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| IALA Guideline |

1111-1

Producing Requirements for the Core VTS system

Edition 2.0

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# INTRODUCTION

This document addresses the core VTS system and needs to be read together with the other G.1111 guidelines as listed below.

* G.1111 Establishing Functional and Performance Requirements for VTS systems
* **G.1111-1 Producing Requirements for the Core VTS system (this guideline)**
* G.1111-2 Producing Requirements for Voice Communications
* G.1111-3 Producing Requirements for RADAR systems
* G.1111-4 Producing Requirements for AIS and VDES systems
* G.1111-5 Producing Requirements for Environment Monitoring systems
* G.1111-6 Producing Requirements for Electro Optical systems
* G.1111-7 Producing Requirements for Radio Direction Finder systems
* G.1111-8 Producing Requirements for Long Range Sensor systems
* G.1111-9 Producing Framework for Acceptance of VTS Systems.

VTS systems are developing new capabilities and functionality as technology advances and as VTS requirements evolve. The new IMO Resolution (Guidelines for Vessel Traffic Services) promotes more interaction between VTS systems and recommends greater connectivity to external third-party services. It is anticipated that VTS systems will be developing new capabilities and functionality over the coming years as such services become available and digital services evolve.

For example, the development of Maritime Autonomous Surface Ships (MASS) is progressing. At the time of publishing this guideline, IALA is producing a new guideline titled “Guideline on the implications of maritime autonomous surface ships from a VTS perspective”.

A VTS system primarily comprises three elements: an IT platform, software functionality and a suite of communication devices and sensors. The Communication devices and sensors are each covered by the new Guidelines G.1111-2 to G.1111-8. This document is defined as the core VTS system because it comprises the IT platform and the software that creates the Traffic image, processes sensor data and provides tools to support decision making. Whilst most communication devices and sensors are unlikely to change over coming years, the software functionality offered by the core VTS system is expected to change with the currently evolving requirements and therefore it is expected that this document (G.1111-1) will be updated more frequently than other G.1111 Guidelines. VTS providers are therefore recommended to regularly monitor the document status to ensure that the latest version is being used.

The main purpose of this document is to assist the VTS Provider in preparing the operational requirements for the core VTS system. For the purpose of maintaining traceability to the previous version of G.1111, this document is structured around the same sub-section titles as was used in that document.

The document focuses on the human aspects of the VTS System design including:

* User Interface;
* decision support;
* data processing;
* external information exchange.

## Definitions

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| **VTS System** | – | within the G.1111 guidelines, the VTS System is the VTS software, hardware, communications and sensors. This excludes personnel and procedures. |
| **VTS Equipment** | – | within the G.1111 guidelines, VTS Equipment refers to the individual items of software, hardware, communications and sensors, which make up the VTS System. |
| **VTS User** | - | within the G.1111 guidelines, VTS User is defined as someone with either an operational, technical, or administrative need to use or access the VTS System. |

## References

1. Convention on Safety of Life At Sea (SOLAS 1974) (as amended).
2. IMO Resolution A.857(20) - Guidelines for Vessel Traffic Services (1997).
3. IALA Vessel Traffic Services Manual.
4. IALA Recommendation R0128 – Operational and Technical Performance of VTS Systems.
5. IALA Recommendation R0119 – The Implementation of Vessel Traffic Services.
6. IALA Guideline G-1045 – Staffing Levels at VTS Centres.
7. IALA Recommendation e-Nav 140 – Architecture for Shore-based Infrastructure ‘fit for e-Navigation’.
8. IALA Guideline 1128 – The Specification of e-Navigation Technical Services.
9. IALA Guideline 1110 on the Use of decision support tools for VTS personnel.

# User Interface

## Introduction

The purpose of this section is to support VTS Providers in the specification and selection of the User Interface for a VTS system.

This section should be read in conjunction with IALA Recommendation R0125 ([1]).

### Definitions

The User Interface is the space where interaction between humans and technology occurs. The goal of this interaction is effective operation and control of the machine on the user's end, and feedback from the machine, which aids the VTS User including VTS Operator (VTSO) gaining and maintaining situational awareness and in making operational decisions.

Specific terms used are as below:

**Maritime domain awareness** – is defined by the International Maritime Organization as the effective understanding of anything associated with the maritime domain that could impact the security, safety, economy, or environment. The maritime domain is defined as all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances.

**Traffic Image** – is the real-time presentation of vessels and objects and their movements, as well as other activities affecting maritime domain awareness.

**Chart** – A chart is a graphic representation of the maritime domain.

### References

1. IALA Recommendation R0125 - The Use and Presentation of Symbology at a VTS Centre.
2. IALA Recommendation R1014 – Portrayal of VTS Information and Data.
3. IHO S-57 – IHO Transfer Standard For Digital Hydrographic Data.
4. IHO S-101 – IHO ENC Product Specification.
5. IALA Guideline G1105 - Shore-side Portrayal ensuring Harmonisation with eNavigation related Information.
6. IALA Guideline G1118 – Marine Casualty / Incident Reporting and Recording, including Near-miss situations as it relates to VTS.

## Characteristics of User Interface

The User Interface (UI) of the core VTS system provides operational functionality to VTS users to enable the provision of an effective VTS. The principal goal of the UI is to provide users with an intuitive, reliable, accurate and efficient way of interacting with the VTS system.

This goal is achieved through a combination of:

* information presentation style and methodology – screens, windows, menus, status bars;
* ergonomically designed physical interface technologies such as mouse, keyboard, touch pad, roller ball, touch screen;
* visual and audible indications
* ergonomically designed UI.

Typically, the UI may comprise the following:

* Traffic Image presentation
* Voice Communication
* Information relating to planned arrivals and departures
* Operational and Emergency situation procedures

In addition, the VTS System may include individual system UI for some communication and sensor components.

The UI should be reliable, designed and built to contribute to the achievement of the overall availability requirements of the entire VTS system. A failure of individual elements should not disable the entire UI, e.g. a failed screen should not make the UI unusable.

These following considerations are equally important but fall outside the scope of this guideline:

* ergonomically designed VTS User workstation – lighting, seating, desk arrangements, noise reduction;
* VTS Centre layout with respect to the overall VTS operational sector layout.

## Operational Requirements

The following sections describe the operational requirements related to the UI.

Refer to the relevant G.1111 series documents for operational requirements regarding the individual equipment components of the VTS System.

### Traffic Image

The Traffic Image consists of a Chart background (see 2.3.1.1) overlaid with real-time vessel positions and Sensor data. It is important that the Traffic Image is designed to complement the VTS User’s role.

The design should ensure the display of information is appropriate to the VTS User’s role and the amount of information does not degrade overall awareness of the Traffic Image.

The Traffic Image is the central part of the UI and provides the following functionality to the VTS User:

* Real time presentation of vessel positions and information relating to their identity, if available
* Chart based information and supporting graphics relating to the maritime environment
* Facilities for monitoring the speed of vessels and alerting of excessive speed or low speed situations
* Facilities for predicting dangerous or near miss situations
* Facilities for protecting assets or other objects within the VTS Area and alerting of unauthorised incursion into a prohibited area
* Facilities for ensuring adherence to defined routes and alerting about divergence from routes or TSS
* Monitoring of Aids to Navigation and other environment monitoring sensors and providing alerts if the data exceeds pre-defined thresholds.

#### Chart

In a VTS system the Chart is a graphic representation of the sea area and adjacent coastal regions including the VTS area and relevant navigational features. This Chart forms the background for the Traffic Image. The VTS Provider should specify required chart coverage, scales, layers and updating period.

In a VTS system the Chart can consist of one of more of the following:

* Electronic Navigational Chart (ENC) (e.g. based on S-57 or S-101) and;
* Raster charts (e.g. Admiralty nautical charts (ARCS));
* Other types of vector nautical charts;
* Satellite images, land maps, GIS sources, etc.

The use of up-to-date ENCs is recommended to maximise consistency with charts used on board ships (it should be noted that if licensed charts go out of date, they may add text or other markings that could degrade the Traffic Image).

Other factors to consider include, but are not limited to:

* cost related to maintaining up-to-date Charts;
* the requisite Chart layers selected for display;
* optional layer selection by the VTS User;
* use of locally derived layers.

The UI should support both automated and manual management of layers. It should be possible to automatically update Charts without affecting the continuity of VTS operations.

The Chart presentation should utilise a consistent symbology set and colour palette suited to the local operating environment.

The current ENC standards, i.e. S-57/S-101, (reference [2] and reference [3]) are designed for navigational purposes and care should be taken when using them in a VTS System. Specifically, it should be ensured that the VTS UI specification includes the capability for authorised personnel to amend the portrayal of the Chart to suit the VTS operational requirements.

The Chart should support zoom and pan operations without introducing errors or distortions, i.e. all distances, depths and bearings should remain consistent during zooming and panning of the Chart.

#### Sensor data

The UI should have the ability to display sensor data in accordance with the Operational requirements defined by the VTS Authority. The display of sensor data (e.g. radar video, AIS, Electro Optics, RDF, etc) may support operational objectives and may consider factors such as:

* Real-time situational awareness;
* Recent situational awareness of vessel positions;
* Visual confirmation of the real-time Traffic Image;
* Detection and identification of small targets;
* Redundancy.

#### Vessel Presentation

Vessel presentation is addressed by IALA Recommendation R0125 (ref. [1]). Each vessel should be displayed in a consistent manner such that the VTS User can intuitively understand the true geographical position of the vessel. This is achieved by displaying the vessel symbol in its true position relative to the underlying or reference Chart. In addition, this positional information can be augmented by the presentation of the geographical coordinates of the vessel or by its bearing and distance from a selected location.

The UI should be capable of displaying all the information associated with each vessel displayed in the VTS User’s view. The VTS User should be able to selectively choose what information to display in accordance with local operational requirements. A straight forward and intuitive method should be employed to ease selection.

The information should be displayed either in textual or in graphical form as appropriate, e.g. course and speed vectors.

### Decision Support

The UI should be able to support the portrayal of Alerts (Caution, Warning, Alarm and Emergency alarm) in accordance with G.1110. The portrayal of these Alerts including thresholds often need to be configurable.

Functionality can be made available to the VTS User in a number of different implementations including, but not limited to:

* graphical 'icons’ or ‘tool buttons' often supported by short descriptive phrases. It should be possible, in the UI, to select display of buttons, text or both. User configurable 'tool bars' may be used to group tool buttons;
* context sensitive menus, with content depending on cursor location;
* dedicated function keys and/or key-stroke short-cuts.

The UI interaction should be intuitive and efficient. Wherever possible, the number of keystrokes should be minimised. Input fields should be, where possible, filled with appropriate default values by the VTS System.

* Supporting functionality for Decision Support Tools (See Guideline G-1110)

### Voice communication

Voice communication with vessels and other stakeholders within the VTS area is the most important part of the VTS system and therefore the UI for the radio equipment should be easy to use.  The Voice communications UI may be integrated with the Traffic Image presentation or may be separate.  Many modern VTS systems provide a touch screen user interface.  The VTS User may be provided with the following facilities:

* Radio selection and status
* Channel / Frequency Selection
* Squelch control
* Digital Selective Calling (DSC)
* Facilities to replay recorded conversations
* Microphone or footswitch with Press To Talk capabilities
* Headset and/or Speaker.

Details about the operational requirements of the Voice communications equipment is provided in IALA Guideline 1111-2.

### Radar

Radar is often regarded as a critical sensor input for VTS systems, due to its ability to accurately detect and track objects and their movements without requiring any transmission signal from the object itself, unlike sensors such as RDF or AIS. It is important to note that Radar does not identify an object. Radar data comprises Radar video and tracks and may include both dynamic and static objects, including but not limited to vessels, navigation aids, islands, bridges, offshore structures and coastlines.

The VTS User may be provided with the following facilities:

* Real time Radar video plot representing an objects present position and afterglow of moving objects representing their past positions
* Real time Radar track data (label) and symbol
* Radar control and settings possibly using User profiles/permissions
* Selection/choice of the Radar for the Traffic Image.

The UI should be configurable to enable the VTS User to obtain more information about the Radar tracking sources of a target and to optimize the performance of the radar in variable conditions.

Details about the Tracking function is provided in Chapter 4 – Data Processing of this Guideline.

Details about the operational requirements of the radar sensor equipment is provided in IALA Guideline 1111-3.

### AIS and VDES

An Automatic Identification System (AIS) uses a transponder on board a ship to provide a means for locating and identifying vessels. AIS position reports received from AIS transponders by AIS Base Stations and/or Receivers located onshore are be used for Tracking and AIS static and voyage related data may be displayed within the Traffic Image. It is important to note that AIS Transponders are designed for use on board and not for use on shore as part of VTS Equipment.

To enable identification, consideration should be given to the inclusion of AIS data in the Data Fusion process with Radar tracks and displayed within the Traffic Image of the VTS System.

The VTS User may be provided with the following facilities for:

* control of the update rate of Dynamic messages, which can be increased or decreased as a traffic situation requires
* deploying Virtual and / or synthetic Aids to Navigation, which will appear on the ECDIS of ships within the coverage area
* portrayal of Class A, Class B and AIS-SART transmissions
* sending short text messages for display on board the ship’s Minimum Keyboard Display (MKD).

As AIS became more heavily used for maritime safety, situational awareness and port security, the need for additional channels dedicated to data transmission within the VHF spectrum was created. The VHF Digital Exchange System (VDES), with its increased data transmission capabilities, may be used as a component within a VTS system to support the digital exchange of an expanded variety of information between both vessels and VTS providers and between vessels within and external to VTS areas.

Details about the operational requirements of the AIS and VDES equipment is provided in IALA Guideline 1111-4.

### Environmental Information

The UI should be able to display information derived from the available meteorological and hydrographical sources as required for historical, real time and forecast data.

Depending upon the nature and extent of the available data, and the operational context in which the data may be used, the data may be integrated with the Traffic Image or the data may be displayed on a standalone display device.

Details about the operational requirements of the Environment Monitoring System(s) is provided in IALA Guideline 1111-5.

### Electro-Optical Sensors

An Electro‐Optical System (EOS) may consist of imaging devices, such as daylight CCTV, day/night CCTV, Infrared, Thermal and laser‐illuminated cameras and other imaging devices. The EOS data can provide a visual image that may assist the VTS User in the detection, recognition and identification of vessels and / or objects within the VTS Area.

The VTS User may be provided with the following facilities for:

* Point and Click within the Traffic Image to enable the VTS User to quickly direct the camera(s) to a position, vessel or object of interest
* A moving target (vessel) can be selected in the Traffic Image so that the camera follows its movement
* Manual Control of the camera(s) may be provided
* Ability to Record and Playback of Video data.

Electro Optic / Thermal camera derived data (video) may be overlaid in a separate window on the Traffic Image or displayed separately.

Details about the operational requirements of the Electro Optic / Thermal Cameras is provided in IALA Guideline 1111-6.

### Radio Direction Finder

Radio Direction Finder (RDF) equipment can be used to assist the VTS User with vessel location and identification during communication from the vessel and is often useful in Search & Rescue operations. RDF provides a bearing line on the Traffic Image that indicates the direction of a radio transmission.

The VTS User may be provided with the following facilities for:

* Channel / Frequency selection
* Colour of bearing line (for multi-channel RDF Receivers).

Details about the operational requirements of the Radio Direction Finder is provided in IALA Guideline 1111-7.

### Long Range Sensor systems

The use of information derived from long‐range sensors can supplement information in a VTS System and may support the monitoring of vessel activities located beyond the VTS Area. However, it should be noted that long-range sensor data may not be real time and therefore careful consideration should be given to the inclusion of this data in the real time Traffic Image.

Typical long-range sensor systems include:

* Long Range Identification and Tracking (LRIT);
* Satellite AIS/VDES;
* HF Radar;
* Satellite‐based Synthetic Aperture Radar (SARSAT).

Details about the operational requirements of the Electro Optic / Thermal Cameras is provided in IALA Guideline 1111-8.

### Replay

The ability to record and replay the Traffic Image that was presented to VTS Users in real time is regarded as a critical part of the VTS system and may be used as evidence in cases of infringement.  The Replay UI may be integrated with the Traffic Image or may be separate.  VTS systems should ensure that Recording continues while Replaying.

The VTS User may be provided with the following facilities:

* Fully synchronised Replay facilities
* Selection of the source data (Voice communications, Sensors, Data Processing) and time period
* Selection of any combination of sources
* Instant replay of the Traffic Image and Voice Communications for a configurable time period
* Pause/Stop/Speed selection
* Export in an industry standard format.

The Recording of all source data should be automatic and archived at regular intervals. Access to system administration settings should be configurable as approved by the VTS Provider taking into consideration the ability to disable, delete, modify, export and archive recordings.

Details about the Recording and Archiving function is provided in Chapter 4.4 of this Guideline.

### Internal monitoring

The UI should be capable of presenting the overall status of the VTS System including all the major system components/subsystems and the infrastructure. Typically, this will include:

* communications – data and voice;
* sensors;
* main Information Technology (IT) elements – software, servers, processors, PC, workstations, data storage and network.

It is essential that VTS Users are provided with an intuitive, timely and readily accessible view of the VTS System status and health. The required level of detail may depend upon the role of the user. Sub-system status may be summarised hierarchically to suit each anticipated situation.

### External Information Exchange

External connectivity of VTS Systems is becoming increasingly important to provide information such as:

* Connection to other VTS systems
* Connection to Allied Services
* Connection to third party service providers (eg Meteorological forecasts, Cloud based services, e-Navigation Maritime Services).

Display of such additional information should be selectable by the VTS User. Specifications for specific VTS implementations should include functional descriptions of the various operational information sets that are required to be displayed to the VTS User.

Details about the External Information Exchange is provided in Chapter 5 – External Information Exchange of this Guideline.

## Specific Design, Configuration, Installation and Maintenance Considerations

### Physical Layout

The provision of Vessel Traffic Services is the prime objective of the VTS User and the physical layout of the VTS centre should serve to enhance the ability to provide the service.

The VTS centre layout should consider:

* room layout;
* ambient lighting and comfort settings;
* noise levels, background machine noise as well as voice communications;
* screen specifications, including resolution, size, etc.;
* number of screens per VTS User workstation and their arrangement;
* number of workstations and operational sectors;
* wall screen displays.

To provide optimal operating conditions in a VTS centre, it is of paramount importance to create a comfortable and supportive environment to facilitate the ability to concentrate with minimal distractions.

When contemplating a new or refurbished VTS centre, consideration should be given to seek ergonomic design consultancy to assist in defining the optimum design for the centre, particularly to minimize fatigue factors during VTSO watch schedules.

The environment should consider the advantages of air-conditioning, good and appropriate lighting, minimisation of externally and internally generated noise distractions, nearby rest facilities to minimise user downtime, and well-designed interaction with the available voice communications.

The layout should also consider emergency procedures and the role of the VTS centre in emergencies, as part of a regional or national infrastructure.

### Screen Layout

The screen layout needs to consider the appropriate use of multiple windows, pop-up windows, locked and flexible window positioning, overlapping and side by side windows containing chart data, textual information and dedicated status information etc. The relative importance of each information type needs to be accommodated within the adopted design, in particular the VTS Traffic Image should remain visible.

In the case of workstations employing multiple screens, care should be taken to ensure that the same concepts of window management are extended over the entire screen layout. It is important to ensure the VTS User can easily keep track of the cursor position.

The UI should consider allowing selection and filtering of the presented information to tailor the screen to the task in hand, including dedicated search functionality.

The UI may also support the interactive and automated provision of help text to the VTS User. For example, hovering the mouse over a particular tool button can result in the screen of a concise help reference for the use of that particular tool.

# DECISION SUPPORT

## Introduction

In accordance with IALA Guideline 1110 [1], Decision Support Tools (DST) are used to help enhance situational awareness and the decision-making process of VTS Users by providing analysis and insight to developing or emergency situations, in real time, near real time and for long-term planning.

Due to the perpetually evolving nature of VTS related concepts and technologies, consideration should be given to the continual development and refinement of DSTs as appropriate to meet future needs.

### Definitions

Alarm A high priority alert requiring immediate attention and action (IMO Res. A.1021(26)).

Alert An announcement of abnormal situations and conditions requiring attentions (IMO Res. A.1021(26)).

Caution Lowest priority of an alert. Awareness of a condition which does not warrant an alarm or warning condition, but still requires attention out of the ordinary consideration of the situation or of given information (IMO Res. A.1021(26)).

Decision-maker A person or group authorized to make decisions.

Decision support tool A tool to assist the decision-maker in real-time, near real-time and long-term planning.

Emergency alarm Highest priority of an alert. Alarms which indicate immediate danger to human life or to the ship and its machinery exits and require immediate action (IMO Res. A.1021(26)).

Long term planning Refers to the action of analysing currently available information to proactively manage predicted future events.

Near real-time Refers to predictions of developing situations.

Real-time Refers to the immediate action taken to respond to current or developing situations.

Warning Condition requiring immediate attention, but not immediate action (IMO Res. A.1021(26)).

### References

1. IALA Guideline 1110 on the Use of decision support tools for VTS personnel.
2. IAMSAR Manual.

## Characteristics of Decision Support Tools

Decision Support may consider such aspects as vessel behaviour, vessel traffic development, legal criteria, incident management, environmental monitoring and forecasts, organisational and operational procedures. It can correlate and combine these aspects to give validated advice.

Decision Support Tools may be self-learning, make real-time risk assessments and/or provide recorded and statistical data to the VTS Provider to improve safety, efficiency and environmental protection. In view of this, Decision Support Tools should be configured or tailored for each VTS, as appropriate. Alerts, raised by Decision Support, should be presented in a timely and relevant manner aligned to operational requirements.

Decision Support Tools are reliant on the timeliness, accuracy and integrity of the incoming data and the underlying model-based analysis of that data. Decision Support Tools may also be used to evaluate the performance of the VTS itself. For example, as stated in Section 1, the process of establishing a Vessel Traffic Service supported by a VTS system starts with a risk assessment of a potential VTS area. The risk analysis process leads to the identification of mitigation measures which will contribute to the definition of operational requirements for the VTS. Decision Support Tools may then assess whether these operational requirements have been achieved.

Decision Support Tools should be able to assist decision-makers by providing facilities that aid the management of risk situations and, thereby, reduce the level of risk. In addition, appropriate Decision Support Tools may also provide a means of measuring the level of risk reduction achieved and assessing near miss situations.

## Operational Requirements

Decision Support Tools may help the VTS User and other decision-makers with the implementation of the appropriate predefined and approved procedures for Route management, traffic management, monitoring and protection of assets, environmental and fairway monitoring, incident response and anomaly detection.

Decision Support Tools aim to reduce the workload of VTS Users. They may be based upon real-time, near real-time or long term, assessment of risks associated with the traffic situation. Where the risk level exceeds a pre-defined threshold, an Alert may be raised, for example from Caution to Warning, and the VTS User may be advised of the recommended risk mitigation options.

Management facilities should be provided for the adjustment of alert thresholds and the possibility of de-activation. However, it is recommended that the appropriate alert thresholds should be part of the agreed operational procedures to ensure that the deployed system is fit for purpose. Alert parameters should be set at levels appropriate to support the goals of the VTS service, being careful to avoid excessive notifications that may cause operator fatigue, distraction, and other factors that may negatively impact overall safety and efficiency.

Management reports may be generated from alert statistics and/or VTSO actions for analysis.

To reduce repeated alerts relating to the same vessel and situation, the reporting of alerts should incorporate filtering techniques, such as hysteresis.

Management reports may be generated from alert statistics and/or VTS User actions for off-line analysis.

The following is a list of common Decision Support Tools groups.

### Route Management

Route management includes the Sailing or Route Plan used by visiting ships and is an important aspect in ensuring safety within the VTS area.  Over time, the VTS system records many ship visits and the routes that they use.  These can be analysed for long term planning purposes to optimise safety and thereby define safety limits for each route used within the VTS Area.  High risk situations on a route can then be configured to provide useful alerts and ETAs for the VTS User when monitoring vessel movements in real time. For example, compliance with a Sailing Plan may alert a VTS User when a ship's track is outside the route spatial or temporal boundaries that have been defined for that specific ship.

Decision Support Tools can provide route analysis for the long-term planning of route management and for definition of alert thresholds to support real time operations.

### Traffic Management

Planning the arrivals and departures and understanding the limits for different types of ship is also an important part of ensuring safety within the VTS area through the definition of thresholds for providing useful alerts to the VTS User.  These alerts may include:

* Close quarters and Collision Avoidance
* Grounding Alerts
* Speed Alerts
* Time slots
* Just in Time Arrival
* Anchor Watch
* Air draft clearance.

It also enables the definition of near miss alerts for different types of ship that can be further analysed when improving the overall safety measures of the port or TSS.  Real time and near real time monitoring supported by appropriately configured alerting will support the VTS User.

Decision Support Tools enable the VTS Provider to plan the most effective use of alerts for real time and near real time operations.

### Monitoring and protection of assets

A VTS Area may include some significant assets that have certain risks or vulnerabilities such that the VTS User may wish to apply special monitoring and management techniques to ensure safety of vessel traffic and of the assets. Examples of such assets may include: Offshore Platforms (including FPSOs) and pipelines; Offshore windfarms; subsea cables; protected wrecks; and Marine Aids to Navigation, etc.

The protection of assets within the VTS area may involve the establishment of a protection zone around the asset with Alerts being triggered if an unauthorised vessel enters the protection zone. The protection zone may be established based upon national legal requirements or may be the output of the risk assessment process that was undertaken when establishing the operational procedures. The size, shape and access permissions for the protection zone around the asset will be defined through the long-term planning assessment such that the VTS system can be correctly configured to provide the asset protection required. This may consider typical traffic patterns (Route Management) in order to quantify risk and to provide Alert thresholds based on near miss and zone violations.

Decision Support Tools may provide forecast alerts relating to the risk of an unauthorised vessel entering the protected area and/or an Alert when the vessel enters the protected area.

### Environment and Fairway Monitoring

The VTS User should always be aware of environmental factors that could affect normal vessel traffic operations. Poor weather conditions may impact the expected time of arrival for a vessel and the overall plan for the services that would be supplied to that vessel when it arrived at its berth. It is therefore important to forecast the impact of weather within the VTS area and while a vessel is en-route from its previous port.

Ensuring adequate under keel clearance is an important factor in the planning and efficient management of ship visits, especially in approach fairways. VTS Providers should consider monitoring tidal height and water depth and assessing the result against the draught information from visiting ships to ensure unhindered access including factors such as squat modelling and water density factors.

In line with the IMO Greenhouse Gas strategy, it is intended that emissions from ships will be reduced in accordance with the target dates published by the organisation. VTS Providers may consider measuring and recording emissions from visiting ships.

Environmental factors that may be considered in a long-term planning context and for real time monitoring may include but are not limited to:

* Wind speed & direction
* Rainfall
* Temperature
* Humidity
* Atmospheric Pressure
* Visibility
* Tidal Height
* Water depth
* Current speed & direction
* Ice and Oil Spill Detection
* Ship gas emissions.

### Incident Response

Where the VTS Provider is tasked to support Incident response, it is essential that the VTS system provides comprehensive recording of the real time traffic image such that any incident can be replayed and analysed in order to improve operational procedures and reduce incidents.

Decision Support Tools may help visualize and plan the allocation of resources to assist in the prediction of where an object, person or vessel may drift over time, which together with search planning tools may ensure a quick and appropriate response is initiated.

Decision Support Tools may be provided for the VTS User to record additional details that can be associated with all the vessels involved in the Incident.

Further reference should be made to national guidance and the IAMSAR Manual.

### Anomaly Detection

VTS Providers are encouraged to consider setting threshold limits related to appropriate routes for the VTS Area in terms of a vessel’s speed, rate of turn, etc so that the VTS User is alerted when abnormal behaviour or an unexpected route deviation arises.

### Collision Avoidance

Collision avoidance tools are intended to alert VTS users to potential collision incidents. Such tools may use CPA / TCPA and/or safety domain concepts.

The Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) are numerical indices characterizing the imminence of a close approach between two vessels. These indices must be pre-defined and interpreted together with a logical AND function. The definition of these indices should consider the range and azimuth (bearing) accuracy of the sensors, especially in the case of radar-only vessel tracking, as the sensor accuracy will impact the accuracy of the CPA and TCPA calculations.

Safety domains establish a zone around each vessel and monitor if another vessel will potentially enter that zone. Safety domains may be particularly relevant in areas of dense traffic. The size and shape of the zone can be used to reduce the number of false Alerts.

If different areas are monitored according to different rules concerning alert thresholds, it should be possible for the VTS Users to visualize the different zones and the associated alert levels.

If different alert levels are supported, the display of an alert should provide clear indication of the criticality of the alert.

### Anchor Watch

Anchor watch should alert a VTS User that an anchored ship has drifted beyond the safe limits of its defined anchorage. Anchor Watch zones are Monitoring Zones that are based on a given vessel position and include its legitimate movement due to tidal conditions and the relevant sensor accuracy. The boundary should therefore be derived according to the greatest distance from the anchorage point (low tide limit). The ship should remain inside this zone in all but the most extreme conditions and alerts should advise the VTS User that the vessel has drifted beyond the Anchor Watch limits.

Distances should be expressed in the standard unit of distance.

Where meteorological and/or hydrographical forecast information is available, a Decision Support Tool may be able to alert the VTS User that changing conditions could put certain vessels at risk of breaching their Anchor Watch limits.

### Grounding Avoidance

A Grounding Alert requires details of the draught of the vessel and the bathymetry. Tidal information can be used for more accurate calculations. The Alert is raised if the estimated under-keel clearance along the predicted path of the vessel is less than a pre-defined threshold. The source of draught information should be checked to ensure accuracy.

Depending on the capabilities of the VTS, the accuracy of bathymetric maps, of water height due to the tide and of the draught of the vessel, the grounding threshold may be adjusted by VTS authorities based upon their assessment of acceptable risk parameters, e.g. to allow for squat and variations in water density. It is recommended that these thresholds should be determined assuming worst case data accuracy.

### Air Draught Clearance

Air Draught is an Alert that requires the air draught of the vessel, the obstacle clearance, bathymetry and tidal information. The Alert is raised if the estimated clearance is less than a threshold.

Depending on the capabilities of the VTS, the accuracy of bathymetric maps, of water height due to the tide and of the air draught of the vessel, the Air Draught threshold may be adjusted by VTS authorities based upon their assessment of acceptable risk parameters e.g. to allow for squat and variations in water density. It is recommended that these thresholds should be determined assuming worst case data accuracy.

### Area related

These warn the VTS User that a ship has, or is about to, penetrate a stationary or moving pre-defined area or cross a pre-defined navigational line.

International regulations, national recommendations or VTS Providers may define areas where no shipping is allowed under normal circumstances. These areas may be Special Protected Areas (SPA) or Marine Protected Areas (MPA), Prohibited zones, or Particularly Sensitive Sea Areas (PSSA), as defined by IMO or national authorities.

### Speed Limitations

These warn VTS Users whenever a ship's speed is outside pre-defined speed boundaries (SOG).

Competent and VTS authorities may define upper and lower speed limits for navigation in certain areas such as port zones and traffic lanes. To implement this functionality, sufficiently accurate and reliable speed estimation should be available to avoid false Alerts.

## Specific Design and Installation Considerations

The selection of DST for a VTS system should be considered in conjunction with a historical analysis of the specific behaviour, characteristics of the vessels, typical routes, and hazards that may affect the efficient and safe movement of vessels within the VTS area affected.

Refer to IALA Guideline 1110 [1] section 3, for examples of where DSTs may assist in ensuring the safety and efficiency of navigation, through route and traffic management, monitoring and protection of assets, environmental and fairway monitoring, incident response and anomaly detection.

# DATA PROCESSING

## Introduction

A VTS System uses data processing to create the traffic image, to manage ship visits, to support the VTS user with decision support tools and to record activity.

This section will provide further information to support VTS Providers in the management of data associated with ship visits, the processing and data fusion of radar data in order to provide high quality track data for the traffic image and the recording of activity for analysis purposes.

### 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** - is everything that is potentially useful and relevant to the VTS User.

**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.

**Information** - is the result of the processing of the Data. It should be appropriately useful and appropriately clear to aid the VTS User and the decision-making processes. In the context of a VTS System, there are many pieces of data, each with its own importance, validity and integrity.

**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. VTS User 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.

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

**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 VTS User.

**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.

### References

1. NIMA Technical Report TR8350.2 - Department of Defense World Geodetic System 1984, Its Definition and Relationships With Local Geodetic Systems, third edition - amendment 2 (June 23, 2004).
2. IEEE Std. 686-1997 - IEEE Standard Radar Definitions.
3. IHO S-57 – IHO Transfer Standard For Digital Hydrographic Data.
4. IHO S-101 – IHO ENC Product Specification.

## 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 VTS User, 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.

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 VTS User 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 fusioncan 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 VTS User 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 VTS User (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:

* 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;
* 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 VTS User. 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 requirements.

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 VTS User. 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 VTS User 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 VTS User, 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 VTS User 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 VTS User should receive a warning of imminent track termination, and also the VTS User 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 (SafeSeaNetSesame, 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 VTS User 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 VTS User 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

| Parameter | Typical span of Parameter |
| --- | --- |
| Number of confirmed tracks | From ≤ 500 to ≥ 2500 dependant on area covered, traffic density and smallest size of objects to be tracked. |
| Time for initiation of a tentative track | From 5 to 60 s, or 3 to 10 sensor observations. |
| Time for classification as a confirmed track | From 5 to 60 s, or 3 to 10 sensor observations. |
| Time from data loss to automatic track termination | ≥ 60 s, or ≥ 10 sensor observations, whichever occurs first. |
| Speed of tracked surface objects | From ≤ 50 knots to ≤ 70 knots dependant on fastest target in the VTS area. |
| Turn rate of tracked objects \*) | From ≤ 10°/s (SOG ≤ 5 knots) to ≤ 20°/s (SOG ≤ 5 knots). |
| Transversal acceleration of tracked objects \*) | From ≤ 2.5 m/s2 (SOG > 5 knots) to ≤ 5 m/s2 (SOG > 5 knots). |
| \*) The transversal acceleration = SOG \* turn rate, thus for slow moving targets the turn rate is the limitation, whereas the transversal acceleration is the limitation for fast targets. | |

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

| Parameter | | Receiving data from Basic radar sensor | Receiving data from Standard radar sensor | Receiving data from Advanced radar sensor |
| --- | --- | --- | --- | --- |
| Accuracy in track position | Range (relative to sensor location) | The greater of:  ≤ 0.5 % to 0.75 % of range covered by the individual radar  ≤ 5m to 10m + selected effective pulse length  or half the target extent in range | | |
| Bearing (relative to sensor location) | ≤ 1°, X-band radar sensor  ≤ 2°, S-band radar sensor | | ≤ 0.5° |
| Accuracy of track speed | Speed over Ground (SOG) | ≤ 2 knots | ≤ 1 knot | ≤ 1 knot |
| Course over Ground (COG) | ≤ 5° | ≤ 2° | ≤ 2° |
| Timing | Time from track confirmation to achievement of specified track accuracy | ≤ 120 s | | |

**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

| Parameter | Discussion | Operational Consequence |
| --- | --- | --- |
| Time to initiate tracks | This can be measured from the point of first observation to either the creation of a tentative track or the establishment of a confirmed track. In addition, the contribution of the display function to latency may need to be assessed separately. | The design has to consider the trade-off between fast establishment of new tracks vs. the associated false track rate. |
| Probability of false (confirmed) tracks | This is dependent on clutter conditions, traffic density, sensor sensitivity, sensor resolution and the perceived need to detect and track very small targets – the acceptable rate should be specified per area per unit time. Typical values might be 3 to 4 per hour although this is likely to conflict with a requirement for very small target detection. | Displaying tracks which do not represent real targets will increase workload and may result in incorrect VTS User actions being taken. |
| Average false track duration before termination | The tracker should react quickly to confirmed tracks which subsequently fail to exhibit reliable track behaviour. | Continued display of tracks which do not represent real targets will increase workload and may result in incorrect VTS User actions being taken. |
| Probability of failure to confirm a genuine track | The tracker performance in combination with the sensor network should minimise the probability of failing to establish a genuine track after the first reliable sensor observation. | Delays to the establishment of a track will impact the traffic image and may result in incorrect VTS User decisions. |
| Probability of track loss | This concerns track continuity. Assuming good sensor visibility of the target, the tracking function should provide reliable and accurate track updates over the entire life time of the track. | Frequent track loss will lead to reduced confidence in the track measurement accuracy and the ability of the system to follow manoeuvring targets. In congested traffic areas, this could be critical to safe vessel passage. |
| Probability of successful management of two targets merging and then correctly splitting | In the highly likely event of two (or more) targets merging into one sensor resolution cell, the tracker should be able to use the combined and unresolved observation to update the merged tracks until after some time when the targets 'de-merge', the tracker should successfully split and update the previously merged tracks with correct numbering and track identification. | The VTS User needs to be presented with the best tracking information available before, during and after the merging event. |
| Track identity swap rate | The tracker design should minimise the probability of track identities incorrectly swapping between two tracks (and ensure that incorrect swapping is quickly corrected). | The VTS User needs to be presented with accurate and correctly associated tracking information against targets of interest. |
| The probability of multiple tracks being created from one target | This parameter is often specified for VTS applications in areas covering inland waterways in which large vessels, travelling close to the (radar) sensor location create multiple plots which result in multiple tracks. | Presentation of multiple tracks, relating to a single large object, can create confusion and inappropriate VTS User decision making. The tracker should be able to identify group behaviour within plots and tracks and reduce these to a single track representing the large vessel. The positional reference point for such a target needs to be understood and interpreted appropriately. |
| Latency of track update | This parameter needs careful definition – time of sensor observation to track update (i.e. not including display function etc.). | Minimal latency will provide a traffic image which is close to real time, but some latency is inevitable, especially when microwave links are included in the VTS network to link remote sensors sites to the VTS centre. (Satellite AIS can also suffer significant and often unacceptable latency).  Delays in presentation of the surface picture can lead to delayed awareness of the need for VTS User action. |
| Coasting period (before track termination) | The time, measured from the last track update with an associated sensor measurement, to automatic track termination. | Genuine target tracks do not just disappear (unless they are at the extremes of available sensor coverage) so the deletion of tracks is a trade-off between lost genuine tracks, prolonging of track seduction (e.g. onto clutter), and prolonging of incorrectly confirmed false tracks. |

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.

## Ship visit and VTS Data Management

The data held in a VTS system is often important when managing processes for ship visits or transits through a VTS area. Often referred to as a Management Information System for ports or transits this database supports a workflow for the planning, utilisation and recording of the resources allocated to a ship’s visit. When integrated with the VTS system, it should receive real-time updates of the progress and status of the ship visit. Typically, the database may include the following resources; Pilots, Tugs, Berths, Linesmen, Waste facilities and other services that may be provided to safely and efficiently handle a ship during a visit or transit.

The database may provide information that enhances the VTS traffic image such as showing when a Pilot is on board a ship. The database is often a critical source of data that may need to be validated for generating statistical reports such as the utilisation of resources during a configurable time period and for invoicing.

When specifying the requirements, the VTS Provider should consider their specific workflow/process when managing a ship visit. This is workflow/process is often stated in the VTS Providers Standard Operating Procedures, VTS User Guideline or the relevant safety management system.

The types of data typically may include:

* voyage data;
* cargo data;
* vessel data;
* incident data;
* contact data;
* pilots and tugs data;
* berths data;
* traffic analysis data;
* local hazards data;
* VTS Equipment data such as status, build state, version, faults, spares, maintenance;
* Shore-based personnel (VTS Users, Pilots, Tugs, Linesmen, etc) data, which may be subject to privacy considerations;
* Other service data.

It may be appropriate to integrate the database with the VTS provider’s invoicing system to automate the collection of all chargeable services related to the ship’s visit to facilitate account management by systems associated with the port finances (i.e. not directly associated with VTS operations).

## Recording and Archiving

The recording of real-time data and vessel activity as seen and heard by VTS personnel is a critical component of the VTS System design so that a consistently accurate replay of events can be reproduced. These recordings serve multiple purposes, which can include but are not necessarily limited to quality assurance, procedural review, incident investigation, training, and legal court documentation.

Recording of sensor data, voice communications, the traffic image, and other elements as required by the VTS provider should occur automatically and the replay of recordings should not interfere with ongoing VTS personnel responsibilities, nor require recording facilities to be paused while recordings are being retrieved, compiled, or removed from the system for archiving.

It is recommended that the VTS system has the capacity for recording a minimum of thirty (30) days activity. The need for archiving data to separate external media should be derived from operational procedures, with appropriate storage devices considered for the type of data being stored, resolution quality (if applicable), any legal security requirements necessary to keep the data secure and free from tampering, and the period of time the data is required to be kept.

Details about the Replay function is provided in Chapter 2.3.10 – Replay in this Guideline.

# EXTERNAL Data EXCHANGE and Information Sharing

## Introduction

The purpose of this section is to support VTS Providers in the specification and selection of tools supporting collaborative data exchange between the VTS System and external systems to improve the operational efficiency of the VTS.

This is emphasised in the latest IMO Guideline on Vessel Traffic Services which states that effective harmonized data exchange and information sharing is fundamental to overall operational efficiency and safety.  VTS providers are encouraged to make use of automated reporting where possible. Typical examples of information exchange may include VTS to VTS, VTS to Ship, Ship to VTS, VTS to Pilot Portable Units and VTS to third party online services.

Specific examples of information exchange may include the sharing of Sailing/Route Plans and en-route updates of vessel positions to provide information to VTS providers prior to reaching the VTS area.   Such facilities may be provided through third party service providers, LRIT, VDES Satellite Service (when implemented) or by direct VTS to VTS using IVEF or VTS to ship using e-navigation maritime services.

VTS Providers should refer to the following IALA references for the sharing of maritime data for:

* legal issues and processes, may be found in IALA guideline N° 1086
* IALA data model domains, may be found in IALA guideline N° 1087
* technical aspects, may be found in IALA guideline N°1130.

When producing the VTS system specification, the VTS Provider is encouraged to consult the references and consider changes that may occur in the lifetime of the VTS system, which may typically be 10-years.

### Definitions

For general terms used throughout this section, please refer to references.

### References

1. IALA Standard 1060 – Digital Communication Technologies
2. IALA Standard 1070 – Information Services
3. IALA Recommendation R0145 – On the Inter-VTS Exchange Format (IVEF) Service
4. IALA Guideline N° 1086 – The Global Sharing of Maritime Data and Information
5. IALA Guideline 1087 – Procedures for the Management of the IALA Domains Under the IHO GI Registry
6. IALA Guideline N° 1130 – Technical Aspects of Information Exchange between VTS and Allied or Other Services.

## E-navigation

The IMO defines e-navigation as "the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."

E-navigation is intended to meet present and future user needs of shipping through harmonization of marine navigation systems and supporting shore services such as VTS. It is expected to provide digital information and infrastructure for the benefit of maritime safety, security and protection of the marine environment, reducing the administrative burden and increasing the efficiency of maritime trade and transport.

## IHO/IALA Data modelling domains

IHO adopted S-100, which is a framework geospatial standard for hydrographic and related data. S-100 is aligned with the ISO 19100 series of geographic standards, thereby making the use of hydrographic and other geographic data more interoperable than using the present IHO S-57 data transfer standard.

IALA is establishing the S-200 domain, in consultation with the IHO. A supervisory structure has been established (IALA Guideline 1087) that uses the range S-201 to S-299 for product specifications compliant with the IHO S-100 standard, covering fields within the IALA remit, including Aids to Navigation (AtoN), Vessel Traffic Services (VTS), positioning systems and communication systems.



For more information VTS Providers are encouraged to see:

* IHO S-100; <https://iho.int/en/s-100-universal-hydrographic-data-model>
* IALA S-200; https://www.iala-aism.org/technical/data-modelling.

## Characteristics of External Information Exchange in VTS

As specified in the latest IMO Resolution, VTS systems should share information as this is fundamental to overall operational efficiency and safety of the VTS. To be effective, data exchange and information sharing must be harmonised with international standards and implemented within a secure infrastructure.

Table 24 and Table 25 provide a list of purposes for maritime information exchange. This list is not exhaustive and simply provides an indication of the range and diversity of such maritime data.

1. Typical Information Exchange between VTS and Vessel

|  |  |
| --- | --- |
| Purpose | Type of Information Exchange |
| Traffic management | Voyage Plan  Requested Times of Arrival  Berth Availability |
| General information exchange | Risk identification and avoidance  Monitoring of cargo, vessel status and resources  Voyage monitoring (e.g. under keel clearance and track keeping)  Meteorology and hydrography  Cargo management (planning, loading and discharging)  Logistics support (shipboard) |
| Regulatory Compliance | Reporting  Environmental protection |
| SAR response (pending individual VTS responsibilities) | Medical and aeronautical support  Incident assistance |

1. Typical Information Exchange between VTS and Shore-based Entities

| Purpose | Type of Information Exchange |
| --- | --- |
| Traffic management | VTS support including real-time Traffic Image  Anchorage and berth management  Bridge and lock management |
| Hazard management | Risk analysis  Incident reporting and investigation  Contingency planning  Emergency towage and salvage |
| SAR | Medical and aeronautical support  Incident assistance |
| Logistic chain support | ETA at Berth  Cargo handling  Voyage monitoring  Port operation  Forward planning movements  Pilotage and allied services |
| Law enforcement | Maritime contraventions  Fisheries enforcement  Customs  Port state control  Border control / immigration  Port health inspections  Security |
| Environmental protection | Pollution monitoring  Incident response  Waste management |
| Waterways infrastructure management (including inland waterways) | AtoN operations and system optimisation  Infrastructure maintenance and update |
| Maritime safety information (MSI) | Navigation warnings (S-124), etc |

## Data Management Considerations

### Data Validity

Users should always be aware of the validity and completeness of the data to ensure that actions taken are based on timely, accurate and appropriate information.

Where a specific data service is being used, it is recommended that the parties involved in the data-sharing agreement should establish a Service-Level Agreement (SLA). The SLA should clearly define the responsibilities for quality and delivery of the data.

Where a service provider if receiving data from one party and forwarding it to another, then it is recommended that agreed data delivery templates should be used to ensure that the data is correctly interpreted upon receipt.

It is recommended that data exchange performance is monitored in accordance with key performance indicators (KPI) as agreed in the SLA.

### Access to Information

SLAs should clearly state requirements for provision, security, confidentiality and permitted use of all externally exchanged information.

Clear and realistic principles and rules regarding access should be established by the VTS Provider. These principles and rules should recognise national and international legislation and guidance.

The reception and use of data, broadcast by radio, is subject to ITU-R: Radio Regulations [2], article 17 on Secrecy.

### Data Security and Confidentiality

The VTS system must be installed and maintained within a secure network infrastructure. Firewall protection of the system and encryption of data (where practical) should be considered in order to avoid the loss of sensitive information. Cyber security software should always be maintained at the most recent version and the use of penetration tests should be considered in order to determine and resolve any cyber security weaknesses that could be exploited.

There are many instances where data is deemed sensitive and needs to be protected for competitive and privacy reasons. Examples of this include fleet information or location of fishing grounds. In both cases, unsecured data could compromise investors or introduce competitive advantages/disadvantages.

In many cases confidentiality is already protected by legislation but this is not universal throughout the maritime domain. Furthermore, the requirement to protect access to data may go beyond the limits of primary legislation. Confidentiality measures should to be taken to protect information to the required security level through data encryption, password protection, proper authentication, and restricted data access privileges.

Authentication means that the sending and receiving parties can identify each other with confidence.

Encryption may be used to ensure that data is only accessible to authorised parties. The level of encryption required depends on the sensitivity of the data.

### Legal Limitations

Many national states, in the lawful exercise of their authority, place legal limits on the exchange and public dissemination of data and information. These include protections on intellectual and commercial property rights, and limitations on third party use of data and information.

In the course of exchanging maritime data and information in the interest of safety, security and efficiency, these limitations shall be respected and the authorities involved should be aware of their rights and obligations under law. In particular, data transmitted should be consistent with the laws of the national authority. Authorities need to be aware of any exposure to liability that might occur from their actions or inactions with regards to data and information exchange.

Further information is available in IALA G1086 [28].

### Data Integrity

Data integrity is a key concern for users and providers alike. For example, key navigation decisions should be based upon timely, accurate and consistent data.

Timely data is data that is received when needed. This may be in advance of an event or in real-time as appropriate. The VTS Provider should state when data, such as a notification of arrival, is required. It is the responsibility of the sender to ensure that enough time is allocated for the data to be communicated and received.

Real-time data should be time stamped as close as possible to the time of capture. Network latency should also be considered when exchanging time-critical data. Within IP networks, the concept of Quality of Service (QoS) may be used to prioritise the delivery of time-critical data. In such a case, it is important that QoS be implemented from source to destination, as data may travel through multiple IP networks.

Data often travels circuitous routes undergoing multiple handovers, from source to destination, allowing for corruption to occur either accidentally or through deliberate actions. Where required, appropriate measures should be taken to avoid such data corruption (e.g. by encryption of the data).

### Communication Links

The transfer of data between sender and receiver requires connectivity via a network. A network comprises appropriate hardware and software interconnected by communication channels.

Different technical solutions and architectures can be used when establishing a data sharing network. Consideration should be given to the:

* services provided by the network;
* quality of services required by the users;
* constraints on infrastructure.

The sharing of maritime data and information can take place either through the Internet or through dedicated private networks. The Internet is public, while dedicated networks are private. Consideration should be given to the security related characteristics of these network types.

When designing a network for sharing maritime data, consideration should be given to transmission protocols, bandwidth, volume, communication / data distribution strategy, security aspects such as authentication and confidentiality as well as data integrity. It is recommended that spare bandwidth is always included to enable additional services to be added at a future date.