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**IALA Recommendation V-128**

**On**

**Operational and Technical Performance Requirements for VTS Equipment**

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***AISM***Association Internationale de Signalisation Maritime ***IALA***

International Association of Marine Aids to Navigation and Lighthouse Authorities

Document Revisions

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

|  |  |  |
| --- | --- | --- |
| Edition / Date | Page / Section Revised | Requirement for Revision |
| Edition 1.1  June 2005 | Addition of Annex 6 – Hydrological and Meteorological equipment | Annexes added as they are completed to ensure all aspects of VTS equipment are covered. |
| Edition 2.0  December 2005 | Restructured to include operational performance requirements.  Annex 2 amended to reflect new annex on operational performance requirements.  Annex 6 renamed to Annex 5  Annex 1,3,4,6 added | Annexes added as they are completed to ensure all aspects of VTS operations and equipment are covered. |
| Edition 3.0  June 2007 | Editorial changes to correct errors in paragraph numbering, cross references etc.  Structure of annexes harmonised, part of Annex 2 moved to new IALA Guideline (Establishment of Radar Services)  Clarification of text, few sentences in annex 1 and 2. | Inconsistence in cross references, table of contents etc. in edition 2.0  Varying structure of individual annexes  Users of the document provided ideas to clarification of text on some subjects. |
| Edition 4.0  Xxxx xxxx | Document rewritten and updated to improve user friendliness, to include additional considerations and to include new technology  Annex 7-13 added  Local Port Services added | New technology emerging  Feedback from users indicated need to make the document more user friendly, and to include additional considerations for ports, inland waterways and offshore |
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|  |  |  |

**Recommendation on Operational and Technical Performance Requirements for VTS Equipment**

(Recommendation V-128)

THE COUNCIL:

**RECALLING** the function of IALA with respect to safety of navigation, the efficiency of maritime transport and the protection of the environment;

**NOTING** that Chapter V (12) of the International Convention for the Safety of Life at Sea 1974 (SOLAS 74 as amended) requires Contracting Governments planning or implementing VTS wherever possible to follow the guidelines adopted by the Organization by Resolution A. 857(20);

**NOTING ALSO** that IMO Resolution A.857(20), Annex section 2.2.2recommends that in planning and establishing a VTS, the Contracting Government or Governments or the competent authority should *inter-alia* establish appropriate standards for shore and offshore-based equipment;

**NOTING FURTHER** thatNational Members provide shore infrastructure to support the aim of IMO to improve the safety of navigation and the protection of the environment;

**RECOGNISING** that IALA fosters the safe, economic and efficient movement of vessels through improvement and harmonisation of aids to navigation, including vessel traffic services, worldwide;

**RECOGNISING ALSO** that harmonisation of vessel traffic services would be enhanced by the introduction of international technical performance requirements for VTS;

**HAVING CONSIDERED** the proposals by the IALA VTS Committee on Operational and Technical Performance Requirements for VTS;

**ADOPTS** the Operational and Technical Performance Requirements for VTS as set out in this recommendation as follows:

Annex 1 – Core Operational requirements

Annex 2 – Radar

Annex 3 – Automatic Identification System (AIS)

Annex 4 – Environmental Monitoring

Annex 5 – Electro-Optical equipment

Annex 6 – Radio Direction Finders

Annex 7 – Long Range sensors

Annex 8 – Radio Communications

Annex 9 – Data Processing

Annex 10 – Human Machine Interface (HMI)

Annex 11 – Decision Support

Annex 12 – External Information Exchange

Annex 13 – Verification and Validation

RECOMMENDS that Competent Authorities providing Vessel Traffic Services take into consideration the appropriate Operational and Technical Performance Requirements contained in the Annexes to this recommendation when establishing appropriate standards for shore and offshore-based VTS.

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Abbreviations

|  |  |
| --- | --- |
| º | Degree |
| ± | Plus or minus |
| > | Greater than |
| ≤ | Less than or equal to |
| ≥ | Greater than or equal to |
| µs | microsecond |
| A R and M | availability, reliability and maintainability |
| AIS | Automatic Identification System |
| AREPS | Advanced Refractive Effects Prediction System |
| ASL | Above Sea Level |
| AtoNs | aids to navigation |
| CARPET | Computer Aided Radar Performance Evaluation Tool |
| CAT | Costumers Acceptance Tests |
| CCTV  COG  CPA | Closed Circuit Television  Course Over Ground  Closest Point of Approach |
| CW | Continuous Wave |
| dB | DeciBel |
| dBi | DeciBel isotropic |
| dBm | DeciBel milliWatt |
| DF | Direction Finder |
| EIA | Electronics Industry Association |
| EO | electro optic |
| EPIRB | Emergency Position Indicating Radio Beacons |
| ETA | Estimated Time of Arrival |
| ETA | estimated time of arrival |
| ETD | Estimated Time of Departure |
|  |  |  |
| FAT  FATDMA  FMCW | Factory Acceptance Test  Fixed Access TDMA  Frequency Modulated Continuous Wave |
| FTC | Fast Time Constant |
| GHz | GigaHertz |
| GIT | Georgia Institute of Technology |
| GLOSS | Global Sea Level Observing System |
| GOOS | Global Ocean Observing System |
| GPS | Global Positioning System |
| HCI | human computer interface |
| IALA | International Association of Marine Aids to Navigation and Lighthouse Authorities |
| ICAO | International Civil Aviation Organization |
| IEC | International Electro-Technical Commission |
| IEEE | The Institute of Electrical and Electronic Engineers |
| IMO | International Maritime Organization |
| IOC | International Oceanographic Commission |
| IP | Ingress Protection |
| ITU | International Telecommunication Union |
| kHz | kiloHertz |
| Ku-band | 12.0 – 18.0 GHz |
| Ka-band | 26.4 – 40 GHz |
| kW | kiloWatt |
| LNFE | Low Noise Front End |
| LRIT | Long Range Identification & Tracking |
| m | metre |
| m/s | metre/second |
| m2 | square metre |
| MDS | Minimum Detectable Signal |
| MHz | MegaHertz |
| mm/h | millimetre per hour |
| MMI | man machine interface |
| MMSI | Maritime Mobile Service Identity |
| MOB | Man over board |
| MRCC | Maritime Rescue Co-ordination Centre |
| MSC | Maritime Safety Committee |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time to Repair |
| N/A | Not applicable |
| nm | Nautical Mile (also nmi) |
| NMEA | National Marine Electronics Association |
| PD | Probability of Detection |
| PFA | Probability of False Alarm |
| PRF | Pulse Repetition Frequency |
| PW | Pulse Width |
| R | Range |
| RAID | redundant array of independent disks??? |
| RCS | Radar Cross Section |
| RDF | Radio Direction Finder |
| RDF | Radio Direction Finder |
| RF | Radio Frequency |
| RMP | Recognized Maritime Picture |
| SAIS | satellite AIS |
| SAR | Search and Rescue |
| SART | search and rescue transponder |
| SAT  S-band | Site Acceptance Test  2.0 – 4.0 GHz (NB military designation is F-band) |
| TBA | to be advised |
| TBC | to be confirmed |
| TCPA | Time to Closest Point of Approach |
| UTC | Universal Time Co-ordinated |
| UTM | Universal Transverse Mercator |
| VHF | Very High Frequency |
| VOIP | voice over internet protocol |
| VTS | Vessel Traffic Services |
| VTSO | Vessel Traffic Services Operator |
| WMO | World Meteorological Organization |
| X-band | 8.0 – 12.0 GHz (NB military designation is I-band) |
| XML | Extensible Mark-up Language |

To integrated with above:

MMSI Maritime Mobile System Identifier

MKD Minimum Keyboard & Display

POB Persons on Board

RATDMA Random Access TDMA

SOG Speed over Ground

SOLAS Safety of Life at Sea

SOTDMA Self Organizing TDMA

TDMA Time Division Multiple Access

UTC Universal Time Clock

VTS Vessel Traffic Service

# Core Operational Requirements

## INTRODUCTION

In 1997 the IMO Maritime Safety Committee adopted Regulations for Vessel Traffic Services (VTS) that have since been included in SOLAS Chapter V (Safety of Navigation) as Regulation 12.This Regulation specifies the responsibilities of contracting governments to arrange for the establishment of VTS in certain vulnerable areas under their control.

The purpose of this Recommendation is to assist the VTS authority in the definition, establishment and upgrades of a VTS system. The document addresses the relationship between the Operational Requirements and VTS system performance requirements. More specifically:

* Core Operational requirements
* Radar
* Automatic Identification System (AIS)
* Environmental Monitoring
* Electro-Optical equipment
* Direction Finders
* Long Range sensors
* Radio Communications
* Data Processing
* Human Machine Interface (HMI)
* Decision Support
* External Information Exchange
* Verification and Validation

In addition relations to systems for Local Port Services are discussed where appropriate and the guidance may also be used in that context.

### Prerequisites

As stated by the VTS manual the prerequisites for Vessel Traffic Services (VTS) and Local Port Services (LPS) are:

Vessel Traffic Services

* Authorised by the Competent Authority;
* Staffed by V-103 certificated personnel;
* Equipped as appropriate to provide INS/NAS/ TOS;
* Interacts with traffic; and
* Responds to traffic situations.

Local Port Services

* Does not require to be authorised by the Competent Authority;
* Staffed and trained appropriate to task; and
* Equipped appropriate to task

## References

VTS-manual

Solas

## Core Operational Requirements for a VTS System

The main functions of a VTS are to mitigate risks associated with shipping and to improve efficiency. The different types of risks and environments have led to various types of VTS including coastal and offshore, port, estuary or inland VTS.

For instance a coastal VTS assist the safe and expeditious passage of shipping through coastal waters, particularly where there is a high density of maritime traffic or an area of environmental sensitivity or through difficult navigation conditions. Similarly, a port, estuarial or inland VTS support shipping when entering or leaving ports and harbours or when sailing along rivers or through restricted waters.

An important task of an offshore VTS is to avoid ships collisions with offshore structures e. g. oil platforms and wind farms.

All VTS types may offer, in principle, all services as defined in the IMO resolution A.857(20). When determining the required performance of a VTS system, the following should be taken into account:

* The identified risks
* The type of VTS (coastal and offshore, port, estuary or inland VTS)
* The VTS services to be provided (INF, TOS, NAS)
* Requirements from Allied Services
* Types and number of targets
* The geographical area
* Prevailing meteorological conditions

### Levels of capabilities

All the above factors determine the complexity of the traffic situation. In addition, specific operational requirements such as the need to detect small targets in adverse conditions or ice monitoring, may increase the required performance.

In order to facilitate the definition of required performance, three levels of capabilities for VTS are defined as follows:

**Basic** – performance for a VTS area with low complexity, where an Information Service and/or a Navigational Assistance Service will be provided.

**Standard** – performance for a VTS area with low or medium complexity, where an Information Service, Navigational Assistance Service and /or a Traffic Organisation Service will be provided.

**Advanced** – performance for a VTS area with high complexity and/or specific operational requirements.

Special cases are:

**Ports and inland waterways** – performance for ports and inland waterways with increased demand to handle large nearby structures, but reduced requirements to sea condition

**Offshore** – performance for oil platforms and other offshore installations, typically with advanced detection requirements, but reduced requirements to target separation.

A risk assessment and the determination of the specific operational conditions shall be made by the VTS authority prior to the allocation of capabilities

### Allocation of Capabilities to meet Operational Requirements

Requirements of the VTS equipment may have a high impact on acquisition and life-cycle costs of a VTS system and therefore is paramount to properly allocate capabilities to satisfy Operational Requirements.

A specific capability could be assigned to an entire VTS area or to particular subsections as illustrated in the example given by Figure 1‑1



Figure 1‑1 Example of assigned capabilities in a Generic VTS area, by the VTS authority

Advanced capability was chosen in areas (A, B and C) for the following reasons:

* Dangerous cargo imposes a high risk to environment and populated areas
* Security, including the need for detection of small targets
* Dense traffic in a complex separation scheme including a bridge crossing

Standard capability was chosen in areas (D, E and F) for the following reasons:

* Wind farm close to a traffic lane imposes a navigational hazard
* Traffic in confined areas such as Ports and Inland waterways

Basic capability was chosen for the remainder of the VTS area (G)

#### Ports and inland waterways

VTS for ports and inland waterways will typically be subject to high demand to handle targets in close vicinity of each other and with large nearby structures and obstructions, but requirements to sea condition are low

#### Offshore

VTS in areas with oil platforms and other offshore installations will typically be subject to advanced detection requirements, but with relaxed requirements to target separation due to low traffic density.

## VTS System Considerations

### Objectives

The purpose of vessel traffic services is to improve the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment and/or the adjacent shore area, worksites and offshore installations from possible adverse effects of maritime traffic.

The benefits of implementing a VTS are that it allows identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. It can also assist in prevention of pollution and co-ordination of pollution response.

The efficiency of a VTS will depend on the reliability and continuity of communications and on the ability to provide good and unambiguous information. The quality of accident prevention measures will depend on the system's capability of detecting a developing dangerous situation and on the ability to give timely warning of such dangers.

### Types of Vessel Traffic Services

As stated in the VTS manual an authorised VTS will be capable of offering one or more of the following types of service:

* Information Service (INS)

**Definition:** An Information Service provides essential and timely information to assist the on-board decision-making process.

* Traffic Organisation Service (TOS)

**Definition:** A Traffic Organisation Service is a service to provide for the safe and efficient movement of traffic and to identify and manage potentially dangerous traffic situations. A Traffic Organisation Service provides essential and timely information to assist the on-board decision-making process and may advise, instruct or exercise authority to direct movements.

* Navigational Assistance Service (NAS)

**Definition:** A Navigational Assistance Service may be provided in addition to an Information Service and/or Traffic Organisation Service. It is a service to assist in the on-board navigational decision-making process and is provided at the request of a vessel, or when deemed necessary by the VTS. It is a service that provides essential and timely navigational information to assist in the on-board navigational decision-making process and to monitor its effects. It may also involve the provision of information, warning, navigational advice and/or instruction.

### Site Survey

Prior to establishment or extension of a VTS comprehensive site surveys should be performed, including but not limited to:

* Coverage
* Access
* Availability of power, telephone lines etc.
* Protection of the environment and that installation sites are selected with due respect to neighbours
* Other environmental issues including EMI/EMS, wind (be aware of high / asymmetrical loads on antennas) influence from sea conditions, precipitation, ice etc.

Added value from the site survey is the involvement of stakeholders early in the process. design awareness and early awareness of performance issues, e.g. as a result of missing site availability.

### System Architecture

A VTS System should have the capability to be flexible and easily upgraded and maintained alongside the routine operations of the VTS Centre without the need for interrupting the service.

Any VTS should as a minimum be equipped with automatic identification systems, voice communication and reporting facilities, however several other features will often be included as lustrated by the example in Figure 1‑2

Guideline for the overall user requirements can be found in the VTS manual, the following annexes and other IALA guidelines, how to cope with traffic density and specify overall/regional capacity, declaration of supported services, ship support in an emergency situation, how many user seats are required, what are the requirements to operational skills, decision support, language and training. The same apply to data collection, data processing, data fusion, data management and data presentation.

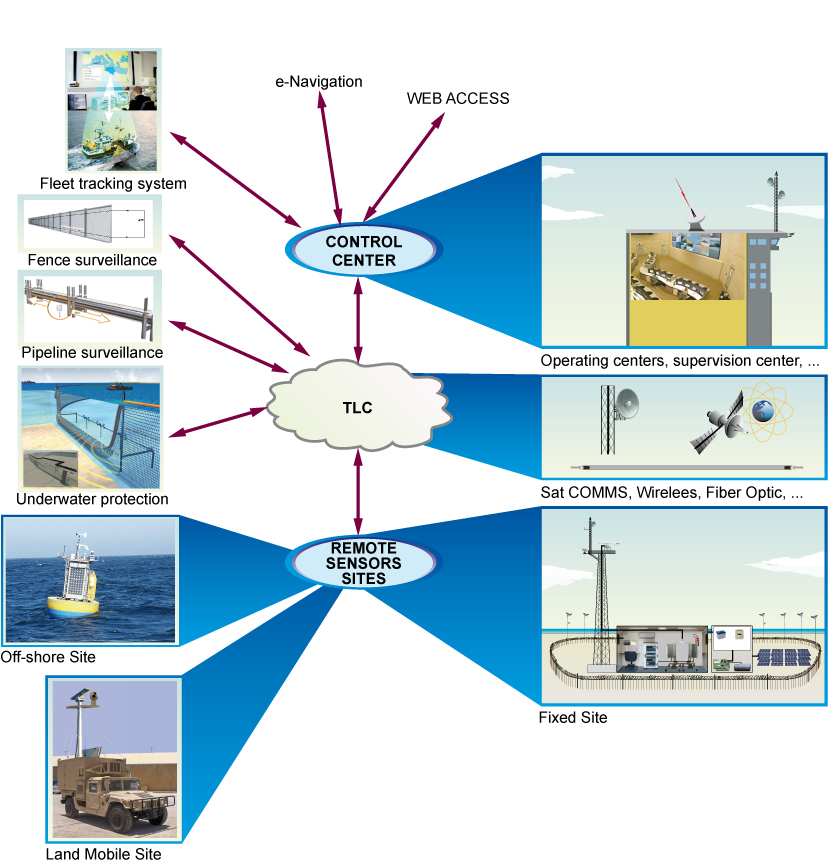


Figure 1‑2 VTS system

Shipping data and port (berth planning etc) and/or waterway management data is normally an integral part of the VTS, so may management of tugs, management of pilotage, protection of static bridges, management of moveable bridges etc. be.

#### Communication infrastructure

Reliable communications is of outmost importance for any VTS and the infrastructure (e.g. line of sight radio communications, IP networks and public wide area network) must be robust and reliable. Therefore the VTS Authority should consider subjects such as redundant data paths, techniques to overcome link outages, selection of used data when multiple versions exist, data compression, bandwidth requirements, data integrity, encryption, error correction, internet protocols and other communication standards to be used.

Add text about implication of bandwidth requirements

#### System boundary

The typical VTS system consist of equipment, functions and ser vices as illustrated by Figure 1‑2 and interfacing to the exterior, preferably utilising generic interface standards for

* 1. Providing the VTS operators the necessary tools
  2. Interaction with ships
  3. Cooperation with adjacent VTS
  4. Obtaining information from external sources e.g. satellites (LRIT), met office weather data and external hydrographical data.
  5. Information exchange with other agencies (allied services) using the VTS data (coastguard, homeland security, police, customs etc)

#### System states and modes

Fundamentally there is one operational state of a VTS (24/7 or less in some circumstances). In addition supporting states, modes for graceful degradation, redundancy and maintenance shall be defined.

#### Set-up and maintenance

In order to achieve an maintain the required availability any VTS shall include set-up and maintenance facilities. For larger systems this will typically include maintenance console(s), facilities for replay, facilities for calibration of sensors and facilities for alignment of the total system, e.g. alignment of overlapping sensors to a common reference in terms of compass, mapping and time

### Availability

Availability is defined in IMO Resolution A.915 (220 Ref.40) as:

*“The percentage of time that an aid, or system of aids, is performing a required function under stated conditions. The non-availability can be caused by scheduled and/or unscheduled interruptions”.*

Several sources of information is typically available to the operator of a VTS system, resulting in reduced requirements to availability from individual sensors. Overlap between sensors can also reduce requirements to the individual sensor.

The recommended availability for VTS services available to the operators are defined by Table 1‑1

Table 1‑1 Recommended availability figures



The figures include hardware and software. Scheduled maintenance activities with significant disturbance to the VTS operation is also included.

It should be noted that VTS in very critical areas may call for more than 99.95% availability in which case redundant servers and communication systems may be needed - or even duplicated operational centres.

Some redundancy or sensor overlap may also be required, or different types of sensors may support each other.

#### Calculation of Availability

Administrations may choose to calculate service availability using one of two methods:

* by waterway model
* sensor combination model

**Waterway model:** In this model administrations need to define which waterways are high risk and which waterways are low risks. Separate calculations for high and low risk are required, providing both exist within the coverage area. Individual waterway availability calculations are then averaged to produce one figure for each waterway risk category. If desired, a figure for each waterway may be reported.

**Sensor combination model:** In this model, administrations must define which sensors serve low risk waterways and which serve high risk waterways. The overall availability is calculated by combining the availability of the associated individual sites.

### Redundancy

Individual sensor site (remember parameter hand over)

Between sensors,

between various types of sensors

### Precautionary measures to extreme events

VTS Authorities responsible for VTS in areas subject to extreme events, such as earthquake and tsunami should specify requirements to construction accordingly.

This will typically include special requirements to equipment shock resistance, alignment capabilities, civil works and power supply.

### Recording, Archiving and Replay

Provision should be made for the storage, security, retrieval and presentation of this information.

The data type, resolution and period of time for which information gathered by a VTS is required to be stored should be identified in internal procedures. This time period should be such that it allows for the full retrieval of data post-incident/accident, in compliance with national requirements and those of the incident/accident investigation procedures of the VTS authority and other authorised parties. This type of information should include:

* Communications, internal and external as defined in IALA Recommendation V-127
* Sensor data, i.e. data used to generate the traffic image such as radar, CCTV, AIS and long-range sensor data.
* Shipping information data, i.e. vessel and cargo data, including vessel movement information.
* Meteorological and hydrological data; and
* Data from other sources if relevant.
* Synchronization of voice / track data

The IMO recommends a minimum of 30 days for the time-period to allow for the full retrieval of data post-incident/accident. The VTS authority should define the period of time and temporal resolution of sensor data and other tracking performance parameters depending on traffic density and types of tracks.

If required by the VTS Authority, the data should be recorded automatically and capable of being replayed onto a separate replay system.

## Design, installation and maintenance considerations

### Establishing and updating VTS

Refer to the IALA manual for guidance on project work

Discuss progressive integration planning

Discuss maintenance precautions

### Standards applicable to VTS equipment’s

VTS equipment are subject to a variety of local, regional and international standards and it is the responsibility of the VTS authority to meet those standards.

The below tables summarise the general recommendation to specification levels and corresponding standards, however, local regulations or requirements may set additional or alternative requirements to the individual VTS or location.

Additional specific requirements to types of equipment e.g. Radar are listed in the relevant Annexes.

#### International standards







Regional standards

Summary of environmental capabilities and constraints

### Climatic influence

Based on MIL-STD-810, IALA defined simplified climatic categories suitable for stationary VTS systems, Very Hot, Normal and Severe Cold.

Allowance for daily cycles, primarily based on variations in temperature and relative humidity levels is included.

#### Normal Climatic Category

The Normal Climatic Category covers a broad range of climatic conditions in which equipment materiel should operate and survive storage and transportation. This includes the most densely populated and heavily industrialized parts of the world as well as the humid tropics. The entire range of associated design conditions does not necessarily occur in any one place; however, a single condition (high temperature, low temperature, high humidity) occurs in a wide area. When taken together, the recommendations for the Normal Climatic Category should be valid for equipment used throughout the corresponding area.

The conditions for individual zones of the category are described as follows.

**a. Humid tropic zone.** Humid tropic areas are included in the Normal Climatic Category rather than being considered an extreme category because humid tropic temperatures are moderate and their humidity levels are equaled at times in some of the other mid-latitude areas. The feature of the humid tropics most important for materiel system design is the persistence of high humidity coupled with moderately high temperatures throughout the year. This combined environmental condition not only promotes corrosion, but also greatly increases insect and microbiological damage.

**b. Intermediate zone.** These are mid-latitude areas that do not combine higher temperatures with higher humidity throughout the year, and at the same time are not climatically extreme enough to meet the conditions for neither Hot nor Cold Climatic Categories. This zone includes the daily cycles shown in table CI, plus a condition known as "cold-wet" which can occur within the mild cold daily cycle at or near the freezing point (2 to -4°C (35 to 25°F)) with relative humidity tending toward saturation (100 to 95% RH) and negligible solar radiation.

**c. Cold zone.** In the Cold zone, the temperature during the coldest months, extremes may be very low; however, at open waters cold extremes below -30°C are unlikely.

#### Very Hot Climatic Category

This Climatic Category includes coastlines and inland waterways at the hot-dry low-latitude deserts of the world. During summer in these areas, outdoor ambient air temperatures above 43°C (110°F) occur frequently. However, except for a few specific places, outdoor ambient air temperatures will seldom be above 49°C (120°F). These approximate temperatures of the free air in the shade approximately 1.5 to 2 meters (about 5 or 6 feet) above the ground (in an instrument shelter).

The thermal effects of solar loading can be significant for materiel exposed to direct sunlight, but will vary significantly with the exposure situation. The ground surface can attain temperatures of 17 to 33°C (30 to 60°F) higher than that of the free air, depending on the type/colour of the ground surface, radiation, conduction, wind, and turbulence.

Air layers very close to the surface will be only slightly cooler than the ground, but the decrease in temperature with height above the surface is exponential. Temperatures at approximately 0.5 to 1 meter (about 2 to 3 feet) will be only slightly warmer than that observed in an instrument shelter at about twice that height.1

In winter, temperatures are likely to be in the same range as for the Normal Climatic Category.

Littoral regions are sometimes subject to very high absolute humidity. However, in these hot-wet areas, the highest outdoor ambient air temperatures and highest dew points do not occur at the same time.

#### Severe Cold Climatic Category

In the Severe Cold areas, the temperature during the coldest month in a normal year may be colder than -46°C (-50°F). Temperatures colder than -51°C (-60°F) occur no more than 20 percent of the hours in the coldest month of the coldest part of northern Siberia where temperatures as low as -68°C (-90°F) have been recorded. Because extremely low temperatures are not controlled by a daily solar cycle, they persist for a long enough period of time to cause materiel to reach equilibrium at extremely low temperatures.

It is recommended to seek assistance in military standards for design to such conditions.

### Determining climatic categories

#### Normal climatic considerations

All outdoor systems should be designed for at least the Normal Climatic Category, meaning that design temperatures will include the outdoor ambient air temperatures range of -30°C through +45°C. Allowance for sun radiation must be made in addition to that.

#### Extreme climatic considerations

Equipment intended to be installed and used in extreme climates (very hot and severe cold), in areas with extreme non-thermal weather conditions such as corrosive agents from oil installations, blowing sand and dust will require additional planning, design, and testing considerations.

#### Special considerations

**a. Storage and transit**. Environmental conditions for storage and transit modes may be more severe than those of operational modes because of the possibility of induced/combined environments (e.g., heat, humidity, shock, vibration, etc.), higher levels of some factors (e.g., high temperature in temporary open storage or during delays between transit modes), or greater materiel exposure times.

**b. Design of sheltered equipment.** The shelter becomes the materiel platform, and the environmental characteristics that the sheltered materiel will see depend upon the location and design of the shelter.

### Wind

Wind specifications will have an impact on the cost of equipment and civil works and it is therefore recommended only to specify that required for operation + add a safety margin for survival in the extreme situation. Data, including those for extreme situations are normally available from local metrological services

Additional complications for VTS is that equipment often is located where windloads are asymmetrical with horizontal as well as vertical components and turbulence caused by wind gradient, venturi effects, air density (temperature) obstructions or tropical cyclones as described in the following.

This all affect the wind load on equipment and structures.

Furthermore, increased wind speed due to such effects and especially vertical wind components can be dangerous to equipment and especially to rotating antennas and this may call for reinforcements or restrict physical location.

#### The Beaufort scale

According to the Wikipedia the scale was originally devised in 1805 by [Francis Beaufort](http://en.wikipedia.org/wiki/Francis_Beaufort). The initial scale of thirteen classes (zero to twelve) did not reference [wind speed](http://en.wikipedia.org/wiki/Wind_speed) numbers but related qualitative wind conditions. Rotations to scale numbers were standardized only in 1923.

The Beaufort scale was extended in 1946, when Forces 13 to 17 were added.[[4]](http://en.wikipedia.org/wiki/Beaufort_scale#cite_note-3#cite_note-3) However, Forces 13 to 17 were intended to apply only to special cases, such as tropical cyclones. Nowadays, the extended scale is only used in Taiwan and mainland China, which are often affected by typhoons.

Note that wave heights in the scale are for conditions in the open [ocean](http://en.wikipedia.org/wiki/Ocean), not along the shore. Also note that numerous sea state models exist. The GIT model, and NOT the Beaufort scale and NOT the Douglas scale has been adapted to this recommendation.

Table 1‑3 The modern Beaufort scale vs. the GIT and WMO sea state models

| **Beaufort number** | **Wind Description** | **Wind speed** | **Land**  **conditions** | **Sea**  **conditions** | **Sea**  **State**  **photo** | **Significant Wave height** | **WMO Sea state model** | **Douglas (GIT) sea state model (CARPET)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **0** | [Calm](http://en.wikipedia.org/wiki/Calm) | < 1 km/h  < 1 mph  < 1 [kn](http://en.wikipedia.org/wiki/Knot_(unit))  < 0.3 [m/s](http://en.wikipedia.org/wiki/Metre_per_second) | Calm. Smoke rises vertically. | Flat. | [Beaufort scale 0.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_0.jpg) | 0 [m](http://en.wikipedia.org/wiki/Metre)  0 [ft](http://en.wikipedia.org/wiki/Foot_(length)) | 0  Calm (glassy)  0.0m | 0  Calm  0.0m |
| **1** | [Light air](http://en.wikipedia.org/wiki/Light_air) | 1.1–5.5 km/h  1–3 mph  1–2 kn  0.3–1.5 m/s | Smoke drift indicates wind direction and wind vanes cease moving. | Ripples without crests. | [Beaufort scale 1.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_1.jpg) | 0–0.2 m  0–1 ft | 1  Calm (rippled)  0 - 0.1m | 1  Smooth  0.1 m |
| 2  Smooth (wavelets)  0.1 - 0.5m |
| **2** | [Light breeze](http://en.wikipedia.org/wiki/Light_breeze) | 5.6–11 km/h  4–7 mph  3–6 kn  1.6–3.4 m/s | Wind felt on exposed skin. Leaves rustle and wind vanes begin to move. | Small wavelets. Crests of glassy appearance, not breaking | [Beaufort scale 2.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_2.jpg) | 0.2–0.5 m  1–2 ft | 2  Slight  0.3m |
| **3** | Gentle breeze | 12–19 km/h  8–12 mph  7–10 kn  3.4–5.4 m/s | Leaves and small twigs constantly moving, light flags extended. | Large wavelets. Crests begin to break; scattered whitecaps | [Beaufort scale 3.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_3.jpg) | 0.5–1 m  2–3.5 ft | 3  Slight  0.5 - 1.25 m | 3  Moderate  0.7 m |
| **4** | Moderate breeze | 20–28 km/h  13–17 mph  11–15 kn  5.5–7.9 m/s | Dust and loose paper raised. Small branches begin to move. | Small waves with breaking crests. Fairly frequent [whitecaps](http://en.wikipedia.org/wiki/Wind_wave). | [Beaufort scale 4.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_4.jpg) | 1–2 m  3.5–6 ft | 4  Rough  1.2 m |
| 4  Moderate  1.25 - 2.5 m |
|  | 5  Very rough  2.0 m |
| **5** | Fresh breeze | 29–38 km/h  18–24 mph  16–20 kn  8.0–10.7 m/s | Branches of a moderate size move. Small trees in leaf begin to sway. | Moderate waves of some length. Many whitecaps. Small amounts of spray. | [Beaufort scale 5.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_5.jpg) | 2–3 m  6–9 ft |
|  | 6  High  2.9 m |
| 5  Rough  2.5 - 4 m |
| **6** | Strong breeze | 39–49 km/h  25–30 mph  21–26 kn  10.8–13.8 m/s | Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over. | Long waves begin to form. White foam crests are very frequent. Some airborne spray is present. | [Beaufort scale 6.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_6.jpg) | 3–4 m  9–13 ft |  |
|  | 7  Very High  3.9 m |
| **7** | High wind, Moderate gale, Near gale | 50–61 km/h  31–38 mph  27–33 kn  13.9–17.1 m/s | Whole trees in motion. Effort needed to walk against the wind. | Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray. | [Beaufort scale 7.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_7.jpg) | 4–5.5 m  13–19 ft | 6  Very rough  4 - 6 m |
|  | 8  Precipitous  5.1 m |
| **8** | [Gale](http://en.wikipedia.org/wiki/Gale), Fresh gale | 62–74 km/h  39–46 mph  34–40 kn  17.2–20.7 m/s | Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded. | Moderately high waves with breaking crests forming spindrift. Well-marked streaks of foam are blown along wind direction. Considerable airborne spray. | [Beaufort scale 8.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_8.jpg) | 5.5–7.5 m  18–25 ft |  |
| 7  High  6-9 m |  |
| **9** | Strong gale | 75–88 km/h  47–54 mph  41–47 kn  20.8–24.4 m/s | Some branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over. | High waves whose crests sometimes roll over. Dense foam is blown along wind direction. Large amounts of airborne spray may begin to reduce visibility. | [Beaufort scale 9.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_9.jpg) | 7–10 m  23–32 ft |  |  |
|  | 8  Very high  9-14 m |
| **10** | [Storm](http://en.wikipedia.org/wiki/Storm),[[7]](http://en.wikipedia.org/wiki/Beaufort_scale#cite_note-forcenamenote-6#cite_note-forcenamenote-6) Whole gale | 89–102 km/h  55–63 mph  48–55 kn  24.5–28.4 m/s | Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt shingles and shingles in poor condition peel off roofs. | Very high waves with overhanging crests. Large patches of foam from wave crests give the sea a white appearance. Considerable tumbling of waves with heavy impact. Large amounts of airborne spray reduce visibility. | [Beaufort scale 10.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_10.jpg) | 9–12.5 m  29–41 ft |  |  |
| **11** | Violent storm | 103–117 km/h  64–72 mph  56–63 kn  28.5–32.6 m/s | Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have curled up and/or fractured due to age may break away completely. | Exceptionally high waves. Very large patches of foam, driven before the wind, cover much of the sea surface. Very large amounts of airborne spray severely reduce visibility. | [Beaufort scale 11.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_11.jpg) | 11.5–16 m  37–52 ft |  |  |
| 9  Phenomenal  >14 m |
| **12** | [Hurricane](http://en.wikipedia.org/wiki/Hurricane) Force[[7]](http://en.wikipedia.org/wiki/Beaufort_scale#cite_note-forcenamenote-6#cite_note-forcenamenote-6) | ≥ 118 km/h  (≥ 32.8 m/s) | Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and barns are damaged. Debris may be hurled about. | Huge waves. Sea is completely white with foam and spray. Air is filled with driving spray, greatly reducing visibility. | [Beaufort scale 12.jpg](http://en.wikipedia.org/wiki/File:Beaufort_scale_12.jpg) | ≥ 14 m |  |  |

#### Gradient wind effect

The wind speed drops the closer to the earth it is, this is because as the wind passes over the earth (or sea) it's movement generates friction or drag, causing the speed to drop.

The more uneven the earth (or sea) surface is, the greater the effect of this friction is, and the higher the difference between the wind speed at ground level and the wind speed higher up in the radar mast or tower. This phenomenon is called the Gradient wind effect. The earth generally causes more friction than the sea.

The example in Figure 1‑2 shows that with a gradient wind speed of 45 m/s, the actual wind speed at the height of 80 meter is indeed depending on the surroundings roughness characteristics.



**Figure 1‑3 Example on the effect on gradient wind on a radar antenna. Average wind speed profiles over terrain with three different roughness characteristics for of 45 m/s in higher altitude**.

Note that wind data from meteorological services normally are for measurements in 10 meter elevation.

#### The venturi effect

The Venturi effect is a jet effect; as with a funnel the velocity of the air increases as the cross sectional area decreases, with the static pressure correspondingly decreasing. According to the laws of fluid (or air) dynamics, the velocity must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy.

This means that if the wind passes upwardly on a slope, it generates a venturi effect and provide a strong increase in the wind velocity at a given height above the surface. The height can be determined by local measurement, but may vary with wind speed and direction. It is as example not recommended to install radar antennas directly in the venturi.



Figure 1‑4: Simplified illustration of the venturi effect on a slope



Figure 1‑5 Simplified illustration of the venturi effect around a building

#### Air density

When air becomes warm, the molecules moves faster and the air expands and causes the air's volume to increase. Because density is the mass of the air divided by the volume of the air, and since the mass remains the same, the density decreases.

| Temperature [°C] | Air density [kg/m3] | Normalized 20 °C = 1 |
| --- | --- | --- |
| 35 | 1.15 | 0.95 |
| 30 | 1.16 | 0.97 |
| 25 | 1.18 | 0.98 |
| 20 | 1.20 | 1.00 |
| 15 | 1.23 | 1.02 |
| 10 | 1.25 | 1.04 |
| 5 | 1.27 | 1.05 |
| 0 | 1.29 | 1.07 |
| -5 | 1.32 | 1.09 |
| -10 | 1.34 | 1.11 |
| -15 | 1.37 | 1.14 |
| -20 | 1.39 | 1.16 |
| -25 | 1.42 | 1.18 |

#### Turbulence

Turbulence phenomenon is caused when an interruption or impediment is introduced to the air (or liquid) flow.

For example, a river may flow smoothly until it hits a boulder, at which point the water around the obstacle will become turbulent as it moves around or over it. In the air, turbulence can be caused by obstacles on the ground, ranging from mountains to buildings.

Turbulence is characterized by apparently random and chaotic three-dimensional vorticity, and the agitated, irregular motion usually involves movement at various rates of speed, this is why turbulence can be very difficult to predict.



Figure 1‑6: Example of turbulence around a building

#### Tropical cyclones

Tropical systems are officially ranked on one of several tropical cyclone scales according to their maximum sustained winds and in what oceanic basin they are located as Table 1‑4 from the Wikipedia show.

Today, hurricane force winds are sometimes described as Beaufort scale 12 through 16, very roughly related to the respective category speeds of the Saffir–Simpson Hurricane Scale, by which actual hurricanes are measured, where Category 1 is equivalent to Beaufort 12. However, the extended Beaufort numbers above 13 do not match the Saffir–Simpson Scale.

Table 1‑4 classification of tropical cyclones

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tropical Cyclone Classifications (all winds are 10-minute averages)** | | | | | | | | | | |
| [**Beaufort scale**](http://en.wikipedia.org/wiki/Beaufort_scale) | **10-minute sustained winds** | | | **N Indian Ocean (**[**IMD**](http://en.wikipedia.org/wiki/Indian_Meteorological_Department)**)** | **SW Indian Ocean (**[**MFR**](http://en.wikipedia.org/wiki/M%C3%A9t%C3%A9o-France)**)** | **Australia (**[**BoM**](http://en.wikipedia.org/wiki/Bureau_of_Meteorology_(Australia))**)** | **SW Pacific (**[**FMS**](http://en.wikipedia.org/wiki/Fiji_Meteorological_Service)**)** | **NW Pacific (**[**JMA**](http://en.wikipedia.org/wiki/Japan_Meteorological_Agency)**)** | **NW Pacific (**[**JTWC**](http://en.wikipedia.org/wiki/Joint_Typhoon_Warning_Center)**)** | **NE Pacific & N Atlantic (**[**NHC**](http://en.wikipedia.org/wiki/National_Hurricane_Center)**,** [**CHC**](http://en.wikipedia.org/wiki/Canadian_Hurricane_Centre)**, &** [**CPHC**](http://en.wikipedia.org/wiki/Central_Pacific_Hurricane_Center)**)** |
| [**knots**](http://en.wikipedia.org/wiki/Knot_(unit)) | **km/h** | **mph** |
| 0–6 | <28 | <52 | <32 | Depression | Tropical Disturbance | Tropical Low | Tropical Depression | Tropical Depression | Tropical Depression | Tropical Depression |
| 7 | 28-29 | 52-56 | 32-35 | Deep Depression | Tropical Depression |
| 30-33 | 56-63 | 35-39 |
| 8–9 | 34–47 | 63-89 | 39-55 | Cyclonic Storm | Moderate Tropical Storm | Tropical Cyclone (1) | Tropical Cyclone (1) | Tropical Storm | Tropical Storm | Tropical Storm |
| 10 | 48–55 | 89-104 | 55-64 | Severe Cyclonic Storm | Severe Tropical Storm | Tropical Cyclone (2) | Tropical Cyclone (2) | Severe Tropical Storm |
| 11 | 56–63 | 104-119 | 64-74 |
| 12 | 64–72 | 119-135 | 74-84 | Very Severe Cyclonic Storm | Tropical Cyclone | Severe Tropical Cyclone (3) | Severe Tropical Cyclone (3) | Typhoon | Typhoon | Hurricane (1) |
| 13 | 73–85 | 135-159 | 84-99 | Hurricane (2) |
| 14 | 86–89 | 159-167 | 99-104 | Severe Tropical Cyclone (4) | Severe Tropical Cyclone (4) | Major Hurricane (3) |
| 15 | 90–99 | 167-185 | 104-115 | Intense Tropical Cyclone |
| 16 | 100–106 | 185-198 | 115-123 | Major Hurricane (4) |
| 17 | 107-114 | 198-213 | 123-132 | Severe Tropical Cyclone (5) | Severe Tropical Cyclone (5) |
| 115–119 | 213-222 | 132-138 | Very Intense Tropical Cyclone | Super Typhoon |
| >120 | >222 | >138 | Super Cyclonic Storm | Major Hurricane (5) |

For VTS it may not be feasible to continue full operation at very high wind speeds e.g above Beaufort scale 12 and it may e.g be advisable to stop radar antennas to reduce the risk of damage in severe conditions

### Lightning protection

Lightning protection is often subject to national or local legislation taking local conditions, severity, earth conductivity, power grid constraints etc. into account. The guidance from country to country differ depending of lightning frequency and severity. As a consequence requirements to the number and type of lightning arrestors, number of earthling points and cross section of lightning conductors vary.

Furthermore, the individual equipment design may set special requirements.

In general principles are:

1. That lightning arresters shall be higher than other equipments and designed to protect the entire installation. They should have separate down conductor(s) on the exterior of buildings and the down conductors must not be connected to metal parts of buildings such as steel reinforcements, handrails and antenna masts.
2. Safety grounding of equipment should be kept separate from lightning protection
3. Potential equalization must be done in earth never in the top of the equipment

### Warning lights

Note that high structures may include warning lights at the radar towers for air traffic. It is recommended to consult local aviation authorities on that subject.

### Access

As part of the design of VTS or VTS equipment locations, the VTS authority should analyse the needs for access for installation and service. Fencing and other protective means against illegal intrusion will also be needed in many cases.

### Electrical Power

VTS equipment is often installed in harsh environments and lack of reliable power may require back up and/or Uninterruptable Power Supplies (UPS).

The VTS authority should analyse the needs at the installation and assure that the availability of electrical power is included in the availability considerations.

## Marking and identification

All equipment should be marked with manufacturer name, type and serial number

Local or national legislation may require signposts etc.

National and/or local regulations may require the posting of signs to notify the public that they are under surveillance.

## Safety and security precautions

For each installation the VTS authority should perform a hazard analysis and determine requirements in accordance to that.

A safety analysis should at least include:

* safety switch to stop rotating antennas,
* precautions regarding electromagnetic radiation, rotating machinery and electrical shock, railings on masts etc.
* instructions to personnel performing maintenance
* protection of the general public

Security measures should at least consider:

* access restrictions
* alarm systems
* protection of data

## Documentation

Documentation should be provided in electronic and/or paper format, at least including:

* Certificates and permissions as required by law (e.g. CE marking, permission to radiate, permit to build and acoustic noise certificate)
* Instructions to health care (e.g regarding radiation, electrical safety and rotating machinery)
* Test procedures, test certificates, "As build" documentation, etc
* Operating instructions
* Maintenance instructions (preventive and corrective) inclusive of procedures and spare parts catalogue.

Recommendation to verification is handled by ANNEX 13

## Local Port Services Considerations

As stated in the VTS manual Local Port Services (LPS) is applicable to those ports where it has been identified from their Formal Risk Assessment that a VTS is excessive or inappropriate. It does not imply a lower standard or a poorer service to their customers.

The main difference arising from the provision of LPS is that it does not interact with traffic, nor is it required to have the ability and/or the resources to respond to developing traffic situations and there is no requirement for a vessel traffic image to be maintained.

It should be noted that LPS are outside of the scope of VTS, as they do not meet international standards, although they will invariably meet the standards of a lower level of capability sufficient to meet local needs.

# Radar

## Introduction

The purpose of this Annex is to support VTS authorities and integrators in the selection of radar sensors for new and existing VTS systems. The radar solution to a given VTS application may consist of one or more networked radar sensors. Unlike other applications, VTS radars normally need to operate simultaneously on short and long range and this leads to receiver dynamic range requirements that far exceed, for example, those required on board a ship. However, in some cases marine navigational radar may fulfil requirements in a VTS area with low complexity or as a gap filler within a radar sensor network.

Weather-related phenomena pose significant challenges to the design and specification of radar sensors. Ducting, for example, may influence VTS radars more than ships’ radars. Additionally, more effective clutter suppression for sea, rain and land may be required than that normally associated with a conventional shipboard radar.

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

The use of multi-sensor integration, including radar, AIS and other sensors, imposes additional demands on radar sensor performance and accuracy. False and inaccurate information from the radar sensors, when improperly associated with information from other radars or sensors, may lead to increased risks to safe navigation and security-related decisions. Such false and inaccurate information can arise from antenna side lobes, time side lobes, Doppler side lobes, ghost targets (multiple reflections), range ambiguous returns and inappropriate data processing. Appropriate assessment of data integrity and accuracy from the radar sensor(s) is a vital requirement arising from the overall VTS solution.

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

## Definitions and clarifications

### Definitions

For general terms used throughout this annex refer to:

IEEE Std 686-1997 IEEE Standard Radar Definitions.

Specific terms are defined as follows:

**Azimuth (Antenna) Side Lobes** - antenna responses (in azimuth) outside the intended radiation beam. Weighting of the illumination function allows a significant reduction of these lobes, but some response outside the intended direction is unavoidable, normally presenting an irregular pattern with "peaks" and "nulls". The side lobes may produce responses from targets in unwanted directions, allowing disturbing signals (intentional or not) to enter the receiver, and in addition makes the radar detectable by receivers which are not illuminated by the main beam.

**Availability** is the probability that a system will perform its specified function when required.

**Blind Spots** – typically resulting from either blind range (the Range corresponding to an echo delay of one or more PRIs: the echo then arrives at the receiver while the radar is transmitting a new pulse and the receiver is blanked) or Blind speed (target speeds which produce Doppler shift which are integer multiples of the radar PRF, which are therefore aliased to zero Doppler and cancelled by the clutter rejection filtering). **Blind spots** can also arise behind significant obstructions in the field of view (buildings, land masses, oil tankers)

**Chirp** - frequency modulation of the carrier frequency applied within the radar pulse to increase its bandwidth and therefore the range resolution (see also pulse compression)

**Coherence** - capability of a system to keep a stable phase reference during the target illumination time in order to properly exploit the received phase information for MTI, pulse Doppler processing or other purposes

**Doppler** - shift in frequency of a wave due to the relative motion between the transmitter and the receiver. Frequency shift is relative target velocity/wavelength. Radar echoes are shifted twice this value because this shift must be accounted for in both the forward and the return path.

**Doppler Side Lobes** - when using Doppler processing (or MTI) the integrated ideal pulse always presents a response outside the integration peak (across all Doppler filters) known as Doppler side lobes. Their main effect is to limit the capability to discriminate weak returns in proximity of strong returns (with side lobes of the same order of magnitude as the primary response of the weak return).

**FMCW - Frequency Modulation - Continuous Wave** - A type of radar where a continuous wave instead of pulse is transmitted. The range information is derived by frequency modulating the carrier with a saw tooth waveform and comparing the echo FM modulation envelope with the reference

**Ghost Targets (Ghost Echoes)** – undesirable radar echoes resulting from a number of sources. For example multipath related wave reflections caused by large structures or surface reflections, time sidelobes, antenna azimuth sidelobes, and Doppler sidelobes.

**Interference rejection** - this function is included to seek to reduce or eliminate interference received from transmitters utilising the same or nearby frequencies. One common technique is to compare adjacent range cells in the present "live" video signal with the video signal from the previous sweep. The output video signal to the display device is inhibited should the comparison indicate the presence of interference.

**Normal weather and propagation conditions** are the conditions not exceeded 99% to 99.9 % of the time as defined by the individual VTS authority. The rest of the time is considered having **adverse weather and propagation conditions**.

**Plot extraction –** the process of determining the likely target related radar returns from the radar video signal. This typically consists of comparing the video voltage level with a threshold which can be (dynamically) adapted to local background noise and clutter conditions.

**Polarisation** of a radar signal is determined by the orientation of the electrical field. In the case of **circular polarisation** the field rotates left or right.

**Pulse** – typically a pulse (modulated in the case of pulse compression radar) of RF energy transmitted from the radar

**Pulse Compression** – A technique used to achieve a wide pulse bandwidth (and, therefore, enhanced range resolution) using long pulse (for high pulse energy with limited peak power) by introducing an intrapulse modulation (e.g., chirp frequency modulation or Barker discrete phase modulation) and performing a correlation on the received echo.

**Radar** - as referred to in this document relates to all aspects of the radar from sensor through to the presentation of radar information from one or more radar sensors to the VTS operator.

**Radar Cross Section** – an assessment of the cross sectional area presented by a reflector (typically a target or unwanted “clutter”) to the transmitted radar energy. The RCS can vary with frequency and target attitude,

**Radar information** – a generic term potentially referring to the radar picture/video, target data, clutter data, topographical data, navigation aids, SARTs etc.

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

**Radar PFA** – isthe probability of false alarm at the output of a radar, subsequent to plot extraction, but prior to tracking, and presentation. Note, in some systems the boundary of the radar and its achieved PFA complicate this definition – clarification may be required to minimise misunderstanding arising from, for example, noise related threshold crossings vs. unwanted radar energy reflections (unwanted targets, clutter etc.) or side lobe effects (ghost targets).

**Radar Plots** - A likely target report resulting from integration of the received echoes inside the antenna beamwidth. Each target report contains range and bearing information

**Radar video** – a time varying voltage signal proportional to the sum of the RF signals being received and the RF noise inherent in the receiver itself. Traditionally, radar video is an analogue signal with associated azimuth reference information. Recently, radar systems have become available which provide equivalent data in proprietary digital format.

**Radar tracks** - A target report resulting from the correlation, by a special algorithm (tracking) of a succession of radar reported positions (radar plots) for one object. The report normally contains filtered position and speed vector information.

**Range ambiguous returns** – the measured range of a target typically assumes that the target true range is less than the first range ambiguity (the Range corresponding to an echo delay of one PRI) whereas large targets beyond this range can be detected but typically with (incorrect) ambiguous range measurement. Techniques exist for the resolution of range ambiguity if required. See also blind spots above.

**Range Side lobes –** see time side lobes (below)

**Reliability** - the probability that a system, when it is available performs a specified function without failure under given conditions for a given period of time.

**Sea characteristics** – often described by sea state but additional parameters can also be of interest. Sea characteristics include wave/swell height, direction and speed of waves/swell, distance between waves/swell, salinity etc.

**Standard Atmospheric Condition** - The International Commission of Air Navigation (ICAN) uses a definition for a standard atmosphere, defining temperature and pressure relative to the height. In the troposphere (0 meters to 11,000 meters), the temperature is defined to be 15 °C at the surface and changing -6.5 °C/km.

**Squint** - the potential angular difference between the beam pointing direction at different transmission frequencies. When present, this effect is measured and calibrated during radar sensor commissioning.

**Target fluctuations** – (also known as Glint or Swerling characteristic) - Fluctuation of a target radar cross section (RCS) (and, therefore, of the received echo amplitude) due to changes in the target attitude and illuminating frequency. For complex targets (consisting of a number of reflecting surfaces), RCS is normally strongly dependent on the angle of observation

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

**Time Side Lobes** - when using pulse compression the correlated pulse always presents responses outside the correlation peak (before and after it) known as time (or range) side lobes. Their main effect is to limit the capability to discriminate weak returns in proximity of strong returns (with side lobes of the same order of magnitude as the primary response of the weak return).

### IALA target types for range coverage modelling

For calculation purposes, the IALA simplified target types are defined in Table 2‑1.

Typical targets of interest are modelled as point targets with conservative estimate of Radar Cross Section and height. This is normally sufficient for estimation of detection range for consideration in VTS radar sensor coverage. However, further considerations are required for the overall design of radar systems as discussed later in this annex.

Advice on radar performance estimation, including concerns regarding fluctuations are also discussed later in this annex.

Table 2‑1 IALA target types



### References

|  |  |  |
| --- | --- | --- |
| [1] | IEEE Std 686-1997 | IEEE Standard Radar Definitions |
| [2] | Merrill I Skolnik | Introduction to Radar Systems, McGraw-Hill Higher Education, ISBN 0-07-290980-3 |
| [3] | P.D.L. Williams, H.D, Cramp and Kay Curtis | Experimental study of the radar cross section of maritime targets, ELECTRONIC CIRCUITS AND SYSTEMS, July 1978. Vol. 2. No 4. |
| [4] | Ingo Harre | RCS in Radar Range Calculations for Maritime Targets. <http://www.mar-it.de/Radar/RCS/RCS_18.pdf> |
| [5] | IMO | Performance Standards for radar reflectors (latest edition) |
| [6] | International Telecommunications Union (ITU) | ITU-R SM.1541 Unwanted emissions in the out-of-band domain |
| [7] | International Telecommunications Union (ITU) | ITU-R SM.329-9 Spurious emissions |
| [8] | The International Organisation for Standardisation( ISO) | ISO 8729 Ships and marine technology – Marine radar reflectors |
| [9] | IALA | IALA 1056 Guideline for VTS radar service |
| [9] | ICAN | Std Atmosphere |

### Software tools

|  |  |
| --- | --- |
| CARPET | Computer Aided Radar Performance Tool  TNO (Toegepast Natuurkundig Onderzoek) Physics and Electronics Laboratory, P.O. Box 96864, 2509 JG The Hague, Netherlands, <http://www.tno.nl> |
| AREPS | Advanced Refractive Effects Prediction System  Space and Naval Warfare Systems Center, San Diego, <http://sunspot.spawar.navy.mil>. |

The use of off-the-shelf performance tools for assessment of the latest radar sensors employing complex multiple pulse waveforms may require specialist assistance to obtain appropriate and valid performance predictions.

## Radar System solutions

The radar coverage required for a VTS application may consist of multiple radar sensors either co-located or distributed to optimise availability, radar data integrity, security constraints and equipment access considerations. With this in mind, there are a number of design decisions regarding the cost, complexity, location and detailed design of the radar sensors within a VTS.

In addition, there are design decisions and trade-offs to be considered for each radar sensor. These might include magnetron vs. solid state, transmission power, antenna size, receiver technology, signal processing and waveform design, all of which need to be considered together in the specifications of each radar sensor within the VTS network. This detailed assessment of radar design should not be undertaken by the VTS authority.

Therefore, the VTS Authority should keep options open, avoiding detailed technical specifications, and requiring that VTS vendors propose solutions to meet the specified operational and functional requirements based on the recommendations in this document.

## Radar types

VTS radars could be of the following types:

* Pulse Radar (usually Magnetron based)
* Pulse Compression radar (usually Solid State)
* Frequency Modulated Continuous Wave, FMCW (usually Solid State)

A general explanation of each radar type will follow.

### Pulse Radar

A pulse radar typically transmits high peak power RF pulses (10 to 50 kilowatt) for very short duration (50 to 1000 nano seconds). The transmission is made with a pulse repetition frequency (PRF) of typically 1000 to 4000 pulses per second. Upon reception, the returned signal is amplified, demodulated and processed.

Main characteristics include:

* It is a well known and proven technology
* Increased pulse duration translates into longer-range detection, but poorer range resolution and less ability to penetrate adverse weather conditions.
* Normally with fixed transmission frequency(ies)
* May require wide frequency band allocation for compatibility with adjacent equipment

Additional challenges include:

* The need to reduce out of band transmissions. Note that ITU requirements for shipborne radar are less stringent than for land based radar.

### Pulse Compression radar

A pulse compression radar transmits low peak power modulated chirps (typically up to 200 watts and eventually higher) with a typical pulse duration of up to 100 micro seconds. The transmission is made with a chirp repetition frequency of typically 1000 to 20000 chirps per second. Upon reception, the returned signal is amplified, pulse-compressed and processed

The energy in the chirp of a pulse compression radar is comparable to the energy emitted in a pulse from a magnetron radar, The longer chirps are converted into short pulses upon reception by the process of pulse compression, therefore high range resolution can be maintained at all ranges.

Main characteristics include:

* It is based on well known and proven principles, but the high power at high frequency solid state amplifier technology relies on recent developments
* No need for magnetron replacement due to solid state power amplifier, reducing the need for periodic maintenance.
* Increased ability to penetrate adverse weather conditions facilitating smaller target detection
* Transmission frequencies can be programmed, which adds flexibility
* Cleaner spectrum than magnetron radars, which means fewer emissions outside the allocated frequency band(s)

Additional challenges include:

* The need for sophisticated interference rejection due to the longer chirps transmitted
* The need for simultaneous short and long range detection increases complexity
* High power solid state amplifiers operate with large currents therefore requiring careful design to obtain high reliability
* By nature the pulse compression radar creates so-called time side lobes. Avoiding such side lobes, requires sophisticated techniques, alternatively side lobes suppression may imply reduced detection of small targets in the vicinity of larger targets

### Frequency Modulated Continuous Wave

Frequency modulated continuous wave radar transmits low peak power continuous wave forms (typically up to 50 watts). The waveforms are repeated with a typical rate of 500 to 2000 per second. Upon reception, the returned signal is amplified, compressed and processed

The energy in a frequency modulated continuous wave radar is comparable to the energy emitted in a pulse from a magnetron radar, The waveforms are converted into pulses upon reception, therefore high range resolution can be maintained at all ranges.

Main characteristics include:

* It is based on well known and proven principles
* No need for magnetron replacement due to solid state power amplifier, reducing the need for periodic maintenance.
* The ability to detect from very short range
* Transmission frequencies can be programmed, which adds flexibility
* Cleaner spectrum than magnetron radars, which means fewer emissions outside the allocated frequency band(s)

Additional challenges include:

* Dynamic limitations restrict the ability to handle small and large targets simultaneously. This also affects long range detection
* Target revisit rate is low compared to typical VTS target kinematics
* The need for sophisticated interference rejection, even more than for pulse compression radars
* By nature FMCW creates so-called time side lobes. Suppressing the side lobes may imply reduced detection of small targets in the vicinity of larger targets
* More complicated antenna system, 2 antennas or complicated antenna feed.

## Antennas

The selection of antenna parameters (height, gain, side lobes, rotation rate, polarisation etc.) for a given installation is integral to the resulting radar performance and VTS authorities are advised to avoid specifying detailed antenna parameters in favour of identifying operational needs such as coverage area requirements (based on risk assessments), track update rates (based on tracker design and typical target manoeuvres in high density areas), range performance, overlapping and redundant coverage. The identified operational needs will allow the radar designer some flexibility to achieve the best solution within the constraints of cost and location options.

### Antenna Principles

Typically, the VTS radar design includes an antenna which provides a narrow beam in azimuth and a wide beam in elevation. Thus, the VTS antenna is not designed to measure the target elevation (from which target height might be determined) or to separate targets on the basis of elevation angle difference.

The installed antenna height is determined based on avoidance of physical obstructions, and the compromise between the need for close range visibility vs long range performance. (see also section 2.7.1.1)

The radar designer, in his selection of antenna characteristics, needs to optimise the compromise between antenna size (and cost), track update rate, integration time on target (related to rotation rate and azimuth beamwidth and contributing to target detection range) and azimuth target separation and accuracy. In addition, the choice of transmission frequency influences the size vs beamwidth compromise.

In the future (post 2012), there is the possibility that flat face electronic scanning antennas may be introduced to the VTS market. These have advantages in terms of no rotating parts, flexible beam management, no lost time or energy looking over land and the possibility to focus attention (and radar detection time) to enhance detection performance and update rate dynamically to improve radar data in some key directions. Note this antenna technology may also have disadvantages in terms of cost and perceived complexity.

### Antenna side lobes

The antenna designer uses an amplitude weighting function to control the azimuth side lobe levels to a level which recognises the requirements for close in (<10 degrees form the main lobe peak) azimuth side lobes and the requirements for side lobes beyond this region. Side lobes are specified as a ratio (in dB) relative to the antenna beam peak.

The antenna gain defined from a specific point in the radar system is specified as a ratio above “isotropic” (dB or dBi) and can be increased by increasing the physical size of the antenna although this will also reduce the beamwidth.

Elevation side lobes are not typically specified for VTS antennas. They are unlikely to be a major contributor to the performance of the VTS radar system.

### Antenna robustness

The installation of a radar can introduce problems resulting from high winds. In some cases it may be appropriate to separately specify both the survival wind limits and a lower operational wind limit within which the system shall not be degraded due to the normal weather conditions specified for that location. High winds can affect the motor and gearbox design and can affect the instantaneous rotation rate at varying angles to the predominant wind direction. The build-up of ice in some climates should also be a consideration.

In extreme conditions, it may be appropriate to house the rotating radar antenna within a static radome although this can increase costs and RF losses and complicate maintenance of some components.

### Antenna accessibility

When siting a radar, the accessibility should be carefully considered – for example an access ladder and maintenance platform may be required to ease maintenance on a tower or tall building.

### Choice of Upmast vs Downmast Transceivers

The radar designer may also have a choice of whether to locate the transceiver upmast or downmast. In the latter case, a waveguide run may be required to link the RF output / input of the transceiver to the antenna. Such a run of waveguide will introduce losses which should be considered as a part of the evaluation of the predicted performance of a given radar installation. Conversely, an upmast transceiver installation may be more difficult to access for maintenance and servicing than a downmast transceiver which might also benefit from an environmentally controlled location.

Further issues might include the need to transfer high bandwidth video (on copper or fibre or microwave link etc) which can influence the radar designer’s selection of whether to use an upmast or downmast transceiver.

## Characteristics of Radar Targets

VTS radar targets are defined by their height above sea level, their speed and manoeuvrability, their polarisation characteristics, their radar cross section (RCS) and the fluctuations in RCS.

### Radar Cross Section

A target may be observed when transmitted radio energy is reflected back from the target to the receiver. The amount of energy reflected is directly proportional to the radar cross section of the target.

The RCS is defined as the ratio between the power [in W] scattered by the target back towards the radar receiver and the power density [in W/m2] hitting the target. Thus RCS is measured in m2 and has the dimensions of area.

**Note:** There is no simple relationship between the physical size of the target and the RCS. The reflected energy depends on several factors, such as the radar operating frequency or frequencies, the angle of incidence of the radio waves, target speed, material and geometry.

The RCS of a target will fluctuate as a result of target movements, frequency and environmental effects with consequences on the detection and presentation of the target.

### Polarisation

Radio waves are polarised and objects will often reflect differently for the polarisation used. This can be utilised by radar system designers, where rules of thumb are that:

* Target returns from linear polarisation, (horizontal or vertical) in general will be stronger than returns from circular polarisation
* Normally linear polarisation (horizontal or vertical) will result in substantially higher rain clutter returns than circular polarisation.
* Normally vertical or circular polarisation will result in higher sea clutter returns than horizontal polarisation, especially for lower sea states.
* Non-metallic and natural objects, such as human beings will return linear polarised radio waves much better than circular polarised radio waves.
* Most radar reflectors will be poor reflectors for circular polarised radio waves.
* Distant ships with vertical masts tend to give the strongest return for vertical polarisation, whereas the opposite tends to be the case for modern ship designs without tall masts.

In summary complex designs are possible in which operators may select the polarisation. However, this adds to equipment costs and adds to the VTS operator workload – the resulting performance benefits are unlikely to justify this complexity.

In general the best cost/performance combined with ease of operation is achieved by horizontal polarisation. Circular or switchable may however be appropriate to achieve acceptable performance for operation in areas with extreme (tropical) rainfall.

### Complex target models

The point target characteristics in Table 2‑1 will normally be sufficient for range calculation of specific targets of interest in VTS.

However, the design of a radar system shall consider the overall characteristics of all objects within coverage range of the individual radar and Table 2‑2 provides an overview of such characterises for targets, typically of interest to VTS radar. Data is primarily based on reference [3] and [4], supplemented by data obtained from the experiences of IALA VTS committee members.

Table 2‑2 Typical target characteristics.

| Target | | Typical characteristics at X-band | | |
| --- | --- | --- | --- | --- |
| RCS | Height | Fluctuations etc. |
| A | Aids to Navigation without radar reflector. | Up to 1 m2 | 1 to 4 m ASL | Rapidly fluctuating, highly dependent on sea characteristics. Polarisation characteristics will often vary depending on wind. |
| B | Aids to Navigation with radar reflector. | 10 – 100 m2 | Rapidly fluctuating, wind and currents may tilt to blind angles and lobing may cause reflectors to be in blind spots. Most radar reflectors will be poor radar targets in case of circular polarisation |
| C | Small open boat, fibreglass, wood or rubber with outboard motor and at least 2 persons onboard, small speedboat, small fishing vessels or small sailing boats. | 0.5 – 5 m2 | 0.5 to 1 m ASL | Rapidly fluctuating may be hidden behind waves up to 50 % of the time.  Slow moving targets tend to lie lower in the water than fast moving ones and therefore RCS visible to the radar tends to increase with speed.  Humans and non-metallic targets will give poor radar return in case of circular polarisation |
| D | Inshore fishing vessels, sailing boats and speedboats, equipped with radar reflector of good quality. | 3 – 10 m2 | 1 to 2 m ASL | Rapidly fluctuating. |
| E | Small metal ships, fishing vessels, patrol vessels and other similar vessels. | 10 – 100 m2 | 2 to 4 m ASL | Moderately fluctuating. |
| F | Coasters and other similar vessels. | 100 – 1000 m2 | 6 to 10 m ASL | RCS is highly dependent on aspect angle of the individual vessel. Rate of fluctuations is typically moderate. |
| G | Large coasters, Bulk carriers, cargo ships and other similar vessels. | 1000 – 10,000 m2 | 10 to 25 m ASL |
| H | Container carriers, tankers and other similar vessels. | 10,000 – 2,000,000 m2 | 15 to 40 m ASL |
| I | Buildings, cranes. Stacks of containers and other large structures. | Up to 1,000,000 m2 | Depends on site | Insignificant. |
| J | Floating items, oil drums and other similar items. Birds, floating or flying. | Up to 1 m2 | 0 to 0.5 m ASL | Rapidly fluctuating, highly dependent on sea characteristics. |
| K | Flocks of birds. | Up to 3 m2 | Sea level and up | Rapidly fluctuating, flight paths tend to be characteristic of given species in given areas of interest. |
| L | Jet Skis and other personal water craft | Up to 0.5 m2 | 0 to 1 m ASL | Rapidly fluctuating but virtually independent of aspect angle |
| M | Wind turbines (onshore and offshore) | Up to 1,000,000 m2 |  | Fluctuations for towers are insignificant. Rotating parts give a wide spectrum of Doppler shifts with RCS up to hundreds of m2 |

Note: Modern warship design seeks to minimise RCS and as a result the above figures cannot be related to such vessels.

RCS on targets using S-band is typically 40 % of the RCS in X-band except for small non-metallic targets where difference between the 2 bands can be much higher.

To determine RCS on targets using other radar bands, such as Ka and Ku the standard radar textbooks should be consulted to scale from the X-band figures in tables 2-1 and 2-2.

### Target speed and manoeuvrability

When assessing the requirements for both the tracking function and the radar sensor, the VTS Integrator needs to understand the range of target speeds and manoeuvres that might reasonably be expected and, where appropriate, any particular coverage areas in the VTS where extreme manoeuvres are most likely to occur. The VTS Authority should ensure that the range of target speeds and manoeuvres is specified as part of the operational needs.

## Operational Requirements

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

The operational requirements may be determined by:

1. Definition of the radar coverage of the VTS area, based on possible radar location(s), the navigation characteristics, and the subdivision into requirements for Basic, Standard and/or Advanced capability derived from the assessment of risks (as described in Annex 1).
2. Definition of targets to be detected
3. Determination of environmental capabilities and constraints
4. Determination of other influencing factors, radar location(s), obstructions
5. Definition of targets detection requirements in weather and propagation conditions normal for the VTS area.
6. Definition of radar dynamic capabilities and constraints

This might be an interactive task involving iterations including evaluation of achievable performance versus overall system cost. It might for example be better to start with simpler solutions, meeting the available budget, than to be left without any radar coverage.

### The area

The VTS area should be subdivided into requirements for Basic, Standard and/or Advanced capability as discussed in ANNEX 1, paragraph 1.3.2 and the need for radar and other sensors coverage shall be defined on the basis of a risk assessment.

The selected location of radar(s) and their height should ensure that the desired coverage requirements are met.

#### Antenna height

The figures below illustrate how the height of the antenna above the water line affects the maximum and minimum detection range performance.

Careful consideration should be given to optimise radar location(s) and antenna height(s) to ensure appropriate coverage of the VTS area.



Figure 2‑1 Target range and visibility

### Targets to be detected

The radar in a VTS should be capable of detecting and tracking all types of surface objects defined by the VTS authority in weather conditions normal for the individual site.

Table 2‑3 lists the IALA target types to be detected for Basic, Standard and advanced Capability. Refer to Table 2‑1 for IALA target definitions. Obviously, smaller targets at close range are detectable by radars in any of the 3 categories, but table 2-3 indicates the minimum requirement.

Table 2‑3 Targets to be detected



In addition any special objects of interest should be specified separately.

### Determination of environmental capabilities and constraints

The environmental conditions of the VTS area should be described, including the annual cycle. This should include conditions to be expected as normal over a 12-month period as well as extreme events.

Restrictions with respect to operation and access to site(s) due to weather should also be included.

It is highlighted that individual assessments for individual VTS sites must be made. A standard set of specifications for environmental requirements cannot be made to cover all VTS installations, and the tables included in this paragraph are only indicative, giving performance obtainable by traditional magnetron radars.

New technology radars may allow for additional performance within economical reach.

#### Precipitation

Information about precipitation over the VTS areas should be obtained from meteorological services, and the VTS authority should define the required radar performance requirements in clear conditions as well as for normal precipitation conditions.

Note that rising coastline tends to increase precipitation over land at some locations, and normal as well as extreme precipitation over sea may therefore differ substantially from precipitation statistics determined for land-based meteorological stations.

Table 2‑4 provides typical precipitation data used in VTS radar specifications. It should be noted that intensities may exceed these values for brief periods of time, but it might not be economically feasible to design for such occasions.

Table 2‑4 Typical precipitation specification levels (rainfall rate) for VTS radar



Note that rainfalls are rare in dry/hot regions, maybe only once or twice per year and the Authority should consider if rain shall be specified at all.

Also note that designing a system to perform in tropical rain showers will typically call for S-band radars. However, the worst rain conditions may only be present for a few hours per year, and reduction in performance on other parameters, may not justify the additional investment.

#### Sea Clutter

Numerous Sea clutter models exist, however, the CARPET models derive the mean sea clutter reflectivity from the clutter model developed by the Georgia Institute of Technology (GIT). The average wave height is derived from the hydro-graphic sea state so that fully developed sea conditions are assumed. The hydrographical sea state scale with the corresponding wind speeds and average wave heights are shown below.

Table 2‑5 Douglas (GIT) Sea state table



This has also been adapted for this recommendation, providing values of the clutter reflectivity under standard propagation conditions for calculation purposes. Note, this mean sea clutter reflectivity is used for performance assessments within the CARPET modelling. Real world experience at a given site may not align with this simplified model.

Table 2‑6 provides typical sea state requirements used in VTS radar specifications, S and X band.

Table 2‑6 Typical sea state specification levels for VTS radar (Douglas Scale)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| IALA Target type | **Basic** | | **Standard** | | **Advanced** | |
| **General** | **Ports and inland waterways** | **General** | **Ports and inland waterways** | **General** | **Ports and inland waterways** |
| 1 | NIL | | NIL | | SS 4 | SS 3 |
| 2 | SS 3 | SS 3 | SS 5 |
| 3 | SS 3 | SS 2 | SS 4 | SS 6 |
| 4 | SS 4 | SS 5 | SS 7 |
| 5 | SS 5 | SS 6 | SS 8 |

### Other influencing factors, obstructions, interference etc.

Obstructions, e.g. topography, buildings and other man made structures may block or reflect radar signals. Other radars and sources of electromagnetic radiation may cause interference.

Inland and harbour VTS will often require special considerations as the number of structures, their density and their close ranges can create very complex distortions. Additional care must be taken to assess and mitigate effects caused by natural and man made structures such as bridges, buildings, river banks, sheet metal pilings, and steep bends.

#### Shadowing effects

Radar detection may be blocked by shadowing effects that, to the extent possible, should be avoided. Such effects include:

* Targets being hidden by larger targets or other obstructions
* Masking of small targets by the effects of range and time side lobes

These effects can be minimised by the appropriate siting of radars and selection of equipment with low side lobes.

#### Multipath effects

The classical radar multipath behaviour associated with air targets and sea surface reflections has limited application and relevance to a system designed for the detection of surface targets. This effect is included within CARPET and, for VTS scenarios, results in shorter detection ranges than might be expected from free- space calculations.

However, multipath conditions resulting from reflections from large buildings and large vessels can still impact on VTS radar performance resulting in the possibility of target signal cancellation or enhancement. This effect is hard to predict and it is unreasonable to expect to model multipath affected performance unless a (potentially expensive) site specific radar model is developed.

In addition, ghost targets can exist. These derive from undesirable radar echoes resulting from multipath related wave reflections caused by large structures, buildings or vessels.

#### Influence from Wind farms

Wind turbines produce large static target-like returns which, from a VTS Operator’s perspective, are normally easy to distinguish from vessel traffic.

The complex return from a wind turbine is made up of two key elements

* The tower and generator housing offering a large static zero-Doppler RCS, in some cases up to 1 million square meters.
* The rotating blades of the turbine offering a complex spread of non-zero-Doppler RCS, typically up to 100 square meters, which will vary with wind direction and speed.

This composite return will be seen as a large static target by a conventional pulse radar, whereas FMCW and coherent radars using Doppler processing will see a complex target spread across the Doppler domain.

The influence, independent of the applied radar technology, will be reflections causing unwanted ghost echoes and suppression of nearby targets. The large RCS may also result in antenna sidelobe returns, resulting in reduced detectability. The symmetrical layout of wind farms may add further to the disturbances.

Solid state radar technology (with or without Doppler processing) using pulse compression techniques may in addition suffer reduced detectability due to time side lobes and disturbing Doppler shifts.

Add illustrations

### Interference

Interference can be split into susceptibility (received interference) and compatibility (transmitted interference).

To minimise interference, separation between wanted and unwanted transmissions has to be optimised – this can be achieved by a combination of frequency separation, physical separation of transmission sites, antenna directionality, sector blanking, separation by time and also by ensuring that all the systems competing for the same or adjacent spectrum do not transmit excessive and unnecessary transmit power levels or transmit time periods. The radar receiver design will typically be very sensitive (to achieve the required performance), although gain control techniques (swept gain or STC) offer further resistance. Waveform designs incorporating staggered PRFs and processing schemes designed to reject known interference patterns can also aid the radar receiver to suppress unwanted returns.

#### Radar susceptibility

In the case of any radar installation, (e.g. a permanent VTS installation of a radar or of each radar in a VTS network), the performance of that radar can be detrimentally affected by received emissions from other radiating sources (physically adjacent VTS radars, maritime shipborne radars, and other users (legitimate or otherwise) of the electromagnetic spectrum. Typically, local legislative regulations and restrictions will control and minimise unwanted received signals but elimination of such signals is likely to be impossible. National spectrum allocation authorities must always be approached by a VTS integrator when considering any changes to a VTS network (radar, microwave link, communications etc.) to enable a holistic view of the changes and how they might affect all users.

The radar design can assist in minimising the susceptibility to unwanted received interference, e.g. by utilising low antenna side lobes, avoiding large reflecting surfaces, minimising receiver front end bandwidth etc.

Note that FMCW and pulse compression radars may typically require larger front end receiver bandwidths than conventional magnetron systems. The multi-pulse waveforms transmitted (and consequently received) by pulse compression radars have to achieve a compromise between pulse chirp bandwidth (related to range cell size and hence range resolution), use of frequency diversity (to optimise performance in clutter), unwanted pulse to pulse interaction etc. vs. spectrum usage and hence unwanted susceptibility with other transmitting spectrum users. FMCW radars transmit and receive (at low levels) for 100% of the time across a swept bandwidth.

#### Radar compatibility with other users

In the case of any radar installation (e.g. a permanent VTS installation of a radar or of each radar in a VTS network), the performance of adjacent systems can be detrimentally affected by transmitted emissions from the radar in question (physically adjacent VTS radars, maritime shipborne radars, and other users (legitimate or otherwise) of the electromagnetic spectrum). Typically local legislative regulations and restrictions will control and minimise unwanted transmitted signals but elimination of the influence of such signals is likely to be impossible. As with susceptibility above, National spectrum allocation authorities must always be approached by a VTS integrator when considering any changes to the RF sub systems within a VTS network.

The radar design can assist in minimising the impact of transmitted signals, for example by utilising low antenna side lobes, avoiding large reflecting surfaces, minimising transmit power, consideration of peak and mean power levels, sector blanking, physical location of the radar etc.

Note that conventional magnetron radars require larger peak power levels than pulse compression and FMCW radar systems. The magnetron technology can result in unnecessary wideband spectral emissions unless steps are taken to include frequency band pass filtering (which has an inherent loss to the wanted signal). However, pulse compression radars and FMCW radars, although utilising lower peak powers, use techniques which may include frequency modulation, pulse to pulse frequency variation, frequency diversity etc. all of which increase the use of the spectrum and increase the chances of unwanted degradation of adjacent systems.

#### VTS radar network considerations

When considering the design of a network of radars, such as that required by some complex VTS locations, radar-to-radar interoperability cannot be ignored. Although the probability of the antennas of two radars pointing directly at each other is likely to be small, the receivers should each be protected against such an event. The more likely case is when one radar antenna is pointing at the other whilst the other is pointing somewhere else – a calculation of the unwanted received power reduced by the selectivity of the own radar antenna (its peak to sidelobe ratio) may not be sufficient to avoid unwanted receiver saturation or at least “blindness”. Consequently, the VTS radar network may need to use frequency separation between the unwanted transmission and the wanted receive signals. This is typically known as frequency planning and a competent radar supplier should be able to offer to undertake a study to identify the impacts and assess the need for a transmission plan to ensure that radar interoperability is possible.

Although pulse compression and FMCW radars are typically wider band, the use of digital frequency synthesis enables these radars to offer multiple, selectable transmission centre frequencies, which support the frequency planning, if needed, and therefore the interoperability of radar systems within a VTS radar network. Magnetron radars are typically tuned in the factory to a single transmission frequency.

### Target Detection requirements

The detection performance of a radar in a VTS should be sufficient to meet the requirement in the individual VTS areas, Basic, Standard and/or Advanced.

The VTS Authority shall ensure that the specified detection performance is achieved. It is strongly advised to consult experts with a sound operational and technical knowledge about the subject.

Factors affecting the detection performance of radar systems including noise, interference, clutter, and propagation shall be taken into account. Special local conditions such as heavy rainfall should be taken into account.

#### Determination of radar coverage

The recommended method for determination of radar coverage and range performance is a combination of site inspections and radar system performance predictions.

The evaluation shall include:

* Calculation of range detection performance, focused on the smallest targets of interest in poor weather conditions. All applicable losses must be included in calculations.
* Evaluation of the effects from propagation conditions and obstructions.
* An evaluation of dynamic requirements.

The calculations may be supplemented by comparison and/or validation test.

It will typically not be possible to encounter all combinations of variables, and calculations are therefore made on the basis of a simplified model of the targets and the environment based on statistical information. It is important to understand the limitations and tolerances this entails.

#### Probability of detection and probability of false alarm

The probability of detection and false alarm rates used for calculations should comply with that required to meet the operational performance required.

At specified maximum coverage ranges, the single scan probability of detection values for VTS will typically lie in the range from 0.7 to 0.9.

It is normally desirable not to have noise and clutter spikes presented to the operator in each scan. Therefore, optimal false alarm rates for VTS applications normally lie in the range from 10-4 to 10-5 for the radar video display. The false alarms taken into account in the calculations should include unwanted information from noise and clutter, as presented to the operator or to the tracker (after signal processing), but not signals from other unwanted objects.

Different values may apply for the tracking, on condition that the tracking requirements are meet.

### Calculation of radar detection performance

The achievable target detection range is highly dependant on several factors including antenna height, target characteristics, weather and atmospheric propagation conditions. In the design of radar systems it is furthermore very important not only to focus on maximum detection range but also on radar quality at all ranges, the ability to handle clutter, the ability to suppress interferences and the ability to simultaneous handling of defined (small and large) targets in the VTS area covered by radar.

Calculation for magnetron radars can be performed by the CARPET program from TNO. CARPET may not be sufficient for determination of performance for pulse compression and magnetron radars, where it may be necessary to rely on vendor furnished information, possibly supported by performance tests.

**Warning:** The cumulative detection stated by CARPET can be very misleading if used for determination of VTS detection performance.

The below table includes **typical examples** of detection and tracking ranges for X-band magnetron based radar systems for Basic, Standard and Advanced, in standard atmospheric conditions.

Table 2‑7 Typical range performance for X-band magnetron radars

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna elevation | IALA Target type | **Basic** | | **Standard** | | **Advanced** | |
| **Clear** | **2 mm/h rain** | **Clear** | **4 mm/h rain** | **Clear** | **10 mm/h rain** |
| 20 m ASL | 1 | NIL | | NIL | | 5 NM | NIL |
| 2 | 7 NM | 4NM | 7 NM | 6 NM |
| 3 | 7 NM | 4 NM | 8 NM | 5NM | 9 NM | 7 NM |
| 4 | 9 NM | 8 NM | 11 NM | 9NM | 12 NM | 10 NM |
| 5 | 12 NM | 10 NM | 13 NM | 11 NM | 14 NM | 13 NM |
| 50 m ASL | 1 | NIL | | NIL | | 10 NM | NIL |
| 2 | 10 NM | 7 NM | 12 NM | 9 NM |
| 3 | 10 NM | 6 NM | 12 NM | 8 NM | 14 NM | 12 NM |
| 4 | 13 NM | 12 NM | 15 NM | 13 NM | 17 NM | 15 NM |
| 5 | 16 NM | 15 NM | 18 NM | 17 NM | 20 NM | 18 NM |
| 100 m ASL | 1 | N/A | | NIL | | 12 NM | NIL |
| 2 | 13 NM | 5 NM | 16 NM | 10 NM |
| 3 | 17 NM | 10 NM | 18 NM | 16 NM |
| 4 | 20 NM | 19 NM | 22 NM | 20 NM |
| 5 | 23 NM | 22 NM | 25 NM | 23 NM |

It is normally sufficient to calculate detection range for small and medium size targets, therefore IALA targets type 6 and 7 are not included in the table.

The influences from sea clutter increases substantially and high elevated antennas are not applicable for Basic.

It should be noted that radar performance predictions are indications and not guarantees of real world performance. There are many variables within a CARPET-based prediction that can only be considered to be approximations of target, radar and environment behaviour.

The below table includes **typical examples** of detection and tracking ranges for S-band magnetron based radar systems for Standard and advanced, in standard atmospheric conditions.

Table 2‑8 Typical range performance for S-Band magnetron radars

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna elevation** | **IALA Target type** | **Standard** | | **Advanced** | |
| **Clear** | **?? mm/h rain** | **Clear** | **16 mm/h rain** |
| **20 m ASL** | 3 | 4 NM |  |  |  |
| 4 | 7 NM |  |  |  |
| 5 | 10 NM |  |  |  |
| **50 m ASL** | 3 | 7 NM |  |  |  |
| 4 | 11 NM |  |  |  |
| 5 | 14 NM |  |  |  |
| **100 m ASL** | 3 | 10 NM |  |  |  |
| 4 | 14 NM |  |  |  |
| 5 | 18 NM |  |  |  |

It should be noted that radar performance predictions are indications and not guarantees of real world performance. There are many variables within a CARPET-based prediction that can only be considered to be approximations of target, radar and environment behaviour.

Use of radar prediction models requires full understanding of their validity and limitations which may preclude their use at some frequencies.

### Influence from propagation

The performance of surface based radar systems is strongly influenced by the electromagnetic properties of the atmosphere and the surface of the Earth. In free space, electromagnetic waves propagate in straight lines from the antenna toward the targets and back. However, radars located near the Earth’s surface must deal with, and adjust to the diffraction and refraction of the propagating wave.

Performance should, in all cases, be evaluated assuming Standard Atmospheric Conditions, combined with precipitation and sea state information for the individual location. Evaluation of the effects from adverse propagation should in addition be included for hot, dry areas of the world, e.g. the Arab Gulf.

#### Propagation in the Standard Atmosphere

An electromagnetic wave observed at a target consists of a summation of an infinite number of contributions from different paths to the target leading to constructive and destructive contributions at the target. The return path suffers from similar effects. For small low targets this results in shorter detection ranges, than the distance calculated by simple line of sight calculations.

In addition, the barometric pressure and water vapour content of the standard atmosphere decreases rapidly with height, and the temperature decreases slowly with height. This causes the electromagnetic waves to bend a little towards the Earth’s curvature.

Radar parameters, losses in transmission lines (not only waveguide), processing losses, clutter and precipitation add to the complexity and, even for the Standard Atmosphere, it is necessary to combine this with propagation factors by radar calculation tools in order to determine the predicted performance for a VTS radar sensor. This is typically modelled by increasing the radius of the Earth by a multiplier (1.33) and assuming straight line propagation.

#### Sub-refraction and Super-refraction

Sub-refraction, bending the electromagnetic waves up, and super-refraction, bending the electromagnetic waves down, exists when the atmosphere deviates from the standard.

Sub-refraction can be caused by fast reduction of temperature and slower reduction of water vapour content with height, bending the electromagnetic waves towards space. However, this phenomenon occurs rarely in nature.

Super-refraction (can be caused by temperature increase with height (generally by temperature inversion) and/or rapid decrease of water vapour with height, decreasing N. Decreasing the refractivity gradient will eventually cause it to reach the critical gradient, at which point an electromagnetic wave will travel parallel to the Earth’s curvature.

#### Ducts and Trapping Layers

Super-refraction will develop into trapping layers, if the refractivity gradient decreases beyond the critical gradient, at which point the electromagnetic wave will be trapped and follow the Earth’s curvature.

Ducts act like waveguides for propagating waves bordered by trapping layers or the Earth’s surface. To couple into and remain in a duct the angle of incidence must be small typically less than 1°.

Ducting can be categorized into three main types:

* Evaporation duct:
  + Weak, caused by evaporation from the sea surface, and only at low levels (maximum of 40 meter ASL).
  + Generally increasing the radar horizon, especially for low mounted antennas.
* Surface-based duct:
  + Surface ducts caused by low level inversion (increase of temperature /decrease of humidity with height), up to 500 meters ASL.
  + Increase of radar range, depending on duct and antenna height.
* Elevated duct:
  + 0.2-2 km above the surface
  + Typical no effect on surface-based antennas.

The effects are typically increased range but also increased amounts of noise and 2nd / multiple time around returns which may appear as false radar returns..

Notice that the electromagnetic waves are refracted (bent) and not reflected by the trapping layers.

##### Evaporation Ducts

Evaporation ducts exist over the ocean to some degree, almost all the time. A change in the moisture distribution without an accompanying temperature change will lead to a trapping refractivity gradient. The air in contact with the ocean surface is saturated with water vapour, creating a pressure that is decreasing to some value above the surface.

This will cause a steep refractivity gradient (trapping) near the surface, but gradually equalise towards normal refractivity gradient at a certain height, which is defined as the evaporation duct height.

Evaporation ducts are generally increasing the radar detection range and the antenna can be located above the duct and still have extended propagation strength.

For typical coastal radar installations, evaporation duct heights of 6 – 15 meters lead to the longest detection ranges. Evaporation duct heights of more than 10 meters will also introduce an increased amount of clutter, setting additional demands to clutter processing and noise reduction capabilities.

I.e. investigations of weather data from the Arab Gulf area show that evaporation ducts exist all the time with typical duct heights of 5 to 25 meters, resulting in increased radar range in 80% of the time and increased clutter in 50% of the time.



Figure 2‑2 Coverage diagram, in normal atmosphere (left) and including an evaporation duct (right).

##### Surface-based Duct

Surface based ducts can be much stronger than evaporation ducts. They occur when the air aloft is hot (and dry) compared to the air at the Earth’s surface. Over the ocean and near land masses, dry continental air may be advected over the cooler water surface; either directly from leeward side of continental land masses or by circulation associated with sea-breeze.



Figure 2‑3 Example of simulated radar coverage in surface based + evaporation ducting conditions.

In addition to the temperature inversion, moisture is added to the cool marine air by evaporation, increasing the trapping gradient. In costal areas, this leads to surface trapping ducts. However, away from land, this trapping layer may well rise from the surface thereby creating an elevated duct.

The electromagnetic wave will be refracted towards the surface of the Earth and be trapped in the duct like in a waveguide. This kind of trapping condition greatly increases the surface detection range - and the amount of noise received. Note that surface detection may occur far beyond the radar horizon with a “dead zone” in between.

Surface based ducts are often combined with evaporation ducts and examples of radar performance in such conditions, as illustrated by Figure 2‑3.

##### Elevated Duct

Generally, elevated ducts occur from descending, compressed and thereby heated air, from anticyclones, approaching the marine boundary layer and causing ducts. Elevated ducts may also occur from elevating surface-based ducts.

Surface detection might also occur in this case far beyond the radar horizon with a “dead zone” in between, adding noise to the radar image.



Figure 2‑4 Coverage diagram, elevated duct

##### Severe ducting at coastlines adjacent to hot flat deserts

The large temperature variation between night and day in desert areas and the associated pressure differences between land and sea tend to cause very strong temperature inversion during night time and result in strong sea breeze in the afternoons. This can result in very severe ducts. This type of duct can be very low, as little as 15 meters has been experienced

Range performance is very different for an antenna positioned inside or above these ducts, and radar systems with an antenna positioned within such a duct will have substantial increase in the detection range for surface targets. If the antenna is positioned above the trapping layer (outside the duct), the electromagnetic wave will be refracted and the detection range for surface targets will be substantially reduced.

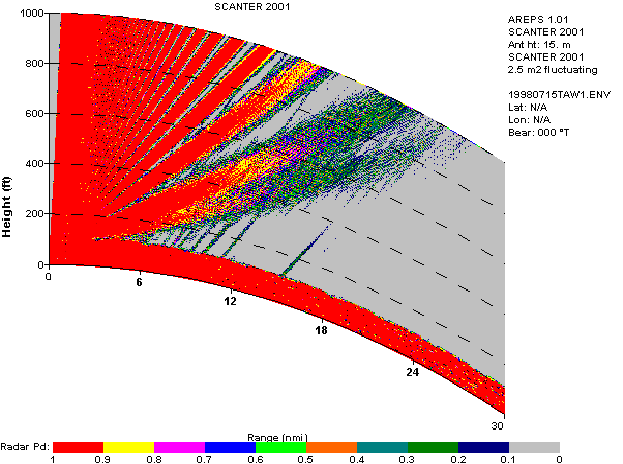
 

Figure 2‑5 Coverage diagram based on a measured condition at a coastlines adjacent to hot flat deserts. The radar detection using antennas positioned inside the duct (left) and above the duct (right) corresponded to the simulated coverage diagram.

The sea breeze also cause eddies over the sea, forming distinctive sea clutter patterns. The eddy results in a “snake” like pattern moving forth and back for a few hours in the afternoon on hot days with strong sea breezes (see Figure 2‑6). Of course, this may disturb display and tracking.



Figure 2‑6 One hour of recordings with trials (snail tracks) shown in red.   
The yellow “snake” at sea is an eddy moving forth and back with a speed of app. 4 knots.

### Target separation and target accuracy

Target separation (sometimes referred to as discrimination) requirements and target accuracy requirements should be considered separately.

#### Target separation

In normal weather and propagation conditions, surface objects within the VTS area should be separated in presentation, and individually tracked without track swap, at any applicable target speed when they are positioned apart and with distances as defined by the individual VTS authority.

The system should be designed in such a way that the required radar separations based on risk assessments can be achieved in the identified area(s) covered by the VTS service. At long range, the impact of the height and type of antenna on the resolution performance should be taken into account. The system should also be capable of displaying and tracking all detectable targets of interest simultaneously in normal conditions, preferably without the need for manual adjustments by the operator.

Table 2‑9 provides separation requirements for point targets, suitable for Basic, Standard and Advanced capability. These apply to the separation of two similar sized point targets.

For larger (non-point) targets the definition of separation is highly dependent on physical size, aspect angles, pulse stretch etc. The VTS authority is recommended to express target separation requirements in operational terms rather than radar subsystem parameters.

The special case of offshore installations will normally require target separation equivalent to Basic capabilities, whereas other operational requirements are Advanced.

Table 2‑9 Target Separation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Minimum target physical spacing for separation in display and tracking | | | **Capability** | | | | | |
| **Basic** | | **Standard** | | **Advanced** | |
| **Display** | **Tracking** | **Display** | **Tracking** | **Display** | **Tracking** |
| In range | | Short range applications (<5 nm coverage – include waterways, harbours etc) | 25 m | 40 m | 20 m | 30 m | 15 m | 25 m |
| Long range applications (up to 20 nm coverage – littoral waters, offshore etc) | 75 m | 100m | 60 m | 75 m | 50 m | 60 m |
| Very long range applications (>20 nm coverage) | N/A | | 100 m | 125 m | 80 m | 100 m |
| In azimuth | X-band | Angle between targets as seen from the radar | 1.2o | 1.3o | 0.7o | 0.8o | 0.55o | 0.6o |
| Or distance in metres, whichever is the greater | 25 m | 40 m | 20 m | 30 m | 15 m | 25 m |
| Corresponding –3 dB antenna horizontal beam width | ≤0.7o | | ≤0.45o | | ≤0.4o | |
| S-band | Angle between targets as seen from the radar | N/A | | 3.5o | 4o | 1.8o | 2o |
| Or distance in metres, whichever is the greater | 20 m | 30 m | 15 m | 25 m |
| Corresponding –3 dB antenna horizontal beam width | ≤2o | | ≤1.25o | |

#### Target accuracy

The system should be designed in such a way that the defined radar target accuracy can be achieved in the entire area(s) covered by the VTS service. At long ranges, the impact of the height and type of antenna on the measuring accuracy should be taken into account.

The quantified radar sensor measurement accuracy requirements contribute to the radar measurement noise estima­tion assumptions made in the design of the target tracking function. Therefore, the target tracking requirements contained in Table 9-1 should be used in combination with knowledge of the design of the target tracking function to derive the individual radar sensor measurement accuracy requirements. These radar sensor measurement accuracy requirements also need to consider the plot extraction function and additional errors that this function may introduce.

### Radar dynamic capabilities and constraints

#### Dynamic requirements

The dynamic range of the radar should, in normal weather and propagation conditions, detect and process the surface objects specified by the VTS authority. This should be achieved without significant side lobes, degradation of target appearance, degradation of detection or degradation of separation capability.

The dynamic range is determined by:

* The ratio between the largest nearby objects expected and the smallest distant objects to be detected
* Target return signal fluctuations including multipath

Requirements for the radar(s) can be determined from the characteristics of the objects in the coverage area of the individual radar. Table 2‑2 summarises the characteristics of objects typically considered and the corresponding dynamic range, as a function of RCS and detection range, can be determined from Figure 2‑7



Figure 2‑7 Dynamic characteristics of signal received versus target RCS and target range [nautical miles] for point targets, free space

The figure represents targets in free space. This is normally sufficient for the determination of VTS radar requirements when combined with 10 dB allowance for target fluctuations and lobing.

**Notes:** If more accurate determination than that from the graph in Figure 2‑7 is deemed necessary, this can be performed using performance evaluation tools, combined with evaluations of near range effects.

The off-the-shelf radar performance evaluation tools typically avoid a representation of the receiver dynamic range limitations.

Technology limitations may restrict compliance with the extreme dynamic range that could be derived from fig 2-7. The numbers suggested in the notes in fig. 2-7 are achievable at the time of publication of this document (2012).

#### Side lobes

Side lobe effects can also restrict the achievable dynamic range in the proximity of large returns from targets or clutter.

Antenna, range and Doppler side lobes should be sufficiently low to avoid masking of smaller targets in the proximity of large returns from targets or clutter. In addition, low side lobes minimise the probability of false targets arising from other large returns. Table 2‑10 recommends the maximum allowed signal presented to the display and plot extractor, originating from antenna and range (or time) side lobes.

Table 2‑10 Maximum side lobe level relative to non-saturating target signals

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Recommendation level** | | |
| **Basic** | **Standard** | **Advanced** |
| Maximum near side lobe level, within +/- 10° in azimuth and +/- 250 metres in range from any target | - 50 dB | - 55 dB | - 58 dB |
| Maximum far side lobe level, outside +/- 10° in azimuth and +/- 250 metres in range from any target | - 65 dB | - 68 dB | - 70 dB |

Typically, azimuth (antenna) side lobes are the only contributor in traditional magnetron pulse radars. FMCW and pulse compression radars are subject to range as well as azimuth side lobes. Radars incorporating Doppler or MTI processing are also subject to Doppler side lobes which can limit detectability of smaller targets competing with large clutter, but do offer considerable performance benefits when compared to radars without Doppler or MTI processing. Currently (2012), typical VTS radars do not achieve Doppler side lobe levels which are comparable to the figures in table 2-10 due to cost constraints.

Note that antenna side lobes are attenuated during transmission as well as reception. The level (in dB) presented to the operator will therefore in general be half (in dB) of that specified for the antenna, however, other factors may contribute.

Also note that structures near antennas (in some cases up to 100 meters) tend to distort wave propagation and thereby increase the azimuth side lobe level in the direction of such structures.

## Functional Requirements

The radar service in a VTS should as a minimum support the operational functions specified by ANNEX 9 as well as the functions listed below.

These functions may be hosted by the radar sensors or other parts of the VTS system

### Operational outputs

The output from a radar service should include radar image data and track data. In addition, the output from the radar service may include clutter data to enable identification of, for example; squalls, oil spills, ice detection, wave height, etc.

### Operator functions

Radar functions should be designed and implemented to optimise performance and minimize operator workload to the level practical. Ideally, the operator should only need to control basic functions such as start and stop.

Each radar site should be designed and equipped to reduce the adverse effects of rain and sea clutter and enhance the probability of target detection and it is recommended to make adaptation to changing weather conditions, etc. automatic to reduce operator workload, However, it might be necessary to implement dedicated operational modes e.g. for adaptation to weather.

Manual override of automatic functions should always be possible

### Clutter and noise reduction / Management

Appropriate, clutter reduction or clutter management should be available to meet the performance requirements.

This will typically include:

* White noise suppression
* Interference rejection
* Sea and rain clutter processing
* Adaptation to varying propagation conditions.

The features should preferably be automatic for systems requiring standard or advanced capabilities.

### Elimination of false echoes

The radar should also be designed and installed so as to eliminate, to the maximum extent possible, false echoes caused by side lobes, reflections from nearby structures or second/multiple time around echoes.

### Built-in test features

Built-in test features should include monitoring of functions and performance. Communication of summary alarms and system status to a central monitoring system may be required. It is recommended that detailed BITE results are made accessible for remote monitoring, especially for radars installed in locations that are difficult to access.

### Service access

Service access should be possible at the individual radar location.

A local service display at each radar sensor, providing radar control, BITE results and other specified radar information is recommended.

To the extent practical, service access should be possible remotely, for example, at the central monitoring location for the VTS network.

The following section will be moved to Annex 1, therefore not reviewed at VTS35 WG2

## Radar design, installation and maintenance considerations

### Safety precautions

Rotating machinery

Radiation hazards

Electrical shock

### Access

### Design

Interface, data communication requirements

WG types, length, losses

WG dehumidifiers

Maintenance

**Windload on antennas**

Include short description of turbulence, asymmetrical wind, vertical vind components etc with reference to the descriptions in annex 1.

4.5 Free sight

The diameter of the platform, the height of the fence, the height of the pedestal and the vertical beam width are all factors affecting the free sight. As a rule of thumb use 1.5 times the lower limit of the vertical beam width (see Fig. 4.9) - in this angle there must be free sight. In blanked sectors or directions of low practical importance this rule may be ignored.

Normally the height of the pedestal is variable to achieve free sight.

Also concerning the lightning conductor TERMA recommends to place this in a blanked sector or in a direction of low practical importance. Due to the tiny size of the rod this will normally not have any practical influence on the radar picture.

When the antenna is mounted, ensure that no equipment or material is blocking the antenna’s free rotation before turning on the antenna motor.

5.1 Mounting the waveguide

It is recommended to use a support for at least every 60 cm and for every 40 cm in critical bends. Do not bend the elliptical waveguide more than allowed by a minimum bending radius of 200 mm (E plane) and 400 mm (H plane) and do not twist it more than 3º per meter.

Be careful when the elliptical waveguide is cut. Humidity and foreign bodies (especially copper dust and copper swarfs) inside the waveguide will cause decreased performance.

#### Extreme events

Authorities responsible for VTS areas subject to adverse weather such as cyclones, typhoon, hurricane, and tornado should consider the potential impact and specify requirements to equipment survival. Radar operation is normally suspended in such conditions.

Refer to Annex 1 section 1.4.4 for general precautions

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Refer to ANNEX 13 for verification

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Depending on the services that a VTS is to carry out, the radar coverage can be:

* nil (automatic identification systems, voice communication and reporting only)
* partly (covered areas chosen intentionally with some blind sectors)
* totally by one radar sensor (without any blind sectors)

Large VTS areas and to cover for shadow effects of other vessels, two or multiple radar sensors may be required. Stereographic processing of images from 2 or more radars may also be utilised for elimination of false (ghost) echoes.

The application of other sensors will also depend on the services that a VTS is to carry out

# Automatic Identification System

## Introduction

Class A AIS transponders were introduced by IMO as a mandatory carriage requirement in 2004 and are therefore fitted to all SOLAS vessels. Class B AIS was introduced in 2008 as a voluntary carriage device but that could be implemented as a mandatory regional requirement if local regulations are put in place. For the VTS Authority, Class A Vessels are the primary interest as these will interact with the port and will be users of port services. AIS is typically implemented as part of a VTS in one of two configurations:

* Integrated with Radar
* Standalone, without Radar

The Annex will address the features and functions of AIS as they relate to a VTS Authority and it will therefore focus on the Ship to Shore and Shore to Ship AIS communication.

### Objective of AIS

The VTS objectives of AIS are defined as follows:

* Automatically receive information from an AIS equipped vessels, including the ship’s identity, type, position, course, speed, navigational status and other safety-related information
* Monitor and track AIS equipped vessels
* Exchange data with AIS equipped vessels
* Support value added functions over AIS infrastructure
* Manage AIS based Aids to Navigation (including virtual and synthetic AtoNs).

## Physical Implementation of VTS AIS

### Equipment

A VTS Authority is a shore-based operation and, as such, it cannot use the same physical (mobile) transponder equipment that is for installation on board a vessel. The Physical Equipment options for a VTS Authority are as follows:

* AIS Basestation
* AIS Receiver
* AIS Repeater
* AIS Aid to Navigation (AtoN)

An AIS Basestation is the preferred physical equipment for the implementation of a VTS System. However, for smaller VTS installations in VTS areas of low traffic density and where the reception of just the core AIS information is sufficient, then an AIS Receiver may be considered as sufficient to support the required VTS Operator tasks.

An AIS Repeater may be used to extend the operational area of a VTS system where coverage cannot be achieved by a single unit. This provides a simple means of extending the AIS coverage, however, it must be remembered that repeating messages over the AIS network reduces the overall capacity of the system. Therefore, AIS Repeaters are not recommended for use in areas of high traffic density.

AIS can be an integral part of an Aid to Navigation such that the AtoN position, and other AtoN related data, can be transmitted over the AIS network and received by ships.

### AIS Licensing and Siting

An AIS Basestation will need to be licensed by the appropriate national Radio Communications or Broadcast Authority in most countries. The licensing process will also determine any restrictions regarding the siting of the AIS Basestations and their aerials. Permitted AIS Basestation sites are determined based upon a cellular mapping of all Basestation sites (See section 7 of IALA Recommendation A-124). AIS Cells are 30nm x 30nm square with a limit of two (2) Basestations to each cell. One of the AIS Basestations within a cell is configured to transmit its Fixed Access TDMA (FATDMA) information on one of the AIS VHF frequencies and the other Basestation is configured to transmit its FATDMA information on the other AIS VHF frequency. However, if an adjacent cell has less than 2 Basestations (this can include a cell that is adjacent and inland), then additional Basestations can be included by borrowing the allocation from the adjacent cell. The cell size also means that AIS VHF aerials should not be positioned higher than approximately 35m above sea level.

The limit of two Basestations per cell is to ensure that the number of FATDMA slots is not excessive in any one geographic area. AIS Basestations can transmit their own position so that the port appears on the ECDIS display of incoming vessels. However, the position transmission is repeated in a fixed slot on every AIS net cycle and therefore it is consumes a fixed amount of the AIS bandwidth. If there are too many timeslots allocated for FATDMA it reduces the availability of Random Access TDMA (RATDMA) slots which are used by the AIS transponders on board vessels for their normal position and ID transmissions.

*It should also be noted that if the Basestation does not need to transmit its own position and therefore does not use FATDMA, then the number of Basestations per cell can be increased.*

Every AIS Basestation has an MMSI (Maritime Mobile System Identity). Where a VTS system has multiple AIS Basestations to cover a large VTS Area, each Basestation can be given the same Virtual MMSI so that the whole VTS system appears with a single identity. The MMSI will normally be issued by the appropriate national Radio Communications or Maritime Authority when licensing the use of AIS frequencies.

## Operational requirements

A VTS needs to gather information about the vessel traffic within the VTS area. Vessels need to be identified and monitored as they transit through the VTS area and visit ports. The VTS may use multiple sensors to achieve the necessary data gathering and AIS contributes to this task.

AIS provides timely, relevant and accurate information to VTS Operators to support the compilation of the VTS traffic display. It provides automatic vessel position reports and movement information as it is received at Basestation sites. Where radar is installed as part of the VTS sensor suite, the AIS information should be correlated with the radar target data to ensure that each vessel within the VTS area is represented by a single track on the VTS Traffic Display. AIS also provides supporting information about the ship and its current voyage that may be integrated with other port operations.

The provision of information from the VTS to the mariner is supported by AIS through the use of short text messaging and the binary messages within the AIS protocol. Further value added functions may be implemented using the binary messages subject to functional approval through the IALA Binary message register (www.e-navigation.nl/asm).

The key Operation Requirements relating to AIS are therefore defined as follows:

* Provision of vessel identification and location information to the VTS traffic image
* Provision of vessel manoeuvring and voyage related data to the VTS
* Provision of facilities to enable transmission of information between the VTS to the mariner

## Functional requirements

### Support to the VTS Traffic Image

#### Target Tracking

Automatic Identification System (AIS) provides identification and location information to enable the VTS Operator to monitor and track ships within the VTS Area. AIS transmissions consist of bursts of digital data ‘packets’ from individual stations, according to a pre-determined time sequence. AIS data consists of shipboard information such as position, time, course over ground (COG), speed over ground (SOG), heading, etc.

AIS enhances situational awareness for the VTS by improving the possibility of detecting other ships that are obscured from direct line of sight. As a cooperative means of tracking, the AIS element of a VTS will receive data from any vessels that is equipped with a transponder even in severe sea and rain clutter conditions.

#### Aids to Navigation

In addition, AIS AtoNs (including real, synthetic and virtual AtoNs) will be presented to the VTS Operator through the Traffic image.

#### Extended Coverage

Where the VTS Area extends beyond the coverage of a single AIS Basestation, the preferred approach should be that the VTS Network should extend to enable additional Basestations to be connected such that full coverage is achieved. Where it is not possible to extend the VTS network, AIS Repeaters can be used.

Every AIS basestation will have an MMSI number. However, when a VTS is operating multiple AIS Base Stations, it can present a single address, known as a virtual MMSI number. This will enable the ships to send and receive AIS messages in the VTS area using only one MMSI regardless of the number of base stations in use.

### Maneuvering and Voyage Related Data

AIS provides facilities for Mariners to enter details of their voyage, ETA and cargo etc. This Static data is part of the standard AIS transmissions at 6 minute intervals or on request. The static data will be received by the VTS system and can be used to support VTMIS applications such a Port Information Management databases.

As vessels maneuver, AIS will adjust the dynamic reporting rate to respond to the rate of change of the data. For a fast maneuvering vessel, the reporting rate will be increased to every 2 seconds or reduced to 10 seconds for slower maneuvers. Rate of turn is transmitted if available.

### Information Exchange between VTS and Mariner

#### Text messaging

AIS provides facilities to enable the VTS Authority to send free format text messages to a vessel at sea. These are intended to be safety related messages. The text message will appear on the MKD Display of the on board AIS system.

These text messages can be addressed either to a specified destination (MMSI) or broadcast to all ships in the area. Their content should be relevant to the safety of navigation, e.g. an iceberg sighted or a buoy not on station. Such messages can contain a maximum of 158-162 characters. Although unregulated, these messages should be kept as short as possible.

**Note**: The VTSO should not assume that all messages have been read on-board.

#### Binary Messaging

In addition, AIS has facilities for sending and receiving binary messages (there are 7 binary messages within the AIS protocol) and these can be used for “value added” supporting applications. It should be noted that the approval of the appropriate national maritime administration may be required for the use of the AIS VHF data link for a supporting application. An example of a supporting application may be: “Persons on board” or “Boarding Card” recording and transmission for passenger vessels.

For further details, see IMO SN/Circ.236, dated 28 May 2004, Guidance on the Application of AIS Binary Messages.

The AIS infrastructure and protocol provides facilities to enable application developers to produce new functionality and capability though the use of the binary messaging features. All such developments and message sets should be approved by the appropriate national or regional maritime authority and must be consistent with the purpose of AIS in respect to enhancing Safety of Life at Sea.

Approved binary messages and functions are managed by IALA ([www.e-navigation.nl/asm](http://www.e-navigation.nl/asm)).

It is recommended that National Authorities should monitor and coordinate the use of binary messaging within their area of responsibility to ensure that the necessary facilities for ship reporting via the VHF Data Link (VDL) are not compromised.

#### Pilot Port

An on board Class A AIS transponder includes a Pilot Port that can be used to display a complete AIS picture on a Pilot’s Portable Display.

### Aids to Navigation

AIS Basestations, as part of a VTS System, can be configured to broadcast Virtual and Synthetic Aids to Navigation (AtoN). A virtual AtoN is an AIS signal that marks a navigation point where there is no physical marker. A synthetic AtoN is an AIS signal that marks a position where a physical object is located. Virtual and Synthetic AtoNs will appear on the on board ECDIS.

AIS may be integrated with real AtoNs for monitoring and control purposes and so that other data sources hosted on the AtoN can be managed through the main VTS Traffic Display. AIS AtoNs can also be configured to transmit further virtual or synthetic AtoNs.

### Assigned Mode

VTS may use the AIS Service capability to change the reporting mode (from autonomous to assigned mode, for example) of selected shipboard AIS units. This will enable the ship station to operate according to a specific transmission schedule, as determined by a competent authority.

## Graphical presentation

In the VTS Centre, AIS-data is usually viewed on an electronic chart, either separately or combined with the radar data.

### Symbol usage

The IALA Guidelines on AIS include a description of the recommended AIS target symbols, but these were originally intended for the onboard ECDIS/ECS systems. As the guidelines point out, the given symbols are not necessarily adequate in the VTS context. The main difference is that a VTS-operator may prefer a much wider range of information than is necessary onboard a ship. For example traffic management may necessitate the use of symbols which depict different types and sizes of vessels. Further it may be necessary to show which vessel have pilots embarked, and which do not.

### Interaction with radar tracks

A target that is tracked by radar and also carries an AIS transponder should be displayed with one symbol based on a fusion of the dynamic information received from the two sensor types. The user may have the option to display the input from each sensor with two different symbols. It should also be possible to identify which sensor(s) are used to derive the target position.

## Specific design, configuration installation and maintenance considerations

### Interference

National regulations may regulate the use of AIS frequencies. AIS may be susceptible to interference from adjacent channels. When siting AIS Basestations, due consideration should be given to frequency allocations adjacent to AIS channels to avoid possible service disruption.

### Coverage aspects

In general, AIS design coverage ranges should approximate VHF voice communication ranges. However, actual vessel traffic density or geographic considerations (i.e., mountains or other VHF occlusions) may determine the need for additional base stations .

When estimating the size of the operational coverage (operational cell) for shore facilities, an important consideration is the traffic load – number of mobile AIS stations within the area.

For example, calculations in one port have indicated that an AIS Base Station could accommodate less than 300 active AIS units.

For further information, please refer to IALA Guidelines on the Automatic Identification System (AIS) Volume 1, Part II – Technical Issues, Edition 1.1

### Installation & Maintenance

The AIS Basestation equipment should be housed in an indoor and controlled environment, as would be used for other IT network components. AIS Basestations are typically 19” rack mountable and therefore all network and power connections will normally reside within the 19” equipment rack. Installation should therefore be simple and uncomplicated. For remote sites, where access may take more than 1 or 2 hours, the concept of a duplicated / hot standby configuration should be considered.

Standard maintenance procedures would apply to the Basestation and network connectivity. However, for the outdoor aerial equipment, regular check should be made to ensure that the aerials, and cable runs to the aerials, are not damaged in any way.

# Environmental Monitoring

## Introduction

The protection of the environment is an issue that has grown significantly in importance, both politically and socially, over recent years. The environmental impact of normal commercial activities is analysed such that risk reduction measures can be determined and implemented. Traditionally, VTS Authorities have collected environmental data simply to support their VTS activities however, many VTS Authorities have their VTS areas in, or alongside, marine protected areas or Maritime Reserves where any damage to the environment would potentially result in a considerable media interest and political ramifications.

Therefore, the modern VTS should consider two aspects of environmental monitoring:

* Navigation Data Collection
* Environmental Protection

Navigation Data Collection includes the traditional environment monitoring sensors, typically referred to as the hydrological / meteorological (hydro/meteo) systems. Typical meteo variables are those provided by weather stations and include air temperature and humidity, wind velocity and direction, and visibility. In certain locations, hydro variables such as tidal level, and current direction and velocity may also be required. Hydrological data may be obtained through sensors or available in tables/databases from national authorities. Sensors providing this data, usually located at remote sites (databuoy) and communicate data to a Vessel Traffic Services Centre (VTS centre) via a telecommunications or radio link. Alternatively, wave height, direction and current could be derived from the main VTS radar through software processing.

Environmental Protection would include implementing additional capability that would protect the nearby environment from any polluting incidents that may be caused by visiting vessels. This could be achieved though the software processing of the VTS radar signals or by specialist sensors that are designed to detect oil, or other pollutants, in the water.

At the VTS centre, graphical and/or numeric information is presented for use by the operators.

### Scope

The aim of ANNEX 4 of this recommendation is to:

* identify functional and operational requirements for environmental data in VTS; and
* provide guidance on design and installation of such equipment

### Objectives

Hydrological, meteorological, Oil Spill and any other environmental information, that the VTS Authority requires, may be integrated into VTS applications to provide the operator a real-time assessment of the environmental situation in the VTS area of responsibility. Information collected from this equipment can be provided to ships to assist in assessing the conditions.

A number of countries operate tide gauges and current meters to assist the prediction of tidal heights and streams or for the broadcast of real-time information to shipping. The Intergovernmental Oceanographic Commission (IOC) is responsible for co-ordinating the Global Sea Level Observing System (GLOSS) program to establish global and regional networks of sea level stations for providing essential information for international oceanographic research programmes. GLOSS operates under the Global Ocean Observing System (GOOS) http://gosic.org/ios/GOOS-Main-Page.htm. IALA supports and encourages participation in the GLOSS program.

## References

There are many applicable IMO, IEC, WMO and other requirements. These include, but are not limited to:

|  |  |
| --- | --- |
| IMO Resolution A.686(17) | Code on Alarms and Indicators (and MSC.39(63) Adoption of amendments to the Code on Alarms and Indicators) |
| IMO Resolution A.694(17) | General Requirements for Shipborne Radio Equipment forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids |
| IMO | SOLAS (i.e. Chapter V, Regulation 12) |
| IEC 529 | Degrees of protection provided by enclosures (IP Code) |
| IEC 721-3-6 | Classification of environmental conditions |
| IEC 60945 | Maritime Navigation and Radio communication Equipment and Systems |
| WMO | International Meteorological Vocabulary  Guide to Meteorological Instruments and methods of Observation |
| NMEA 0183 | Standard for Marine Electronic Devices (IEC equivalent) |

### Definitions

For general terms used throughout this document refer to the World Meteorological Organization (WMO).

## Characteristics of Environmental Sensors in VTS

The hydro/meteo sensors used for VTS systems are usually installed at VTS centres or other related sites such as radar sites however they might also be sited on third party sites e.g. a navigation buoy or lighthouse. These sensors measure parameters such as wind speed/direction, barometric pressure, air temperature and current speed/direction in real time. The hydro/meteo data is then transmitted to the VTS centre and presented to the VTSO in order to support the safety navigation of vessels. In cases of severe weather conditions this information is particularly important.

## Functional Requirements

This section states what the hydro/meteo system should be able to do and which sensors should be integrated into the VTS system.

Measurements are transmitted by the telecommunication system to a VTS centre and displayed in user-selectable format. The measured data is to be presented both numerically and graphically ( in chronological order) and is then stored for at least one year, depending upon the VTS authority. It is essential that a VTS Centre has access to local hydro/meteo information relevant to the VTS area(s) and can, if required by the VTS Authority, disseminate this to their users and allied services.

A VTSO centre can pass the measured hydro/meteo information to vessel(s) in the VTS area(s) by an appropriate radio communication link.

## Operational Requirements

Briefly, operational requirements are qualitative and quantitative parameters that specify the desired capabilities of a system and serve as a basis for determining operational effectiveness.

Operational requirements may include ergonomics, operational controls and information presentation. Due to the varied nature of hydrological and meteorological equipment in VTS, it is not possible to specify ergonomic or operational control requirements. – see CI in Appendix 3.

### Information Presentation

The results of the measurements should be transmitted in WMO standard units and displayed in user-selectable format.

The measurements should be available to VTS operators through an integrated display or separate instruments. Data may be presented numerically and/or graphically. A log of the latest 24 hour measurements should be available to the VTS operators either numerically or graphically.

### Malfunctions and Indicators

As a minimum requirement, malfunctions, warnings, alarms and indicators should respond to the requirements of IMO Resolution A.686(17) and MSC.Circ.39(63). Additional requirements may be required, depending on the individual type / purpose of sensor.

### Accuracy

Where a VTS Authority determines a need to establish their own monitoring stations, it should be noted that the individual VTS Authorities should determine the accuracy and availability requirements for each VTS Centre, as these will be based on individual circumstances. **Error! Reference source not found.**gives an indication of typical measuring range and minimum accuracy requirements.

Note: The target availability should be as prescribed by IMO A.915(22).

Table 4‑1 Indication of typical minimum accuracy

| **Parameter** | **Measuring Range** | **Minimum Accuracy** | **Remarks** |
| --- | --- | --- | --- |
| Height of Tide | 0 to 10 m | ≤ ± 2% |  |
| Rate of Tidal Stream/ Current | 0 to 300 cm/s | ≤ ± 1% |  |
| Direction of Tidal Stream/Current | 0 to 360 degrees | ≤ ± 5 degrees |  |
| Wave height | 0 to 10 m | ≤ 0.5m for ≤5m  ≤ ± 10% for >5m |  |
| Wave Direction | 0 to 360 degrees | ≤ ± 20 Degrees |  |
| Wind speed | 0 to 75 m/s | ± 0.5 m/s for ≤10 m/s  ± 5% for >10 m/s |  |
| Wind Direction | 0 to 360 degrees | ≤ ± 3 degrees |  |
| Visibility | 10 to 20,000 m | ≤ 50 m for ≤ 600 m  ≤ 10% for > 600 m –  ≤ 1 600 m  ≤ 20% for > 1500 m |  |
| Air Temperature | -10 to +50 degrees | ≤ ± 0.3 degrees | Hot, cold climate category area should be specified the measuring range. |
| Air Humidity | 0 to 100% RH | ≤ ± 2% RH |  |
| Air Pressure | 920 to 1080 hPa | ≤ ± 0.3hPa |  |
| Sea Surface Temperature | -2 to + 40 degrees | ≤ ± 0.1 degrees | Hot, cold climate category area should be specified the measuring range |
| Ice Coverage | - | - | Measured by satellite remote sensing |
| Ice Thickness | - | - | Measured by satellite remote sensing |
| Oil spill | - | - | Measured by satellite or radar remote sensing |
| Salinity | 0 to 70 PSS | ≤ ± 1% |  |

The VTS Authority should specify the time periods over which the various data parameters should be updated and may be averaged, if required, as these factors will depend upon the local circumstances pertaining to the VTS Centre.

#### Reliability, accuracy, range, resolution and units

The reliability, accuracy, range, resolution and units of the measurements should satisfy the minimum requirements as determined by WMO.

### Technical requirements

For hydro/meteo systems within a VTS system measurement sensors should be installed and located according to recommendations from a VTS authority in consultation with hydrologist/meteorologist(s). The Sensor identification and location should be provided.

The measurements/sensors may include:

* Wind speed / Wind direction / Wind gust
* Air temperature / Relative humidity
* Precipitation
* Barometric Pressure (atmospheric pressure)
* Visibility
* Water temperature / Water level
* Height of tide
* Current speed (may be required at various depths)
* Current direction (may be required at various depths)
* Wave height / direction
* Ice coverage / thickness
* Ice coverage
* Salinity
* Oil spill

## Design, installation and maintenance considerations

Key aspects to design and installation include:

* Durability and resistance to environmental conditions
* Interference
* Power supply requirements /options
* Installation
* Maintenance, and
* Technical challenge

### Durability and Resistance to Environmental conditions

Electronics installed externally should be in an environmental enclosure. IEC requirements for environmental conditions should be applied as practicable.

### Interference

These sensors comply with applicable international standards and regulations. IEC requirements (IEC 60945) refer.

### Power Supply Requirements / Options

Relevant IEC requirements should be applied. In remote locations, due to the low power, consumption of hydro/meteo sensors, authorities should consider use of alternative power (e.g., solar panels, wind vanes, etc.), in lieu of generators, when commercial power is not available.

### Installation

Requirements concerning the installation of sensors, wiring and the arrangement of the equipment providing hydro/meteo information to the VTS centre should be determined. Operational requirements will determine where sensors are to be located and how many are required. Sites for sensors should be selected based upon optimizing data relevant to the VTS. Other considerations include:

* availability of power,
* protection against vandalism,
* housing and collocation with existing VTS, AtoN, or other suitable infrastructure

Relevant IEC requirements should be applied. For example:

* IEC 529 "Degrees of protection provided by enclosures (IP Code)"
* IEC 721-3-6 "Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Ship environment"
* IEC 60945 "Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results"

The requirements of environmental condition should be decided by the VTS authority and referred to Annex 1, 1.5 General design, configuration installation and maintenance consideration.

### Maintenance

Possible requirements, in addition to IMO Assembly Resolution A.694(17) concerning maintenance, should be determined. Citing considerations for sensors should include maintenance, repair, and accessibility requirements.

### Technical Challenge

The new sensing technology has been developed using satellite remote sensing or radar remote sensing technology for detecting ice coverage area, density of surface ice or oil spill area, wave height/direction and so on. The VTS system should be prepared to use emerging technology in order to maintain or improve services.

### Interfacing

The data to be interfaced for the hydro/meteo service are described under ‘Functional Requirements / Sensors’.

For the interfacing of hydro/meteo services to VTS equipment, several different standards are in use. Among those standards, the Standard for Marine Electronic Devices, NMEA 0183, has been applied for these applications. In addition, the WMO has developed an interface standard for hydro/meteo applications.

For the interface between a VTS and its users, hydro/meteo data should follow standardized data exchange formats, e.g., XML. (In addition, a time stamp and source should be provided.)

### Backup Arrangements

Depending on the individual type of the equipment, requirements concerning back-up and fall-back arrangements should be determined.

### Safety Precautions

Depending on the individual type of the equipment, requirements in addition to IMO Resolution A.694(17) should be determined.

# Electro Optical Equipment

EOS = Electro Optical Sensors

PTZ = Pan, Tilt and Zoom

## Introduction

EOS consists primarily of a range of visual sensors that includes Daylight CCTV, day/night CCTV and thermal imaging cameras such as Infrared and laser illuminated cameras.

Within the VTS surveillance context, these sensors can provide additional visual situational awareness and can be a useful addition to the data derived form Radar, AIS and other sensors.

EOS derived information may be integrated into VTS applications to provide the operator with additional real-time situational awareness in the VTS area of responsibility.

### EOS Components

An EOS is made up of the following components:

* The imaging device that produces the electronic image
* The lens that creates the field of view and focuses the incoming light on to the image device
* The sensor housing
* For PTZ EOS, the electromechanical PTZ mechanics

## References

AD to update References specific to EOS

Electronics Industry Association (EIA) Recommended Standard RS-170

Relevant SOLAS requirements; SOLAS Chapter V (Safety of Navigation) as Regulation 12

Resolutions with more specific requirements, such as:

NMEA 0183 – Standard for Marine Electronic Devices (IEC equivalent 60945)

IEC 529 "Degrees of protection provided by enclosures (IP Code)"

IEC 721-3-6 "Classification of environmental conditions, Part 3: Classification of groups of environmental parameters and their severities; Ship environment"

IEC 60945 "Maritime navigation and radio communication equipment and systems - General requirements, methods of testing and required test results"

As defined by Electronics Industry Association (EIA), Motion Picture Experts Group (MPEG) and Joint Photographic Experts Group (JPEG).

## Characteristics

### Definitions

**Detection**: The VTS operator can, on the VTS display, notice that “something” (moving or not) is on the water surface.

**Recognition:** The VTS operator can recognize what has been detected and classify it according to its shape (container ships, ferry boat, fishing boat…)

**Identification:** The VTS operator can identify, with 100% surety, the identity of a ship (with the company name, the ship name, the ship flag, etc)

EOS may be effective in a limited area not covered by other sensors or provide supplemental information with other sensors (e.g., identification).

In addition information derived from EOS provides valuable and additional supporting evidence in playback analysis and incident investigations.

Within the context of EOS there is an extensive range of technology and characteristics available. These characteristics range from simple, short range, day light surveillance capability through to very sophisticated long range thermal and day/night capable technology.

VTS authorities should consider the need for low-light level, infrared, colour, intensified and laser-gated low light level, as well as digital image processing and video compression of EOS installations.

Additional characteristics to be considered with regard to EOS include, zoom capability, width and depth of field of view, resolution, and light sensitivity.

It is very important to realise that the level of sophistication also determines the capability of the sensor to operate in less than optimum conditions, i.e. fog, rain and night time operations. Rain and fog can have a very debilitating effect on some EOS sensor performance. This should be taken in to account when planning the use of EOS in the VTS surveillance context.

The level of integration of the EOS display within the overall VTS should also be carefully considered. Integration can range from a purely standalone display to a fully integrated EOS picture within the VTS system display technology it’s self.

In order to support high definition video with useable frame rates, data bandwidth requirements for remote high capability EOS sensors can be very demanding. Care should be taken in analysing the bandwidth requirements when planning the implementation of high definition EOS sensors.

Where more than one camera is installed to cover a VTS area, it may be desirable for the output from multiple cameras to be provided in one composite picture.

In addition to the sensors themselves there is also a wide range of image processing capability available. These capabilities range from simple video presentation to sophisticated image processing including image recognition and analysis, automated tracking and alerting/alarm capabilities.

## REQUIREMENTS

### Operational Requirements

#### Sighting of the sensor

Factors to be taken into account when deciding on where to place an EOS sensor include:

* The desired line of sight, field of view and the operational range for the sensor and operational importance of the surveillance area.
* The availability of existing infrastructure such as power, data communications and security. Where possible, consideration should be given to collocating a new EOS sensor with existing or planned sensors, e.g. radar.
* Maintenance………….
* The existence of strong and intermittent light sources that can adversely affect the performance of the EOS sensor, particularly low light and infrared cameras.
* The existence of man-made structures such as cranes, cooling towers, chimneys and so, all of which can either block the field of view or significantly alter the local environmental conditions – clouds from cooling towers

#### Sensor Selection

The operational needs should be the main factor to be taken in to account when selecting the type of sensor to be used for a particular surveillance zone.

Operational needs to be considered include:

* Night time operations – extended night operations in a particular area will typically drive the need to use lowlight, day/night, IR or even laser illuminated capable imaging sensors
* Typical or average size of the anticipated targets of interest e.g. VLCC or small fishing boats, or both.
* The typical operating environmental conditions. Prevailing dust conditions, heavy rains, high ambient temperatures etc, will dictate the minimum technical capabilities of the imaging sensor to be selected.

#### Detection Recognition and Identification

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Detection, needs should be carefully considered when specifying the functional requirements for an EOS sensor. The operational requirement should specify at what maximum range a VTS Operator must be able to detect a target

#### Recording and Replaying of Data

The EOS sensor data should be recorded automatically and should be capable of being replayed, as required by the VTS Authority. Replay of CCTV should not interfere with ongoing operations. This may require a separate display system for playback. The VTS Authority must determine the quality of recording and playback (e.g., frames per second, resolution, period).

The VTS Authority shall ensure that the minimum recording and replay functionality specified shall also support the legal requirements for incident replay and analysis as specified in the local jurisdiction.

Synchronisation with system time, voice recording and main VTS system recording

### Functional Requirements

#### Pan Tilt and Zoom

There are both fixed sensors and sensors that are able to be controlled in terms of direction (pan) vertical axis (tilt) and in zoom.

Fixed sensors are typically placed so as to provide general surveillance of fixed area of interest such as fairways and approaches to bridges and locks.

PTZ sensors can be controlled directly by the VTSO using typically a joy stick device, or keyboard.

Depending upon the level of integration with the VTS system software the PTZ can also be controlled directly by the VTS application.

The VTS application can:

* control the sensor via automated tracking of a contact seen by the VTS,
* can also cause the sensors to react to various alarm-like conditions including:
  + anchor watch violations,
  + traffic scheme violations,
  + speed violations and the like.

The VTS operator can, from within the VTS application, direct a PTZ sensor to survey a specific area, zone or activity, for instance pilot boarding and disembarking operations.

It shall also be possible, from within the VTS application, for the operator to set up automated scan sequences to cover selected areas, in turn and without manual intervention

The extent of PTZ control will be dependent on geography of the waterway, camera installation site, etc.

#### Precision and repeatability

Precision means the ability to set the pan, tilt and zoom to the requested position within a fine tolerance. Repeatability means the ability to reliably recreate this request any number of times with the same level of precision.

The degree of precision will alter with the type of application. For instance, when specifying a long range surveillance sensor, at maximum zoom, this type of sensor will have a relatively narrow field of view. So in this case the PTZ shall be required to have a high degree of precision.

Sensors with a wider field of view will not require a PTZ capability with such a precise capability.

#### Auto Focus

Focus should be an intrinsic and automated function within the EOS and should be specified accordingly.

#### Image processing

There are many image processing techniques and capabilities available, and the list continues to grow.

Authorities should, where possible, specify only those capabilities that they know to be useful in the specific application.

Such techniques may include:

* Image Enhancement
* Video content analysis
* Video tracking

#### Other functions

Where possible, authorities should specify EOS such that the majority of operational parameters e.g. spectral diversity, contrast enhancements and so on are hidden from the operators and are only made available to specialised maintainers.

## Design, installation and maintenance considerations

### Durability and resistance to environmental conditions

#### Vibration

EOS systems can be susceptible to performance degradation due to excessive vibration of the installation.

This is particularly relevant in strong wind conditions.

Authorities should take care to ensure that the supporting infrastructure for the EOS is properly specified to meet both the expected environmental conditions and the appropriate building regulations of the jurisdiction.

As an additional measure Authorities may consider specifying additional soft anti vibration capabilities in the EOS such as image stabilizers.

#### Specific environmental safeguards

EOS systems shall be specified with the following external and internal environmental safe guards:

* Lens wipers
* Replaceable clear lens filters to protect exposed optics
* Internal heaters and anti-condensation capabilities
* Mechanical lens protection as required – e.g. thermal cameras

### Data Communications

By its nature, EOS video output can consume a considerable amount of data communication bandwidth. Therefore due consideration should be given to ensuring that sufficient bandwidth is made available for this purpose.

There are a number of industry standard techniques that can be used to reduce the bandwidth consumed by the EOS. Such techniques include the use of IP digital based communications rather than analogue communication, proprietary compression techniques and standard video formats such as MPEG. Modern Cameras are typically supplied with direct digital output. Where cameras are selected that do not have digital output, it is recommended that digital encoders are included in the overall design and installed at the sensor head.

However, care should be taken when selecting compression techniques. Increased compression will be accompanied by a corresponding reduction in the end video quality.

### Maintenance

Typically EOS sensors will require a heavier maintenance requirement than other VTS system components. This is particularly relevant to the high end thermal and laser gated type sensors. These sensors often include cooling and other specific system support items and these cameras do not enjoy high MTBF figures.

When selecting such devices it should be noted that maintenance requirements can become significant.

Given that EOS sensors are often installed high on towers or on dedicated poles, care should be taken to ensure that ease of access for cleaning, maintenance and replacement is taken in to account in the overall EOS implementation.

### Laser Safety Precautions

EOS sensors typically do not radiate significant energy patterns. However this statement is not true for laser augmented EOS sensors.

When specifying the use of such augmented sensors, local national standards and international industry standards for the use of laser must be strictly enforced.

AD to include laser standards here

# Radio Direction Finders

## Introduction

RDF is a sensor system that supports VTS and SAR operation by indicating the direction/bearing to a VHF transmitting device during time of transmission. Two or more appropriately located RDF are needed to estimate and display the position of a ship, e.g. calling on channel 16 on a VTS console. This may be used to correlate with a radar target to identify a ship not equipped with AIS and therefore assist the evaluation of the traffic image. Because of its co-operative structure RDF is not suitable of being used for continuous tracking.

## Operational Requirements

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

The operational requirements may be determined by definition of:

1. The RDF coverage area, based on possible RDF location(s), the navigation characteristics, and the subdivision into requirements for Basic, Standard and/or Advanced capability
2. The frequency range of RDF equipment including SAR frequencies if necessary
3. The number of simultaneously monitored VHF channels
4. Detection requirements as a function of:

* Types of ships to be detected (with regard to the radio range the antenna height is of interest)
* Meteorological conditions

1. Required bearing accuracy parameters
2. Other influencing factors, RDF location, obstructions

### RDF coverage Area

The VTS area should be subdivided into requirements for Basic, Standard and/or Advanced capability as discussed in ANNEX 1, paragraph 1.3.1 and the need for RDF and other sensors coverage shall be defined on the basis of a risk assessment.

In order to ensure accurate identification on the VTS display the use of two or more separate RDF bearing stations are required. Bearing angles on the target should be as close to 90º as possible

### Frequency range

Whereas the main purpose of RDF is detection of VHF communication devices, the frequency range of RDF should correspond to the frequencies used for VHF communications. Additionally standard SAR frequencies (121.5 MHz, 243 MHz and 406 MHz) may be required if SAR operations should be supported by VTS.

### Number of simultaneously monitored VHF channels

Depending on its hardware configuration, RDF can simultaneously work on single or multiple frequencies. This achieved by use of one or several VHF receivers (typically 4-8).

The single-receiver RDF can be switched to any VHF channel at any time. It can be done manually or automatically in so-called scanning mode when RDF automatically scan pre-defined list of VHF channels. Thus, several VHF channels can also be monitored using single-receiver RDF but not simultaneously.

There also may be a need to simultaneous monitor several VHF channels. For example, SAR channels and VHF channel 16 may require to be monitored continuously while all other working VHF channels selectively. In such situation use of multi receivers RDF may be required.

### Detection performance

The detection performance of a RDF in a VTS should be sufficient to meet the requirement in the individual VTS areas, Basic, Standard and/or Advanced.

The VTS Authority shall ensure that the specified detection performance is achieved. It is strongly advised to consult experts with an operational and technical knowledge about the subject.

Factors affecting the detection performance of RDF systems including interference and propagation shall be taking into account. Special local conditions such as heavy rainfall should be taken into account.

The recommended method for determination of RDF coverage and range performance is a combination of site inspections and RDF system performance calculations.

The evaluation shall include:

* Calculation of VHF Radio Range based on RDF antenna height and minimal VHF antenna height on the target of interest
* Calculation of all applicable losses (target’s VHF transceiver power, required RDF sensitivity, losses in VHF cable etc.)
* Evaluation of the effects from propagation conditions and obstructions
* Influence of meteorological conditions

The calculations may be supplemented by comparison and/or validation test.

### Bearing accuracy

One of the most important parameter of the Radio Direction Finder subsystem is the bearing accuracy. Besides the technical characteristics of the RDF equipment, many other factors may significantly deteriorate the bearing accuracy in real conditions. Therefore, the following aspects should be taken in account when planning bearing accuracy requirements:

* RDF equipment bearing accuracy - typically specified by RDF manufacturers for “near to ideal” conditions.
* DF antenna installation environment. Multipath signal propagation caused by reflection from surrounding objects can significantly deteriorate the bearing accuracy (refer to sub-heading “Specific Design and Installation Considerations)
* Received signal strength. Low level of received signal may significantly deteriorate the bearing accuracy. The major factors affecting received signal strength are:
* Distance to the target
* DF receiver(s) sensitivity and RDF antenna feed losses
* Weather conditions
* Output power and duration of transmitted signal
* Acceptable delay between signal detection and output for presentation. This delay is caused by internal processing of received signal within RDF to achieve declared accuracy and is typically about 1-2 seconds.

Quality of factory and on-site RDF calibration. Proper calibration may help to compensate the factors, which adversely affect the bearing accuracy and achieve better performance.

The recommended bearing accuracy for the types of capability are provided in **Error! Reference source not found.**

Table 6‑1 Bearing Accuracy

|  |  |  |  |
| --- | --- | --- | --- |
|  | Type of Capability | | |
| Basic | Standard | Advanced |
| Recommended Bearing Accuracy | ≤ ± 5º | ≤ ± 3º | ≤ ± 2º |

6.1.6 Environmental capabilities and constraints

## Functional Requirements

### VHF channel(s) management

There are two types of RDF systems available on the market: single channel receiver RDF containing one receiver and multi channel receivers RDF containing two or more receivers for simultaneous receive and processing on different frequencies.

Selecting the appropriate RDF type is determined by the operational requirements (see above)

Single channel receiver RDF should as a minimum include:

* Remotely controlled selection of VHF channel
* Automatic channels scan function from pre-defined list of working channels
* Prioritization of SAR channels in scanning mode

Multi channel receiver RDF should as a minimum include

* Remotely controlled selection of VHF channels for each receiver
* Automatic channels scan function from pre-defined list of working channels for one or arbitrary number of receivers
* Simultaneous output of detected bearings for all receivers

### SAR functionality

In case VTS is purposed to assist in SAR operations, corresponding functionality of RDF equipment may be required. Depending on the tasks, the following functionality may be requested:

* Detection of devices transmitting on SAR frequencies
* Automatic filtering of ELT tones of MOB EPIRB devices
* Receiving and decoding of COSPAS\SARSAT digital data including coordinates and output of decoded data to VTS

### Man Over Board EPIRB detection capabilities

This capability of RDF equipment ensures detection of specific standardized ELT codes transmitted by EPIRB devices. This functionality ensures minimizing the probability of false alarm caused by spurious transmissions on SAR frequencies.

### COSPAS\SARSAT detection and decoding

This capability of RDF equipment ensures receiving and decoding of digital data transmitted by COSPAS\SARSAT radio beacons. Received data contain identification number and the measured geographic coordinates of the radio beacon, which can be used for planning of SAR operation.

### Build In Test and diagnostic

Built-in test features should include monitoring of functions and performance. It is recommended that results are made accessible for remote monitoring, especially for RDFs installed in locations that are difficult to access.

## RDF design installation and maintenance considerations

### RDF antenna installation

The design of a complete RDF system requires careful consideration especially with regard to the DF antenna installation site. The following aspects should be considered when planning RDF antenna installation place:

* RDF antenna should be placed on a very stable support to avoid any rotation or torque as this directly affect RDF performance
* Antenna height should be enough for detection of the VHF transmitting device in interest having minimal VHF antenna height
* Any object causing shadowing in the RDF sector of interest should be avoided
* Any rotating\moving objects (like radar antenna, PTZ CCTV etc.) should be placed on safe distance from the RDF antenna according to RDF manufacturer recommendations (or maybe include some general figures into this doc???)
* Safe distances from RDF antenna to big reflecting objects (like buildings, masts, cranes, forest etc.) should be kept according to RDF manufacturer recommendations (or maybe include some general figures into this doc???) .
* Surrounding landscape (mountains etc.) may significantly decrease the RDF bearing accuracy and distance performance due to multipath signal distribution. So, the landscape around the installation place should be as flat as possible.

### Lightning protection

Typically, the RDF antenna is placed on very top of the mast, so the special attention should be paid to the antenna’s lightning protection. From one side lightning protection should ensure reliable protection of RDF and other installed on the mast equipment, from other side not affect RDF performance causing re-reflection or shadowing of incoming VHF signal.

6.1.8 Calibration

Requirements for factory and on-site RDF calibration

# Long Range sensors

## Introduction

VTS equipment provides the VTS Authority with real time data from short range line of sight sensors such as radar and AIS. On occasions the use of information derived from long range sensors (typically long range radar, satellite communications systems and satellite AIS) can provide supplementary information for the VTS or Coastal Authority. It may assist in locating vessels that have not arrived on schedule or detect vessels that arrive unannounced. This may assist the authorities in assessing any security risks or in other situations may provide input data for search planning should a rescue be required.

Typical Long Range Sensors include:

* LRIT (Long Range Identification & Tracking)
* Satellite AIS
* HF Radar
* Satellite based Synthetic Aperture Radar (SARSAT)

This section will provide an overview of each of the above and identify the benefits, limitations and applicability of these sensors to VTS and Coastal Authorities.

## Long Range Identification & Tracking (LRIT)

LRIT is a mandatory carriage requirement for SOLAS vessels. It provides a position report at regular intervals based upon the area of operation. The normal reporting interval is every 6 hours. LRIT data is received by International Data Centres (IDC) and is available to the flag authority and to the maritime authorities of transit and destination countries.

Based upon the normal reporting cycle, LRIT data may up to 6 hours old when received and therefore not as accurate as the real time data received from the primary sensors such as radar and shore-based AIS. However, in circumstances where a vessel has arrived unexpectedly or gone missing, the LRIT information could provide additional information to assist in a security assessment or to enable search planning activities to be initiated.

### Specific design, configuration, installation & maintenance considerations

LRIT is an established service that does not require any special design, configuration or installation on the part of the VTS Authority as these are handled by the existing LRIT infrastructure. The VTS Authority may need to be granted access permission by the national maritime authority and allocated a username by the International Data Centre. Once access has been granted the VTS Authority will be able to integrate the LRIT data with the VTS Traffic Display as appropriate for his operational requirements.

It should be noted that LRIT data normally carries an airtime cost per position report and that the IDC may charge for the provision of the data.

As the applications for LRIT data continue to evolve, other uses and benefits may be determined and implemented.

## Satellite AIS

An AIS receiver in a satellite will extend the coverage range considerably and make it possible to monitor ship traffic beyond the range of terrestrial AIS receivers and radars. The Satellite AIS data will be provided through a Service Provider to which the VTS Authority will need to subscribe, possibly for a monthly fee.

The satellite service listens to the AIS environment within its footprint area and stores the data on board the orbiting satellite until it passes over a ground station where it can download the data. This will mean that the data received by the VTS Authority will not be real time and may be 1 – 2 hours old (possibly more).

In areas with high ship traffic density the sheer number of AIS messages being received at the same time cause data collisions from different self-contained resolution cells occupying the same time-slot. Advanced de-collision algorithms are employed by the different service providers of satellite AIS data but in a high traffic density situation, it may be impossible to reliably extract accurate data.

Satellite based AIS data is now becoming increasingly available via commercial as well as national government sponsored satellite AIS systems.. The operational systems comprise several satellites in different constellations, i.e. polar-orbiting constellation or a mix of equatorial and polar orbiting satellites. The effect of different orbiting constellations will be the availability and location of Ground stations to receive the satellite AIS data. The more frequently the service can download the data, the less latency between the received data and the real time position of the actual vessels.

### Specific design, configuration installation and maintenance considerations

Satellite AIS is an established service that does not require any special design, configuration or installation on the part of the VTS Authority as these are handled by the satellite AIS Service Providers. The VTS Authority may need to subscribe to a service on offer from a satellite AIS Service Provider. Once the service provision has been agreed and implemented, the VTS Authority will be able to integrate the satellite AIS data with the VTS Traffic Display as appropriate for his operational requirements.

As the applications for satellite AIS data continue to evolve, other uses and benefits may be determined and implemented.

The main difference between the terrestrial and satellite AIS data, besides the geographic coverage, is the data latency, i.e. the age of the AIS message when it is actually received by the VTS system. Aside from the signal path to and from the AIS satellite receiver, a delay is also introduced when the received signal is decoded. Currently two methods of decoding are in use:

## HF Radar

One rarely used technology that can offer long range detection of vessels is HF radar. This has one major advantage over other long range detection technologies in that it does not require cooperation from the vessels to be detected. There are generally two types of HF radars, those that use the low level earth surface “hugging” refraction duct and those that use reflection from the layer to layer boundaries in the ionosphere above the earth (skywave).

Both system types suffer from unpredictable propagation path characteristics which can support medium and large object detection (metal ships) to hundreds of nautical miles in some conditions but often offers very little detection performance. This makes specification of achievable performance and detection “availability” a challenge to both radar customers and radar suppliers. The vagaries of the propagation paths can also introduce unpredictable positional measurement errors affecting both angle and range even when an object is clearly detected.

The HF radar installation requires some careful selection of suitable coastal terrain which may not suit all potential VTS locations. Similarly, suitable sites will rarely support the necessary infrastructure (power, communications, access for installation and maintenance) and these need to be factored into the installation and operational costs.

Optimising the nature of HF radar may impose high workload on specialised, highly trained operators.

If the limitations are acceptable, this technology offers valuable passive detection in open waters, expensive to obtain by other means (airborne sensors and satellite).

## Synthetic Aperture Radar (SARSAT)

Satellite based Synthetic Aperture Radar (SARSAT) can provide vessel target information at ranges beyond that of shore based sensors, including HF Radar. However, such services will probably only provide a single image of a specific area once per day through a few orbiting satellites. Images are stored on board the satellite until they can be downloaded as the satellite passes over a ground station. The image is processed, following download from the satellite, to detect ships within the area and radar information (without identity) can be derived that can be used to recognise the type of vessel. This type of service is for analysis of vessel movement and not for any form of near real time monitoring. In addition to the latency between the required image capture and the download when passing over a ground station, there is also a further latency related to the processing of the received data. The application is useful for detecting illegal fishing activity within the deep water areas of a country’s Exclusive Economic Zone and for detecting oil spills and pollution.

### Specific design, configuration, installation & maintenance considerations

SARSAT is available from a variety of established service providers and does not require any special design, configuration or installation on the part of the VTS Authority. The VTS Authority will need to subscribe to a SARSAT image service and costs are involved on a per image basis. Once access to such a service has been established, the VTS Authority will be able to integrate the SARSAT target data with the VTS Traffic Display as appropriate for his operational requirements.

# Radio communications in VTS

## Introduction

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

## References

Relevant SOLAS requirements;

* SOLAS Chapter IV (Radiocommunications)
* SOLAS Chapter V (Safety of Navigation) – Regulation 12
* SOLAS Chapter V (Safety of Navigation) – Regulation 19

IALA World Maritime Radio Communications Plan Edition 1

Resolution A.694(17) - General Requirements for Shipborne Radio Equipment forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids;

IEC 60945 "Maritime navigation and radiocommunication equipment and systems - General requirements, methods of testing and required test results"

ETSI EN301 929-2 v1.2.1 Electromagnetic compatibility and radio spectrum matters (ERM): VHF transmitters and receivers as Coast Stations for GMDSS and other applications in the maritime mobile service.

ITU-R M.493-11 Digital selective-calling system for use in the maritime mobile service.

ITU-R M.541-9 Operational procedures for the use of Digital Selective Calling equipment in the Maritime Mobile Service.

ITU-R M.689-2 International maritime VHF radiotelephone system with automatic facilities based on DSC signalling format.

ITU-R M.1082-1 International maritime MF/HF radiotelephone system with automatic facilities based on DSC signalling format.

ITU-R M.1842-1 Characteristics of VHF radio systems and equipment for the exchange of data and electronic mail in the maritime mobile service.

## Characteristics of Radiocommunication equipment

Radiocommunication is the central ingredient in the operation of VTS. Radiocommunications links are used to collect position, safety, and general information from shipboard personnel and remote sensing devices. These links are also the primary means through which services are delivered to VTS participants.

### Coverage

Radiocommunication equipments are adapted to guarantee the coverage of the GMDSS ( www.imo.org):

* Area A1 Within range of VHF coast stations with continuous DSC (digital selection calling) alerting available (about 20-30 miles)
* Area A2 Beyond area A1, but within range of MF coastal stations with continuous DSC alerting available (about l00 miles)
* Area A3 Beyond the first two areas, but within coverage of geostationary maritime communication satellites (in practice this means Inmarsat). This covers the area between roughly 70 deg N and 70 deg S.
* Area A4 The remaining sea areas. The most important of these is the sea around the North Pole (the area around the South Pole is mostly land). Geostationary satellites, which are positioned above the equator, cannot reach this far.

### VTS Radiocommunication

VTS Radiocommunication comprises both voice and data services and potentially video applications using equipment within the frequency bands indicated above for the relevant GMDSS area.

#### Very High Frequency (VHF)

The Maritime VHF band comprises 25KHz channels within the 156MHz and 162.025MHz. These are mainly used for voice communication except channel 70 (DSC) and Channels 87, 88, 75 and 76 (AIS frequencies 1 to 4). The VTS Authority may require VHF Channels to be designated / licensed by the National Radio Authority for specific types of operations (eg. Coast Station Radio License). Specific channels are determined to provide safety watch, DSC, and VTS information.

The VHF equipment must comply with national and international regulations, particularly with the Master Plan of shore-based facilities for GMDSS. The use of simplex, duplex and semi-duplex channels as well as 25KHz channels can be used in accordance with the appropriate ITU-R and national regulations. Additionally 12.5KHz channels are also allowed under Appendix 18 of the Radio Regulations in accordance with ITU-R M.1084.

VTS Centres require a means of clear and easy to use voice communication for interacting with ships. Within the VHF band, the VTS Centre will require the availability of a number of radio channels relative to the number of ship movements and the size of the VTS area. In addition to distress calling, DSC provides a means of direct calling to vessels through the use of the MMSI and other routine call functions.

Data communication between ship and shore or ship to ship shall be implemented within the VHF Marine Band for e-navigation and VHF Data Exchange (VDE) in accordance with ITU-R M.1842-1. Following the introduction of this regulation, a digital infrastructure over Maritime VHF shall be available.

#### Medium and High Frequency (MF and HF)

MF and HF may be used on a regional basis where long range communication is required. The VTS Authority may require specific channels to be designated by the National Radio Authority for specific types of operations. The equipment must comply with national and international regulations. Exceptionally communication via sat-com might be required, depending on geographic terrain, shoreline of country and service provided by the VTS.

## REQUIREMENTS

The shipborne equipment must meet the functional requirements of the relevant IMO performance standards and the ITU-R Radio Regulations. Shore based equipment should conform to the appropriate standard, where available, such as ETSI for EU Member states.

### Radiocommunications Coverage

VTS Radiocommunications shall be in accordance with ITU-R Radio Regulations. Depending upon the circumstances, radiocommunication equipment should be capable of receiving signals from appropriately equipped ships.

VHF radio reception is generally dependent upon the line-of-sight distance between VTS receive site and the ship antenna heights. As a minimum requirement, the radiocommunications range should facilitate VTS ship communications before the ship enters a VTS area of responsibility.

### Digital Selective Calling

Routine calls using DSC can be initiated by the VTS in order to direct a VHF call to a specific vessel through MMSI based addressing. In addition, DSC is also used for distress calling. Further details are provided in ITU-R M.541-9 and ITU-R M.689-2

### Recording and Playback of Data

Radiocommunications shall be recorded automatically and shall be capable of being replayed synchronised with other VTS data.

### Malfunctions, warnings, alarms and indications

Refer to relevant requirements of Resolution A.686(17) and Resolution MSC.39(63).

### Availability

The requirements for the availability of radiocommunication equipment are dependent on the mandate of the VTS Authority and the national Administration. Fallback arrangements are described in paragraph 8.6.1 . Please reference Annexe 1

## Specific Design, Installation & Maintenance Considerations

### Durability and resistance to environmental conditions

Electronic equipment installed externally should be in an environmental enclosure. As regards environmental conditions, the IEC requirements should be applied as far as relevant.

### Interference

Radiocommunications equipment complies with applicable international standards and regulations - see IEC 60945 which covers the general requirements for navigation and radio equipment and includes interference. Equipment should be installed in accordance with manufacturer’s instructions and specifications to avoid interference.

### Power supply

IEC requirements should be applied as far as relevant. In remote locations, authorities should consider the use of renewable power sources (e.g., solar panels, wind turbines, etc.) as an alternative to diesel generators. In addition, uninterruptible power supplies could be considered as a backup to the primary power supply.

### Site selection and Installation

Requirements concerning the installation of radiocommunciation equipment, wiring and the arrangement of the equipment in the VTS Centre and in remote sites should be determined. Operational requirements will determine where radiocommunication transceivers and antennas are to be located and how many are required. Sites for radiocommunication equipment should be selected based upon optimizing the coverage of the VTS area.

Consideration should be given to the power output of the radio system at the antenna instead of the power output at the radio equipment. Where multiple transceivers are combined and/or filtered through to a single antenna, the effective radiated power (ERP) is significantly reduced.

Care must be taken when co-locating antenna sites that proper separation is maintained. To avoid channel saturation, consideration should be given to subdividing the VTS area into communications sectors based upon channel use with adjacent sectors using separate channels.

Other considerations include availability of power, physical security of the site, housing, and co-location with existing VTS, AtoN, or other suitable infrastructure.

### Maintenance

In addition to the requirements of IMO Assembly Resolution A.694(17), the siting and installation of radiocommunication equipment should make provision for accessibility, maintenance and repair.

## INTERFACING

Although there is an internationally agreed interface standard for interfacing electronic equipment on board ships, there is however no specific standard for VTS radiocommunication ashore. The interface standard will thus be dependent on the requirements of the VTS authority and the equipment being installed.

### BACK-UP AND FALL-BACK ARRANGEMENTS

The provision of redundant radiocommunication equipment is recommended via the use of duplicated equipment in case of failure.

Additionally, consideration should be given to a business continuity plan such as handing over to another VTS and maintaining a portable radio facility such as satcom or mobile telephone.

# Data Processing

## Introduction

This annex describes the collection and processing of sensor data to establish and maintain the VTS Traffic situation and the related environment. The following data processes are typical:

* Maintaining the traffic situation
  + Collecting sensor data
  + Tracking and Data fusion
  + Target identification
  + Target data augmentation using data from VTS Databases
* Assessing the environment
  + Weather Conditions
  + Water Conditions
  + Seabed/riverbed profile

## Abbreviations and References

## Characteristics

### Maintaining the Traffic Situation

#### Introduction

A typical VTS will use a variety of sensors to collect information necessary for its operation. Some sensors require cooperation of the target to obtain a measurement. Depending on the systems, available on-board, a vessel may or may not be able to cooperate in the measurement process. A vessel that is able to do so is a cooperative target. However, if it is not able or not willing to do so, it is referred to as non-cooperative target. If a target is cooperative, the measurement data may originate from the target itself. In that case, the sensor is called a dependent sensor, because the target provides the data.

#### Collecting Sensor Data

##### Radar

Plot extraction (see IALA Guideline 1056) should be automatic. The plot extraction process should be able to handle a minimum of plots per rotation (see Table 55.1).

In most cases, a VTS system will use one or more radar sensors to monitor the real-time traffic situation. Radar is a non-cooperative sensor in the sense that targets are usually detected without any particular action on the side of the target. Note that, especially small targets like sailing boats, may increase their visibility as a radar target by using specially crafted radar reflectors.

The radar image may be presented to the operator without further processing. This allows a trained operator to get a better perception of the target and its environment. If the targets are sufficiently close to the radar, such as during port approach, the resolution of radar allows target features like an approximate length, width or even orientation can be distinguished. This warrants presentation of the radar image on its own.

On the other hand, radar provides range and bearing measurements, relative to the sensor position. These measurements can be used to automatically determine the position, groundspeed and course over ground of a target. Typical VTS radars use a rotating antenna with a 1s to 10s rotation period. This means that a target is observed once about every rotation. This observation period matches with the expected movements and accelerations of VTS targets.

##### AIS

AIS position information is obtained from the ship navigational system and is, generally, a GNSS-derived position, which may or may not be differentially corrected. This latter fact is indicated in the AIS message.

AIS are basically a digital VHF communication system that provides information from sensors onboard cooperative targets (i.e. targets carrying an AIS transponder). AIS information is sent in packets. This is position information, but also information that identifies the ship (MMSI and ship name) and whether it carries any dangerous cargo or not. Apart from this, AIS can be also used to exchange safety-related information and other information, as detailed in [A.124].

AIS position information is obtained from the ship navigational system and is, generally, a GNSS-derived position, which may or may not be differentially corrected. This latter fact is indicated in the AIS message though.

##### Long-range sensors

This concerns Long-Range Identification and Tracking (LRIT), satellite AIS and information of AIS networks beyond the area of direct interest of the VTS. Long range sensors are not usually necessary for VTS operation (INF, NAS or TOS). They may provide information, though, that assists in long-term planning and may be relevant for allied services as well.

##### Electro-optical

These types of sensors could be divided in two main groups: Short distance gap fillers for a specific area surveillance, and medium range visual identification. Depending on the operational requirements, these sensors also could be used for different purposes e.g. target tracking, target height.

##### Radio Direction Finder

This type of sensor provides the information about the relative bearing to the target transmitting on radio frequency channel. The main purpose of this sensor is assess direction to the speaker you are in relation with. Depending on the operational requirements, use of multiple Direction Finders may allow to determine absolute position of transmitting device.

#### Tracking and Data Fusion

##### Introduction

All sensor measurements have limited accuracy and are affected by more or less random errors. In order to obtain a reliable estimate of a target position and speed vector, measurements need to be processed by a tracking filter. A tracking filter uses a model of the sensor and a model of the target movement to provide a best estimate of, at least, the target position, course and speed over ground.

##### Tracking

* Sensor level versus track level fusion
* Tracking filters?
* Reference WGS84, projection
* Performance figures

##### Initiation

Radar

AIS

The accuracy of the AIS position information should be taken into account when initiating an AIS track.

Electro optics

Radio Direction Finder(s)

LRIT

Satellite based

Track initiation should be automatic, semi- automatic or manual depending on the concept of operations.

In automatic track initiation mode, all plots in a scan should be considered potential targets. Some of the plots will be associated with previously established tracks, while the remaining plots should be considered as candidates for new tracks, i.e. tentative tracks.

Tentative tracks will become confirmed tracks if plots from consecutive scans “fit into the picture” within reasonable physical manoeuvrability limits, otherwise the tentative tracks are discarded.

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.

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.

##### Maintaining Track

If automatically or manually, created tentative tracks persist over a certain length of time the tracks should be promoted to confirmed tracks. Confirmed tracks should be shown on the display. 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.

##### Track Termination

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.

Plot extraction and tracking performance

The requirements in respect of plot extraction and tracking should be defined by the individual VTS authority, on the basis of local conditions, number of radar sensors in a system etc. Table XXX suggests values for each individual radar sensor in a system.

.

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 | | ≥ 1000 | ≥ 2500 | ≥ 5000 |
| Number of confirmed tracks | | ≥ 100 | ≥ 200 | ≥ 300 |
| Time for confirmation of tentative track | | ≤ 1 minutes | | |
| Time from track confirmation to achievement of specified 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) | ≤ 0.75 % of range covered by the individual radar or 10m + selected pulse length, 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° |

##### Track initiation and track maintenance

The radar PD should be adapted to the role of the VTS. The automatic track initiation and track maintenance is optimised accordingly.

Recommendation for the minimum radar PD for track initiation is given in Table 55.2. For track maintenance a lower minimum radar PD can apply, depending on the tracking principles used by the manufacturers.

Table 9‑2 Track initiation

|  |  |  |  |
| --- | --- | --- | --- |
| Minimum radar PD for track initiation | | | |
| Priority of the VTS | Recommendation level | | |
| Basic | Standard | **Advanced** |
| Surveillance and/or traffic monitoring | 0.9 | 0.8 | 0.7 |
| Safety | 0.9 | | |

##### False tracks

False tracks may appear as a result of noise, clutter (including wakes) and ghost echoes. However, the number should not be significant if the recommended values given in XXX are respected.

The maximum number of false tracks allowed is dependent on role of the VTS. False tracks should be avoided in safety critical areas and occasionally accepted in areas where surveillance and traffic monitoring is the priority.

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.

##### Track loss

Track loss may occur as a result of PD < 1 in combination with targets manoeuvring, especially in the vicinity of obstructions such as bridges.

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 55.1 and Table 55.2 are respected.

The VTS authority should address critical areas, such as the vicinity of bridges, and explain expectations to tracking to allow VTS suppliers to make solutions accordingly.

##### Track swap

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.

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.

#### Target Identification

#### Target data augmentation using data from VTS Databases

#### AIS target maintenance

##### Track Initiation

AIS is an automatic reporting system that doesn’t require any kind of extraction or poling. After receiving of first valid position message AIS track can be initiated. Since dynamic and static information come in different messages, at the time of track initiation the full identification may not be possible and should be confirmed afterward when information is available.

##### Maintaining Track

The AIS track can be maintained as long as the position updates are received with acceptable update rate.

##### Track Termination

##### Sensor Data fusion

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.

##### Automatic data fusion

The automatic data fusion aims at providing the user with combined set of information where data originated from different sensors are linked together for a given target.

Data fusion should not degrade the quality of the information coming from the most reliable source and at certain extend improve it.

By the nature data fusion process provides the redundancy in terms of sensor data use.

##### Manual data fusion

On top of automatic data fusion, the operator may be able to de-associate some of the automatically fused data; or force an association, which could not be done automatically for technical or operational reasons.

##### Centralized fusion

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

##### Target identification

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

Distribution/Access level/”Need to know”

### Assessing the environment

#### Weather Conditions

#### Water Conditions

#### Seabed/riverbed profile

## Requirements

### Operational Requirements

### Functional Requirements

### Performance Requirements

### Interface Requirements

## Specific Design and Installation Considerations

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Moved from annex 2

Table 9‑3 Radar functions

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters / Capability | Basic | Standard | Advanced |
| Path, time and track prediction, |  |  | X |
| CPA, | X | X | X |
| TCPA, | X | X | X |
| Anchor watch, |  |  | X |
| Vessels vector, | X | X | X |
| Course, speed and label/identity, | X | X | X |
| Collision alerts. | X | X | X |

# HMI

## 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

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 the human Vessel Traffic Service providers (the users or VTS Operators). The principal goals of a Data Display system are derived from the fundamental VTS requirements. These derive from the fundamental needs to minimise the probability of hazard occurrence, and to maximise the efficiency of all shipping operations in the controlled 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 as such
* 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 provide display of Decision Support data (annex 11) to give visibility of (for example):

* 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.

# 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 must 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 are distant of less 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 must 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 by the use of reliable communication networks.

The scope of this recommendation is to provide members with relevant aspects of exchanging maritime information globally. Details regarding legal issues and processes recommended for sharing maritime data, and more specifically terrestrial and satellite AIS, may be found in IALA guideline N° XX (The global sharing of maritime data and information Ed-0.1-15sept2011).

## Abbreviations and References

IALA dictionary: 5-3-340 Information: The meaning assigned to data by known convention

"Maritime data" is information regarding the maritime domain

IHO

ITU

## Characteristics of data exchange in VTS

### Uses

Comprehensive user needs have been well documented in IMO instruments and other IALA documents. Nevertheless, this technical recommendation offers a brief list of some potential applications or uses for maritime data inftormation. This list is not exhaustive and is offered to provide an indication of the range and diversity of activities that rely on marine data and information for their success, and which will further benefit from mutual exchange of data and information.

VTSs may be specifically concerned either because they are gathering information regarding these subjects and play a key role in providing these to other parts. They may also be concerned because they use, share or need to be aware of certain situations and should have access to this information. Dynamic updating is essential for maintaining the quality of marine data and information. This applies both afloat and ashore.

### Afloat

* Voyage planning and execution
* general VTS interests
  + Risk identification and avoidance (shipboard)
  + Monitoring of cargo, vessel status and resources
  + Track keeping and collision avoidance
  + Planning for sufficient under keel clearance
  + Weather routing
* Mainly port VTS interests
  + Cargo management (planning loading and discharge)
  + Logistics (shipboard)
* Regulatory compliance
  + Reporting
  + Environmental
* Seakeeping (stability and seaworthiness)
* SAR response

### Ashore

* Traffic management
  + VTS operations
  + Anchorage and berth management
* Hazard management
  + Risk analysis
  + Accident investigation
  + Contingency planning
  + Incident reporting
  + Emergency towage and salvage
* SAR
* Pilotage and allied services
* Support to logistic chain
  + Voyage monitoring
  + Port operation
  + Forward planning movements
* Law enforcement
  + Fisheries enforcement
  + Customs
  + Border control/ immigration
* Environmental protection
  + Pollution monitoring and control / response
* Waterways infrastructure management (including inland waterways)
  + AtoN operations and system optimisation
  + Infrastructure
* Maritime safety information (MSI)

## User data needs

An authority, organization or service that intends to undertake any of the above listed activities or operations requires timely, relevant and accurate data and information. Such data and information takes many forms and may be derived from many sources. While primarily focussing on vessels and environmental conditions, it may also address regulatory and technical matters. Furthermore, historical and baseline data and information need to be considered. The following list is, again, not intended to be exhaustive. It is meant to provide an indication of the range of data and information that is gathered, processed and exchanged by shore authorities, organizations and services in the conduct of their business and may be available for sharing.

### 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 (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 must 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.

It is also of concern that there must 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 must also be thought into 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 on the operational field (used by the transmitting VTS for example).

Sensor level sharing of data is usually less costly, but it provides less integrity and quality to data or the maritime information.

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 it may be transmitted after transiting through a VTS, but 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 transmitted after having been controlled after the sensor level according to the specifications given in Annex 10 (Data processing). It usually is information that also has been used by a VTS before being transmitted to other parties. As such, this information fulfils the suitability for purpose mentioned earlier and it is supposed to be exploitable by the end user.

### 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 thereafter as possible. Where time stamp is not the time of origin, it is desirable that the difference involved 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 of the aforementioned uses will be considerable. Given that many of these uses also require access to archive or historic data and information, consideration must 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. E.g., 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 localization 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 must be respected and the authorities involved must 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 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 equipments, 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.

### 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.

## Legal requirements to type approvals

Legal requirements vary from country to country, they are in continuous development and it is the responsibility of the VTS authority to ensure compliance.

National requirements to the VTS authority shall of cause be met, however, the tendency is to adopt international and regional standards and the below list reflect the most commonly used legislations and methods to ensure compliance.

On some aspects, the law requires test by accredited institutions on other aspects the VTS Authority can decide.

At time of editing of this document the following status on legal requirements to type approvals was obtained.

### Electrical Safety

Refer to Low Voltage Directive (LVD) 73/23/EEC or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU) and best ensured through fulfilling standard IEC60950-1, 2.ed

### Mechanical Safety

Refer to Machinery Directive 2006/42/EC applies to mechanical parts of the radar system, i.e. antennas, gearboxes or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU) Compliance can be documented by a mechanical safety analysis.

### Radiation Safety (Radar)

Refer to Physical Agents Directive 2004/40/EC or equivalent.

Compliance is required in order to obtain CE marking (mandatory within EU)

Compliance can be documented through measurement of RF power densities from transmitting radio equipment and radar.

However, for pulsed energy, measurement of power densities require sophisticated test equipment and it is normally accepted to verify worst case radiation levels and determine corresponding safety distances through an engineering report on power densities around the antenna utilizing the guidelines laid down by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

### ElectroMagnetic Compatibility

Refer to EMC Directive 2004/108/EC or equivalent.

Generic EMC standards used:

* Immunity as industrial equipment acc. to IEC 61000-6-2
* Emission as residential equipment acc. to IEC 61000-6-3.

Compliance is required in order to obtain CE marking (mandatory within EU)

### Radio Spectrum Requirements

#### EU Requirements:

Refer to R&TTE Directive 1999/5/EC or equivalent.

No harmonized test standards exist, it is recommended to follow the below guidelines:

* ECC/Recommendation (02)05 (2004): “Unwanted emissions”
* ERC/Recommendation 74-01 (2011): “Unwanted emissions in the spurious domain”

#### ITU Recommendations:

* ITU-R Recommendation SM.1541-3 (2011): “Unwanted emissions in the out-of-band domain”
* ITU-R Recommendation SM.329-11 (2011): “Unwanted emissions in the spurious domain”

#### US Federal Requirements

NTIA - Manual of Regulations and Procedures for Federal Radio Frequency Management

#### Chinese Radio Transmission Type Approval

Chinese Authorities require dedicated Chinese Type Approval, Compliant to ITU recommendations.

Special rules apply for Hong Kong (OFTA approval required)

### RoHS

Radar systems shall be designed to comply with the RoHS directive 2011/65/EU (RoHS II) by July 22. 2017.

China RoHS is also becoming a national requirement, but e.g. not affecting design of radar transceivers yet, but already requiring additional marking and documentation.

### Chemical Substances

REACH Directive (Regulation (EC) No 1907/2006)

Manufacturer must be able to document that no banned substances in concentrations above the limits are present in the product.

## Additional type tests

### Equipment in general

IALA recommends that all equipment is type tested , preferably by accredited institutes, to the standards and specification levels stated in ANNEX 1

ESD - They are labeled with yellow/black triangles.

### Software Verification

Remember network

## Factory Acceptance Test

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 must 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. Be specially aware of Safety Instructions.

### Procedure (Does it fall under the intention of V 128?)

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

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

### Procedure (Does it fall under the intention of V 128?)

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.

### Scenarios

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.

#### Continuous coverage

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

- insert illustration

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.

#### Test with controlled targets

Comparison to calculated performance, tolerances

#### Calibration of reference targets for radar

## The 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:

|  |  |  |
| --- | --- | --- |
| **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. |

### 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. This should be monitored, critical failures detected must be reported to operators without significant delay, temporary change to fallback methods (e.g. switch to other sensors) may be necessary and corrective measures shall be performed.

### 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)