# Data Processing

#### Tracking and Data Fusion

##### Introduction

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 by a tracking filter. The track filtering process reduces the effect of random errors, allows predictions of the future target behaviour and passively identifies change in target behaviour. This contributes to the VTS system’s ability to provide course correction, hazard reduction, collision avoidance, early warning of security risks, environmental protection, port management etc.

The tracking process accepts sensor measurements of recent target observations from the available VTS sensor network (and other sources when available), and attempts to combine these with existing tracks from a managed database of live tracks for the purposes of display, data reduction, decision support and provision of track data to other agencies and users. When such recent target observations do not successfully combine with existing tracks, new tentative tracks are postulated and monitored until they either become firm tracks or are discarded as likely false alarms.

Track lifecycle (diagram?)

A tracking filter uses a model of the sensor 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 for new potential track updates. In addition it can provide monitoring of the progress of a vessel along its intended course relative to planned time of arrival at way points etc.

Design of effective track data processing and associated tracking filters is a complex subject requiring considerable understanding of the target characteristics, sensors characteristics, local area geography and environment characteristics and complex mathematical techniques. The following sections attempt to provide the VTS authority with an overview of the subject and further advice should be sought from experts in this field as required.

Note that for the purposes of VTS tracking, the scope of objects to be tracked is limited to surface vessels and environmental phenomena that might impact on VTS operations. In addition it is limited to data originating from fixed land based sensors and satellite detection systems. In the future, expansion to include data from shipborne sensors may become a reality.

Some standard terms need to be outlined for clarity (as below)

TBA (sensor, plot, observation, track, coast, etc.)

It is also recommended that a fusion process is included to take advantage of data available from multiple sensors and external sources. 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, velocity, manoeuvre etc.). In addition, the fusion process can be designed to detect errors and anomalies in the data from single sensors (which differ from other sensor derived data).

Data fusion trackers which combine inputs from a number of sources generally accept plot data (rather than single sensor track data). In the absence of measurement bias (which should be calibrated to have minimal impact), the output of data fusion 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. Data fusion also provides redundancy to minimise the consequences of sensor failure or poor detection.

Although normally a fully automatic process, it may be appropriate to include a facility to allow the VTSO to override the automatic association rules (forcing association or separation of sensor contribution to a given track or tracks).

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

Within this Recommendation, the tracking section will consider data from various sources including:

* Radar sensors
* Adjacent VTS area or other agency tracks
* AIS and SAIS
* LRIT
* RDF
* EOS
* Possibility of manually input data (eg via voice comms)

Note, that contributions from mobile sensors (ship based sensors etc) are not considered, although this additional enhancement and complexity may become reality in the future.

The tracker design should take into account the need to translate positional information into a common geographical reference system. One common standard for this is WGS84. This translation process requires an understanding of the attributes of each sensor, for instance AIS provides accurate Cartesian coordinates with common accuracy in all directions (on the surface) whereas radar, RDS etc measures position in terms of polar coordinates, ie. 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.

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.

Another important performance parameter to consider is processing latency throughout the tracking system. The time stamping of data enables the tracks to be correctly formed but does not guarantee that the data is presented in a timely fashion to the VTSO (or external system) in order to allow appropriate decision making in time to avoid an undesirable incident.

##### Plot extraction

This 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 (S)AIS or LRIT plot for instance is known to originate from a single GNSS receiver and provide a time stamped position which can be assumed, with significant confidence, to originate from one target.
* A radar, RDF, 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 that need to be resolved, or at least highlighted for downstream resolution

Radar video 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 to the VTS tracking process. The downstream plot association process contributes significantly to the selection of wanted radar plots from unwanted radar plots.

Note: some systems may introduce the possibility of multiple thresholding of plots to introduce different thresholds (ie different PD and PFA) for plot extraction. Downstream plots exceeding the lower thresholds are candidate for firm track updates whereas only plots exceeding higher threshold are candidates for initiation. This type of solution should be a design decision to improve compliance with the VTS objectives and should not be mandated by the VTS system requirements.

There is also the specialised process of extracting extended object information to enable downstream tracking of features such as icebergs or oil slicks.

Extracted plots typically include some or all of the following:

* time of measurement
* measured position (cartesian or polar) and positional uncertainty
* identity
* speed (and direction)
* physical size
* signal strength
* sensor measurement noise

In the majority of cases a plot extraction process will be fully automatic, relying on programmed algorithms tuned to optimise the process to the sensor characteristics and the topography of the coverage area. In some circumstances, a VTSO manual override facility may be considered useful but the use of such a facility should be minimal and avoided as far as possible.

A well designed tracking system will include consideration of how the plot rate, including the plot false alarm and duplicate plot rates will influence the downstream processes of plot to track association, and track initiation. The data transfer restrictions (if any) and downstream processing capacity should be aligned to the predicted plot extractor outputs in worst case conditions of high traffic density, and weather related false alarms.

The VTS system might require some special features to facilitate environment monitoring which may require plot density map or special plot record formats (for extended targets), identification of jamming (accidental or intentional), etc

Typical performance parameters to be specified might include:

* Number of plots per unit time
* Number and type of sensors
* Probability of extracting a false plot
* Probability of extracting multiple plots which originate from one object
* Probability of failing to extract a detection (subject to appropriate input data)
* Plot extractor latency (a tradeoff with plot to plot correlation eg from scan to scan, is needed here)

##### General tracking principles

###### Track Initiation

The extracted plots are passed to the track maintenance process (see below) and those which fail to correlate with existing tracks become candidates for the initiation of new tracks.

It can be assumed that a new (S)AIS related plot or 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. Whereas radar plots which have failed to associate, require additional confidence building algorithms before being initiating new tracks. Such algorithms might include the collection of non-conflicting data relating to a number of sensor updates (such as M out of N rules or other probabilistic assessments) which link together to suggest that presence of reasonable and predictable target behaviour.

Note that individual angle-only plot records (eg from RDF and EOS type sensors) cannot become tracks without support from other sensors, although triangulation of two angle only plots can be sufficient.

The assessment of predictable target behaviour requires knowledge of the type of targets which are to be tracked and the magnitude of measurement errors that are associated with each sensor type. There is also the possibility of the (S)AIS data being corrupted which may invalidate its use throughout the track initiation process. Integrity assessments of known fixed test targets or established tracks with updates from more than one sensor type (NB not all originating from GNSS measurements) should be communicated from the point of detection (of the integrity assessment) to all areas of the tracking process to minimise the impact of this VTS system failure mode. NB external agencies should share such integrity assessment information both into and out of the VTS system.

Note that predictable target behaviour can be erroneously represented by multiple plots from extended clutter – this possibility may be unavoidable but the tracking system should be able to react quickly once it becomes clear that a false track may have been created. False tracks from whatever mechanism, should be avoided in safety critical areas and occasionally accepted in areas where surveillance and traffic monitoring is the priority.

The track initiation process should establish a list of uniquely identified, tentative tracks which are each updated with subsequent associating sensor data as it becomes available. Tentative tracks which fail to become firm tracks are discarded. Tentative tracks which become firm tracks are promoted out of the tentative track list into the track list.

The track initiation process may be automatic, semi- automatic or manual depending on the VTS concept of operations.

In automatic track initiation mode, all plots should be considered as potential targets.

It should also be possible to initiate a track manually. In manual track initiation a plot on the radar display is selected by the operator using a graphical tool. When selected, this plot should form the starting point for a tentative track which eventually should be confirmed or discarded, as in the automatic case described above.

When designing the optimum radar sensor network for a VTS area, it is useful to understand the expected range of first track formation and display for a target entering the VTS area. This range is closely related to the assumed probability of an individual detection (a plot), the sensor update rate (allowing for the possibility of detection by multiple sensors) and the track initiation rules and therefore a term often used is the minimum radar PD for target detection in support of the track initiation process.

The probability of successful track initiation is related to the thresholds used in the (radar) plot extraction process and these thresholds may be adapted to suit the integrity requirements of the VTS application. The selection of appropriate thresholds should be aligned to the plot PFA (eg 10e-4 or 10e-6) from which the predicted target SNR can be used to assess the range at which a required PD is achieved. The system designer should consider the probability of false track formation in deriving the appropriate plot PFA. This complex assessment and trade-off may need expert input to arrive at an overall solution that achieves the aims of the VTS. Typical examples of suitable radar detection probabilities (PD) for different VTS applications are shown in the table below:

Table tba Track initiation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Suggested radar individual plot PD for track initiation assessment | | | | |
| Priority of the VTS | Recommendation level | | | |
| Local port service | Basic | Standard | Advanced |
| Surveillance and/or traffic monitoring | 0.9 | 0.9 | 0.8 | 0.7 |
| Safety | 0.9 | | | |

There is a trade-off between the time for confirmation of tentative track and the number of false tracks. A longer confirmation time implies less false tracks and it should be possible to balance this trade-off in the setup of the VTS.

The display of raw sensor video, extracted plots and tentative tracks may overload the VTSO with unconfirmed information and therefore it is recommended that the display HMI includes the possibility to hide some or all of this information.

###### Track Maintenance

Upon promotion of a tentative track to a confirmed track, the track maintenance process becomes active. This process includes the lifecycle stages of full tracking, fading / coasting, merging, splitting and, eventually, track loss.

The extracted plots are passed to the track maintenance process and those which correlate with existing tracks are used to update those tracks.

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 track correlation process involves the forward prediction of the track attributes (eg position) to a time which corresponds with the timestamped update(s) contained within the candidate plot information. After allowance for elapsed time since last update, measurement noise and the possibility of reasonable target manoeuvre, a test for correlation with the candidate plot or plots 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: track updates will arrive asynchronously from any available sensor.

Data contained within the associating plot is used to update the attributes of the track.

Various mathematical techniques are available to forward predict and update the track position and trajectory information for instance alpha-beta, Kalman, IMM etc..

In complex traffic situations it may also be appropriate to consider the use of advanced algorithms such as multiple hypothesis techniques to monitor a number of candidate solutions for the track history before making a decision based on sensor information that will be received in the future.

The probability of successful track maintenance is related to the thresholds used in the (radar) plot extraction process and these thresholds may be adapted to suit the integrity requirements of the VTS application. The selection of appropriate thresholds should be aligned to the plot PFA (eg 10e-4 or 10e-6) from which the predicted target SNR can be used to assess the range at which a required PD is achieved. The system designer should consider the probability of incorrect plot to track association and processor load in deriving the appropriate plot PFA. This complex assessment and trade-off may need expert input to arrive at an overall solution that achieves the aims of the VTS. Typical examples of suitable radar detection probabilities (PD) for different VTS applications are shown in the table below:

Table tba Track Maintenance

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Suggested radar individual plot PD for track maintenance | | | | |
| Priority of the VTS | Recommendation level | | | |
| Local port service | Basic | Standard | Advanced |
| Surveillance and/or traffic monitoring | 0.9 | 0.9 | 0.8 | 0.7 |
| Safety | 0.9 | | | |

The VTS system design needs to optimise the single sensor update rates to suit the predicted target manoeuvre capability and speed, the number of overlapping sensors, the tracker design etc.. to arrive at an optimum design that appropriately balances sensor update rate, resolution and integration time, target detectability, signal quality, measurement noise etc. In addition, track association complexity and processor demand (eg due to the number of candidate plots) increases as the correlation window size increases.

The track maintenance process needs to guard against the possibility of track seduction arising from false candidate plots originating from false alarms or clutter signals, reflections, unwanted echoes, birds etc.

Note that predictable target behaviour can be erroneously represented by multiple plots from extended clutter – this possibility may be unavoidable but the tracking system should be able to react quickly once it becomes clear that a false track may have been created.

The track maintenance process needs to include rules for the possibility of track inputs fading and as a result allowing the track to coast. This likelihood needs to be both allowed and guarded against so that potential new tracks are quickly associated with existing, but coasting, tracks and so that tracks can be terminated an appropriate time after the last reliable update.

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 both tracks. The use of (S)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.

The track maintenance process needs to include rules for track splitting, to optimise the situation in which track information updates indicate two tracks arising from one. Correct labelling of one or both resultant tracks may require the track maintenance function to switch the data in the near future when it becomes apparent that the track data has been corrupted. A new tentative track may also need to be formed.

The rules for fading, coasting, splitting, and merging may all 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 for submarines, the possibility of obscuration by fixed and moving objects in the area of interest, the need to track extended objects such as icebergs, oil slicks and weather effects (and to monitor their size and changes in their shape).

In some VTS applications there may be an associated security objective requiring the tracking process to include a threat assessment function.

###### Termination and loss of track

If a confirmed track either moves outside a user defined maximum range, into a user defined non-tracking area, if the quality of the track falls below a predefined minimum, 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 the operator should receive a warning as defined by the VTS Authority.

Track loss may occur as a result of lost signal strength in combination with manoeuvring targets, especially in the vicinity of obstructions such as bridges, land masses etc... 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.

The track termination process should consider hiding the track from the display update and /or delete the track from the track database.

The rules 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 also be required to allow for unexpected appearance and disappearance of submarines, the possibility of obscuration by moving objects in the area of interest, the need to track extended objects such as icebergs, oil slicks and weather effects (and to monitor their size and changes in their shape).

###### Performance of tracking functions ?

The determination of parameters to specify a VTS tracking system design is a complex task and the ultimate achieved performance is heaviliy dependent on the sensor data provided as inputs to the tracking process. The sensor requirements should consider information provided elsewhere in the other Annexes of these Recommendation and are therefore not repeated here.

The plot extraction process, considered here as part of the tracking process, can be located within the sensor or at the input to the tracker and there may be significant advantages to be gained in these decisions. For example, the extraction of radar plots and their Doppler information within the radar may enhance plot extraction and provide a further discriminator (instantaneous velocity – albeit ambiguous in some circumstances) to aid the association processes. The extraction of GNSS position data is always appropriately located within the sensor.

Key tracking parameters to consider are:

* Range of target characteristics (RCS, size, speed,, maneouvrability, draft, height, type etc)
* Max no plots per „rev / unit time etc
* Plot desnity in smaller areas
* Capacity for (Max) no initiations per second
* Max number of overlapping sesnors
* Measuremnt error fromeach sesnor type
* Plot update probability
* Number of hypotheses running vs any one track
* Track positionand velocity accuracy
* Latency of track update
* Coasting period
* Track list capacity constraints – „max“ number of tracks and tentative tracks
* False track per unit time
* Probability of merging / splitting, ident swapping
* Min and max number of updates from nothing to firm track
* Probability of fault detection /loss of sensor integrity
* Limitations of track numbering schemes (reuse of idents etc..)

The tracking system should be able to handle at least a certain number of tentative tracks and to initiate tracks and eventually to confirm tracks under certain conditions of PD and PFA.

The tracking system should be able to handle at least a certain number of confirmed tracks (Table 55.1) and to maintain tracks under certain conditions of PD (Table 55.2) and PFA ≤ 0.01.

The requirements in respect of plot extraction and tracking should be defined by the individual VTS authority, on the basis of local conditions, number and type of (radar) sensors in a system etc. Table XXX suggests values for the VTS area of each individual radar sensor in a system (in some cases these may be dependant on up.

Table 9‑1 Radar tracking performance parameters

| Plot Extraction and Tracking Performance for each individual radar in a system | | | | |
| --- | --- | --- | --- | --- |
| Parameter | | Recommendation level | | |
| Basic | Standard | Advanced |
| Number of plots per antenna rotation | | Sufficient to support the predicted VTS traffic density AND the sensor false alarm rate(s) | | |
| Number of confirmed tracks | | Sufficient to support the predicted VTS traffic density AND to include an allowance for false confirmed track rate | | |
| Time for confirmation of tentative track | | ≤ 1 minutes | | |
| Time from track confirmation to achievement of specified track accuracy | | ≤ 2 minutes | | |
| Time from data loss to automatic track termination | | ≥ 1 minutes | | |
| Speed of tracked objects | | ≤ 50 knots | | ≤70 knots |
| Turn rate of tracked objects | | ≤ 10°/second | | ≤ 20°/second |
| Accuracy in track position | Range [[1]](#footnote-1) | The greater of :   * 0.75 % of range covered by the individual radar * 10m + selected pulse length * or half the target extent in range   whichever is the greater | | ≤ 0.5 % of range covered or 5m + pulse length |
| Bearing a | ≤ 1°, X-band  ≤ 2°, S-band | | ≤ 0.5°, X-band  ≤ 1°, S-band |
| Accuracy of track data | Speed a | ≤ 2 knots | ≤ 1 knot | ≤ 1 knot |
| Course a | ≤ 5° | ≤ 2° | ≤ 2° |

A level generally accepted is that each operator should correct up to one track loss per hour in all areas where the recommended values given in Table ?.1 and Table ?.2 are respected.

###### Track merging, splitting, swapping

Swapping of track identity may occur as a result of targets moving close together or even merging for a period of time, especially if targets are overtaking with small difference in speed and course. Add crossing paths as well.

A simple method of manual correction should be employed.

In the case of AIS information being available for the radar track(s) in question, automatic correction should be performed.

The problem may also be addressed by implementing operational procedures to separate targets or to prevent overtaking in critical areas.

Definition of merging, splitting and ident swapping vs cooperative and non cooperative target types

###### Track identification

Internal and External Databases (Lloyd’s, SafeSeanet, single-hull database, various incident/black lists) – semi-static information

Distribution/Access level/”Need to know”

Function to assign new track numbers

Ais, LRIT

Passive sensor data (camera, radar size, expected time and route, etc.)

Fused vs individual track functions, handover of ident to adjacent /overlapping tracked areas (VTS etc)

###### Track data

Eg from VTS databases

Shipping routes,

Passage planning vs actual tracks

Availability of some / all track data to ..? (individual plot extractors...other allied agencies etc..).

###### Track presentation and display

WGS84

Overlay on VTS ECS

Use of symbols

Textual data

Colours etc..

Usability of “busy” traffic scenario on the VTS display

Source of track inputs and missing expected track inputs

##### Tracking using Individual sensor data

Radar, ais, eos, rdf, lrit, sais ,other

Characteristics of each sensor type, eg xy, R theat, theta only update rate, integrity checking, cooperative target data, etc..

General principle that it is better to feed a fused tracking process with “raw” plot data rather than individually tracked sensor streams of data.

##### Tracking using fused sensor data

Sensor data fusion is a process of collection of data from multiple sources and creation of combined and more robust information. Part of data fusion can be automatic, other part may require operator assistance. The data fusion process should consider the fact that information sources are not time synchronized, and the quality of information coming from different sensors is variable.

Time stamping, data latency, measurement errors, physical “gap filling”, absolute accuracy in all “directions” (not just in range (for radar) or just in angle (for EO or RDf etc))

Remember DB management,

SARTS presentation/ detection ?

# VTS Data Display Systems

## Introduction

The purpose of this Annex is to support VTS authorities and integrators in the selection of Data Display sub systems for new and existing VTS systems. The essential features of a Data Display system are discussed (the principal HCI or MMI interface to the VTS Operator) including the need to present the information necessary and not all the data available.

The principles of a good HCI / MMI design and the goals to be achieved are also discussed. Various types of data are categorised (static and dynamic chart data, supporting textual data and separate highlighted presentation of alarms and alerts). Finally the consideration of simulation, recording and playback facilities are discussed.

## Definitions and clarifications

### Definitions

HCI

HMI

MMI

TBA

### Abbreviations

Moved to top of document

### Supporting documents

Documents from eNav portrayal group TBC

(ref S57/S63/S100 data

charting standards (definitions of colours and symbology) TBC)

TBA

## HCI / MMI / User Interface

### Principles

The Data Display system provides the major operational interface between the VTS equipment and end users (eg VTS operators, allied services). The principal goals of a Data Display system are derived from the fundamental VTS requirements such as to minimise the probability of hazard occurrence, and maximise the efficiency of all shipping operations in the VTS area. From these, lower level goals can be derived such as ease of use (to minimise errors and optimise efficiency), high VTS functional availability, the importance of data integrity, and the ability to learn from and improve upon current activities (collection and analysis of performance metrics) and undesirable events.

To achieve these goals an effective Data Display and user interface will have some key features which are discussed further in the sections below. At a summary level these include:

* The Data Display system needs to include the ability to “tune” the user interface to the operators’ roles and particular evolving needs (i.e. The presentation may need to be customisable within defined boundaries, standardised for a particular role or area of responsibility with the ability to adapt on-the-fly to align the information being displayed with the current situation being managed)
* The Data Display system needs to present current and high integrity information. Low integrity data needs to be clearly identified.
* The Data Display system should provide appropriate ease of access to valid information which is relevant and used both frequently and infrequently
* The Data Display system design should ensure that key information is highly visible and / or audible, whereas access to lower level information needs to be “appropriate” (i.e. most used data is most easily accessible, but conversely, access to less frequently used information needs to be intuitive)
* The Data Display system design needs to make use of audio (alerts, alarms etc) where appropriate
* The Data Display system design needs to adhere to “standardised” presentation formats (to minimise training and hazards arising from unfamiliarity)) but this principal should not be so prescriptive as to stifle innovation and adoption of new technology and new commercial standards and products
* The Data Display system needs to include recording of key input data and user interactions and such recordings need to be available for subsequent replay and / or analysis
* NB there is an important difference between *data* and the appropriate filtering of this data to provide the necessary *information* required to support current VTS operations (data can be real time, non real time etc)
* This annex needs to recognise other work read across from eNav portrayal group etc. TBC

There are a small number of options available to the Data Display system designer to achieve the necessary transfer of information to the human user. These are discussed in the following sections but fundamentally consist of graphical screen based presentation, textual or tabular screen based presentation, the use of dedicated lights and indicators either within or external to the screens / monitors, the use of audible indicators, the use of audible communications paths. Similarly VTS Operators transmit decisions and information to various “stakeholders” by voice communications, e mail, dedicated messaging and TBA Where in VTS 128 are these output mechanisms discussed?

### Chart display

The principal display format for the VTS Operator is the Electronic chart showing the coastline, shipping lanes, area based hazards etc.. This graphical display combines the static information (current local navigation chart data with port and VTS assets, local hazards etc.) with the dynamic data (vessel traffic locations, asset availability etc.) to enable the VTS Operator to maintain an appropriately detailed (but not over-cluttered) situational picture of the current vessel traffic and potential hazards to the safe and effective operation of the VTS area.

Some important issues to consider include:

* chart data needs to be up-to-date and easily updated at appropriate time intervals
* chart data needs to be augmented with local hazard information (static and dynamic), such as under keel clearance, air draught, high predicted traffic densities, wind, tide and current restrictions on vessel manoeuvrability and required (dynamic?) separations, short term incidents and restrictions to vessel traffic etc.
* Chart data needs to include presentation of AtoNs, SARTS etc.
* Chart presentation needs to utilise standardised symbology (ref TBA)
* Chart presentation needs to utilise standardised colours (ref S57/S63/S100 data and charting standards TBC)
* Chart manipulation features to enable the VTS Operator to control presentation functions such as zoom, chart orientation, scroll, layering / filtering of information presentation
* The monitor / display real estate design 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
* The console design may incorporate multiple displays with dedicated and back-up functionality

### Presentation of Vessel Data

Associated with the relatively static information in the chart based graphical presentation (see above), there are important dynamic (i.e. rapidly changing) pieces of information to be displayed to aid the traffic awareness and decision making processes expected of the VTS Operator. For instance the location of vessels needs to be presented. This should ideally consist of presentation of the fused combination of all available vessel positioning data (radar, AIS, optical sensors, RDF, LRIT etc.). This makes the assumption that the Data Processing function can successfully fuse the data and assess validity and integrity of the fused output. In addition to current location, the VTS Operator may also need to understand the history of vessel tracks, and the tracker predictions for navigation of vessels in the future.

Access to raw sensor data may be seen as a requirement by some VTS system designers but an effective track fusion process should negate this in future VTS systems. Potential future hazards may need to be highlighted on the display. Standardised symbology and standardised use of colour needs to be established to reduce the chances of errors and to reduce the training and familiarisation time for new and temporary VTS Operators. The Data Display interface should allow the VTS Operator to easily select a vessel and interrogate the vessel database to establish identity, route, pilotage, berthing, communications channels etc. for that object. Similarly the selection of a tracked object should allow the operator to quickly understand the validity, integrity and any sensor issues associated with the fusion process for the track of that object.

The Data Display interface should also allow selection and filtering of the presented information to tailor the display to the task in hand.

There should be a generic search facility that can be accessed to allow displayed object highlighting, hiding or filtering (e.g. highlight a vessel with a certain name, or highlight all vessels requiring access to one particular port asset or group of assets etc..) within a complex traffic situation

The Data Display interface should also allow the introduction and control of a Manual track process by the VTS Operator. (TBC)

The Data Display interface should also allow presentation of advance alert of possible hazards based on the decision support algorithms.

The Data Display interface should also allow Interaction with recording system, although during normal VTS use, this may be automatic and invisible to the operator.

### Status Summary (of VTS sub systems)

The Data Display interface should also allow sub-system status to be summarised (hierarchically) so that the right level of information is presented for each anticipated situation.

The Data Display should ensure that the VTS Operator is immediately aware of any degradation to system status. The use of both audible and visual alerts may be considered appropriate.

On-request, the VTS Operator may need to access detailed VTS sub system status (to include; sensors, tracking (and data processing), decision support, communications, power, satellite based data etc.). Similarly, the VTS Operator may need to access detailed status information relating to port assets (locks, bridges, pilot availability, tug availability, berth availability etc.)

The Data Display system should provide appropriate presentation of the outputs of the decision support processes (traffic capacity alerts, collision alert, weather condition alert etc.)

Interaction with recording system may be a secondary function of the Data Display system.

Interaction with scheduled maintenance and logistics information (and recognition of non critical faults which have reduced available redundancy) may also be required.

### Audio and Visual Alarms / alerts

The Data Display system should provide a hierarchy of alerts with appropriate acknowledgement and cancellation of these alerts as considered necessary to support operational procedures. The types of alerts should be matched to the severity of the information being highlighted. Consideration may need to be given to the use of visual alerts and appropriate audible alerts.

Alert notification, acknowledgement and cancellation activity should be recorded by the recording system.

### Interaction with BITE and Fault Reporting systems

The following section discusses the system level BITE and how this might interact with the HMI to the VTS Operator and the supporting maintenance organisation responsible for maximising system availability.

Note that care has to be taken to avoid confusing various terms such as Alert, fault, hazard and alarm. In this section the term alarm is used for a report of (suspected) equipment fault.

#### BITE

##### Automated BITE

The various components of the system making up a VTS should each be specified with equipment monitoring and, where appropriate, Built-in-test functions which provide data to a centralised fault monitoring function within the system. The HMI associated with this centralised function should provide a summary alarm status to the VTS operators and access to more detailed hierarchically organised alarm data to either the VTS Operator workstations or dedicated maintainer workstations. Note the collection of fault data from detection sensors, VTS assets (bridges, locks, tugs etc), power systems, weather sensors, user reports, etc should all be considered.

Where possible, the HMI display should provide the usual chart, traffic and textual information to the VTS operator accompanied with appropriate warnings of faults detected within the system and how these impact the VTS functionality (eg. increased vessel spacing alongside other critical functionality (weather, etc..)). For instance if the power supply to one radar sensor has failed this might or might not affect the ability of the VTS operator to maintain normal or degraded system level operation and traffic service – the Decision Support processes should determine the system status and the HMI should provide a method to communicate this to the VTS Operator.

##### Manually initiated BITE

The BITE system should be specified at system level to achieve the required critical system availability and as part of the system, manually initiated signal or data injection may add to the fault coverage and isolation. The HMI for this interaction with the BITE system should be available to a maintainer (or VTS operator in a small system).

##### Fusion / sensor integrity alarms

The data processing function may provide indication of sensor integrity and availability to the BIT system. This should either automatically, or with manual intervention, affect the presentation of sensor data to reflect unexpectedly poor data integrity or accuracy.

##### Asset status

The decision support HMI should reflect the fault information relating to VTS assets and their current status

##### BITE system reliability

The reliability of the BITE system itself should be considerably greater than the total system being monitored.

##### Fault reporting

As indicated above, the HMI design should enable both the summary and hierarchy of alarm information (critical and non-critical alarms) to suit the VTS Operator role and separately to suit the equipment maintainer.

In addition, the fault reports should contribute to system status and this requires an appropriate HMI presentation and interaction.

Fault history records and associated timestamping should be available for post event evaluation by various stakeholders. This should be stored and controlled independently or alongside the recording and playback system.

##### Maintainer interaction with equipment

Equipment design and installation design should consider the physical access and minimal functionality disruption requirements of a safety related system providing a round-the-clock service.

To maximise system availability, graceful degradation and redundancy will enable critical equipment downtime for scheduled and unscheduled maintenance. Similarly mean time to repair requirements should be considered at system level (ie including installation restrictions and spares ranging and storage storage etc) to minimise downtime and maximise system availability. In addition, the fault reporting system should be easy to use, reliable, accurate (ie pinpointing the most likely effective repair strategy) and fully supportive of the overall system availability. Equipment set up after LRU replacement should be minimised. Repair and associated equipment set up and recalibration should, where possible, be designed to be achieved by minimised skill level personnel with minimal access difficulties and few special tools.

## Display Hardware and Ergonomics

### Location (does this belong in this section?)

The physical location of a VTS centre needs to consider the objectives of accessibility (wanted and unwanted), security (access control, system integrity, anti terrorism etc.), the need to be central (not necessarily in the physical domain) to hazards and the control of hazard mitigation activities, central to system data paths, and to maximise the access to relevant information (windows to outside world (physical or virtual))

There may be appropriate Security regulations and standards that should be referenced here to minimise the chances of unwanted physical and virtual intrusion into the VTS centre or the systems and sub systems contributing to the VTS functionality.

Consideration should be given to the need for VTS system growth in terms of equipment size, footprint, future redundancy enhancements, separation of simulation, training, and incident playback and analysis in a separate area from “live” VTS operations.

### Type of layout

When specifying the operations room for the VTS centre, consideration should be given to the maximum number of users, the roles to be carried out in parallel in worst case situations, the hierarchy of roles and users, the size of operational consoles, system network design and interfacing to and from the consoles,

The console design should consider the number of screens per user (information to be presented should be appropriate and avoid operator data overload, the size, format (4:3, 16:9) and orientation (landscape, portrait) of the screens.

Where possible open commercial standard formats (architecture and interfaces) should be sought to minimise obsolescence and maximise options for future system growth potential.

The layout should also consider emergency procedures and role of VTS centre in emergencies (maritime, land based, civil unrest, security, military, disaster recovery, environmental etc.) as part of a coherent regional or national infrastructure where required.

### Environment

The VTS centre user environment should be of paramount importance to create a comfortable office type background to facilitate concentration and minimise distractions. Chairs and consoles should offer comfort for long periods of use and a range of settings to optimise the user experience. 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 (e.g.. via voice switching system to combine telephone, hotlines, ship to shore, operator to operator, VTS to VTS, VOIP, etc..). Methods of data entry (keyboard, mouse, etc.) should also be optimised to suit the operator workload during the most stressful of situations.

### Reliability and fall back

The reliability and availability of display system should not be the weakest link in the VTS centre. The A, R and M numerical requirements for the display system should be derived from top-down analysis of critical failures, built-in redundancy and the overall VTS system under consideration.

The display system equipment design should ensure that scheduled maintenance is minimised and non-intrusive. Unplanned maintenance should be considered by suitable design of equipment access and provision of fall-back regimes.

Where necessary to achieve the A, R and M objectives, the possibility of immediate transfer to an adjacent user position (in the event of failure) should be provisioned. The power supply to the VTS centre (and other critical VTS sub systems) should consider emergency power system back up. (NB at system level not just display system). Hardware redundancy within the Display System and as part of the VTS system design concept should be considered to optimise the system level approach to achievement of the A, R and M requirements. This may also need to include the provision of multiple interfaces to the Display System from critical VTS sub systems to minimise the consequence of interface failure.

Based on hazard analysis, a second back-up VTS centre might be appropriate (with all essential facilities of the primary centre location) This should allow easy transfer of current data to another location capable of maintaining the VTS service in the event of an emergency situation resulting in temporary closure of the primary VTS Centre.

Consideration should be given to integration within a National disaster recovery concept (as required) (NB at system level not just display system)

The location of the VTS centre and its backup location(s) should maximise the achieved level of Immunity to natural disasters (flood, earthquake etc.) (NB at system level not just display system). The location of the VTS centre should also involve consideration of anti-terrorism objectives to minimise impact of intrusion and / or destruction (NB at system level not just display system)

## Data Interfaces to support the Data Display System

### Information held in Databases

#### Database principles

Information and data are not the same. The display system needs to present the information required and not the data available. Where possible the entry of data should be automated and read across from originating sources to minimise errors and reduce the possibility of data conflicts. Where possible, data checking (completeness, validity etc.) should be at source (i.e. when first entered into a system which subsequently connects to the VTS system).

Stale data (i.e. that not updated at the expected interval) should be identifiable and flagged to the user as appropriate. In addition, data conflicts (between databases, between sensor updates etc.) should be detected and highlighted to the users (sub systems and Operators) as appropriate.

The database performance, e.g. as measured by interrogation latency, should be appropriate to the data type and the data update rate. Back up regimes should be in place to allow retrieval of data from each critical database affected by an unplanned or catastrophic event.

#### Vessel database (attributes of the record for each vessel.)

See ref TBA for typical data to be held for each vessel (for example Vessel’s Name, Call Sign, IMO Number, MMSI, ETA, ETD, Draft, cargo, originating port, destination). This data is mostly static data relating to each vessel and its current voyage (logistic data) – the database performance requirements are therefore relatively low.

#### Track database

The track database contains sensor plot data, fused track data, validity and integrity measures for the each piece of positional and navigation data. It should also contain predictions about course and time to key manoeuvre and traffic pinch points. Multi hypothesis track predictions may be necessary to allow management of track merging and splitting, false alarm control and sensor error identification. Note that the display system requires unique and unambiguous identification of all the vessels in the track table.

It is likely that time stamping of data entries and data outputs back to a common time reference (local network time server or similar) will be necessary. Coasting and lost tracks should be flagged. Metrics should be collected to allow assessment of the general traffic management “picture” to be monitored and subsequently analysed. The track table size should be sufficient to accommodate n times the heaviest traffic predictions.

The Data Display system design should ensure accurate, frequent and low latency of the information from the track database.

The track database should be able to provide advance warning of track table capacity overload. In addition, the tracking process should assess sensor bias and noise errors and update rates and record issues in the track database. This information should then be presented to the VTS operator and fault managements system as appropriate.

#### Database of Pilots and tugs

The optimisation of VTS operations will probably require data to enable pilot management and tug asset management (availability, capability, current and planned tasks).

It is anticipated that this database will be a relatively slow changing (low performance) database.

#### Database of berths and capabilities plus other port resources

The optimisation of VTS operations will probably require data to enable efficient management of available berth and anchorage locations, plus movement planning restrictions arising from locks and bridges.

It is anticipated that this database will be a relatively slow changing (low performance) database.

#### Charts

The Electronic charts should preferably be compliant with S57/S63/S101.

The Data Display system should facilitate incremental and full set chart updates.

Distribution of published charts to clients should be an easy and, where possible automated, operation.

The Data Display system should include a mechanism to verify published chart status against current to ensure use of latest publications.

#### Local hazards

In support of the presentation of local chart information and to the Decision Support process, a database of the local identified hazards may be required. Typically this might include static and slow changing hazards such as, underwater hazards, bridges, traffic high density points, shore side hazards, and more dynamic hazards such as Oil (and chemical) spills, ship system failure (thrusters, rudder, AIS, radio, etc..), man overboard, coastguard events etc..

It may also be appropriate to capture the generic types of dynamic hazards (even if these are not current)

#### Equipment status, build state, version records

It may be appropriate to integrate logistics management data to allow occasional access to equipment records etc. for various reasons.

#### Spares and consumables stock and storage locations

It may be appropriate to integrate logistics management data to allow occasional access to spares and consumables records etc. for various reasons.

#### Equipment scheduled and unscheduled maintenance

It may be appropriate to integrate maintenance planning and management data to allow occasional access to assess equipment availability records etc. for various reasons.

#### VTS personnel

It may be appropriate to integrate personnel management data to allow occasional access to staff records etc. for various reasons.

#### Fault records

Consideration should be given to holding a database of equipment faults and warning messages to allow failure modes to be analysed and intermittent faults to be highlighted and appropriately managed. Access to such data is unlikely to require the facilities of a full VTS Operator’s console.

#### Accounts with shipping companies and dockside cargo handlers etc.

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)

### Sensors and vessel Tracking

#### Sensor data

It may be necessary, as part of the VTS system concept and operational procedures, to display raw sensor data directly to the VTS Operator. This includes radar video and plots, AIS (and SAIS) plots and associated data, LRIT plots, RDF derived positional data, Camera video etc.

In many cases this sensor data will be normally hidden from the operator, assuming that it is automatically fused with similar data within the Data Processing (track fusion process) yet in other cases (such as optical video from daylight and EO cameras), it may be necessary to display the video on demand or even at all times depending on the operator needs. To minimise information overload, the track fusion process should be designed to reduce the need to display raw sensor data in the majority of situations.

#### Track data and control of tracking and sensor fusion

The Data Display system will overlay the output from the track fusion process (uniquely identified tracks) onto the electronic chart display – as such the Data Display automatically receives the appropriately weighted fused summary from all available sensors

The Data Display should be able to indicate the principal sensors contributing and failing to contribute to the fused output

The Data Display system should be able to display the received assessment of sensor integrity (accuracy (bias and noise), staleness, corruption, faults) and if appropriate an indication of what action to take based on this assessment (repair, warning to ship (potential on board AIS fault etc.)

The Data Display system should also be able to warn the VTS Operator of unexpected and unreasonable Manoeuvres (these may provide an early indication of possible ship system failure, but may also indicate track confusion (merging and splitting) within the Data Processing function.

#### Sensor status information

The Data Display system should also be able to display any detected issues with the normally available sensors (faults, staleness, change of sensor status, etc.)

#### Sensor control capability

The Data Display system should provide the VTS Operator with the ability, where appropriate to enter commands to control the vessel tracking sensors. However, where possible, the sensors should be fully autonomous.

### Meteorological and Hydrographic data

The Data Display system should be able to display the information derived from the available meteorological and hydrographical data (locally gathered and passed from other agencies.

It should also be possible for the VTS Operator to access raw data and recent history and any status or fault information from the local sensors. This may be textual, graphical (e.g. vs. time) or may need to be added to the chart display.

Other information that may need to be accessed include the list of sensors, their current status, fault history, battery life etc.

### VTS asset status

The Data Display system needs to provide the VTS Operator with access to the assets within the VTS area (bridges, locks, tugs, berths etc.) to allow understanding of their current status. In some cases, the Operator may need to directly control some of these assets (bridge raising etc.) and associated monitoring sensors (CCTV, road traffic sensors, water levels, etc)

### Decision support tools presentation

The Data Display system should integrate Decision Support tools into the system. (Annex 11) For example, these may include:

* Automated alarms and warnings
* Manual input of new situation requiring urgent action
* List of generic situation / hazard and automatic / manual selection of appropriate recommended procedures
* Presentation of recommended procedures and checklists
* Presentation of key contacts
* Display changes to allow focus on management of the situation (automatic / manual)

### Hazard Management

#### Emergency systems interfaces (SAR)

The Data Display system should provide display of information and recognition and reaction to various types of external and internal alerts. Such alerts may consist of:

* External telephone
* Ship communications
* AIS code?
* Unexpected SART detection
* Decision support – automated early warnings
* Liaison with external agencies (monitoring of non VTS events which may become VTS events)

#### External alerts (security etc)

The Data Display system should provide display of information and recognition and reaction to various types of external alerts (not related to SAR) such as:

* VTS asset security breach
* Detection of unknown vessels / water users which may indicate security situation
* Responsibility vs. other agencies for coastal asset security
* Weather warnings
* Use of decision support to standardise response and use of checklists to generic (predictable) situations

#### Disaster management and recovery

The Data Display system should provide display of information and recognition and reaction to various types of potential environmental and wide scale threats to the environmental and to support national or regional solutions to non-maritime events (where required). The display system may need to provide display of:

* Operational procedures etc
* Checklists
* Key contact details for external agencies who might need to be aware / involved

### On line simulation and training facilities

The Data Display system may be required to support various simulation facilities to allow some secondary functions to be carried out. These might include:

* competency assessments of VTS operators
* training of new VTS operators

It is important that such activities are non-intrusive to normal operations. Note that “back room” interaction and control of the stimulators to manage the training, and assessment exercises also need to be specified and appropriately located. A library of scenarios and associated generation files to be used for training and assessment may need to be established, stored and maintained. It may also be useful to be able to load a recorded incident into the simulator for analysis, training illustration and improvement of VTS Operator procedures.

### Recording system and playback

#### Recording and playback principles

The Data and Display system should be able to record sufficient data to allow replay of an event – either as if “live” or just based on what happened. The recording system should be based on hazard assessment.

The Data and Display system should be able to support recreation of an incident in terms of data flow into (and out of) the VTS centre (sensor data, status of various databases, audio and video recording, operator keystrokes, data processing actions during the event, ). Where possible it should also the semi automatic generation of reports for authorities and other stakeholders.

Given the possibly vast amount of data that could be involved, the solution should be cost effective in terms of storage capacity (vs. time history captured) future expansion, data backup and use of cost effective and reliable storage medium.

#### Recording

The Recording process should work as an autonomous 24/7 service. Preferably the process should be a redundant solution on a separate server.

Recorded data should be compressed/encrypted to ensure un-tampered data sets.

#### Replay

Initiation of replay should be done from the same type of equipment and application as used for live data representation.

It should be possible to search for specific incidents based on geographical area, date/time and vessel particulars.

Sources selected for reply (at least streaming sources) should fully synchronized on replay.

The provision and time and key event based searching through the recordings and a fast forward facility of some critical streams of the recorded data should be considered.

#### Access to recorded data

Data should be recorded to a closed server environment with security policy access to the physical storing media.

Storing medium should facilitate redundancy solutions such as RAID and backup solutions. Procedures for reuse of data storage (after one month or.) should be put in place.

The design should include means to restore historical data for replay or to query a database.

# Decision Support

## Introduction

This annex describes the uses that can be derived from processed data in order to help the VTSOs to assess the situation or to make decisions. Some useful information for the VTSOs can be directly derived from sensor information display and do not require further refinement whereas the decision support indicators are usually estimated from more complex processes involving multiple sensors information and/or high level processing implying temporal and spatial prediction.

Those decision support tools are designed to assist the VTSOs in their current tasks by synthesizing multiple pieces of information in order to produce an alert when a risk threshold is overcome concerning a vessel situation, an area monitored or a function supervised.

Typical decision support tools include, but are not restricted to, closest point of approach (CPA), time to CPA (TCPA), collision alert, area penetration, route adherence, speeding, anchor watch or grounding alerts.

Though these tools functions current working condition and settings may be preset by the manufacturer at the time of delivery, trainings and documentation should clearly inform the user regarding the basic principles and proper use of these tools, including their capabilities, limitations and possible errors.

## Definitions

Target: any object fixed or moving whose position and motion is determined by measurement of range and bearing.

Tracking: the computer process of observing the sequential changes in the position of a target in order to establish its motion.

CPA: the Closest Point of Approach is the shortest distance separating two ships when observing their course over time. This measure is directly linked to the mutual risks shared by the two ships along their roads. The CPA is permanently computed in real-time on-board ships and in the VTSs in order to anticipate a risky situation.

TCPA: the Time to CPA is the estimated time left before two ships reach the point where their mutual distance is minimal.

Predicted points of collision: A graphical representation of where predicted collision intercept points lie with respect to designated ship and other targets.

Tracking filters: in order to predict the time to reach a position or the position of a mobile in the future, one may use models describing how the observed system evolves in time and space; these models may also be referred to as tracking filters.

* Simple models rely on few data, such as the last speed and heading observed in conjunction with a simple hypothesis such as constant speed and constant direction, in order to predict the spatial and temporal evolution of a mobile at sea.
* More complex filters may use historical data, such as the evolution of speed and the evolution of heading, in conjunction with more complex hypothesis based on human factors, dynamic properties of the mobile, the sea state and sea currents, in order to predict the spatial and temporal evolution of mobiles at sea. Some high level tracking systems may also use multiple model computation simultaneously before choosing the most likely or before computing a weighted mean of the different estimated positions.

History: equally time-spaced past positions of a target which is being tracked.

Map lines: also called Nav lines, the navigational facility whereby the observer can define lines to indicate channels or Traffic Separation Schemes.

## Characteristics

Support tools are not mandatory so they may differ depending on the needs and functions of the VTS, the system designer, the manufacturers. Some of these services may be provided by sensor manufacturers or integrators whereas some high level functions may me designed at system level, beneficing from the information gathered by multiple sensor networks.

In order to assist VTSOs fulfilling their tasks of surveillance in a specific context, some decision support tools may require user input such as the vessel(s) concerned or the area supervised. On the contrary, some more generic tools or basic warning systems, such as CPA or TCPA, are permanently estimated and should warn the VTSOs if the vessels courses closes within the predefined limits.

Some of these tools may be classified as critical risk assessment tools because they reflect the risk of collision or groundings, those are for instance CPA, TCPA, grounding alert. Other decision support tools are not so critical because they are linked to local regulations or recommendations.

## Requirements

### Operational Requirements

Like other information displayed to the VTSOs, the decision support tools aim at lowering the workload of VTSOs without interfering with the current tasks they are mandated for. The VTSOs should always be able to choose the thresholds of the different alarms displayed, whether they are automated, semi-automated or manual. However, it is recommended that limits to these thresholds cannot be exceeded (for instance, negative values cannot be assigned to thresholds corresponding to distance or time related values).

VTSOs may deactivate such alarms in order to lighten the sum of information displayed. It should be possible to cancel the display of unwanted data displayed within 3s. The cancellation of an alarm raised by any of the decision support tools should be confirmed by the operator.

In specific situations such as high traffic zones, decision support tools such as CPA and TCPA may raise a high number of alarms permanently. It should be possible to suppress the alarms linked to these risk indices for a whole area. In such a case, the area where no alarm can be raised should clearly be indicated on the display according to the display recommendations provided in Annex 10 : Traffic Situation Display.

VTSOs should be aware that permanent cancellation of alarms regarding a specific location or one or more designated vessels, if it is justified at the time of cancellation, may prove itself dangerous moments later by hiding a new hazardous situation, or a recurrent unusual behaviour. It is therefore recommended that if a permanent cancellation of alarms in a given zone is decided, this zone is limited to a well known place on which VTSOs are clearly informed and give a particular attention. In the case where the cancellation concerns a specific vessel, it is recommended that the cancellation is not permanent and does not exceed XX minutes before the tools are able to raise a new alarm related to that vessel.

VTSOs may always be able to switch on/off the different modes of warning, sounds or displays. In the case where all modes of warning are deactivated, a clear indication should state that on the display (see traffic situation display recommendations for more details).

VTSOs may adapt the range of the display in order to have a global situation display or to focus on a specific zone that is to be under close surveillance. Nonetheless, VTSOs should be able to perceive an alarm raised by the system out of the displayed zone. This is possible through different means, the use of multiple screens in the VTS, one dedicated to global surveillance and one allowing for free zooming and displacement of the area under surveillance. If only one screen is present, it can also be obtained through the use of a separate window smaller than the global picture and superimposed on the global picture (see traffic situation display recommendations for more details). In any case, the system should ease the localisation by the VTSO of an alarm in order to warn him or to allow him quick suppression of the alarm.

Alarms such as CPA or TCPA have been validated for on-board as well as for onshore operations and are the only collision alarms shared by both VTSOs and navigators. Though these tools are shared by VTS and vessels, their implementation, the sensors and information they are based on and the thresholds used to raise the alarm may differ.

In the case where the supervising system in charge of the computation of the different decision support tools does not receive any low level information such as sensor information or information produced during the data processing steps (de-noised sensor information, precise and reliable positioning), the system is said to be blind and all positions and alarms are computed on an estimated basis. The system is in dead reckoning mode and should clearly display that information to the VTSOs. Knowing that in dead reckoning mode, the precision of the estimations decreases as time passes, it also should clearly state the confidence level on the alarms displayed, and after a low level threshold of confidence is crossed, the system should not automatically display any alarm which risk of misleading the operator. The system should focus on the best possible positioning of vessels, and let the VTSOs in charge of requesting estimations of risk indices for the critical decision support tools.

### Functional Requirements

The low level data processing steps may produce a composite indication of position, navigation and timing. High level processing tools such as decision support tools may use this information as an input. The use of such information in high processing steps should not have performance inferior to that which could be obtained using only radar information.

Automatic or manual acquisition should have a performance not inferior to that which could be obtained by the user of the display through the use of a classical geometric tool (use of vectors for CPA/TCPA, use of circle of avoidance for anchor watch or use of drawn limits for area penetration).

The features described in the table below should preferably be automatic for systems requiring standard or advanced capabilities.

Table 11‑1 Decision Support Functions

| **Parameters / Capability** | **Basic** | **Standard** | **Advanced** |
| --- | --- | --- | --- |
| CPA, | X | X | X |
| TCPA, | X | X | X |
| Collision alerts. | X | X | X |
| Grounding alert | X | X | X |
| Anchor watch, |  |  | X |
| Area penetration | X | X | X |
| Speeding |  |  | X |
| Route adherence |  |  | X |
| Path, time and track prediction |  |  | X |

#### CPA/TCPA

CPA and TCPA are numeric indices characterizing the imminence of a close approach between two vessels. These indices must be interpreted together with a logical AND between the two criterions defined beforehand.

Where the use of VTS is requiring basic capabilities, one threshold may be defined for CPA and one for TCPA. VTS addressing advanced capabilities may also have to monitor zones where basic capabilities are needed. In this case, it may be useful to distinguish areas with different levels of alarm.

If different areas are monitored according to different rules concerning alarms thresholds, it should be possible for the VTSOs to visualize the different zones and the alarm levels associated.

If different alarm levels are accessible, the display of an alarm associated with a given level should allow VTSOs to appreciate immediately the level of criticity urgency?? of the alarm.

Thresholds described in the table below are given as an example and as specified in the operational requirements, these thresholds may be adjusted depending on the needs of the VTS, its capabilities and the traffic density.

Table 11‑2 CPA/TCPA Thresholds

|  |  |  |  |
| --- | --- | --- | --- |
| Alarms / Capability | Basic | Standard | Advanced |
| Level 1 | (CPA < 4 nm) AND  (TCPA < 20 min) | | |
| Level 2 |  | (CPA < 2 nm) AND  (TCPA < 15 min) | |
| Level 3 |  | | (CPA < 1 nm) AND (TCPA < 10 min) |
| Collision alert | Whenever two ships closer than 1 nm | | |

#### Anchor watch

Anchor watch aims at warning the VTSO that a ship who has been assigned at a given anchorage zone does not drift out of the zone otherwise than in manoeuvre. Usually, only VTS with advanced capabilities have such zones under their surveillance. These areas are defined based on a given position and a distance of avoidance, both of them defining the circle of avoidance inside of which the ship is supposed to stay when not in manoeuvre.

Distances of avoidance may be expressed in standard distance measures such as meters or these distances may also be expressed in number of links or shackles in order for the VTSOs to be able to inform the vessel whatever its mode of count.

In the decision support processing of anchor watch, if the VTS knows of the variation of the circle of avoidance according to tide level, the boundary should be set according to the greatest distance from the anchorage point (low tide limit).

#### grounding alert

Grounding alert is an alarm that depends on the draft of the vessel, the bathymetry and the water height due to the tide. The alarm is raised if the estimated "under keel clearance" crosses a low threshold.

Depending on the capabilities of the VTS, the precision of bathymetric maps, the precision of water height due to the tide and the draft of the vessel, the threshold may be adapted by VTS authorities. The threshold may directly be affected by the precision of bathymetric maps, precision of these maps should be added to the lowest recommended thresholds.

Table 11‑3 Grounding Error Thresholds

|  |  |  |  |
| --- | --- | --- | --- |
| Alarms / Capability | Basic | Standard | Advanced |
| Lowest recommended threshold | 2m + precision level of maps and other errors sources | 1m + precision level of maps and other errors sources | 0.5m + precision level of maps and other errors sources |

For instance, given a bathymetric map with an error inferior or equal to 1.5m, the alarm for a standard VTS should at least be set to 2.5m.

#### Area penetration

Area penetration is an alarm that warns the VTSOs whenever a ship is penetrating a predefined area or crosses a navigational line that should not be crossed.

International regulations, national recommendations or VTS authorities may define areas where no shipping is allowed under normal circumstances. These areas may be Traffic Separation Schemes, Special Areas and Particularly Sensitive Sea Areas as defined by IMO or areas defined by national authorities that may be forbidden temporarily to shipping for security or safety measures.

Area penetration support tools are based on the ship's position in regard of the zones under surveillance. If precise positioning of the ship and the limits of its hull are accessible, the alarm may be based on the penetration of any part of the ship in the designated area. If the precision level of positioning is low, the alarm may be based on the crossing of the area by an ellipsoidal shape around the estimated position of the ship, this ellipsoid should be proportioned so as to reflect the limits of the ship with 95% confidence (one may refer to Annex 9 Data Processing for a definition of a precise and reliable positioning).

#### Speeding

Speed alert aims at warning VTSOs whenever a ship's speed is excessive.

National authorities or VTS authorities may define speed limits for navigation in certain areas such as port zones. If precise and reliable speed estimation is accessible the alarm may be based on instantaneous speed observed. If the speed is assessed based on a unique sensor and is subject to noise, special care such as meaning of speed over a short period, outlier filtering through median filtering or such processes should allow for false alarm avoidance.

#### Route adherence

Route adherence is a support tool aiming at warning VTSOs in the monitoring of a ship's routing. This tool is essentially a support tools used in the context of Navigation Assistance Services or Traffic Organisation Services.

Usually, before such a tool can be used, the VTSO should know the routing plan of the ship and according to that plan, he may define a corridor in order to monitor that the ship is following the intended route. The definition of this corridor is bounded by the position of the ship, the destination of the ship or a waypoint, and the width of the corridor that is a distance (expressed in nautical miles or in meters).

In some cases, as in the case of an existing deep water route, this corridor may be predefined. The corridor follows the route composed of one or multiple segments and the width of the corridor depends on the constraints linked to the sea floor. The limits of the corridor are then constituted by polylines.

As in the case of the area penetration support tool, the distance from the ship to the nominal route may take into account a precise positioning of the ship and its hull, or an ellipsoid linked to the estimated position of the ship (one may refer to Annex 9 Data Processing for a definition of a precise and reliable positioning).

#### Analysis and prediction

##### Traffic monitoring and analysis

Traffic monitoring is a theme which may serve multiple purposes such as information and knowledge of the traffic, determination of input parameters to prediction models, efficiency of traffic management tools or risk assessment tools.

Traffic analysis may be based on ship positioning but it may also use other quantitative data such as speed, bearing, size, sea currents, winds, etc. and qualitative data such as type of ship, destination, origin, flag state or ship owner.

These data may be informed through measurements by one or multiple sensors but they may also come from declarative statements.

Special care should be given on data pre-processing such as filtering of erroneous measurements, sampling rate at constant time or constant distance. The limits of exploitation of the statistics should be known a priori in order to choose the most appropriate approach. The confidence level given to the different data should also be taken into account, be it the noise attached to measurements or the confidence in qualitative data gathered through declarative process (destination or ETA field in AIS data for instance).

The traffic analysis should always state the duration of the analysis, the field of interest and the nature of data analysed (traffic density for all ships or depending on the class of vessel, mean speed, mean speed of the 90th percentile of ships, etc.) and the size of the geographical or time sampling rate such as “per nautical mile square” or “by hour”.

Some processes are static, considering a given set of data of the past as input, whereas some processes will be constantly evolving, considering historical data of fixed depth from the current time.

##### Path time and track prediction

In advanced systems, there may be a complementary constraint on the notion of route adherence which is not only based on distance but is also based on time. In accordance with the routing plan given by the ship, the support tool is able to indicate if the ship accesses certain areas timely as it was planned. These areas are usually located around way points, but the monitoring may also be continuous.

In the case of a continuous estimation of the route adherence, a window of time evolves along the corridor, may it be composed of one or multiple parts, and the support tool controls that the vessel is inside the lateral boundaries of the corridor as well as inside the longitudinal boundaries defined by the space-time window.

The space time window is located around the theoretical position of the vessel considering the mean speed the vessel should have had in order to be timely around the defined ways points. The distance between the limits of the spatial window are such that the distance before or after the theoretical position is equal to the theoretical speed of the ship multiplied by the flexibility of time given to the support tool (10min, 20min, 30min).

The flexibility of time considered may be fixed by the VTSO or automatically defined by traffic statistics considering mean passage time observed, either for all ships or considering the nature and charge of specific ship classes.

In special cases such as when the speeds observed along a route are not usually constant, a speed profile along the route may be estimated through traffic analysis. The speed may not be constant due to different factors such as the tide, the presence of currents or the influence of the wind on the speeds observed. In such cases, models describing the evolution of the speed profiles along this route may be used as an input to determine the centre of the space-time window (theoretical position of the vessel from the initiation of the support tool to the current time).

Special attention should be paid to the way the model is build and used. Data driven approaches (top-down models) and data-informed approaches (bottom-up models) should be distinguished.

In data driven approaches, the model is build in order to stick to the collected data or statistics. The parameters inside the model may not necessarily to observable or physical data. The result is usually closer to the final observed data (as compared with mean behaviour), but as data are often missing or rare for extreme behaviours, those behaviours will likely be more difficult to simulate with good precision.

In data informed approaches, the model is based on hypothesis linking different logical input parameters, the expression of the model is intellectually satisfying because these inputs have meanings. But even though a great amount of tuning is done to clearly establish the links between the input parameters, there may always be missing or fuzzy input parameters, so that in the end, the results may easily diverge from data observed. On the other hand, given the correct input parameters (more easily informed because measurable) they may be able to simulate a wider range of behaviours.

Such models may be used to predict the passage time of ships with greater precision than in the simple route adherence tools based on constant speed hypothesis. They aim at predicting the passage times on a meso-scale basis (from 1 nautical mile to a few tenths of nautical miles) or a macro-scale basis (from tenth of nautical miles to hundreds to nautical miles).

These tools may be used in conjunction with tracking filters which aim at predicting the track of a mobile from micro scale (from a few meters to 1 nautical mile). These tracking filters behave like the dead reckoning tracking in essence but with more complex hypothesis. Dead reckoning is a first order (or linear) simple tracking filter. It does not account for noisy data whereas tracking filters intend to account for noisy measurements and to simulate non linear evolutions.

Usually, dead reckoning is used with a given hypothesis (constant speed and constant bearing) when no further measurements will be available. On the contrary, tracking filter are designed to work in monitored environments in order to improve localisation by constantly updating the model (be it linear or non linear) with a feedback loop and a probabilistic approach accounting for sensor noise (which allows for optimal positioning estimation).

One must remember that though more evolved than dead reckoning approach, these models are based on hypothesis and that they diverge from truth as time passes if they are not updated with measurements. Using them in order to predict the precise track of vessels for the seconds or minutes to come proved to be efficient if updated, but if no update is available, there is no reason to believe that the hypothesis they are based on is more adapted to the situation. Tracking filters may diverge from reality as well as dead reckoning mode if the behaviour of the mobile changes without being observed.

Among those filters we find a whole family based on Kalman approach. The Kalman filter was the first of this family of tracking filters, based on linear prediction but capable of optimal prediction of positioning by accounting for noisy measurements. Extended Kalman filter (EKF) or Unscented Kalman filter (UKF) can account for non linear systems with noisy measurements. The extended Kalman filter (EKF) is probably the most widely used estimation algorithm for non-linear systems. However, it is difficult to implement, difficult to tune, and only reliable for systems that are almost linear on the time scale of the updates. The UKF is more robust to non linear systems.

The more recent approaches based on tracking filter may combine multiple filters of the Kalman family, each of them acting in the framework of a given manoeuvre hypothesis such as constant speed, constant acceleration, constant turning etc. The Interactive Multiple Models (IMM) approach uses two or more filters which run in parallel, each of them using a different model for target motion or errors. The IMM performs an optimal weighted sum of the output of all the filters and is able to rapidly adjust to target manoeuvres.

(One may refer to Annex 9 Data Processing for details on precise and reliable positioning).

#### Incident or Accident management

Incident or accident management is a support tool allowing for monitoring of the resources available and deployed in a crisis context. Depending on the nature of the incident, the operation may focus on SAR, environmental protection, prevention of other incident resulting from the original crisis.

In order to assist the VTS in monitoring the situation and playing a role in crisis management, these tools should help to visualize the allocation of resources depending on the task and on the areas concerned. For instance, these tools should help the VTS to organize different teams composed of vessels and aircraft in order to cover a given areas in case of SAR operation, this can be done with graphical overlay, identification of the resources and historical track display in order to identify the areas already covered during the operation. This can also be achieved by displaying zones unsuitable for navigation, factors influencing the decisional processes such as sea currents and winds, and it may also include an operational assistance for monitoring the operation such as a clear report of the steps, actors and actions organised. This report should be easy to share with other parties in order to manage the interactions with other services, onshore or at sea.

#### Simulation and Training

Simulation and training tools allow VTSOs to simulate operations in a complete environment including all the tools that may be used in real situations. Input data to the system may be based on simulated data or on recorded data.

Usually, simulated data are used in the validation process before systems are implanted in the VTS. They allow for operators to test the ergonomics of the system, test the different tools and express their needs and comments. Once the systems are implanted, connected to the sensors, and if the system is able to perform recording of real data, (as recommended in the operational requirements), the preferred way to exploit the simulation and training tools is based on real data and real situations.

This may help VTSOs to analyse and practice on the most usual configuration as well as on difficult operational procedures that the VTS had to face in the past. The simulation should as much as possible stick to the reality of working of the system in usual conditions, exploit the same sensors in input, exploit the real data recorded even if erroneous or noisy and exploit the same software version of the different tools.

There may be multiple uses for recording and replay, some may be directed towards the VTSOs needs (practice and analysis) whereas some others are directed towards the company who designed the system in order to make its products and tools evolve.

These two approaches should be differentiated. During practice and analysis, if the simulation is based on real data, the system should perform in the same conditions it has worked during the real situation. The system may replay the real situation that has been recorded as an output of the system, in that case, interactions with the VTSOs are limited and the system replay is not interactive. If input data to the system have been previously recorded, the replay should perform the same computation steps than in normal conditions, including calculation steps that made the situation difficult to analyse in real time.

In the feed back and improvement process that implies communications with the industrial, if real data were recorded, the computation steps of the simulation may be changed in different manners in order to better handle difficult situations and to answer more accurately to the VTSOs needs. In that case, the display during the training and simulation process may differ from the display the VTSOs used to visualize the first time during the real situation.

## Specific Design and Installation Considerations

### Interface Requirements

As suggested in VTS manual, the output of decision support tools may be recorded in complement to raw data and the image displayed to VTSOs. This recording is recommended for multiple purposes among which, the review of accidents, incident investigation, technical evaluation, quality monitoring for continuous improvement, statistical analysis, training purposes or for use as evidence following an accident or incident.

VTS authorities should be aware of the usefulness of such practice even when recording raw data or the maritime picture on the other hand. It is of the VTS authority to determine the frequency of sampling but it should be adapted to the goals pursued by the replay options. Low frequency sampling may be sufficient for traffic analysis purposes whereas nominal sampling is preferred if the tool is to be used to simulate the real environment of the VTSOs (recording entirely the raw data or recording entirely the output of the system at its nominal sampling rate).

Depending on the system design, the system may be directly interfaced with the sensors providing data (in the case the company that designed the system has the know how of the low level processing of data) or the system may be of higher level (if the company is an integrator and benefits of pre-processed outputs from the sensors). In the case the system designer masters the processing of raw data information, it is recommended that he uses these raw data as much as possible without chopping too much the data processing flow. Tracking filters for instance work better when processing directly the raw data than after some pre-processing has altered the completeness of the data (including noise).

Decision support tools play an important role in the traffic image displayed to VTSOs, as such, they should comply with data display recommendations listed in Annex 10 - Data portrayal, and the output of the traffic image should also comply with the recommendations listed in Annex 12 - Data information exchange and IVEF format for further readability and exploitation.

# External Information Exchange

## Introduction

VTS centres should be equipped with the ability to communicate with relevant allied services, National Points of Contact (NPOCs) for services, such as LRIT and SafeSeaNet, and neighbouring VTS centres, where appropriate. This annex describes the relevant technical issues. Details, regarding legal issues and processes recommended for sharing maritime data (more specifically terrestrial and satellite AIS), may be found in IALA guideline N° XXX (The Global Sharing of Maritime Data and Information, Ed-0.1-15sept2011).

## References

IALA Guideline N° XXX – “The Global Sharing of Maritime Data and Information, Ed-0.1-15sept2011”

IALA Recommendation V.145 – “On the Inter-VTS Exchange Format (IVEF) Service”

IHO S-100 – “IHO Universal Hydrographic Data Model”

## Characteristics of Data Exchange in VTS

### Possible External Uses of VTS Data

This section indicates possible uses for maritime data that may have been collected by a VTS. It should be noted that this list is not exhaustive and simply provides an indication of the range and diversity of the uses of such maritime data.

VTSs may be considered as focal points for data, since VTSs use data from various different sources for their day-to-day operation. This data can be useful to parties outside of the VTS, because it may improve the efficiency of their operation (e.g. pilots) or they need to be aware of certain situations, for example, advance information for vessels transiting one VTS area, but destined for another. Therefore, a VTS may play a key role in providing this data externally.

The following tables give an overview of external uses of VTS-related data for various purposes.

#### VTS / Vessel

|  |  |
| --- | --- |
| General VTS | * Risk identification and avoidance * Monitoring of cargo, vessel status and resources * Voyage planning and execution (e.g. under keel clearance and track keeping) * Weather and hydrography |
| Port VTS | * Cargo management (planning loading and discharge) * Logistics (shipboard) |
| Regulatory Compliance | * Reporting * Environmental |
| SAR response (pending individual VTS responsibilities) |  |

#### VTS to Shore-based Users

|  |  |
| --- | --- |
| Traffic management | * VTS operations * Anchorage and berth management |
| Hazard management | * Risk analysis * Incident reporting and investigation * Contingency planning * Emergency towage and salvage |
| SAR |  |
| Pilotage and allied services |  |
| Support to the logistic chain | * Voyage monitoring * Port operation * Forward planning movements |
| Law enforcement | * Maritime contraventions * Fisheries enforcement * Customs * Port state control * Border control/ immigration * Port health inspections |
| 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) |  |

### VTS Data

An authority, organisation or service that intends to undertake any of the activities or operations indicated in the previous section, requires timely, relevant and accurate data. Such data takes many forms and may be derived from many sources. A VTS primarily focusses on vessel movement and environmental monitoring, but it may also have an interest in regulatory and technical matters. Furthermore, VTS historical and baseline data might be of use to external parties as well e.g. for strategic purposes.

The following table describes the type of data that may be available from a VTS and could be relevant to external users

|  |  |
| --- | --- |
| Vessel data | * Static * Dynamic * Voyage related data (cargo, crew, passengers, route, etc.) * Defects (including local intelligence on defects) * Incident reports * Anomalous activities |
| Environmental data | * Hydrographic * Meteorological * Physical environment * Ecological * Oceanographic (e.g. tsunami) * Special areas of conservation * Oil spill / pollution detection and reporting * Signal propagation (atmospheric data) |
| Regulation and references | * Port state control * Technical references |

## Operational, functional and performance requirements

### Data integrity

Data integrity is a key concern of both users and providers.

Source data holders are often reluctant to allow access to their data. If the intention is free and open exchange of data there should be a process trusted by all parties (providers and recipients) to enable access.

Users expect that data provided will be accurate and consistent. Furthermore, they expect the data to be authentic in that they are derived from credible sources which can be validated.

Another concern is that there should be some means of confirming data integrity along the data supply chain because the route from provider to user may be a chain of different links with various opportunities for interference. Loss of integrity may be accidental or occur through deliberate interference.

Data should be transmitted using recognised formats such that the receiver will understand the format used by the sender.

Timeliness can be regarded as a part of data integrity (Sec. 4.4 Timeliness refers)

Quality of data is also very important. Data therefore should include some form of quality marker information (Sec. 4.4 Data quality and integrity refers)

Quality and integrity of data is also relevant for the transmission process between sender and user.

### Architecture of sharing

##### Suitability for purpose

Users need to be aware of the limitations of the data or information to avoid taking action based on inappropriate, incomplete or inaccurate data.

This suitability for purpose is obtained by transmitting information that has been used by the VTS at an operational level.

S.

Information may be shared with or without being controlled by the sender. Usually, if the information shared is at sensor level, data may be routed directly from sensor to different receivers or transmitted after passing through a VTS. This may be with or without control or processing of the raw data. As such, it is of the responsibility of the receiver to ensure this information meets its own operational requirements before being used in an operational context.

##### System level sharing of processed data

The information is usually transmitted after having been processed by a VTS before being transmitted to other parties. Refer also to Annex 10 (Data processing).

### Data models

Exchange of data requires an understanding of the meaning of each and every data item. This concerns the way in which data values are encoded and the exact meaning of data items. The former is specified by data format, the latter is reflected in the data model.

The data model unambiguously defines the semantics of the data item, the structure of a data item and the permissible values of a data item.

Since the use of data models is fundamental to the exchange of data, IMO, at NAV57, decided to institute the principle of a Common Maritime Data Model and the IHO S-100 has been proposed to be the baseline of this model.

The IHO S-100 standard is a framework standard intended to allow development of data models and associated product specification for a variety of common and maritime specific information. The data models used in the domains of maritime safety, security and more generally that may be used or acquired by VTS are described in the "data registry".

### Timeliness

Information should be received when needed. This may be in advance of an event, real time, near real time or historic as appropriate. Data should be time stamped as appropriate to the nature and use of the information. Time stamp should preferably be at the time of origin, but if not, it should be stamped as soon as it is receipted by the system. Where time stamp is not the time of origin, it is desirable that any potential latency be flagged.

Quality of service (QoS) covers the prioritisation of certain data above others in order to guarantee a timely delivery of the data. Higher priority data will be delivered faster than a lower priority item.

In real-time or near real-time systems, it may be necessary to ensure that some data types have priority above others. Furthermore, when Data Sharing Networks use infrastructure, which also is used by other data systems (such as internet, email or phone services), it may be necessary to ensure quality of service for the preferred system.

### Storage

The volume of data and information involved in many cases will be considerable. Given that many of these uses also require access to archive or historic data and information, consideration should be given to providing adequate capacity for retaining and archiving these records.

Some formats are well-suited for transfer and sharing of data and maritime information whereas some formats are more suited for long term archiving of data. (Sec 5.2.2 Common formats gives example of common data formats)

### Access to data and information

The reception and use of broadcast information is subject to ITU-R Radio Regulations article 17 on Secrecy. Clear and realistic principles and rules regarding access to AIS and other navigation safety data should be defined and adopted by the international community.

National competent authorities could have criteria to ensure that exchanged data is of the highest quality such as the established international system of exchanging Maritime Safety Information. The quality of exchanged information should be made known to the end user.

Exchange of data may be clearly defined for both sender and user through the use of a sharing agreement. This document should state clearly the level of service needed and provided, the security and privacy wanted for the data. Finally, it should clearly state the use of the data, if it is to be used in operational environment, for maritime purposes or for academic or historical studies for instance.

### Data security and confidentiality

Information that requires protection includes localization of sensitive information such as localisation of fishing grounds or personal identification information. Personal data includes identity data relating to vessels as well as individuals.

Users are concerned with issues of data security and confidentiality and in particular any commercial sensitivity of data as it relates to release of information that may compromise investors or introduce competitive advantage/disadvantage.

In many cases confidentiality is already protected by legislation but this is not universal throughout the maritime domain. The requirement to protect access to data may go beyond the limits of primary legislation. Confidentiality needs, at least to be protected by appropriate levels of access rights to data exercised through physical security encryption and password protection.

If personal and commercial identification is not needed, for academic studies for instance, all related data may be blanked in order to suppress any doubts on the legal issues linked to the exchange of maritime information.

Data confidentiality should be defined in the sharing agreement. It means that the data is protected against eavesdropping. No other parties other than the sender and receiver are able to read the data. Data confidentiality can be obtained by physical protection, authentication or data encryption. The main objective is to prevent access to the data source or to data link.

Authentication means that the sending and receiving parties are able to unambiguously identify each other. This means that each party knows who he is communicating with.

Encryption is commonly obtained by using a secret key that is only accessible to authorised parties. Depending on the sensitivity of the data, a certain level of data encryption may be required.

### 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 received should be consistent with the laws of the national authority receiving the data.

Authorities need to be aware of any exposure to liability that might occur from their actions or inactions with regard to data and information exchange.

### Communication links

The transfer of data from A to B requires connectivity via a data link or more generally a network. A network comprises appropriate hardware and software interconnected by communication channels. In the maritime world, both aboard ship and shore side, data links may be wired or wireless.

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

the physical distance between the sending and receiving parties,

the services provided by the network,

the quality of services requested by the users.

The processes established to guarantee the quality of the services provided by a data sharing network should be carefully defined and monitored and could be part of a Quality Management System.

Global sharing of maritime data and information can take place either through the internet or through dedicated networks. The internet is public, while dedicated networks are generally closed. Consideration should be given to the security related characteristics of theses different network types.

Systems used for global sharing of maritime data and information are in reality a network of networks.

When designing a network for global sharing of maritime data, consideration should be given to transmission protocols, bandwidth limitations, communication / data distribution strategy, security aspects such as authentication and confidentiality as well as data integrity.

A selection between the options available should be based on a number of criteria, including the type of data being transferred, volume of data, types and number of clients connected to the network.

Although bandwidth cost is ever decreasing, there is still a cost associated with the transfer of a certain data item. So the value of the conveyed information has to be balanced against the cost of transmitting it. Another trade-off is the time required to transfer a data item versus a higher required bandwidth (with increased cost). In the future, one can expect to have more flexibility in terms of roaming i.e. dynamic choice of communication links with different bandwidths coverage and costs.

## Specific Design and Installation Considerations

### Interface Requirements

As mentioned earlier, many ways exist in order to ensure one that he is able to exchange and disseminate data and maritime information while meeting the recommended level of security and integrity regarding the data.

If the network used is administrated by the VTS, it is possible to make sure that the data links (sub-network, protocols, ports and sockets) used for data sharing are differentiated from supervising tasks such as sensor monitoring and administration of other parts of the system.

Common authentication and encryption methods and protocols:

Basic rules of authentication and network security

Advanced methods based on specific software, protocols and materials.

### Relevant technical standards

#### Common standards

It is widely acknowledged that there are already a significant number of standards covering description and transfer of data. However, still a few gaps remain that need standardisation, particularly in the field of equipment monitoring and control, interfacing of various sensors etc.

It is necessary to use the most appropriate standard for the current task although there are a number of choices. Some relevant standards and formats are listed below:

ISO 19100 series

19119:2005: identifies and defines the architecture patterns for service interfaces used for geographic information

19115:2003: defines schema (template???) required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.

19139:2007: defines Geographic MetaData XML (gmd) encoding, an XML schema implementation derived form ISO 19115

IHO digital data transfer standards

S-52: Portrayal: provides specifications and guidance regarding the issuing and updating of Electronic Navigational Charts (ENC), and their display in ECDIS. S-52 comprises a number of separate documents.

S-57: The IHO Transfer Standard for Digital Hydrographic Data

S-100: New developed standard for marine data and information data modelling. S-100 will incorporate the requirements of S-57 for ENCs and ECDIS. Significantly it will be aligned with the ISO 19100 series of geographic information standards.

S-63: IHO Data Protection Scheme: An IHO standard used to enable the authentication, integrity and confidentiality of ENC data throughout the data distribution chain from Producer Hydrographic Office to individual seafarer licence holder.

Since maritime information can be spatial information and related to the field of Environment, further guidance can be found in the European INSPIRE directive for establishing an infrastructure for spatial information as well as the CF - Climate and Forecast Metadata convention (WMO).

#### Common formats

Some of these following formats are well suited for real-time data transport, while the others should be considered for storage and retrieval of historical data on a non real-time basis.

Table 12‑1 Common Standardised Data Formats

|  |  |  |  |
| --- | --- | --- | --- |
| Format name | Responsible organization | Description | Application |
| IEC 61162 | IEC | Maritime navigation and radiocommunication equipment and systems - Specification for communications between marine electronic devices. | Real-time |
| IVEF | IALA | Inter VTS Exchange format (IALA recommendation V-145) | Real-time |
| ITU-R 1371-4 | ITU | Technical characteristics describing the format of NMEA phrases used in the maritime domain. | Real-time |
| NetCDF | UCAR/Unidata | NetCDF is a set of open software libraries of the Open Geospatial Consortium.  This self-describing, machine-independent data format, supports the creation, access, and sharing of array-oriented scientific data. | Non Real-time |
| HDF5 | HDF Group | A data model, library, and file format for storing and managing data. | Non Real-time |

# Verification and Validation

VTS equipment shall be verified prior to operation and the most important performance parameters should be monitored continuously or periodically during operation.

This includes:

1. Type approval of individual equipment, as required by law in individual countries.
2. Other equipment specific verification tests as required by the individual VTS authority
3. Verification of equipment prior to delivery in the form of Factory Acceptance Tests
4. Verification of individual equipment or systems upon installation and Setting To Work, but prior to prior to operational used, in the form of Site Acceptance Tests
5. In operation test, e.g. during an initial operation period of a new or updated VTS
6. Continuous or periodic monitoring of selected functions and parameters during operation of the VTS

The overall specifications should be agreed in contractual documents, and it is recommended that FAT, SAT, CAT (in operation test) and other procedures are agreed upon before conducting test.

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

## Planning and Management of Activities

Implementing, extending or upgrading an existing VTS should be planned and managed in details like any other construction and building project. For upgrade and extension projects this shall include planning of cutover activities to minimise disruption.

The establishment and validation of acceptance plan(s) and a verification matrix is necessary to assist all stakeholders. This will for example call upon:

* Early prototyping for the validation of critical parts and user interface to minimise risk at a later stage in the programme
* Focus on acceptance of HMI
* Verification of incoming and outgoing interfaces
* Verification of fall back modes, graceful degradation, redundancy within the VTS system
* Check on latency of data presentation
* Verification of performance (including minimum coverage) during the various stages of acceptance
* Verification of radio communications (including satcoms and radio links), Bit Error Rate, Signal to Noise etc.
* Verification of overlapping sensor coverage, including different sensor types and associated correlation
* Coordination and definition of Factory Acceptance test, Setting to Work, Site/System Acceptance Tests and possible In Operation Test

As the overall complexity of VTS is high it is often desirable to avoid very detailed technical requirements, but focus on operational performance to be validated by inspection, analysis, demonstration and test.

Hardware and Software shall be included.

### Renewal, Update or Extension of Existing VTS

Prior to FAT (ideally prior to contract award), the VTS Authority should specify its requirements for maintaining a level of service during the transition from the old system to the new system. Recognising these requirements, the supplier(s) and the VTS Authority should propose and agree a Cutover Plan taking into account parallel working, the use of temporary interfaces between the old system components and the new system components and in some cases recognizing that the new equipment may have to form part of the interim and / or final system configuration prior to final acceptance.

In many circumstances it will not be possible to maintain the desired continuity of service throughout the planned installation activities and this needs to be understood by all stakeholders. Alternative procedures offering minimal safety provision, possibly including reduced traffic levels, should be invoked by the VTS Authority. Any undesirable system or sub system downtime should be declared and understood at contract negotiation with associated contractual incentives or penalties forming part of the contract if appropriate.

## Customer Acceptance Tests

The Customer shall, in cooperation with the Contractor, prepare, and be responsible for, a plan for the Customer acceptance test, which shall include test procedures for verifying that the delivered equipment and/or software meet the agreed requirements (the “Acceptance Test Plan”), as a basis for the Customer’s completion of its comprehensive assessment by way of the acceptance test.

The Contractor shall, prepare the underlying documentation for the Acceptance Test Plan. The underlying documentation shall include acceptance procedures and acceptance criteria, so as to enable the Customer to proceed with its work on the Acceptance Test Plan.

The Acceptance Test Plan shall describe how the Customer acceptance test is to be carried out, and shall contain detailed descriptions of the tests to be performed, as well as of the acceptance criteria.

The Customer shall submit a draft Acceptance Test Plan to the Contractor for comments in reasonable time prior to the commencement of the acceptance test. The Contractor shall examine the Acceptance Test Plan and give written feedback as to whether it is deemed sufficient to achieve satisfactory testing of the solution.

The Customer acceptance test shall, unless otherwise agreed, be based on the following definitions of errors:

Table 13‑1 Error categories

|  |  |  |
| --- | --- | --- |
| **Level** | **Category** | **Description** |
| **A** | Critical error | - Error that results in the stoppage of the system, the loss of data, or in other functions that are of critical importance to the Customer not being delivered or not working as agreed.  - The documentation is incomplete or misleading, and this results in the Customer being unable to use the system or material parts thereof. |
| **B** | Serious error | - Error that results in functions of importance to the Customer not working as described in the Agreement, and which it is time-consuming or costly to avoid.  - The documentation is incomplete or misleading, and this results in the Customer being unable to use functions that are of importance to the Customer. |
| **C** | Less serious error | - Error that results in individual functions not working as intended, but which can be avoided with relative ease by the Customer.  - The documentation is incomplete, imprecise or easily misunderstood. |

### Factory Acceptance Test (FAT)

The purpose of the Factory Acceptance Test is to prove that the individual apparatus is conformal to contractual specifications, is well manufactured, and ready for packaging and shipment.

The purpose is also to review the quality control documents and ensure the overall functionality of the complete system.

This will normally include Functional and Performance testing to agreed procedures. Test 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. Evaluation of e.g. image quality and instrument readouts may demand experienced operators. One should especially be aware of Safety Instructions.

* Test procedures will normally follow the standards defined by manufacturers. They should include:
* References to project name, customer, software revisions, hardware revisions, part and serial numbers etc.
* List of test instruments and check if “Calibration valid until” date is OK.
* Review of quality control documents including manufactures Declaration of Conformity and Configuration Item Records
* Visual inspection, are the equipment without visible physical defects, properly marked, and connected in accordance with good workman practice (grounding, shielding etc.)
* Functional tests including complete verification of any safety measures, check of power failure and recovery from that, and sample check of functions in general.
* Performance tests at least including measurement of most important parameters. The procedures should also specify measurement tolerances.
* Signatures

The VTS authority may select to witness the FAT. In case of the manufacturer being ISO certified, the VTS Authority might also decide to rely on reporting from the manufactures QA organization.

After FAT, the vendor shall make sure that any finding are corrected, that all settings are in normal operational state and that equipment is ready for shipment, turn power switches off etc.

### Installation and Site Acceptance Test (SAT)

The VTS Authority should assure:

* Check of civil works, structures etc. are completed and in good condition prior to installation of any equipment.
* Check of equipments after shipment, ensure that all parts and documentation are delivered and in good condition.
* That manufacturer’s instructions are followed when lifting equipment.
* Good workmanship practice is followed when installing equipment, special precautions to safety switches, grounding, shielding and lightning protection may be required.

Different approach may be applied for First Of Class (FOC) and Rest Of Class (ROC) if a series of identical equipment is installed, however, the VTS Authority should always assure that safety legislations are met for each individual installation.

**CAUTION:** High voltages may be present at several points in equipment. Such voltages may cause injury and even death.

Equipment may contain parts and assemblies sensitive to damage by electrostatic discharge (ESD). Always use ESD precautionary procedures when touching, removing, or inserting such parts and assemblies.

RADIATION HAZARD may be present. E.g., do not transmit into a stopped radar antenna, and beware of any safety distances specified.

Keep a safe distance from rotating antennas. Always check that the safety switch is turned off before starting work on a rotating antenna unit.

Upon installation and Setting-to-Work, Site Acceptance test should be performed by the vendor(s) and witnessed by the VTS Authority.

The purpose of the Site Acceptance Test is to prove that the overall system functions and performance is conformal to contractual specifications, is well installed and integrated, and ready for operational use.

This will normally include Functional and Performance testing to agreed procedures. Test will normally be performed for the overall system and possibly also for separate features, services and sections of the system.

Personnel conducting the test should be familiar with set-up and operation of the features and services in test. Evaluation of e.g. image quality may demand experienced operators.

Test procedures will normally follow the standards defined by vendors, but for overall system functionality and performance, tailored to the individual contract. They should include:

* References to project name, customer.
* Verification to check that equipment is as tested during FAT. Verify software revisions, hardware revisions, part and serial numbers etc. If updates, e.g. installation of new software, have been performed after FAT, it may be necessary to repeat elements of testing performed during FAT.
* Inspection of check lists from installation and setting to work.
* Visual inspection of the installed equipment, are the equipment without visible physical defects, properly marked, and connected in accordance with good workman practice (grounding, shielding, lightning protection etc.)
* Verification of safety and security measures including but not necessary limited to physical access barriers, network firewalls, warning signs and protection against radiation hazards.
* Functional tests including complete verification of any safety measures, check of power failure and recovery from that, and test of functions in general.
* Verification of overall most important parameters. It should not repeat those measurements made during FAT, but may e.g. include calculation or measurement of overall losses in installed systems. The procedures should also specify acceptable tolerances on such calculations and/or measurements.
* Cross check of information from different sensors and check of alignment.
* Verification of sensor and overall system performance by scenarios.
* Signatures.
* Deviation and waiver management.

Site acceptance test should include test scenarios utilizing traffic of opportunity and/or predefined controlled test objects. Such scenarios should address, normal and extreme situations e.g. risks of collision, and handling of rapid manoeuvrings.

Recording of trajectories over long time, from traffic of opportunity, will test coverage and reveal any unexpected shadows etc.

This may also include an evaluation of sensor range performance if characteristics of targets are known, i.e. for test of radar target characteristics may be obtained by combination of AIS and database information about individual tests. Likewise, the characteristics and position of AToNs will be known.

### Scope of the Acceptance Test

The Customer acceptance test shall comprise software and/or equipment that form part of the deliverables. The Customer acceptance test should include the following tests:

* 1. function test
  2. robustness test
  3. integration test
  4. volume, capacity and response-time test
  5. review of all documentation
  6. installation test
  7. test of operating procedures, including back-up copying.

The Customer shall keep records of the entire test, showing which tests have been carried out and, for each individual test area:

1. when the test was performed
2. who performed the test
3. the outcome of the test.

Software and/or equipment shall be put into regular operation after the Customer acceptance test has been successfully completed and approved

## In Operation Monitoring and Calibration

### Continuous Monitoring

The majority of equipment used in VTS will include Built-in-Test Facilities. These should be monitored and any critical failures detected should be reported to the VTSO without significant delay. A temporary change to a fall-back (e.g. a switch to other sensors) may be necessary and corrective measures shall be taken.

### Off-line Test and Calibration

Off-line test and calibration should be performed according to a scheduled plan of preventive actions provided by the manufacturer.

1. Within one standard deviation (Gaussian distribution) when sailing on a straight course. Note that verification may require simulated tracks or other methods due to the fact that it may be impossible to direct a test target to sail with sufficient accuracy. [↑](#footnote-ref-1)