better utilize the inherent capabilities of the new technology and working methods. The decisions made should be risk based at the same time as the improved capabilities in the new and advanced methods are allowed to be utilized to further enhance the industry safety levels. This means that the industry must be open for change. Potentially much of the existing core scope with respect to redundancy verification (typically verification of the system’s ability to handle the relevant failure modes) should be kept (note that the evidence generation may be based on new methods) while other parts of the traditional scope could be deleted or replaced to improve and maximize the potential gain provided by the new methods. It is therefore expected that the new methods will provide possibilities to change (potentially increase) both scope and frequency where this is considered beneficial to reduce risks. Potentially, with new technology, this could be done in a cost-efficient way, without increasing the burden on operations, compared to current methods.

With the introduction of new methods, it is also considered useful for the industry to look at the way DP verification scope are manged and how results from the verification activities are reported. In the same time as the verification methods are modernized, also the traditional FMEA test documents should be the same. Traditionally, results from each test session are documented in form of filled in test programs, e.g. in pdf format. In order provide better flexibility future schemes should be less calendar based and each test activity may be handled individually in terms of test frequency (i.e. individual due dates on each verification item). The traditional DP FMEA trial programs reporting is not very efficient in this respect, and it is believed these could be replaced by more digitalized DP verification applications, encompassing all vessel DP verification activities. Such systems could potentially organize and keep track of all DP verification activities, including when, what and how to test, and keep an historic record of all results. Items could then have individual due dates (i.e. test frequency), and it would be easy to provide updated verification status for each verification item, and of the complete DP system. The program may be built up of smaller blocks/methods, but should be organized so that it is keeps track of the verification activities for the complete DP system and makes it possible to, at all times, maintain and document the status, on a component, subsystem and system level. It is considered that such a system would increase the efficiency of documenting a vessels DP system status, e.g. for vetting purposes.

Data Management

As for any data based service, data-based verification can only be effective and successful when the data are manged to ensure that they are suitable for the intended use. This is often referred to as data quality. The data will typically be influenced by several factors and in order to ensure that data is suitable for the intended verification purposes. The D-Class standard intends to set requirements to factors that needs to be suitably handled to provide the sufficient data quality:

- Sensors. Requirements include:
  - Identification by ID marking, making it possible to identify the physical sensor (data source) in a dataset.
  - Sensors requirements shall be described, including:
    - performance requirements
    - locations
    - possible degradations
    - installation and calibration
    - data collector performance

- Flow of data. It must be possible to track the data flow through the system (data linage) to ensure sufficient verification and integrity of the data.

- Data quality. A data quality assessment is proposed to be performed in accordance with ISO 8000-8.The assessment must describes how accurate the data are, related to what is being represented and the relevant usage. The data shall be addressed with respect to syntactical rules, conformance to real world entities, and the extent to which the purpose of the application is served. Reference will also be made to [6].

- Data processability: When relevant, the data will be required to be provided in non-proprietary, license-free, not encoded, nonbinary, or platform specific formats.

- Organisational maturity. Organizations collecting and applying sensor data as an integrated part of classification systematics must have the ability to provide sufficient data quality according to requirements. This comprise all relevant processes, technologies and activities that are required to measure, ensure and improve data quality. It is the intention that organizations must document sufficient organisational maturity in a self-assessment including (as found relevant for the specific organization):
  - Data governance: That defines policies, processes, roles and responsibilities required for continuous improvement and improvement in data quality.
  - Organisation and people: With sufficient competency and ability to fulfil responsibilities to achieve governing goals related to data quality.
  - Data quality processes: Implemented to support the data quality policies and governance.
  - Requirements: Covering data integration, reporting, analytics and operation.
  - Metrics and dimensions: Establish and structure the logical rules to be programmed and executed on data. These rules will be used to generate the data quality assessment results.
  - Process efficiency: Measuring the performance of the data quality governance, management, processes and tools that have been implemented.
  - Architecture, tools and technologies: Required to support the data quality governance and execute data quality measurements and reporting.

  - Standards: Data and metadata standards. Domain models, data exchange standards etc.

- Security mechanisms: Security mechanisms must be in place to assure security of data transfer and storage. See [7] for further guidance.

Data collection and delivery to class will in general be required to be by automatic means, and performed in such a way that the collection of data and the data content is not depending on test personnel capacities or interpretation.

Algorithm-based Verification

It is as discussed expected to be a steadily increased use of algorithms in verification in the maritime industry. In the future, these algorithms may even act as verifiers in the sense that they generate evidence and possibly make decisions, i.e. go/no-go on the target systems operational status. It may be expected that such functions can come to play a role in case the industry chooses to apply more servitization based business models. If used as basis for such services it is anticipated that there will be a need for ensuring that the algorithms are able to delivery objective, genuine and non-biased results (e.g. evidence used to support classification or other decision processes).

To ensure that the generated evidence is genuine, trustworthy, and with adequate quality, high attention must be paid towards such (integrated) automated and data-driven verification functionality. This verification functionality may go under different names, such as “Built-In-Test-Equipment” (BITE). They will be algorithm-driven, and perhaps based upon Machine Learning (ML). Such systems must be verified, as they generate evidence, possibly with minimum human involvement, evidence of which assessment towards the specified acceptance criteria is based upon. Even some parts of the assessment itself, may become autonomous through the use of algorithms, increasing the importance of the rigour and intensity of which these algorithms need to be verified. Such algorithms are, in their own right, complex software-intensive systems, posing the same challenges in the verification as any other complex system, such as lack of transparency, their intractability, difficulties of establishing expected results, and built-in cognitive and societal biases that decreases the level of objectiveness in the generated evidence.

When data algorithms are part of any verification method, it must be clearly defined what prerequisites, sensibility and performance requirements apply for the algorithms. It must also be possible to verify the sensibility and performance of the algorithms and their presence and agency (role, purpose, actions, responsibility, and autonomy) should be documented and made known to the class society.

For further reading on properties of evidence and evidence generation, see [18].

Results, D-Class deliveries and provisional conclusions

The digitalization of class services has ongoing for many years, but in the last couple of years this development has been accelerating. The D-Class initiative aims to provide a standard for how to do validation and verification of new verification methods as basis for an improved and less invasive classification scheme for verification of DP systems. Such a standard is understood to be needed in order to ensure that new verification methods are effective and capable of delivering according to their specifications. The overall goal is to ensure existing or increased safety levels, and that the potential risk of reducing safety levels is correctly manged, when introducing new methods.

The D-Class project will deliver a draft requirements document describing the requirements for how to safely enable the use of modern technology. The new proposed requirements document is intended to be to be sent on external hearing in the spring of 2019. When formally released it is the intention that this document can be as basis for accepting new alternative schemes and methods in relation to verification of

DP systems. Potentially the document may be used also to accept such methods for verification in relation to other systems and notations when found relevant.

During the process, some of the key elements needed to reach the goal of a more digital, efficient and flexible verification scheme that has been identified are:

- The role of class as an independent assessor must be maintained. This requires processes and tools which ensures that the body evidence delivered to class are genuine, tamper free and complete (as per approved specifications).
- New verification methods must be accepted by document approval and their efficiency demonstrated through testing.
- The approval must include requirements for a specific body of evidence to be delivered (e.g. a specified data set). I.e. for each verification activity/process, what shall be delivered and in which format. The main reason is to ensure efficient and transparent verification of stated acceptance criteria.
- Thorough data management will be required to ensure sufficient data quality.
- The scope and frequency of verification activities should be adjusted in order to utilize the capabilities within the new technology.
- Validation towards existing methods will be needed to ensure that the intentions of equivalent or better safety levels are met.
- Discussions among the project group members has also indicated that reduction of duplication of verification activities should be targeted.

It is anticipated that a standard, like the proposed requirements document, will be useful when equipment manufacturers want to upgrade their systems to include class approved verification functionality, and for DP vessel owners, operators and FMEA consultants when considering new verification methods and schemes.

The D-Class project will also deliver results from the initiated pilots. Some of these results may are shared within the D-Class work group participants, some with other industry players not part of the D-Class, while other results may be kept internal between pilot participants. This will be decided as part of each pilot.

Acknowledgements

D-Class projects wants to acknowledge the internal and external participants in the D-Class workshop group, and D-Class pilots project partners.

References

[1] IMO MSC/Circ.645 Guidelines for vessels with dynamic positioning systems
[2] IMO MSC.1/Circ. 1580 Guidelines for vessels and units with Dynamic Positioning (DP) systems
[3] Recommended Practice DNV-RP-D102 Failure Mode and Effect Analysis (FMEA) of Redundant Systems
[4] Recommended Practice DNV-RP-E306 Dynamic Positioning Vessel Design Philosophy Guidelines
[5] Recommended Practice DNV-RP-E307 Dynamic Positioning Systems - Operation Guidance
[6] DNVGL-RP-0497 Data quality assessment framework
[7] DNVGL-RP-0496 Cyber security resilience management for ships and offshore units in operations
[8] ISO 14224 Collection and exchange of reliability and maintenance data for equipment (see also API Std. 689)
[9] ISO 13379-1 Condition monitoring and diagnostics of machines - Data interpretation and diagnostics techniques
[10] ISO 27000 Information technology - Security techniques - Information systems – Requirements
[11] ISO 5725-1 Accuracy of measurements methods and results

[12] ISO 18436 Condition monitoring and diagnostics of machines - Requirements for training and certification of personnel
[13] ISO 13381-1 Condition monitoring and diagnostics of machines-Prognostics
[14] ISO 8000-2 Data quality - Vocabulary
[15] ISO 8000-8 Data quality - Information and data quality: Concepts and measuring
[16] DNV GL RU-Ships Pt.6 Ch.5 Sec.21 Cyber Security
[17] Approval of manufacturers System and software engineering Document code: DNVGL-CP-0507 DNV GL class programmes (CP) Type approval Cyber security capabilities of control system components
[18] Properties of evidence and evidence generation. Odd Ivar Haugen DNV GL, MTS DP Conference 2018
[19] DNV GL-RU-OU-0300 Fleet in Service
[20] DNV GL RU-Ships Pt.6 Ch.3 Sec.1 Dynamic Positioning Systems - DYNPOS and DPS
[21] DNV GL RU-Ships Pt.6 Ch.5 Sec.2 Dynamic Positioning Systems with Enhanced Reliability - DYNPOS(E,ER)
[22] DNV GL RU-Ships Pt.7 Fleet in Service Ch.1 Sec.6.12 Dynamic Positioning Systems