|  |
| --- |
| IALA Guideline |

1???

Operational and Technical Acceptance of VTS Systems

Edition 1.0

Document date

Revisions to this IALA Document are to be noted in the table prior to the issue of a revised document.

|  |  |  |
| --- | --- | --- |
| Date | Page / Section Revised | Requirement for Revision |
| month/year approved by Council | aaaaa | aaaaaa |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

1 INTRODUCTION 6

2 AIMS AND OBJECTIVES 6

2.1 Check list G1111 6

3 VERIFICATION AND VALIDATION PROCESS 6

3.1 Validation and Verification process 7

3.1.1 Verification and Validation Methods 8

3.1.2 Verification Process 9

3.1.3 Validation Process 9

3.2 Planning and Management of Activities 11

3.3 Acceptance Testing 11

3.3.1 The Acceptance Test Plan (ATP) 11

3.3.2 Factory Acceptance Test (FAT) 12

3.3.3 Installation and Site Acceptance Test (SAT) 12

4 GUIDELINES 13

5 VERIFICATION AND VALIDATION CORE OPERATIONAL AND TECHNICAL REQUIREMENT 13

6 RADAR 14

7 AUTOMATIC IDENTIFICATION SYSTEM 15

7.1 Introduction 15

7.2 Verification items 16

7.3 Validation items 16

8 ENVIRONMENTAL MONITORING 18

9 ELECTRO-OPTICAL SYSTEMS 19

10 RADIO DIRECTION FINDERS 19

11 LONG RANGE SENSORS 20

12 RADIO COMMUNICATIONS 20

13 DATA PROCESSING 85 21

13.1 Introduction 21

13.1.1 Verification of Function and Performance Requirements 22

13.1.2 Validation of Function and Performance Requirements 22

13.2 Definitions and References 23

13.2.1 Definitions 23

13.3 Tracking and Data Fusion 24

13.3.1 Plot Extraction 26

13.3.2 Tracking 27

13.3.3 Track Data Output 28

13.3.4 Track Management 29

13.3.5 Environment Assessment 29

13.3.6 Tracking and Data Fusion Performance Parameters 30

13.4 Management of VTS Data 31

14 VTS HUMAN / MACHINE INTERFACE 32

15 RADIO COMMUNICATIONS 32

16 RADIO COMMUNICATIONS 33

16.1 Introduction 33

16.2 Purpose and Objectives 33

16.3 Standards and References 33

16.4 Design, Installation and Maintenance 33

16.5 Radio Communications Coverage 33

16.6 Recording and playback of data 34

16.7 System Malfunctions, Warnings, Alarms and Indications 34

17 DECISION SUPPORT 34

18 EXTERNAL INFORMATION EXCHANGE 34

19 DEFINITIONS 35

19.1.1 Definition of Verification according to ISO:9000-2005 §3.8.4 35

19.1.2 Definition of Validation according to ISO:9000-2005 §3.8.5 35

20 ACRONYMS 35

21 REFERENCES 36

ANNEX A G1111 reference Matrix 37

List of Tables

Table 1 Typical System Tracking Performance Parameters 31

Table 2 Single Radar Sensor - Tracking Performance Parameters (specific) 31

Table 3 Single Sensor - Tracking Performance Criteria 31

Table 4 Specification, verification and validation template for VTS systems 39

List of Figures

Figure 1 V model 8

Figure 2 Typical Terminology of Tracking Functions and Processes 25

# INTRODUCTION

At present, this document is a collection of information collected and processed during VTS-42, to be brought forward to VTS 43.

It is by no means representing the expected final outcome of the work to either update G1111 with further information on the acceptance of VTS systems or to make a separate guideline on the subject.

# AIMS AND OBJECTIVES

This guideline presents a common source of information to assist Competent Authorities and VTS Authorities in the operational and technical acceptance of VTS systems. Tailoring is required to verified and validate the specific and relevant performance requirements from the generic information included within this document. The Guideline shall not be used as a test procedure without such tailoring.

The aim of this document is not to repeat international standard on verification and validation processes but to address considerations specific to VTS systems.

* describing the process;
* how to verify compliance with individual system requirement (compliance with order);
* how to validate operational and technical performance described in G1111 step by step.

## Check list G1111

* *core operational and technical requirement;*
* *radar;*
* *Automatic Identification System (AIS);*
* *environmental monitoring;*
* *electro-optical equipment;*
* *Radio Direction Finders;*
* *long range sensors;*
* *radio communications;*
* *data processing;*
* *Human / Machine Interface (HMI);*
* *decision support;*
* *external information exchange;*
* *verification and validation.*

Additional points:

* *system;*
* *specific requirement.*

# VERIFICATION AND VALIDATION PROCESS

*Refer to International Standard documentation*

The performance of VTS equipment should be verified prior to operation. This may include the following verification and validation activities:

* type approval of individual equipment, as required by law in individual countries;
* other equipment specific verification tests as required by the individual VTS Authority;
* verification of equipment prior to delivery in the form of Factory Acceptance Tests;

Verification of individual equipment or systems upon installation and Setting-to-Work, but prior to operational use in the form of Site Acceptance Tests. The overall specifications should be agreed in contractual documents. It is recommended that FAT, SAT, and other procedures are agreed before conducting tests.

Procedures may be generic to the individual equipment and/or specific to the individual contract.

## Validation and Verification process

For the establishment or modification of a VTS system the tendered system requirements should be verified prior to contract and validated through the phases of the project establishing or modifying the VTS system.

The associated operational and technical acceptance should utilise verification and validation processes related to a Generic Project Life-cycle Model called the V-model in System Engineering terms, as detailed in [4] and [5] and adapted to VTS as illustrated by **Error! Reference source not found.**.

*Refer to process in IALA Guideline 1111 & IALA Recommendation V-119*



1. V model

It should also be noted that a project often experience iterations between the phases as described in IALA Guideline 1111 [3].

### Verification and Validation Methods

The basic verification and validation methods adopted by IALA is:

1. *Inspection (I):* An examination of the item against applicable documentation to confirm compliance with requirements. Inspection is used to verify properties best determined by examination and observation (e.g. paint colour, weight, physical dimensions, etc.).
2. *Similarity (S):* Similarity is most appropriate where a design is being modified or is very similar to an existing verified system. When verifying by similarity, a common scenario is to perform an analysis to ensure the design and operational environment is similar enough to claim similarity.
3. *Analysis (A):* Use of analytical data or simulations under defined conditions to show theoretical compliance. Analysis (including simulation) is used where verifying to realistic conditions cannot be achieved or is not cost-effective and when such means establish that the appropriate requirement, specification, or derived requirement is met by the proposed solution.
4. *Demonstration (D):* A qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation. Demonstration (a set of verification activities with system stimuli selected by the system developer) may be used to show that the system or subsystem response to stimuli is suitable. Demonstration may also be appropriate when requirements or specifications are given in statistical terms (e.g. mean time to repair, average power consumption, etc.).
5. *Test (T):* An action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated. These verifications often use special test equipment or instrumentation to obtain very accurate quantitative data for analysis.
6. *Certification (C):* Written assurance that the product has been developed and can perform its assigned functions in accordance with legal or industrial standards. The development reviews and verification results form the basis for certification; however, outside authorities, without direction as to how the requirements are to be verified, typically perform certification(e.g. CE certification, UL certification, etc.).

The verification and validation cost generally increase when going down the method list, but also provides increased confidence that the requirement is actually met. The methods therefore involve balancing the most cost-effective mix of adequate testing against minimizing the risk of not meeting a requirement. Inadequate verification postpones problems to the validation phase, where costs for implementing needed changes to remedy the possible non-conformance is typically much larger.

*Illustration of cost*

### Verification Process

Prior to contract the VTS vendor should to demonstrate that the tender requirements are fulfilled by the system offered. This is typically done in the form of compliance statements, also stating the validation methods to be used.

The extent of verification needed during the design is highly dependent on the system complexity and the need to make new developments.

Verification during the design is a vendor responsibility; however, the VTS Authority may want to witness and/or approve part of the process.

*Important to state in contract, what will be the base for validations*

### Validation Process

The purpose of the Validation Process is to provide objective evidence that the services provided by a system when in use comply with stakeholders’ requirements, achieving its intended use in its intended operational environment.

This process performs a comparative assessment and confirms that the stakeholder requirements are correctly fulfilled. Where deviations are identified, these are recorded and guide corrective actions. The VTS authority shall ratify the system validation.

The validation process may cover the following validation examples depending on type of system:

* acceptance tests (FAT, SAT…);
* possibly, In-operation test (determining that availability, maintainability criteria etc. are meet).

#### Input

Primary inputs to the Validation Process include the following:

* concept documents, e.g. use cases or operational scenarios;
* stakeholder & system requirements;
* system verification documentation.

*To be revisited ?*

#### Output

Output of the validation process includes (not chronological):

* validation methods for each requirement and *how* the requirements shall be validated;
* validation plan including the strategy to be followed during the validation process;
* validation procedure/specification including requirements for any systems, tools, software or resources needed to enable validation of the system under test.;
* validated system (approved system baseline);
* validation report – Including documentation of the validation activity results, a record of any recommended corrective actions, design feedback, Corrective Actions already taken, and evidence that the system element or system satisfies the requirements, or not;
* documented acceptance of the validation report results – typically as a FAT and SAT.

*To be revisited ?*

#### Process Steps

Validation activities shall be prepared and reviewed together with the stakeholder requirements. For the validation, it is not sufficient to indicate the validation method. It is also needed to document *how* the stakeholder requirements shall be validated, and which validation activities the customer shall witness. As an example, there is a big difference if a requirement shall be tested with targets of opportunity or if the customer presupposes calibrated and certified targets, as the latter is much more expensive in both cost and schedule.

The validation process consists of the following activities:

1. Plan Validation:
   1. Create validation plan that includes the strategy for validating the system or product entities throughout the life cycle. Specifies the sequence of validation activities, pass/fail criteria and corrective actions. Specifies resources such as staffing and responsibilities, prerequisites, risk, contingency, approach and overall test environments.
   2. Schedule and confirm validation enabling systems or resources.
   3. Provide feedback to requirement and design process. Analysing how to validate stakeholder requirements in detail might trigger a change in requirements due to cost or feasibility
2. Release the validation specifications and/or procedures:
   1. Develop validation specification that demonstrates that the system is fit for its purpose and satisfies the stakeholders’ requirements. The validation report may be an annotated validation specification.
3. Perform Validation:
   1. Ensure readiness to conduct validation – system, enabling systems, and trained operators.
   2. Conduct validation per established procedures to demonstrate conformance to stakeholder requirements. Validation is typically witnessed by customers, representative or assigned QA.
   3. If anomalies are detected, analyse for corrective actions and detect trends in failure to find threats to the system and evidence of design errors.
   4. Recommend corrective actions and obtain stakeholder acceptance of validation results.
4. Document validation results (including nonconformities):
   1. Conclude on the verification documentation with the approving customers.

## Planning and Management of Activities

Implementing, extending or upgrading an existing VTS should be planned and managed in detail. This could include planning of cutover activities to minimise disruption of the VTS operation.

The establishment and agreement of acceptance plan(s) and verification matrices may be necessary to assist all stakeholders. This may, for example, call upon:

1. Proper attention on HMI acceptance and ergonomics.
2. Verification of interfaces.
3. Verification of fall back modes, graceful degradation, and redundancy within the VTS system;.
4. Latency checks of data presentation.
5. Verification of performance parameters, including coverage.
6. Verification of radio communication parameters, such as bit-error rates, signal-to-noise ratios, etc.
7. Verification of overlapping sensor coverage, including different sensor types and associated correlation.
8. Co-ordination and definition of Factory Acceptance Test, Setting to Work and Site/System Acceptance Tests.
9. Early prototyping to validate critical parts (e.g. user interfaces) can minimise risk at a later stage in the programme.

## Acceptance Testing

### The Acceptance Test Plan (ATP)

The Acceptance Test Plan (ATP) is a collection of stages, tests, analysis, and acceptance criteria that allows the suppliers to demonstrate to the customer that their requirements have been met. For example, Factory Acceptance Test (FAT) and Site Acceptance Test (SAT) may be two key tests within an ATP.

The Contractor, in co-operation with the Customer, may be responsible for the creation of the ATP. The agreed Acceptance Test Plan should be available prior to the commencement of the acceptance testing. The ATP scope shall cover the complete system that forms the overall deliverable.

For each stage of acceptance testing, a test procedure should be issued by the Contractor based on the agreed acceptance methods and procedures captured in the ATP.

Test procedures should demonstrate compliance to the Customer’s functional and performance requirements. They should include an agreed test script which includes a list of requirements and corresponding verification tests, with their measurements, to demonstrate compliance.

At each stage of acceptance testing, test records should be issued and retained. Test records may include, as a minimum:

* configuration details;
* date of the test;
* who performed the test;
* the outcome of the test such as pass/fail, measurements, or findings.

Upon successful completion of the acceptance activities, described in the ATP, the system is considered ready for operational use.

### Factory Acceptance Test (FAT)

If applicable, the Factory Acceptance Test demonstrates, prior to shipping and as far as agreed, that the equipment and/or system conform to contractual specifications. The VTS Authority may elect to attend or to be represented at the FAT.

The FAT will normally include Functional and Performance testing to agreed procedures. Tests will normally be performed for individual units and, in some cases, for pre-assembled systems.

The FAT may also include Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) type reviews.

Personnel conducting the test should be familiar with set-up and operation of the equipment in test. The Customer’s representative(s), if in attendance, should be appropriately qualified to accept the equipment and understand issues that may arise during the testing. Safety Instructions should be noted.

The outcome of a FAT should be recorded in a test report or certificate. These typically include:

* references to project name, customer, software revisions, hardware revisions, parts and serial numbers etc.;
* list of instruments and their calibration status;
* functional test results including verification of safety measures;
* performance test results;
* signatures.

After the FAT, the Supplier should ensure that any issues that arise are addressed.

### Installation and Site Acceptance Test (SAT)

Prior to the installation of equipment, the Supplier and Customer should agree that preparatory work, such as civil works and structures, is satisfactorily completed.

After installation and setting-to-work, the SAT should take place. The purpose of the SAT is to confirm full functional compliance and system integration of the installed equipment.

The SAT may also include final Functional Configuration Audit (FCA) and final Physical Configuration Audit (PCA) type reviews.

The Supplier should confirm to the Customer that:

* all supporting documentation is available;
* equipment is as tested during FAT, i.e. the software and hardware revisions do not invalidate the FAT results.

If these conditions are not met, additional activities should be jointly agreed and resolved.

The outcome of a SAT should be recorded in a test report or certificate. These typically include:

1. References to project name, customer, software revisions, hardware revisions, parts and serial numbers etc.
2. List of instruments and their calibration status.
3. Functional test results including verification of safety measures.
4. Performance test results;.
5. Signatures.

After the SAT, the Supplier should ensure that any issues that arise are discussed and appropriate actions are agreed and managed to a satisfactory conclusion.

# GUIDELINES

# VERIFICATION AND VALIDATION CORE OPERATIONAL AND TECHNICAL REQUIREMENT

G1111 (section 1.3) states that it is important to write well-structured, individual requirement statements within the published requirements documentation. This statement combining the relevant operational requirements with the technical requirements shall be the basis for the verification and the validation

1.4.1 Availability and Reliability

Verification of overall system as well as individual components reliability is an integral part of a design following the principles of the V-model. Calculations and analysis done during the design process are important to eliminate weak points and determine maintenance costs of the installed system.

Calculations and Failure Mode Analysis do often pay an important role in the technical acceptance of a VTS system, however, detailed analysis may be very time consuming and it will always result in theoretical figures. The practical and cost effective way of validating Availability and Reliability may therefore be a combination of analysis and ‘In Operation Test’ made during the first months of operation – possible followed by corrective actions.

Methods

1. Verify

*There might be a need to advise more on specific methods*

1.4.2 Recording, Archiving and Replay

Technical acceptance of Recording, Archiving and Replay will typically consist of functional tests in combination with validation of archive capacity.

1.4.3 Design, Installation and Maintenance Considerations

1.4.3.1 Climatic Categories for outdoor installations

1.4.3.2 Wind Considerations

1.4.3.3 Special Considerations

1.4.3.4 Installation Considerations

1.4.3.5 Design and Installation Documentation

1.4.3.6 Design Standards Applicable to VTS Equipment

1.4.3.7 Equipment Approval

# RADAR

The purpose of this section is to support Competent and VTS authorities in the validation of radar performance and its contribution to the VTS traffic image (situational awareness).

The validation shall focus on Operational Requirements, (e.g. coverage, targets to be detected and target separation) rather than Technical Specifications, (e.g. Transmitted power, pulse characteristics and antenna data) of radar sensor(s).

*Weather, sea conditions and geographical constraints pose challenges to the detection capability of radar sensors in VTS. The use of multi-sensor integration, including radar, AIS and other sensors also needs to be taken into account.*

*Specific security requirements may introduce particular challenges to the radar sensor where there could be a need to detect small targets in heavy clutter conditions or where small versus large target discrimination is essential.*

2.2 Definitions and References 30

2.2.1 Definitions 30

2.2.2 Definition of IALA Target Types for Range Coverage Modelling 32

2.2.3 References 33

2.3 Radar System Solutions 34

2.3.1 General 34

2.3.2 Radar Types 34

2.3.3 Antennas 36

2.4 Characteristics of Radar Targets 36

2.4.1 Radar Cross Section 36

2.4.2 Polarisation 37

2.4.3 Complex Target Models 37

2.4.4 Target RCS Fluctuations 39

2.4.5 Target Speed and Manoeuvrability 39

2.5 Operational Requirements 39

It is recommended that the VTS Authority should specify the Operational and associated Validation Requirements rather than Technical Specifications of radar sensor(s).

The operational requirements may be determined by:

* Definition of the radar coverage of the VTS area;
* Definition of targets to be detected;
* Determination of environmental capabilities and constraints;
* Determination of other influencing factors, radar location(s), obstructions;
* Definition of targets detection requirements in weather and propagation conditions normal for the VTS area;
* Target separation and positional accuracy
* Update rate
* Definition of radar dynamic capabilities and constraints.

2.5.1 Definition of Radar Coverage 39

2.5.2 Targets to be detected 40

2.5.3 Determination of Environmental Capabilities and Constraints 41

2.5.4 Target Separation and Target Accuracy 51

2.5.5 Update rate 53

2.5.6 Radar Dynamic Capabilities and Constraints 53

2.6 Functional Requirements 55

2.6.1 Operational Outputs 56

2.6.2 Operator Functions 56

2.6.3 Clutter and Noise Reduction / Management 56

2.6.4 Elimination of False Echoes 56

2.7 Radar Design, Installation and Maintenance Considerations 56

2.7.1 Service Access 56

2.7.2 Antenna Accessibility 57

2.7.3 Antenna Robustness 57

2.7.4 Choice of Upmast versus Downmast Transceivers 57

2.7.5 Built In Test Equipment 57

2.7.6 Protection against Extreme Events 57

2.8 Verification of Function and Performance Requirements 57

It is recommended to base acquisition of radars and subsequent verification after installation on the basis of measured performance data using real targets.

Such measurements should be carefully analysed including the influence from weather and propagation.

**Note**:

Verification of radars using floating point targets, such as corner reflectors or Lunenburg reflectors, is subject to large inaccuracies due to sea surface movements and variations in propagation.

It is suggested to measure the radar cross section of real targets and use those for actual measurements.

Radar cross section measurement of targets should be made in calm sea conditions, at close range and using stable (not moving) Luneburg reflectors as reference.

# AUTOMATIC IDENTIFICATION SYSTEM

## Introduction

The purpose of this section is to support Competent and VTS authorities in the validating AIS performance, AIS service and its contribution to the VTS traffic image (situational awareness).

The operational requirements to validate are the following:

* automatically receive information from AIS-equipped vessels, including the ship’s identity, ship type, position, course and speed over ground, navigational status and other safety related information;
* monitor and track AIS-equipped vessels;
* exchange data with AIS-equipped vessels;
* support value added functions over the AIS infrastructure;
* manage AIS-based Aids to Navigation (including virtual and synthetic AtoN).
* provision of vessel identification and location information to the VTS traffic image;
* provision of vessel manoeuvring and voyage related data to the VTS;
* provision of facilities to enable transmission of information between the VTS and the mariner.

Note that the validation procedure as to be adapted to the contractual requirement and in particular depend from available Physical Equipment (AIS base station; AIS limited base station; AIS receiver; AIS repeater; AIS Aid to Navigation (AtoN)).

## Verification items

The Competent and VTS authorities may verify that the following documents have been issued:

* AIS equipment test sheet issued by the AIS equipment manufacturer.
* AIS equipment compliance certificate issued by the AIS manufacturer including international standard (XXXX) and national or reginal regulation (CE Certificate)
* An MMSI number attribution issued by the appropriate national authority (Radio Communications or Broadcast Authority in most countries). Note that when several AIS base stations cover a large VTS Area, each base station can be given the same virtual MMSI.
* License has been attributed for every AIS base station by the appropriate national authority (Radio Communications or Broadcast Authority in most countries).
* Every AIS base station has a MMSI (Maritime Mobile Service Identity).
* Configuration document stating at the minimum that:

The correct MMSI number has been configure for each AIS equipment

If there is two base stations in and AIS Cell 30NM x 30 NM, one of the AIS base stations within a cell is configured to transmit its Fixed Access TDMA (FATDMA) information on one of the AIS VHF frequencies and the other base station is configured to transmit its FATDMA information on the other AIS VHF frequency.

## Validation items

| G1111 | Scope | Procedure | Expected Result |
| --- | --- | --- | --- |
| 3.5 Operational Requirement | Check the AIS Coverage: | Check AIS track position report and information on the traffic image.  A cooperative vessel, with a verified AIS | All vessels equipped with an AIS transponder within the expected coverage area are displayed.  Cooperative vessel is tracked in the complete coverage area.  Note that weather condition, AIS network overload or specific consideration may affect the coverage ref to G1111 §3.7 for more information |
| 3.6.1.1 Target Tracking | Check that Vessel Position Report are available for VTSO |  | AIS tracks are display in the traffic image at the correct position  AIS information including the ship’s identity, ship type, position, course and speed over ground, navigational status and other safety related information are available.  The portrayal of the AIS tracks is consistent with the information received from the vessel (label, heading, outline size, …) |
| 3.6.1.2 Aids to Navigation | Check that AIS AtoN Report are available for VTSO AIS |  | AIS AtoNs are display in the traffic image at the correct position.  AIS AtoNs information including identity, type and other transmitted information are available |
| 3.6.1.3 Voyage-Related Data | Check that voyage, ETA and cargo are available to VTSO  Voyage, ETA and cargo are part of the standard AIS transmissions at 6 minutes intervals or on request. | Due to the absence of any commonly agreed procedure to update this data, it may not be present, be outdated or simply incorrect.  Consequently, the verification of this information shall be done with a cooperative vessel for which |  |
| 3.6.2 Information Exchange between VTS and Mariner |  | Coopering Vessel equipped with AIS shall be identified prior to the test |  |
| 3.6.2.1 Text Messaging | Check that VTSO and Mariner can exchange text message | Broadcast a message to all vessels fitted with AIS.  Acknowledge through VHF the good reception of AIS message | Vessel officer confirm the reception of the AIS message on its will appear on the Minimum Keyboard Display (MKD) of the on board AIS system |
|  |  | Send a message to specific vessels fitted with AIS.  Acknowledge through VHF the good reception of AIS message | Vessel officer confirm the reception of the AIS message on its will appear on the Minimum Keyboard Display (MKD) of the on board AIS system |
|  |  | Request to the Vessel Officer to send an AIS message to VTS. (It may be necessary to communicate the VTS MMSI number to the Vessel Officer). | VTSO is notify that an AIS message is received and can read the send message. |
| 3.6.2.2 Binary Messaging | Verify that the relevant “global” or “regional” binary messaging can be exchanged with mariners |  |  |
| 3.6.2.3 Aids to Navigation | AIS base stations, as part of a VTS System, can be configured to broadcast synthetic and/or virtual aids to Navigation (AtoN). |  |  |
| 3.6.3 Assigned Mode | VTS may use the AIS Service capability to change the reporting mode (from autonomous to assigned mode, for example) of selected shipboard AIS units. |  |  |

# ENVIRONMENTAL MONITORING

4.1 Introduction 64

4.2 Definitions and References 64

4.2.1 Definitions 64

4.2.2 References 64

4.3 Characteristics of Environmental Sensors in VTS 65

4.4 Operational Requirements 65

4.4.1 Information Presentation 65

4.4.2 Malfunctions and Indicators 65

4.4.3 Accuracy 65

4.5 Functional Requirements 66

4.6 Design, Installation and Maintenance Considerations 67

4.6.1 Suitability to Meet Range, Accuracy and Update Rate Requirements 67

4.6.2 Location within the VTS Area and its Approaches 67

4.6.3 Durability and Resistance to Environmental Conditions 67

4.6.4 Interference 67

4.6.5 Power Supply Requirements / Options 67

4.6.6 Installation 67

4.6.7 Maintenance 68

4.6.8 Interfacing 68

4.6.9 Backup Arrangements 68

4.6.10 Safety Precautions 68

# ELECTRO-OPTICAL SYSTEMS

5.1 Introduction 69

5.2 Definitions and References 69

5.2.1 Definitions 69

5.2.2 References 69

5.3 Characteristics 69

5.4 Operational Requirements 70

5.4.1 Sensor Site Selection 70

5.4.2 Sensor Selection 70

5.4.3 Detection, Recognition and Identification 70

5.4.4 Recording and Replay 71

5.5 Functional Requirements 71

5.5.1 Pan, Tilt and Zoom 71

5.5.2 Precision and Repeatability 71

5.5.3 Auto Focus 71

5.5.4 Image Processing 71

5.5.5 Configuration 72

5.6 Design, Installation and Maintenance Considerations 72

5.6.1 Durability and Resistance to Environmental Conditions 72

5.6.2 Data Communications 72

5.6.3 Maintenance 72

# RADIO DIRECTION FINDERS

6.1 Introduction 74

6.2 Operational Requirements 74

6.2.1 RDF Coverage Area 74

6.2.2 Bearing Accuracy 75

6.2.3 Frequency Range 76

6.2.4 Number of Simultaneously Monitored VHF Channels 76

6.3 Functional Requirements 76

6.3.1 VHF Channel Management 76

6.3.2 SAR Functionality 77

6.3.3 Man Overboard EPIRB Detection Capabilities 77

6.3.4 COSPAS/SARSAT Detection and Decoding 77

6.4 Design, Installation and Maintenance Considerations 77

6.4.1 Antenna Installation 77

6.4.2 Lightning Protection 77

6.4.3 Calibration 77

6.4.4 Built-In Test and Diagnostics 77

# LONG RANGE SENSORS

7.1 Introduction 78

7.2 Long Range Identification and Tracking (LRIT) 78

7.3 Satellite AIS 78

7.4 HF Radar 79

7.5 Synthetic Aperture Radar (SARSAT) 79

# RADIO COMMUNICATIONS

8.1 Introduction 81

8.2 Definitions and References 81

8.2.1 Definitions 81

8.2.2 References 81

8.3 Characteristics of Radio Communication Equipment 81

8.3.1 Coverage 82

8.3.2 VTS Radio Communication 82

8.4 Operational Requirements 83

8.4.1 Radio Communications Coverage 83

8.4.2 Recording and Playback of Data 83

8.5 Functional Requirements 83

8.5.1 Digital Selective Calling 83

8.5.2 Malfunctions, Warnings, Alarms and Indications 83

8.6 Specific Design, Installation and Maintenance Considerations 83

8.6.1 Durability and Resistance to Environmental Conditions 83

8.6.2 Interference 83

8.6.3 Power Supply 83

8.6.4 Site Selection and Installation 84

8.6.5 Maintenance 84

8.6.6 Interfacing 84

8.6.7 Back-Up and Fall-Back Arrangements 84

8.6.8 Development and Innovations 84

# DATA PROCESSING 85

9.1 Introduction 85

9.2 Definitions and References 85

9.2.1 Definitions 85

9.2.2 References 86

9.3 Tracking and Data Fusion 86

9.3.1 Plot Extraction 88

9.3.2 Tracking 89

9.3.3 Track Data Output 90

9.3.4 Track Management 91

9.3.5 Environment Assessment 91

9.3.6 Tracking and Data Fusion Performance Parameters 91

9.4 Management of VTS Data 95

## Introduction

The purpose of this section is to support Competent and VTS authorities in the validation of Data processing, its performance parameters and its contribution to the VTS traffic image (situational awareness).

The validation shall focus on Operational Requirements of a recognized up-to-date traffic image, rather than Technical Specifications, using the principles of target racking and data fusion. Additionally, it introduces the issues of managing various types of information required within and outside the VTS.

the trade-off between a higher target detection probability, a larger initiation delay or a larger false target rate,needs to be taken into account.

It is recommended that the VTS Authority should specify the Operational and associated Validation

Requirements rather than Technical Specifications of Data processing

The operational requirements may be determined by:

1. Definition of the Tracking and Data Fusion of the VTS system;
2. The Tracking and Data Fusion sections consider sensor data from various sources including:
   1. Radar sensors.
   2. Adjacent VTS area or other agency tracks.
   3. AIS and Satellite AIS.
   4. LRIT.
   5. Electro-Optical Systems (EOS).
3. Extracted plots include the following attributes:
   1. Time of measurement.
   2. Measured position (Cartesian or polar) and positional uncertainty.
   3. Originating sensor.
4. In addition, the plots attributes may include:
   1. Identity.
   2. Radial (Doppler) speed.
   3. Physical extent of the plot.
   4. Signal strength.
5. Definition of targets to be detected.
6. Determination of environmental capabilities and constraints.
7. Determination of the required probability of target detection and minimum acceptable latency in weather and propagation conditions normal for the VTS area.
8. Target separation and positional accuracy.
9. Update rate.
10. The required positional accuracy of the track and other associated track information (identity, target type, COG, SOG, manoeuvre etc.).
11. Definition of sensors capabilities and constraints.

### Verification of Function and Performance Requirements

1. It is recommended to base acquisition of sensors and subsequent verification after installation on the basis of measured performance data using real targets.
2. Such measurements should be carefully analysed including the influence from weather and
3. propagation.
4. Note: Verification of radars using floating point targets, such as corner reflectors or Lunenburg reflectors, is subject to large inaccuracies due to sea surface movements and variations in propagation.
5. It is suggested to measure the radar cross section of real targets and use those for actual
6. measurements.
7. Radar cross section measurement of targets should be made in calm sea conditions, at close range and using stable (not moving) Luneburg reflectors as reference.

### Validation of Function and Performance Requirements

1. All individual sensor measurements have limited accuracy and are affected by random errors. In order to obtain a more reliable estimate of a target position and speed vector, measurements need to be processed.
2. The traffic image is created by processing the raw data from the available sensors of the VTS network.

## Definitions and References

### Definitions

For general terms used throughout this section refer to:

IEEE Std 686-1997 IEEE Standard Radar Definitions.

Specific terms are defined as follows:

**Confirmed track** – a track that has previously passed the criteria for track initiation, tentative track formation and has been subsequently promoted to a confirmed track.

**Data Fusion** – in the tracking context, data fusion is the combining of observation updates from more than one sensor to create one track based on all available sensor information.

**False Plot** – a plot resulting from a phenomenon unrelated to VTS operation or from a reflection of an actual object.

**False Track** – A track created using sensor data that happens to behave in target-like manner but actually relates to phenomena unrelated to VTS operation or results from reflections of actual objects.

Note, the sensors and indeed the tracking process may not be able to differentiate between small detectable objects unrelated to VTS operation (birds for example) and at the same time to correctly detect and track small objects that are related to VTS operation.

**Latency** - a measure of time delay experienced in a system. Used here to indicate the time from a sensor first gathering data relating to a target, to the time the corresponding data is presented to the user (e.g. VTSO display or decision support process).

**PD** – is the probability of target detection at the output of a sensor, subsequent to plot extraction, but prior to tracking, and presentation. Note, in some systems the boundary of the sensor and its achieved PD complicate this definition – clarification may be required to avoid misunderstanding arising from, for example, data compression or video processing.

**Plot** - A generic term to describe the report resulting from a sensor observation.

**Plot extraction** – the process of determining measurement values for a sensor observation from the raw sensor data. In the case of a radar sensor, this typically consists of comparing the video level with a threshold which can be (dynamically) adapted to local background noise and clutter conditions.

**Plot to Track Association** – the process of determining correlation of new sensor plots with existing tracks.

**Radar** - as referred to in this document, this relates to all aspects of the radar from sensor through to the availability of radar information (for presentation) from one or more radar sensors to the VTSO.

**Radar track (report)** - A target report resulting from the correlation, by a special algorithm (tracking filter) of a succession of radar-reported positions (radar plots) for one object.

**Radar video** – a time-varying signal, proportional to the sum of the radio frequency (RF) signals being received and the RF noise inherent in the receiver itself. Radar video can be an analogue signal with associated azimuth reference information, and/or video data (including amplitude) in digital format.

**Sensor** – in the tracking context, a sensor is a device for observing and measuring, as a minimum, position information for a target or potential target.

**Sensor PFA** – is the probability of false alarm (plot) at the output of a sensor, subsequent to plot extraction, but prior to tracking, and presentation. This is generally expressed as an average number per unit area.

**Signal to Noise ratio** – the ratio of a measurement of the power of a return from a target vs. the local sensor noise around the location of the target

**Tentative track** – in the early part of the track lifecycle, a track is considered to be a tentative track until sufficient criteria are passed for it to be promoted to a confirmed track or for it to be discarded as a likely false track.

**Track** –the geo-spatial data, accumulated by the system, relating to an object of interest. As a minimum, this consists of unique identity, timestamp, current position and velocity, the associated quality of that information and other relevant attributes.

**Track Coasting** - A feature that maintains tracks in the absence of expected sensor updates.

**Tracking** - The process of following an object to enable historical, current and future target positional and velocity information to be displayed and otherwise processed in support of the VTS system objectives.

**Tracking PFA** - is the probability of false track at the output of the tracking process, prior to presentation. This is normally defined as number of occurrences per unit area per unit time.

**Track initiation** – this is the process of first creating a track from plots that could not be associated with existing tracks.

**Track Merging** – as two approaching tracks come together, it may not be possible for the available sensors to individually discriminate and therefore to measure their continued presence and position. If this situation persists for some time, one of the tracks may be maintained whilst the other is terminated.

**Track Splitting** – a single track may unpredictably split into two or more discernible objects which may invoke rules for track initiation on some or all of the resultant likely tracks.

**Track swapping** – the (usually unwanted) transfer of a track identity (track label) to another track. This can break the intended association between a track and a physical object.

**Track termination** – the process of permanently removing a track.

## Tracking and Data Fusion

An up-to-date established traffic image is essential to the successful operation of a VTS. This is typically presented as a map showing fixed geographical and man-made features and moving objects to aid decision support and general traffic management of the VTS area. The traffic image is created by processing the raw data from the available sensors of the VTS network.

All individual sensor measurements have limited accuracy and are affected by random errors. In order to obtain a more reliable estimate of a target position and speed vector, measurements need to be processed.

The Tracking and data fusion process accepts sensor data from the available VTS sensor network and other available sources. Then, it attempts to combine these with existing tracks for the purposes of building a traffic image. When such data do not successfully combine with existing tracks, the Track Initiation process postulates new tentative tracks which are subsequently monitored until they either become confirmed tracks or are discarded as likely false alarms.

The resulting traffic image is displayed to the VTSO, can be used in decision support and may be provided to other agencies and allied services.

The tracking process uses models of the sensors and a set of concurrent models of the target movement to provide a best estimate of, at least, the target position, course and speed over ground (COG, SOG). These models are also used to optimise the association process to combine new measurements with the existing tracks.

Some standard terms need to be outlined for clarity (see Figure 2).



1. Typical Terminology of Tracking Functions and Processes

It is recommended that a VTS system takes advantage of data available from multiple sensors and external sources by integrating this data in an appropriate way. Integration can be as simple as overlaying, selectable, multiple layers of track data on the VTSO display but significant advantages can be gained by processing and combining the data within the Data Processing function. The use of data from all available sources can significantly improve the positional accuracy of the track and other associated track information (identity, target type, COG, SOG, manoeuvre etc.). In addition, track fusion can include error and anomaly detection in the data from single sensors (which may incorrectly differ from other sensor derived data).

Fusion of the data can be either combining tracks created from individual sensors or introducing the raw measurements from all sensors directly into the track filtering process. In both cases, the track fusion process may have to deal with (un-calibrated) biases in the data originating from the different sensors (e.g. the North alignment of radar sensors).

In a fully calibrated system (i.e. with minimum measurement bias), the output of a data fusion tracker (multi-sensor tracker) should not reduce the quality of the information coming from the most reliable source and in general additional accuracy or other benefits should reasonably be expected. Track fusion also provides redundancy to minimise the consequences of sensor failure or poor detection.

Track fusion is an automatic process and as such, it is recommended that VTSO interaction with this process is limited.

Within this Guideline, the Tracking and Data Fusion sections consider sensor data from various sources including:

* radar sensors;
* adjacent VTS area or other agency tracks;
* AIS and Satellite AIS;
* LRIT;
* Electro-Optical Systems (EOS).

Note: contributions from mobile sensors (ship borne sensors etc.) are not normally considered, although this additional enhancement and complexity may become more widespread in the future.

The availability of more data bandwidth from ship to shore may facilitate this enhancement in the future.

The design of the Tracking and data fusion process should take into account the need to translate positional information into a common geographical reference system. One common standard datum for this is WGS84. This translation process requires an understanding of the attributes of each sensor, for instance AIS provides geographic coordinates whereas radar measures position in terms of polar coordinates, i.e. range from the sensor and bearing relative to North, even though the data may have been translated at source, the measurement errors used within the track correlation process should reflect the type of data.

As mentioned above, there is also the need to accurately calibrate various sensors to the common reference system, and to each other, so that a detectable point target is measured to have a common location from all sensors providing data on such a target. Such calibration can take the form of manual set up and routine checking and/or on-the-fly identification and correction of measurement bias within the tracking process.

The time stamping of sensor data, accurately reflecting the time of observation and measurement, is essential to enable the correct and accurate traffic image to be established and maintained. Another important performance parameter to consider is communication and processing latency through the VTS system and in particular within the Tracking and data fusion process. This is a separate design consideration to that of time stamping to ensure that the data is presented in a timely fashion to the VTSO (or external system).

### Plot Extraction

The plot extraction process lies between the collection of raw sensor data and the extraction of useful information from that data. It is highly dependent on sensor type:

1. An AIS, satellite AIS or LRIT plot is known to originate from a single GNSS receiver and provides a time stamped position which can be assumed, with significant confidence, to originate from one target.
2. A radar or EOS plot has to be extracted from raw data using a thresholding process to separate it from noise related excursions. In addition, multiple candidate plots may arise from one object (due to target physical size, sensor attributes etc.) and these need to be associated and reduced to one plot where possible within the extraction process. Ambiguities may also exist in the plot measurement and they need to be resolved, or, at least, highlighted for downstream resolution.

The plot extraction process requires specialised and dedicated processing to optimise the trade-off between target detection probability and false alarm rate whilst also extracting positional data. In addition, a strong radar plot may originate from any reflecting surface or surfaces and may not be related to a vessel or object of interest. The subsequent plot to track association process contributes significantly to the selection of wanted radar plots from unwanted radar plots. Besides the extraction of single object plots, the plot extraction process may also provide additional attributes or extended object information to enable subsequent tracking of, for example, icebergs or oil slicks.

Extracted plots include the following attributes:

* time of measurement;
* measured position (Cartesian or polar) and positional uncertainty;
* originating sensor.

In addition, the plots attributes may include:

* identity;
* radial (Doppler) speed;
* physical extent of the plot;
* signal strength.

In general, the plot extraction process is fully automatic, relying on programmed algorithms tuned to optimise the process to the sensor characteristics and the topography of the coverage area.

### Tracking

#### Plot-to-Track Association

Plot-to-Track Association is the selection of the most likely track, representing the object, for each (incoming) plot and the identification of plots which do not associate with any existing track.

The extracted plots are passed to the tracking process and those which fail to correlate with existing tracks become candidates for the initiation of new tracks. Those plots which correlate successfully with existing confirmed or tentative tracks will be used to update the associating track.

Plot-to-Track association involves the forward prediction of the track attributes (e.g. position) to a time which corresponds with the time-stamped update(s) contained within the new plot. After allowance for elapsed time since last update, measurement noise and the possibility of reasonable target manoeuvre, a test for correlation with the new plot is used to either associate the plot or discard the plot (from this track). This process is repeated for all tracks (and plots) so that the discarded plots can be passed to the track initiation process.

Note: plots arrive asynchronously from any available sensor.

#### Track Initiation

The plots remaining un-associated following the plot to track association process may contain plots originating from real targets. These plots are used in the track initiation process to establish a list of uniquely identified, tentative tracks.

In general, the track initiation process is automatic but geographic limitations may be invoked upon areas where automatic initiation should and should not occur. Although VTS systems often include the possibility for manual track initiation, reliance on this method of initiation can significantly load and distract the VTSO. The dependence on this type of track initiation should, therefore, be kept to a minimum.

It can be assumed that an externally sourced (and likely to be externally maintained) track is very likely to become a track in the VTS area of interest and therefore a track can be initiated. AIS plots which have failed to associate, typically initiate a new tentative track. Radar plots, which have failed to associate, require additional confidence building algorithms before completing the initiation of new tracks.

The track initiation process in combination with the plot extraction process needs to strike a balance between the ability to detect true targets of a certain type (especially small targets) and the possible initiation of false tracks. Lowering the plot detection threshold or relaxing the initiation rules, allows more true targets to be detected at the expense of an increased false track rate. This will require system level tuning (supported by modelling if appropriate) to optimise performance and achieve the VTS operational needs.

In other words, there is a trade-off between a higher target detection probability, a larger initiation

delay or a larger false target rate.

#### Track Maintenance

Within a tracking system, the tracks generally pass through the following stages:

* tentative tracking;
* confirmed tracking (including the possibility of coasting);
* track termination.

The following sections, track updating and track validation, describe the regular repeated processing

that occurs within these stages.

##### Track Updating

The extracted plots which associate with existing tracks are used to update those tracks by combining the plot data with the track predictions in accordance with the chosen tracking filter(s). Various mathematical techniques are available to forward predict and update the track position and trajectory information. These techniques vary from simple to very complex with a more or less increasing level of performance. In complex traffic situations it may be appropriate to consider the use of the more advanced algorithms.

As track paths approach or cross each other, additional rules are required to minimise the chances of lost tracks as all the available update information may tend to be associated with one rather than with both tracks. The use of AIS sensors and high resolution passive sensors reduces this possibility, but in some circumstances lost updates to one or both tracks may be inevitable. In real traffic situations, the approach of a small pilot vessel to a large shipping vessel will create this situation on an everyday basis.

##### Track Validation

Tracks should be validated against the possibility that they are, or have become, false tracks. Assessment of track quality and erratic track update behaviour may be considered as techniques to provide validation. The tracking system should be able to react quickly and initiate termination rules once it becomes clear that a false track may have been created (see Section 9.3.4.1 for further information). False tracks, from whatever mechanism, should be avoided in safety critical areas and occasionally accepted in other areas where surveillance and traffic monitoring is the priority. Note; operational requirements regarding the detection of small targets may result in an increase in the probability of false tracks.

It may be appropriated to not terminate tracks immediately when there are no sensors measurements but allow some time during which the track is coasting. In such cases, coasting rules may be defined to take into account the need for intentional track coasting such as in areas obscured from sensor coverage.

### Track Data Output

Consideration needs to be given to the output of track data to other VTS sub-systems such as the display of the established traffic image to the VTSO. The display is not normally considered to be part of the Tracking Function, but the appropriate tracking information will need to be available for display and for presentation on demand. It may also be appropriate to offer the ability to access and display raw sensor data, plot data and tentative track data.

The display of confirmed tracks is likely to be essential to the VTSO tasks and therefore it is recommended that the display HMI minimises the possibility of unintentionally hiding this information.

The HMI aspects of the display function will consider the use of symbols, colours, text etc. for the display of track information. Typically, track information will be presented onto an electronic chart (using a common reference) of the VTS area.

Track information, which might be required for display to the VTSO, includes:

* current location;
* vessel Identity;
* speed and course over ground;
* track history;
* contributing sensors (and lack of updates i.e. coasting);
* associating plot data;
* destination and ETA;
* passage plan;
* cargo;
* crew and passenger details.

Note: there is a trade-off in the HMI to be considered between presentation clarity, data overload, track density and VTSO interaction to interrogate a track for additional information.

### Track Management

#### Track Termination

If a confirmed track either:

* moves outside a user defined coverage area;
* moves into a user defined non-tracking area;
* has track updates which do not follow the expected behaviour; or
* if the track cannot be updated with new plots over a certain length of time,

then the track should be terminated. In certain cases, as defined by the VTS Authority, the VTSO should receive a warning of imminent track termination, and also the VTSO may be provided with a facility, via the HMI, to manually terminate a track.

Track loss may occur as a result of targets not being detected by sensors for a certain time. Note: the loss of target detection is likely to occur in the vicinity of obstructions such as bridges, land masses etc. In order to cover expected areas of poor detection, the system may be configured to bridge gaps in coverage e.g. by coasting previously reliable tracks. The VTS Authority should address any critical areas, such as the vicinity of bridges, and explain expectations to tracking to allow VTS suppliers to design appropriate rules in such critical areas. Another source of track loss is the occurrence of target manoeuvre outside the expected behaviour.

The conditions for track termination may need to be adaptable and adjustable in different areas or traffic / weather conditions. This additional complexity may be set up on system commissioning, user adjustable or even automatically reactive to real world data.

In addition to the above there may be some special classes of tracked objects that require special track processing. Special rules may be required to allow for unexpected appearance and disappearance of submarines, the possibility of obscuration by moving objects in the area of interest or the need to track extended objects such as icebergs, oil slicks and weather effects (and to monitor their size and changes in their shape).

#### Track Identification

Tracks should be uniquely identified, noting that other methods of vessel identification may conflict or overlap, such as internal and external databases (Lloyds, SafeSeaNet, single-hull database, various incident/black lists, on-board identity, adjacent VTS and other allied services etc.) and local identification methods such as those arising from AIS data, voice communications and associated direction finding, camera recognition (manual and automatic).

### Environment Assessment

The VTSO may need to be informed of environmental changes which may affect VTS operations and/or the ability to detect objects within the VTS area. The VTS system may provide special features to facilitate environment monitoring and assessment including, for example, hydrographic sensors and cameras to further aid environmental monitoring.

### Tracking and Data Fusion Performance Parameters

The effective use of the VTS traffic image, reliant on accurate and reliable tracking and positioning of the objects of interest in relation to fixed and movable hazards within the VTS area, is fundamental to safe and efficient management of the VTS traffic. The following sub-sections describe the relevant parameters.

#### Input Parameters Required to Design and Implement a Tracker

Key tracking system input parameters to be specified by the VTS system designer, based on the parameters specified by the VTS Authority, include:

* range of target characteristics (size, speed, manoeuvrability, height, type etc.);
* maximum number of targets to be tracked;
* typical desirable and undesirable traffic behaviour, including traffic “lanes”, traffic density, shallow waters, low bridges, narrow waterways etc.;
* anticipated variations in weather and sea/water conditions;
* external inputs and outputs to / from the tracking function;
* acceptable VTSO interaction with the tracking function;
* sensor network design including its specific characteristics including latency.

#### Performance Parameters

The determination of performance parameters to specify a VTS tracking system design is a complex task and the achieved tracking performance is heavily dependent on the sensor data provided as inputs to the tracking process. The sensor requirements should consider information provided elsewhere in the other sections of this document.

The location and configuration of the sensor network determines the attainable performance of the VTS system. A tracker design needs to be tuned to optimize overall performance (i.e. accuracy, resolution and minimal track confusion) and the overall performance is unlikely to be constant throughout the VTS area. The VTS system design should therefore ensure that the achievable performance is aligned with the required performance for each of the areas within the VTS coverage area. It should be noted that track formation range is not the same as the sensor network detection range – this needs to be considered when deriving the network coverage and how this relates to the tracker behaviour.

Test scenarios may be developed jointly with users and the tracking experts to explore the anticipated performance of the VTS system as a whole, especially in critical (hazardous) areas of the VTS. Generic traffic test cases can be proposed for a generic sensor solution, but the resultant tracker may have weaknesses in an actual application even though it demonstrates compliance with such generic test cases.

The tracking characteristics needed are highly dependent on local conditions which should be analysed individually. The following tables discuss some of the tracker performance parameters and criteria that may be considered.

1. Typical System Tracking Performance Parameters
2. Single Radar Sensor - Tracking Performance Parameters (specific)

Note: the accuracy figures suggested above need to be assessed as RMS error (measured parameter vs. truth) for well-behaved (non-manoeuvring) targets in moderate environmental conditions. Positional accuracy should be verified with a small but detectable target, whereas SOG and, especially, COG should be verified using large targets moving under power (i.e. not tidal), without manoeuvre and, for the determination of COG, a recommended minimum speed of 10 knots.

1. Single Sensor - Tracking Performance Criteria

Requirements for sensor fault detection and loss of sensor data integrity should also be considered; for example, the tracker may be used to identify consistent bias errors in the data from one sensor;

#### Additional Track Management Requirements

The tracker should be able to provide advance warning of track capacity overload.

The track capacity should be sufficient to accommodate ≥2 times the heaviest traffic predictions, including an allowance for false tracks.

## Management of VTS Data

Besides the Tracking function, there are other Data Processing functions that may need to be considered within the VTS design. Typically, data processing is the collection and extraction of data to provide information.

The data is everything that is potentially useful and relevant to the VTS operation.

Processing involves summarising, analysing, converting, recording, sorting, calculating, disseminating, storing, aggregating, validating, tabulating etc.

The information is the result of the processing of the input data. It should be appropriately useful and appropriately clear to aid the VTSO, external users and the manual and automatic decision making processes. In the context of a VTS, there are many pieces of data, each with its own importance, validity and integrity.

Centralised data fusion aims to integrate data from different systems at regional or national level using inter-system data exchange.

Types of information may include:

* voyage Data;
* vessel Data;
* incident Data;
* contacts Data;
* charts;
* pilots and Tugs;
* data of Berths and Capabilities plus Other Port Resources;
* traffic analysis data;
* local hazards;
* VTS Equipment Status, Build State, Version Records;
* VTS Spares and Consumables Stock and Storage Locations;
* VTS Equipment Fault Records;
* VTS Equipment Scheduled and Unscheduled Maintenance;
* VTS Personnel.

It may be appropriate to integrate shipping accounts data to automate alignment with cargo movements, shipping movements, handling charges etc. to facilitate account management by systems associated with the port (i.e. not directly associated with VTS operations). Often this functionality may be managed by the Local Port Authority.

# VTS HUMAN / MACHINE INTERFACE

10.1 Introduction 97

10.2 Definitions and References 97

10.2.1 Definitions 97

10.2.2 References 97

10.3 Characteristics of User Interface 97

10.4 Operational Requirements 97

10.4.1 Traffic Image and Information Display 98

10.4.2 Environmental Information 99

10.4.3 Decision Support Presentation 99

10.4.4 Electro-Optical Sensor Data Display and Control 99

10.5 Functional Requirements 99

10.5.1 System Status and Control 99

# RADIO COMMUNICATIONS

10.6 Specific Design, Configuration, Installation and Maintenance Considerations 100

10.6.1 Physical Layout 100

10.6.2 Screen Layout 100

# RADIO COMMUNICATIONS

## Introduction

Radio communication equipment is typically integrated into VTS applications to provide the VTSO with a real-time assessment of the situation in the VTS area of responsibility as well as a means to deliver timely services to VTS participants. Information collected and disseminated via this equipment can assist in assembling the traffic image and in supporting safe navigation of the VTS area.

## Purpose and Objectives

The purpose of this section is to support Competent and VTS authorities in the validation of Radio Communication System performance, supporting the design of the Radio Communication System and its contribution to the VTS traffic image (situational awareness).

The objectives of this validation will be to ensure the VTS system fulfils the following radio communication related objectives:

* conforms to relevant local and international standards;
* achieves design, installation and maintenance requirements;
* achieves required radio communications coverage;
* achieves required recording and playback of data;
* demonstrates and displays required system malfunctions, warnings, alarms and indications

## Standards and References

Standards and references as per G1111 and customer supplied.

## Design, Installation and Maintenance

To be detailed – using G1111 as basis.

## Radio Communications Coverage

Validation of Radio Communication equipment to guarantee required coverage should be based upon the following:

* Area A1 - Within range of VHF coast stations with continuous DSC (digital selection calling) alerting available (about 20-30 nautical miles);
* Area A2 - Beyond Area A1, but within range of MF coastal stations with continuous DSC alerting available (about 100 nautical miles);
* Area A3 - Beyond the first two areas, but within coverage of geostationary maritime communication satellites (in practice this means INMARSAT);

This covers the area between roughly 70°N and 70°S.

* Area A4 - The remaining sea areas.

The most important of these is the sea around the North Pole (the area around the South Pole is mostly land). Geostationary satellites, which are positioned above the equator, cannot reach this far.

## Recording and playback of data

Recording and replay of radio communications should be validated to ensure that all designated radios record data as per recording and replay guidelines in G1111 and customer requirements.

## System Malfunctions, Warnings, Alarms and Indications

From the system verification tables all radio communication system malfunctions, warnings, alarms and indications should be defined.

Where system malfunctions, warnings, alarms and indications can be raised via controlled means or by triggers of opportunity, these should be validated to ensure adequate performance.

# DECISION SUPPORT

11.1 Introduction 102

11.2 Definitions and references 102

11.2.1 Definitions 102

11.2.2 References 102

11.3 Characteristics of Decision Support Tools 102

11.4 Operational Requirements 103

11.4.1 Collision Avoidance 103

11.4.2 Anchor Watch 103

11.4.3 Grounding Avoidance 103

11.4.4 Air Draught Clearance 104

11.4.5 Sailing Plan Compliance 104

11.4.6 Area related 104

11.4.7 Speed Limitations 104

11.4.8 Incident or Accident Management 104

# EXTERNAL INFORMATION EXCHANGE

12.1 Introduction 105

12.2 Definitions and References 105

12.2.1 Definitions 105

12.2.2 References 105

12.3 Characteristics of External Information Exchange in VTS 105

12.4 Data Management Considerations 106

12.4.1 Suitability for Purpose 106

12.4.2 Access to Information 107

12.4.3 Data Security and Confidentiality 107

12.4.4 Legal Limitations 107

12.4.5 Data Integrity 107

12.4.6 Data Models 108

12.4.7 Architecture of Sharing 108

12.4.8 Storage 108

12.4.9 Communication Links

# DEFINITIONS

### Definition of Verification according to ISO:9000-2005 §3.8.4

Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: The term “verified” is used to designate the corresponding status.

Note 2 to entry: Confirmation can comprise activities such as

* performing alternative calculations;
* comparing a new design specification (3.7.3) with a similar proven design specification;
* undertaking tests (3.8.3) and demonstrations;
* reviewing documents prior to issue.

### Definition of Validation according to ISO:9000-2005 §3.8.5

Confirmation, through the provision of objective evidence (3.8.1), that the requirements (3.1.2) for a specific intended use or application have been fulfilled

Note 1 to entry: The term “validated” is used to designate the corresponding status.

Note 2 to entry: The use conditions for validation can be real or simulated.

# ACRONYMS

AIS Automatic Identification System

AtoN§ Aid(s) to Navigation

ATP Acceptance Test Plan

CE Conformité Européenne (European Conformity)

COG Course over Ground

COSPAS Cosmicheskaya Sistema Poiska Avariynyh Sudov (Russian; Space System for the Search of Vessels in Distress

COTS Commercial Off the Shelf

DSC Digital Selective Calling

EOS Electro-Optical Sensor

EPIRB Emergency Position Indicating Radio Beacon

ETA Estimated Time of Arrival

FCA Functional Configuration Audit

FAT Factory Acceptance Test

FATDMA Fixed Access Time Division Multiple Access

GNSS Global Navigation Satellite System

G1111 IALA Guideline 1111 on the Preparation of Operational and Technical Performance Requirements for VTS Systems

HF High frequency (3 – 30 MHz)

HMI Human / Machine Interface

IALA International Association of Marine Aids to Navigation and Lighthouse Authorities - AISM

IEEE Institute of Electrical and Electronic Engineers

INCOS International Council on Systems Engineering

INMARSAT International Maritime Satellite Organization

ISO International Standardization Organisation

LRIT Long Range Identification and Tracking

MKD Minimum Keyboard and Display

MMSI Maritime Mobile Service Identity

NM nautical mile

PCA Physical Configuration Audit

PD Probability of target detection at the output of a sensor

RCS Radar Cross Section

RF Radio frequency

SARSAT Synthetic Aperture Radar

SARSAT Search and Rescue Satellite-Aided Tracking

SAT Site Acceptance Test

SoC Statement of Compliance

SOG Speed over Ground

Std Standard

UL Underwriters Laboratories Inc.

VHF Very High Frequency (30 MHz to 300 MHz)

VTS Vessel Traffic Services

VTSO VTS Operator(s)

WGS84 World Geodetic System 1984 (datum and spheroid)

# REFERENCES

1. IALA Recommendation V-119 on the Implementation of Vessel Traffic Services
2. IALA Recommendation V-128 on the Preparation of Operational and Technical Performance Requirements for VTS Systems
3. IALA Guideline 1111 on the Preparation of Operational and Technical Performance Requirements for VTS Systems
4. ISO 15288:2008 Systems and Software Engineering – System life cycle processes
5. INCOSE-TP-2003-002-03.2.2 INCOSE Systems Engineering Handbook. A Guide for System Life Cycle Processes and Activities, Ver. 3.2.2 October 2011
6. G1111 reference Matrix

*Separate annexes may need to be developed for subsystems*

Table 4 provides a specification, validation and verification template for VTS systems following the structure of IALA Guideline 1111 providing compliance matrix intended for use at time of proposal as well as verification and validation matrix intended to be filled out during acceptance tests of the delivered solution.

The VTS authority might adapt the table to the individual requirements whereas proponents offering VTS solution not in any way shall modify the tables by editing text, deleting or adding a line. Only the fields marked as SoC (Statement of Compliance) and Clarification shall be completed as part of the proposal work

For compliance statements there are 4 types of fields:

1. Heading: section heading, no responses required.
2. Information: informative text to provide further clarification – no responses required.
3. Implicit: a requirement which is further subdivided into “children requirements. All children requirements must be complied to, in order to fully comply to an implicit requirement. A “partially comply” can be responded if one or more children requirements are not compliant.
4. Requirement: a mandatory requirement associated with a single “shall” statement.

Requirements shall be answered with one and only one of the following text:

1. C: “Comply” - the requirement is fully met by the proposed system, with no need for modification (COTS).
2. WC: “Will Comply” the requirement is not currently met by a COTS system baseline SW/HW but will do so after development or modification.
3. WPC: “Will Partially Comply” - the requirement will partially do so after modification. The proponent must explain in detail the required modification(s), how it will improve the system and where it will meet and not meet the requirement.
4. PC: “Partially Comply” - The current COTS baseline does not fully meet the requirement. Clarification is required.
5. NC: “Not Compliant” - The current COTS baseline does not meet the requirement and cannot be migrated to the PC, WPC or WC state in the near future.

Verification and validation shall follow the requirements set by the VTS-authority using the following methods:

1. *Inspection (I):* An examination of the item against applicable documentation to confirm compliance with requirements.
2. *Similarity (S):* Similarity is most appropriate where a design is being modified or is very similar to an existing verified system.
3. *Analysis (A):* Use of analytical data or simulations under defined conditions to show theoretical compliance.
4. *Demonstration (D):* A qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation.
5. *Test (T):* An action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated.
6. *Certification (C):* Written assurance that the product has been developed and can perform its assigned functions in accordance with legal or industrial standards. The development reviews and verification results form the basis for certification; however, outside authorities, without direction as to how the requirements are to be verified, typically perform certification(e.g. CE certification, UL certification, etc.).

Where also suggest methods and appropriate stage:

* during design;
* as part of Factory Acceptance Test;
* as part of Site Acceptance Test;
* or as part of an Operation Test.

1. Specification, verification and validation template for VTS systems

| **Item** | Description | Requirements | G1111 Reference | Compliance Statement *(Contractual agreement - shall this be included?)* | | Verification and Validation of delivered solution | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SoC** | **Clarification** | **Test method** | **Milestone** | **Procedure** | **Expected results per contractual requirements** | **Result incl. reference to reporting & description of possible corrective actions** |
| 1 | **INTRODUCTION** | **Heading** |  | **N/A** |  |  |  |  |  |  |
| 1.1 | **Scope** | **Heading** |  | **N/A** |  |  |  |  |  |  |
|  | This document covers the technical requirements for the delivery and associated life cycle support of …… | Information |  |  |  |  |  |  |  |  |
| 1.3 | **Core Requirements** | **Heading** |  | **N/A** |  |  |  |  |  |  |
| 1.3 | **Operational Requirements** | **Heading** | **1.3** | **N/A** |  |  |  |  |  |  |
| 1.3.1 | The VTS area, (VTS sub-areas) (and sectors) are delineated …. | Information |  |  |  |  |  |  |  |  |
| 1.3.2 | The of services to be provided include (INS, TOS, NAS) | Information |  |  |  |  |  |  |  |  |
| 1.3.3 | Types and sizes of vessels expected to participate in the VTS include: | Information |  |  |  |  |  |  |  |  |
| 1.3.4 | Navigational Hazards and traffic patterns are described in ….. | Information |  |  |  |  |  |  |  |  |
| 1.3.5 | Human factors including health and safety issues include ….. | Information |  |  |  |  |  |  |  |  |
| 1.3.6 | Tasks to be performed by System users include…. | Information |  |  |  |  |  |  |  |  |
| 1.3.7 | Refer to ……. For operational procedures, staffing level and operating hours of the VTS | Information |  |  |  |  |  |  |  |  |
| 1.3.8 | Co-operation with external stakeholders will include ……. | Information |  |  |  |  |  |  |  |  |
| 1.3.9 | Refer to ….. for information about physical security of the VTS Centre and remote sites *(possible classified documentation)* | Information |  |  |  |  |  |  |  |  |
| 1.3.10 | Refer to ….. for information on Business continuity, availability, reliability and disaster recovery | Information |  |  |  |  |  |  |  |  |
| 1.3.11 | The Legal framework is described by ….. | Information |  |  |  |  |  |  |  |  |
| 1.3 | **Technical Implementation** | **Heading** | **1.3** | **N/A** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 1.4.1 | **Availability and Reliability** | **Heading** | **1.4.1** | **N/A** |  |  |  |  |  |  |
|  | Note that multiple means of communications and multiple sources of sensor information may result in reduced requirements for the availability of each item of equipment individually. | Information |  | N/A |  |  |  |  |  |  |
|  | Overall System Availability shall be XX.X % | Requirement |  |  |  | Analysis during design | FAT |  |  |  |
| Measurement | IOT |  |  |  |
|  | Individual sensor a… | Requirement |  |  |  |  |  |  |  |  |
|  | Individual sensor b… | Requirement |  |  |  |  |  |  |  |  |
|  | Communication …. | Requirement |  |  |  |  |  |  |  |  |
|  | Etc. | Requirement |  |  |  |  |  |  |  |  |
| 1.4.2 | **Recording, Archiving and Replay** | **Heading** | **1.4.2** | **N/A** |  |  |  |  |  |  |
| 1.4.2.1 | Stored and archived data shall include:   * ….. | Requirement |  |  |  |  |  |  |  |  |
| 1.4.2.1 | Storage capacity shall be for a minimum of \_\_ days | Requirement |  |  |  |  |  |  |  |  |
| 1.4.2.1 | Data shall be recorded automatically and be capable of replay without impact to on-going VTS operations. | Requirement |  |  |  |  |  |  |  |  |
|  | Information shall be synchronised of for replay | Requirement |  |  |  |  |  |  |  |  |
| 1.4.3 | Design, Installation & Maintenance | **Heading** | **1.4.3** |  |  |  |  |  |  |  |
| 1.4.3.1 | **Climatic Categories for outdoor installations** | **Heading** |  | **N/A** |  |  |  |  |  |  |
|  | The outdoor installations will be subject to  “Basic”, “Hot”, “Cold” “Severe Cold” /  “Coastal/Ocean”, “hot dry”, “hot humid” climate condition *(delete as appropriate)* | Information | 1.4.3.1 | N/A |  |  |  |  |  |  |
|  |  | Requirement |  |  |  |  |  |  |  |  |
| 1.4.3.2 | **Wind Considerations** | **Heading** | **1.4.3.2** | **N/A** |  |  |  |  |  |  |
|  |  | Information |  |  |  |  |  |  |  |  |
|  |  | Requirement |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| 1.4.3.3 | **Special Considerations** | **Heading** | **1.4.3.2** | **N/A** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |

To be discussed if it is relevant to have Compliance & Verification and Validation in separated rows – or make 2 tables – also should we make separate annexes for each type of subsystem.