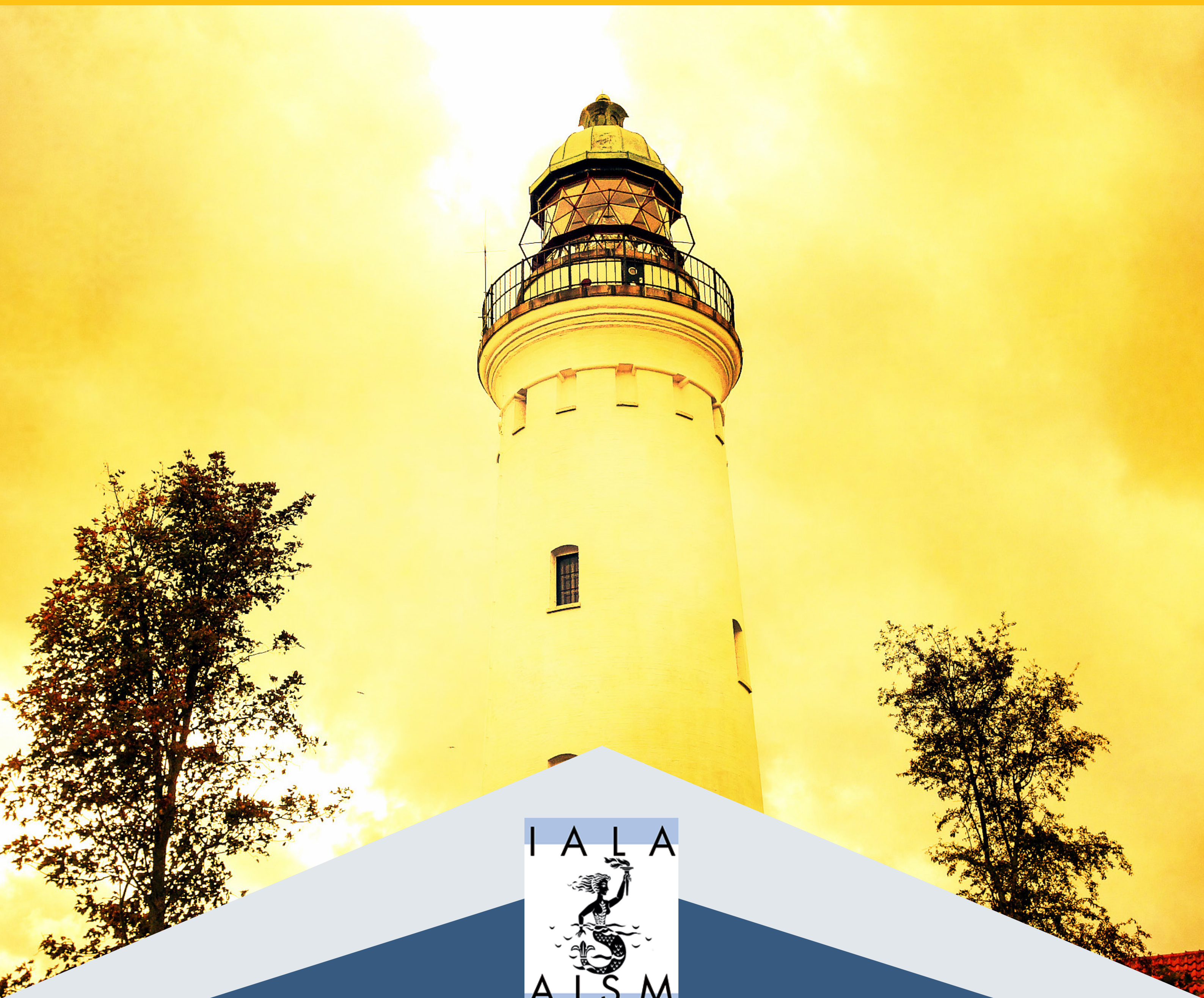
INTERNATIONAL ASSOCIATION OF MARINE
AIDS TO NAVIGATION AND LIGHTHOUSE AUTHORITIES



IALA
AISM

NAVGUIDE

AIDS TO NAVIGATION MANUAL

2014

SEVENTH EDITION

ACKNOWLEDGMENTS

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AIDS TO NAVIGATION MANUAL

2014

SEVENTH EDITION

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FOREWORD

FOREWORD

The NAVGUIDE has been a signature document and information source for IALA members and users now many years. The 2014 edition of the Guide continues on with this proud tradition and sees it updated with the latest information and developments in the field of Aids to Navigation technology and application.

The Guide is a product of four years collaboration by the world's leading experts on Aids to Navigation, produced by the four primary Committees of IALA, Aids to Navigation Management (ANM), Engineering, Environment and Preservation (EEP), e-Navigation (e-NAV) and Vessel Traffic Services (VTS). The ANM Committee has the primary oversight for its editing and production.

The Guide plays an important role within the IALA information suite and is regarded as a primary source of information for Aids to Navigation practitioners around the world, along with the other IALA Standards, Recommendations, Guidelines, Manuals and other publications.

As one of the 'must have publications' for Aids to Navigation practitioners, the Guide also has recently been incorporated as one of the key guidance documents for IALA's World-Wide Academy (WWA), Aids to Navigation Management training syllabus. 2014 saw the inaugural dedicated one-month Aids to Navigation Management Course conducted at IALA Headquarters in France and it is hoped that the success of this course will be replicated in other regions of the world over time.

The Guide has been translated into many other working languages over the years and IALA encourages this practise and is keen to work with country members to assist in this process and its dissemination into all regions of the world where English may not be the primary working language.

The 2014 edition of the IALA NAVGUIDE also sees its primary means of distribution being in a digital format which will be available on the new look IALA website (www.iala-aism.org) along with all the other information sources available to IALA members and users of Aids to Navigation. I encourage readers of this Guide to also consult the IALA website for other information references that may assist you in your day-to-day work in the field of Aids to Navigation.

As always, IALA is receptive to feedback on how the Guide may further be developed for future editions and welcomes suggestions for improvements (contact@iala-aism.org).

In closing, I would like to thank the IALA membership for helping to produce this 2014 edition of the NAVGUIDE and reflect on the unique nature of IALA that allows professionals from around the world who are already very busy in their own organisations, contribute their expertise to assist the international maritime community in improving and harmonising maritime aids to navigation.

Gary Prosser, IALA Secretary-General
April 2014


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1 INTRODUCTION TO IALA-AISM

1 INTRODUCTION TO IALA-AISM

1.1 Purpose and Scope

The purpose of this manual is to assist Aids to Navigation (AtoN) authorities in the harmonisation of marine AtoN by providing a first point of reference on all aspects of providing an AtoN service. The manual also provides references to more detailed guidance from IALA, IMO and related organisations on specific topics.

1.2 Background

Shipping is an international industry that is regulated through various organisations. Nations have recognised that it is both effective and appropriate to regulate and manage shipping on an international basis.

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a non-profit, international technical association devoted to the harmonisation of marine aids to navigation. IALA was formed in 1957 as a technical association to provide a framework for aids to navigation authorities, manufacturers and consultants from all parts of the world to work with a common effort to:

- harmonise standards for aids to navigation systems worldwide;
- facilitate the safe and efficient movement of shipping;
- enhance the protection of the marine environment.

The aim of IALA is to foster the safe and efficient movement of vessels through the improvement and harmonisation of marine aids to navigation worldwide, and by other appropriate means. It sets out to:

- harmonise aids to navigation systems and related services, including e-Navigation, Vessel Traffic Services, and emerging technologies, through international cooperation and the provision of standards;
- ensure that all coastal states contribute to an efficient global network of aids to navigation and services for the safety of navigation, through capacity building and the sharing of expertise.

The functions of IALA include:

- developing international cooperation by promoting close working relationships and assistance between members;
- collecting and communicating information on recent developments and matters of common interest in regard to aids to navigation including service delivery quality and efficiency, equipment reliability and contractor performance;
- addressing emerging navigational technologies, hydrographic matters, e-Navigation and vessel traffic management;

- liaising with organisations representing the aids to navigation users;
- liaising with relevant organisations such as the International Maritime Organisation (IMO), the International Hydrographic Organisation (IHO), the World Association for Waterborne Transport Infrastructure (PIANC), the Commission on Illumination (CIE), and the International Telecommunications Union (ITU);
- improving the global operation and management of aids to navigation systems and related services including Vessel Traffic Services (VTS) through capacity building activities and the World Wide Academy (WWA);
- providing specialist advice or assistance on aids to navigation issues including technical, organisational or training matters;
- establishing Committees or Working Groups to:
  - formulate and publish appropriate IALA recommendations, guidelines and manuals;
  - contribute to the development of international standards and regulations;
  - study specific issues.
- encouraging IALA members to develop policies that address social and environmental issues associated with establishing and operating aids to navigationch includes:
  - preservation of historic lighthouses;
  - use of aids to navigation as a base for the collection of data for other governmental or commercial services.
- organising Conferences, Symposiums, Seminars, Workshops and other events relevant to aids to navigation activities.

1.3 Membership

IALA has four types of members:

National Membership: Applicable to the national authority of any country that is legally responsible for the provision, management, maintenance or operation of marine aids to navigation.

Associate Membership: Applicable to any other service, organisation or scientific agency concerned with aids to navigation or related matters.

Industrial Membership: Applicable to manufacturers and distributors of marine aids to navigation equipment for sale, or organisations providing aids to marine navigation services or technical advice under contract.

Honorary Membership: May be conferred for life by the IALA Council to any individual who is considered to have made an important contribution to the work of IALA.

1.4 National Members

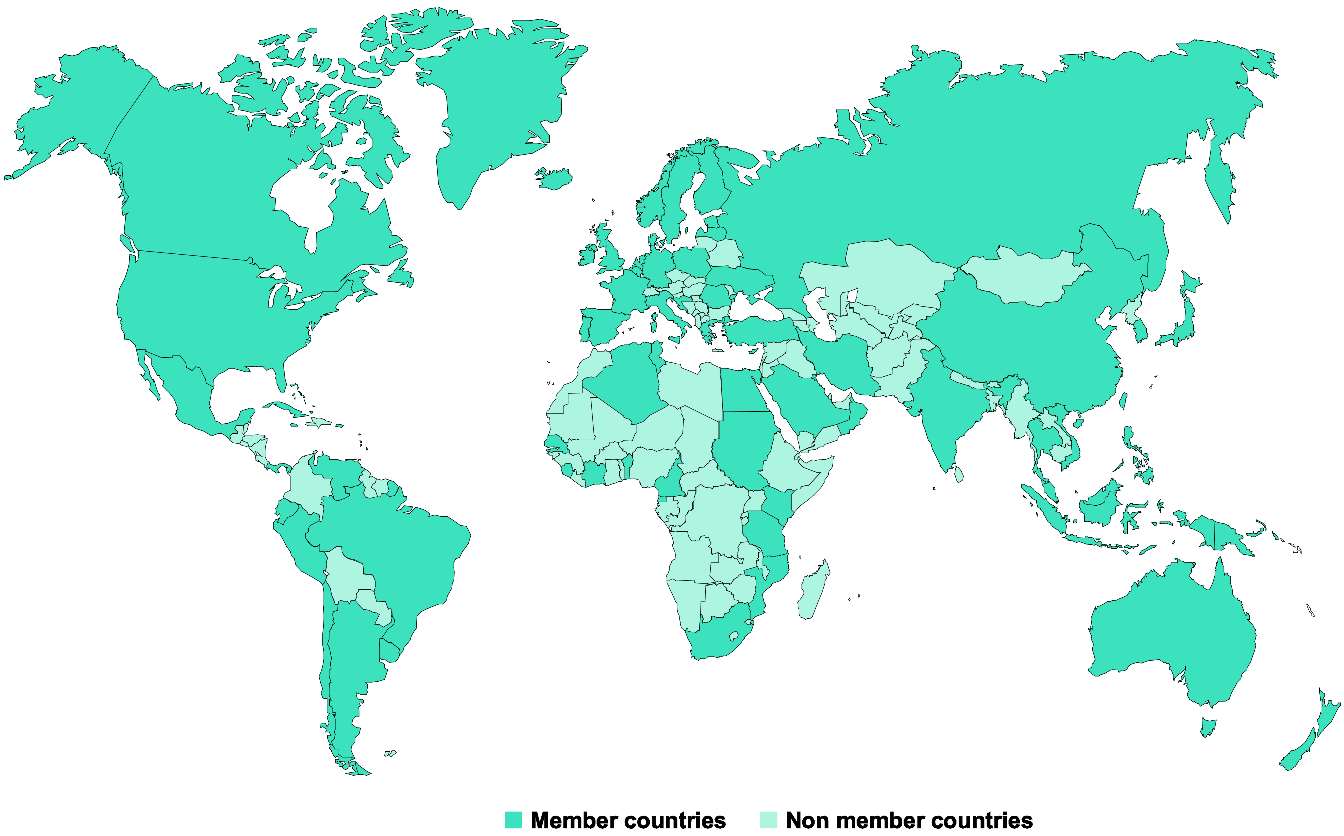


Figure 1 - IALA National Members

1.5 IALA Structure

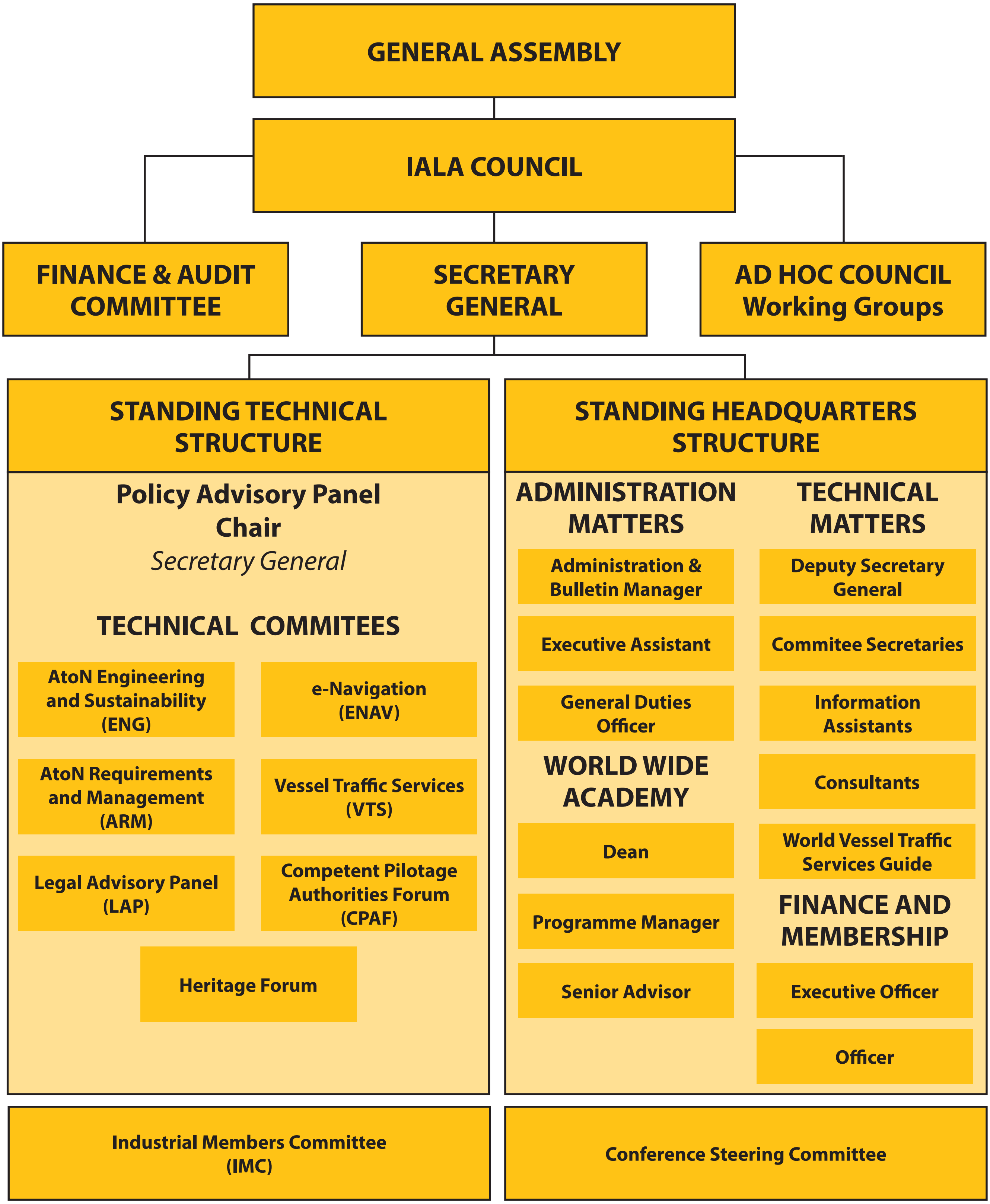


Figure 2 - IALA Organizational Structure

1.5.1 IALA Council

IALA is administered by a Council of up to twenty-two elected and two non-elected Councillors. The elected positions are determined by a ballot of all national members attending a General Assembly. Only one national member from any country may be elected to the Council and there is a general aim to draw Councillors from different parts of the world to achieve a broad representation on the Council.

The non-elected positions are held by the head of the national authority that will host the next IALA Conference and the head of the national authority that hosted the last IALA Conference.
The Council members elect a President, Vice President and a Financial Advisory Committee for the four (4) year term between Conferences. The Council also appoints a Secretary General to act as legal representative and Chief Executive of IALA.

The Council meets at least once each year and can be convened by either the President, the Vice President, the Secretary General, or at the request of any two councillors.

The functions of the Council are to:

- implement the overall policy of IALA as defined by its aims or by the General Assembly;
- establish Committees relevant to the aims of IALA and approve the positions of Chairman and Vice Chairman on each Committee;
- determine rules of procedure for Committees and their terms of reference;
- determine and review the strategic direction of IALA;
- approve IALA recommendations, standards and guidelines;
- decide the venue and the year of the next IALA Conference;
- establish rules for participation in IALA Conferences;
- convene General Assemblies;
- approve the annual budget and accounts;
- decide membership matters;
- determine the rate of subscriptions.

1.5.2 General Assembly

The General Assembly of the members of IALA is convened by the IALA Council and is normally concurrent with IALA Conferences, held every 4 years. The General Assembly, among other things, decides the overall policy of IALA and its Constitution and elects the members of the Council. National Members have voting rights at a General Assembly.

1.5.3 Policy Advisory Panel

The Policy Advisory Panel (PAP) is a group that comprises the Secretary General, members of the IALA Secretariat, the Chairs and vice-Chairs of each Committee and special advisors to IALA. The Panel meets at least once a year to review the work being done by the Committees.

The role of the PAP is to:

- identify any overlap of work between the Committees and to ensure that the work of the Committees is on schedule;
- review the general operation of the Committees;
- advise the IALA Council about the facilities at the Headquarters.

1.5.4 Committees

Committees are established by the Council to study a range of issues, as determined by the General Assembly, with the aim of preparing recommendations and guidelines for IALA members. In addition, the Committees prepare submissions to International Organisations. A committee may also be asked to provide continuous monitoring of elements of subjects that could influence decisions concerning the provision of Aids to Navigation, including Vessel Traffic Services.

The Council develops terms of reference for each Committee when it is established. The Council then reviews and amends terms of reference, as necessary, immediately prior to each Conference.

Committees meet regularly and are important to the work of IALA because they keep abreast of developments, including technological developments, relating to their area of expertise and prepare, review and revise relevant IALA publications in accordance with their approved Work Programme. The programmes for the Committees generally cover a 4-year study period, from one Conference to the next.

The documents created by the Committees address topics relating to management, operations, engineering, emerging technologies and training, and must be approved by the IALA Council.

All IALA members are invited to participate in the IALA Committees which include:

- AtoN Engineering and Sustainability (ENG) including the Heritage Forum;
- AtoN Requirements and Management (ARM);
- e-Navigation (ENAV);
- Vessel Traffic Services (VTS).

In addition to the Committees, IALA also uses two advisory forums:

Legal Advisory Panel (LAP): LAP is a group that comprises a chairperson and vice chairperson (both as appointed by the Council), IALA members with interest in legal affairs, representatives of relevant international organisations (as approved by the Secretary-General), and experts (as appointed by the Secretary-General).

The role of LAP is to provide:

- support to IALA on legal issues affecting IALA national members;
- support to IALA as an organisation on legal issues;
- guidance to the membership on best practices in the provision of aids to navigation services.

LAP is providing a forum to discuss legal matters of common interest with regards to the provision of aids to navigation services and identify where external legal advice may be needed.

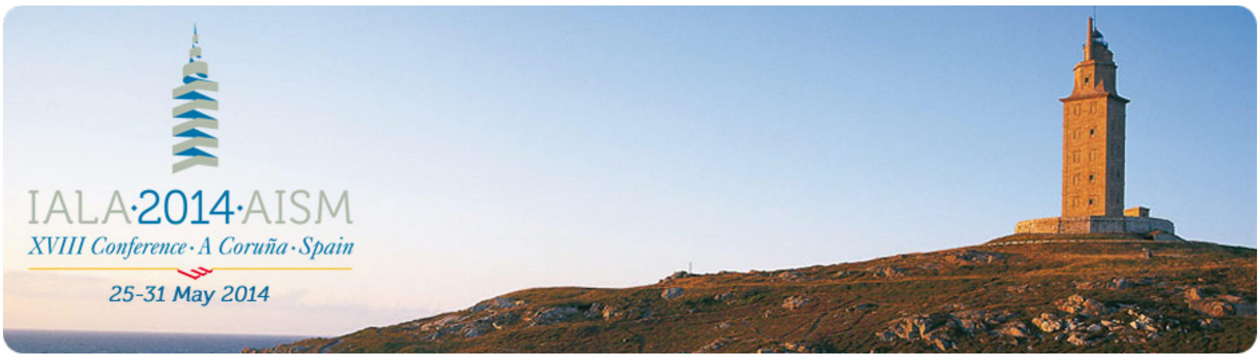
LAP is responding to issues and concerns that may be raised through the IALA Secretariat with respect to the development and providing guidance on the provision of aids to navigation services. Furthermore, LAP is identifying and maintaining a work programme to respond to changing issues within the aids to navigation environment.

Competent Pilotage[1] Authority Forum (CPAF): The CPAF is a group that comprises a chairperson (to be elected), IALA members, competent pilotage authorities (as invited by the Secretary-General), representatives of relevant international organisations (as approved by the Secretary-General) and the Secretary-General of the International Marine Pilots Association (IMPA) (observer status).

The role of the CPAF is to provide a forum for competent pilotage authorities to discuss pilotage matters with the aim of harmonising pilotage governance on an international basis, concentrating on pilotage governance (management and regulation) and not pilotage service issues.

The forum will list key issues of common concern for competent pilotage authorities and will identify an action plan to work proactively with related international organisations to promote harmonization of service delivery.

1.5.5 Conferences, Symposiums and Exhibitions



IALA holds a general aids to navigation Conference every four (4) years. These Conferences may be attended by IALA members and also by non-member aids to navigation authorities.

[1] Competent pilotage authority means the national or regional governments legally responsible for the provision of a pilotage system.

Papers, presentations and discussions address a wide range of marine aids to navigation issues. The work of IALA over the previous four years is also presented. All members are invited to submit papers for discussion.

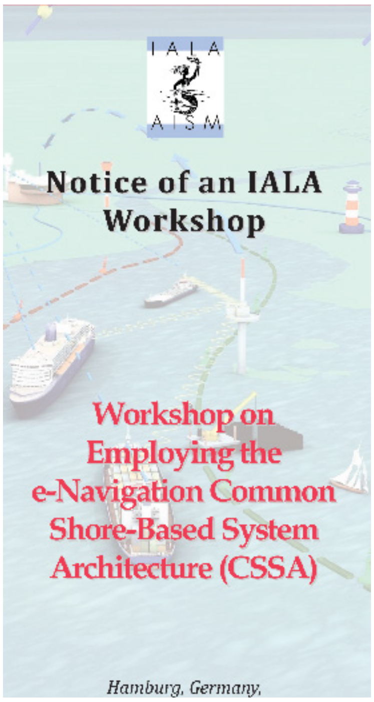
The Industrial Member's Committee traditionally organizes an Industrial Exhibition in conjunction with the Conference.

IALA traditionally holds the General Assembly in conjunction with the Conference. The IALA work term traditionally spans the four (4) years between Conferences.

In addition, IALA may hold a Symposium on a specific topic of interest to the members. An example is the IALA VTS Symposium, held every four (4) years, two years separated from the IALA Conference.

1.5.6 Workshops and Seminars

IALA convenes Workshops and Seminars to address topics that may arise during the work term.



Workshops are special meetings convened for the purpose of making maximum use of the technical expertise of participants to further the work of the Association on a specified subject or topic. They also enable skills and comprehension of new techniques to be learned by detailed lectures combined with simulation or similar "hands on" methods.

Seminars are small meetings of specialists on a specified subject or topic convened for the purpose of consultations by means of the presentation of papers on the subject or topic followed by question and answer sessions.

IALA has published internal guidelines on the preparation of a Workshop or Conference. Approval to convene a Workshop or Seminar may be given by the Council on the recommendation of the Secretary General.

1.5.7 Forums

In order to promote exchange of information and coordination of AtoN provision, IALA arranges a number of forums where IALA members and other interested parties can meet periodically to discuss specific topics.

1.6 IALA Publications

IALA is responsible to its membership for production of a comprehensive set of publications that have the primary objective of facilitating a uniform approach to marine AtoN positioning, navigation and timing systems worldwide.

The types of publications include:

IALA Recommendations:
These documents represent the highest level of IALA documentation equivalent to a 'standard' in an intergovernmental organization). Recommendations provide direction to IALA members on uniform procedures and processes that will facilitate IALA objectives. IALA recommendations contain information on how members should plan, operate and manage Aids to Navigation. Recommendations may reference relevant International Standards and IALA Guidelines.

IALA Guidelines:
These documents provide detailed information on an aspect of a specific subject, indicating options, best practices and suggestions for implementation. IALA Guidelines relate to planning, operating and managing Aids to Navigation.

IALA Manuals:
These documents provide an overall view of a large subject area. Whilst aimed at introducing a subject to a widely varied readership, reference is also made to IALA Guidelines and IALA Recommendations, as well as other related international documents, as an indicator of further study.

IALA publications are governed by a set of principles including:

Usability – The system should be as intuitive as possible, be inclusive for all IALA documents while maintaining the existing numbering scheme for IALA Recommendations.

Visibility - Presentation of documents should present a 'common look and feel', providing a visual indication of an IALA document, as well as a visual clue as to the type of IALA document.

Validity - The date of issue and date of amendment/edition should be clearly visible to ensure that members have the most up-to-date information available.

Availability - Documentation related to the safety of navigation should ideally be provided to all who have need of the information – i.e. available, in electronic form, at no charge for download from the IALA web.

1.6.1 IALA Recommendations

IALA Recommendations represent the highest level of IALA documentation. Recommendations provide direction to IALA members on uniform procedures and processes that will facilitate IALA objectives. IALA recommendations contain information on how the members should plan, operate and manage Aids to Navigation and may reference relevant International Standards and IALA Guidelines.

Recommendations are identified by an alphanumeric (hundred series) number:

- A-### representing recommendations relating to AIS issues.
- E-### representing recommendations relating to Engineering and Environmental issues.
- e-NAV-### representing recommendations relating to e-Navigation issues.
- H-### representing recommendations relating to Heritage Considerations
- O-### representing recommendations relating to Operational and Management issues.
- R-### representing recommendations relating to radio-navigation issues.
- V-### representing recommendations relating to VTS issues.

There is an implicit expectation that individual national members will observe and implement IALA Recommendations.

IALA Recommendations are available in PDF format on the IALA website, for download by interested parties, free of charge (www.iala-aism.org).

1.6.2 IALA Guidelines

These documents provide detailed, in-depth information on an aspect of a specific subject, indicating options, best practices and suggestions for implementation. IALA Guidelines relate to planning, operations and managing Aids to Navigation.

Guidelines are identified with a sequential numerical reference (thousand series), but with no letter indication. They continue to be identified by their title – e.g. 'IALA Guideline 1001' 'IALA Guidelines on the Design of Leading Lines'.

IALA Guidelines are available in pdf format on the IALA website, for download by interested parties, free of charge (www.iala-aism.org).

1.6.3 IALA Manuals

IALA Manuals provide members, non-members and training institutions with an overall view of a large subject area – for example the NAVGUIDE and the IALA VTS Manual. While introducing the subject to a varied audience, reference is also made to IALA Guidelines and IALA Recommendations, as well as other related international documentation.

> *IALA Manuals are available from IALA Headquarters at a nominal charge to cover printing and shipping costs.*

1.6.4 IALA Dictionary

The IALA Dictionary provides a listing of words and phrases used to explain and describe planning, operations, management, equipment, systems and scientific terms relevant to AtoN.

1.6.5 IALA World Wide Academy

The World Wide Academy (WWA) facilitates capacity building through provision of model training courses and activities to improve the global operation and management of aids to navigation systems and related services including VTS.

1.6.6 Other Documentation

Other documentation available from IALA on request includes:

- Conference Proceedings;
- Reports (meetings, workshops, seminars, etc.);
- IALA Bulletin (a quarterly magazine);
- IALA List of Publications.

IALA endeavours to provide all publications at no or minimal cost.

1.6.7 Related Organisations

IALA works in close cooperation with a number of other international maritime organisations to further its objective of harmonising marine AtoN.

International Maritime Organisation (IMO)

The IMO is a specialist agency of the United Nations with 168 Member States and three Associate Members. IMO is based in the United Kingdom with over 300 staff. IMO's main task is to maintain a comprehensive regulatory framework for shipping. Its remit today includes safety, environment concerns, legal matters, technical cooperation, maritime security and the efficiency of shipping. IMOs specialised committees and sub-committees are the focus for the technical work to update existing legislation or develop and adopt new regulations. IMO is attended by maritime experts from Member governments and interested intergovernmental and non-government organisations.

IMO is responsible for key treaties such as Safety of Life at Sea 1974 (SOLAS), the MARPOL convention for the prevention of pollution by ships and the STCW convention on standards of training of seafarers.

The World Association for Waterborne Transport Infrastructure (PIANC)
PIANC is a global, non-political and non-profit organisation providing guidance for sustainable waterborne transport infrastructure for ports and waterways. PIANC is a forum where professionals around the world join forces to provide expert advice on cost-effective, reliable and sustainable infrastructure to facilitate the growth of waterborne transport. Established in 1885, PIANC is the leading partner for government and private sector in the design, development and maintenance of ports, waterways and coastal areas. Members include national governments and public authorities, corporations and interested individuals.

International Electrotechnical Commission (IEC)
The IEC is the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies. These serve as a basis for national standardisation and as references when drafting international tenders and contracts. The IEC charter embraces all electrotechnologies including electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication, and energy production and distribution, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety and the environment.

International Telecommunications Union (ITU)
The ITU is the leading United Nations agency for information and communication technology issues, and the global focal point for governments and the private sector in developing networks and services. Established for approximately 145 years, ITU is based in Geneva, Switzerland, and its membership includes 191 Member States and more than 700 Sector Members and Associates. ITU coordinates the shared global use of the radio spectrum, promotes international cooperation in assigning satellite orbits, works to improve telecommunication infrastructure in the developing world, establishes the worldwide standards that foster seamless interconnection of a range of communications systems and addresses global challenges, such as mitigating climate change and strengthening cybersecurity.

1.8 Definitions

Aid to Navigation (AtoN): Any device or system, external to a vessel, which is provided to help a mariner determine position and course, to warn of dangers or of obstructions, or to give advice about the location of a best or preferred route.

Automatic Identification System (AIS): A broadcast transponder system, operating in the VHF maritime mobile band by which a vessel communicates a range of ship and voyage information.

Competent Authority: The authority made responsible, in whole or in part, by the Government for the safety, including environmental safety, and efficiency of vessel traffic and the protection of the environment. Refer to IMO Resolution A.857(20).

Mandatory Ship Reporting System: A ship reporting system that requires the participation of specified vessels or classes of vessels, and that is established by a government or governments after adoption of a proposed system by the International Maritime Organization (IMO) as complying with all requirements of regulation V/8–1 of the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS), except paragraph (e) thereof.

Stakeholder(s): Any individual, group, or organization able to affect, be affected by, or believe it might be affected by a decision or activity. The decision maker(s) is a stakeholder.

2 CONCEPTS AND ACCURACY OF NAVIGATION

2 CONCEPTS AND ACCURACY OF NAVIGATION

Competent aids to navigation authorities are generally established to provide a navigational safety regime that facilitates trade and economic development. The primary services are therefore directed towards the needs of commercial trading vessels. In some areas, authorities may provide additional services for ferries, fishing and recreational vessels and specialised maritime activities.
This chapter looks at the methods of navigation and accuracy requirements from the perspective of commercial trading vessels.

2.1 Navigation Methods

IMO Resolution A.915(22) defines navigation as "the process of planning, recording and controlling the movement of a craft from one place to another."

Wherever possible it is recommended that reliance on a single method of determining position is avoided. The principal methods of marine navigation are briefly described as follows:

Terrestrial Navigation: navigation using visual, radar and, (if appropriate) depth sounding observations of identifiable, conspicuous features, objects and marks to determine position.

Celestial or Astronomical Navigation: navigation using observation of celestial bodies (ie sun, moon, planets and stars) to determine position.

Dead Reckoning: navigation based on speed, elapsed time and direction from a known position. The term was originally based on the course steered and the speed through the water, however, the expression may also refer to positions determined by the use of the course and speed expected to be made good over the ground, thus making an estimated allowance for disturbing elements such as current and wind. A position that is determined by this method is generally called an estimated position.

Radionavigation: navigation using radio signals to determine a position or a line of position (e.g. eLORAN, GPS, DGPS etc).

2.2 Accuracy Standards of Navigation

IMO Resolution A.915(22) established accuracy standards for maritime navigation.

Table 1 presents the relevant standards adopted in Appendixes 2 and 3 of IMO Resolution A.915(22). Appendix 2 includes the requirement for an accuracy of 10 m on ocean navigation, while IMO Resolution A.953(23) mentions that "where a radionavigation system is used to assist in the navigation of ships in ocean waters, the system should provide [an accuracy of] 100 m with a probability of 95%".

Application	Absolute Horizontal Accuracy (95%) / (m)
General Navigation:	
Ocean	10-100
Coastal	10
Restricted waters	10
Port	1
Inland waterways	10
Hydrography	1-2
Oceanography	10
Aids to Navigation Management	1
Port Operations:	
Local VTS	1
Container/cargo management	1
Law enforcement	1
Cargo handling	0.1

Table 1 - Minimum Maritime User Requirements

2.3 Phases of Navigation

Typically, navigation is divided into three phases: ***ocean navigation***, ***coastal navigation*** and ***restricted waters*** navigation. Some documents have introduced other phases, namely harbour approaches, port and inland waterways navigation.

The ***harbour approach*** phase is an aspect of the restricted waters phase, but will be treated separately in this manual.

Port and inland waterway navigation are two aspects of ***restricted waters*** navigation and will not be dealt with separately in this manual, as the precautions and measures required for restricted waters navigation also apply to these waters.

2.3.1 Ocean Navigation

In this phase, the vessel is typically:

- beyond the continental shelf (200 metres in depth) and more than 50 nm from land;
- in waters where position fixing by visual reference to land, charted fixed offshore structures, or to fixed or floating aids to navigation, is not practical;
- sufficiently far from land masses and traffic areas that the hazards of shallow water and of collision are comparatively small.

Although the IMO has adopted stricter accuracy requirements (see *Table 1*) the minimum navigational requirements for the Ocean Phase are considered to be a predictable accuracy of 2 to 4 nm, combined with a desired fix interval of 15 minutes or less (maximum 2 hour fix interval). The required accuracy in the Ocean Phase is based on providing the ship with the capability to correctly plan the approach to land or restricted waters.

The economic efficiency aspects of shipping (e.g. transit time and fuel consumption) are enhanced by the availability of a continuous and accurate position fixing system that enables a vessel to follow the shortest safe route with precision.

2.3.2 Coastal Navigation

In this phase, the vessel is typically:

- within 50 nm from shore or the limit of the continental shelf (200 meters in depth);
- in waters contiguous to major land masses or island groups, where transoceanic routes tend to converge towards destination areas and where inter-port traffic exists in patterns that are essentially parallel to coastlines.

The vessel may encounter:

- ship reporting systems (SRS) and coastal vessel traffic services (VTS);
- offshore exploitation and scientific activity on the continental shelf;
- fishing and recreational boating activity.

The Coastal Phase is considered to exist when the distance from shore makes it feasible to navigate by means of visual observations, radar and, if appropriate, by depth (echo) sounder. As with the Ocean Phase, the distances from land can be varied to take account of the smaller vessels and local geographical characteristics.

Although the IMO has adopted stricter accuracy requirements (see *Table 1*), international studies have established that the minimum navigation requirements for commercial trading vessels operating in the Coastal Phase is a navigation system capable of providing fix positioning to an accuracy of 0.25 nautical miles, combined with a desired fix interval of 2 minutes to a maximum of 15 minutes).

More specialised maritime operations within the Coastal Phase may require navigational systems capable of a higher repeatable accuracy, either permanently or on an occasional basis. These operations can include marine scientific research, hydrographic surveying, commercial fishing, petroleum or mineral exploration and Search and Rescue (SAR).

It is not always practical, given the manning of most vessels, to plot fixes at the desired interval of 2 minutes on a chart in the traditional way. GPS and DGPS (and in the future, in some areas, enhanced Loran (eLORAN)) provide a means of exceeding the IMO Coastal Phase requirements for positional accuracy and fix rates when integrated with Electronic Chart Systems (ECS) or Electronic Chart Display Information System (ECDIS) technology

2.3.3 Harbour Approach

This phase represents the transition from coastal to harbour navigation. In this phase the:

- vessel moves from the relatively unrestricted waters of the coastal phase into more restricted and more heavily used waters near and/or within the entrance to a bay, river, or harbour;
- navigator is confronted with a requirement for more frequent position fixing and manoeuvring the vessel to avoid collision with other traffic and grounding dangers;

The ship will generally be within:

- the coverage areas of aids to navigation of varying complexity (including lights, racons, leading lights and sector lights);
- pilotage areas;
- the boundaries of SRS and VTS.

Safety of navigation issues that arise during the Harbour Approach Phase impose more stringent requirements on positional accuracy, fix rates and other real-time navigational information than those required during the Coastal Phase.

GPS and DGPS (and in the future, in some areas, enhanced Loran (eLORAN) provide a means of achieving the Harbour Approach requirements for high positional accuracy and fix rates at better than 10-second intervals when integrated with Electronic Chart Systems (ECS) and the Electronic Chart Display Information System (ECDIS) technology.

2.3.4 Restricted Waters

While similar to the Harbour Approach Phase, in the proximity to dangers and the limitations on freedom of manoeuvre, a Restricted Waters Phase can also develop during a coastal navigation phase, such as in various Straits around the world.

The Pilot or Master of a large vessel in restricted waters must direct its movement with great accuracy and precision to avoid grounding in shallow water, striking submerged dangers or colliding with other craft in a congested channel. If a large vessel finds itself in an emerging navigational situation with no options to alter course or stop, it may be forced to navigate to limits measured to within a few metres in order to avoid an accident.

Requirements for safety of navigation in the Restricted Waters Phase make it desirable for navigation systems to provide:

- accurate verification of position almost continuously;
- information depicting any tendency for the vessel to deviate from its intended track;
- instantaneous indication of the direction in which the ship should be steered to maintain the intended course.

These requirements are not easily achievable through the use of visual aids and ships' radar alone, but as with Harbour Approach navigation, they can be achieved with a combination of GPS/DGPS (and in the future enhanced Loran (eLORAN)) and Electronic Chart Systems (ECS) or Electronic Chart Display Information System (ECDIS) technology.

Photo Courtesy of Wasser und Schifffahrtsdirektion (Germany)

2.4 Measurement Errors and Accuracy

Good practice in both navigation and aids to navigation design dictates that an indication of the error or uncertainty in measuring a parameter or in obtaining a position fix should be reported along with the derived result.

2.4.1 Measurement Error

The ***measurement error*** is defined as the difference between the true value and the measured value. In general, three types of errors are recognised:

Systematic Errors: Also known as fixed or bias errors. They are errors that persist and are related to the inherent accuracy of the equipment, or result from incorrectly calibrated equipment. This type of error can to some extent be foreseen and compensated for.

Random Errors: Cause readings to take random values either side of some mean value. They may be due to the observer/operator, or the equipment, and are revealed by taking repeated readings. This type of error can neither be foreseen, nor totally compensated for.

Faults and Mistakes: Errors of this type can be reduced by appropriate training and by following defined procedures.

2.4.2 Accuracy

In a process where a number of measurements are taken, the term ***accuracy*** refers to the degree of conformity between the measured parameter at a given time and its true parameter at that time.The term ***parameter*** includes: position, coordinates, velocity, time, angle, etc..

For navigational purposes, four types of accuracy can be defined:

Absolute Accuracy (Geodetic or Geographic Accuracy): The accuracy of a position with respect to the geographic or geodetic coordinates of the Earth.

Predictable Accuracy: The accuracy with which a position can be defined when the predicted errors have been taken into account. It therefore depends on the state of knowledge of the error sources.

Relative or Relational Accuracy: The accuracy with which a user can determine position relative to that of another user of the same navigation system at the same time.

Repeatable Accuracy: The accuracy with which a user can return to a position whose coordinates have been measured at a previous time using uncorrelated measurements from the same navigation system.

For general navigation, the ***Absolute*** and ***Predictable Accuracy*** are the principal concerns.

Repeatable Accuracy: This is of interest to fishermen, the offshore oil and gas industry, ships making regular trips into an area of restricted waters and authorities when positioning floating aids.

Accuracy of a Position Fix: A minimum of two lines of position (LOP) are necessary to determine a position at sea. Since there is an error associated with each LOP, the position fix has a two dimensional error. There are many ways of analysing the error boundary; however, the radial position error relative to the true position, taken at the 95% probability level, is the preferred method.

Navigational Position Fixing Measurements: *Table 2* shows the typical accuracy (95% probability) achieved using common navigational instruments or techniques.

Process	Typical accuracy (95% probability)	Accuracy at 1 NM (metres)
Magnetic compass bearing on a light or landmark	±3° Accuracy may deteriorate in high latitude	93
Gyro-compass bearing on a light or landmark	0.75° X secant latitude (below 60° of latitude)	< 62
Radio direction finder	±3° to ±10°	93 - 310
Radar bearing	±1° Assuming a stabilized presentation and a reasonably steady craft	31
Radar distance measurement	1 % of the maximum range of the scale in use or 30 metres, whichever is the greater	
LORAN-C / CHAYKA	30 m	
eLoran	8-10 m	
GPS	5-10 m	
DGPS (GNSS) (ITU-R M.823/1 Format)	1-3 m	
Dead Reckoning (DR)	Approximately 1 nautical mile for each hour of sailing	

Table 2 - Fixing Processes and Systems

2.5 Hydrographic Considerations

2.5.1 Charts

The IMO definition[2] of a nautical chart or nautical publication is a special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorised Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation. Nautical charts provide a graphical representation of a plane surface of a section of the earth's sea surface constructed to include known dangers and aids to navigation.

The principal international organisation on charting matters is the International Hydrographic Organisation (IHO).

The IHO is an intergovernmental consultative and technical organization that was established in 1921 to support the safety in navigation and the protection of the marine environment.

[2] SOLAS Chapter V, Regulation 2.

The object of the IHO is to bring about the:

- coordination of the activities of national hydrographic offices;
- greatest possible uniformity in nautical charts and documents;
- adoption of reliable and efficient methods of carrying out and exploiting hydrographic surveys;
- development of the science of hydrography and the techniques employed in descriptive oceanography.

IMO is the body responsible for determining international standards for the quality of hydrographic surveys and chart production.

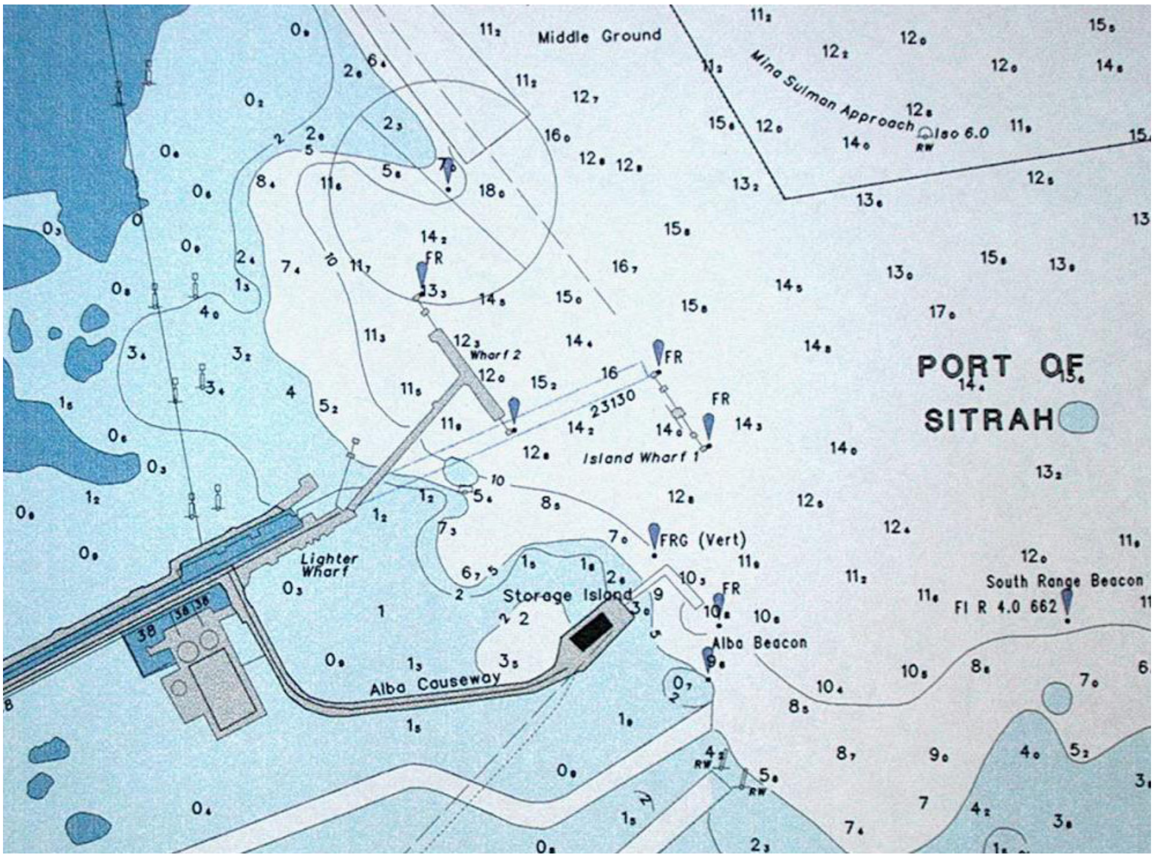


Figure 3 - Nautical Chart (Wikimedia Commons)

2.5.2 Datum

In its simplest form, a datum is an assumed or defined starting point from which measurements are taken.

A more complex example of a datum is a Geodetic Datum used in the mathematical representation of the earth's surface. Many different data (plural of datum) have been devised over time to define the size and shape of the earth and the origin and orientation of coordinate systems for chart and mapping applications. These have evolved from the consideration of a spherical earth, through to the geoid and ellipsoidal models, and also the planar projections used for charts and maps.

The ***geoid*** model considers the earth's surface to be defined as the equipotential surface[3] that would be assumed by the sea level in the absence of tides, currents, water density variations and atmospheric effects.

A further approximation uses an ***ellipsoid***, which is a smooth mathematical surface, to give a best-fit match of the geoid. Early ellipsoid models were developed to suit the mapping and charting of local regions or countries. However they would not necessarily provide a satisfactory solution in other parts of the world. Some nautical chart still carry a legend referring to a local datum, for instance, Ellipsoid Hayford or International – Datum Potsdam, Paris or Lisbon

Chart Datum

Chart datum is defined as the datum or plane of reference to which all charted depths and drying heights are related. It is relevant to a localised area and is a level that the tide will not frequently fall below. It is usually defined in terms of ***Lowest Astronomical Tide*** (and in some cases by Indian Spring Low Water).

Levelling Datum or Vertical Control Datum

These are generic terms for levelling surfaces that are used to determine levels or elevations. Using nautical charts as an example:

- water depths are measured from Chart Datum to the seabed;
- elevations of land masses and man-made features are referenced to either ***Mean High Water Springs*** (where there are predominantly semi-diurnal tides) or ***Mean Higher High Water*** (where there are predominantly diurnal tides)[4];
- clearance heights for bridges are generally referenced to ***Highest Astronomical Tide***.

These levels are depicted in *Figure 4.*

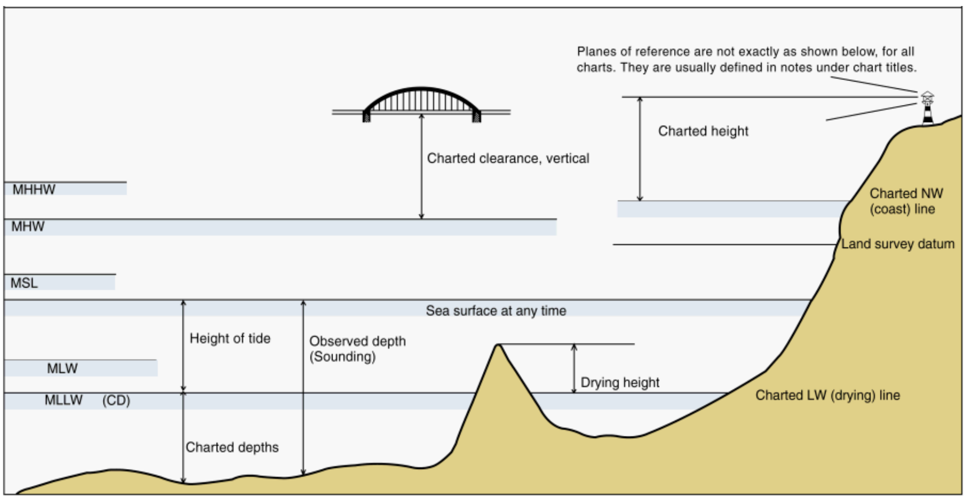


Figure 4 - Levelling or Vertical Control Datum (IHO)

[3] These have the same potential gravity at each point.
[4] It should be noted that elevations of land features on maps are generally referenced to **Mean Sea Level**.

Level Description	Abbreviation
Highest Astronomical Tide: the highest tidal level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions (IHO Dictionary, S-32, 5th Edition, 2244)	HAT
Mean Higher High Water: the average height of higher high waters at a place over a 19-year period. (IHO Dictionary, S-32, 5th Edition, 3140)	MHHW
Mean High Water Springs: the average height of the high waters of spring tides. Also called spring high water. (IHO Dictionary, S-32, 5th Edition, 3144)	MHWS
Mean Sea Level: the average height of the surface of the sea at a tide station for all stages of the tide over a 19-year period, usually determined from hourly height readings measured from a fixed predetermined reference level. (IHO Dictionary, S-32, 5th Edition, 3156)	MSL
Mean Low Water Springs: the average height of the low waters of spring tides. Also called spring low water. (IHO Dictionary, S-32, 5th Edition, 3150)	MLWS
Mean Lower Low Water: the average height of the lower low waters at a place over a 19-year period. (IHO Dictionary, S-32, 5th Edition, 3145)	MLLW
Indian Spring Low Water: a tidal datum approximating the level of the mean of the lower low water at spring tides. Also called Indian tidal plane. (IHO Dictionary, S-32, 5th Edition, 2427) ISLW was defines by G.H. Darwin for the tides of India at a level below MSL and is found by subtracting the sum of the harmonic constituents M2, S2, K1 and O1 from Mean Sea Level	ISLW
Lowest Astronomical Tide: the lowest tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. (IHO Dictionary, S-32, 5th Edition, 2936)	LAT

Table 3 – Levels Relevant to Aids to Navigation in Coastal and Restricted Waters

Chart Datum Issues

Until satellite navigation became commonly used, nautical charts were generally produced to local and national datum. The now widely used GPS positioning system uses an earth centred datum referred to as World Geodetic System[5] 1984 (WGS-84) which is considered to be the best compromise for representing the whole of earth's surface.

Generally, WGS-84 is the geodetic system associated with the differential correction information broadcast by maritime DGPS stations using the ITU-R M.823/1 signal format.

[5] The World geodetic system (WGS) is a consistent set of parameters for describing the size and shape of the earth, positions of a network of points with respect to the centre of mass of the Earth, transformations from major geodetic data and the potential of the Earth. (IMO Resolution A860(20)).

The IHO Technical Resolution B1.1 recommends that all countries that issue national navigational charts should base these on the WGS 84 geodetic system. For many countries this simple objective represents a formidable workload and will take a number of years to achieve. Consequently, many nautical charts will continue to refer to data other than WGS-84 and discrepancies of several hundred metres can exist between a GPS derived position and the charted position.

During this transitional period, it is important for navigators and other persons using charts to:

- be aware of the datum applicable to the chart in use;
- include the applicable reference datum when communicating a measured position;
- determine whether or not a satellite derived position can be directly plotted onto a chart. In some cases a chart will include information for adjusting a satellite derived position to align to the chart datum;
- be aware that some GPS receivers have the facility to automatically convert (and display) WGS-84 positions into other geodetic coordinate systems. The user should be aware of the settings that have been applied to the receiver.

Examples of the styles of note found on some charts[6] are shown in *Figure 5*.

SATELLITE-DERIVED POSITIONS
Positions obtained from the Global Positioning System (GPS) in the WGS 1984 Datum must be moved 0.09 minutes SOUTHWARD and 0.06 minutes WESTWARD to agree with this chart.

SATELLITE-DERIVED POSITIONS
Positions obtained from the Global Positioning System (GPS) in the WGS 1984 Datum can be plotted directly onto this chart.

SATELLITE-DERIVED POSITIONS
Positions obtained from the Global Positioning System (GPS) in the WGS 1984 Datum cannot be plotted directly onto this chart. The difference between GPS positions and positions on this chart cannot be determined; mariners are warned that these differences may be significant and are advised to use alternative sources of positional information, particularly when closing the shore or navigating in the vicinity of dangers.

Figure 5 – Examples of GPS Notes on Charts

2.5.3 Accuracy of Charts

At a national level, it is important that the Authorities responsible for aids to navigation and hydrographic services work together to ensure that both the network and the mix of aids to navigation are provided, and the available charts are appropriate for mariners to navigate safely. Source quality indication are provided for official ENC charts (ZOC, zones of confidence), source quality indication might also be indicated on the back of some national papercharts. Mariners should always consider this information, as official charts (both electronic and paper) might be based on old measurements of poor or unknown quality.

[6] Examples taken from Australian Charts.

1	2	3	4	5
ZOC [1]	Position Accuracy [2]	Depth Accuracy [3]	Seafloor Coverage	Typical Survey Characteristics [5]
A1	± 5 m	=0.50 + 1%d Depth (m) – Accuracy (m) 10 – ± 0.6 30 – ± 0.8 100 – ± 1.5 1000 – ± 10.5	Full area search undertaken. All significant seafloor features detected [4] and depths measured.	Controlled, systematic survey [6] high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.
A2	± 20 m	= 1.00 + 2%d Depth (m) – Accuracy (m) 10 – ± 1.2 30 – ± 1.6 100 – ± 3.0 1000 – ± 21.0	Full area search undertaken. All significant seafloor features detected [4] and depths measured.	Controlled, systematic survey [6] achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder [7] and a sonar or mechanical sweep system.
B	± 50 m	= 1.00 + 2%d Depth (m) – Accuracy (m) 10 – ± 1.2 30 – ± 1.6 100 – ± 3.0 1000 – ± 21.0	Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echosounder [5], but no sonar or mechanical sweep system.
C	± 500 m	= 2.00 + 5%d Depth (m) – Accuracy (m) 10 – ± 2.5 30 – ± 3.5 100 – ± 7.0 1000 – ± 52.0	Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.
D	worse than ZOC C	Worse Than ZOC C	Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.
U	Unassessed - The quality of the bathymetric data has yet to be assessed			

Table 4 – Zones of Confidence (IHO)

The accuracy requirements for general navigation can be related to the scale of the chart necessary for each part of the passage which in turn will be determined by the local conditions and type of vessel. Chart scales with the corresponding accuracy requirements recommended by IHO and the equivalent dimension of a 0.5 mm dot on a chart are found in *Table 5*.

Chart scale[7]	Corresponding need for accuracy (metres)	Approximate pencil width (0.5 mm) equivalence (metres)[8]	Application
1:10,000,000	10,000	5000	
1:2,500,000	2,500	1250	Ocean navigation
1:750,000	750	375	Ocean navigation
1:300,000	300	150	Coastal navigation
1:100,000	100	50	Coastal navigation
1:50,000	50	25	Approach
1:15,000	15	7.5	Approach
1:10,000	10	5	Restricted waters
1:5,000	5	2.5	Harbour plans

Table 5 – Chart Scales, Applications and Related Accuracy Considerations

2.5.4 Charted Buoy Positions

No reliance can be placed on floating aids always maintaining their exact positions. Buoys should, therefore be regarded with caution and not as infallible navigating marks, especially when in exposed positions. A ship should always, when possible, navigate by bearings of fixed objects or angles between them, and not by buoys.

[7] The chart scale is generally referenced to a particular latitude eg. 1:300,000 at lat 27° 15' S.
[8] This information may be helpful in assessing the practical accuracy requirements for laying buoy moorings.

3 AIDS TO NAVIGATION

3 AIDS TO NAVIGATION

A marine **Aid to Navigation (AtoN)** is a device or system external to vessels that is designed and operated to enhance the safe and efficient navigation of vessels and/or vessel traffic. A marine aid to navigation should not be confused with a **navigational aid**. A navigational aid is an instrument, device, chart, etc., carried on board a vessel for the purpose of assisting navigation.

This chapter describes the major types of visual and other physical aids to navigation in current use and provides comments on the application and performance of the various technologies. Vessel Traffic Services (VTS), are also considered by IALA as satisfying the definition of an aid to navigation. However these are covered in separate chapters due to their increasingly significant role in contributing to navigation safety.

The concept of e-Navigation has recently gained significant momentum and a framework is being developed under the auspices of the IMO. IALA has been requested by the IMO to develop the shore-based aspects of the conceptual framework and systems architecture for e-Navigation. Chapter 4 of the Navguide covers e-Navigation. Radionavigation systems form a key element of the e-Navigation infrastructure and are therefore covered in Chapter 4.

3.1 Visual Aids to Navigation

Visual marks for navigation can be either natural or man-made objects. They include structures specifically designed as short range aids to navigation, as well as conspicuous features such as headlands, mountain-tops, rocks, trees, church-towers, minarets, monuments, chimneys, etc.
Short range aids to navigation can be fitted with a light if navigation at night is required, or left unlit if daytime navigation is sufficient.

Navigation at night is possible, to a limited extent, if the unlit aids are provided with:

- a radar reflector, and the navigating vessel has a radar;
- retro-reflecting material, and the vessel has a searchlight. This approach would generally only be acceptable for small boats operating in safe waterways and with the advantage of local knowledge.

Visual aids to navigation are purpose-built facilities that communicate information to a trained observer on a vessel for the purpose of assisting the task of navigation. The communication process is referred to as *marine signalling*.

Common examples of visual aids to navigation include lighthouses, beacons, leading (range) lines, buoys (lit or unlit), lightvessels, daymarks (dayboards) and traffic signals.

The effectiveness of a visual aid to navigation is determined by factors such as:

- type and characteristics of the aid provided;
- location of the aid relative to typical routes taken by vessels;
- distance (**range**) of the aid from the observer;
- atmospheric conditions;
- contrast relative to background conditions (**conspicuity**);
- the reliability and availability of the aid.

Visual aids to navigation can be distinguished by a wide range of characteristics such as:

- type; shape; size; colour; names, retro-reflective features; letters and numbers;
- lit/unlit; signal character; light intensity; sectors; inclusion of subsidiary aids;
- fixed structure; floating platform; construction materials;
- location; elevation; relationship to other aids to navigation and observable features.

Refer to IALA publications:
- *Recommendation O-130 on Categorisation and Availability Objectives for Short Range Aids to Navigation;*
- *Guideline 1035 on Availability and Reliability of Aids to Navigation.*

Photo Courtesy of Danish Maritime Authority

3.1.1 Signal Colours

IALA has made recommendations on colours for lighted aids to navigation and for surface colours for visual signals on aids to navigation.

Marine aid-to-navigation signal lights use a six-colour system comprising white, black, red green, yellow and blue, as defined in IALA Recommendation E-200 Part 1. Although the colour regions defined in this IALA recommendation agree with those given in the International Commission on Illumination (CIE) Standard S 004/E 2001[9] "Colours of Light Signals", the boundaries of each colour region differ in some cases. Furthermore, in their standard, CIE recommend that signal systems should normally comprise no more than four colours.

Recommended surface colours for visual signals on aids to navigation are as follows:

- Ordinary colours should be limited to white, black, red, green, yellow or blue[10].
- Orange and fluorescent red, yellow, green or orange may be used for special purposes requiring high conspicuity.

Refer to IALA publications:
- *Recommendation E-106 for the Use of Retroreflecting Material on Aids to Navigation Marks within the IALA Maritime Buoyage System;*
- *Recommendation E-108 for the Surface Colours Used as Visual Signals on Aids to Navigation;*
- *Guideline 1015 on Painting Aids to Navigation Buoys (including reference to the practical guide on surface colours).*

The CIE standard on the measurement of colours (colorimetry) is based on three reference colours (ie. a tri-stimulus system) that in varying combination can generate the visual spectrum of colours. A particular ***colour function*** is described by the symbols; **X**, **Y** and **Z** that represent the proportions of the reference colours.

Using ratios of the tri-stimulus values, such that: X + Y + Z = 1, colours can be defined in terms of ***chromaticity*** using just the x [= X / (X+Y+Z)] and y [= Y/ (X+Y+Z)] values. The advantage of this arrangement is that colours can be mapped on a two-dimensional ***chromaticity diagram***.

CIE colour standards for marine signalling can be depicted as areas on the chromaticity diagram. These areas are defined by boundaries expressed as functions of x and y (equations).

---
[9] CIE S 004/E 2001 replaces CIE 2.2 - 1975, "Colours of Light Signals".
[10] Blue surface colours may be used in inland waterways, estuaries and harbours where the colours may be seen at close range. See IALA Recommendation E108. In addition, blue lights are being tested for use on emergency wreck marking buoys – IALA Recommendation O-133 refers.

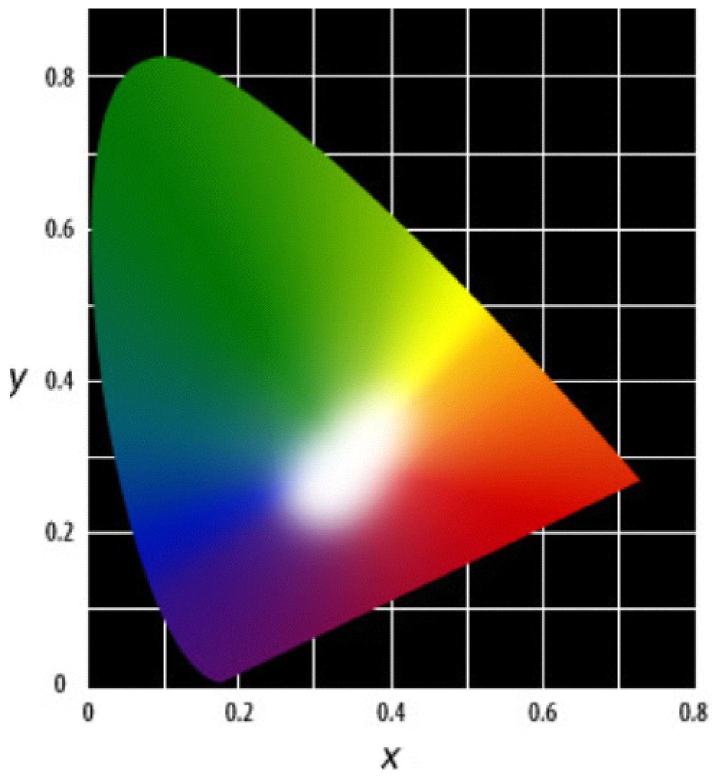


Figure 6 - Illustration of the Colour Zones on the 1931 CIE Chromaticity Diagram

Please note that the colour rendering is only indicative and should not be taken as fully accurate.

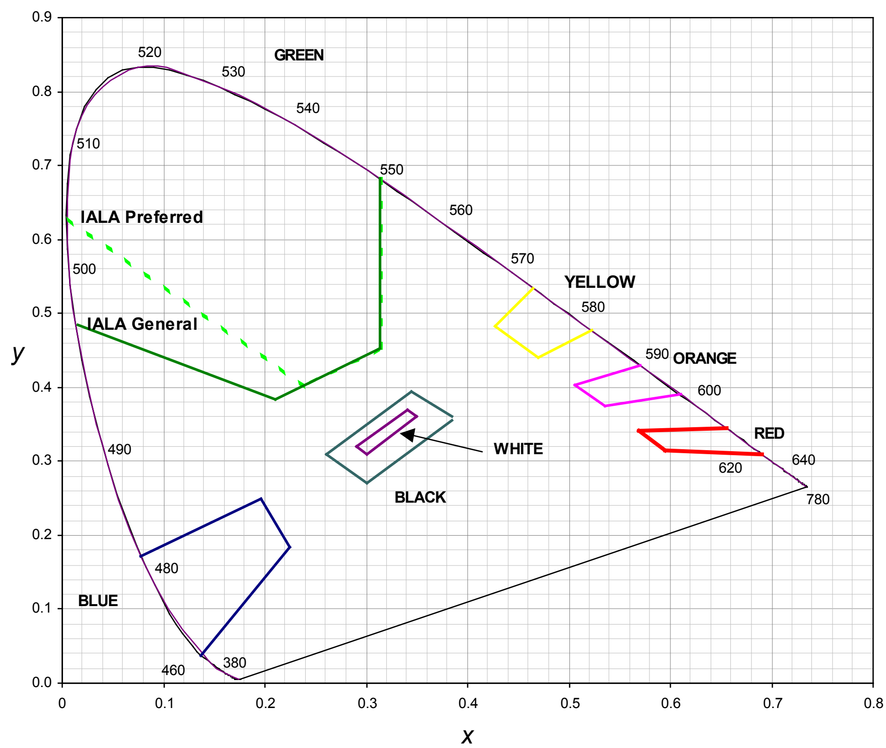


Figure 7 – IALA Allowed Chromaticity Areas of Ordinary Surface Colours

As plotted on the 1983 CIE chromaticity diagram - Courtesy of CIE

If the chromaticity co-ordinates of a coloured light, filter material or a paint product are known, its acceptability for marine signalling applications can easily be determined.

The CIE standard for signalling colours has recently been revised, with some adjustments to the boundaries of signal colours. Further information on surface colours can be found in IALA Recommendation E108 on the surface colours used as visual signals on aids to navigation. Information for light signal colours is shown in IALA Recommendation for the colours for light signals on aids to navigation, December 1977. For further details on this issue, refer to CIE S 004/E-2001 Colours of Light Signals[11].

3.1.2 Visibility of a Mark

The visibility of a mark is affected by one or more of the following factors:

- observing distance (range);
- curvature of the Earth;
- atmospheric refraction;
- atmospheric transmissivity (meteorological visibility);
- height of the aid above sea level;
- observer's visual perception;
- observer's height of eye;
- observing conditions (day or night);
- conspicuity of the mark (shape, size, colour, reflectance, and the properties of any retro-reflecting material);
- contrast (type of background such as lighting, vegetation, snow, etc.);
- mark lit or unlit;
- intensity and character.

Refer to IALA publications:
- *Recommendation E-106 for the Use of Retroreflecting Material on Aids to Navigation Marks within the IALA Maritime Buoyage System.*
- *Recommendation E-108 for the Surface Colours Used as Visual Signals on Aids to Navigation.*

3.1.3 Meteorological Visibility

Meteorological visibility (V) is defined as the greatest distance at which a black object of suitable dimensions can be seen and recognised by day against the horizon sky, or, in the case of night observations, could be seen if the general illumination were raised to the normal daytime level. It is usually expressed in kilometres or nautical miles.

[11] CIE website address: www.cie.co.at/cie

Photo Courtesy of Australian Maritime Safety Authority

3.1.4 Atmospheric Transmissivity

The atmospheric transmissivity (T) is defined as the transmittance, or proportion of light from a source, that remains after passing through a specified distance through the atmosphere, at sea level. This is expressed as a ratio. But since the atmosphere is not uniform over the observing distances of most visual aids, a representative value is used:

- typically, the atmospheric transmissivity is taken as T = 0.74 over one nautical mile;
- a figure of T = 0.86 is occasionally used in regions where the atmosphere is very clear.

A number of countries collect data on atmospheric transmissivity for different parts of their coastline. This enables the luminous range of lights to be:

- calculated more precisely;
- better matched to local conditions and user requirements.

3.1.5 Atmospheric Refraction

This phenomenon results from the normal decrease in atmospheric density from the Earth's surface to the stratosphere. This causes light rays that are directed obliquely through the atmosphere to be refracted (or bent) towards the Earth in accordance with Snell's Law.

3.1.6 Contrast

The ability to detect differences in luminance between an object and an otherwise uniform background is a basic visual requirement and is used to define the term contrast. It is represented by the equation:

$$C = \frac{(L_o - L_B)}{L_B}$$

where: C = contrast
L_B = luminance of background (cd/m^2)
L_O = luminance of object (cd/m^2)

The contrast at which an object can be detected against a given background for 50% of the time, is called the threshold contrast. For meteorological observations, a higher threshold must be used to ensure that the object is recognised.

> *A contrast value of 0.05 has been adopted as the basis for the measurement of meteorological optical range.*

3.1.7 Use of Binoculars

While it is generally assumed that observations will be made with the naked eye, mariners will quite often use binoculars. This can allow:

- a light being observed, or the characteristics resolved, at a greater luminous range than with the naked eye;
- a limited improvement in the sensitivity of leading lights;
- about a 30% improvement in the detectable difference from a given bearing;
- the identification of a light operating against background lighting conditions.

Generally, the most suitable binoculars for use at sea are considered to be the type with a magnifying power of 7 and an objective lens of 50 mm at night, and 10 x 50 binoculars by day.

3.1.8 Range of a Visual Mark

The range of an aid to navigation can broadly be defined as the distance at which the observer's receiver can detect and resolve the signal. In the case of visual marks the observer's receivers are his/her eyes. This broad definition of range leads to a number of more specific definitions that are described below.

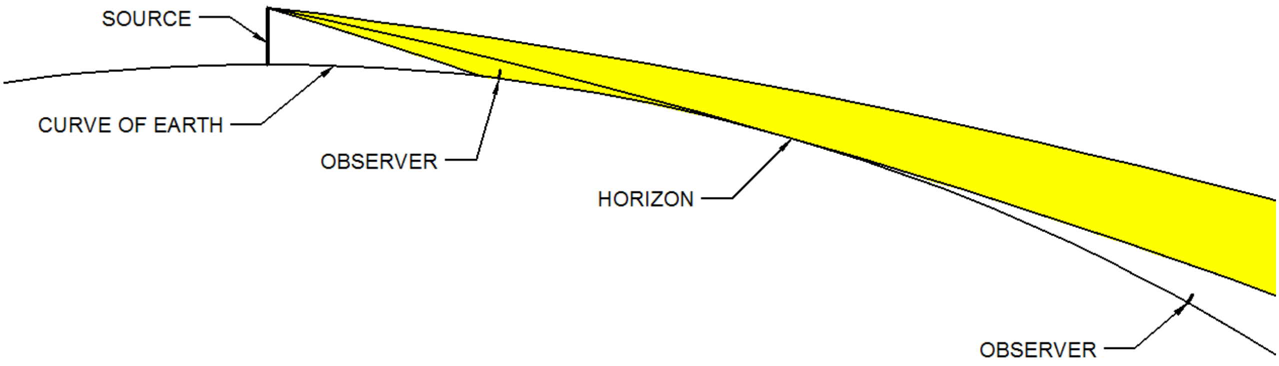


Figure 8 – Effect of Exceeding Geographical Range

3.1.9 Geographical Range

This is the greatest distance at which an object or a light source could be seen under conditions of perfect visibility, as limited only by the curvature of the earth, by refraction of the atmosphere, and by the elevation of the observer and the object or light.

As the observer moves further away from the object or light source, there will come a point where the object or light source is obscured by the Earth. This is illustrated in *Figure 8*.

Observer Eye Height Metres	**Elevation of Mark / metres**										
	0	**1**	**2**	**3**	**4**	**5**	**10**	**50**	**100**	**200**	**300**
1	2.0	4.1	4.9	5.5	6.1	6.6	8.5	16.4	22.3	30.8	37.2
2	2.9	4.9	5.7	6.4	6.9	7.4	9.3	17.2	23.2	31.6	38.1
5	4.5	6.6	7.4	8.1	8.6	9.1	11.0	18.9	26.9	33.3	39.7
10	6.4	8.5	9.3	9.9	10.5	11.0	12.8	20.8	26.7	35.1	41.6
20	9.1	11.1	12.0	12.6	13.1	13.6	15.5	23.4	29.4	37.8	44.2
30	11.1	13.2	14.0	14.6	15.2	15.7	17.5	25.5	31.4	39.8	46.3

Table 6 – Graphical Range Table in Nautical Miles

The values in *Table 6* are derived from the formula:

$$R_g = 2.03 \times \left(\sqrt{h_o} + \sqrt{H_m} \right)$$

where:
R_g = geographical range (nautical miles)
h_o = elevation of observer's eye (metres)
H_m = elevation of the mark (metres)

The factor 2.03 accounts for refraction in the atmosphere. Climatic variations around the world may lead to different factors being recommended. The typical range of factors is 2.03 to 2.12.

Meteorological Optical Range

This is the distance through the atmosphere that is required for 95% attenuation in the luminous flux of a collimated beam of light using a source colour temperature of 2700ºK.

The meteorological optical range is related to the atmospheric transmissivity by the formula:

$$V = d\frac{\log 0.05}{\log T} \quad \text{or} \quad T = 0.05^{d/V}$$

Where: V = meteorological optical range (nautical miles)
d = distance (nautical miles)
T = atmospheric transmissivity

It is often convenient to simplify the above expression by giving the distance term a value of one, such that:

$$T = 0.05^{1/V} \quad \text{or} \quad T^V = 0.05$$

Visual Range

This is the maximum distance at which the contrast of the object against its background is reduced by the atmosphere to the contrast threshold of the observer. The visual range can be enhanced if the observer uses binoculars, although the effectiveness depends on the stability of the observer's platform. Visual Range can be interpreted as the distance that a given light is seen by an observer.

Luminous Range

This is the maximum distance at which a given light signal can be seen by the eye of the observer at a given time, as determined by the meteorological visibility prevailing at that time. It does not take into account the: height of the light, observer's height of eye, or curvature of the Earth.

Nominal Range

Nominal range is the luminous range when the meteorological visibility is 10 nautical miles, which is equivalent to a transmission factor of T = 0.74. Nominal Range is generally the figure used in official documentation such as nautical charts, Lists of Lights, etc.
Nominal range assumes that the light is observed against a dark background, free of background lighting.

3.2 Aids to Navigation Lights

Until the first application of electricity for lights late in the nineteenth century, all artificial light was produced by fire. Illuminants progressed from pyres of wood (used up until the 1800's), to oil wick lamps, vaporised oil and gas burners, then electric arc and tungsten filament lamps. Optical devices matched these developments, first with reflector systems and later with lenses.

It is interesting to note that the efforts to understand the human perception of light, to improve the efficiency and effectiveness of aids to navigation illuminants and optical apparatus, were at the forefront of scientific endeavours for many years.

The glass lens design pioneered by Augustine Fresnel around 1820 remains a principal element of the modern aid to navigation light, although present day lenses are often made of plastic rather than glass.

A few countries still use aids to navigation lighting systems that burn acetylene or propane gas. They are typically preferred for their robustness and simplicity of operation. However, the majority of aids to navigation lighting systems use electricity of various types as their power source. Electricity is generally more efficient than gas. Increasingly, electric AtoN lights are powered by renewable energy sources such as solar, wind or wave power.

Lamps used in electric light systems have been specifically designed for aids to navigation applications. However, lamps selected from the enormous range of commercial products have also been used or adapted for aids to navigation.

Light Emitting Diode (LED) technology is a widely used alternative to filament lamps.

3.2.1 Gas Lights

Acetylene

Acetylene (Carbide gas) lighting systems originated from the inventions of Gustaf Dalén in the early 20th century and were made by a number of suppliers. Acetylene gas has the unusual property of burning with a white flame when correctly mixed with air. This enabled the development of exceptionally reliable open flame lanterns.

Acetylene lighting technology was further enhanced by the development of the Dalen "mixer" that allowed gas and air to be drawn into a chamber and then consumed in an incandescent mantle to produce a brighter light source than the open flame type. The incandescent mantle can be operated as a flashing source inside a fixed lens or as a continuous source inside a rotating lens. Related developments included a gas-operated mechanism for rotating a lens and a clockwork powered automatic mantle changing device.

Propane

Propane gas has been used as fuel for gas burning light systems. The lighting equipment uses an incandescent mantle burner to make a white flame as the gas burns with a yellow/orange flame when an open flame burner is used.

Refer to IALA publication:
- *Practical Note for the Safe Handling of Gases.*

3.2.2 Electric Lights

Incandescent Filament Lamps

Tungsten filament

These light sources have been in use since the early 1900's. Many special lamp designs have been used over the years, as filament size, shape, and location must be well matched to the lens system. It can be operated directly from an appropriate electrical supply and has a nominal voltage of 6 to 240 V, both Alternating Current (AC) and Direct Current (DC).

Typical use:

All types of lighted beacons (for example, leading lights, sector lights, 360° lights, lanterns on light buoys). Some countries and manufacturers have adopted standard designs, with reference codes, for lamps designed especially for lighthouse applications. These designs typically include filament supports to maintain filament shape and ensure an even output over 360 degrees in azimuth.

Technical data:

- Power: 2 to 1000 Watts , exceptionally 3,500 Watts
- Efficiency: 9 to 19 lumens per Watt
- Lifetime: 300 to 1500 hours

Advantages:

- Coding can be easily achieved by interrupting the electrical supply;
- Filament geometry can be designed to match the optic;
- Diffusing envelope (e.g. pearl or etched) can improve lens illumination when used in older optics, but at the expense of reduced intensity;
- Broad colour spectrum output provides good performance with most coloured filters;
- Optical output is reasonably stable over its lifetime, but the lamp envelope may start to blacken before lamp failure;
- Remote monitoring by current sensing is simple.

Disadvantages:

- Relatively short lifetime;
- Safe disposal appropriate for metal and glass waste;
- Specialist AtoN lamps are expensive;
- Colour rendering is not in the preferred white region (tends towards yellow);
- Efficiency poor.

Safety:

- High envelope temperature when in use;
- Operating voltages may be hazardous;
- Possible risk of electrical arcing which is harmful to the human eye;
- General glass hazard.

Disposal:

- Safe disposal appropriate for metal and glass waste.

Tungsten Halogen

The tungsten halogen lamp encloses a small amount of halide with inert gas, and the tungsten evaporating from the hot filament combines with the halogen to diffuse around the envelope wall. Due to careful design the envelope operates at high temperature, and this prevents deposition of tungsten on the glass. The tungsten-halide is then carried by convection towards the filament where it is decomposed and the tungsten metal deposited back onto the filament. It can be operated directly from an appropriate electrical supply and has a nominal voltage of 12 to 240 V, both AC and DC.

Typical use:

All types of lighted beacons, but several lamps could be used in a cluster in large rotating optics, to produce a large light source similar to the original non-electric light source.

Technical data:

- Power: 5 to 1000 Watts, exceptionally 1500 and 2000 Watts
- Efficiency: 20 to 25 lumen per Watt
- Lifetime: 300 to 4000 hours

Some very bright lamps have a short working life.

Advantages:
- Coding can be easily achieved by interrupting the electrical supply, but see below;
- Higher luminance than tungsten lamps;
- Output very stable over lifetime;
- Colour rendering good in white preferred region;
- High performance general-purpose lamps available at low cost;
- Small lamp sizes (10 to 100W) are very mechanically robust;
- Envelope sizes are typically smaller than tungsten lamps, and may allow smaller optic system sizes.

Disadvantages:
- The filament size is usually small hence the geometry is poor when modernising old lens systems;
- Generally low operating voltage results in high current requiring careful design of lamp holder and associated wiring;
- A cluster of several lamps will be required to match these small lamps to existing large optics;
- Lamps are not made specifically for AtoN use and specifications may change without notice;
- The flashing of tungsten halogen lamps may lead to the interruption of the halogen cycle with consequent blackening of the envelope and premature failure. Practical trials are recommended with the proposed operating voltage and duty cycle or consultation with other IALA members;
- Lamps should not be touched with bare hands due to consequential reduction in lamp life.

Safety:
- Operating voltage may be hazardous;
- General glass hazards;
- Very high surface temperatures because of the small envelope size;
- Possible high UV radiation risk (dependant on lamp type);
- Risk of explosion with high-pressure lamp types.

Disposal:
- Consult local and national disposal regulations.

Discharge Lamps

Fluorescent
Operates 110 to 240 V system voltage with control circuitry to provide a high starting voltage.

Typical use:
- Direction arrows, signs and light tubes or bars used for leading lights;
- Applications where large areas of illumination are an advantage.

Technical data:

● Power:	8 to 100 Watts
● Efficiency:	80 to 100 lumen per Watt
● Lifetime:	Up to 20,000 hours

Advantages:

- High luminous efficiency;
- Large illuminated area. In suitable applications no optical elements are needed thus providing a very low cost AtoN;
- Very wide range of commercially available products at low prices;
- Many colours available (no additional colour filters needed).

Disadvantages:

- Low luminance;
- Difficult to use with lens systems due to source size;
- Light output falls considerably over lifetime;
- Requires control circuitry matching lamp and supply voltage;
- Complex circuitry needed to flash;
- Possible interference problems.

Safety:

- Mains voltage;
- General glass hazard;
- Internal tube coatings may be hazardous if exposed and they contain traces of gaseous mercury;
- High voltage due to starting equipment.

Disposal:

- Tube coatings may be hazardous and contain traces of mercury;
- Consult local and national disposal regulations.

Low Pressure Sodium Vapour Lamps

110 and 240 V AC with associated control circuitry. Only available in yellow colour.

Typical use:

- Flood lighting and external illumination of structures, towers, locks etc.

Technical data:

● Power:	20 to 180 Watts
● Efficiency:	180 lumen per Watt
● Lifetime:	10,000 hours

Advantages:

- Long life;
- High luminous efficiency;
- Mercury free;
- Low envelope surface temperature;
- Can be used to provide yellow signal colour;
- Minimum attraction for insects.

Disadvantages:

- Only produces yellow light;
- Low luminance.;
- Not practical to flash;
- Limited operating positions.

Safety:

- General glass hazards;
- High AC voltage;
- Chemical hazard due to sodium content.

Disposal:

- Consult local and national disposal regulations.

High Pressure Sodium Vapour Lamps

110 or 240 V AC with associated control circuitry.

Typical Use:

- White lamps may be used as AtoN light source.

Technical data:

- Power: 50 to 400 Watts
- Efficiency: 90 lumen per Watt
- Lifetime: 10,000 hours

Advantages:

- Long life;
- Mercury free;
- High efficiency;
- Available in white.

Disadvantages:

- Cannot be flashed;
- Only practical as white;
- Low red content makes colour filtering impractical;
- High strike voltage to start;
- Complex lamp changer required due to long warm-up period and cool-down necessary before restart;
- Arc tube geometry is poor for most optics;
- Light output falls over life and white colour degrades to yellow.

Safety:

- General glass hazards;
- High AC voltage;
- Chemical hazards giving rise to disposal or health problems.

Disposal:

- Consult local and national disposal regulations.

Metal Halide

The metal halide lamp is one of a family of High Intensity Discharge (HID) lamps. Its arc tube is made of silica glass. The principles of emission are as follows: 1) High voltage from the ballast initiates current flow between the electrodes; 2) As the lamp temperature rises, metals in the lamp evaporate, and light emission occurs. Working with control circuitry allows input voltages of 12 V to 240 V for 110 V and 240 V power sources

Typical Use:

- Used as a fixed light source in rotating optics, fixed lenses with rotating screens and general floodlighting.

Technical data:

- Power: 10 to 2,000 Watts
- Efficiency: 80 to 110 lumen per Watt
- Lifetime: 6,000 to 20,000 hours

Operating lifetime is very dependent on the number of times that lamp is switched on.

Advantages:
- High luminous efficiency;
- Clear envelope types have high illuminance;
- Coated envelope types have good geometry for traditional lenses;
- Long life;
- Many commercial lamp types available;
- Colour rendering is good, within IALA preferred white region;
- Absence of a filament means good resistance to vibration and shock.

Disadvantages:
- Not practical to flash;
- Initial warm-up is slow;
- Cooling time needed before re-strike hence complex lamp changer design;
- Difficult to remote monitor by simple current sensing;
- Light output falls with life;
- Red spectrum is limited so red filtering is possible but poor, green is good.

Safety:
- High voltage hazards;
- High UV radiation;
- Possible interference problems;
- Possible explosion hazard;
- General glass hazard;
- May contain hazardous metal.

Disposal:
- CConsult local and national disposal regulations as there may be some mercury content.

Xenon Lamps

Typically 110 V and 240 V. Xenon lamps are discharge lamps, with the xenon gas enclosed in a silica tube at high pressure. An electrical discharge through the xenon gas generates a high intensity white light. Xenon discharge is commonly used in camera flash guns. Charging DC supply requires complex control circuitry. These lamps are available as pulsed or continuous discharge types.

Typical Use:
- A specialised light source used where high intensity is of paramount importance. Can be used in fixed or rotating optics.

Technical data:
- Power: 150 to 2,000 Watts
- Efficiency: 35 lumen per Watt
- Lifetime: 2,000 hours

Advantages:
- High luminance enabling high intensities to be achieved with suitable optics;
- Broad white colour spectrum allowing good colour filtering.

Disadvantages:
- Electrical control system is complicated;
- Lamp changer design is very complex;
- Short lamp life;
- Electronic control components have short life;
- Relatively expensive;
- Power consumption is variable due to the charging/discharging cycle of the system, resulting in varying loads on the power supply system.

Safety:
- High voltage hazard;
- Possible danger of explosion as the pressure in the lamp is high;
- High UV radiation;
- High surface temperature;
- General glass hazards.

Disposal:
- Consult local and national disposal regulations as there may be some mercury content.

Light Emitting Diode (LED)

Coloured LED

Electronic semiconductor devices that produce near monochromatic light. The semiconductor junction is encapsulated in a clear plastic housing that usually incorporates a lens. Several LEDs may be grouped together in a cluster, or an array, to provide a light source of the required size and intensity with lamp redundancy. LEDs operate from a low voltage DC supply. Correct operation depends on accurate control of the supply current.

White LED

A semiconductor junction emitting blue/violet light is encapsulated with an integral phosphor such that both blue and broad band yellow light are emitted together to form a near white light. Research is in progress on combining red and green LED lights to produce a white light within the IALA chromaticity specification. LED marine lanterns are sometimes reported as having intense colours and ranges longer than the current IALA calculation method would suggest. Current work by IALA is investigating this.

Typical Use:

- A Lighted beacons on buoys and other short and medium range AtoN, but longer range LED lanterns are increasingly available in the market;
- Range lights consisting of flat arrays of LEDs or single high power LEDs;
- Signs and signals formed by arrays of LEDs in the shape of letters, numerals, signs etc.

Technical data:

- Power: Single LED: 1milliWatt to over 32 Watts, Cluster LED: 1 to 60 Watts of higher
- Efficiency: Luminous Efficacy of LEDs is improving steadily.
- Lifetime: 100,000 hours

Operating lifetime will depend on the LED junction operating temperature and operating environment.

Advantages:

- Very long life (if input power and temperature are carefully controlled) and hence low whole life costs;
- Life is so long that lampchangers are not considered necessary;
- High luminous efficiency in red and green;
- Light produced in saturated signal colours therefore coloured filters not needed;
- Mechanically robust when compared with conventional lamps;
- Light switching times are very fast;
- Relatively cool operation;
- Easy to cluster LEDs.

Disadvantages:

- Complex electronic control needed to achieve long life and high performance;
- Generally difficult to match to existing optics;
- Luminous efficiency decreases slowly with life;
- White LEDs will be outside the new CIE (2001) white colour region;
- White LEDs will be very inefficient with red and green filters;
- Lamp life can be severely reduced if input power and temperature are not carefully controlled.

Safety:

- No special hazard.

Disposal:

- Consult local and national disposal regulations.

Lasers

A laser is a device that produces a coherent collimated beam of monochromatic light. Their use has not been established in AtoN light systems, despite efforts over recent decades. However, research continues into the use of lasers to improve the visibility and sector distinction of fairway lighting.

Typical Use:
- High power lasers can be used to provide a line of light in the sky where particles of dust, water, etc., are illuminated by the laser beam to provide a leading line. These devices require considerable electrical power (several kW);
- Low power lasers are being tested by the Canadian Coast Guard where the laser is aimed directly at the mariner. Different coloured lasers are used to identify areas of navigational importance. Laser light is visible at useful range in daylight.

Technical data:
- Power requirements are modest (tens of Watts);
- Laser projectors are expensive and require complex control systems.

Advantages:
- Single wavelength (Monochromatic);
- Highly directional;
- Simple optic design.

Disadvantages:
- High power requirements for high power lasers;
- System complexity may be a problem at some locations.

Safety:
- Possible eye damage under certain conditions;
- Apply appropriate American Society for Testing and Materials (ASTM) safety standards;
- Detailed procedures are required for safe servicing.

Refer to IALA publication:
- *Guideline 1043 on Light Sources Used in Visual Aids to Navigation.*

3.2.3 Photometry of Marine Aids to Navigation Signal Lights

Measurement of Light

In science, the behaviour of light is normally seen in the context of either a form of electromagnetic radiation or particle motion. This is the so-called "wave/particle duality" nature of light. The latter includes the concept of "rays" of light that are used in analyzing the interactions of light and lenses. The units of interest for electromagnetic applications of light are generally metres (wavelength) and Watts (power).

The study of photometry and the use of lights for signal application has necessitated a parallel set of units to be developed to account for the physiological aspects of how the human eye evaluates a light source, as shown in *Table 7*.

The spectral sensitivity of the human eye (or the response of the eye to different coloured light) has been evaluated in tests of large numbers of people. The results have been presented as a standard spectral sensitivity distribution or V(λ) curve for photopic (daytime) observers and V′(λ) for scotopic (night time) observers.

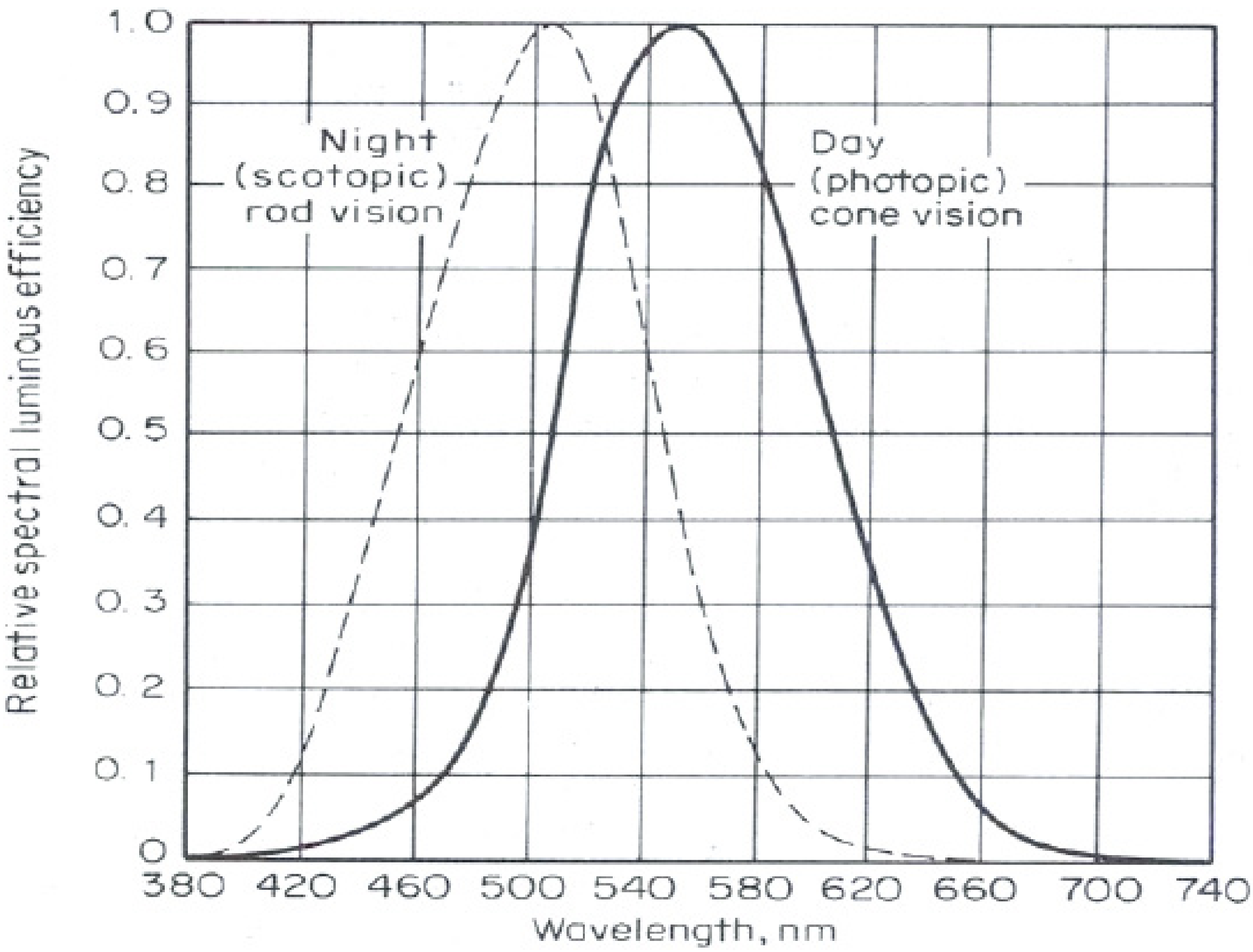


Figure 9 – Spectral Sensitivity Distributions or V(λ) and V′ (λ) Curves for the Human Observer

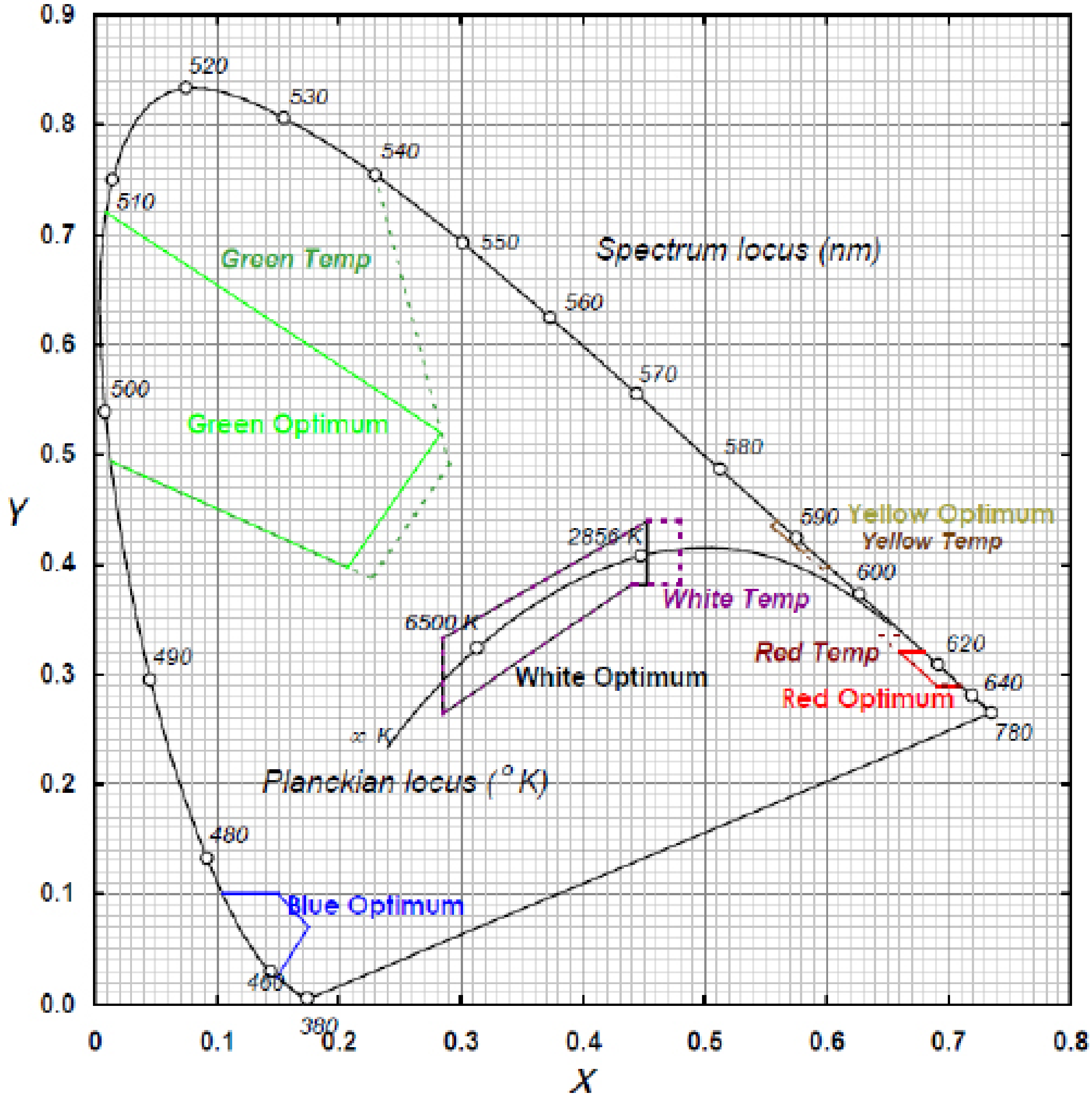


Figure 10 – Chromaticity Regions of the Recommended IALA Colours for Lights

IALA Optimum boundaries are represented by solid lines while IALA Temporary boundaries are represented by dashed lines.

Units of Measurement

Term	Description	Unit	Abbreviation
Luminous Flux	This is the total light emitted from the source. The peak sensitivity of the human eye occurs at about 555 nanometres, a wavelength that corresponds to green. At this wavelength, the photometric equivalent of one watt is defined as 680 lumens.	lumens	lm
Luminous Intensity	This is the part of the luminous flux in a particular direction. Also expressed as the luminous flux per solid angle.	candela	cd
Luminance (Brilliance)	This is the portion of the luminous flux emitted in a specific direction by the surface area of a luminous body. This variable is an important term for rating the brightness impression of light sources and illuminated objects.	candelas per square meter *and also as* candelas per square centimetre	cd/m2 cd/cm2
Illuminance	This is the density of the luminous flux incident on a surface. It is the quotient of the luminous flux by the area of the surface when the surface is uniformly illuminated.	lumens per square metre *or* lux	lx
Luminous Efficacy	This is the ratio of luminous output to radiometric output of a light source. It can also be applied to the efficiency with which electrical power is converted to visible radiation.	lumens per watt of electrical power consumed	
Colour Temperature	This related to the temperature of a black body. As a body heats up, it goes through a series of different colours from red through yellow and white, to blue white. The colour appearance of a tungsten filament lamp is similar to a black body at the same temperature.	Kelvin	°K
Colour Rendering Index	Characterises the colour rendering quality of the light from a lamp. It is the same for all incandescent lamps by definition and equal to the maximum value of 100.		CRI

Table 7 – Photometric Units of Measurement

Threshold of Illuminance

In physical terms, the threshold of illuminance is the lowest level of illuminance from a point source of light, against a given background level of luminance, that causes a visual response at the eye.
For visual signalling applications, the threshold of illuminance (E) is taken to be 0.2 µlux at the eye of the observer.

In the case of leading lights of limited range and with a high level of shore illumination, the above figures may be found too low. It is recommended that to observe the relative position of the lights easily and to derive the maximum possible accuracy from leading and sector lights, it is generally necessary to have a minimum illuminance of 1 µlux at the eye of the observer. This condition is to be met at the outer limits of the useful segment for the minimum meteorological visibility under which the leading lights are to be used.

IALA Recommendation on the Definition of the Nominal Daytime Range of Maritime Signal Lights, Intended for the Guidance of Shipping by Day (1974) provides the method of designing AtoN lights for use in daylight.

For lights on floating aids, care must be taken to provide adequate vertical divergence so that the minimum illuminance at the observer is maintained as the floating aid rolls and pitches.

Luminous Intensity

The luminous intensity of a navigation light is directly proportional to the luminance of the light source. The size of the light source is inversely proportional to its luminance and directly proportional to the divergence of the optic system.

Candela (cd) is the measurement unit used to quantify the luminous intensity of a lighted aid to navigation.

Inverse Square Law

Light emitted from a source radiates out in all directions. For a point source, the wave fronts of light can be imagined to generate a series of spherical surfaces. As shown in *Figure 11*, the further the light travels from the source, the greater is the surface area of the sphere and consequently, the lower the illuminance. Since illuminance is measured in lumens per square metre, and the surface area of a sphere increases in proportion to the square of the radius, the illuminance decreases in proportion to the square of the distance from the source. The decline in illuminance with distance is described as an inverse-square law.

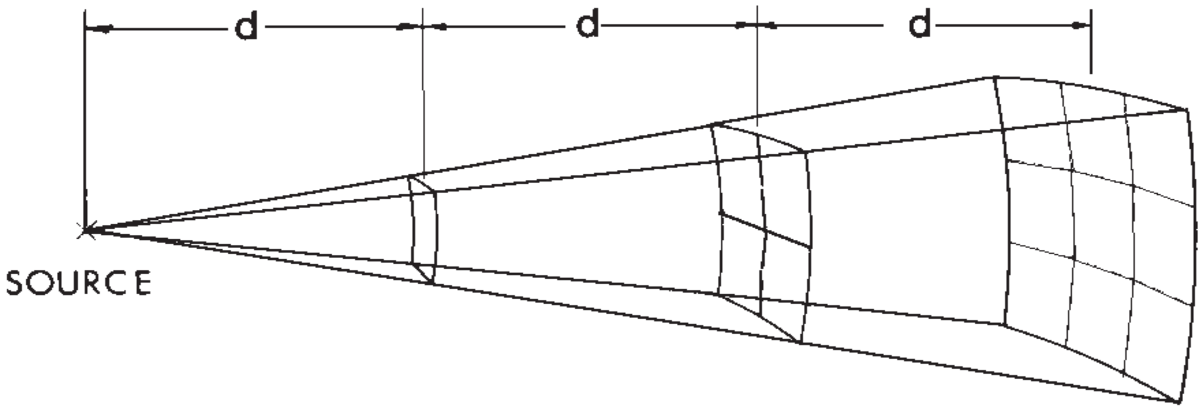


Figure 11 - Illustration of the Inverse Square Law Concept

Allard's Law

The illuminance of a light source reaching an observer's eye determines whether the light is seen. The relationship between the illuminance produced at the observer's eye, the luminous intensity of the light source, the distance to the observer and the atmospheric transmissivity is given by the relationships shown in Allard's Law:

$$E = \frac{I \times T^{d}}{d^{2}}$$

where: E = illuminance at the observer's eye (lm/m^2)
I = effective intensity of the light source (cd)
T = atmospheric transmissivity
d = distance between the light source and the observer.

Because T is measured per nautical mile, d in the numerator must also be in nautical miles. In the denominator, d is in metres.

Allard's law applies only when the luminance of the background is small compared to the average illuminance of the light.

Refer to IALA publication:

- *Recommendation E-200-2 on Marine Signal Lights - Part 2 - Calculation, Definition and Notation of Luminous Range*

Colorimetric Measurement of Lights (Colour Measurement)
The measurement of the colour of lights is described in CIE Publication No 15.2 (1986) ***Colorimetry***. There are two main types of instrument for measuring the colour of a light: one is a ***colorimeter***; the other is a ***spectroradiometer***.

Colorimeters usually comprise three photoreceptors, each with a coloured filter. Each filter is matched to the response of one of the three eye receptors, red green and blue and such devices are called 'tristimulus' colorimeters. The colorimeter gives three outputs, one for each filtered receptor, and these correspond to the X, Y and Z functions of the human observer.

Spectroradiometers consist of a monochromator and photoreceptor. The monochromator splits the light into individual wavelengths (much like a prism makes a rainbow) and is usually rotated in steps past an exit slit. The photoreceptor, behind the exit slit, measures different sections of the spectrum as the monochromator is rotated. The output is a series of readings enabling a graph of power against wavelength to be displayed. Results may then be weighted with the X, Y and Z functions of the human observer to produce colour information.

Stepping monochromators of the type described previously are fairly slow in operation and are not suitable for measuring flashing lights. **Tristimulus colorimeters**, on the other hand, enable much faster measurements of colour. New types of spectradiometer, known as **'array-based' spectroradiometers**, are now available. Instead of a single photoreceptor and a rotating monochromator, a fixed monochromator has its output directed at an array of charge-coupled devices (CCDs). Such devices are capable of much faster measurement speeds than stepping monochromators.

Recent developments in colour measurement have resulted from the technology of digital cameras. **'Imaging photometers'**, as they are known, are little more than calibrated digital cameras, some with tristimulus filtering. They are capable of fast measurement of a whole scene, making them useful for work outside the laboratory. However, the accuracy of some cheaper devices leaves much to be desired.

In summary:

- Tristimulus colorimeters are fast, however cheaper models suffer errors when measuring narrowband light sources such as LEDs;
- Stepping monochromators are expensive and slow but very accurate;
- Array-based spectroradiometers are fast, relatively inexpensive, but can suffer with stray light errors;
- Imaging photometers are expensive and not very accurate, but can record a whole scene and not just one light.

Resultant data from colour measurements are usually displayed on a chromaticity chart, developed by the CIE in 1931. The three X, Y, Z values are reduced to two x, y values as shown in *Figure 11*.

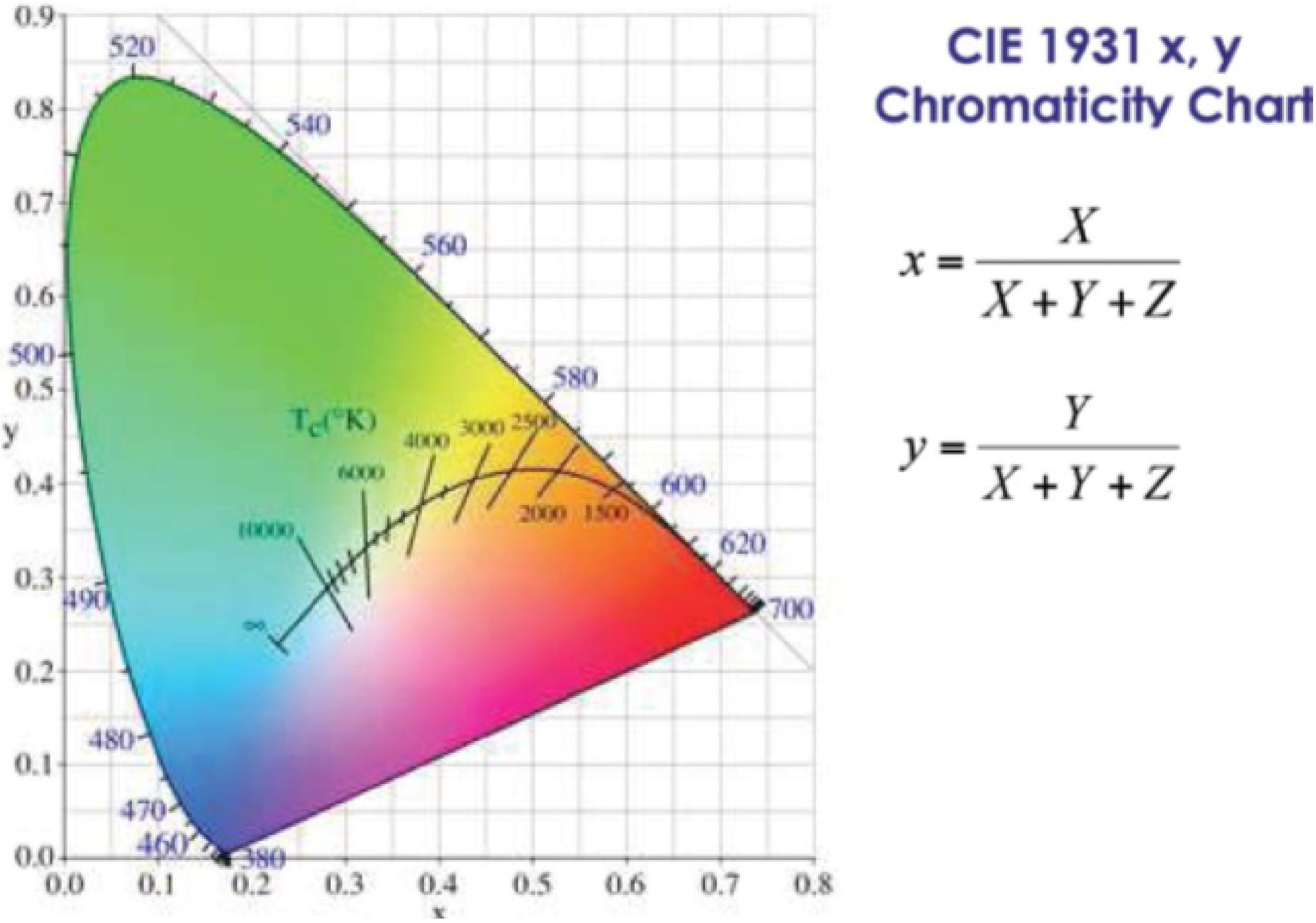


Figure 12 - CIE 1931 x,y Chromaticity Chart

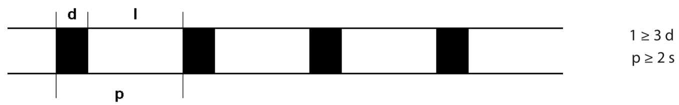
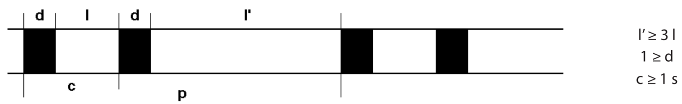
3.2.4 Rhythms and Characters

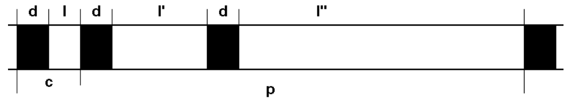
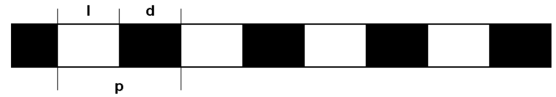
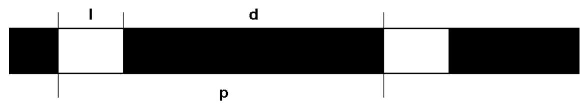
IALA has produced a recommendation on the characters for light on aids to navigation. The tables of classifications and specifications of aid to navigation characters are provided in *Table 8*.

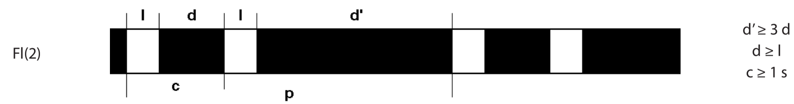
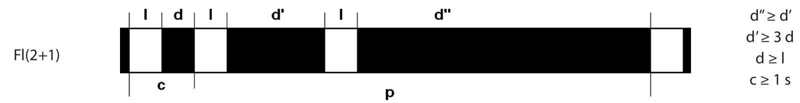
Refer to IALA publication:

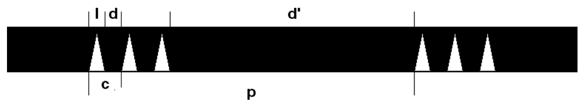
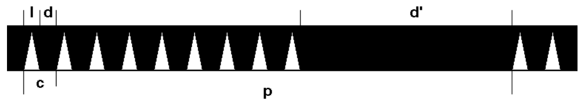
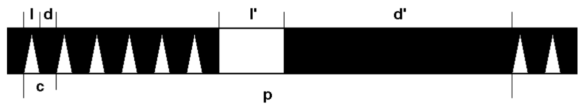
- *Recommendation E-110 for the rhythmic characters of lights on aids to navigation.*

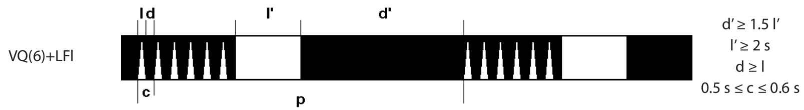
The Rhythmic Characters of Lights are provided in *Table 9*.

	Class	Abbre-viation	General Description	IALA Specifications	Use in the Martime Buoyage System
1	FIXED LIGHT	F	A light showing continuously and steadily.	A single fixed light should be used with care because it may not be recognized as an aid to navigation light.	A single fixed light shall not be used.
2	OCCULTING LIGHT		A light in which the total duration of light in a period is longer than the total duration of darkness and the intervals of darkness (eclipses) are usually of equal duration.	A light in which the total duration of light in a period is clearly longer than the total duration of darkness and all the eclipses are of equal duration.	
2.1	Single-Occulting Light	Oc	An occulting light in which an eclipse is regularly repeated	The duration of an appearance of light should not be less than three times the duration of an eclipse. The period should not be less than 2 s.  Example: l = 3 s; d = 1 s; p = 4 s	A single occulting *White* light indicates a safe water mark.
2.2	Group-Occulting Light	Oc(#) eg. Oc(2)		The appearances of light between the eclipses in a group are of equal duration, and this duration is clearly shorter than the duration of the appearance of light between successive groups. The number of eclipses in a group should not be greater than four in general, and should be five only as an exception. The duration of an appearance of light within a group should not be less than the duration of an eclipse. The duration of an appearance of light between groups should not be less than three times the duration of an appearance of light within a group. In a group of two eclipses, the duration of an eclipse and the duration of the appearance of light within a group should not be less than 1 s. In a group of three or more eclipses, the duration of an eclipse and the duration of an appearance of light within the group should not be less than 2 s. Oc(2)  Example: l' = 6 s; l = 2 s; d = 1 s; c = 3 s; p = 10 s	

	Class	Abbreviation	General Description	IALA Specifications	Use in the Martime Buoyage System
2.3	Composite Group-Occulting Light	Oc(# + #) eg. Oc(2 + 1)	A light similar to a group occulting light except that successive groups in a period have different numbers of eclipses.	This class of light character is not recommended because it is difficult to recognize. Oc(2 + 1)  1″≥ l′ l′≥ 3 l l ≥ d c ≥ 1 s Example: l″ = 9 s; l′ = 3 s; l = 1 s; d = 1 s; c = 2 s; p = 16 s	
3	ISOPHASE LIGHT	Iso	A light in which all the durations of light and darkness are clearly equal.	The period should never be less than 2 s, but preferably it should not be less than 4 s in order to reduce the risk of confusion with occulting or flashing lights of similar periods.  l = d p ≥ 2 s Example: l = d = 2 s; p = 4 s	An isophase *White* light indicates a safe water mark.
4	FLASHING LIGHT		A light in which the total duration of light in a period is shorter than the total duration of darkness and the appearances of light (flashes) are usually of equal duration.		A single occulting *White* light indicates a safe water mark.
4.1	Single-Flashing Light	Fl	A flashing light in which a flash is regularly repeated (at a rate of less than 50 flashes per minute).	The duration of the interval of darkness (eclipse) between two successive flashes should not be less than three times the duration of a flash. The period should not be less than 2 s (or not less than 2.5 s in those countries where a quick rate of 50 flashes per minute is used).  d ≥ 3 l p ≥ 2 s Example: d = 3 s; l = 1 s; p = 4 s	A single flashing *Yellow* light indicates a special mark.
4.2	Long-Flashing Light	LFl	A single-flashing light in which an appearance of light of not less than 2 s duration (long flash)[15] is regularly repeated.	The term “long flash”, which is used in the descriptions of the long-flashing light and of the light characters reserved for south cardinal marks, means an appearance of light of not less than 2 seconds duration. The term “short flash” is not commonly used and does not appear in the Classification.  d ≥ 3 l p ≥ 2 s Example: d = 8 s; l = 2 s; p = 10 s	A long flashing *White* light with a period of 10 s indicates a safe water mark.

	Class	Abbre-viation	General Description	IALA Specifications	Use in the Martime Buoyage System
4.3	Group-Flashing Light	Fl(#) eg. Fl(2)	A flashing light in which a group of flashes, specified in number, is regularly repeated.	The eclipses between the flashes in a group are of equal duration, and this duration is clearly shorter than the duration of the eclipse between successive groups. The number of flashes in a group should not be greater than five in general, and should be six only as an exception. The duration of an eclipse within a group should not be less than the duration of a flash. The duration of an eclipse between groups should not be less than three times the duration of an eclipse within a group. In a group of two flashes, the duration of a flash together with the duration of the eclipse within the group should not be less than 1 s. In a group of three or more flashes, the duration of a flash together with the duration of an eclipse within a group should not be less than 2 s (or not less than 2.5 s in those countries where a quick rate of 50 flashes per minute is used).  Example: d' = 6 s; d = 2 s; l = 1 s; c = 3 s; p = 10 s	A group flashing *White* light with a group of two flashes, in a period of 5 s or 10 s, indicates an isolated danger mark. A group flashing Yellow light with a group of four, five or rarely six flashes indicates a special mark.
4.4	Composite Group-Flashing Light	Fl(#+#) eg. Fl(2+1)	A light similar to a group-flashing light except that successive groups in a period have different numbers of flashes.	Light characters should be restricted to (2 + 1) flashes in general, and should be (3 + 1) flashes only as an exception.  Example: d'' = 9 s; d' = 3 s; d = 1 s; l = 1 s; c = 2 s; p = 16 s	A composite group flashing Red or Green light with a group of (2+1) flashes indicates a modified lateral (preferred channel) mark. A composite group flashing Yellow light indicates a special mark.

	Class	Abbre-viation	General Description	IALA Specifications	Use in the Martime Buoyage System
5	QUICK LIGHT		A light in which flashes are repeated at a rate of not less than 50 flashes per minute but less than 80 flashes per minute.	A light in which identical flashes are repeated at the rate of 60 (or 50) flashes per minute. The higher rate of flashing is preferred.	
5.1	Continuous Quick Light	Q	A quick light in which a flash is regularly repeated.	Fl(2 + 1)  d″ ≥ d′ d′ ≥ 3 d d ≥ l c ≥ 1 s Example: l = d = 0.5 s; p = 1 s	A continuous quick *White* light indicates a north cardinal mark.
5.2	Group Quick Light	Q(#) eg. Q(3), Q(9), or Q(6)+LFl	A quick light in which a specified group of flashes is regularly repeated.	Q((3))  d ≥ l d′>d 1 s ≤ c ≤ 1.2 s Q((9))  d ≥ l d′>d 1 s ≤ c ≤ Q((6)+LFl  d′ ≥ 3 l′ l′ ≥ 2 s d ≥ l 1 s ≤ c ≤ 1.2 s	A group quick *White* light with a group of three flashes, in a period of 10 s, indicates an east cardinal mark. A group quick *White* light with a group of nine flashes, in a period of 15 s, indicates a west cardinal mark. A group quick *White* light with a group of six flashes followed by a long flash of not less than 2 s duration, in a period of 15 s, indicates a south cardinal mark.

	Class	Abbre-viation	General Description	IALA Specifications	Use in the Martime Buoyage System
6	VERY QUICK FLASH		A light in which flashes are repeated at a rate of not less than 80 flashes per minute but less than 160 flashes per minute.	A light in which identical flashes are repeated at the rate of 120 (or 100) flashes per minute. The higher rate of flashing is preferred.	
6.1	Continuous Very Quick Flash	VQ	A very quick light in which a flash is regularly repeated.	Example: l = d = 0.25 s; p = 0.5 s 	A continuous very quick *White* light indicates a north cardinal mark.
6.2	Group Very Quick Light	VQ(#) eg VQ(3), VQ(9), or Q(6)+LFl	A very quick light in which a specified group of flashes is regularly repeated.	The number of flashes in a group should be three or nine. An exceptional light character is reserved for use in the IALA Maritime Buoyage System to indicate a south cardinal mark.  Example: d′ = 3.75 s; l = d = 0.25 s; c = 0.5 s; p = 5 s  Example: d′ = 5.75 s; l = d = 0.25 s; c = 0.5 s; p = 10 s  Example: d′ = 5 s; l′ = 2 s; l = d = 0.25 s; c = 0.5 s; p = 10 s	A group very quick *White* light with a group of three flashes, in a period of 5 s, indicates an east cardinal mark. A group very quick *White* light with a group of nine flashes, in a period of 10 s, indicates a west cardinal mark. A group very quick *White* light with a group of six flashes followed by a long flash of not less than 2 s duration, in a period of 10 s, indicates a south cardinal mark.

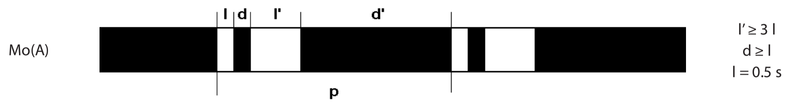
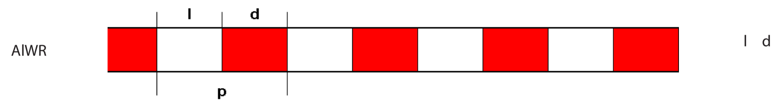
	Class	Abbrevi-ation	General Description	IALA Specifications	Use in the Martime Buoyage System
7	ULTRA QUICK LIGHT		A light in which flashes are repeated at a rate of not less than 160 flashes per minute.	A light in which flashes are repeated at a rate of not less than 240 flashes per minute and not more than 300 flashes per minute.	
7.1	Continuous Ultra Quick Light	UQ	An ultra quick light in which a flash is regularly repeated.		
8	MORSE CODE LIGHT	Mo(#) eg. Mo(A)	A light in which appearances of light of two clearly different durations are grouped to represent a character or characters in the Morse Code.	Light characters should be restricted to a single letter in the Morse Code in general, and should be two letters only as an exception. The duration of a "dot" should be about 0.5 s, and the duration of a "dash" should not be less than three times the duration of a "dot".  Example: l' = 1.5 s; l = 0.5 s; d = 0.5 s; d' = 4.5 s; p = 7 s	A Morse Code *White* light with the single character "A" indicates a safe water mark. A Morse Code *Yellow* light, but not with either of the single characters "A" or "U"*, indicates a special mark.
9	FIXED AND FLASHING LIGHT	FFl	A light in which a fixed light is combined with a flashing light of' higher luminous intensity.	This class of light character should be used with care because the fixed component of the light may not be visible at all times over the same distance as the rhythmic component.  Example: d = 3 s; l = 1 s; p = 4 s	
10	ALTERNATING LIGHT	Al## eg AlWR	A light showing different colours alternately.	This class of light character should be used with care, and efforts should be made to ensure that the different colours appear equally visible to an observer.  Example: l = d = 2 s; p = 4 s	

Table 8 - Classification of the Rhythmic Characters of Lights

Mark	Rhythmic Character of the Light	Remarks and Further Recommendations
LATERAL	All recommended classes of rhythmic character[12], but a composite group flashing light with a group of (2 + 1) flashes is solely assigned to modified lateral marks that indicate preferred channels.	Only the colours Red and Green are used.
Modified Lateral	Composite group flashing light with a group of (2 + 1) flashes, in a period of not more than 16 s.	The duration of the eclipse after the single flash should not be less than three times the duration of the eclipse after the group of two flashes.
CARDINAL		Only the colour White is used.
North Cardinal	(a) Continuous very quick light. (b) Continuous quick light.	
East Cardinal	(a) Group very quick light with a group of three flashes, in a period of 5 s. (b) Group quick light with a group of three flashes, in a period of 10 s.	
South Cardinal	(a) Group very quick light with a group of six flashes followed by a long flash of not less than 2 s duration, in a period of 10 s. (b) Group quick light with a group of six flashes followed by a long flash of not less than 2 s duration, in a period of 15 s.	The duration of the eclipse immediately preceding a long flash should be equal to the duration of the eclipses between the flashes at the very quick rate. The duration of a long flash should not be greater than the duration of the eclipse immediately following the long flash. The duration of the eclipse immediately preceding a long flash should be equal to the duration of the eclipses between the flashes at the quick rate. The duration of a long flash should not be greater than the duration of the eclipse immediately following the long flash.
West Cardinal	(a) Group very quick light with a group of nine flashes, in a period of 10 s. (b) Group quick light with a group of nine flashes, in a period of 15 s.	
ISOLATED DANGER	(a) Group flashing light with a group of two flashes, in a period of 5 s. (b) Group flashing light with a group of two flashes, in a period of 10 s.	Only the colour White is used. The duration of a flash together with the duration of the eclipse within the group should be not less than 1 s and not more than 1.5 s. The duration of a flash together with the duration of the eclipse within the group should be not less than 2 s and not more than 3 s.
SAFE-WATER	(a) Long flashing light with a period of 10 s. (b) Isophase light. (c) Single occulting light. (d) Morse Code light with the single character "A".	Only the colour White is used.
SPECIAL	(a) Group occulting light. (b) Single flashing light, but not a long flashing light with a period of 10 s. (c) Group flashing light with a group of four, five or (exceptionally) six flashes. (d) Composite group flashing light. (e) Morse Code light, but not with either of the single characters "A" or "U"` [13].	Only the colour Yellow is used. A group flashing light with a group of five flashes at a rate of 30 flashes per minute, in a period of 20 s, is assigned to Ocean Data Acquisition Systems (ODAS) buoys.

Table 9 - Rhythmic Characters of the Lights in the IALA Maritime Buoyage System

[12] A single fixed light shall not be used on a mark within the scope of the IALA Maritime Buoyage System because it may not be recognized as an aid to navigation light.

[13] A Morse Code white light with the single character "U" is assigned to offshore structures.

Maximum Periods for Light Characters

Character Class	Maximum Period (seconds)
Isophase light	12
Single-occulting light	15
Single-flashing light	15
Group very quick light	15
Group-occulting light of two eclipses	20
Long-flashing light	20
Group-flashing lights of two flashes	20
Group-quick light	20
Group-occulting light of three or more eclipses	30
Group-flashing light of three or more flashes	30
Composite group-flashing light	30
Morse code light	30

Table 10 - Maximum Period for Rhythmic Characters of Aids to Navigation Lights

Refer to IALA publication:
- *Recommendation E-110 for the rhythmic characters of lights on aids to navigation.*

Timing of Astronomical Events

The nighttime operation of lighted aids to navigation is emphasised but daytime role is often as important. The astronomical events that define the transitions from day to night are shown below.

Event	Condition	Illumination (Lux)	Comment
Sunset / Sunrise	Upper edge of the sun's disc is coincident with the horizon.	600	
Civil Twilight (start / end)	Centre of sun is at a depression angle of six (6) degrees below the horizon.	6	Large objects are seen but details are not discernible. Brightest stars and planets are visible and the sea horizon is clearly defined.
Nautical Twilight (start / end)	Centre of sun is at a depression angle of twelve (12) degrees below the horizon.	0.06	It is dark for normal practical purposes and the sea horizon is not normally visible.
Astronomical Twilight (start / end)	Centre of sun is at a depression angle of eighteen (18) degrees below the horizon.	0.006	Illumination is less than that from starlight and other natural light sources in the sky.

Table 11 - Timing of Astronomical Events

Switch-on / Switch-off Light Levels

For lighted aids to navigation that only operate at night, the ambient light levels at which an AtoN light switches on should be chosen so that the AtoN light switches on while the ambient light level is sufficiently high to allow safe navigation, while not switching on during overcast conditions when the AtoN is not necessary for safe navigation.

Refer to IALA publications:

- *Guideline 1038 on Ambient Light Levels at which Aids to Navigation Should Switch On and Off.*

Night Operations

Nominal Range and Luminous Intensity

Table 12 is an extract of the IALA recommendation for the notation of luminous intensity and range of lights and provides a conversion between nominal range and luminous intensity.

Nominal Range (nautical miles)	Luminous Intensity (candela)	Nominal Range (nautical miles)	Luminous Intensity (candela)
1	0.9	12	3600
1.5	2.4	13	5700
2	5	14	8900
2.5	9	15	14000
3	15	16	21000
3.5	24	17	32000
4	36	18	49000
4.5	53	19	73000
5	77	20	110000
6	150	21	160000
7	270	22	240000
8	480	23	360000
9	820	24	520000
10	1400	25	770000
11	2200	26	1100000

Table 12 - IALA Conversion Table for Luminous Intensity and Nominal Range for Night Observations

This table assumes an atmospheric transmissivity of T=0.74 and a threshold of illumination of 0.2 μlux.

Background Lighting

Nominal range at night is calculated with no allowance for glare from background lighting. Excessive background lighting, from street lights, neon signs etc., frequently makes an aid to navigation light less effective and, in some cases, it becomes completely lost in the general background clutter. Such a light can be made more conspicuous by increasing its intensity, changing its colour or by varying its rhythm.

Glare

Glare can be caused by bright lights emitted from the shore, such as car headlights, or from another vessel indiscreetly using a search-light. An aid to navigation light can also cause glare if it is too bright for the shortest viewing distance, especially when the focal plane of the light and the observer's eye are at the same height. This situation can arise with two station leading lines. For aids to navigation lights it is generally accepted that the illuminance at the eye of the navigator from the light:

- should not exceed 0.1 lux;
- should be reduced to 0.01 lux if the background is very dark.

Refer to IALA publications:

- *Recommendation E-112 for Leading Lights (including excel program);*
- *Guideline 1023 for the Design of Leading Lines.*

In situations where glare is a problem, one or more of the following alterations may lead to a satisfactory result:

- raise the focal plane of the light so that the mariner uses the loom of the light or a less intense part of the vertical distribution of the light;
- reducing the illuminance of the light source;
- reducing the size of the optic;
- masking the optic with, for example, perforated metal sheet;
- screen unnecessary arcs of the light;
- use two or more lower intensity lights instead of one higher intensity light.

Whatever methods are used, it will be necessary to measure or calculate the intensity and distribution of the modified light or lighting system.

Intensity Losses

Some lighting equipment has to be installed inside a protective lantern housing. Unless it is practicable to measure the luminous intensity of the complete installation, it is normal practice to apply a de-rating factor to the intensity of the lighting equipment to allow for the reflection and transmission losses at the lantern glazing, generally referred to as the *glazing loss factor*.

Glazing bars or astragals may reduce the intensity of the light at certain bearings. The installation of non-vertical astragals will overcome this reduction to a certain extent. The focal plane of the light should be positioned away from any horizontal glazing bars or intersection.

IALA recommends that, in the absence of more definitive information, the glazing loss factor be taken as 0.85 for a system in clean condition.

Refer to IALA publication:
- *Recommendation E200-0 on Marine Signal Lights Part 0 - Overview.*

Service Conditions Factor

Under normal operating conditions the luminous intensity of a light is likely to degrade between service (maintenance) intervals. There are several components to this degradation:

- meteorological conditions (which may only be temporary);
- dirt and salt deposition (which can be minimised by an efficient regular programme of cleaning of the optical system and housing);
- progressive deterioration of the light source over the service interval.

It is clearly impossible to represent such a complex array of factors in any simple way, and a proper assessment of the various effects could only be made by measurements on site at regular intervals. However, in order to give a more realistic figure for the performance of the light under normal operating conditions than when the luminous intensity is measured in a laboratory or on a photometric range, it may be appropriate to apply a *service conditions factor* to the measured intensity.

Day Operations

A number of authorities have established daytime lighted leading lines in major ports and waterways to achieve a more consistent performance than is possible with dayboards.

Nominal Daytime Range and Luminous Intensity

Refer to IALA publications:
- *Recommendation E200-2 On Marine Signal Lights Part 2 – Calculation, Definition and Notation of Luminous Range;*
- *Recommendation E-111 on Port Traffic Signals.*

Figure 13 and *Table 13* are extracts of Recommendation E200-2 On Marine Signal Lights Part 2 – Calculation, Definition and Notation of Luminous Range (December 2008) and provides a conversion between nominal daytime range and luminous intensity.

Threshold value for illuminance: $E_t = 1 \times 10^{-3}$ lx

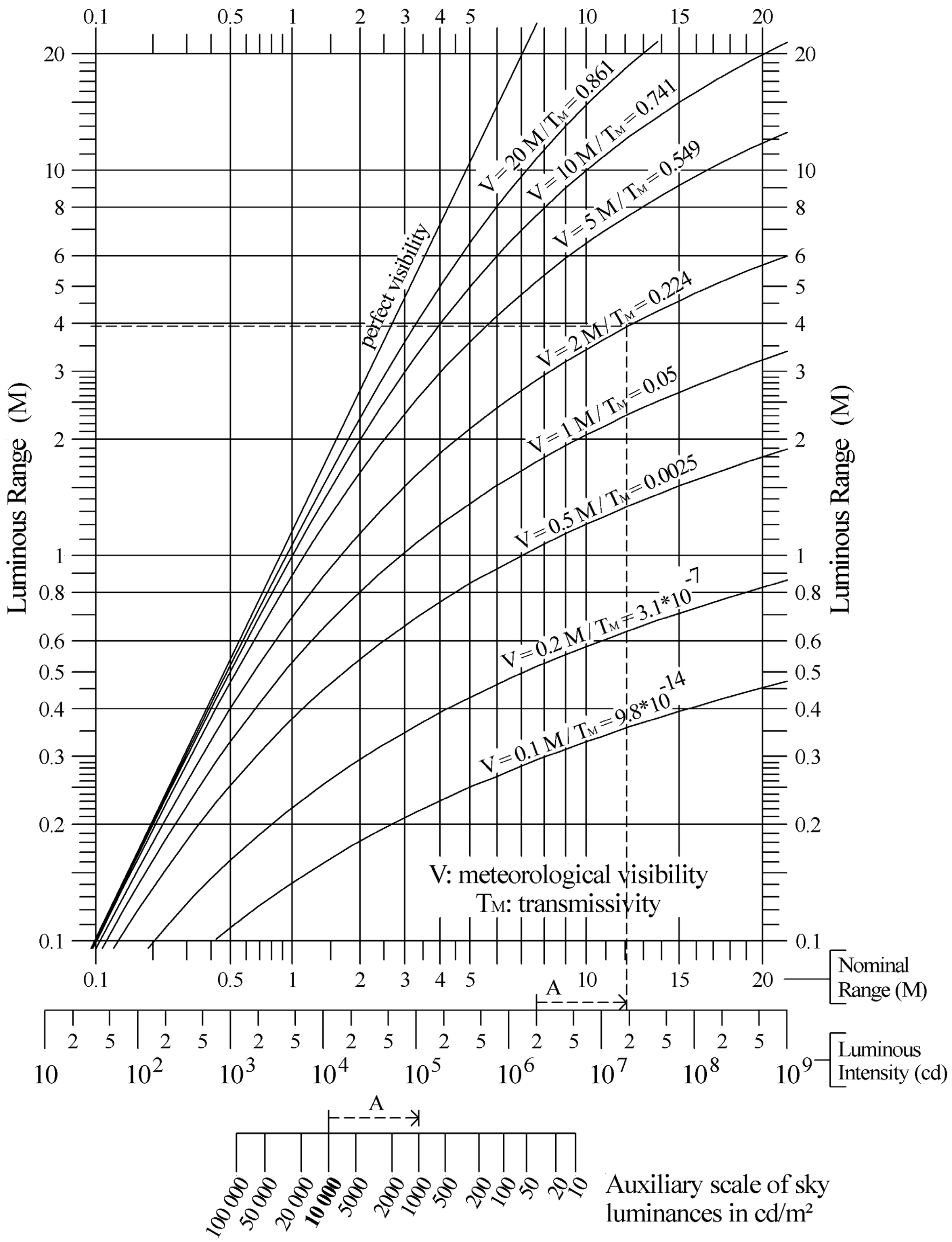


Figure 13 – Daytime Luminous Range Diagram

Luminous Intensity	Nominal Range (Rounded)	Luminous Intensity	Nominal Range (Rounded)
kilocandelas (10^3 cd)	nautical miles (M)	megacandelas (10^6 cd)	nautical miles (M)
1 – 12.0	1	1.02 – 1.82	7
12.1 – 45.3	2	1.83 – 3.16	8
45.4 – 119	3	3.17 – 5.32	9
120 – 267	4	5.33 – 8.78	10
268 – 538	5	8.79 – 14.2	11
539 – 1010	6	14.3 – 22.6	12
		22.7 – 35.6	13
		35.7 – 55.5	14
		55.6 – 85.6	15
		85.7 – 130	16
		131 – 198	17
		199 – 299	18
		300 – 449	19
		450 – 669	20
		670 – 993	21
		994 – 1460	22

Table 13 – IALA Conversion Table for Luminous Intensity and Nominal Daytime Range

Luminous Range Diagram for Daytime Use

The Luminous Range Diagram, shown in *Figure 12* enables the mariner to determine the approximate range at which a light may be sighted, by day in the meteorological conditions prevailing at the time, and for various levels of sky luminance (refer to *Table 13*).

Meteorological Condition	Luminance in cd/m²	Required Illuminance E_t in 10^{-3}lx
Very Dark Overcast Sky	100	0.013
Dark Overcast Sky	200	0.024
Ordinary Overcast Sky	1 000	0.107
Bright Overcast Sky or Clear Sky Away from the Direction of the Sun	5 000	0.506
Bright Cloud or Clear Sky Close to the Direction of the Sun	10 000	1
Very Bright Cloud	20 000	1.98
Glaring Cloud	50 000	4.91

Table 14 – Required Illuminance in Varying Meteorological Conditions

The graph has been drawn for a sky luminance of 10 000 cd/m². For other values of sky luminance mark off along the scale of abscissae the distance between the luminance of 10 000 cd/m² and that under consideration as it appears on the auxiliary scale.

Example:
Suppose that it is required to calculate the luminous range of a light of 2 000 000 cd for a meteorological visibility of 2 nautical miles under an ordinary overcast sky (luminance 1 000 cd/m²).

Measure the distance A separating graduations 10 000 cd and 1 000 cd on the auxiliary scale. Transfer this distance to the scale of abscissae from the graduation corresponding to 2 000 000 cd ($2x10^6$ cd) in the same sense. A point slightly to the right of graduation corresponding to 12 nautical miles is obtained. Erect from this point a parallel to the axis of ordinates to meet the curve for 2 nautical miles visibility. Read off the luminous range on the vertical scale against the point so obtained. It should read approx. 4 nautical miles.

Daymarks (Dayboards)
The size of a dayboard should be determined for the maximum useful viewing distance and minimum visibility conditions. Daymarks used on leading lines are typically rectangular with the long side vertical. The aspect ratio for the rectangle is commonly 2:1 (height = 2 x width).

The typical operational range of daymarks under different visibility conditions is shown in *Table 15*.

Operational Range of Daymarks (Nautical Miles)					
Minimum visibility (Nautical Miles)	Daymark Height (Metres) / Aspect Ratio h=2w				
	1.8	2.4	3.7	4.9	7.3
1	0.5	0.7	0.9	1.0	1.1
2	0.6	0.9	1.2	1.4	1.5
3	0.6	1.1	1.5	1.9	2.1
4	0.7	1.3	1.8	2.3	2.7
5	0.8	1.5	2.1	2.7	3.3
6	0.8	1.6	2.3	2.9	3.6
7	0.9	1.7	2.4	3.3	4.0
8	0.9	1.7	2.6	3.5	4.2
9	0.9	1.9	2.8	3.8	4.5
10	1.0	2.0	3.0	4.0	5.0

Table 15 – Typical Operational Range of Daymarks

Guidance on the impact of background lighting and meteorological conditions on light intensity required to achieve a particular range is provided in *Table 16*.

Nominal Range	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)	Intensity (cd)
Background Lighting or Metreological Condition (see 1.3.3)	None	Minor	Substantial	Day VDO	Day DO	Day OO	Day BO	Day BC	Day VBC
Luminance (cd/m^2)				100	200	1000	5000	10000	20000
Illuminance (lx)	2.00E-07	2.00E-06	2.00E-05	1.30E-05	2.39E-05	1.07E-04	5.06E-04	9.99E-04	1.98E-03
Transmissivity (per M)	0.74	0.74	0.74	0.74	0.74	0.74	0.78	0.79	0.81
Visibility (M)	10	10	10	10	10	10	12	13	14
Range (M)									
0.2	0.03	0.3	3	2	3	16	73	144	284
0.5	0.20	2	20	13	24	107	492	961	1,890
0.7	0.41	4	41	27	50	222	1,010	1,970	3,870
1	1	9	93	60	111	495	2,230	4,310	8,410
2	5	50	500	325	597	2,670	11,400	21,700	41,700
3	15	152	1,520	986	1,810	8,110	33,000	61,600	116,000
4	36	364	3,640	2,360	4,350	19,460	75,400	138,000	256,000
5	77	767	7,670	4,990	9,170	41,000	151,000	271,000	495,000
6	149	1,490	14,900	9,690	17,800	79,700	279,000	492,000	883,000
7	274	2,740	27,400	17,800	32,700	146,000	488,000	843,000	1,490,000
8	482	4,820	48,200	31,300	57,600	258,000	818,000	1,390,000	2,410,000
9	824	8,240	82,400	53,500	98,400	441,000	1,330,000	2,210,000	3,770,000
10	1,370	13,700	137,000	89,200	164,000	734,000	2,110,000	3,430,000	5,770,000
11	2,240	22,400	224,000	146,000	268,000	1,200,000	3,270,000	5,230,000	8,650,000
12	3,600	36,000	360,000	234,000	430,000	1,920,000	5,000,000	7,840,000	
13	5,700	57,000	570,000	370,000	681,000	3,050,000	7,530,000		
14	8,910	89,100	891,000	579,000	1,070,000	4,770,000			
15	13,800	138,000	1,380,000	897,000	1,650,000	7,390,000			
16	21,200	212,000	2,120,000	1,380,000	2,530,000				
17	32,300	323,000	3,230,000	2,100,000	3,860,000				
18	48,800	488,000	4,880,000	3,170,000	5,840,000				
19	73,400	734,000	7,340,000	4,770,000	8,770,000				
20	110,000	1,100,000		7,130,000					
21	163,000	1,630,000							
22	242,000	2,420,000							
23	357,000	3,570,000							
24	524,000	5,240,000							
25	767,000	7,670,000							
26	1,120,000								
27	1,630,000								
28	2,360,000								
29	3,420,000								
30	4,940,000								

Abbreviation	*Meteorological Condition*	*Luminance (cd/m^2)*
Day VDO	*Very Dark Overcast Sky*	*100*
Day DO	*Dark Overcast Sky*	*200*
Day OO	*Ordinary Overcast Sky*	*1,000*
Day BO	*Bright Overcast Sky away from Sun*	*5,000*
Day BC	*Bright Sky or Cloud near Sun*	*10,000*
Day VBC	*Very Bright Cloud*	*20,000*
Day GC	*Glaring Cloud*	*50,000*

Table 16 – Night and Day with Background

This table is intended as guidance only. It is not to be used for Nominal Range Publication.

3.2.5 Fixed Aids to Navigation

The IALA International Dictionary of Aids to Marine Navigation defines a beacon as "a fixed artificial navigation mark" that can be recognised by its shape, colour, pattern, topmark or light character, or a combination of these. While this functional definition includes lighthouses and other fixed aids to navigation, the terms lighthouse and beacon are used more specifically to indicate importance and size.

Lighthouse: A lighthouse is generally considered to be a large conspicuous structure (visual mark) on land, close to the shoreline or in the water that:

- acts as a daymark;
- provides a platform generally for higher range marine AtoN signal lights.

Other aids to navigation such as audible signals and radio aids to navigation may be located on or near the lighthouse. A lighthouse may be a staffed or automated facility, although the staffing of lighthouses is becoming less common. An automated lighthouse will often be remotely monitored and in some cases remotely controlled.

Beacon: Visual characteristics of a beacon are often defined by daymarks, topmarks, and by numbers. A marine signalling light, if fitted, would generally be of a lower range than lighthouses. In navigable channels a pile beacon may be used as an alternative to a buoy[13].

Purpose of Lighthouses and Beacons

A lighthouse or beacon may perform one or more of the following navigational functions:

- mark a landfall position;
- mark an obstruction or a danger;
- indicate the lateral limits of a channel or navigable waterway;
- indicate a turning point or a junction in a waterway;
- mark the entrance of a Traffic Separation Scheme (TSS);
- form part of a leading (range) line;
- mark an area;
- provide a reference for mariners to take a bearing or line of position (LOP).

[13] In these situations the beacon will generally show a colour scheme and topmarks in accordance with the IALA Maritime Buoyage System.

Other purposes for which a lighthouse can be used include:

- base for AIS equipment; racon; radar; radionavigation systems; reference station for DGNSS;
- coastwatch or coastguard functions;
- VTS functions;
- base for audible (fog) signals;
- collection of meteorological and oceanographic data;
- radio and telecommunication facilities;
- tourist facilities.

3.2.6 Floating Aids to Navigation

A floating aid to navigation serves a similar purpose to a beacon or lighthouse. However the floating aid to navigation is normally associated with locations where:

- it would be impractical due to water depth, seabed conditions or cost to establish a fixed aid;
- the hazard shifts over time (eg. sand banks, an unstable wreck, etc.);
- the aid is at high risk of damage or loss from ice flows or ship impacts and as a consequence is treated as expendable;
- a temporary mark is required.

Buoys: Buoys are defined as *minor floating aids* and whilst it is normal that they are lit there are instances where no light is installed.These types of aids to navigation are specifically covered by the IALA Maritime Buoyage System and tend to have circular hull forms in range of 1 to 3 m diameter. Buoys may be fitted with sound signals.

In addition, due to limitations of the structure, the following may apply:

- where lights are exhibited they are usually solar or primary battery powered, however gas powered buoys are still in operation;
- where lights are exhibited, due to power limitations, light ranges are restricted to typically 2 to 5 nautical miles, although much higher ranges are used in some applications;
- additional services are restricted due to limited power on a buoy but racon and AIS units are sometimes deployed in addition to a light;
- electric fog signals are used on buoys in some countries.

Light Vessels, Lightships, and Large Navigational Buoys: Light Vessels, Lightships, and Large Navigational Buoys (LNB), sometimes referred to as LANBYs, are defined as *major floating aids* and may carry one or more of a RACON, AIS AtoN, sound signal, and in some cases, a radio beacon in addition to the aid to navigation light. A light vessel may also display a white riding light to signify a vessel at anchor.

These types of aids to navigation:

- generally have high operating costs;
- are only deployed at critical locations;
- are often assigned an availability target that is higher than for a buoy;
- are not specifically covered by the IALA Maritime Buoyage System.

Some light vessels continue to be manned, but the trend is towards automation, often with remote monitoring and control.

Refer to IALA publication:
- *Recommendation O-104 for 'Off Station' Signals for Major Floating Aids to Navigation.*

Synthetic Buoy - Photo Courtesy of China Maritime Safety Administration

Ice Buoy - Photo Courtesy of Cybernetica AS

LANBY - Photo Courtesy of Commissioners of Irish Lights

Spar Buoy - Photo Courtesy of Zeni Lite Buoy Co

Figure 14 – Examples of Floating Aids

Maritime Buoyage System

The IALA Maritime Buoyage System (MBS) represents one of IALA's major contributions to enhancing the safety of navigation. As recently as 1976 there were more than thirty buoyage systems in use worldwide and conflicting sets of rules applied. In 1980 Lighthouse Authorities from fifty countries and representatives from nine international organisations reached agreement on the rules for a single system. In 2010 the MBS was revised. Key changes made included the introduction of an emergency wreck marking buoy and fixed marks. The full name of the revised system is therefore IALA Maritime Buoyage System and other Aids to Navigation, still being referred to as the MBS.

The MBS uses 7 types of Aids to Navigation, which may be used in combination. The mariner can distinguish between these aids by identifiable characteristics. The system includes:

- Lateral Marks[14];
- Cardinal Marks;
- Isolated Danger Marks;
- Safe Water Marks;
- Special Marks;
- Emergency Wreck Marking Buoy;
- Other Marks.

The General Principles and Rules of the IALA Maritime Buoyage System can be found in *Annex D*.

Below are additional considerations when using the MBS.

Cardinal Marks

As stated in paragraph 3.2.4 of the MBS, it is very important to take into consideration possible confusion when using a number of Cardinal Marks in proximity to each other. The Competent Authority should therefore be cautious in the use of cardinal marks when planning the overall AtoN system in a specific area.

In areas with large tidal ranges the colour scheme for identification should be above the Highest Astronomical Tide (HAT).

Isolated Danger Marks

The extent of a danger is often not uniform, and the nautical chart should be consulted to verify its extent.

When planning the overall AtoN system, the Competent Authority should if possible ensure that Isolated Danger Marks are used only to mark dangers where there is navigable water all-round.

[14] Lateral marks differ between buoyage regions A and B.

Special Marks

Although Special Marks are not generally intended to mark channels or obstructions, these could be used where there is a specific need for navigational guidance and where other marks would not be suitable. For example, to define a route within a channel, such as for deep draught vessels in a fairway marked by lateral marks, or special purpose channels for small craft.

The Competent Authority should be aware that when Special Marks are used for different purposes in proximity to each other it may be difficult for mariners to distinguish between them. In such situations the use of other marks may be more appropriate. The use of Special Marks with pictograms could also be considered.

Emergency Wreck Marking Buoy

The Emergency Wreck Marking Buoy (EWMB) is meant for prompt response to mark new dangers such as a wreck. It should therefore only be on station until the Competent Authority is satisfied that information concerning the new danger has been sufficiently promulgated or the danger is otherwise resolved. An appropriate risk assessment should be used to determine how long the EWMB should be deployed. If the new danger is expected to remain, the Competent Authority should mark it with a regular marking scheme.

The EWMB should be equipped and of a size that facilitates its detection under all sea conditions. Upon a decision to use the EWMB, it should be deployed without unnecessary delay. This can be met by the use of EWMBs that are stored onboard a vessel ready for deployment. It should be taken into consideration that a smaller buoy, in some instances, may be deployed more rapidly. If necessary it could subsequently be replaced with a larger buoy.

Refer to IALA publications:

- *Maritime Buoyage System (with supporting guidelines);*
- *Guideline 1046 on a Response Plan for the Marking of New Wreck.*

IALA also has a consolidated recommendation and guidelines for marking areas for specific navigational needs in relation to a variety of man-made structures including aquaculture facilities and offshore resource production and energy generation structures

Performance Criteria for Floating Aids

Availability is defined as the probability that an aid to navigation or a system of aids to navigation, as defined by the Competent Authority, is performing its specified function at any randomly chosen time. This is expressed as a percentage of total time that an aid to navigation or a system of aids to navigation should be performing their specified function[15].

[15] As adapted from the IALA Guidelines on Availability and Reliability of Aids to Navigation, Theory and Examples (Edition 2, December 2004).

The availability of a floating aid is the principal measure of performance determined by IALA. The recommended availability targets are indicated in *Table 17.*

Description of Aid	Availability Target	
Floating aids to navigation that are considered to be of primary navigational significance.	Category 1	at least 99.8%
Floating aids to navigation that are considered to be of navigational significance.	Category 2	at least 99%
Floating aids to navigation that are considered to be of less navigational significance than Category 1 or 2.	Category 3	at least 97%

Table 17 - Availability Targets

The availability objective assigned to floating aids to navigation conforming to the IALA Maritime Buoyage System should also apply to the topmark.

Refer to IALA publications:

- *Recommendation O-130 on Categorisation and Availability Objectives for Short Range Aids to Navigation;*
- *Guideline 1035 on Availability and Reliability of Aids to Navigation.*

Technical Considerations for Floating Aids to Navigation

There are various technical considerations that should be taken into account, including: cost; design factors; positioning and markings.

Cost

The cost of establishing a floating aid at a given location will generally be less than for a fixed structure. The cost difference increases with increasing water depth and exposure to wind and waves.

In contrast, the maintenance cost of floating aids to navigation tends to be high relative to the capital value. This has caused many authorities to critically examine the potential for savings through design changes, use of alternative materials, alternate service deliveries (contracting out) and amending maintenance practices, generally with the aim of extending maintenance intervals.

Where an authority operates a large number of floating aids, it may become practicable to operate a dedicated buoy tender vessel with specialised equipment to minimise buoy change-out times and to improve occupational safety.

Refer to IALA publication:

- *Guideline 1047 on Cost Comparison Methodology of Buoy Technologies.*

Floating Aid Design

The process of designing a buoy to meet specific requirements is a specialised task. It involves, but is not limited to:

- defining the operational performance characteristics;
- defining the equipment, power requirements and power source(s);
- defining the type and capabilities of the vessels that will be used to service the buoy;
- selecting the initial type proportions and mooring for the buoy;
- integrating of equipment and power supply;
- considering of the maintenance requirements;
- identifying deployment and recovery techniques;
- protecting equipment from damage;
- providing the ability to rectify faults without having to lift the buoy;
- determining the buoy response to the wave, wind and current conditions at the site(s);
- optimising the design.

Refer to IALA publications:

- *Maritime Buoyage System (and supporting guidelines);*
- *Guideline 1006 on Plastic Buoys;*
- *Guideline 1011 on a Standard Method for Defining and Calculating the Load Profile of Aids to Navigation;*
- *Guideline 1036 on Environmental Considerations in Aids to Navigation Engineering;*
- *Guideline 1037 on Data Collection for Aids to Navigation Performance Calculation;*
- *Guideline 1040 on the Maintenance of Buoys and Small Aids to Navigation Structures;*
- *Guideline 1042 on Power Sources and Energy Storage for Aids to Navigation;*
- *Guideline 1043 on Light Sources Used in Visual Aids to Navigation;*
- *Guideline 1094 on Daymarks;*
- *Guideline 1099 on the Hydrostatic Design of Buoys;*
- *Recommendation E-106 on the Use of Retroreflecting Material on Aids to Navigation Marks within the IALA Maritime Buoyage System.*

Mooring Design

The mooring system for a floating aid to navigation is the sum of the components that keep the aid within a nominated area. These components have to withstand the forces of wind, wave and current on the floating aid and drag on the mooring line. Methods for determining the forces are covered in the IALA Guideline 1066 on the Design of Floating Aid to Navigation Moorings.

The basic assumptions made are that the:

- mooring system tethered to the buoys sinker is usually tangential to the sea bed;
- buoy axis is vertical under the most common conditions of current and wind;
- ratio of the breaking stress of the mooring system to the calculated stress is not less than 5 under the most unfavourable conditions of current and wind;
- reserve buoyancy of the fully equipped floating aid is greater than the combined loads of current and wind under the most unfavourable conditions.

An approximate value for the minimum length of a chain mooring is given by the following formula:

- $L_{min} = 3H$ for depths less than 50 metres;
- $L_{min} = 2H$ for depths greater than 50 metres;
- $L_{min} = 7H$ for shallow moorings where breaking waves occur.

  L = Length of mooring line (m)
  H = Depth[16] of water (m)

Swing Radius

Details are provided for the calculation of the swing radius and for the design of site specific moorings in the Guideline 1066 on Design of Floating Aids to Navigation Moorings.

Refer to IALA publications:
- *Recommendation E-107 on Moorings for Floating Aids to Navigation;*
- *Guideline 1066 on the Design of Floating Aids to Navigation Moorings.*

Positioning of Floating Aids

The charted position of a floating aid defines the nominal (or true) position for the anchor. With most floating aids there is potential for the mooring anchor/sinker to be moved off-station during storms or for positional errors to occur while laying the anchors/sinkers.

Anchors/sinkers have traditionally been laid while taking cross bearings and/or horizontal sextant angles from fixed visual marks. When out of sight of land the process may have relied on radionavigation or radio-positioning aids. While some authorities may still use these procedures, the use of DGPS position fixing is increasingly seen as the preferred method. The benefits of DGPS position fixing are: convenience, accuracy and repeatability. A buoy tender using DGPS can generally be brought to within 10 metres of the nominal buoy position at the time of releasing the anchor/sinker.

[16] This is defined as the maximum depth of water and includes the highest tide level and half the maximum wave height at the particular site.

If the anchor/sinker is allowed to free-fall, its final resting position will depend on the prevailing current, water depth, shape of the anchor/sinker and the nature of the seabed. Controlling the decent of the anchor/sinker may serve to improve the positional accuracy of the buoy.

Markings and Topmarks

Markings
Floating aids to navigation are often identified by names, abbreviations of names, letters and/or numbers. Authorities should ensure that the actual marking is identical to the List of Lights reference and the charted marking.

Topmarks
The type, colour and arrangement of topmarks on a buoy are shown in the IALA Maritime Buoyage System, extracts of which are shown in Annex A.

Topmarks can either be conical, cylindrical, or spherical in shape or they can be a diagonal cross.

Conical Topmarks:
Used for lateral and cardinal marks.

- The vertical height of a cone from base to apex should be about 90% of the base diameter;
- For cardinal marks, the separation distance between cones should be about 50% of the base diameter of the cone;
- The vertical clear space between the lowest point of the topmark and all other parts of the mark should be at least 35% of the base diameter of the cone;
- In the case of a buoy, the base diameter should be 25%-30% of the diameter of the buoy at the waterline.

Cylindrical 'Can' Topmarks:
Used for lateral marks.

- The vertical height of a cylinder should be 1 to 1.5 times the base diameter;
- The vertical clear space between the lowest part of the cylinder and all other parts of the mark should be at least 35% of the diameter of the cylinder;
- In the case of a buoy, the base diameter of the cylinder should be 25%-30% of the diameter of the buoy at the waterline.

Spherical Topmarks:
Used for isolated danger and safe water marks.

- In the case of a buoy, the diameter of the sphere(s) should be at least 20% of the diameter of the buoy at the waterline;
- For isolated danger marks the separation distance between spheres should be about 50% of their diameter;
- The vertical space between the lowest part of the sphere(s) and all other parts of the mark should be at least 35% of the diameter of the sphere(s).

Diagonal Cross 'X' Topmarks:
Used for special marks.

- In the case of a buoy, the arms of the 'X' should be diagonally contained within a square with length of side of about 33% of the buoy diameter at the waterline. The width of the arms of the 'X' should be about 15% of the length of side of the square.

Vertical/Perpendicular Cross '+' Topmark:
Used for Emergency Wreck Marking Buoy.

- For a pillar-shaped buoy, the arms of the '+' should be contained within a square with length of side of about 33% of the buoy diameter at the waterline. The width of the arms of the '+' should be about 15% of the length of side of the square. For a Spar buoy, the arms of the '+' should be contained within a square with length of side 1 to 1.5 times the diameter of the spar.

3.2.7 Sector Lights and Leading (Range) Lines

A sector light is an aid to navigation that displays different colours and/or rhythms over designated arcs. A common means of creating a sector is to fit a coloured filter in front of the main light. However, sector lights with LED light sources are being introduced to the market thereby reducing the need for filters as they produce the coloured light. A sector can also be produced by filtering or by using a secondary light (or several lights) on the same structure. The secondary light can take any of the following forms:

- Range (directional) light;
- Beacon with a coloured lens, masked to achieve the sector angle;
- Beacon fitted with internal or external filter panels;
- Beacon or beacons with different coloured light sources, masked to achieve the sector angle;
- Precision Direction Light.

The limits or boundaries of a sector are not always precisely cut off due to the characteristics of the light source, fading of colours or changing rhythms between adjacent sectors.

For a beacon fitted with coloured filter panels, the reason for the lack of a precise transition at the sector boundary is readily apparent from *Figure 15* which shows the light source, lens and filter geometry. The transition zone is defined by an "*angle of uncertainty*". A similar geometry exists with multiple coloured beacons and masking

Bearings, directions of leading (range) lines and limits of sectors should always be stated in terms of the bearings that would be seen by the mariner. Bearings may carry a suffix 'TBS" or True Bearing from Seaward as confirmation.

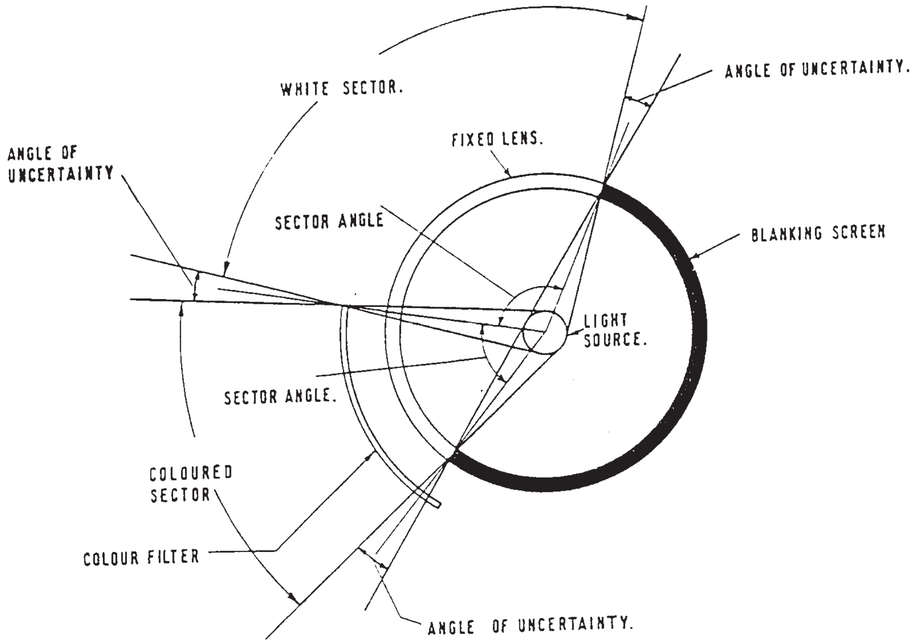


Figure 15 – Angle of Uncertainty

It can also be noted that:

- the observed angle of uncertainty is generally less than the geometric angle due to the relative intensities of sector colours (ie. colour mixing) as the observer passes through the transition zone;
- if space on the aid to navigation structure is not a limiting factor, it is usually possible to achieve an angle of uncertainty of around 0.25º with this type of sector arrangement;
- the angle of uncertainty can be reduced by decreasing the physical width of the light source or by increasing the radial distance to the coloured filter;
- in situations where the main light has a large projected area, such as a rotating lens or reflector array, it is generally preferable to use a separate sector light rather than installing a coloured filter in front of the main light.

From time to time specialised sector lights have been developed to exhibit different rhythms over different sector bearings. This capability is found in some **Precision Direction Lights** (PDL)[17].

A PDL is a specialised form of sector light that can generate sharply defined sector boundaries. This feature is particularly useful for applications that require one or several narrow sectors or high precision boundaries. The PDL may use a white light source with coloured filter, but newer designs are utilising LED and possibly laser as a light source.

PDL sector lights are very precise, allowing a complete colour change at a sector boundary to occur over an angle of less than 1 minute of arc in most models.

Applications

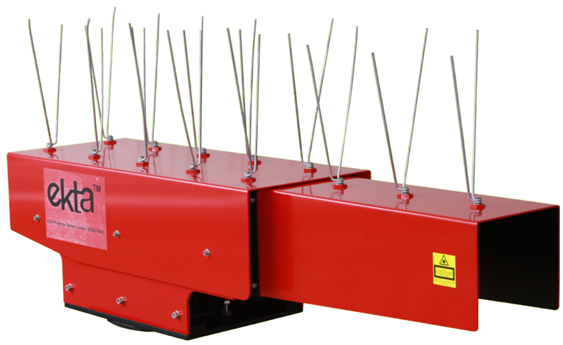
The design of sector lights can be a complex task. The process should be carried out with reference to an accurate chart of the area. In some cases good local knowledge is also required.

A sector light may indicate one or more of the following:

- boundaries of a navigable waterway;
- change of course position;
- shoals, banks, etc.;
- an area or position (eg. an anchorage);
- the deepest part of a waterway;
- position checks for floating aids.

A PDL allows for further applications that include the ability to:

- produce narrow sectors with an angle of uncertainty down to approximately one minute of arc;
- define the central zone of a channel;
- accurately mark one side of a straight channel (a pair of PDLs can cover the permutations of converging, diverging and parallel channels);
- define different rhythms over adjacent sectors.



LED Sector Projector Light - Photo Courtesy of Cybernetica AS

[17] Also known by the trade name of PEL light.

Examples

Some examples of sector lights applications are illustrated in *Figure 16* and *Figure 17*.

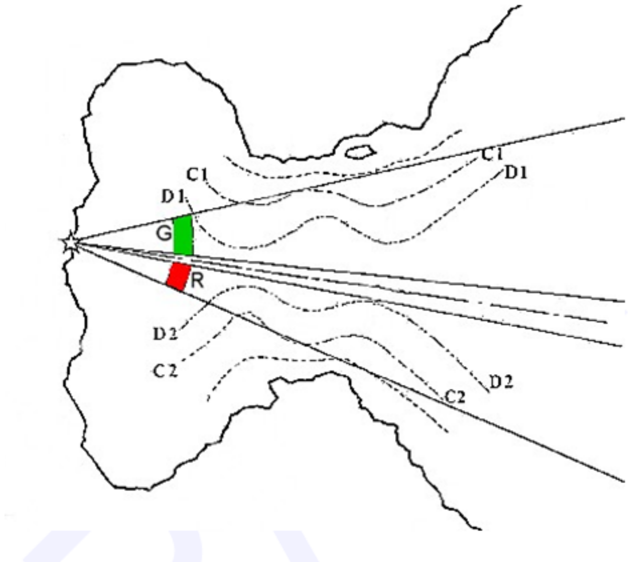


Figure 16 - Sector Light Application

This illustration follows the IALA Maritime Buoyage System colour convention for Region A ('red to port when approaching the aid from seaward'). The white sector should, if possible, be wide enough to provide a margin of safety for a vessel that inadvertently leaves the white sector. Curves C and D indicate depth contours or limiting dangers that dictate the boundaries of sectors.

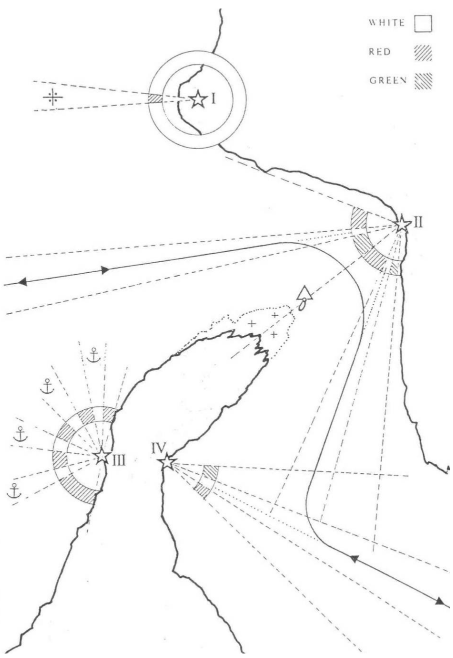


Figure 17 - Various Applications for Sector Lights

The function of each light in *Figure 17* is described below:

- Light I is a coastal white light with a red sector indicating a danger.
- Light II is a sector light obscured over the shore, with two white sectors indicating a safe channel. When sailing towards the sector light it shows red to port and green to starboard following the IALA Maritime Buoyage System colour convention for Region A and vice versa for Region B. The boundary between the red and the green sector also indicates the position of a buoy.
- Light III is a sector light with a red light and 4 white sectors indicating four anchorage positions. It is obscured over the shore.
- Light IV is a sector light with a white sector indicating a safe channel.

Design Considerations for Sector Lights

Where a single sector light defines a navigable channel the following points should be considered:

- **Lateral Position:** There is no reference of the vessel's lateral position within the channel until a sector boundary is reached. This may cause a problem in channels subject to a strong cross current. For vessels with local knowledge, the zones defined by the angle of uncertainty can sometimes provide a useful guide to the vessel's proximity to a sector boundary;
- **Safety Margin:** Where practicable, there should be a margin of safety between the sector boundary and adjacent hazards. If an appropriate safety margin cannot be achieved within the sector boundary, the hazards could be marked separately.
- **Angle of Uncertainty:** Zones defined by the angle of uncertainty should be considered an additional margin of safety over the actual sector boundary;
- **Vessel Size:** The design process for a sector light needs to consider the draught and manoeuvrability of the largest vessels likely to utilise the sector, how quickly they can respond once they cross a sector boundary and the situations that may develop when other vessels are in the vicinity;
- **Lights and Filters:** When using an incandescent light source the sector design should take account of the spectral distribution of the light source and the proportion of this light transmitted through the filter material as this will affect the resultant colour and intensity of the light exhibited. The process should also check for potential glare problems;
- **Flash Characteristic:** The period of the light flash should be selected to provide ample time for a mariner to recognise the transitional phases that occur at the sector boundary ;
- **Sector Colours:** A white light is normally the first preference for a lighthouse or beacon. If a single coloured sector is added, red is often used. If a white sector light is used to mark a navigation channel, coloured sectors may be used either side of the white to indicate the lateral limits. In such cases it is common practice to use red and green sectors that follow the convention of the IALA Maritime Buoyage System;

- **Lamp Position and Type:** The position of the light source within the optical system is critical for the correct alignment of the sectors. When replacing lamps or using lampchangers, it is important to ensure that the light source (e.g. filament) position is identical. If a lampchanger is incorporated, the sector system should be designed for the widest light source used in the lampchanger.

Refer to IALA publication:
- *Guideline 1041 on Sector Lights.*

Transits / Leading (Range) Lines
A transit is defined as the alignment of two or more marks. A Leading (or Range) light is a specialised application of a transit.

Leading (Rear Range) Light - Photo Courtesy of the Canadian Coast Guard

A simple transit can be used to:

- Provide a turning reference;
- Define a clearing line for the limits of safe navigation;
- Provide a distance mark along a waterway.

A leading line is an aid to navigation system that comprises two separated structures with marks or lights that, when viewed from the centreline or deepest route along a straight section of channel, are aligned.

In a two station leading line, the structures lie along an extension of the centreline of the nominated channel. The rear structure must have a greater elevation than the front structure to enable both marks or lights to be viewed simultaneously.

A leading line provides a vessel with a heading reference and a visual indication of the size and direction of any cross track error.

Purposes of Leading Lines

A leading line may be used to:

- indicate the centreline of a straight section of a navigable channel;
- indicate to deep draught vessels the deepest part of the waterway;
- indicate the navigable channel where fixed and floating aids to navigation are not available[18] or do not satisfy the accuracy requirements for safe navigation;
- define a safe approach bearing to a harbour or river entrance, particularly where there are cross currents;
- separate two-way traffic (ie. when passing a bridge).

Design Considerations for Leading Lines

A well-designed leading line will enable the type and size of vessels that typically use the channel to:

- Identify the marks or lights when the ship is at the inner and outer sections of the channel and readily detect cross track position errors from the centreline of the channel;
- Detect cross track position errors with sufficient sensitivity that the channel can be utilised without abrupt changes to the vessel's heading and speed;
- Observe both lights together, by selection of leading light character rhythms that appropriately overlap in their free running condition. In some situations it may be preferable to provide additional equipment to synchronise the light characters;
- Observe the lights in all ambient conditions for which they are designed to be used without glare. If lights are to be used for both day and night operations light intensities will need to be varied.

The characters of rhythmic leading lights should be selected so that the front and rear lights, in their free running states, can generally be observed together. In some situations it may be preferable to provide additional equipment to synchronise the light characters.

If lights are to be used both day and night, the light intensities should be adapted for each situation to avoid glare at night. Radar transponders (RACONs) may be used as leading line markers.

Refer to IALA publications:
- *Recommendation E-112 for Leading Lights (including excel program);*
- *Guideline 1023 for the Design of Leading Lines;*
- *Recommendation for a Definition of Nominal Daytime Range of Maritime Signal Lights Intended for Guidance of Shipping by Day.*

[18] For example, in waterways where the aid may be drifting or destroyed due to ice conditions.

3.2.8 Integrated Power Supply Lanterns

Integrated Power Supply Lanterns (IPSL) have application advantages for certain situations. By incorporating modern technologies, they can be small, durable, reliable, cost effective and fully self contained. Technological advances in light emitting diodes (LEDs), photovoltaics (Solar Panels) and batteries complement each other and facilitate a compact lantern. In order to operate efficiently, these lanterns must be designed for a wide range of solar conditions (i.e. sunlight available to charge the lantern) while maintaining a specified optical output over the expected operating lifetime.

The application criteria for IPSL include nominal light ranges up to 5nm, areas with good solar insolation, areas that suffer from vandalism or theft and small buoys with limited weight carrying ability. They are not suitable where high duty cycle rhythmic characters are required or in areas suffering from icing. An IPSL device houses power source, power storage, LED light source, rhythmic character coding and switching together in a single unit. IPSL can accept external programming commands and include options for GPS and communication modules.

Refer to IALA publication:

- *Guideline 1064 on Integrated Power Systems Lantern.*

4 E-NAVIGATION

4 E-NAVIGATION

4.1 Introduction

e-Navigation is a broad strategic vision led by IMO for the harmonisation of marine navigation systems and supporting shore services, underpinned by user needs. The concept involves the utilization and integration of all available navigational tools to secure a greater level of safety and accident prevention. Implementation of e-Navigation will, at the same time, deliver substantial operating efficiencies with resulting commercial benefits.

e-Navigation will incorporate the use of new technologies in a structured way and ensure that their use is compliant with the various electronic navigational and communication technologies and services that are already available.

Research indicates that around 60% of collisions and groundings are caused by direct human error. Despite advances in bridge resource management training, it seems that the majority of watchkeeping officers make critical decisions for navigation and collision avoidance in isolation, due to a general reduction in manning.

In human reliability analysis terms, the presence of someone checking the decision-making process improves reliability by a factor of 10. If e-navigation could assist in improving this aspect, both by well-designed onboard systems and closer cooperation with vessel traffic management instruments and systems, risk of collisions and grounding and their inherent liabilities could be dramatically reduced.

However, although e-navigation may be able to improve the situations described above, there is also a need to recognize the role of the practice of good seamanship, the provision of suitable training and the use of procedures.

In 2006, seven IMO Member States made a joint submission to the Maritime Safety Committee to "*develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic tools, in a holistic and systematic manner.*"

IMO, supported by other international organisations such as IALA and IHO and the maritime industry, has made substantial progress in translating the concept of e-navigation to an operational reality. It is expected that by 2014, IMO will approve a strategic implementation plan.

4.2 Definition

The definition of e-Navigation adopted by IMO is:
"e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment."

WHAT DOES THE "E" IN E-NAVIGATION STAND FOR?
It is generally accepted that the IMO concept of "e-Navigation" can be thought of as a brand, without the need for "e" to be specifically defined.

The concept of e-Navigation was proposed by IMO Member States in 2006 as a process for the harmonisation, collection, integration, exchange and presentation of maritime information. As such, the "e" could have stood for "enhanced" or "electronic", but this would unnecessarily limit what can be done within e-Navigation. It must be noted that generic electronic marine navigation already exists in many forms and should not be confused with this specific IMO initiative.

4.3 Vision

A vision of e-navigation is embedded in the following general expectations for the onboard, ashore and communications elements:

Onboard
Navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface, and a comprehensive system for managing guard zones and alerts. Core elements of such a system will include, actively engaging the mariner in the process of navigation to carry out his/her duties in a most efficient manner, while preventing distraction and overburdening.

Ashore
The management of vessel traffic and related services from ashore enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency.

Communications
An infrastructure providing authorized seamless information transfer onboard ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits. commands and include options for GPS and communication modules.

4.4 Strategy and Implementation

In 2008, IMO approved the development of an e-Navigation Strategy Implementation Plan. This includes the development of a technical architecture, gap analysis, cost benefit analysis and the creation of a detailed implementation plan. A structured and phased approach is required to capture evolving user needs, making use of the existing agreed methodology.

The Strategy Implementation Plan includes priorities for deliverables, a schedule for implementation and provision for the continual assessment of user needs. Implementation will be a phased, iterative process. The architecture for e-navigation will encompass hardware, data, information, communications technology and software. It will be based on a modular and scalable concept and will cater for continued development and enhancements.

The deployment of new technologies is to be based on a systematic assessment of how the technology can best meet defined and evolving user needs within the e-navigation concept. Development of usability standards and further development of the IMO Human Element Analyzing Process (HEAP) will also be undertaken.

Implementation of e-Navigation will commence once IMO approves a Strategy Implementation Plan (expected to be in 2014), which is expected to include:

- Identification of responsibilities to appropriate organizations/parties;
- Transition arrangements;
- A phased implementation schedule along with possible roadmaps;
- Priorities for deliverables, resource management and a schedule for implementation and the continual assessment of user needs;
- Proposals for a systematic assessment of how new technology can best meet defined and evolving user needs;
- A plan for the development of any technology and institutional arrangements necessary to fulfill the requirements of e-navigation in the longer term;
- Proposals on public relations and promotion of the e-navigation concept to key stakeholder groups;
- Identification of potential sources of funding for development and implementation, particularly for developing regions and countries and of actions to secure that funding.

High Level User Needs

The IALA methodology was used to capture evolving user needs. It was based on the elements contained within the accepted definition of e-navigation and applied templates to define specific user needs based on the harmonized collection, integration, exchange, presentation, analysis and human element aspects for all users. Following extensive feedback from Member States, other maritime organizations, and interested parties, an analysis was conducted resulting in the identification of high-level generic user needs for both ship and shore users. Thus the needs of a typical SOLAS ship and a generic shore authority have been used as the basis for the identification of the high-level user needs described below. A more detailed user needs may have to be identified as a part of the implementation plan.

1) Common Maritime Information/Data Structure

Mariners require information pertaining to the planning and execution of voyages, the assessment of navigation risk and compliance with regulation. This information should be accessible from a single integrated system. Shore users require information pertaining to their maritime domain, including static and dynamic information on vessels and their voyages. This information should be provided in an internationally agreed common data structure. Such a data structure is essential for the sharing of information amongst shore authorities on a regional and international basis.

2) Automated and Standardized Reporting Functions

E-navigation should provide automated and standardized reporting functions for optimal communication of ship and voyage information. This includes safety-related information that is transmitted ashore, sent from shore to ship borne users and information pertaining to security and environmental protection to be communicated amongst all users. Reporting requirements should be automated or pre-prepared to the extent possible both in terms of content and communications technology. Information exchange should be harmonized and simplified to reduce reporting requirements. It is recognized that security, legal and commercial issues will have to be considered in addressing communications needs.

3) Effective and Robust Communications

A clear need was expressed for there to be an effective and robust means of communications for ship and shore users. Shore-based users require an effective means of communicating with vessels to facilitate safety, security and environmental protection and to provide operational information. To be effective, communication with and between vessels should make best use of audio/visual aids and standard phrases to minimize linguistic challenges and distractions to operators.

4) Human Centred Presentation Needs

Navigation displays should be designed to clearly indicate risk and to optimize support for decision making. There is a need for an integrated "alert management system" as contained in the revised recommendation on performance standards for Integrated Navigation Systems (INS) (Resolution MSC.252(83)).

Consideration should be given to the use of decision support systems that offer suggested responses to certain alerts, and the integration of navigation alerts on board ships within a whole ship alert management system. Users require uniform and consistent presentations and operation functionality to enhance the effectiveness of internationally standardized training, certification and familiarization.

The concept of S-Mode has been widely supported as an application on board ship during the work of the Correspondence Group. Shore users require displays that are fully flexible supporting both a Common Operating Picture (COP) and a User Defined Operating Picture (UDOP) with layered and/or tabulated displays. All displays should be designed to limit the possibility of confusion and misinterpretation when sharing safety-related information. E-navigation systems should be designed to engage and motivate the user while managing workload.

5) Human Machine Interface

As electronic systems take on a greater role, facilities need to be developed for the capture and presentation of information from visual observations, as well as user knowledge and experience. The presentation of information for all users should be designed to reduce "single person errors" and enhance team operations. There is a clear need for the application of ergonomic principles, both in the physical layout of equipment and in the use of light, colours, symbology and language.

6) Data and System Integrity

E-navigation systems should be resilient and take into account issues of data validity, plausibility and integrity for the systems to be robust, reliable and dependable. Requirements for redundancy, particularly in relation to position fixing systems, should be considered.

7) Analysis

E-navigation systems should support good decision making, improve performance and prevent single person error. To do so, shipboard systems should include analysis functions that support the user in complying with regulations, voyage planning, risk assessment, and avoiding collisions and groundings including the calculation of Under Keel Clearance (UKC) and air draughts. Shore-based systems should support environmental impact analysis, forward planning of vessel movements, hazard/risk assessment, reporting indicators and incident prevention.

Consideration should also be given to the use of analysis for incident response and recovery, risk assessment and response planning, environment protection measures, incident detection and prevention, risk mitigation, preparedness, resource (e.g., asset) management and communication.

8) Implementation Issues

Best practices, training and familiarization relating to aspects of e-navigation for all users should be effective and established in advance of technical implementation. The use of simulation to establish training needs and assess its effectiveness is endorsed. E-navigation should as far as practical be compatible forwards and backwards and support integration with equipment and systems made mandatory under international and national carriage requirements and performance standards. The highest level of interoperability between e-navigation and external systems should be sought where practicable.

4.5 IALA's Role

IALA's e-Navigation Committee has contributed substantially to the formulation of the IMO Strategy for the implementation of e-Navigation and to the Strategy Implementation Plan. The working groups of the e-NAV Committee are developing shore user requirements, information systems and data structures, a World Wide Radio Navigation Plan, a Radio Communications Plan, enhanced AIS, VHF Data Exchange and a shore-side architecture, together with a documentation structure to encompass the whole of e-Navigation.

4.5.1 Maritime Service Portfolios

A Maritime Service Portfolios (MSP) defines and describes the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate. MSPs should be developed to achieve harmonization, modernization, integration and simplification on board and ashore, taking into account the use of the IHO's S-100 standard.

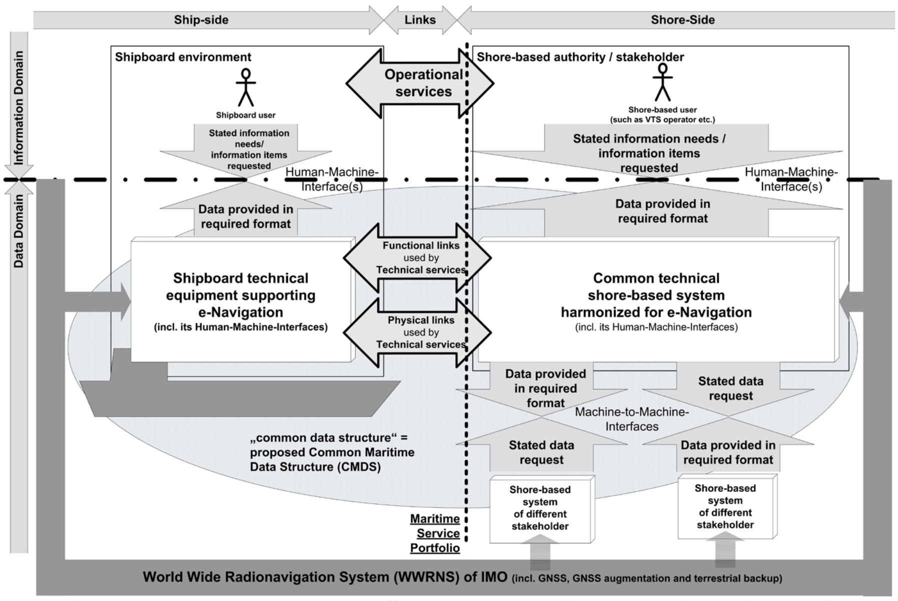
The objective of the MSP concept is to align global maritime service with the need for information and communication services in a defined operational area. To achieve such, the first step should be to identify the need for information services and communication infrastructure in the different areas. A set of services will require a certain communication infrastructure capacity, varying from area to area.

It has been agreed that the MSP areas are divided into:

- Harbour operations;
- Operations in coastal and confined or restricted waters;
- Transocean voyages;
- Offshore operations;
- Operations in Arctic, Antarctic and remote areas.

4.5.2 IMO Adopted Overarching Architecture

IMO has defined and adopted the overarching architecture as given in *Figure 18* NAV57, WP.6, as adopted by MSC90, May 2012, refers). It is composed of a number of elements, which are introduced – in a step-by-step fashion – in the following sections.



Note: There are operational and technical interactions between different shipboard environments. These are not shown for simplicity's sake in this figure.

Figure 18 - IMO Adopted Overarching Architecture

4.5.3 User's Perspective in Architectural Terms

One way of understanding the concept of e-Navigation is to look at it from a user's perspective. As visualized in *Figure 19*, the architecture can be divided into three parts; ship side, shore side and the interaction between ship and shore. This represents the overarching architecture from a users' perspective.

The ship side represents the users on-board a ship, whilst the shore side typically represents users from communities like Vessel Traffic Services (VTS), Allied Services and even users from communities within the logistics domain.

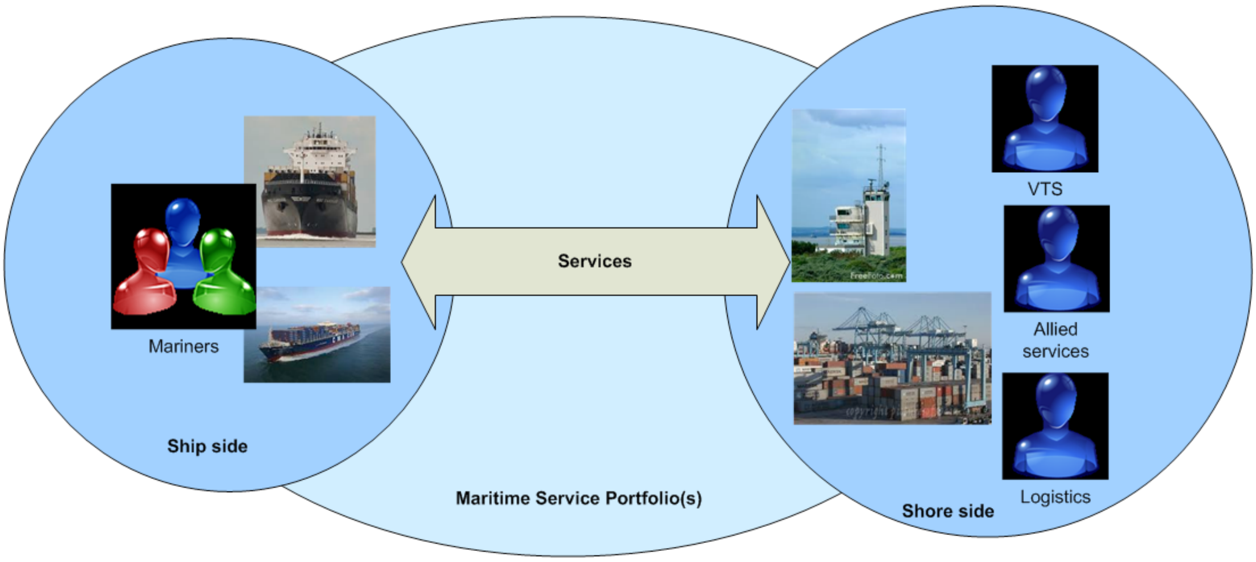


Figure 19 - e-Navigation Users' Perspective at a Given Moment and Given Place

To enable both sides to communicate and to exchange information, e-Navigation uses the general term "service". From a user's perspective, the important services will be the "operational services". However, there also needs to be "technical services" to be able to provide these operational services (*Figure 20*). Altogether, these services are referred to as the Maritime Service Portfolio (MSP).

A MSP defines and describes the whole set of operational and technical services and the level of these services, as provided by a stakeholder in a given sea area, on a waterway, or in a port, as appropriate. The MSP concept was conceived to achieve harmonisation, simplification, and tighter interaction of services and systems on board and ashore. It will be further developed based upon the IMO concept of a "Common Maritime Data Structure" (CMDS).

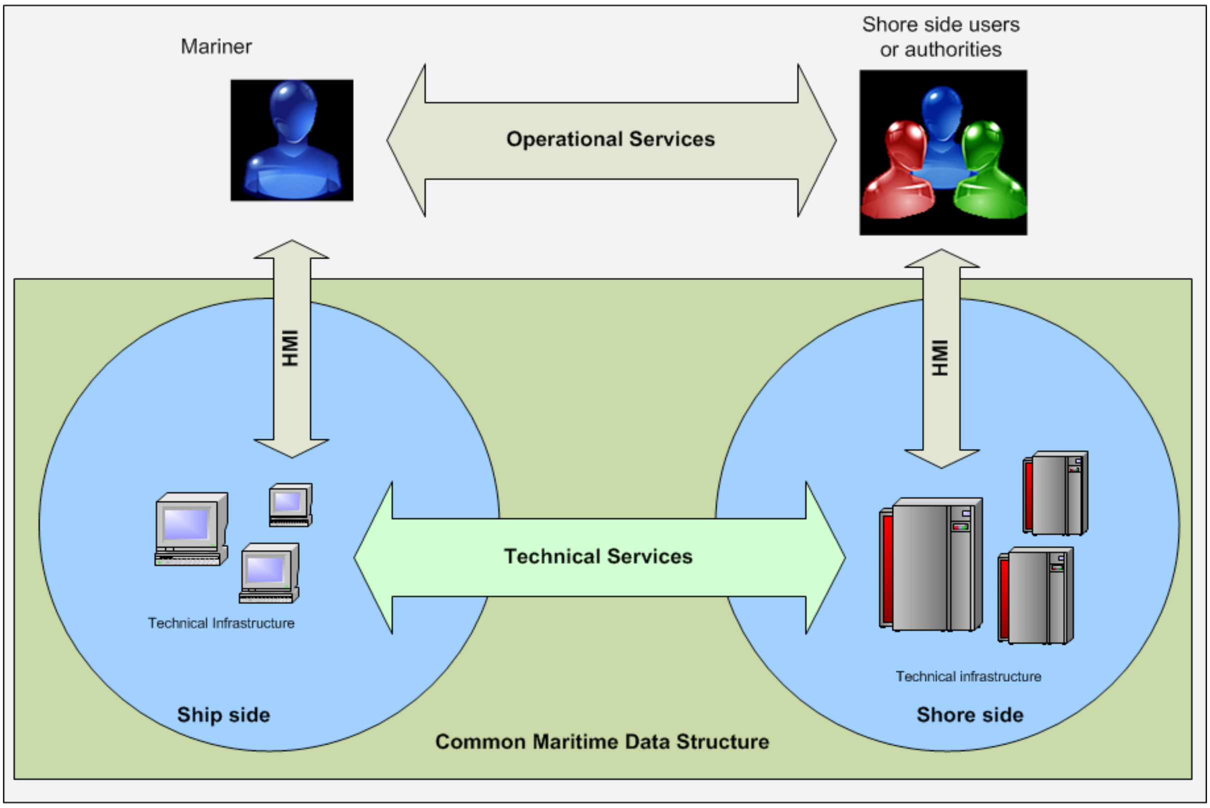


Figure 20 - The e-Navigation Services Concept

4.5.4 The Common Maritime Data Structure

The purpose of the IMO defined Common Maritime Data Structure (CMDS, see *Figure 21)* is to harmonise data exchange in the maritime domain by providing a common, authoritative reference. The CMDS is an abstract representation of entities within the maritime domain. It should be accessible by any stakeholder or implementer and should be the reference for the development of maritime services, applications and databases.

Considering the extent of the maritime domain, with all of its stakeholders, the responsibility for the CMDS is subdivided into smaller units, each of which is governed by a recognised authority. However, these authorities cooperate to harmonise the CMDS as a whole (e.g., to avoid duplication of entries). This is one of the main tasks of the IMO established IMO/IHO Harmonisation Group on Data Modelling (HGDM).

IHO developed the IHO GI Registry[19], based on its S-100 standard, as a tool for data modelling for the specification and production of Electronic Navigational Charts (ENC) and Digital Nautical Publications (DNP). The GI Registry is generic in setup and has been adopted by IMO as the tool to develop the CMDS.

[19] A registry is simply a bookkeeping device where definitions/ specifications are kept in organised locations known as registers. The registry eases the tasks of development of new things, by providing a centralised source for finding definitions/ specifications.

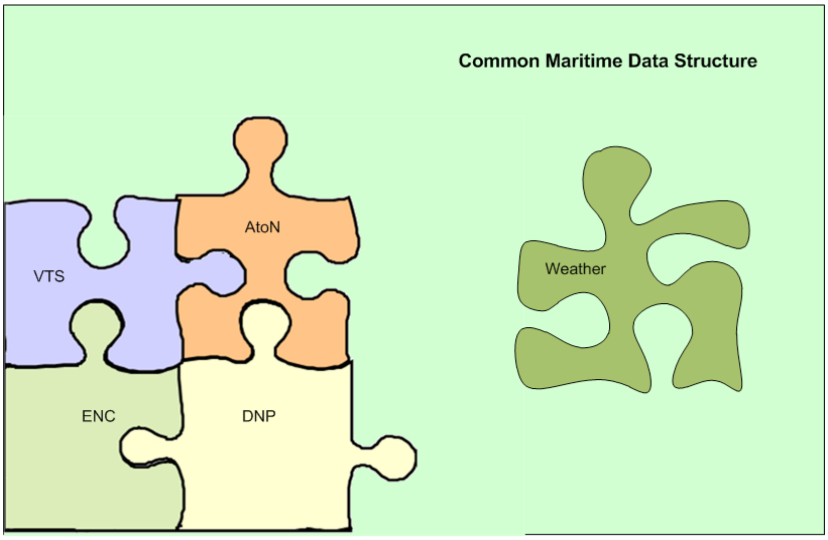


Figure 21 - The Harmonised Common Maritime Data Structure

Figure 22 describes the simplified generic structure of the GI Registry. The major features of the registry include registers for:

- **Product Specifications** – includes everything needed to fully describe and specify a product such as data exchange protocols and references to HMI and CMDS entities from the GI Registry.
- **Human-Machine Interface (HMI)** – HMI definitions/ specifications can also include references to CMDS entities from the GI Registry. (This register is named Portrayal by IHO.)

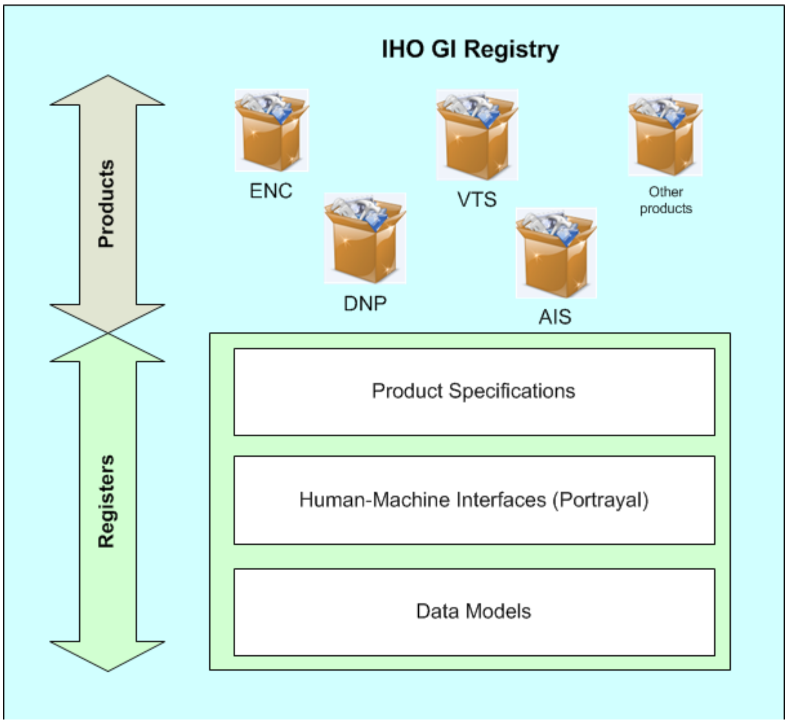


Figure 22 - Simplified View of the IHO GI Registry

4.5.5 Shore-based Requirements

IALA members use shore-based systems (which are composed of products) to provide commonly recognised operational services, for example, in the realms of Aids-to-Navigation and VTS. Many of these shore-based systems have a similar architecture. This architecture has been captured in the Common Shore-based System Architecture (CSSA). In *Figure 23*, below, the responsibility of the shore-based service provider is within the oval.

Figure 23 also shows a more detailed representation of the technical services already introduced by *Figure 20*. The common elements of the technical services are:

- Data Collection (e.g., radar, AIS, etc.);
- Data Exchange (ship/shore and shore/ship; e.g., VHF Data Exchange, AIS, etc.);
- Data Processing;
- Gateway (shore/shore; e.g., LRIT Service Centre, inter-VTS services, etc.);
- Human-Machine Interface (HMI).

Note that not all technical services require all of these elements. The arrows indicate data flows between these common elements. The data that is exchanged is modelled within the CMDS.

IALA is a Domain Owner within the IHO Registry for the domains of AtoNs, VTS and AIS and is accepted by IHO as a Submitting Organisation.

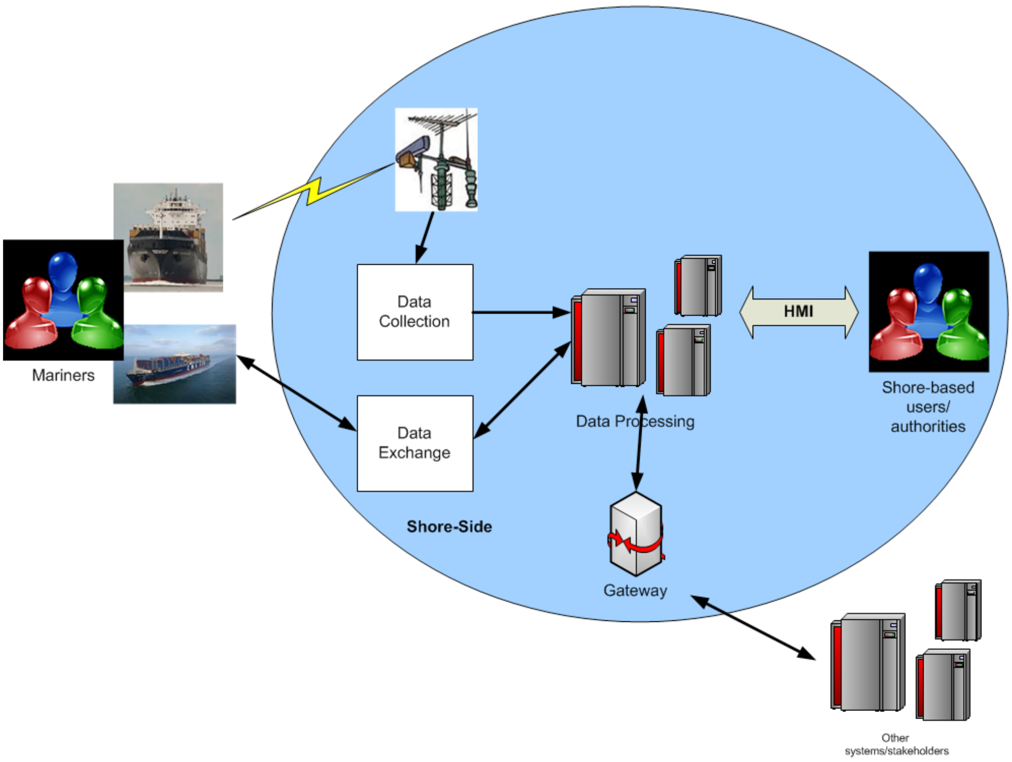


Figure 23 - Simplified View of the Common Shore-based System Architecture (CSSA)

In addition, e-Navigation will impact the shore-based systems by requiring harmonization. The concept of the CSSA was developed to accommodate the requirements imposed by provision of e-Navigation services.

Existing legacy systems do have varying degrees of compliance to e-Navigation. Most of these systems will require amendment or eventual replacement in order to support e-Navigation services and achieve full e-Navigation compliance.[20]

4.6 Technology for e-Navigation

Many sub-systems or components will have to be developed, enhanced or provided to realise the full integrated concept of e-Navigation. Crucial among these are Positioning, Navigation and Timing (PNT), communications and information systems. It should be noted that not all of the following technologies or systems will be needed within the e-Navigation concept.

4.7 IALA Plan

IALA has developed a World Wide Radio Navigation Plan (WWRNP) aimed at providing the WWRNS to support e-Navigation. One key concept in this plan is the separation of the generation of correction data from the means of transmission, to facilitate broadcasting by a variety of methods. This could lead to the integration of terrestrial systems (DGNSS beacons, e-Loran, AIS) to provide shared data channels and common correction sources, as well as additional ranging signals, contributing to a redundant position-fixing solution, complementary to, but independent of GNSS.

Future standards for position-fixing systems should be considered in the context of position-fixing requirements for e-Navigation. This WWRNP could be the basis for a submission to IMO as a contribution to the WWRNS. The plan provides guidance to IALA members regarding potential future developments, which will enable members to identify areas requiring resource allocation and research activity.

4.8 Electronic Position Fixing Systems

4.8.1 Global Navigation Satellite Systems

Global Navigation Satellite System (GNSS) is a generic term for a satellite system that provides a world-wide position determination, time and velocity capability, for multi-modal use.

GNSS is based on a constellation of active satellites, which continuously transmit coded signals in one or more frequency bands. These signals can be received by users anywhere on the earth's surface to determine their position and velocity in real time, based on ranging measurements.

[20] Refer to in particular MSC85/26, Annex 20, paragraphs 9.9.1., 9.1.5, and 9.9.3.

If a GNSS conforms to IMO Resolution A1046(27) for a World-Wide Radionavigation System (WWRNS), the receivers of that GNSS will satisfy the IMO carriage requirements for position fixing equipment referred to in Chapter V of the SOLAS Convention.

GNSS receivers, in combination with other equipment, are able to provide PNT information such as:

- absolute positioning;
- relative positioning (this can be further processed to derive speed over ground (SOG), course over ground (COG), etc.);
- timing.

This information may refer to a stationary observer (static positioning) or to a moving observer (kinematic positioning).

Several Global Navigation Satellite Systems (GNSS) have been deployed, fully or partially, or are under development.

Since 1996, the US "Navstar" Global Positioning System (GPS) and the Russian Global Orbiting Navigation Satellite System (GLONASS) have been recognised as components of the WWRNS. In the future, GNSS will include other systems such as "GALILEO", a system currently under construction by the European Union, and "BeiDou", currently under construction by the People's Republic of China. Furthermore, regional GNSS components like "QZSS" from Japan and "IRNSS" from India are planned to become operational in the next few years.

Global Positioning System

The Global Positioning System (GPS) is a three-dimensional positioning, three-dimensional velocity and time system that became fully operational in 1995. The system is operated by the United States Air Force on behalf of the United States Government.

The U.S. Government provides two levels of GPS service. The Precise Positioning Service (PPS) provides full system accuracy to designated users. The Standard Positioning Service (SPS) provides accurate positioning to all users.

The GPS has three major segments: space, control, and user. The GPS Space Segment consists of a nominal constellation of 24 satellites in six orbital planes. The satellites operate in circular 20,200 km (10,900 nm) orbits at an inclination angle of 55 degrees and with a 12-hour period.

The GPS SPS is available on a non-discriminatory basis and free of direct user fees to all users with an appropriate receiver. The service satisfies the requirements for general navigation and harbour approach with a horizontal position accuracy of 9 metres (95% probability)[21].

[21] GPS SPS Performance Standard, 2008.

A modernization program aims to improve the accuracy and availability for all users and involves new ground stations, new satellites, and four additional navigation signals: three new civilian signals known as L2C, L5 and L1C and a new military code called M-Code. Full Operational Capability of the L2C code is not expected before 2016 and for L5 before 2020.

Further information on GPS can be found on the USCG NAVCEN website (www.navcen.uscg.gov). The website also has a link to the latest United States Federal Radionavigation Plan that provides a comprehensive account of current and future developments for GPS.

Global Orbiting Navigation Satellite System
The Global Orbiting Navigation Satellite System (GLONASS) is a three-dimensional positioning, velocity and time system managed by the Russian Space Agency for the Russian Federation.

It is available on a non-discriminatory basis and free of direct user fees to all users with an appropriate receiver. With a full complement of 24 satellites, the service satisfies the requirements for general navigation and gives a horizontal position accuracy in the region of 12.4m (95%) over any 24-hour interval, given a position dilution of precision (PDOP) of 2.[22]

Recent launches have included the improved GLONASS M satellites with a second civil signal. Since 2011, the constellation is being replenished with GLONASS-K satellites that provide a third civil signal on L3.

GLONASS satellites use Frequency Division Multiple Access (FDMA), however new satellites will provide additional signals using code division multiple access (CDMA) to become interoperable with other GNSS.

Further information on GLONASS and future developments can be found on the Russian Space Agency, Information Analytical Centre website (www.glonass-ianc.rsa.ru).

Galileo
Galileo is the European GNSS designed to be interoperable with other GNSS, managed and operated under civil control. It is currently under development by the European Space Agency with funding by European Union. Galileo is aiming at providing an Open Service (OS), providing positioning and synchronisation information intended for high-volume satellite radio-navigation applications, a Commercial Service (CS) for added value professional or commercial applications, and a Public Regulated Service (PRS) restricted to government-authorised users requiring high-level of service continuity. Galileo will in addition provide a Search and Rescue Service (SAR), in support of the COSPAS-SARSAT.

[22] United Nations Office for Outer Space Affairs, "Current and Planned Global and Regional Navigation Satellite Systems and Satellite-based Augmentations Systems", 2010

Deployment started in October 2011 with the launch of the first two In Orbit Validation (IOV) satellites, with a further two due to be launched in October 2012. Target is to reach Initial Operational Capability (IOC) by 2014-2015 starting with a constellation of 18 first generation satellites, which will support the provision of continuous but limited service provision starting in the 2014-2016 timeframe. Complete Galileo Service Provision is due to start in the period 2018-2020 based on the Galileo Full Operational Capability (FOC) configuration and the fully deployed 30 satellites constellation. The first generation of Galileo will incorporate a number of features which were not part of previous GNSS systems. These include a signal in the E1 band with the advanced Multiplex Binary Offset Carrier modulation with improved performances, while ensuring both compatibility and interoperability with GPS and with other systems.[23]

BeiDou

BeiDou (formally known as COMPASS) is a GNSS being developed by China to provide positioning, navigation and timing services to worldwide users. It can also provide wide area differential services with the accuracy of 1m and short messages services with the capacity of 120 Chinese characters each time. In 1994, China started the feasibility study of the BeiDou System. In 2000, two BeiDou experimental satellites were launched to begin a regional system. In 2004, China started to construct the full/final BeiDou Navigation Satellite System which is expected to be completed by 2020.

The BeiDou Navigation Satellite System space constellation will consist of five GEO satellites and 30 non-GEO satellites (27 in medium earth orbit and 3 in inclined geostationary orbit).There will be two levels of service provided; free service to civilians and licensed service to Chinese government and military users. The free service will have 10 meter position accuracy and can synchronize clocks with an accuracy of 10 ns, and measure speeds within 0.2 m/s.[24]

Quasi-Zenith Satellite System

Japan is developing a Quasi-Zenith Satellite System (QZSS). QZSS is based on 3 satellites in highly elliptical, inclined orbits guaranteeing one satellite always in visibility of Japan with a minimum elevation angle of 60 degrees. Each satellite will transmit 6 signals in the L-band: 3 in L1, one in E6, one in L2 and one in L5.

One of the signals aims to provide sub-metre accuracy and integrity while maintaining compatibility with SBAS. The signal in E6 aims to support a commercial service with high data rate (2 kbps). The other signals are GPS-like signals, including L2C and L1C standards.

[23] At the time of writing, further information on Galileo may be found on the internet http://ec.europa.eu/enterprise/policies/satnav/galileo/index_en.htm

[24] At the time of writing, further information on BeiDou may be found on the internet hhttp://www.en.beidou.gov.cn/csnclist.html

Indian Regional Navigational Satellite System

The Indian Regional Navigational Satellite System (IRNSS) will be an independent navigation system covering the Indian region through a space segment of 3 GEO satellites and 4 IGSO satellites. The inclination of the orbital plane of the IGSO satellites is low, so that all the satellites can be seen simultaneously over India. It is planned to launch the first IRNSS satellite in 2009, with system completion by 2011.

Three IRNSS services are anticipated:

- Open Service using signals in the L5 and S bands;
- Precise Positioning Service using signals in the L5 and S bands;
- Restricted Access Service using signals in the L5 band only.

The Open and Precise services target dual frequency users but it is also intended to compute and broadcast ionosphere-corrections to support single frequency users. Owing to the limited coverage of the IRNSS network of reference stations the satellites will, apart from the navigation payload, also include a dedicated C-band uplink/down-link ranging payload to support precise satellite orbit determination.

4.8.2 Differential Global Navigational Satellite System

The aim of GNSS augmentation services such as Differential Global Navigational Satellite System (DGNSS) is the improvement of GNSS based positioning within a given area. In this context various methods can be applied to increase the accuracy of GNSS based positioning and to verify the integrity of applied components (systems, services, sensors) and provided data. An essential basis for DGNSS service provision are own GNSS measurements gathered in real time at single reference stations or a network of them.

In the simplest case the DGNSS service provides 3-dimensional positional correction parameters derived from differences between surveyed and known position at the reference station. This correction method is applied to satellite signals received at the user site which are common to those used at the reference station.

An increase on position accuracy can be expected, if the DGNSS service provides correction terms of ranging errors per satellite in view. This principle is applied by IALA Beacon DGNSS providing range and range rate corrections derived at reference station site from differences between surveyed and known distances to satellites in view. Satellite Based Augmentation Systems (SBAS) provides area correction parameter, whose application enables the determination of range and range correction for users in large-scale regions such as Europe. In this case a network of ranging and integrity monitoring stations (RIMS) is used to measure and model the spatial varying error behaviour.

Accuracies in the centimetre level can be achieved by DGNSS services employing the application of real time kinematic techniques (RTK) for positioning. The gain of accuracy is achieved by the common processing of range and phase measurements collected at reference station and user site to apply single and double difference methods during position determination.

In safety-critical application DGNSS services should be enriched with integrity functions realising the monitoring of data and system integrity in real time. The monitoring can be realised by plausibility and consistency tests as well as methods estimating error behaviour and budgets. Integrity data as results of the integrity monitoring informs the user about the current usability of applied components and provided output data.

The DGNSS service provision is realized by radio signals carrying augmentation, correction, and integrity data. Users operating in service areas and equipped with appropriate receivers can use these augmentation data to:

- enhance accuracy of GNSS based positioning;
- notify faulty satellites or GNSS failure;
- detect satellite signals with increased propagation errors;
- exclude disturbed signals from positioning;
- be informed about the usability of services or other information.

Currently, DGNSS services are provided for operational satellite navigation systems such as GPS and GLONASS. In principle, similar DGNSS services can be provided for future GNSS such as GALILEO, BeiDou and QZSS.

Each DGNSS service can be separated into a part generating and a part distributing the augmentation data. The generation of DGNSS augmentation data requires own GNSS measurements gathered at a single reference station or a network of them. Different DGNSS messages and services may use different generation methods and means of dissemination. At present certain communication channels used for the provision of DGNSS augmentation data are assigned to specific DGNSS services. For example, the provision of DGNSS augmentation data is realized by terrestrial radio transmitters (IALA Beacon Transmitter, AIS) or via satellite transponders (SBAS).

IALA Beacon DGNSS
The aim of IALA Beacon DGNSS is the provision of non-encrypted differential corrections as well as integrity information to maritime users to improve accuracy and integrity of GNSS based determination of position, velocity and time data (PVT). The method of differential positioning was developed in the nineties, is internationally accepted and supported in most coastal waters, especially in areas of high traffic density. The differential corrections are determined at known positions of reference stations or a network of them. For this purpose the difference between expected and measured ranges is used to derive actual range and range rate corrections.

Additionally, integrity monitoring functionalities are implemented to assess the usability of GNSS signals and provided DGNSS service.

The radio link used for the provision of DGNSS correction and integrity data is internationally defined at ITU (Recommendation ITU-R M.823-3). At present the DGNSS signal transmission is realized in the maritime radionavigation band (283.5 to 325 kHz)[25]. At user site type-approved DGNSS radio beacon receivers meeting IEC 61108-4 test and performance standards are necessary to enable the ship-side use of DGNSS services for an improved PVT data determination.

The recapitalisation of DGNSS infrastructure is an ongoing process. Of the options available, some service providers have opted to replace existing hardware with similar dedicated Reference Stations and Integrity Monitors (RSIM); some have invested in software RSIM; while others have adopted a network of reference stations to create virtual RSIMs. Other solutions, such as integration with SBAS may evolve within the enhancement of the maritime PNT system.

The full list of about 400 maritime radiobeacon based DGNSS stations (as notified to IALA by authorities) can be accessed via the IALA website (www.iala-aism.org).

AIS for DGNSS Transmissions
Automatic Identification System (AIS) is a ship to ship and ship to shore data broadcast system, operating in the VHF maritime band, and is described in more detail in section 4.19.

AIS has the capability of providing DGNSS corrections to onboard equipment using standardized transmissions (Message No 17) as described in IALA Recommendation A-124. The use of AIS Message No 17 increases the number of vessels which benefit from DGNSS transmissions, with respect to better accuracy and integrity.

Maritime Phase-Based GBAS (MGBAS)
In the last decades the development of phase-based techniques was driven by surveying to achieve position accuracies with GNSS in the centimetre level. In IALA R-135 the RTK technique was mentioned as an approach to meet maritime requirements on high-precision positioning in port areas and for automatic docking. Several manufacturers of maritime GNSS/DGNSS equipment provide solutions supporting RTK based positioning.

It is noted that RTK is a short-range system and that there is a need to introduce monitoring and assessment of the integrity of RTK services and RTK based positioning in the context of safety-critical applications.

[25] A 1kW transmitter will generally allow position fixing to better than 10 metres over a radius of about 200 nautical miles.

RTK Over AIS

In survey applications the RTK correction information is usually distributed to users via VHF/UHF radio modems or via commercial broadband internet. However when used in hydrographical measurements further away from the shoreline these communication options might not be available all the time. The communication options in these areas would be via satellite or via AIS (the latter is also available only inside coastal VHF coverage usually less than 70km from shoreline).

RTK over AIS is in operational use for selected user groups in some countries and it has been reported to function without major problems and deliver the required positioning accuracy level. The correction data are broadcast to the mobile unit which initiates the transmissions.

When the mobile user requests RTK corrections, the AIS base station will start to reserve time slots (by FATDMA) for transmissions. For example, two 5 slot sequences every second can be reserved for both AIS channels. This will result in approximately 20% loading of the VDL. Using a lower message transmission frequency would not guarantee the expected RTK accuracy, especially on a moving platform. However, a higher transmission rate would cause too much loading on the VDL. The correction delay of about 1-1.5 seconds caused by the transmission over the AIS data link has been reported to be acceptable. When not required, the mobile user stops the request for RTK corrections and the base station stops reserving the time slots and releases them for other use.

The limitations of this technique are that only one mobile user can be served by one AIS base-station at a time, reduced understanding of accuracy due to rapid atmospheric fluctuations and that it may not be applicable in areas of high VDL loading. The channel loading problem may be addressed in the future by using the additional channels allocated for VDES.

4.8.3 Satellite Based Augmentation Systems

Satellite Based Augmentation Systems (SBAS) support wide-area or regional augmentation through the use of additional satellite-broadcast messages. Such systems are commonly composed of multiple ground stations, located at accurately-surveyed points. The ground stations take measurements of the GNSS satellite signals and environmental factors which may impact the signal received by the users. Using these measurements, information messages are created and sent to one or more GEO satellites for broadcast to the end users.

Wide Area Augmentation System

The Wide Area Augmentation System (WAAS) has been implemented by the US FAA to support the use of GPS for general and commercial aviation over continental United States. It was recently extended to cover parts of Mexico and Canada. At present, the WAAS architecture includes 38 reference stations, 3 master stations, 4 up-link stations, 2 geostationary satellite links and 2 operational control centres. Furting information on WAAS can be found on the USCG Navigation Centre website (www.navcen.uscg.gov).

European Geo-stationary Navigation Overlay Service

The European Geo-stationary Navigation Overlay Service (EGNOS) is a joint project of the European Space Agency (ESA), the European Commission (EC) and Eurocontrol. It consists of three GEOs and a network of ground stations and transmits correction and integrity information for GPS and was designed for aviation safety-of-life applications. The system provides correction information in the L1 band through three GEO satellites. EGNOS is presently fully interoperable with the current generation of WAAS and MSAS. Like these systems, EGNOS is planning an evolution towards a dual-frequency capability using the L1/L5 bands. Further information on EGNOS can be found via website (ec.europa.eu/enterprise/policies/satnav/egnos/index_en.htm)

Multi-Satellite Augmentation System

In Japan, the Multi-Satellite Augmentation System (MSAS) is an SBAS similar to EGNOS and WAAS. MSAS has been commissioned for aviation use, with two GEO-links using the L1 band via dedicated satellites shared with communications and meteorological missions. The system has been operational since 2007 and there are plans to add additional services on L5 in the future[26]. Further information on MSAS can be found via the website: (www.kasc.go.jp/_english/msas_01.htm).

GPS-Aided Geo Augmented Navigation System

India is developing a GPS-Aided Geo Augmented Navigation system (GAGAN), which is an SBAS similar to WAAS and EGNOS. GAGAN includes 8 reference stations, 1 mission control centre, 1 up-link station and 1 Geo link through the L1/L5 transponder on the INMARSAT 4-F1 satellite. At the time of writing, further information on GAGAN may be found via the website (www.isro.org).

System for Differential Corrections and Monitoring

Russia is also developing an augmentation to provide corrections for GLONASS and GPS called the System for Differential Corrections and Monitoring (SDCM). This system will consist of 3 geo-stationary satellites, assigned PRN codes 125,140 and 141. Two satellites have been launched and are in operation with the third due to be launched in 2014.

4.8.4 Receiver Autonomous Integrity Monitoring

Receiver Autonomous Integrity Monitoring (RAIM) is a technology developed to assess the integrity of GNSS signals and therefore the integrity of GNSS based positioning. This kind of integrity monitoring is autonomously realized within the user's receiver with special importance for safety-critical applications, such as aviation and maritime.

Range measurements are required from at least 4 GNSS satellites to enable the determination of position, velocity and time data. However the application of RAIM in a navigation receiver requires redundancy in the range measurements.

[26] United Nation Office of Outer Space Affairs.

Safety-critical RAIM algorithm might use only "Fault Detection" (FD) or "Fault Detection and Exclusion" (FDE), which enables the continuation of operation in the presence of a single GNSS satellite and signal failures. To detect a faulty satellite, at least five range measurements are required, whereas to isolate and exclude a faulty satellite, at least six range measurements are required. While RAIM can detect many failure modes, it cannot detect some failures affecting multiple satellites.

The upcoming availability of various GNSS will increase the usable number of navigation signals for RAIM based positioning. New and modernized GNSS supports the provision of GNSS signals in 2 or more frequency bands and improves therefore the capability of GNSS based ranging.

Future advancement in RAIM algorithms should improve the availability and continuity of RAIM based positioning. Such enhanced RAIM techniques – so called Advanced RAIM (ARAIM) – may become available to maritime users (www.navipedia.net/index.php/araim).

4.8.5 Terrestrial Systems

Loran-C

Loran–C was a hyperbolic radionavigation system developed during the 1960's to meet U.S. Department of Defense requirements. The Russian Federation operates a similar radionavigation system called CHAYKA. There are currently about 19 Loran–C and CHAYKA chains operating around the world. The principal coverage areas include Saudi Arabia, China Sea, Korea, North West Pacific, Russian Federation and North West Europe.

Loran–C chains comprise between three to five stations that have a spacing of 600 to 1000 nautical miles. The signal format is a structured sequence of specially designed radio pulses on a carrier wave frequency centred on 100kHz. One of the stations is designated as the 'master' and transmits groups of 9 pulses. The other stations are called 'secondaries' and these transmit groups of 8 pulses.

The spacing between groups of 'master' pulses from a single chain is a characteristic unique to that chain and is referred to as the Group Repetition Interval (GRI).

The 100kHz carrier wave frequency favours the propagation of a stable ground wave over long distances. Careful signal design allows Loran receivers to determine positions using the ground wave and reject the delayed sky wave that would potentially distort the received signal.

The transmissions from each chain are monitored and controlled continuously. System abnormality indicators are built into the signal format and can be identified by the receiver providing inherent integrity warnings.

eLoran

Enhanced Loran (eLoran) is a terrestrial navigation system developed from Loran-C. It is a Positioning, Velocity, and Timing (PVT) service for use by land, sea and air navigation as well as other applications reliant on timing data.

eLoran is independent to and has dissimilar failure modes to GNSS and therefore complements GNSS use. Although offering reduced accuracy, it will allow GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted. eLoran provides positional accuracy in the region of 8 - 20 metres and time and frequency performance (to stratum-1 level) similar to current GNSS.

eLoran differs from Loran-C as it uses an all-in-view method of operation, calculating the distance to all eLoran stations in view. eLoran stations are also synchronised with, but independently of, GNSS time. Synchronising to a common time source allows receivers to employ a mixture of eLoran and GNSS signals.

eLoran receivers calculate the distance from each station by firstly assuming that the entire earth's surface is covered in sea-water. By knowing the speed of the signal over sea-water along with the times of transmission and reception a pseudorange can be calculated. This pseudorange is then adjusted to take into account the propagation delays due to the signal passing over land, these delays are called Additional Secondary Factor delays (ASFs). ASFs are measured by the service provider and are supplied to users as a database built into their receivers. ASFs may change slightly due to weather or seasonal effects, reducing the efficiency of the correction and affecting accuracy. However, this is resolved by installing a differential-Loran reference station nearby, which is able to measure the difference and calculate a correction. The correction information is then passed back to the eLoran station for dissemination to the user over the eLoran data channel.

The inclusion of a data channel as part of the main transmission is one of the inherent features of eLoran and can be used to provide other data services in addition to differential corrections.

For more information the reader is encouraged to seek the advise of Radio technical Commission for Maritime Services Special Committee 127 (SC-127) on eLoran Systems.

Compatibility Between eLoran and Loran-C

Legacy receivers are able to use both eLoran and Loran-C signals as eLoran stations form part of the presently organised chains. However, legacy Loran-C receivers will likely not provide the user with the best accuracy performance.

Users should ensure their receivers are able to decode the Loran Data Channel to receive integrity alerts, UTC time and differential-Loran correction data. They should also ensure their receiver is capable of storing and applying up to date ASF data.

4.8.6 Ranging-mode

Investigations are being conducted on the benefit of expanding the functionality of existing systems; by providing a timing signal from which the user may then calculate their position independently from GNSS and this is known as Ranging-mode (R-mode).

At present the IALA MF beacon system and AIS Services are being considered as candidates for modification to add R-mode functionality. By providing timing information over their normal MF or VHF transmissions, a shipboard receiver may then calculate a distance (range) to the transmitter. By calculating the range to several stations, the user is able to calculate the ship's position. Coverage, geometry and interference questions would need to be investigated.

The provision of R-Mode services would require the availability of an accurate non-GNSS timing source at the transmitter. High stability clocks could be an expensive option and it is more likely that time would be sourced from a low frequency radio time clock or eLoran.

4.9 Radar Aids to Navigation

Radar aids to navigation are devices that provide returns to a ship's radar that help to locate and/or identify a navigation mark.

The IMO carriage requirements contained in (Chapter V, Regulation 19) of the SOLAS Convention 1974 (as amended), states all ships of:

- 300 gross tonnage and upwards to carry a 9 GHz radar;
- 3,000 gross tonnage and upwards to be fitted with a 3 GHz radar or, where considered appropriate by the Administration, a second 9 GHz radar.

Some administrations may impose other carriage requirements.

IMO Resolution MSC.192(79) Adoption of the Revised Performance Standards for Radar Equipment 06 December 2004 states that 9 GHz radars should be capable of detecting radar beacons and should be capable of detecting SARTs and radar target enhancers. By omission, 3GHz radars are not required to detect radar beacons and SARTS. With the removal of the 3GHz radar racon detection requirement, ship-owners are free to use higher performing radars, often referred to as New Technology (NT) radars.

9 GHz radars are also extensively carried by vessels not covered by SOLAS or local regulation. Because of this high rate of carriage, radar aids to navigation in the 9 GHz band are especially useful.

4.9.1 Radar Reflectors

A radar reflector is a passive device designed to return the incident radar pulses of electromagnetic energy back towards the source and thereby enhance the response on the radar display. By design, a radar reflector attempts to minimise the absorption and random scattering effects.

A radar reflector is generally installed as a supplementary device at sites that would also be marked with a light. The main objectives of its use are to enhance:

- target detection at long ranges (for example, for landfall navigation);
- target detection in areas of sea or rain clutter; and
- radar conspicuity of aids to navigation to reduce the risk of collision damage.

The performance of a radar reflector can be defined in terms of its effective radar cross section (RCS). This is a value determined by comparing the strength of radar signals returned by the radar reflector with the equivalent return from a radar reflective sphere of 1 m^2 reflecting area.

The range at which a radar reflector target can be detected is dependent on the heights of the radar antenna and the reflector and the output power of the radar. There are analogies to the geographical range of visual marks. The radar performance of corner cluster reflectors may vary considerably from one make to another.

Use of small radar reflectors can also be subject to multipath fading effects. Please see IALA Guideline No. 1010 on Racon Range Performance for a discussion on multipath fading.

Most radar reflectors are designed for use by 9 GHz radars. The reflectors are also usable with 3 GHz radars; however, the effective radar cross section is about an order of magnitude less.

4.9.2 Radar Target Enhancers

A Radar Target Enhancer (RTE) is a device that amplifies and returns the pulse from a ship's radar to give an enhanced image on the radar screen. The returned signal from an RTE is not coded. The RTE was designed primarily for buoys and small vessels that might normally carry a passive radar reflector. RTE testing has shown RTEs to have provided an effective radar cross section (RCS) of about 100 m^2, compared with an RCS of 20 to 30 m^2 for passive radar reflectors typically fitted to buoys.

To date, commercially available RTEs only operate in the 9 GHz band.

RTE use is subject to multipath fading effects. Please refer to IALA Guideline No. 1010 on Racon Range Performance for a discussion on multipath fading.

4.9.3 Radar Beacon

Radar beacons (racons) are receiver/transmitter devices operating in the maritime radar frequency bands (9 and 3 GHz) that enhance the detection and identification of certain radar targets. Please note that IMO MSC.192(79) removed the requirement for 3GHz radar to detect racons.

A racon responds to the presence of a ship's radar by sending a characteristic pulse train. The response appears as a coded mark (or "paint") on the ship's radar display (refer *Figure 24*) that highlights the range and bearing of the racon. The display paint can be fixed to a specified length or can be dependent on the radar range setting and uses a Morse character for identification.

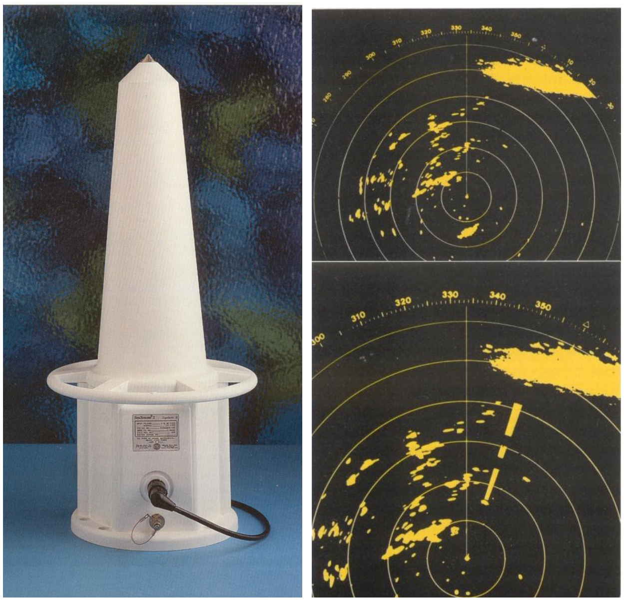


Figure 24 - A Racon (left) and a Radar Display (right) with and without the Racon Character

Applications

A racon is generally considered to be a supplementary aid to navigation installed at sites that would also be marked with a light. The number of vessels capable of making use of a racon is effectively unlimited.

A racon can be used for:

- ranging and identification of positions in ice conditions or on inconspicuous coastlines;
- identification of aids to navigation, both seaborne and land based;
- landfall identification;
- indicating centre and turning point in precautionary areas or Traffic Separation Scheme (TSS)
- marking hazards;
- indicating navigable spans under bridges;
- identifying leading lines.

4.9.4 Frequency-Agile Racon

A frequency-agile racon responds on the frequency on which it is interrogated and the response can be re-painted on each radar sweep. The purpose of frequency agility is to provide a signal to the radar that is within the receiver bandwidth of the radar.However, to avoid masking other features on the radar screen, the racon response is usually switched on and off on a preset cycle.

Signal Characteristics

Racons operate in the 9 GHz band with horizontal polarisation, and/or in the 3 GHz band with horizontal and optionally vertical polarisation.

Preferred Terminology	Alternatives		
9 GHZ	9300 9500 MHZ	X - BAND	3 CM
3 GHZ	2900 3100 MHZ	S - BAND	10 CM

Table 18 - Preferred Terminology for the Description of Racon Operating Frequencies

4.9.5 Racon Performance Criteria

The availability of a racon is the principal measure of performance determined by IALA. In the absence of any specific considerations, IALA recommends that the availability of a racon should be at least 99.6%.

Refer to IALA publications:
- *Guideline 1010 on Racon Range Performance;*
- *Recommendation R-101 on Maritime Radar Beacons (Racons);*
- *Recommendation O-113 for the Marking of Fixed Bridges Over Navigable Waters.*

4.9.6 Racon Technical Considerations

There are a number of technical considerations in the use of racons to assist the navigation of a ship:

- The angular accuracy of the bearing between the ship and racon depends entirely on the interrogating radar, while the accuracy of the range measurement depends on both the radar and racon;
- When racons are used in leading line applications, an alignment accuracy of about 0.3 degrees can be expected;
- When the ship is very close to the racon, side-lobes from the radar antenna can trigger the racon. The resulting multiple responses on the radar display may be a distraction and can mask other targets. Side-lobe suppression techniques are standard features of frequency agile racons.

4.9.7 Use with New Technology Radars

All currently available and installed racons are designed for use with high power pulse radars. In comparison, NT radars use low power transmissions with long pulses. Due to the low received peak signal strength and long pulse at the racon, current racons may not detect NT radars and may not transmit a response usable by NT radars. Studies have shown that pulsed NT radars are able to reliably trigger racons at shorter ranges than would have been achieved with a conventional magnetron pulsed radar. Note that FMCW radars (also grouped into the family of New Technology radars) are a special case which require individual analysis and measurement. The IMO regulations regarding X band radars and racons remain unchanged and although detection and triggering range might be reduced, it is the responsibility of manufacturers of X band NT radars to retain racon functionality.

Despite changes to the IMO regulations relating to S band racons, existing racons with 3 GHz capability will continue to be useful to 3GHz pulse radars of both Magnetron and pulsed New Technology variants although advanced clutter reduction techniques optimised in the knowledge that display of Racon signals is no longer a functional requirement in this frequency band, may attenuate or even remove the Racon pulse train from the radar video and display. There may be a need to replace all high power pulse radars, thereby impacting all racons with 3 GHz pulse capability.

4.9.8 Radar Referenced Positioning

Algorithms may be developed to allow the radar display to be overlaid upon the electronic chart using detectable recognised navigational features (racons, passive radar beacons or land edge patterns etc.). This technique, although unlikely to challenge the accuracy of a GNSS based position fix, might be adopted as part of a PNT integrity assessment and/or as a back-up in the event of GNSS service or equipment failure or corruption.

4.9.9 Non-radio Positioning (Inertial)

Many studies have been carried out on the integration of GNSS with Inertial Measurement Units (IMU) for marine navigation. There exist various grades of IMU, from the very expensive navigation grade through tactical grade to low cost units based on the Micro Electro Mechanics System (MEMS).The IMU grade characterizes the achievable performance of data provision covering velocities and orientations. A small IMU grade is associated with higher drift rates. Depending on the different drift rates an IMU can provide contingency functionality for various lengths of GNSS outages.

Additionally, a GNSS – IMU sensor fusion scheme enables an improved integrity monitoring for various output data like position, speed and rate of turn. In combination with a GNSS compass an IMU can provide accurate and stable heading data even for longer GNSS outages. None of the currently available inertial systems is capable of maintaining all levels of navigation accuracy during a lengthy outage of GNSS. For ocean areas, both navigation and tactical-grade IMUs will give protection for appreciable outages over 15 minutes and navigation grade IMUs up to over 1 hour. For the coastal areas the required accuracy of 10 meter could be obtained for 3.5 minutes with a navigation-grade IMU and 1.5 minutes with a tactical grade IMU.

4.9.10 Non-radio positioning (ePelorus)

An electronic pelorus is a device for taking bearings of visual marks and converting them to an electronic format for input to an electronic chart system. Such a device would enable the integration of visual AtoNs with e-Navigation. The concept was promoted in a paper by the Nautical Institute in about 2008, as a backup system for navigation.

Only a costly military version appears to exist at present. However, the feasibility of constructing a low-cost ePelorus from off-the-shelf components is being investigated, to demonstrate its effectiveness as a backup and to evaluate the potential for integrating visual AtoNs with e-Navigation.

4.10 Communications

4.10.1 Maritime Radio Communications Plan

IALA has prepared a Maritime Radio Communications Plan (MRCP) for the communications required to support e-Navigation. The MRCP is intended to meet the key strategy element of identifying communications technology and information systems to meet user needs. This may involve the enhancement of existing systems or the development of new systems. The IALA work starts by identifying existing and future systems, then drawing on the user requirements already identified to assess the information flows and the data channels needed.

4.11 Long Range Identification and Tracking

4.11.1 Introduction

Competent authorities with responsibility for aids to navigation, port security and other shoreside activities are often faced with the requirement to maintain surveillance of maritime approaches to their ports and port facilities for safety, security, and environmental protection.

These authorities are pursuing vessel tracking technologies to assist in the detection, classification, identification, and tracking of vessels. Among these technologies, Long Range Identification and Tracking (LRIT) has been implemented internationally for tracking ships globally.

4.11.2 Concept

Long range identification and tracking (LRIT) is a cooperative surveillance capability. In the simplified LRIT concept (*Figure 25*), a ship carries radio communications equipment that reports identification, position and time to authorities tracking that ship. However, the final implementation of LRIT is more complicated as explained below.

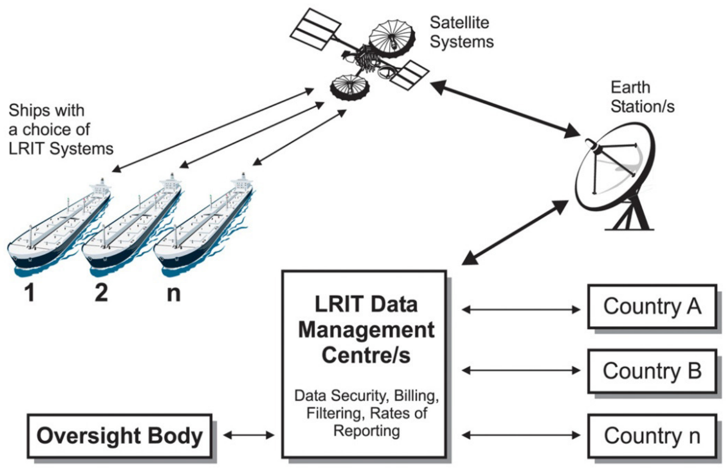


Figure 25 - Simplified LRIT Concept (INMARSAT)

4.11.3 Performance Standards and Functional Requirements

The approved performance standards and functional requirements for long-range identification and tracking lay out the LRIT system architecture (*Figure 26*) and describe how the long-range identification and tracking system works.

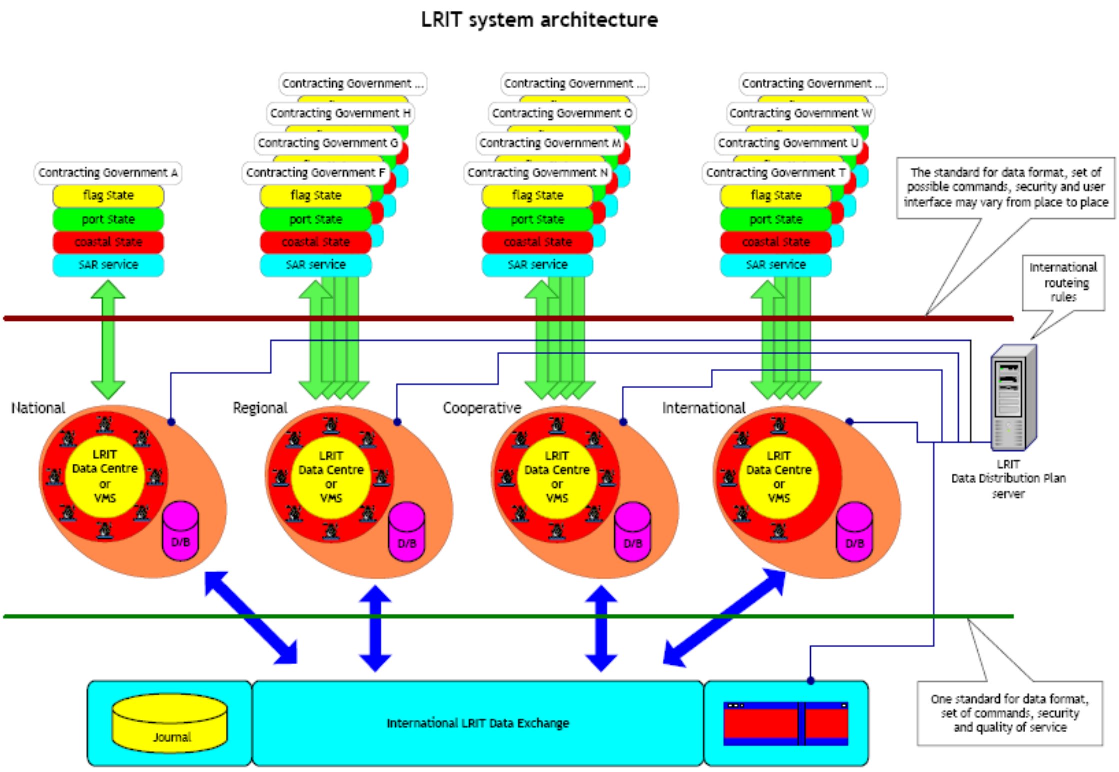


Figure 26 - LRIT System Architecture

In this architecture, the Administration determines whether its ships will report to a national, regional/cooperative, or the international LRIT data centre. Each of these types of centres may use multiple communications service providers. The architecture is also designed to accommodate multiple application service providers. Building on the basic concept noted above, a ship carries radio communications equipment that reports identification, position and time to the national, regional/cooperative, or international LRIT data centre tracking that ship. The Administration of the ship can access the LRIT information directly from the data centre. Other Contracting Governments that are entitled to that information (i.e., port and coastal states) can request the information through their data centre and thence through the international LRIT Data Exchange. The LRIT information is routed to the requesting data centre through the data exchange.

4.12 Automatic Identification System

Automatic Identification System (AIS) is a ship and shore-based data broadcast and interrogation technology, operating in the VHF maritime band, that makes it possible to monitor and track ships from suitably equipped ships, and shore stations.

AIS' characteristics and capability make it a powerful tool for enhancing situational awareness, thereby contributing to the safety of navigation and efficiency of shipping traffic management. Shipboard AIS enables the provision of fast, automatic and accurate information regarding risk of collision allowing the Closest Point of Approach (CPA) & Time to Closest Point of Approach (TCPA) to be calculated from the positional information transmitted by target vessels. AIS increases the possibility of detecting other ships, even if they are behind a bend in a channel or river or behind an island in an archipelago. AIS also solves the problem inherent with radars, by detecting smaller craft, fitted with AIS, in sea and rain clutter.

An AIS unit is a VHF radio transceiver capable of exchanging information such as station identity, position, course over ground, speed, length, ship type and cargo information etc., with other ships and suitable receivers ashore within VHF range. *Figure 27* gives an overview of the system.

Once set up correctly, information from an operational shipboard AIS unit is transmitted continuously and automatically, without any intervention by the ship's staff. AIS transmissions consist of bursts of digital data 'packets' from individual stations, according to a pre-determined time sequence. Therefore, AIS is an important supplement to existing systems, including radar. In general, data received via AIS will enhance the information available to the Officer of the Watch and the Vessel Traffic Service Operator (VTSO).

The International Maritime Organization (IMO) has established carriage requirements for merchant ships. The International Telecommunication Union (ITU) has defined the technical characteristics and ratified the global frequencies. In addition, the International Electrotechnical Commission (IEC) has developed methods for testing AIS for global interoperability.

This section aims to provide a broad overview of AIS. The reference list at the end of this section assists the reader seeking amplifying information on various aspects of AIS.

4.12.1 Purpose & Function

The purpose of AIS is to positively identify vessels, provide additional information in order to assist in collision avoidance and assist in vessel tracking. It also aims to simplify and promote the exchange of information automatically, thereby reducing the need for doing so verbally (e.g. mandatory ship reporting by radiotelephony).

AIS satisfies the following functional requirements, as laid down by IMO:

- in a ship-to-ship mode for collision avoidance;
- as a means for littoral States to obtain information about a ship and its cargo;
- as a VTS tool, i.e. ship-to-shore (traffic management).

AIS automatically exchanges shipboard information (provided by shipboard sensors), between vessels and between a vessel and a shore station(s).

4.12.1 System Characteristics

Frequencies and Capacity

AIS operates on two dedicated VHF FM radio frequencies AIS1 (channel 87B – 161.975 MHz) and AIS2 (channel 88B– 162.025 MHz) in the maritime mobile band. Transmissions consist of bursts of 'data packets' from individual stations, according to an automatically determined time-ordered sequence. Stations organize themselves on the common frequencies (AIS 1 and AIS 2) based on the knowledge of their own transmissions and that of other stations. This method of operation is known as Self Organizing Time Division Multiple Access (SOTDMA). The time slots for AIS transmissions are all precisely aligned to Coordinated Universal Time (UTC), provided for by a Global Navigation Satellite System (GNSS) receiver. This avoids the possibility of two stations transmitting at the same time, in the same slot. There are 2250 time slots available on each frequency per minute, making the total number of slots equal to 4500.

In this architecture, the Administration determines whether its ships will report to a national, regional/cooperative, or the international LRIT data centre. Each of these types of centres may use multiple communications service providers. The architecture is also designed to accommodate multiple application service providers. Building on the basic concept noted above, a ship carries radio communications equipment that reports identification, position and time to the national, regional/cooperative, or international LRIT data centre tracking that ship. The Administration of the ship can access the LRIT information directly from the data centre.

Other Contracting Governments that are entitled to that information (i.e., port and coastal states) can request the information through their data centre and thence through the international LRIT Data Exchange. The LRIT information is routed to the requesting data centre through the data exchange.

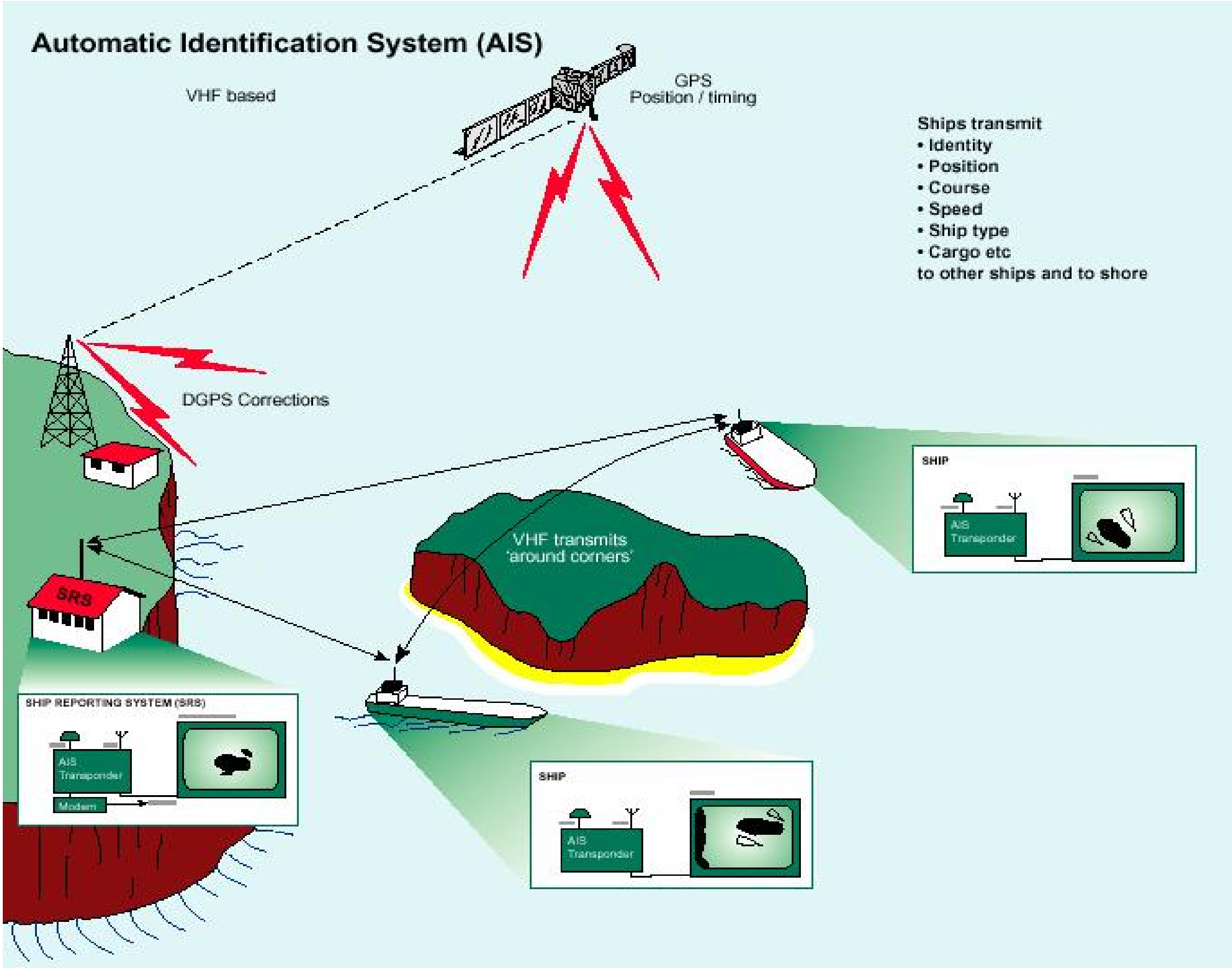


Figure 27 - Overview of the AIS System

4.12.2 Shipboard AIS

A shipboard AIS unit transmits its own data to other vessels and to AIS equipped stations continuously and autonomously. It also receives AIS data of other stations (ship and shore) and can display this data textually and graphically, as required.

Each AIS station consists of a VHF transmitter, two VHF SOTDMA receivers, a VHF DSC receiver, a GNSS receiver (to provide timing for slot synchronisation), and a marine electronic communications link to shipboard display and sensor systems.

Positional information can be derived form the internal GNSS or an external electronic position fixing system. The display panel with the unit is often the only means of showing received AIS data. Together with a keypad, this basic configuration is known as a Minimum Keyboard and Display (MKD).

The display part of a MKD, as a minimum, consists of three lines of data, each showing bearing, range and identity of the target. In practice, most MKDs display more lines of data and may also have a simple graphical display, showing the relative location of targets, rather like the Plan Position Indicator of a radar.

Ideally, AIS information should to be displayed graphically on a radar, ECDIS or on its own dedicated display.

Available Information
The AIS information transmitted by a ship station includes four different data sets:

- **Fixed or static information** is entered into the AIS unit on installation and need only be changed if the ship changes its name, call sign etc. This information is broadcast every six minutes or on request by a shore authority;
- **Voyage related information** (destination, ETA etc) is manually entered and updated during the voyage. This information is also broadcast every six minutes. In order that correct AIS information is broadcast to other vessels and shore authorities, mariners are reminded to enter current voyage related data such as draught, type of hazardous cargo, destination and ETA properly at the beginning of each voyage and whenever changes occur;
- **Dynamic information** is automatically updated from the ship sensors connected to the AIS. This includes COG, SOG, position (with accuracy and integrity flag), time and navigation status (e.g., underway);
- Broadcast or addressed **short safety related messages**, as required.

Refer to IALA publications:
- *Guideline 1028 on the Universal Automatic Identification (AIS) – Volume 1, Part 1 – Operational Issues;*
- *Guideline 1029 on the Universal Automatic Identification System (AIS) – Volume 1, Part 2 – Technical Issues;*
- *Guideline 1082 on an Overview of AIS.*

4.12.3 Shore-based AIS
SOLAS Chapter V, Regulation 19, 2.4 refers to the carriage requirements for AIS. The regulation states that AIS shall provide and receive information from appropriately equipped shore stations. The provision of shore based AIS will be necessary to attain the full benefit of the 1974 SOLAS Convention (as amended).

As AIS can be seen as a tool related to Vessel Traffic Services (VTS), Competent Authorities should consider implementing AIS into existing VTS Centres. Information on the use of AIS in VTS operations is contained in Sections 1015-1027 of the IALA VTS Manual.

Refer to IALA publications:
- *Recommendation A-123 on the Provision of Shore Based Automatic Identification Systems;*
- *Recommendation A-124 on the Automatic Identification System (AIS) Shore Station and Networking Aspects relating to the AIS Service.*

4.12.4 Meteorological & Hydrological Information

IMO is responsible for the AIS Binary Broadcast Messages (AIS Message 8) and a message structure has been defined for meteorological and hydrological information. 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 latter is generally used to overcome the sometimes considerable differences between actual tide heights and predicted values due to meteorological and mean sea level fluctuations. Providing real-time information of this type, for example dynamic under-keel clearance, wave heights or sea state can be seen as applications of e-Navigation, requiring integration between shore-side and ship-borne systems.

4.12.5 AIS Aids to Navigation

A special type of AIS station fitted to an aid to navigation provides positive identification of the aid without the need for a special ship-borne display. In addition, AIS as an AtoN can provide information and data that will:

- complement or replace an existing aid to navigation, providing identity, state of 'health' and other information such as real time tidal height and local weather to surrounding ships or back to a shore authority;
- provide the position of floating aids (mainly buoys) by transmitting an accurate position (corrected by DGNSS) to monitor if they are on station;
- provide real-time information for performance monitoring, with the connecting data link serving to remotely control changes in AtoN parameters or switching on back-up equipment;
- provide local hydrological (hydrographical) and meteorological information;
- possibly replace radar beacons (racons) in the future, providing longer range detection and identification in all weather conditions;
- gather shipping traffic data on AIS fitted ships for future aid to navigation planning purposes.

For practical or economic reasons it may not be appropriate to fit an AIS to an AtoN.

Refer to IALA publications:

- *Recommendation A-126 on the Use of the Automatic Identification System (AIS) in Marine Aids to Navigation;*
- *Recommendation O-143 on Virtual Aids to Navigation;*
- *Guideline 1050 on the Management and Monitoring of AIS Information;*
- *Guideline 1081 on Virtual Aids to Navigation.*

4.12.6 Carriage Requirements

There are two 'types' of AIS units for ship stations. These are termed Class A and Class B units.

Class A ship-borne mobile units must comply with ITU-R M. 1371, and are required to be carried on board those vessels to which Regulation 19 of SOLAS Chapter V applies and meet the IMO performance standard. All these ships were to have AIS fitted by 31 December 2004.

Class B ship-borne mobile equipment, while also complying with ITU-R M.1371, is designed for vessels such as pleasure craft and fishing vessels. These units provide less functionality than Class A units, and do not necessarily meet all the IMO performance requirements. They are designed to operate co-operatively with Class A units.

Administrations can require the carriage of Class B units as part of their domestic requirements.

4.12.7 Cautions When Using AIS

The Officer of the Watch (OOW) should always be aware that other ships, in particular pleasure craft, fishing vessels, warships and some shore stations including VTS centres, may not be fitted with AIS.

The OOW should always be aware that AIS fitted on other ships as a mandatory carriage requirement, might, under certain circumstances, be switched off, particularly where international agreements, rules or standards provide for the protection of navigational information. AIS can also provide incorrect information if the input data is wrong.

Navigators should be aware of the limitations of AIS. In particular, government agencies and owners should ensure that watch-keeping officers are trained in the use of AIS[28]. Because of these limitations navigators are advised that AIS should not be used as the primary means of collision avoidance.

[28] Section 12 of the IALA Guideline 1028 on AIS Volume 1 Part 1 – Operational Issues.

4.12.8 Strategic Applications

From a number of maritime perspectives (such as VTS and regulatory compliance), the availability of comprehensive ship information, offers a mechanism for:

- better monitoring of compliance with national and international regulations for mandatory routeing and reporting systems, Particularly Sensitive Sea Areas, discharging of oil, garbage disposal etc;
- maritime logistics applications such as fleet management, cargo tracking and port facilities (movement of pilot boats, tugs etc);
- better control, co-ordination and response in the event of marine incidents, such as SAR and pollution;
- shore -based navigational assistance;
- shipping information gathered from AIS can be channelled into a central repository of a local, national or regional network serving maritime administrations, port authorities, shipping agents, freight handlers, customs, immigration, etc..

Further information on AIS can be found within IMO, IALA, ITU and IEC documentation.

Refer to IALA publications:
- *Guideline 1026 on AIS as a VTS Tool;*
- *Guideline 1028 - Volume 1, Part I – Operational Issues;*
- *Guideline 1029 - Volume 1 Part II – Technical Issues, Edition 1.1; and*
- *Technical Clarifications on ITU Recommendation ITU-R M.1371-1 Edition 1.5.*

Refer to IMO publications:
- *Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS) (MSC 74(69) Annex 3);*
- *Guidelines for the onboard operational use of shipborne Automatic Identification Systems (AIS) (Resolution A.917 (22), as amended by Resolution A.956 (23));*
- *Performance Standards for the presentation of navigation-related information on shipborne navigational displays (Resolution MSC. 191(79);*
- *SN/Circ. 227 Guidelines for the installation of a shipborne Automatic Identification System (amended by SN/Circ 245);*
- *SN/Circ. 236 Guidance on the application of AIS Binary Messages;*
- *SN/Circ. 243 Guidelines for the presentation of navigation-related symbols, terms and abbreviations SN/Circ. 244 Guidance on the use of UN/LOCODE in the destination field of AIS messages.*

Refer to ITU Publications:

- *ITU-R M.1371-1Recommendation on the Technical Characteristics for a Ship-borne Universal Automatic Identification System (AIS) Using Time Division Multiple Access in the Maritime Mobile Band;*
- *Radio Regulations, Appendix S18, Table of Transmitting Frequencies in the VHF Maritime Mobile Band;*
- *ITU-R M.823-2 Recommendation on the technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in regions 2 and 3.*

Refer to IEC Standards:

- *61993 Part 2: Class A Ship-borne equipment of the Automatic Identification System (AIS) - Operational and Performance requirements, methods of testing and required test results;*
- *61108-1 (2nd edition): navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS);*
- *61162-1 (2nd edition) Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 1: Single talker and multiple listeners;*
- *62320-1: Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS base stations - Minimum operational and performance requirements - methods of test and required test results;*
- *62320-2 Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS aids to navigation - Minimum operational and performance requirements - methods of test and required test result;*
- *62287-2 (Part A and B) Class B AIS (Part A – CSTDMA; Part B – SOTDMA);*
- *61097-14 (pending) Global Maritime Distress and Safety System (GMDSS). AIS search and rescue transmitter (AIS-SART) – Operational and performance requirements: methods of testing and required test results.*

4.12.9 Electronic Chart Display and Information System

Although Electronic Chart Display and Information System (ECDIS), as ship borne equipment, is not an "aid to navigation" as defined by IALA, it deserves to be mentioned because it brings major changes to the manner in which vessels are navigated. ECDIS uses digital vector data in a way that replaces the traditional paper charts with a more versatile electronic product that can draw on a variety of positioning and data inputs, such as GNSS, DGNSS, AIS, radar, echo sounder, compass, an electronic chart, navigational publications, the chart amendments and tidal and meteorological information.

Performance Standards

The performance standards for ECDIS have been defined by the International Maritime Organization (IMO), in conjunction with the International Hydrographic Organization (IHO). IMO Resolution A.817(19) as amended by Resolution MSC.64(67) and by Resolution MSC.86(70) enables maritime administrations to accept ECDIS as a legal alternative to navigation using paper charts and to meet the chart carriage requirements of SOLAS Chapter V/19.

Performance Elements

There are two key performance elements to ECDIS:

- An approved processing system (or 'box') that has been certified as meeting the IEC 61174 and other relevant performance testing specifications;
- Electronic Navigational Charts (ENCs) that have been issued by or on the authority of a government, hydrographic office or other relevant authority and meet the standards set down in the 3rd Edition of the IHO Publication 57 (S-57) and other related IHO standards governing electronic charts;
- Raster Navigation Charts (RNC) that are effectively electronic copies of paper charts and have been issued by or on the authority of a government, hydrographic office or other relevant authority, may be used in an ECDIS to meet carriage requirements, but only in those cases where no ENC has been published covering the area in question.

While an ECDIS 'box' may be capable of reading other forms of electronic charts, it ceases to be a compliant system without the official ENC. Electronic charts that will not satisfy the SOLAS carriage requirements include:

- All electronic charts that are not issued under the authority of a national authority;
- All charts that do not conform to the relevant IHO standards for electronic charts;
- Additional information on ECDIS is available on the IMO and IHO websites.

4.13 Maritime Information

The timely provision and display of maritime information will be an essential component of e-Navigation. Generically called Marine Information Overlays (MIOs), this includes both static and dynamic information capable of being used ashore (e.g., at a VTS Centre) and onboard ships at sea.

Static information could pertain to marine protected areas, sea ice coverage, emergency management/response areas, and seafloor bathymetry. Dynamic operational information would be broadcast via AIS binary messages as time-critical information regarding ship/voyage data, marine traffic signals, area notices, dangerous cargo, environmental, meteorological, hydrographic, and status of AtoN. In particular, mariners require this type information pertaining to the planning and execution of voyages, the assessment of navigation risk and compliance with regulation. The provision and use of MIOs will depend on the current situation and task-at-hand.

At the 54th session of the IMO Safety of Navigation Subcommittee (July 2008) it was recommended that there be Common Maritime Information/Data Structure that would be accessible from a single integrated system. Shore users require information pertaining to their maritime domain, including static and dynamic information on vessels and their voyages. Ideally, this information should be provided in "an internationally agreed common data structure. Such a data structure is essential for the sharing of information amongst shore authorities on a regional and international basis."

At present, there is no specific guidance or standards related to the presentation/display of MIOs on shore-based equipment or systems. However, there are a number of general and equipment-specific international standards that have been adopted by IMO, IHO, and IEC that contain "guidance" related to the presentation/display of various types of shipborne navigation-related information. This is something that will need to be part of e-Navigation development and implementation.

4.14 AtoN Attribute Information

The exchange of information about AtoN between any parties in a digital environment will require an internationally agreed standard so that information can be automatically compiled for sending and automatically understood by systems that receive it.

Such a standard will enable harmonisation of the management of information about AtoN, and in particular information that is relevant to mariners: "situation normal" data (position, colour, shapes, light etc) and also "situation abnormal" (lost top mark, light on reduced range, unlit etc). In GIS terms this sort of information can be described as attribute data (information particular to a GIS object, such as an AtoN) and metadata (data about the attribute data).

4.15 e-Navigation Testbeds

The term testbed is used across many disciplines to describe a platform that is used for research, development or testing. Such a platform is can be protected from a live (or production) environment. However, in the maritime domain, it is often necessary to conduct live tests with appropriate safety precautions in place.

In order for e-navigation solutions to have global application, IALA will facilitate the collation and sharing the outcomes of testbeds. In recent years, some of the more prominent testbeds that have been set up for e-navigation applications include:

- EfficienSea (Baltic Sea);
- ACCSEAS (North Sea);
- Mona Lisa (Baltic Sea);
- The Marine Electronic Highway (MEH) (in the Straits of Malacca and Singapore).

The implementation of e-Navigation will be phased and iterative. Therefore, it is important that outcomes or lessons learnt from test-bed projects be considered in the context of the main elements of the IMO Strategy Implementation Plan (i.e. user needs, architecture, gap analysis and solutions that are the subject of cost-benefit and risk analyses).IALA has taken on the role of coordinating the requirements and results of e-Navigation Test Beds.

5 VESSEL TRAFFIC SERVICES

5 VESSEL TRAFFIC SERVICES

5.1 Introduction

In accordance with the Purpose and Scope of the NAVGUIDE this chapter provides a first point of reference and guidance on more detailed guidance from IMO and IALA.

5.2 Purpose

According to IMO Resolution A857(20), Guidelines for Vessel Traffic Services (VTS):

"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."

5.3 Definition

A VTS, as defined by IMO Resolution A857(20), Guidelines for Vessel Traffic Services, is:

"A service implemented by a competent authority, designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and respond to traffic situations developing in the VTS area."

5.4 Manual

The IALA VTS Manual is acknowledged by the VTS community as being the most comprehensive guide to VTS as well as a point of reference for further detailed study.

The contents are aimed at a wide readership to encompass all who are in any way involved with the policy for provision, operation and effectiveness of VTS, including those with management responsibility at national level and those who deliver services to the mariner.

5.5 Objectives

At its simplest, the main objectives of a VTS are to:

- aid the mariner in the safe use of navigable waterways;
- afford unhindered access to pursue commercial and leisure activities;
- contribute to keeping the seas and adjacent environment free from pollution.

Experience shows that, in general, these ideals are subject to potentially greater and more intense risks in coastal waters particularly at shipping congestion points and at the interface with ports and estuaries. The benefits derived from VTS can be of considerable value and, when properly implemented, outweigh the costs of provision.

5.6 Functions

VTS functions can be subdivided into internal and external functions. Internal functions are the preparatory activities that have to be performed to enable a VTS to operate. These include data collection, data evaluation and decision-making. External functions are activities executed with the purpose of influencing the traffic characteristics. They relate to the primary traffic management functions of rule-making, allocation of space, routine control of vessels and manoeuvres to avoid collisions, as well as other management functions like enforcement, remedial and ancillary activities.

Amongst the most important functions that a VTS may carry out are those related to, contributing to and thereby enhancing:

- Safety of life at sea;
- Safety of navigation;
- Efficiency of vessel traffic movement;
- Protection of the marine environment;
- Supporting maritime security;
- Supporting law enforcement;
- Supporting allied and other services;
- Protection of adjacent communities and infrastructure.

5.7 Vessel Traffic Services

An authorised VTS will be capable of offering one or more of the following types of service:

5.7.1 Information Service

An Information Service (INS) provides essential and timely information to assist the on-board decision-making process.

5.7.2 Traffic Organization Service

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

5.7.3 Navigational Assistance Service

A Navigational Assistance Service (NAS) may be provided in addition to an Information Service and/or Traffic Organization 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.

5.8 Surveillance Requirements

The extent of the VTS area should be taken into account with regard to the surveillance equipment necessary. In principle the equipment should be able to cover an area well in excess of the designated VTS area, to allow for any decrease in performance in poor weather conditions. The surveillance equipment in most common use continues to be radar although other systems, such as the Automatic Identification System (AIS) and CCTV, are used to good effect.

5.9 Equipment Requirements

Traffic density and structure, navigation hazards, local climate, topography, environmental requirements, commercial aspects and the extent of a VTS area sets the requirements for VTS equipment and these factors will have substantial impact on life cycle costs of a VTS and the acquisition of VTS equipment. Equipment may include:

- Communications;
- Radar System;
- Automatic Identification System (AIS);
- Electro Optical Systems (EOS);
- Radio Direction Finders (RDF);
- Hydrometeo Equipment;
- VTS Data System;
- Recording and replay systems.

5.10 Personnel

VTS Operators, masters, bridge watchkeeping personnel and pilots share a responsibility for good communications, effective co-ordination and understanding of each other's role for the safe conduct of vessels in VTS areas. They are all part of a team and share the same objective with respect to the safe movement of vessel traffic.

Depending on the size and complexity of the VTS area, service type provided, as well as traffic volumes and densities, a VTS centre may include VTS Operators, VTS Supervisors and a VTS Manager. It is for the Competent/VTS Authority to determine the appropriate levels in order to meet its obligations and to ensure that appropriately trained and qualified personnel are available.

5.11 Promulgation of information

Information on VTS areas and procedures can be found in internationally recognised marine publications, individual websites and the IALA World VTS Guide.

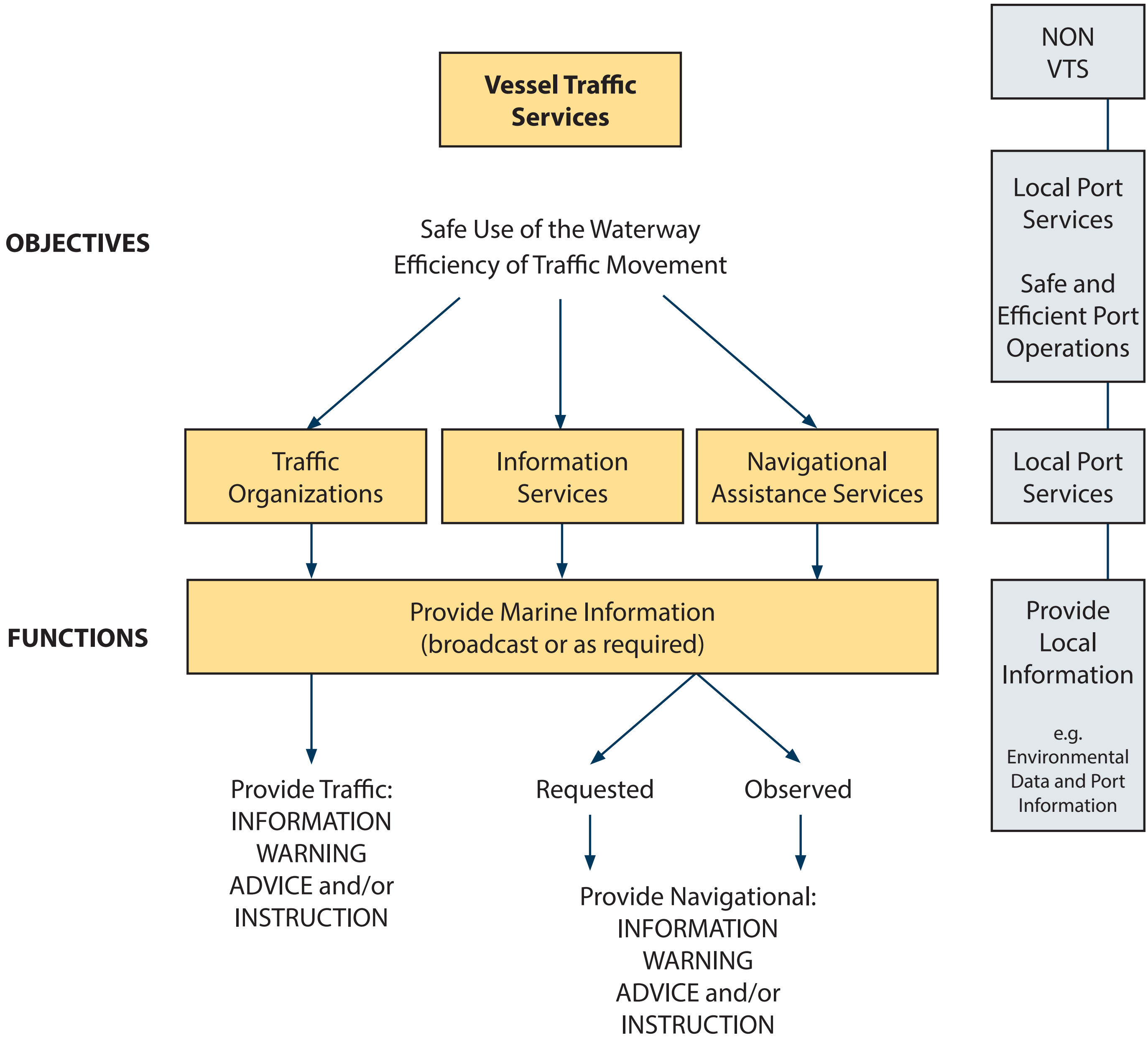


Figure 28 - Overview of Types of VTS Services and Functions

5.12 Summary

Readers are encouraged to refer to the:

- IALA VTS Manual;
- IALA World VTS Guide.

Refer to IALA publications:

- *Recommendation V-102 on the Application of "User pays" principle to Vessel Traffic Services;*
- *Recommendation V-103 on the Standards for Training and Certification of VTS personnel;*
- *Recommendation V-119 on the Implementation of Vessel Traffic Services;*
- *Recommendation V-120 on Vessel Traffic Services in Inland Waters;*
- *Recommendation V-125 on the Integration and Display of AIS and other information at a VTS Centre;*
- *Recommendation V-127 on the Operational Procedures for Vessel Traffic Services;*
- *Recommendation V-128 on the Operational and Technical Performance Requirements for VTS Equipment;*
- *Recommendation A-123 on the Provision of Shore Based AIS;*
- *Recommendation A-124 on AIS Shore Station and Networking Aspects Relating to AIS Service;*
- *Recommendation A-126 on the Use of AIS in Marine Aids to Navigation;*
- *Guideline 1014 on the Accreditation of VTS Training;*
- *Guideline 1017 on the Assessment of training requirements for existing VTS Personnel, Candidate Operators and the Revalidation of VTS Operator Certificates;*
- *Guideline1018 on Risk Management;*
- *Guideline 1026 on AIS as a VTS Tool;*
- *Guideline1027 on Designing and Implementing Simulation in VTS Training;*
- *Guideline1032 on the Aspects of Training of VTS Personnel Relevant to the Introduction of AIS;*
- *Guideline1045 on Staffing Levels at VTS Centres;*
- *Guideline1046 on Response Plan for Marking New Wrecks;*
- *Guideline1055 on Preparing for a Voluntary IMO Audit on VTS Delivery;*
- *Guideline1056 on the Establishment of VTS Radar Services;*
- *Manual on Vessel Traffic Services.*

6 OTHER SERVICES AND FACILITIES

6 OTHER SERVICES AND FACILITIES

6.1 Pilotage

6.1.1 Introduction

Pilotage is a specialised, and usually, licensed service to navigation, specifically in restricted waters. The skill of the pilot draws on local knowledge of the relative positions of geographic points, aids to navigation, submerged features, and waterway limitations. Pilots must also possess a high degree of ship handing skills, be cognisant of the local tides, currents, and climatic conditions, as well as the handling characteristics for the specific ship receiving the pilotage services.

Pilotage may be required in coastal waters, estuarial waters, rivers, channels, ports, harbours, lakes, canals, or enclosed dock systems or any combination of these areas. In addition, deep sea pilotage services are provided in some international waters, such as the North Sea, English Channel, Entrances to the Baltic Sea and the Baltic Sea.

When a pilot boards a vessel, he / she is given "*conduct of the vessel*", but not "*command*". The role of the pilot often includes:

- giving necessary instructions to the ships personnel operating equipment essential to the safe navigation and manoeuvring of the vessel;
- assisting local communication with a VTS centre, port control and other vessels;
- communicating instructions to tugs and linesmen if berthing or sailing;
- providing current and specialist knowledge of:
  - local conditions and traffic;
  - operational status of aids to navigation;
  - sailing directions;
  - restrictions applicable to the piloted vessel.
- being able to quickly adapt to:
  - operational culture aboard the vessel;
  - the vessel's handling characteristics;
  - the state of the navigation equipment aboard.

A Portable Pilot Unit (PPU) can be generally described as a portable, computer-based system that a pilot may bring onboard a vessel to use as a decision-support tool for navigating in confined waters. Interfaced to a positioning sensor such as GPS/DGPS and using some form of electronic chart display, it shows the vessel's position/movement in real-time. In addition, PPUs provide information about the location/movement of other vessels via an AIS interface. Increasingly, PPUs are being used to display other types of navigation-related information such as soundings/depth contours from recent hydro surveys, dynamic water levels, current flow, ice coverage, and security zones.

6.1.2 Types of Pilotage

Pilotage services exist within declared ports but may also exist in some coastal areas, lakes and inland waterways. These areas would normally fall within the definition of restricted waters.

Where pilotage services are licensed, it is usual for the applicable pilotage area to be stated on the licence. The service provider may then be described as a port pilot or a coastal pilot etc.
Various levels of enforcement can be applied to a pilotage area:

- **Compulsory (Mandatory) Pilotage**: Applicable vessels must take a pilot when entering a declared area.

Some Competent Authorities require compulsory (mandatory) pilotage for vessels of certain characteristics and/or carrying specific types of cargo when entering a declared area.

In Particularly Sensitive Sea Areas (PSSA) approved by IMO, Additional Protective Measures may be applied to shipping, which could include compulsory pilotage arrangements.

- **Recommended Pilotage**: An authority can promulgate notices recommending that masters of applicable vessels, who are unfamiliar with a particular area, should engage a licensed pilot.

Photo Courtesy of Instituto Hidrografico (Portugal)

6.1.3 Other Pilotage Considerations

Pilot Services can be provided by public or private operators. However, generally the pilot licensing authority should be government-regulated to maintain the highest standards of service.

The IMO has set the minimum standards for pilots and includes recommendations on the qualification and training of pilots other than deep sea pilots[29]. However individual countries may impose more stringent standards.

Photo Courtesy of Swedish Maritime Administration

When developing proposals for marking restricted waterways, the requirement for pilotage services should be considered concurrently with the selection of the aids to navigation.

6.1.4 Simulation Pilot Training and Certification

The IMO Assembly in 2003 adopted Resolution A.960(23) Recommendations on training and certification and operational procedures for maritime pilots other than deep-sea pilots. IMO Resolutions encouraging the use of pilots on board ships in certain areas are:

- Resolution A.480(IX) (adopted in 1975) recommends the use of qualified deep-sea pilots in the Baltic and Resolution A.620(15) (adopted 1987) recommends that ships with a draught of 13 metres or more should use the pilotage services established by Coastal States in the entrances to the Baltic Sea;
- Resolution A.486(XII) (adopted 1981) recommends the use of deep-sea pilots in the North Sea, English Channel and Skagerrak;
- Resolution A.579(14) (adopted 1985) recommends that certain oil tankers, all chemical carriers and gas carriers and ships carrying radioactive material using the Sound (which separates Sweden and Denmark) should use pilotage services;

[29] IMO Resolution A.960(23).

- Resolution A.668(16) (adopted 1989) recommends the use of pilotage services in the Euro-Channel and IJ-Channel (in the Netherlands); IMO Resolution MEPC.133(53), which recommends that Governments recognize the need for effective protection of the Torres Strait and inform ships flying their flag that they should act in accordance with Australia's system of pilotage for merchant ships 70m in length and over or oil tankers, chemical tankers, and liquefied gas carriers, irrespective of size, when navigating the Torres Strait and the Great North East Channel.
- Resolution A.827(19) (adopted 1995) on Ships' Routeing includes in Annex 2 Rules and Recommendations on Navigation through the Strait of Istanbul, the Strait of Canakkale and the Marmara Sea the recommendation that "Masters of vessels passing through the Straits are strongly recommended to avail themselves of the services of a qualified pilot in order to comply with the requirements of safe navigation.";
- Resolution A.889(21) on Pilot Transfer Arrangements gives recommendations on the construction of pilot ladders;
- Resolution A.960(23) gives recommendations on training and certification and operational procedures for Maritime Pilots other than Deep Sea pilots.

6.2 Ships Routeing

The General Provisions on Ships' Routeing are established by SOLAS Chapter V, Regulation 10.[30]

6.2.1 Objectives

The purpose of ships' routeing is to improve the safety of navigation in converging areas and in areas where the density of traffic is great or where freedom of movement of shipping is inhibited by restricted sea-room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions. Ships' routeing may also be used for the purpose of preventing or reducing the risk of pollution or other damage to the marine environment caused by ships colliding or grounding in or near environmentally sensitive areas.

The precise objectives of any routeing system will depend upon the particular hazardous circumstances which it is intended to alleviate, but may include some or all of the following:

- separation of opposing streams of traffic so as to reduce the incidence of head-on encounters;
- reduction of dangers of collision between crossing traffic and shipping in established traffic lanes;
- simplification of the patterns of traffic flow in converging areas;
- organization of safe traffic flow in areas of concentrated offshore exploration or exploitation;
- organization of traffic flow in or around areas where navigation by all ships or by certain classes of ship is dangerous or undesirable;

[30] Refer to IMO Publication 'Ships; Routeing', IMO, London, 8th Edition.

- organization of safe traffic flow in or around or at a safe distance from environmentally sensitive areas;
- reduction of risk of grounding by providing special guidance to vessels in areas where water depths are uncertain or critical; and
- guidance of traffic clear of fishing grounds or the organization of traffic through fishing grounds.

6.2.2 Definitions

The following terms are used in connection with matters related to ships' routeing:

Approach Channel: Any stretch of waterway linking the berths of a port and the open sea. There are two main segments; the seaway or outer channel, and the main approach or inner channel which lies in relatively sheltered waters.

Area to be Avoided: An area within defined limits in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties that should be avoided by all ships, or just certain classes of ship.

Deep-water Route: An accurately surveyed route within defined limits that is clear of obstructions to a specified depth as indicated on the applicable navigation chart.

Established Direction of Traffic Flow: A traffic flow pattern indicating the directional movement of traffic as established within a traffic separation scheme.

Inshore Traffic Zone[31]: A routeing measure comprising a designated area between the landward boundary of a traffic separation scheme and the adjacent coast, to be used in accordance with the provisions of rule 10(d), as amended, of the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs).

Mandatory Routeing System: A routeing system adopted by the International Maritime Organization, in accordance with the requirements of SOLAS Regulation V/10, for mandatory use by all ships, certain categories of ships or ship carrying certain cargoes.

No Anchoring Area: A routeing measure comprising an area within defined limits where anchoring is hazardous or could result in unacceptable damage to the marine environment. Anchoring in a no anchoring area should be avoided by all ships or certain classes of ships, except in case of immediate danger to the ship or the persons on board.

Precautionary Area: A routeing measure comprising an area within defined limits where ships must navigate with particular caution and within which the direction of traffic flow may be recommended.

Recommended Direction of Traffic Flow: A traffic flow pattern indicating a recommended directional movement of traffic where it is impractical or unnecessary to adopt an established direction of traffic flow.

Recommended Route: A route of undefined width, for the convenience of ships in transit, which is often marked by centreline buoys.

Recommended Track: A route which has been specially examined to ensure, so far as possible, that it is free of dangers and along which, ships are advised to navigate.

Roundabout[31]**:** A routeing measure comprising a separation point or circular separation zone and a circular traffic lane within defined limits. Traffic within the roundabout is separated by moving in a counter clockwise direction around the separation point or zone.

Routeing System: Any system of one or more routes or routeing measures aimed at reducing the risk of casualties, it includes traffic separation schemes, two-way routes, recommended tracks, areas to be avoided, inshore traffic zones, roundabouts, precautionary areas and deep water routes.

Separation Zone or Line[31]**:** A zone or line separating the traffic lanes in which ships are proceeding in opposite or nearly opposite direction or separating a traffic lane from the adjacent sea area; or separating traffic lanes designated for particular classes of ship proceeding in the same direction.

Traffic Lane[31]**:** An area within defined limits in which one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary.

Traffic Separation Scheme[31]**:** A routeing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes.

Two-way Route: A route within defined limits inside which two way traffic is established, aimed at providing safe passage of ships through waters where navigation is difficult or dangerous.

6.2.3 Vessel Manoeuvering

If a waterway is defined as a series of straight and turn sections, the passage of a vessel along the waterway can be described by a number of navigational phases that are illustrated in *Figure 29*. These comprise:

- turning;
- recovery;
- track keeping.

[31] These terms are used in the 1972 COLREGs.

The type of manoeuvre within a section determines the information that the navigator requires from the aids to navigation.

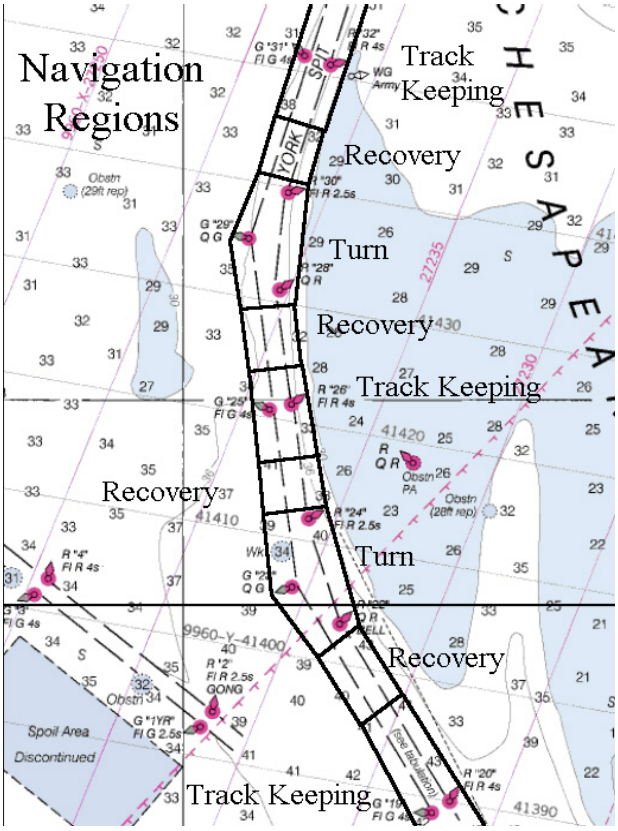


Figure 29 - Vessel Manoeuvring Phases

6.3 Minimum Comprehensive Mix of AtoN for Channels and Waterways

The primary goal of the design of AtoN systems for a waterway is to facilitate safe and efficient movement of vessels. The responsible provision of AtoN systems requires that systems be designed to meet the minimum requirements for safe and expeditious navigation through specific waters in accordance with the type and volume of traffic and the degree of risk.

AtoN are normally intended to function as part of a system(s) and therefore mariners should make use of all information provided by the system of AtoN.

Whether designing a new waterway system or evaluating an existing one, there are many factors that must be considered. The identification of these factors allows Competent Authorities to develop a greater understanding of the risks and threats that are present within a particular waterway.

Waterways will vary in their characteristics. Site analysis, needs analysis, simulation, and operational analysis provide the necessary framework to evaluate the overall risks that may be present and identify measures that reduce the risk to safe transit to an acceptable level.

Once the evaluation has been completed, Competent Authorities should use this information to design the AtoN system. In completing the design it is important to note that the entire waterway must be viewed using a systematic approach, recognizing that each individual element of the waterway design by itself will not reduce transit risk. While individual areas of the waterway must be considered, the overall aids to navigation system must support a smooth transit of the entire waterway. The tools used for waterway design consists of the IALA MBS (Annex A of this document) and the technical tools referred to in section 3.1 (AtoN) and Chapter 4 (e-Navigation), which are also described in IALA Recommendations and Guidelines.

The specific aids to navigation system implemented should enable waterway users to transit an area safely and efficiently, avoiding groundings, obstructions to navigation, and collisions with other vessels. In order to satisfy the information requirements of users, a system of aids to navigation must:

- Be available at the time it is needed;
- Provide timely warnings of channel limits and fixed obstructions to navigation;
- Enable mariners to determine quickly their location within the channel, relative to fixed obstructions to navigation, and relative to other vessels;
- Enable a safe course for the vessel to be determined.

As indicated in "Step 1" of the LOS/OPS statement (refer 8.3), AtoN systems may be provided for the safety of navigation in various areas such as:

- Fairways, dredged channels and canals;
- Waters adjacent to the coast;
- Archipelagic waters, in pristine and/or improved condition;
- Estuarine rivers;
- River systems;
- Straits;
- Isthmuses;
- Open sea.

Once the system has been established, maintaining the availability of this system is critical to controlling overall risks.

It is useful to analyse the functional requirements of the design in a number of parts. For example, the open water component or outer channel, and the inner channel component which may lie in relatively sheltered waters.

The design process requires inputs from a number of disciplines, including:

- ship dynamics;
- vessel size and behaviour;
- human factors;
- maritime engineering;
- aids to navigation;
- the physical environment (including bathymetry and hydrometeorology).

The joint PIANC-IAPH Working Group II-30 in cooperation with IMPA published a document "Approach Channels - A Guide for Design".

6.3.1 Design Considerations

During design, different design parameters should be considered. In this phase the functional requirements have to be translated into physical systems. However, it is often a question of utilising practical experience with AtoN, if the performance parameters are to be met.

Accuracy

The required accuracy depends on the difference between the manoeuvring lane of the ship and the width of that part of the fairway, which is used by a ship of a particular draft. The available under keel clearance has to be taken into account. The ship's manoeuvring lane depends on the ship's beam, length and manoeuvring ability and on environmental conditions (wind, currents, etc.).

Availability

In those areas in which the level of risk has been determined to be high, the use of certain types of aids to navigation may prove to provide greater risk mitigation. However, the planner must also consider higher availability criteria that may be required. Competent Authorities should refer to IALA Recommendation O-130 on Categorisation and Availability Objectives for Short Range Aids to Navigation for additional information in relation to the categorization of individual aids to navigation, the calculation of availability targets, and recommended availability criteria.

AtoN systems should be designed to assist mariners regardless of weather, sea and ice conditions.

Short Range AtoN, especially buoys, should be designed with regard to their visual information, radar information (active or passive) and other modes of information (for example AIS). System design must take into account the visibility and radar availability implications. Designing for worst case visibility is not usually practical; however, reduced visibility due to haze and fog must be considered.

In designing and modernising systems, past incidents such as groundings, collisions or near-misses must be considered. Such incidents should be well documented to ensure accuracy of the information used for a decision to change or not to change the configuration of aids in a system.

Additionally, integrity and continuity can be used to define requirements, if appropriate.

Refer to IALA publication:

- *Recommendation O-130 on Categorisation and Availability Objectives for short range AtoN.*

6.3.2 Dredging Considerations

Competent authorities should consider the contribution that proper use of aids to navigation make in improving positioning accuracy and navigational accuracy and hence to the efficiency of major dredging projects and waterways maintenance. In some instances, the required channel width could be reduced as can the costs for major and maintenance dredging. The PIANC Guide "Approach Channels," contains further information on this matter.

6.3.3 Hydrographic Considerations

Usually, the uncertainty of positioning an AtoN should not be greater than the uncertainty in hydrographic surveys and charts.

Horizontal uncertainty is the uncertainty of a position defined as the uncertainty of the sounding or feature within the geodetic reference frame. Positions should be referenced to a geocentric reference frame based on the International Terrestrial Reference System (ITRS) e.g. WGS84. The position uncertainty, at the 95% confidence level, should be recorded together with the survey data.

The position of the following items should be determined such that the horizontal uncertainty meets the requirements specified:

- Soundings;
- Dangers;
- Other significant submerged features;
- AtoN features significant to navigation;
- Coastline and topographical features.

This includes all uncertainty sources not just those associated with positioning equipment.

6.3.4 Design Validation and Visualisation and the Use of Related Tools

Prior to implementing a new AtoN system or changing an existing one, Competent Authorities should consider using simulation techniques to assess the overall safety and effectiveness of these changes. The use of Geographic Information System (GIS) technology can improve the efficiency of AtoN deployment and waterway layout. GIS enables the volume of traffic to be overlaid (e.g. taken from AIS data), and planning the position and type of AtoN to mitigate the identified risks for all users. Having designed a potential AtoN configuration in this manner, the Competent Authority can use simulation tools to model a ship passages using combinations of various types of vessels , in order to validate the design. Simulation is best done in consultation with appropriate stakeholders eg. local pilots. To achieve a high level of realism in the simulations, GIS data can be integrated to the waterway models used in the simulator.

In addition, simulation could be useful for ensuring sufficient channel width, channel depth, and optimal orientation and design of breakwaters as well as ensuring that the lay-out of a channel and port is suitable from a manoeuvring perspective.

Sophisticated computer simulation techniques are becoming increasingly available, and they provide an important tool to assist in decision making.

Simulating the placement and operation of AtoN by day and night, and under various conditions of visibility assists in ensuring that AtoN are effective and provided in a cost effective manner that suits the purpose of providing a predetermined level of safety. This is particularly important as aids to navigation become more sophisticated (synchronised and sequential lights, LED with flicker, and other new light characteristics).

Refer to IALA publications:
- *Recommendation O-138 on the Use of GIS and Simulation by Aids to Navigation Authorities;*
- *Guideline 1069 on Synchronisation of Lights.*

6.3.5 Economic Considerations

A comparative analysis of cost effective combinations of aids (cost-effectiveness analysis) is required to select from viable alternatives. The effectiveness of different alternatives can be assessed using IALA risk assessment tools, especially the Port And Waterway Safety Assessment (PAWSA) tool as a qualitative risk assessment procedure and the IALA Waterway Risk Assessment Program (IWRAP) as an analytical risk assessment program.

It is necessary to establish comparative direct costs - including maintenance costs - of each proposed AtoN, to assist in determining the most cost-effective system of aids to navigation. Simulation offers a method to help ensure that AtoN are appropriate and cost effective.

6.3.6 Simulation

Simulation tools are capable of providing very realistic and accurate results and input to investigation and evaluation of channel and port design including the placement of AtoN. The purpose of simulation for design evaluation is to evaluate the risks of a given design ship operating in a specific fairway and port area. It also includes evaluation of channel lay-out, placement of AtoN and manoeuvring aspects.

Simulations offer a relatively low cost method to help ensure that the AtoN solution provided meets the users' requirements in an effective and efficient manner.

By providing a simulation tool to the user an overall improvement in safe and efficient operation can be realised by assisting in demonstrating the operation of the waterway, channel design and associated AtoN before the reality of navigating a vessel in the area.

User consultation is an integral part of all AtoN planning and simulation processes. Accurate simulation tools will potentially improve the usefulness of the feedback obtained from users. It is important that the providers of the simulation services include the key stakeholders in the simulation studies including experienced mariners and engineers, local pilots and competent authorities who can ensure that applicable regulations and recommendations are followed.

The use of simulators can be of real benefit in confirming the effectiveness of marking proposals that will have a high cost or that are intended to meet the needs of a complex navigational situation. When defining simulation tools for design evaluation (as opposed to training in, for example generic ship handling or watch keeping) it is important that the ship, tug and area models used are very realistic and accurate and that the simulation provider can document the realism and accuracy such that it does not become a "black-box" study with non-transparent processes.

The requirement for realism and accuracy is increasingly important as the industry is constantly striving for improved safety levels and increased efficiency.

It is important to note that accurate simulation of AtoN is a complicated process due to the challenges of visual simulation. Providing visual images for observation and detection of AtoN during night and day time, at sufficient resolution, light intensity and contrast pushes the capability of modern projectors and monitors to the edge and even beyond. Understanding the human eye and the physics of light are prerequisites for developing adequate simulation models.

A number of different simulation tools are available for design studies and have different usability and applications. The following types of simulation tools are the most common:

- Fast Time;
- Desktop;
- Part Task;
- Full Mission;
- Traffic Flow.

Refer to IALA publications:
- *Recommendation O-138 on the Use of GIS and Simulation by Aids to Navigation Authorities;*
- *Guideline O-1058 on the Use of Simulation as a Tool for Waterway Design and AtoN Planning.*

6.4 The Marking of Man-Made Offshore Structures

There has been an increasing development in man-made structures at sea, which may affect shipping. These structures can be isolated or in groups, small or large, and close to or far from navigation zones.

IALA is monitoring the developments of these structures and will continue to create and update documentation as required to ensure clear and unambiguous marking of waterways for safe navigation, protection of the environment and protection of the structures themselves.

Effective and consistent marking of these diverse structures, during their construction or decommissioning phase and when established, can be a significant challenge for Aids to Navigation Authorities. IALA Recommendation O-139 On the Marking of Man-made Offshore Structures provides comprehensive information on the required marking. This section outlines the general requirements but reference should be made to O-139 for detailed information. The marking of the various structures are set out in five groups:

- Offshore Structures (in general);
- Oil and Gas Platforms;
- Offshore Wind Farms;
- Wave and Tidal Energy Devices;
- Aquaculture Farms.

6.4.1 Offshore Structures in General

The marking requirements defined in this section should be complemented with the marking requirements defined for the specific types of offshore structures/platforms.

Consultation between the stakeholders such as Developers, National Administrations, Authorities, Competent Authorities and Contractors should take place at an early stage. In general, development of all structures mentioned in this Section should not prejudice the safe use of Traffic Separation Schemes, Inshore Traffic Zones, recognised sea-lanes and safe access to anchorages, harbours and places of refuge.

On a case-by-case basis, National Authorities may consider establishing, Recommendation to Avoid, Exclusion or Safety Zones, to prohibit or restrict vessels from entering areas of Offshore Structures in general. Such information must be identified on the nautical charts and publications and promulgated through Maritime Safety Information (MSI).

In order to avoid confusion from a high-density of AtoN (and other general lighting), full consideration should be given to the use of synchronised lights, different light characters and varied light ranges.

The general rules for the marking of Offshore Structures are as follows:

1. The lights shall be placed not less than 6 metres and not more than 30 metres above Mean High Water Springs (MHWS) with a minimum effective intensity of 1400 candelas (approximately 10 Nautical Miles). The lights shall be synchronized with a flashing character according to Mo (U) W ≤15s. The vertical divergence of the projected beam shall be such that the light will be visible from the immediate vicinity of the structure to the maximum luminous range of the light.
2. The fog signals, when implemented, should be placed not less than 6 metres and not more than 30 metres above MHWS with a range of at least 2 Nautical Miles. The character shall correspond to Mo (U) 30s.
3. The minimum duration of the short blast shall be 0.75 seconds. The fog signals shall be operated when the meteorological visibility is 2 Nautical Miles or less. A Visibility Detector will typically be used.
4. Where there is a requirement to identify a particular structure, a radar beacon may be fitted. The character and code length shall be determined by the Authority. Any Racon on a temporary uncharted structure shall be coded Mo (D).
5. Where a number of structures are situated so that the safety of navigation in the area may be secured without each of the structures being individually equipped with lights and sound signals, in accordance with these recommendations, or where the Authority considers that local conditions permit a relaxation of the requirements for the intensity of the light, the Authority shall determine what marking shall be applied.
6. Wherever deemed necessary by the Authority, buoys or beacons shall be placed to mark the perimeter of a group of structures, or to mark channels through a group of structures, or to mark any fixed structure while being erected or dismantled. The characteristics of such marks shall be determined by the Authority in accordance with the MBS.
7. Where underwater obstructions, such as submerged wells or pipelines, exist in depths of water so as to be a hazard to surface borne vessels, they should be adequately marked in accordance with the MBS.
8. The relevant Hydrographic Office should be informed of the establishment of an energy extraction device or field, to permit appropriate charting of same.
9. Notices to Mariners should be issued to publicise the establishment of an offshore device or field. The Notice to Mariners should include the marking, location and extent of such devices/fields.
10. The air navigation authorities may require additional marking of the structure.

6.4.2 Offshore Oil and Gas Platforms

This section supplements the general rules for marking defined in Section 6.4.1. The Offshore Structures mentioned in this section should be marked as a single unit, a block or field, as appropriate, as follows:

1. Any structure shall be marked at night by one or more white lights so constructed and fixed as to ensure that at least one light is visible upon approaching the structure from any direction.
2. Subsidiary red flashing lights shall also be provided ; show the same characteristics as the main white lights, i.e. Mo (U) R ≤15s and be synchronised. These are to be located to mark the horizontal extremities of the structure, excepting those marked with white lights, and interconnecting bridges. Minimum effective range is to be 15cd (approximately 3 Nautical miles).
3. Each structure shall, where practicable, display identification panels with black letters or numbers 1 m high on a yellow background visible in all directions. These panels shall be easily visible in daylight as well as at night, either by the use of illumination or retro-reflecting material.
4. Each structure may carry one or more sound signals so constructed and fixed as to be audible upon approaching the structure from any direction.

6.4.3 Offshore Wind Farms

This section supplements the general rules for marking defined in Section 6.4.1 and must be read in conjunction with it.

When mentioning Offshore Wind Farms (OWF), the following are included: Meteorological Mast, Wind Turbine Generator and Offshore Transformer/Sub-Station.

Each structure shall, where practicable, display identification panels with black letters or numbers 1 m high on a yellow background visible in all directions. These panels shall be easily visible in daylight as well as at night, either by the use of illumination or retro-reflecting material.
Each structure may carry one or more sound signals so constructed and fixed as to be audible upon approaching the structure from any direction.

Some IALA members have carried out trials on OWF to identify whether interference to radar, radio navigation and radio communications is experienced. Trials indicate that OWF structures may affect shipborne and shore based radar systems. This can produce significant interference in some cases. Bearing discrimination was also reduced by the magnitude of the response.

It has been determined that passage close to an OWF boundary, or within the OWF itself, could affect the vessel's ability to fully comply with the International Regulations for the Prevention of Collisions at Sea. Administrations/ developers should keep this information in mind when designing OWF, and they may wish to carry out individual trials to verify the impact of the OWF on navigation.

Marking of Isolated WTG, Meteorological Masts and other Individual Structures

1. The tower of every structure should be painted yellow all around from the level of Highest Astronomical Tide up to 15 metres, on a case-by-case assessment.
2. Alternative marking may include horizontal yellow bands of not less than 2 metres in height and separation.
3. Consideration may be given to the use of additional retro reflective material or downlighting.
4. Due to the increased danger posed by an isolated structure, it should be lit with a white light flashing Mo (U) W up to a maximum of 15s, and with a MER of 10 Nautical Miles (approximately 1400 candelas).
5. The AtoN on the structure of a WTG should be mounted below the lowest point of the arc of the rotor blades. They should be exhibited at a height of at least 6 metres above the level of the HAT. AtoN on WTG should comply with IALA Recommendations and have an availability of not less than 99.0% (IALA Category 2).

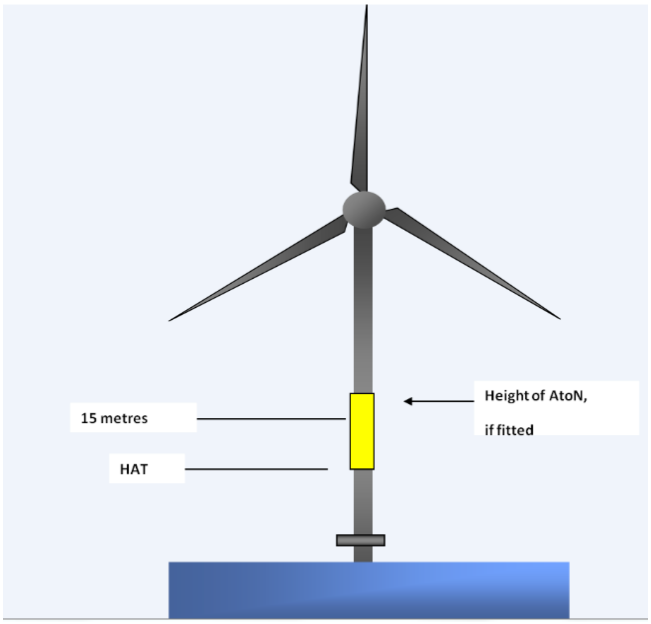


Figure 30 - Sample Marking of an Individual Wind Turbine

Marking of Floating Wind Structures

Due to the specific movement of the floating wind structures, Competent Authorities should take in special consideration the interaction between aviation lights and the navigation in the area.

Marking of Groups of Structures (Offshore Wind Farms)

A Significant Peripheral Structure (SPS) is the 'corner' or other significant point on the periphery of the OWF. Each individual SPS should be fitted with lights visible from all directions in the horizontal plane. These lights should be synchronized to display an IALA Special Mark characteristic, flashing yellow, with a MER of 5 Nautical Miles (as defined in the MBS).

As a minimum, lights on individual SPS should exhibit synchronised flashing characteristics, however the Authority should consider the synchronisation of all SPS. In the case of a large or extended OWF, the distance between SPS should not normally exceed 3 Nautical Miles.

Selected Intermediate structures on the periphery of an OWF, other than the SPS, should be marked with flashing yellow lights that are visible to the mariner from all directions in the horizontal plane. The flash character of these lights should be distinctly different from those displayed on the SPS, with a MER of 2 Nautical Miles. The lateral distance between such lit structures or the nearest SPS should not exceed 2 Nautical Miles.

Depending on the marking, lighting and lateral separation of the peripheral structures, the additional marking of the individual structures within an OWF may be considered as follows:

- Lighting of each structure;
- Individual structures unlighted with retro-reflective areas;
- Individual structures illuminated with down-lights on ladders and access platforms;
- Use of flashing yellow lights with a MER of 2 Nautical Miles;
- Racons;
- AIS AtoN;
- Identifying numbers on each individual structure, whether lit or unlit.

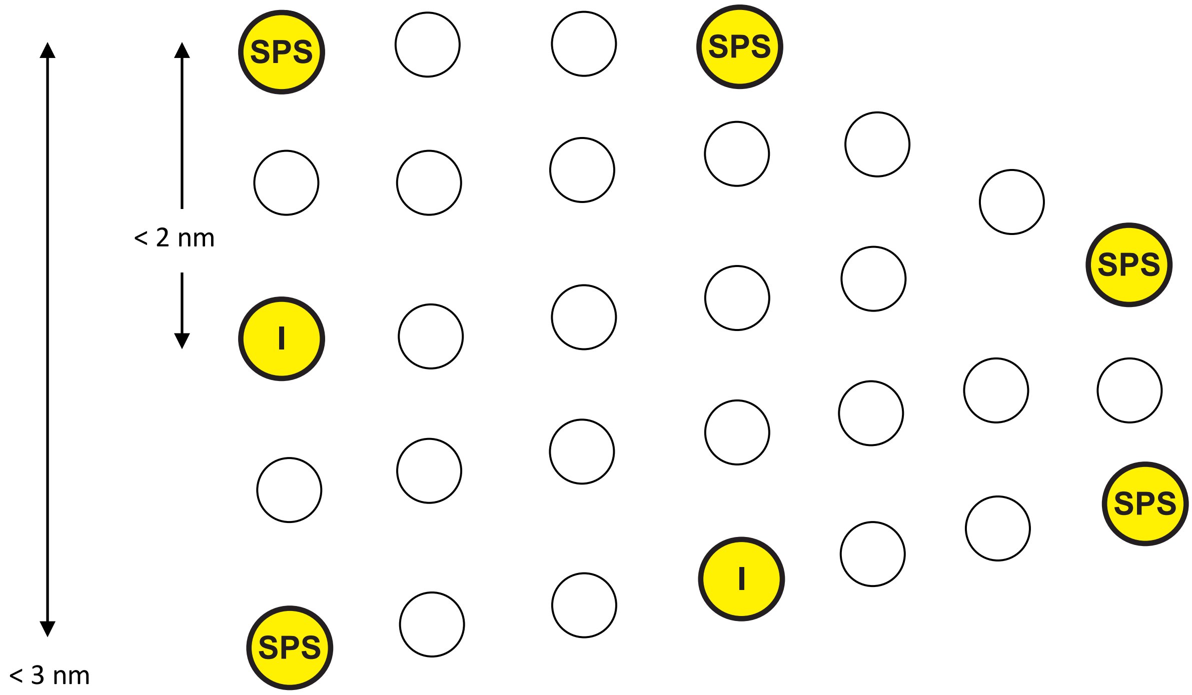
An Offshore Transformer / Sub-Station or a Meteorological Mast, if considered to be a composite part of the OWF, should be included as part of the overall OWF marking. If not considered to be within the OWF block it should be marked as an offshore structure, i.e. flashing Mo (U) W ≤15 s.

Consideration may also be given to the provision of fog signals where appropriate, taking into account the prevailing visibility, topography and vessel traffic conditions. The typical range of such a fog signal should not be less than two 2 Nautical Miles.

6.4.4 Offshore Wave and Tidal Energy Devices

This section supplements the general rules for marking defined in section 6.4.1. and must be read in conjunction with it. Wave and Tidal Energy Devices include: Tidal Generator, Tidal Generator field, Wave Generator, Wave Generator field.

It should be borne in mind that many wave and tidal devices are low freeboard floating structures that are moored to the seabed. They may be moored in deep or shallow water and some may be located on the seabed or just below the surface. Surface piercing and subsurface elements may extend laterally beyond the surface elements. This could include shared moorings and mid-water connections between units that may also carry electricity, control signals, hydraulics or pneumatics associated with the units.



SPS - lights visible from all directions in the horizontal plane. These lights should be synchronized to display an IALA Special Mark characteristic, flashing yellow, with a range of not less than 5 Nautical Miles.

Intermediate structures on the periphery of an OWF other than the SPSs - marked with flashing yellow lights which are visible to the mariner from all directions in the horizontal plane with a flash character distinctly different from those displayed on the SPSs and with a range of not less than 2 Nautical Miles.

It should also be noted that many tidal concepts have fast-moving sub-surface elements such as whirling blades, and these should be taken into account when identifying the marking requirements. Wave and Tidal energy extraction devices should be marked as a single unit or as a block or field as follows:

1. When structures are fixed to the seabed or in the water column and extend above the surface, they should be marked in accordance with the guidance contained in the Section for OWF.
2. Areas containing surface or sub-surface wave and/or tidal devices should be marked by appropriate AtoN in accordance with the MBS. In addition, radar reflectors, retro reflecting material, racons and/or AIS transponders should be considered where the level of traffic and degree of risk requires.

3. The lit AtoN should be visible to the mariner from all relevant directions in the horizontal plane, by day and by night. To improve the effectiveness of the lighting and taking into account background lighting, synchronisation is recommended. Taking the results of a risk assessment into account, lights should have an appropriate MER.
4. Individual wave and tidal energy devices within a site that extend above the surface should be painted yellow above the waterline. Depending on the boundary marking, individual devices within the field need not be marked. However, if marked, they should have flashing yellow lights so as to be visible to the mariner from all relevant directions in the horizontal plane. The flash character of such lights should be sufficiently different from those displayed on the boundary lights with a MER of not less than 2 Nautical Miles.
5. Based on a risk assessment, a single wave and / or tidal energy extraction structure, standing alone, could be marked as described in the MBS, with:
   - An Isolated Danger Mark, if it extends above the surface.
   - Special Mark, if it's not visible above the surface but is considered to be a hazard to surface navigation.

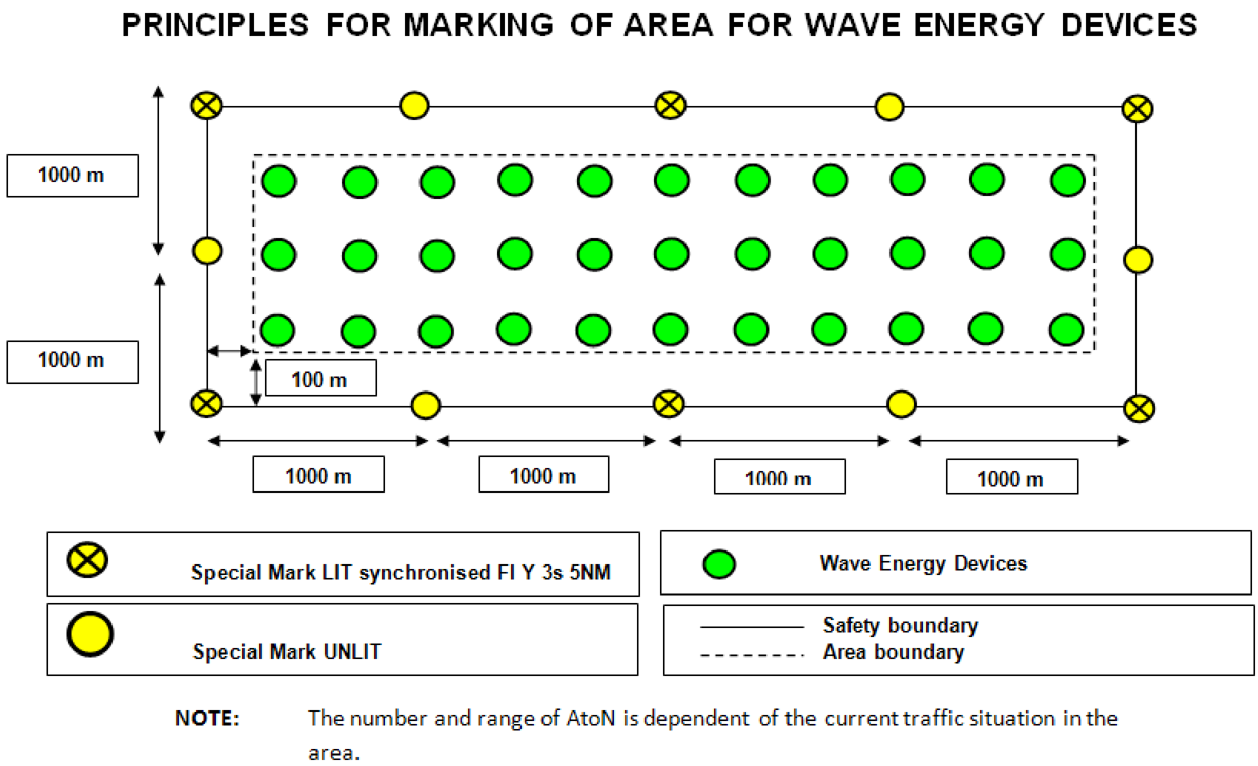


Figure 32 - Sample Marking of Wave Energy Devices

6.4.5 Offshore Aquaculture Farms

This section supplements the general rules for marking defined in section 2.1. and must be read in conjunction with it.

Aquaculture farms should be marked in accordance with this Recommendation and the MBS. The use of electronic AtoN, such as Racons or AIS AtoN may also be considered.

The farm, or group of farms, should be marked depending on their size, extent and location. In some cases it may be sufficient to mark only part of the perimeter, or the centre.

The Authority should bear in mind that the marking recommendations herein may be adjusted in consideration of traffic density, proximity to ports, proximity to dangers, tidal considerations and other factors. Other considerations may be:

- Licensing process;
- Aquaculture farms are normally marked by Special Marks;
- If there is a requirement for vessel traffic between aquaculture farms, then such channels are normally marked by Lateral Marks;
- If the prevailing situation warrants, Cardinal Marking alone may be used to direct vessel traffic away from the aquaculture farm(s);
- Synchronisation of AtoN lighting is recommended to improve the effectiveness of the lighting;
- Taking into account background lighting.

The Authority should be satisfied that the selected lighting has a suitable Minimum Effective Range and sufficient autonomy with the ability to over-winter – especially in higher latitudes. To improve the radar target and radar visibility, radar reflectors and radar reflective material should be considered. Retro reflective material can also be used.

Examples can be found in the following table that illustrate the minimum recommended marking arrangement with Special Marks.

- Rectangular Aquaculture Farms should be marked according to the length of their sides.

Example	X Axis (m)	Y Axis (m)	Area (m^2)	Minimum Marking Requirements
A	≤ 500	≤ 500		One light in centre of farm (consider radar reflector)
B	≤ 2 500	≤ 500		One light on each sea corner; one daymark on each coast corner (consider radar reflector)
C	≤ 500	≤ 2 500		One light on one sea corner; one light on the diagonally opposite coast corner; one daymark on one sea corner and one daymark on the diagonally opposite corner (consider radar reflector)
D	> 500	≤ 2 500	≤ 1 250 000	One light on diagonally opposite corners; daymark on diagonally opposite corners (consider radar reflector)
E	> 900	≤ 2 500	> 1 250 000	One light on each corner (consider radar reflector)

Table 19 - AtoN Layout for Rectangular Aquaculture

- Circular Aquaculture Farms should be marked according to their diameter.

Example	Diameter (m)	Diameter (m)	Minimum Marking Requirements
F		≤ 500	One light in centre of farm (consider radar reflector)
G	> 500	≤ 1000	Two light 180° apart on the circumference; two daymarks positioned 90° to the lights (consider radar reflector)
H	> 1000	≤ 2000	Three lights 120° apart on the circumference (consider radar reflector)
I	> 2000		Three lights 120° apart on the circumference, three daymarks positions 60° to the lights (consider radar reflector)

Table 20 - AtoN Layout for Circular Aquaculture

6.5 Audible Signals

The following provides a brief overview of audible AtoN signals, more detailed information is provided by referring to the following IALA publications.

Refer to IALA publications:
- *Recommendation E-109 for the Calculation of the Range of a Sound Signal;*
- *Recommendation O-113 for the Marking of Fixed Bridges over Navigable Waters;*
- *Recommendation O-139 for the Marking of Offshore Structures;*
- *Guideline 1090 on the Use of Audible Signals.*

6.5.1 Hazard Warning

It has been IALA policy since 1985 that audible signals, also referred to as sound signals, should only be used as a hazard warning. These hazards refer to certain man-made structures such as offshore structures, renewable energy infrastructure, bridges, breakwaters, and isolated AtoN. The Competent Authority shall determine whether a hazard requires an audible signal and the level of reduced visibility per year that justifies its installation (e.g. 10 days of visibility under 1 nautical mile per year).

Where provided, audible signals for navigational hazards should have a usual range of at least 2 nautical miles. In addition, Competent Authorities may require a backup audible signal of a reduced range (these do not necessarily need to be separate units); 0.5 nautical mile usual range is considered adequate for these backup audible signals.

6.5.2 Augmentation of Floating Aids to Navigation

Audible signals may also be used to augment buoys, both lighted and unlighted, to enhance their effectiveness to the mariner in reduced visibility. Audible signals on buoys are most often powered by the motion of the sea and include bells, gongs, and whistles. Buoys may also be fitted with electronic horns. Audible signals on buoys should be used to warn mariners of a particular hazard, such as proximity to shoals, rocks or other hazards; or to alert the mariner to a change in navigational requirements, such as the entrance to a restricted channel. Where electronic audible signals are used to augment buoys, they should have a usual range of 0.25 to 0.5 nautical miles.

6.5.3 Range

Audible AtoN signal range is calculated as nominal and usual and is expressed in nautical miles. Specific ranges cited in the above paragraphs refer to the usual range calculation.

6.6 Nautical Publications

6.6.1 Navigational Warnings

SOLAS Chapter V Regulation 13 requires for contracting governments to provide navigational information to mariners.

Regulation 13 states that "*Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.*"

This information falls into three basic categories:

- information about **planned changes**, such as:
  - dredging, surveying, platform installation, pipe and cable laying;
  - changes to an existing aid or the establishment of new aids to navigation;
  - changes to traffic arrangements;
  - commercial maritime activities;
  - short term events (naval exercises, yacht races, etc.).
- information about navigational **unplanned events,** such as:
  - the failure to aids to navigation;
  - marine incidents (groundings, collisions, wrecks etc.);
  - search and rescue activities.
- **new information** arising from survey work or previously undiscovered hazards.

6.6.2 World-Wide Navigational Warning Service

The promulgation of information on navigational safety is coordinated by means of the World-Wide Navigational Warning Service that was established jointly by the IMO and the IHO in 1977.

The World-Wide Navigational Warning Service is administered through 16 NAVAREAS, as is shown in *Figure 33*. Each NAVAREA has an Area Coordinator who is responsible for collecting information, analysing it, and transmitting NAVAREA Warnings. The delimitation of NAVAREAS is not related to, and shall not prejudice the delimitation of any boundaries between states.

6.6.3 Lists of Aids to Navigation

Lists of aids to navigation (e.g. lights, buoys, radar, audible signals) are produced by (or for) most Competent Authorities as part of the navigational information made available to mariners in support of SOLAS Chapter V Regulation 13.

They provide details of:

- name;
- location;
- the characteristics of the aids;
- operating schedule.

These lists may not include buoys and unlit aids to navigation.

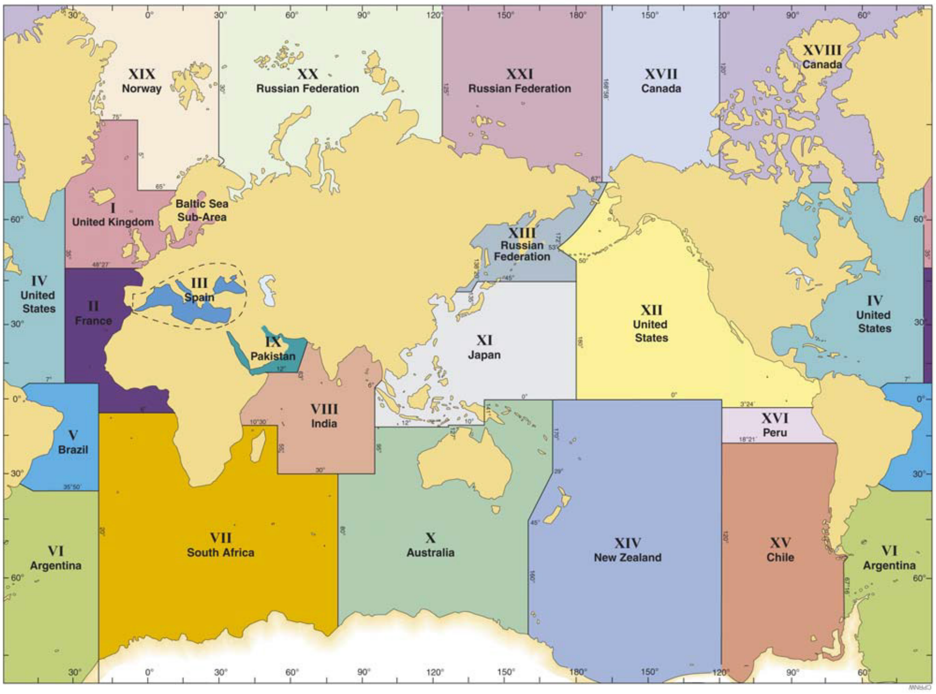


Figure 33 - World-Wide Navigational Warning Service: Limits of NAVAREAS

6.6.4 Standard Descriptions

The Joint IMO/IHO/WMO Manual on Maritime Safety Information (IMO MSC.1/Circ.1310) Edition 3 2009 provides definitions of standard terms to describe particular events that should be used when composing navigational warnings. Some of the terms that are relevant to the condition of aids to navigation have been defined as indicated in *Table 21*.

Term	Definition
UNLIT	Use UNLIT in place of: Out, Extinguished, Not Burning, Not Working.
LIGHT UNRELIABLE	Use LIGHT UNRELIABLE in place of: Weak, Dim, Low Power, Fixed, Flashing Incorrectly, Out of Character, Incorrect colour of light, Sector limits unreliable.
DAMAGED	Use only for major damage, e.g., loss of significant functionality
DESTROYED	Do not use “Temporarily destroyed”.
OFF STATION	Not in charted position, but still in the vicinity of original location. The actual position may be informed, if known.
MISSING	Completely absent from position.
RE-ESTABLISHED	Use for previously charted or listed as DESTROYED or TEMPORARILY REMOVED.

Table 21 - Sample of Standard Terms

The above list of terms and definitions do not adequately cover all of the situations that an Authority might want to use when issuing a navigation warning. An expanded set of definitions of terms for use in navigation warnings is provided for Competent Authorities’ consideration in *Table 22*.

Term	Definition
STATION	The authorised and exact location of an aid to navigation.
ESTABLISHED IN POSITION	Any type of aid placed in operation for the first time at a given station.
RE-ESTABLISHED IN POSITION	Any type of aid placed in operation at a station at which a similar type of aid with identical characteristics had been previously established, but subsequently destroyed, withdrawn or discontinued.
UNLIT	When a light is out because of defective equipment, or any unintentional or deliberate occurrence and it is intended to restore it to normal as soon as practicable.
UNRELIABLE	When an aid of any type is not exhibiting its correct characteristics and it is intended to restore it to normal as soon as practicable.
REDUCED POWER	When an aid of any type is not operating at its correct power, but is exhibiting the correct characteristics and it is intended to restore it to normal replace it as soon as practicable.
OFF STATION	When a floating aid is adrift, missing or out of position and it is intended to replace it as soon as practicable.
ALTERED	When the characteristics or structure of any aid have been altered, without changing the type of aid or its station.
ALTERED IN POSITION	When a change is made to the station of an aid (e.g. its location) without changing the type of aid, character or type of structure.
DESTROYED	Any type of aid that has been damaged to the extent that it is no longer of use as an aid to navigation, but the structure may remain.
RESTORED TO NORMAL	Any type of aid that has been previously described as unlit, unreliable, reduced power or temporarily discontinued and has now been serviced so as to exhibit its correct characteristics and power.
REPLACED IN POSITION	When a floating aid previously described as off station or temporarily discontinued is returned to station or replaced by another with the same characteristics.
TEMPORARILY REPLACED BY	When any aid is discontinued, temporarily withdrawn or off station and another aid of different type or characteristics is immediately established at the same station.
TEMPORARILY WITHDRAWN	When a floating aid has been entirely removed from its station and no similar aid is left in its place, but it is intended to re-establish the aid in the near future.
TEMPORARILY DISCONTINUED	When a sound signal or radio navigation service is silent because of maintenance requirements, or any unintentional or deliberate occurrence, and it is intended to restore it to normal as soon as practicable.
PERMANENTLY WITHDRAWN	When a floating aid has been entirely removed from its station with no similar aid is left in its place and it is not intended to re-establish that aid in the near future.
PERMANENTLY DISCONTINUED	When any aid, other than a floating aid, is removed from a station or the service is terminated or silenced because it is no longer required.

Table 22 - Suggested Expanded List of Standard Terms for Use in Navigation Warnings

6.6.5 Positions

The Joint IMO/IHO/WMO Manual on Maritime Safety Information states that positions should always be given in Degrees, Minutes and decimal minutes in the form:

- DD-MM.mmm N or S;
- DDD-MM.mmm E or W;
- leading zeros should always be included;
- the same level of accuracy should be quoted for both Latitude and Longitude.

Recording of Aids to Navigation Positions

Aids to Navigation positions can be recorded in number of ways:

- where an Authority has operational DGPS stations, a program should be implemented to determine the WGS84 positions of each aid to navigation (fixed and floating) within the coverage area, and for this information to be passed to the hydrographic authority for future use. It is anticipated that the information would assist the hydrographic authority in checking the accuracy of charts, planning future survey requirements and for updating List of Lights.
- in the case of lighted fixed aids to navigation the WGS84 position should be measured close to the focal centre of the light so that the WGS84 elevation is also determined. Alternatively, several positions around the optic or lantern house could be measured and a central position computed.
- in the case of unlighted fixed aids to navigation the WGS84 position should be the base of the structure.
- in the case of floating aids to navigation the WGS84 position should be the position of the anchor.
- each position should be recorded to three decimal places of a minute and include the time, date and details of the measuring equipment.
- where an Authority has to refer to charts of different datum, positions are communicated with the appropriate datum reference. (for example 51° 04.372'N, 100° 26.794'E (WGS 84)).

Refer to IALA publication:
- *Recommendation O-118 for the Recording of Aids to Navigation Positions.*

Bearings

Bearings, directions of leading lines (ranges) and limits of sectors should always be stated in terms of the bearings that would be seen by the mariner. Observing a practice of communicating bearings with the suffix 'TBS' or True Bearing from Seaward will minimise the risk of confusion.

6.6.6 Maritime Safety Information

Within a NAVAREA, there can be a hierarchy of warnings promulgated by the national co-ordinator. Collectively referred to as Maritime Safety Information (MSI), the warning hierarchy covers:

- **NAVAREA Warnings** that are concerned with information that ocean-going vessels require for safe navigation:
  - are transmitted in English and, where appropriate, in other languages;
  - are promulgated by:
    - radiotelephony;
    - Digital Selective Calling (DSC);
    - Enhanced Group Calling (EGC);
    - NAVTEX[32] (used for the automatic broadcast of localised Maritime Safety Information (MSI) using radio telex);
  - cover the specific NAVAREA and portions of adjacent areas;
  - have broadcast schedules which are shown in the List of Radio Signals published by Hydrographic Offices and in the publications of the International Telecommunication Union (ITU);
  - are generally promulgated for a sufficient period of time to ensure its safe reception after which it is cancelled or published in a Notice to Mariners;
- **Coastal Warnings** that are concerned with information relating to a regional area covering 100-200 nautical miles from the coast:
  - are transmitted from a national network of coastal radio stations;
  - are broadcasted at scheduled times;
  - use English and the national language;
- **Local Warnings** that cover the area within the limits of a harbour or port authority:
  - supplement Coastal Warnings;
  - may be limited to the national language.
- **Off-Station Warnings for Major Floating Aids** that pertain to any unmanned Light Vessel / Lightship, or LNB (occasionally referred to as LANBY), is out of position such that it could be misleading to navigation:
  - any light, sound and Racon signal used as aids to navigation should be discontinued;
  - it should, to avoid risk of collision, exhibit two all-round red lights in a vertical line where they can best be seen, which should be exhibited in accordance with COLREGS Rule 27 (A) for a vessel not under command;
  - if requiring a sound signal to be operated, it should be coded MORSE 'D' as prescribed by rule 35 of the COLREGS for a vessel 'Not under command';
  - if requiring a Racon to be deployed, it should be coded MORSE 'D'.

[32] Also known as Narrow Band Direct Printing (NBDP).

Refer to IALA publication:

- *Recommendation O-104 on Off Station' Signals for Major Floating Aids.*

6.7 Tide Gauges and Current Meters

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[33]. The latter is generally used to overcome the sometimes considerable differences between actual tide heights and predicted values due to meteorological and mean sea level fluctuations.

These systems are supplemented in areas of risk by tsunami early warning systems.

Authorities that are procuring or upgrading sea level measurement devices, are encouraged to consider using equipment that can support the requirements of the Global Sea Level Observing System (GLOSS) coordinated by the Intergovernmental Oceanographic Commission. Typically this calls for gauges capable of measuring to centimetre (1 cm.) accuracy in all weather (especially wave) conditions and for the free exchange of hourly sea level data with an International Sea Level Centre. Information on the GLOSS Programme can be found at www.gloss-sealevel.org. Technical recommendations on sea level observations can be found at www.pol.ac.uk/psmsl/manuals/.

6.8 Under Keel Clearance Management Systems

The Under Keel Clearance (UKC) of a vessel should always be such that a safe passage is ensured The IMO Helsinki Committee has quoted a UKC value of 20% -10% of the ship's draught, based on many years practical experience, which should be applied depending on whether the passage is exposed or sheltered. As shown in *Figure 34*, the UKC related to the ship at zero speed and the mean water level must allow for the squat at speed, the ship motions due to waves and swell, heel due to wind and turning and remaining uncertainties in water level and bottom level. Note, however, that the figures advised by IMO address the dynamic UKC, which is the UKC remaining when the vertical motions as well as the squat underway are deducted.

The largest allowance usually has to be made for the wave response. As the wave spectrum is transformed into a motion spectrum of the ship, there is not a specific maximum value to the ship's vertical motions. What allowance has to be reserved for a safe passage then? The key is to define a maximum probability (per unit of time) that the vessel would contact the bottom. This value should be subject to the bottom type (sandy and flat or with rocks), the type of vessel and cargo, the ecological vulnerability of the area and the possibility that the harbour entrance would be blocked as a result of a contact.

33 IALA Recommendation V-128 – Operational and Technical Performance Requirements for VTS Equipment Edition 3.0 June 2007.

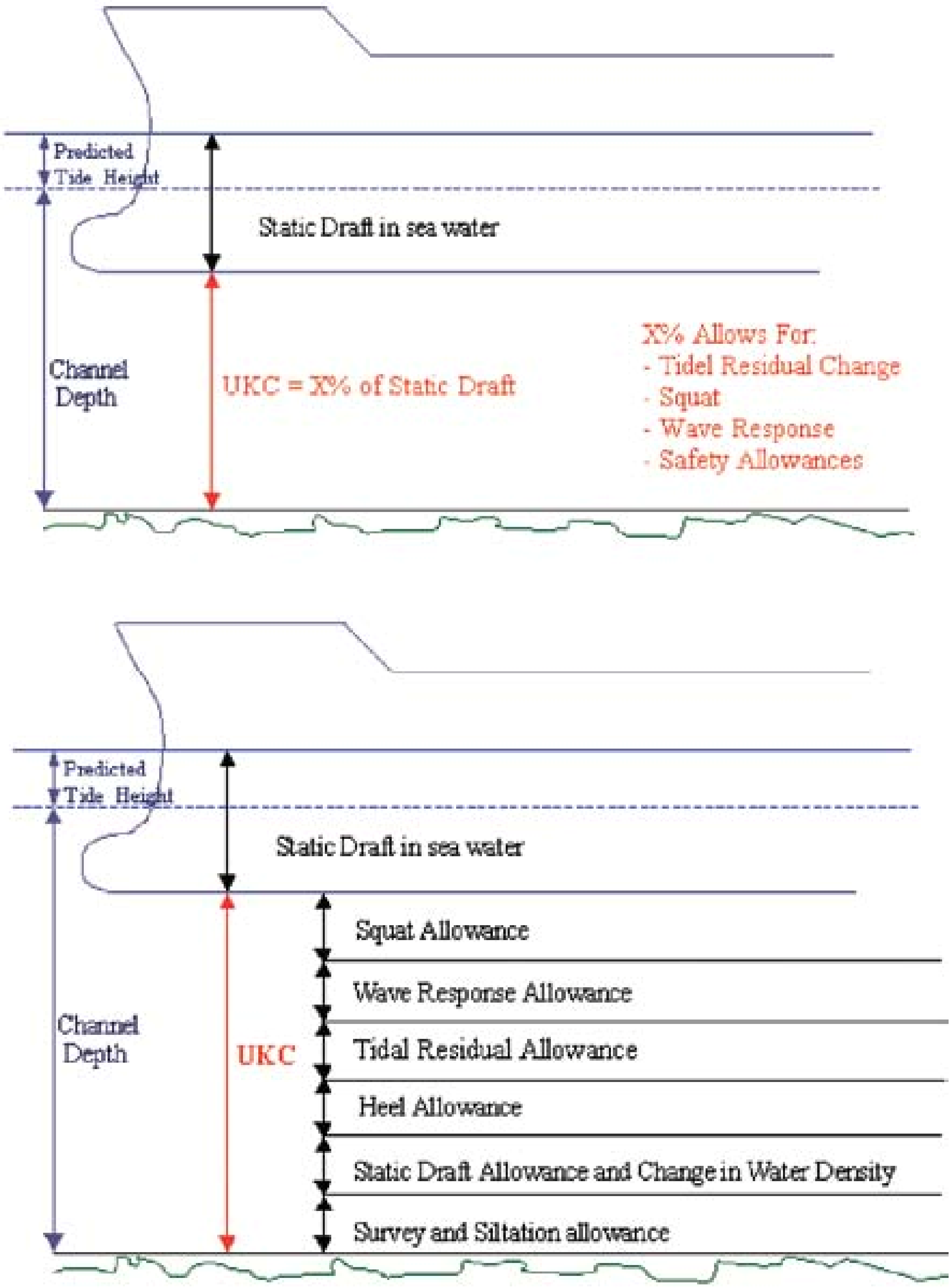


Figure 34 - Vessel Under Keel Clearance (UKC)

For the passage concerned, tidal windows may be calculated on basis of this probability, instead of using a fixed value of UKC. To this end, the expected motion spectrum of the vessel during the passage must be determined. In order to remain maneuverable, a minimum UKC (e.g. 1.0 m) has to be maintained at all times disregarding the motions due to waves. Additionally, the motions during the actual passage may be monitored, so that the passage plan might be adapted if conditions differ from the expectations. UKC management may exist as a system to calculate Probabilistic Tidal Windows for a passage or as a real-time monitoring system to be used during a passage. For both, prediction of conditions over the hours ahead is important to make decisions in time.

There is an increasing use of Probabilistic Tidal Window calculation systems in ports. The general rationale for those is that a fixed UKC criterion will under most circumstances be unnecessary large, in order to ensure that all passages under all permitted conditions will be safe. The fixed UKC criterion is then governed by the worst conditions that only occur during a small percentage of the time. Under more favourable conditions the actual UKC may be smaller without compromising safety, which leads to a better accessibility of the port.

Real-time UKC monitoring may be performed for different purposes and in different ways One purpose is of course to ensure the safety of navigation, providing an early warning if the UKC gets too small. An other important purpose is to evaluate the performance of the prediction systems used, so that these may be improved. The way in which the UKC is monitored depends on the available data sources. To improve a predicted value, the actual value must be deducted from the measured data.

The predicted data comprise:

- Water level;
- Current;
- Wind;
- Wave Height and Direction;
- Water Density.

Other parameters are known with only limited accuracy or certainty:

- Vessel Characteristics (wave response; draught fore, mid and aft);
- Squat, Trim and Heel;
- Acctual Bathymetry.

Metocean models are used for the prediction of wind, water level and current, and wave spectra, often as localised models nested within oceanwide models. Oberved data are provided by tide gauges, wave buoys and other devices as available near the passage. The vertical position of the vessel may in some areas be monitored accurately with GPS in RTK mode. This yields the direct measurement of the bottom elevation, but also the squat of the vessel if the actual water level is known or vice versa.

Vessel transits plans or tidal windows are determined using predicted information. The closer to the time of transit, the more accurate the prediction will be as it is corrected using observed values Transits may be executed with the assistance of portable systems that can receive real-time environmental data (tides, waves, current, weather). This enables a pilot to execute a transit having full regard to real-time environmental conditions. If there is time and maneuvering space for it, the pilot may be able to fine-tune a ship's actual UKC by varying speed, which affects squat/ settlement, and rate of turn, which affects angle of heel, to ensure it remains within predefined limits.

Predictive and real time UKC software applications including associated portable pilot software applications require a ground truthing approach for ensuring their operational integrity and Competent Authorities seeking to implement real time UKC management systems may need to provide additional aids to navigation and related infrastructure (e.g. hydrometeo sensors, fully redundant communications links) to support a real time UKC management system.

Competent Authorities considering implementing UKC management systems should undertake a rigorous assessment of the economic benefits that would accrue to the shipping industry through the extension of tidal windows and the increase in maximum draughts that may be accommodated through the use of real time UKC management systems. Using a probabilistic tidal window regime implies that the larger the draught, the larger the probability that the ship may have to wait one or more tides before passage is safe enough.

It is imperative that a robust operational model(s) and governance framework(s) is in place for the introduction of a flexible UKC system. The accuracy of charted depths and predicted tide levels is integral to the management of UKC. Hydrographic surveys have inherent technical limitations due partly to uncertainties in tidal reductions. Nautical charts can seldom, therefore, be absolutely reliable in their representation of depth. Furthermore, in some areas where there are sand waves the shape and hence the depth of the seabed is constantly changing.

Potential components of that framework include:

- Initial validation of the UKC calculation outputs of the system by an independent person ororganisation e.g. hydrographers, hydrodynamics experts, using accepted validation techniques such as:
  - Regular calibration of sensors providing hydrometeo data inputs;
  - Accuracy limitations of charted depths and tidal predictions must be factored into any UKC system.

Competent Authorities should ensure an appropriate minimum under keel clearance limit is enforced in conjunction with the operation of the UKC management system.

7 POWER SUPPLIES

7 POWER SUPPLIES

7.1 Types

A wide range of power systems and energy sources have been used or contemplated for operating lighthouses and floating aids. Everything from clockwork to radio-active isotopes have been used. Some of the more common types are listed in *Table 23*.

Electric Energy Sources	Non-Electric Energy Sources
Commercial power supply	Acetylene
Photovoltaic solar modules	Propane
Diesel and petrol engine driven generators	Butane
Primary cells	Kerosene
Wind generators	
Wave activated generators	
Fuel cells using alcohol or hydrogen	

Table 23 - Power Sources for Operating Lighted Aids to Navigation.

There is a general trend away from gas, using mains utility electricity where available and photovoltaic solar power where mains is not available.

IALA has created a series of documents to assist in the selection of electrical power systems for aids to navigation.

Refer to IALA publications:
- *Guideline 1067-0 on Selection of Power Systems for Aids to Navigation and Associated Equipment;*
- *Guideline 1067-1 on the Total Electrical Loads of Aids to Navigation;*
- *Guideline 1067-2 on Power Sources;*
- *Guideline 1067-3 on Electrical Energy Storage for Aids to Navigation.*

Refer to:
- *Applicable national standards for the safe handling of gases.*

7.2 Electric - Renewable Energy Sources

7.2.1 Solar Power (Photovoltaic cell)

Solar power is an ideal power source for many aids to navigation applications. It offers:

- a power source with no moving parts;
- no maintenance requirements other than being cleaned;
- *slight* deterioration in power output over its life;
- low life-cycle costs.

When used to power a light, the battery recharging process is separated from the operation of the light source so that the recharge voltage can be optimized without detriment to the *light's operation*.

Potential difficulties associated with solar power are:

- *finding ways to minimise bird fouling;*
- *mounting solar modules vertically is probably the best long-term solution for buoys;*
- *sizing arrays to operate at high latitudes;*
- *protecting solar modules from;*
  - *wave damage on buoys;*
  - *vandalism and theft*
  - *lightning.*

Aids to navigation exposed to icing conditions are perhaps the only applications unsuited to the use of solar modules.

Photo Courtesy of the Australian Maritime Safety Authority

Types

The three common technologies employed in the manufacture of silicon based, solar modules are listed in *Table 24*.

Technology	Comments
Monocrystaline Cells	Made from a thin slice cut from a single large crystal of silicon, usually produced as a circular section rod. Generally have the highest efficiency of the three technologies. If circular wafers of silicon are used the module fill factor is significantly less than with polycrystalline cells. It is now usual for the cells to be trimmed to approximate a square.
Polycrystaline Cells	Made from a thin slice cut from a large cast billet of silicon comprising many crystals. Are slightly less efficient than the mono crystalline cell but they can be shaped to completely fill the module.
Thin Film Technology	Made by depositing thin films of silicon directly onto a glass or stainless steel substrate a thin slice cut from a single large crystal of silicon. The cell has a lower efficiency than either of other technologies but can be multi-layered for enhanced performance. Problems have been found with lifetime of these cells.

Table 24 - Silicon Solar Cell Technology

In addition to the silicon cell technologies, there are two optional module configurations based on the numbers of series connected cells. The standard module normally has 36 cells in series to give an open circuit voltage of around 20 volts. For all battery charging applications, a voltage (charge) regulator is considered essential.

Modern developments in electronics have allowed new voltage (charge) regulators to be developed that use maximum power point tracking (MPPT). This ensures that they operate the solar module at a level to obtain the maximum power, for any given level of irradiance. This operating level is independent to the battery charge voltage level. This technology can lead to up to 30% more output than would be achieved with conventional voltage regulators.

Module or Array Orientation
In the northern hemisphere, solar modules are normally installed facing south and inclined at an angle to the horizontal that is related to the latitude of the site, and vice versa for the southern hemisphere. The inclination angle for solar modules is often optimised for the particular site as part of the sizing calculations.

One of the main problems experienced with solar powered aids to navigation has been bird fouling. Numerous, innovative solutions have been trialed, generally with mixed results. Generally solar modules mounted at an angle or vertically benefit from self washing from rain.

The cost of additional solar modules needed for a vertical installation may be largely off-set by the savings that result from simplifying the mounting arrangements or framework.

7.2.2 Wind Energy

Aids to Navigation Applications
Wind generators (or wind turbines) have been used by a number of IALA Members to power aids to navigation. The most popular type were horizontal axis machines with a two bladed (propeller type) turbine. The maintenance requirements arising from the number of moving parts of a wind generator and susceptibility to storm damage, has limited the use of wind generators.

Installations
Wind generator installations at aids to navigation sites pose a number of problems:

- wind generators tend to require a lot of maintenance if operated in turbulent air flows;
- if the wind generator is installed on a separate mast some distance from the aid to navigation, consideration has to be given to cable voltage drop;
- operation of wind generators to power aids to navigation needs to take into account the impact it may have on any environmental factors associated with the location, such as; flora, fauna, birds, etc.

Wind Generator Types

A comparison of the typical performance of different types of wind generators is shown in *Figure 35*.

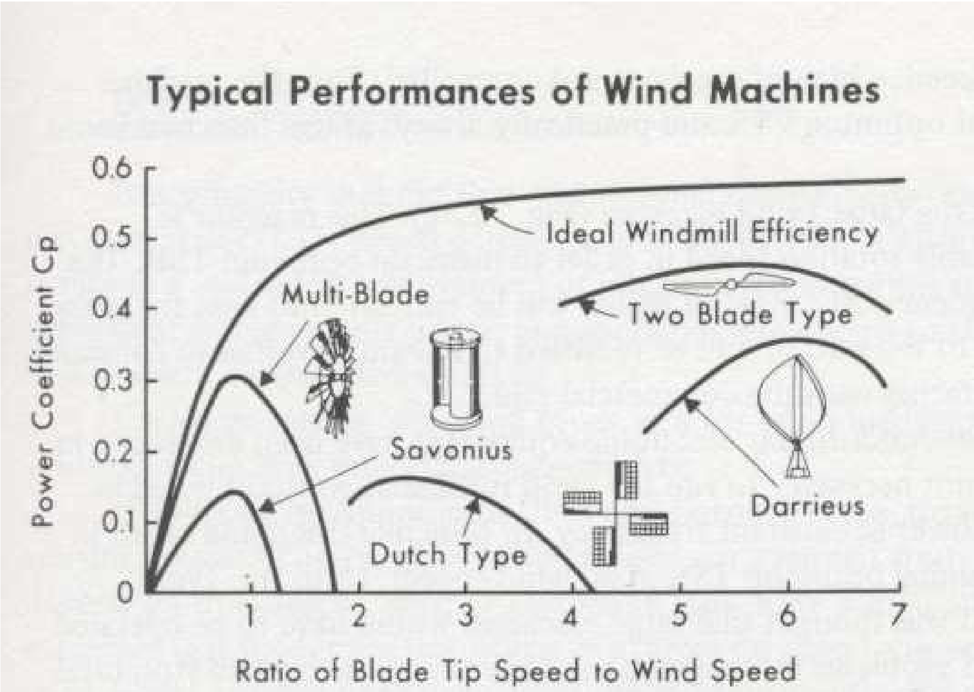


Figure 35 - Comparison of Performance of Wind Generator Types

7.2.3 Wave Energy

The wave activated generator (WAG) was developed in Japan and has been successfully used to power lighted buoys. The interaction between the buoy and wave motions acts as a simple air pump that is used to drive an air turbine and generator. The WAG is mounted on an extension of a hollow tail tube that passes through the buoy hull. With wave heights of 0.5 metres, the power output is almost 100 watts. WAG's have limited life and current systems suffer from excessive wear.

Site conditions will determine the rate at which the tail tube of the buoy accumulates weed and other forms of fouling, and these aspects need to be taken into consideration when developing the maintenance regime for the WAG. WAG's can also be very susceptible to storm damage.

7.3 Rechargeable Batteries

7.3.1 Principal Types

There are two main types of storage battery technologies applied to aids to navigation – lead acid and nickel cadmium. The lead acid type is generally preferred because of its lower cost and higher energy exchange efficiency (95% vs. 80%) than the nickel cadmium battery. However, the nickel cadmium battery can operate in lower temperatures and for a greater number of deep discharge cycles.

Recently, new secondary battery technologies have appeared, including lithium batteries, nickel-metal-hydride (Ni-MH) batteries and lithium-iron phosphate (LiFePO4) batteries. These batteries offer lower weight and longer life span from more charge-discharge cycles, for a given capacity.

Lead Acid

The basic form of this battery uses a lead dioxide positive plate and a pure lead negative plate immersed in an electrolyte of dilute sulphuric acid. These were originally wet or flooded cells. However in recent years various forms of "sealed" cell batteries have become available and are quite common in aids to navigation applications.

Lead acid batteries are available in two main designs, flooded lead acid and valve regulated (VRLA). The VRLA comes in two types, absorbed glass-mat (that use a micro glass separator system to absorb the electrolyte), and gel batteries, that use a jellified electrolyte and polymeric separators to prevent short circuits between the positive and negative plates.

Nickel Alkaline Battery

These batteries use compounds of nickel and, generally, cadmium with a solution of potassium hydroxide as the electrolyte.

Nickel-cadmium cells use perforated steel plates that hold the active material, mainly a nickel hydroxide in the positive plate and a cadmium compound in the negative plate. The construction is generally referred to as a "pocket plate" cell.

A range of valve regulated nickel-cadmium batteries that use a recombination process now complements the traditional flooded cell design. Under normal float charging conditions any gas produced is recombined within the battery and water loss is negligible. However if the battery is overcharged it will vent but water can be added if necessary.

Battery Disposal

A number of countries now have standards and regulations relating to the safe and environmentally acceptable methods of disposing or recycling of batteries.

7.3.2 Primary Cells

Primary cells provide electrical energy by a non-reversible chemical process. They were used in large numbers up until the 1980s to operate buoys and automatic beacon lights. The usage of primary cells has declined sharply since commercial solar power (photovoltaic) modules have become available. A related issue that hastened the decline of primary cells was the tightening environmental standards in a number of countries that required cells to be recovered from site for disposal in an approved manner. Disposal compliance costs, and occupational health and safety aspects of the frequent change-out of primary cells have worked in favour of converting to renewable energy sources (e.g. solar, wind and wave generators).

Zinc-Air Cell

The zinc-air primary cell was a common energy source for operating buoy and beacon applications. The cell uses a porous carbon block to supply oxygen from the air through an alkaline electrolyte to oxidize a zinc anode. Individual primary cells have an open circuit voltage of about 1.2 volts and can supply 1000 to 2000 Ah at a maximum rate of about 1 ampere.

Lithium-Thionyl Chloride Cell

Another type of primary cell in use in buoy applications is the lithium-thionyl chloride cell. This has a higher energy density and a longer shelf life than the zinc-air cell.

Sealed Alkaline Battery

Is commonly used in some countries, and has the benefits of good low temperature performance

Sea-Water Cells

The sea-water cell[34] developed for buoy applications in Norway is a primary cell that uses a magnesium anode and a largely inert copper cathode. The sea water acts both as an electrolyte and the provider of dissolved oxygen for the cathode.

A single cell is installed as part of the buoy tail tube. The motion of the buoy has a beneficial effect in agitating the water to provide an oxygen-rich flow through the cell and carry away the reaction products.

Copper was selected for the cathode material because of its inherent antifouling properties. A magnesium anode was considered environmentally acceptable because it is a naturally occurring element of sea water. The cell produces a voltage of 0.8 to 1 volt under load.

ADC-DC converter is used to raise the voltage to the level required by the load as it is impractical to use more than one cell due to the current leakage that would occur.

7.3.3 Internal Combustion Engine/Generators

Diesel Generators

Diesel engine driven generators are often used as the primary source of electrical power where the location of an aid to navigation is too remote to be supplied from a mains electricity grid. Diesel generators are also used to provide emergency or backup power.

[34] The chemistry of the sea-water cell and the prototype light buoys using this cell have been described in papers for the 1990 IALA Conference and IALABATT 2 and 3.

The generator capacity to support the operational and domestic loads of a standard lighthouse is in the range of 10 to 30 kW. Diesel generators of this size are expected to consume around 0.4 litres of diesel fuel per kWh. However, smaller generators in the range of 2 to 5kW, combined with batteries and inverter-charger systems are now available to meet this variable load demands.

The requirement for diesel generators in lighthouses is decreasing as a result of:

- lighthouse automation (destaffing), and because;
- new beacon and lamp technology that enables a light with a nominal range 18 to 20 nautical miles to be operated from a renewable energy source.

Petrol Engine Generators
Petrol engine generators are a useful source of power for maintenance work, but are less common in permanent installations due to:

- fuel storage and transportation safety issues;
- maintenance requirements on the spark-ignition system;
- the petrol engine generally being regarded as less durable than a diesel.

Thermo-electric Generator
This is a solid-state generator in which a heat source, commonly from a propane burner, is directed onto a thermopile (i.e. an array of thermocouple type elements). Since each thermocouple only produces a voltage of around 0.5 volts, a number are connected in series. This type of generator has a low thermal efficiency (around 5%) and is rarely used.

Stirling Engine Driven Generator
The Stirling engine is an external combustion engine that can be operated on gas or diesel fuel. Packaged generator sets are available that could operate a lighthouse. Typical generators produce 1kW electrical output and 5kW of heat. The heat output could be a useful by-product for maintaining a constant temperature in a lighthouse.

Fuel Cell
This is a solid-state device that uses a catalytic process to oxidise fuel to generate an electrical current. A common fuel is hydrogen, or hydrogen rich fuels such as Methanol. It can be thought of as a continuously fed battery ideally preferring a constant load.

The commercial fuel cell is still a developing technology and at this stage is an expensive power source[35]. Aids to navigation applications are likely to be limited to situations where solar energy (photovoltaic) is impractical due to limited insulation or icing conditions.

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[35] Refer to IALABATT 3 "Fuel cells for aids to navigation".

Fuel cells do present an environmentally suitable solution, as Methanol can be manufactured from sustainable sources and the by-products of the generation of electrical energy is heat and water. There is some interest in the use of fuel cells in hybrid power systems with wind energy or solar energy. These systems are still in development.

7.4 Electrical Loads and Lightning Protection

7.4.1 Electrical Loads

IALA has prepared a standard methodology for calculating and defining the load profile of electric aids.

This covers the loads for:

- lights;
- racons;
- AIS AtoN;
- electric sound signals;
- fog detectors;
- monitoring and telemetry systems;
- charge controllers;
- signal control equipment.

Refer to IALA publication:

- *Guideline 1011 on A Standard Method For Defining And Calculating The Load Profile Of Aids To Navigation.*

7.4.2 Lightning Protection

To assist those engaged in the design of aids to navigation, IALA has produced Guidelines to describe practical methods for the design, installation, inspection and testing of lightning protection systems. The information covers lightning protection for aids to navigation structures, equipment and systems.

Refer to IALA publication:

- *Guideline 1012 on the Protection of Lighthouses and Aids to Navigation Against Damage from Lightning.*

7.5 Non-Electric Energy Sources

There are various non-electric power supplies, the main types used in aids to navigation are acetylene and propane.

Acetylene

Acetylene (C2H2) has been used to operate lights on buoys and unattended aids to navigation for many years. Acetylene can explode if compressed directly, but can be safely contained under low pressure in special cylinders when dissolved in acetone. The manufacture of acetylene, standards for the cylinders and the filling process are usually controlled by government regulations.

Acetylene has been a convenient and reliable energy source for aids to navigation. However appropriate attention should be given to:

- safe handling of cylinders;
- the broad range of explosive mixtures with air (between 3 and 82% acetylene);
- the purity of the gas;
- minimizing leaks in pipe work and fittings.

Propane

Propane gas (C_3H_8) has been used as an alternative fuel to acetylene, particularly in buoys. Although propane has to be consumed in an incandescent mantle burner to provide a white light, it has several advantages over acetylene:

- it is a by-product in oil refining processes;
- its abundance and low cost;
- propane liquefies at a pressure of 6 atmospheres at 17°C, and can be transported in low weight and low cost gas bottles;
- propane will maintain a positive pressure down to -40°C and will not freeze in conditions likely to be encountered at sea;
- placing the bottles in pockets in the buoy or by filling it directly into the body of an buoy, or pressure vessel;
- the comparable containers are the 20 kg propane bottle with gross weight of 48 kg and the 7,000 litre acetylene cylinder, weighing 105 kg;
- furthermore the cost of the propane bottle is only about one third of that of a acetylene cylinder;
- propane is a particularly safe gas, as only some 6% of all its possible mixtures with air are explosive against a figure of 80% for acetylene;
- burns cleanly without the risk of sooting that can occur with a poorly adjusted acetylene burner.

Refer to IALA publication:

- *'Practical Notes' for the safe handling of gases, October 1993.*

Refer to:

- *Applicable national standards for the safe handling of gases.*

8 PROVISION, DESIGN AND MANAGEMENT

8.1 International Criteria

The International Convention for the Safety of Life at Sea, 1974 (as amended), or SOLAS, is one of the oldest international conventions and originates from a conference held in London in 1914 to address aspects of safety at sea following the sinking of the White Star liner Titanic in 1912. Since then, there have been four other SOLAS Conventions, the latest being the 1974 version that came into force in 1980.

The SOLAS Convention is administered by United Nations through the International Maritime Organisation (IMO). The 1974 Convention (as amended) is divided into twelve chapters and within these are a series of regulations. The contents[36] are outlined in *Table 25*.

Chapter	Contents
Chapter I	General Provisions
Chapter II-1	Construction – Subdivision and stability, machinery and electrical installations
Chapter II-2	Construction – Fire protection, fire detection and fire extinction
Chapter III	Life-saving appliances and arrangements
Chapter IV	Radiocommunications
Chapter V	Safety of navigation
Chapter VI	Carriage of cargoes
Chapter VII	Carriage of dangerous goods
Chapter VIII	Nuclear ships
Chapter IX	Management for the safe operation of ships
Chapter X	Safety measures for high-speed craft
Chapter XI-1	Special measures to enhance maritime safety
Chapter XI-2	Special measures to enhance maritime security
Chapter XII	Additional safety measures for bulk carriers
Appendix	Certificates

Table 25 - Contents of SOLAS Convention

SOLAS Chapter V

SOLAS Chapter V, and Regulations 12[37] and 13 in particular, define the obligations on Contracting Governments to provide vessel traffic services and aids to navigation and related information. These Regulations define the primary roles of IALA National Members.

[36] Reference SOLAS Consolidated edition 2004.

[37] For VTS issues, please refer to Chapter 5 of the NAVGUIDE and the IALA VTS Manual.

In December 2000, the 73rd session of the IMO Maritime Safety Committee (MSC) adopted a completely revised SOLAS Chapter V on Safety of Navigation that came into force on 1 July 2002.

In October 2005, IMO adopted IMO Resolution A.973(24) and A.974(24), outlining the IMO Member State Voluntary Audit Scheme which includes all aspects of SOLAS, including Chapter V, Regulations 12 and 13.

SOLAS Chapter V, Regulation 13 - Establishment and operation of aids to navigation states:

1. Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.

2. In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines (Reference is made to IALA) when establishing such aids.

3. Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.

To satisfy the obligations of Regulation 13, the Contracting Government has to make assessments on:

- whether or not to provide particular types of aids to navigation;
- the type, number and location of aids to navigation;
- what information services are necessary to adequately inform the mariner.

8.2 Level of Service

Level of Service (LOS) is the commitment of service by the Competent Authority to mariners who are navigating or operating in an area, as well as clients and/or governments responsible for funding the provision of the relevant service.

Level of service can be articulated through a statement that should be clear, easy to understand and available to all concerned.

8.2.1 Benefits

An established level of service is integral to efficient planning and delivery. It provides users with a clear understanding of the expected services. A level of service also contributes to ensuring that services are delivered in a nationally consistent, integrated, predictable, measurable and fair manner.

8.2.2 Components

A level of service statement should include, at minimum, the following components:

Type

Should describe what the Competent Authority will provide. It is a description of the service provided, such as, visual aids to navigation, radionavigation systems, or Vessel Traffic Services.

Extent

Should describe where and why a service will be provided by the Competent Authority. Most Competent Authorities are bound by the International Convention on the Safety of Life at Sea, 1974 as amended (SOLAS) Chapter 5, Regulation 13, which states that "*Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in cooperation with other Contracting Governments, such aids to navigation as the volume of traffic justifies* [where] *and the degree of risk requires* [why]." The extent of service provided may also vary by Competent Authorities for specific areas, category of users, or due to national obligations.

Quality

Should address to what level the Competent Authority will provide a service. It is a minimum standard at which clients can expect a service to be performed, also known as a performance standard. A performance standard is a benchmark against which actual performance of a service can be measured. It may be expressed in the form of a target such as percentage of availability of a service or service response times.

8.2.3 Layers of Service

A summary of available aids to navigation systems and obtainable accuracies is provided in *Table 26*. It is assumed that radar and visual bearings have 0.5º and radio bearings 2º accuracy respectively.

Distance Off Shore (nautical miles)	Obtainable Accuracies		
	> 500 m	100 - 500 m	< 100 m
Unlimited	Astronomical Fix		GNSS
800 -150	Astronomical Fix		GNSS
150 - 30	Astronomical Fix Radio Beacons		GNSS Precision Systems
30 - 6	Astronomical Fix Radio Beacons Visual Bearings Radio Bearings	Radar Bearings	GNSS Precision Systems
6 or less		Radio Beacons Visual Bearings Radar Bearings	GNSS Precision Systems

Table 26 - Indicative Accuracies of Aids to Navigation Systems

The various type of AtoN have advantages and disadvantages for the user as well as for the provider as indicated in *Table 27*.

System	Users		Providers	
	Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Visual	Can be used to position Convey immediate information Can be used without a chart if user has a good local knowledge	Range depends on site, height, colour, background Limited by visibility Position of floating aids not always accurate	For hazard warning, traffic regulation, guidance, etc. Placement flexible Maintenance requires little training	Maintenance expensive Planning for maintenance depends on weather conditions Logistic system required Training maintenance personnel
Radar	Identification with racon possible in reduced visibility conditions With a racon identification of low coastline Only one aid is required Rapid deployment	Onboard equipment needed Racons may interfere if not placed in an appropriate configuration, aids equipped with radar reflector are difficult to identify	Can replace visual aids Warnings of dangers (New dangers)	Radar reflectors needed Some vessels do not have radar Racon investment expensive Training for maintenance of racons
Radionavigation	Wide scale coverage All weather use Automatic navigation Precision possible	On board equipment needed	Reduced maintenance- Automatic monitoring Reduction of visual aids possible	May not be under Aids to Navigatiion Authority's control Monitoring requirement Training maintenance personnel Large investment

Table 27 - Comparison of Different Types of Aids to Navigation

Refer to IALA publications:

- *Guideline 1004 on Levels of Service;*
- *Guideline 1079 on Establishing and Conducting User Consultancy by Aids to Navigation Authorities.*

8.3 Risk Management

Dealing with "risk" is an intrinsic aspect of human existence. The establishment of the early lighthouses represent a tangible way of addressing some of the problems that arose when humans decided to venture out to sea, and then into global trade and the mass transport of people by ships.

The traditional definition of risk is the probability of an unwanted event occurring, multiplied by the impact or consequence of that event.

$$R = P * C$$

Unwanted events include deprival, loss or injury to persons, property or the environment.

Risk management is a term applied to a structured (logical and systematic) process illustrated further below.

The correct, efficient and useful result of hazard identification, assessment of risk and establishment of risk control measures, in fact the output of a risk management process, is dependent on the application of Human Factors disciplines. The concept of Human Factors and references to relevant models is therefore included in the IALA Guideline 1018 on Risk Management. It is recommended that administrations, organisations and persons involved in a risk assessment process have suitable, updated and in-depth knowledge in the application of Human Factors disciplines.

With the advances of e-Navigation the mariner has been provided with additional real time information to assist with navigation. The positive impact on ship control and navigation has to be incorporated into the formal risk assessment process. For risk control options the continuous development of e-Navigation and man-machine interfaces may provide new possibilities. However, physical AtoN risk control measures will remain important to address the needs of all user groups.

The risk management approach works equally well for identifying the risks at a detailed or broad level. It can also address the risks from different perspectives.

Refer to IALA publication:

- *Guideline 1008 on Risk Management.*

For example, if the issue is the automation and destaffing of a lighthouse, there are likely to be different sets of risk for:

- service providers (aids to navigation authority, the lightkeepers);
- service users (mariners);
- external groups (politicians, local community, conservation groups).

8.3.1 IALA Risk Management Tools

IALA is continuing to improve risk management tools that are capable of:

- assessing the risk in ports or waterways, compared with the risk level considered by Authorities and stakeholders to be acceptable. The elements that can be taken into consideration include those relating to vessel conditions, traffic conditions, navigational conditions, waterway conditions, immediate consequences and subsequent consequences;
- identifying appropriate risk control options to decrease the risk to the level considered to be acceptable. The risk control options available include improved co-ordination and planning; training; rules and procedures including enforcement; navigational, meteorological and hydrographical information; radio communications; active traffic management and waterway changes; and
- quantifying the effect on the risk level of an existing port or waterway that may result from a change or reduction of any of the risk control options in use.

The risk management tools can also assist in assessing the risk level of existing ports and waterways as well as determining the probable risk level of proposed new ports and waterways or if substantial changes to existing ports and waterways are being planned. The tools are based on the use of two models:

- Port And Waterway Safety Assessment tool (PAWSA) which conducts a Qualitative Risk Assessment;
- IALA Waterway Risk Assessment Programme (IWRAP Mk II) which conducts a Quantitative Risk Assessment. The two models can be used individually, sequentially or in parallel.[38]

Applications to use the IALA Risk Management Tool should be made by the Authority concerned to the IALA Secretariat ensuring that registered users are provided with the latest versions of the PAWSA and IWRAP free of charge to the Authority.

All the information necessary to prepare and conduct a PAWSA is contained within the program. However, if guidance is required the IALA Secretariat will arrange this in coordination with the United States Coast Guard.

[38] When available, the Risk Model will be included in the IALA documents available at www.iala-aism.org.

Information on how to use the IWRAP tool is given through IALA IWRAP training seminars and on a dedicated IWRAP WIKI site on the internet (accessible through the IALA website). If further guidance or assistance is required the IALA Secretariat is able to arrange for experts to assist with conducting an IWRAP Risk Assessment.

Authorities are requested to provide copies of the results of risk assessments made by the IALA Risk Management Tool to the IALA Secretariat.

8.3.2 Risk Management Decision Process

The Risk Management process described in the IALA Guideline 1018 comprises five steps that follow a standardized management or systems analysis approach:

a) Identify hazards;
b) Assess risks;
c) Specify risk control options;
d) Make a decision;
e) Take action.

The diagram in *Figure 36* provides a guide to the steps involved in the IALA Risk Assessment and Risk Management process.

Hazard – an unwanted event or occurrence, a source of potential harm, or a situation with a potential for causing harm, in terms of human injury; damage to health, property, the environment, and other things of value; or some combination of these.

Risk - the chance of injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property or the environment or other values.

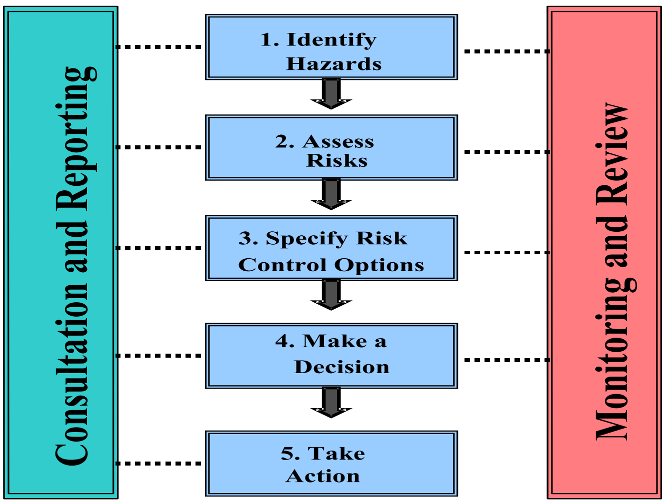

Figure 36 - Risk Assessment and Risk Management Process

The central part of the *Figure 28* illustrates the five steps in the risk management process. In addition the figure suggests a consultation and reporting element throughout the process.

Stakeholders including practitioners and users shall be consulted and receive feed back continuously to ensure the best possible input to the decision makers, to validate decisions and to ensure ownership of the results and actions taken. The monitoring and review part in the right side of the model is vital to ensure a verification of the decisions, to check if initial conditions have changed and to constantly monitor if control measures are implemented effectively.

8.3.3 Levels of Risk

Once the risks have been identified it is generally useful to rank them in order of consequence. Resources can then be assigned to treating the most serious risks first. The matrix at *Figure 37* provides a basis for prioritising risks.

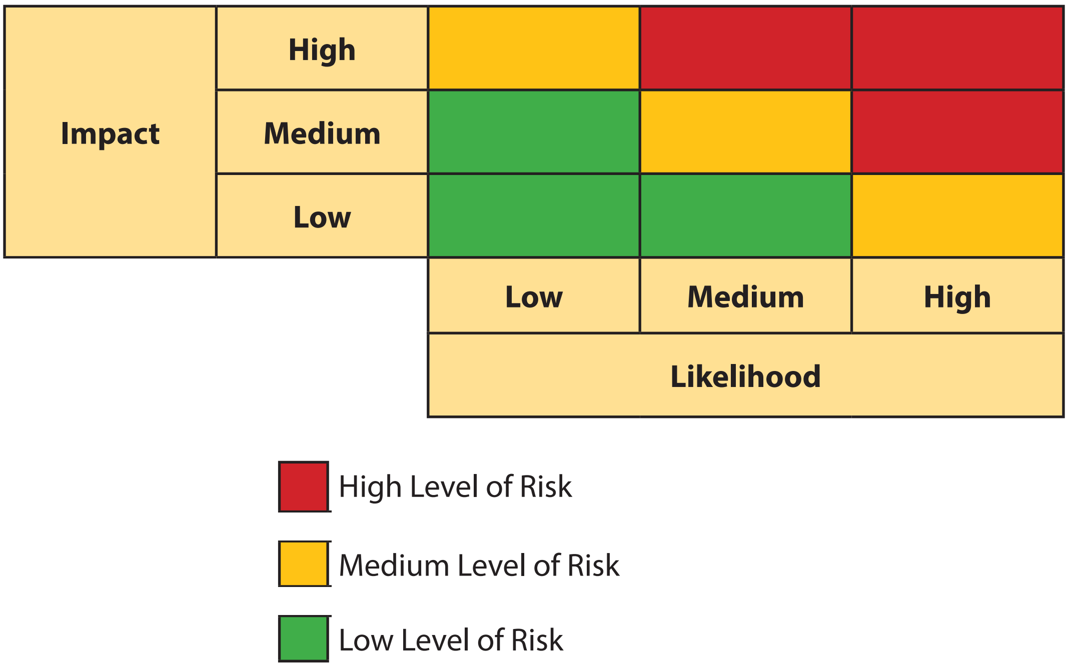

Figure 37 - Risk Matrix

8.4 Availability Objectives

The measurement of 'Availability' provides a quantitative measure of performance or service to the mariner.

'Availability' is a useful indicator of the level of service provided by individual or defined groups of aids to navigation because it is representative of all the considerations, within the control of the Authority, that have gone into providing and maintaining the facility.

These include:

- quality assurance procedures;
- design and systems engineering;
- procurement;
- installation and commissioning;
- maintenance procedures;
- failure response;
- logistics.

To obtain a true representation of Availability, it is necessary to measure the long-term performance of an aid to navigation. To achieve this it is recommended that the calculations should use a time interval greater than 2 years.

8.4.1 Calculation of Availability

The availability of an aid to navigation may be calculated using one of the following equations, and is usually expressed as a percentage:

$$Availability = \frac{(MTBF)}{(MTBF + MTTR)} \quad or \quad \frac{Up\ time}{Total\ Time} \quad or \quad \frac{(Total\ time - Down\ Time)}{Total\ Time}$$

8.4.2 Definition and Comments on Terms

Reliability

This is the probability that an aid to navigation or any nominated system or component, when it is available, performs a specified function without failure under given conditions for a specified time.

Availability

This is the probability that an aid to navigation or system is performing its specified function at any randomly chosen time. It is also defined within IMO resolution A.1046(27) for WWRNS as "The system is considered to be available when it provides the required integrity for the given accuracy level". IALA generally uses the term as a historical measure of the percentage of time that an aid to navigation was performing its specified function. The non-availability can be caused by scheduled and/or unscheduled interruptions.

Continuity

This is the probability that an aid to navigation or system will perform its specified function without interruption during a specified time given that it was operational at the beginning of the period.

For example, if a DGPS station is functioning correctly when a vessel is about to make its approach into a port, the continuity factor is the probability that the DGPS service will not be interrupted in the time it takes the vessel to reach its berth. As for GNSS systems, IALA has proposed that the time interval for continuity calculations be based on a 15 minute time frame in accordance with IMO A.1046(27) for WWRNS.

Redundancy
This is the existence of more than one means, identical or otherwise for accomplishing a task or mission.

Integrity
This is the ability to provide users with warnings within a specified time when the system should not be used for navigation. IMO Resolution A.1046(27) for WWRNS, stares that this time to alarm should be within 10 seconds.

Failure
This is the unintentional termination of the ability of a system or part of a system to perform its required function.

Mean Time Between Failures (MTBF)
This is the average time between successive failures of a system or part of a system. It is a measure of reliability. For components, such as lamps, it is usual to determine the MTBF (or life) statistically by testing a representative sample of components to destruction. As for a system such as a DGPS station, the MTBF is determined from the number of failures that have occurred within a given interval. For example; if four failures occur over a two year interval, the MTBF would be 4380 hours (ie. =24*365*2/4).

Mean Time to Repair (MTTR)
This is a measure of an Authority's administrative arrangements, resources and technical capability to rectify a failure. For a small port, the MTTR times might only be several hours. Meanwhile, an Authority with a more distributed network of aids to navigation may have MTTR times equivalent to several days because of the distances and transport mobilisation limitations.

Failure Response Time
This is a sub-set of the MTTR and relates to the time it takes to be notified of a failure, to confirm the details and mobilise personnel to depart for the aid to navigation.

Refer to IALA publications:

- *Recommendation O-130 on Categorisation and Availability Objectives for Short Range Aids to Navigation;*
- *Guideline 1035 on Availability and Reliability of Aids to Navigation.*

8.4.3 IALA Categories for Traditional Aids to Navigation

IALA provides a method to categorise and calculate aids to navigation availabilities for both individual aids to navigation and systems of aids to navigation as shown in *Table 28*. IALA Recommendation O-130 does not consider other aids to navigation considered in the mix of aids to navigation such as radionavigation systems or Vessel traffic Services (VTS). It does provide guidance on suitable and realistic levels of operational performance for competent authorities to adopt.

Category	Objective	Calculation
1	99.8%	Availability Objectives are calculated over a three-year continuous period, unless otherwise specified.
2	99.0%	
3	97.0%	

Table 28 - Availability Objectives by Category

Category 1

An Aid to Navigation (AtoN) or system of AtoN that is considered by the Competent Authority to be of vital navigational significance. For example, lighted aids to navigation and RACONs that are considered essential for marking landfalls, primary routes, channels, waterways or new dangers or the protection of the marine environment.

Category 2

An AtoN or system of AtoN that is considered by the Competent Authority to be of important navigational significance. For example, it may include any lighted aids to navigation and RACONs that mark secondary routes and those used to supplement the marking of primary routes.

Category 3

An AtoN or system of AtoN that is considered by the Competent Authority to be of necessary navigational significance.

The Recommendation also states that the absolute minimum level of availability of an individual aid to navigation should be set at 95%.

8.4.4 Availability and Continuity of Radionavigation Services

The availability objectives for Radionavigation services have been handled somewhat differently from traditional aids to navigation. This reflects the broader policy formulation process that includes IMO Resolution A.1046(27) for a World Wide Radionavigation System and IALA Recommendation R-121.

Refer to IALA publications

- *Recommendation R-121 on the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz*

Recommendation R121 retains the original definition of availability, but adds a statement about "non-availability".

Non-availability is equivalent to "down time" but as proposed includes both scheduled and/or unscheduled interruptions (ie. preventative and corrective maintenance). The revised equation becomes:

$$Availability = \frac{(MTBO)}{(MTBO + MTSR)}$$

MTBO = Mean time between outages; based on a 2 year averaging period (30 days ocean phase)
MTSR = Mean time to service restoration; based on a 2 year averaging period (30 days ocean phase)

8.4.5 Over and Under Achievement Issues

The actual availability achieved by an individual aid to navigation is a reflection of the quality of the logistical processes, the maintenance regime and the skill of personnel involved. There is a cost associated with prescribing a higher level of availability for a system such as an aid to navigation. This is irrespective of whether or not the increased availability is required by the mariner. There is also a cost associated with the maintenance of unreliable systems. The interrelationship is complex, but the objective is to find the minimum cost solution as illustrated in *Figure 38*.

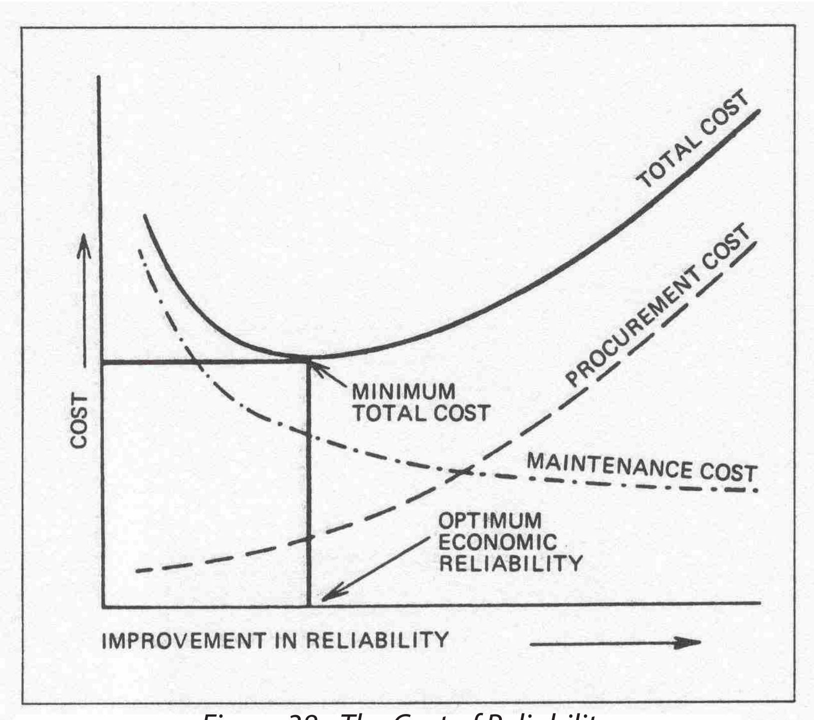

Figure 38 - The Cost of Reliability

Over-Engineering vs. Unreliability

For a lighthouse in a remote location, the cost of time and transport to rectify equipment failures can be very high. From this perspective:

- the one-off cost of over-engineering is generally not as expensive in the long term as the ongoing cost of attending to un-reliable equipment and/or poor system designs;
- a conservative design approach has its merits.

If the aid is not achieving its availability objective, the Authority should ascertain the reasons for this and implement actions that remedy the situation. IALA has recommended that if a facility cannot achieve an availability of 95% (ie. 50 days out per 1000 days) after reasonable endeavours, consideration should be given to withdrawing the facility (as an aid to navigation).

If a single aid within a group is performing above its availability objective, it could be due to either technical or environmental reasons. If the performance difference occurs between sites using similar equipment, and this trend has been established for some time, it may be of benefit to investigate the reasons for the difference.

If a group of aids is found to be over performing for a relatively long period of time, there is an opportunity to review the maintenance practices with a view to determining the reasons, and possibly to consider extending the maintenance intervals or reducing the maintenance effort. This could lead to lower operating costs and issues relating to surplus maintenance capacity.

8.4.6 Continuity

IMO uses a more elaborate definition of Continuity than that given in Section 8.4.2. It states that:

Continuity is the probability that, assuming a fault free receiver, a user will be able to determine position with specified accuracy and is able to monitor the integrity of the determined position over the (short) time interval applicable for a particular operation within a limited part of the coverage area.

This is the same definition of as "mission reliability".

If the service is available at the beginning of the operation, then the probability that it is still available at a time 'T' later is:

$$P = \exp(-t/MTBF)$$

This is the standard expression for reliability and excludes scheduled outages. It uses MTBF and assumes that planned outages will be notified.

The Continuity, or probability that the service will be available after a continuity time interval (CTI), is then:

$$C = exp\ (-CTI/MTBF)$$

If MTBF is much greater than CTI, the equation approximates to:

$$C = 1 - (CTI/MTBF)$$

Where:

MTBF = Mean time between failures based on a 2 year averaging period.

CTI = Continuity Time Interval – in the case of maritime AtoN calculations, is equal to 3 hours.

There is no need to include the availability at the beginning of the time period of the operation because if there is no service, then the operation will not commence.

Example 1: Using the figures in the previous example for a system with a 2 year MTBF, the continuity over a three hour period is 1-(3/17520), or 99.98%

Example 2: Using the figures in the previous example for a system with a 2000 hour MTBF, the continuity over a three hour period is 1-(3/2000), or 99.85%.

8.5 Reviews and Planning

8.5.1 Reviews

In many countries, the network of aids to navigation has been built up over a considerable time, in some cases, centuries. It should be recognised that the nature of shipping is continually changing and this means that the aids to navigation infrastructure should be reviewed periodically. The rate of change varies from place to place, but it would be reasonable to adopt a review process using one of the change management tools that provides:

- a Strategic Plan with a suggested minimum 10 year outlook;
- an Operational Plan with a suggested rolling 5 year work program.

The increasing availability of AIS-derived ship data (type, position, speed, cargo etc.) is proving to be a very useful tool in reviewing the relevance of existing aids to navigation and identifying new requirements. Effective use of AIS data requires a data management strategy and appropriate technology to efficiently store and manipulate very large amounts of data and be able to integrated with other electronic data, for example electronic nautical charts to display shipping patterns.

8.5.2 Strategic Plans

A Strategic Plan is the result of an informed and consultative process that sets the long term goals and objectives for an organization. For a Competent Authority it would include:

- the role of the authority, for example:
  - to promote a high standard of maritime safety;
  - to provide infrastructure and information services to support the safety of navigation in a particular area.
- how the authority will go about discharging its responsibilities, for example:
  - outline of the corporate values of the authority;
  - corporate governance arrangements;
  - funding arrangements;
  - reviews of industry trends;
- an understanding of the users and navigation requirements.

Because of its importance and its effect on the mariners, any strategic plan should be developed as much as possible in full consultation with the mariners and other stakeholders.

8.5.3 Operational Plans

The Operational Plan might cover:

- the implementation of the strategic plan, and may include statements on current policy issues such as:
  - maintenance;
  - current and new technology;
  - the design life of new infrastructure
  - remote monitoring and control;
  - historic lighthouses;
  - environmental culture and safety;
  - the program for aids to navigation reviews;
  - contract services (core and non-core);
  - transport services;
  - sources of revenue;
  - external relationships[39];
  - information, communication and consultation management.
- a list of changes to individual aids to navigation, including any new facilities. The list would reflect:
  - decisions resulting from user and stakeholder consultations;
  - reviews, including those that use:

[39] For example with national, state, territory, and local governmental bodies and international organisations.

    - o risk analysis, risk management procedures (see section 8.3), or;
    - o a level of service process, (see section 3.2), or;
    - o the authority's quality management procedures (see section 8.7)
    - o the authority's technical and maintenance policies etc.
- project schedules that reflect known priorities, such as:
  - government policies;
  - user requirements;
  - available resources;
  - budget (revenue) forecasts and constraints.

8.5.4 Use of Geographic Information Systems in AtoN Planning

The use of Geographic Information Systems (GIS) may assist in effective AtoN planning, including evaluation and validation; ensuring that money is invested wisely in new technology.

Coastal waterways are becoming increasingly congested with vessel traffic and developments such as offshore wind farms, tidal turbines and aquaculture sites, which require to be marked. In addition, light pollution through coastal development, the advent of larger and faster ships and the continued growth in small craft usage means that designing suitable AtoN systems becomes ever more complex. Using GIS, accurate design and provision of AtoN systems as well as suitable simulation can prove very useful and may reduce the chance of costly mistakes being made.

AtoNs are distinctly linked to physical locations and their use by mariners invariably involves the use of more than one AtoN at a time, that is, AtoN networks or systems. These single and interdependent linkages between AtoNs and their physical locations mean that GIS technology can provide AtoN authorities with enhancements in many areas of their business, which may ultimately lead to benefits for mariners.

A GIS captures, displays, stores, analyses and manages spatially referenced data. A key feature of GIS is its analytical functionality, which allows a user to interact with spatial data to determine relationships between different types of data and to produce qualitative (diagrammatic/graphical) and quantitative (numeric/tabular) results.

Refer to IALA publications:
- *Recommendation O-138 on the use of Geographic Information Systems (GIS) and Simulation by Aids to Navigation Authorities;*
- *Guideline O-1057 on the use of Geographic Information Systems (GIS) by Aids to Navigation Authorities;*
- *Guideline O-1058 on the use of Simulation as a Tool for Waterway Design and AtoN Planning.*

8.6 Performance Measurement

Performance measurement is a management tool that can be used to measure, analyse and monitor the performance of a network of aids to navigation and/or specific systems and equipment. The information obtained can be used to:

- show accountability to government and stake holders;
- demonstrate the efficiency and effectiveness of the service being provided;
- monitor and improve occupational health and safety performance;
- compare the performance of:
  - similar systems or equipment in different locations;
  - contract and internally provided services[40];
- amend:
  - system designs;
  - procurement decisions;
  - equipment choices;
  - maintenance procedures and practices;
- increase or reduce maintenance effort;
- adjust maintenance intervals.

8.7 Quality Management

Quality Management Systems have been developed and introduced by numerous businesses, but increasingly are being based on the ISO9000 series of standards. These standards provide a broadly accepted framework for implementing a quality management system.

A generic quality management system is process focused and defines procedures for how things are to be done and what resources are necessary. It addresses:

- who does what?
- what skills and qualifications are necessary?
- what processes have to be followed to get consistent outcomes?
- what resources are necessary to do the work efficiently?

The equipment in aids to navigation systems can be divided into two aspects: the specific AtoN aspect, and the more generic aspect. Each aspect must comply with applicable standards and regulations.

IALA Recommendations and Guidelines provide a basis for the AtoN specific aspect, while international, national or regional regulations apply to the more generic aspects.

[40] Only where the opportunity arises and where both are engaged in substantially similar work.

Refer to IALA publications:
- *Recommendation O-132 on Quality Management for Aids to Navigation Authorities;*
- *Guideline 1034 on product certification procedures;*
- *Guideline 1052 on Quality Management in Aids to Navigation Service Delivery,*

8.7.1 International Standards

ISO 9000 Series
The 1994 quality standard series of ISO 9001, 9002 and 9003 have been jointly revised and amalgamated into ISO 9001-2000.

The new series of standards designated as ISO 9000 comprises:

- ISO 9000 Quality management systems - Fundamentals and vocabulary.
- ISO 9001 Quality management systems - Requirements.
- ISO 9004 Quality management systems - Guidance for Performance Improvement.

ISO 9001 - 2008
ISO 9001 specifies requirements for a quality management system that can be used for internal application by organizations, or for certification, or for contractual purposes. It focuses on the effectiveness of the quality management system in meeting customer requirements. See *Figure 38*.

ISO 9004 - 2009
ISO 9004 gives guidance on a wider range of objectives of a quality management system than does ISO 9001, particularly for the continual improvement of an organization's overall performance and efficiency, as well as its effectiveness. ISO 9004 is recommended as a guide for organizations whose top management wishes to move beyond the requirements of ISO 9001, in pursuit of continual improvement of performance. However, it is not intended for certification or for contractual purposes.

SO 14000
This is a collection of voluntary consensus standards that have been developed to assist organizations to achieve environmental and economic gains through the implementation of effective environmental management systems.

There are three standards that deal with Environmental Management Systems (EMS). These are ISO 14001, 14002 and 14004. ISO 14001 is the only standard intended for third party accreditation. The other standards are for guidance.

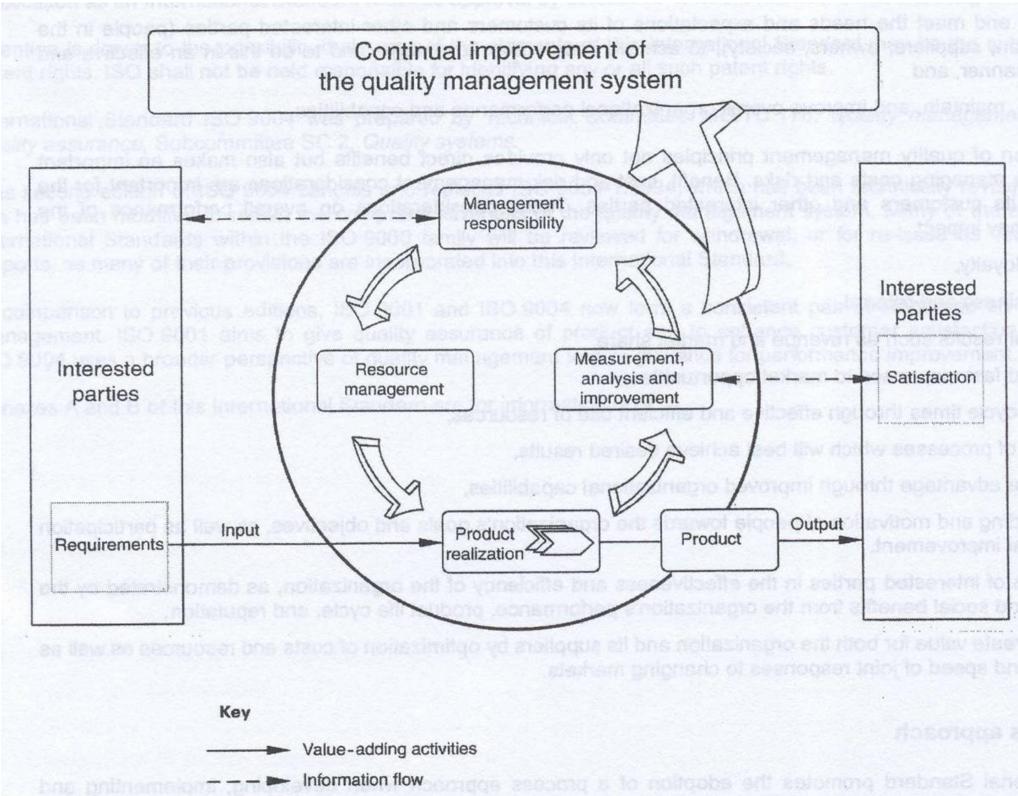

Figure 39 - ISO 9001 Diagram on the Emphasis on Satisfying Customer Requirements

ISO 14001

ISO 14001 specifies the requirements for an environmental management system, to enable an organization to:

- formulate a policy and objectives taking into account legislative requirements and information about significant environmental impacts;
- apply the requirements to those environmental aspects that the organization can control and over which it can be expected to have an influence;
- demonstrate to itself, and to other interested parties, conformance with its stated environmental policy;
- seek certification/registration of its environmental management system by an external organization;
- manage and measure a program of continual improvement.

ISO 14001 does not itself state specific environmental performance criteria.

Refer to IALA publications:

- *Guideline 1077 on Maintenance of Aids to Navigation;*
- *Guideline 1052 on Quality Management in Aids to Navigation Service Delivery;*
- *Guideline 1076 on Building Conditioning of Lighthouses.*

8.8 Maintenance

8.8.1 Guiding Principles for Maintenance

Maintenance is required to ensure that AtoN equipment and systems continue to perform at the levels required by mariners to safely navigate the world's waterways. A maintenance system should be adopted to ensure that AtoN assets deliver the desired performance while minimizing Total Ownership Cost. This performance is normally defined as the level of availability required. Depending on the criticality or category of the AtoN, the same AtoN type might require different maintenance approaches to deliver the required availability outcome in a given location. The following guiding principles may assist Authorities in developing their overall AtoN maintenance strategy.

Minimise the Cost of Ownership

AtoN service providers are accountable to their stakeholders for the provision of a reliable AtoN network that meets international standards for a reasonable cost. Maintenance strategies adopted by authorities should be seeking to reduce the total cost of ownership of their AtoN.

Design for Maintenance

The majority of maintenance costs are determined by the design of the equipment itself. Maintenance costs are the most significant component of the total ownership cost of the equipment or system. Therefore, it is crucial to account for long-term maintenance and logistics support early on in the design process. The goal should be to reduce the need for maintenance, extend the time interval for required maintenance, enable maintenance upon the evidence of need (condition-based maintenance), facilitate the maintenance task by the servicing personnel, and reduce the "logistics footprint" required for maintenance and support. All of these factors will contribute to reducing the total ownership cost over the entire life cycle of the equipment or system.

8.8.2 Improving Efficiency

Authorities have been able to achieve significant cost savings by a number of means.

Automation

Automation can reduce the work load for lightkeepers or allow for de-staffing, which reduces:

- staff costs (payroll);
- power consumption;
- the frequency of stores replenishment;
- commitments on infrastructure such as houses or accommodation facilities, water and fuel storage and in some cases jetties and cargo handling equipment;
- the requirements for station vehicles and equipment.

Equipment

It may be possible to use more reliable equipment, better system designs, with "fail safe" or "fail bystages" features coupled with:

- longer intervals between maintenance visits;
- a review of maintenance management procedures.

In addition, it may be possible to use standardised equipment to simplify spare part management. This could also:

- benefit the purchasing power of the organisation;
- reduce the range of skills required by maintenance staff;
- give more flexibility in the choice of basic qualification when recruiting maintenance staff;
- provide more opportunity to understand the inherent deficiencies in particular pieces of equipment and for remedial actions to be implemented.

Power

The conversion of aids to navigation that operate on oil, gas or primary battery to solar power or self-powered LED lanterns, may provide greater flexibility in scheduling maintenance visits because of the renewable energy source and opportunities for extending maintenance intervals.

Fixed vs Floating

Depending on location, it may be possible to replace floating aids with fixed structures in waterways of moderate depth; particularly if it also allows a dedicated buoy tender to be replaced by some other means of transport such as smaller vessel or launch. A whole-of-life cost benefit analysis should be carried out to assist in any such decisions.

Materials

By introducing low maintenance materials such as high density polyethylene, GRP, stainless steel, etcit may be possible to reduce maintenance requirements and time on site. This may also decrease thenumber of ship-day requirements and reduce the need for construction (or structural maintenance) skills.

Remote Monitoring

Remote monitoring (and control) of distant or isolated aids to navigation can save on the cost of responding to what is later found to be a false outage report. It can also allow for analysis of aids tonavigation systems using risk analysis / risk management techniques that may produce cost savings from a rearrangement and or reduction of the aids to navigation within a nominated area.

8.8.3 Trends

IALA Conference papers, IALA Bulletin articles and feedback from IALA Members demonstrate an increasing trend in the extension of maintenance intervals for aids to navigation sites. The ongoing striving for greater efficiency in the delivery of aids to navigation reflected in measures such as the automation and destaffing of major lighthouses has seen alteration of the maintenance intervals from a daily activity to significantly less frequent regimes.

The optimal maintenance interval for aids to navigation is determined from a consideration of national priorities and the Authority's administrative, technical and environmental constraints. Where cost efficiency and effectiveness is the driving issue, Authorities are:

- using automation, alternative structural materials, more durable coatings and renewable power supplies to contain or reduce costs;
- addressing the potential for new technology to:
  - reduce acquisition and operating costs;
  - extend maintenance intervals;
- reviewing transport service options.

Extension of maintenance intervals at sites exposed to more extreme weather conditions may result in more extensive maintenance works at each visit which may offset some of the cost savings achieved through extension of service intervals.

Refer to IALA publications:
- *Guideline 1007 on Lighthouse Maintenance;*
- *Guideline 1052 on Quality Management in Aids to Navigation Service Delivery.*

8.8.4 Maintenance Intervals

The maintenance intervals for aids to navigation vary from daily in the case of a manned lighthouse to perhaps five years for a light buoy. It is difficult to establish a clear view of typical maintenance intervals other than what is stated in conference and workshop papers. Some examples include:

- major facilities are being inspected on a monthly basis;
- automated lights are being inspected less frequently (quarterly, annually or bi-annually).

Advances in self-contained beacons, lamps, self-powered LED lanterns, solar power supplies and remote monitoring make it relatively easy for a well-designed system on a fixed structure to achieve annual or biannual servicing intervals. Systems that can be maintained in multiples of a year can be set up to take advantage of the times of the year that minimise the weather risk on work schedules and disturbance to flora and fauna.

However, a balance has to be found since longer maintenance intervals affect the authority's knowledge of storm damage, general deterioration to aids to navigation, and control over vegetation growth that could increase the risk of obscuration and fire damage etc. There may also be a detrimental effect on the detailed level of knowledge held by maintenance personnel.

8.9 Service Delivery

Authorities with the responsibility for the provision of aids to navigation are generally at a state or national level. They are usually the sole national regulator of marine aids to navigation infrastructure and services, but are not necessarily the sole provider of these services. In some countries there is a division of responsibility between the authority representing the national government and other organisations that include:

- state and territorial authorities;
- local government organisations;
- port, harbour or waterway authorities;
- local private organisations.

Photo Courtesy of CETMEF (France)

8.9.1 Service Delivery Requirements

Where more than one local authority provides aids to navigation services, the Contracting Government has ultimate responsibility for obligations under the SOLAS Convention.

SOLAS Chapter V, Regulation 13 - Establishment and operation of aids to navigation states:

1. *Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.*
2. *In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing such aids.*
3. *Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.*

8.9.2 Contracting Out

In many parts of the world governments have been selling off government business activities to the private sector. The motivation or occasion for this varies, but includes:

- adding flexibility to how work is carried out;
- breaking down entrenched work practices that are perceived to be inefficient (if this process cannot be done in continuous improvement by the own personnel);
- accessing a wider range of skills and resources on demand;
- recognition that as aids to navigation become more reliable and maintenance intervals are increased, it becomes more difficult to:
  - justify having permanently staffed maintenance depots;
  - maintain the currency of work skills;
  - using on-call contractors in regional locations to improve fault rectification times through reducing the travelling time to the aid.

The key elements to success when contracting out are:

- to define the task for the contractor and the relevant level of service;
- to monitor the performance of the contractor
- to retain sufficient skills within the Authority to understand the functional requirements of the aids to navigation network. This includes:
  - good contract management skills to handle the day-to-day operational issues;
  - personnel to engage in user consultation and forward planning;
  - the knowledge to act as an "informed purchaser" of services;
- to retain control of intellectual property such as:
  - original drawings;
  - documentation covering the design and configuration of individual aids to navigation;
  - a register of assets and spares;
  - a set of key performance indicators to measure the performance of the contractor.

Refer to IALA publication:
- *Guideline 1005 on Contracting Out Aids to Navigation Services.*

8.10 Environment

Aids to navigation play a critical role in protecting the environment by preventing maritime disasters that could have potentially catastrophic ecological consequences at sea and on shore. However, the aids to navigation equipment and activities themselves can create significant environmental damage through pollution, waste generation, and the disruption of ecosystems. It is essential to minimize these negative impacts so that the benefits of aids to navigation are not outweighed by unintended harm to the environment, and to eliminate the potential for pollution and waste of the Earth's limited resources.

Refer to IALA publication:
- *Guideline 1036 on Environmental Considerations in Aids to Navigation Engineering.*

8.10.1 Hazardous Materials

Mercury

A number of historic lighthouses still utilise rotating glass lenses and mercury float pedestals. This was a clever method for providing a heavy lens with an almost frictionless bearing so that it could be turned by a clockwork mechanism. However, given the toxic and corrosive properties of mercury, the following information may assist Competent Authorities to implement appropriate safety procedures.

The mercury float pedestal for a first-order rotating lens[41]contains about 13 litres of mercury. Quantities of mercury may also be found in the electrical slip-ring units in rotating lamp array lighting equipment, some tilt-action switches, high current contact breakers, manometers and thermometers.

Physical Properties

Mercury is a heavy metal that has the unusual property of remaining liquid at normal temperatures (above – 38 degrees celcius).

Spill Risk

The mercury in a lighthouse optic system does not present a significant hazard, unless personnel come into contact with "uncontained" mercury as a result of accidental spills. Such events are usually the result of a mishap during maintenance work, or as a result of a natural disaster such as an earth tremor that displaces mercury from its containment bath.

[41] The quantity of mercury used in higher order optics is shown in Section 8.11.1.

If spilt, the mercury can enter cracks in floors, and is readily absorbed into porous surfaces such as concrete, masonry and timber. When broken into small globules or droplets, the surface area and vaporisation rate rises rapidly. Minute droplets will adhere readily to dust and can form particles that can be inhaled.

Mercury is a corrosive substance if it comes into contact with metals such as zinc and aluminium.

Occupational Hazard

The occupational hazard associated with mercury relates to:

Vapour Inhalation: Some vaporization from a free mercury surface will occur at normal room temperature and this is the most likely first contact that lighthouse personnel will have with mercury. Unless the mercury vapour levels have been measured, personnel are unlikely to be aware of the hazard. If the work-space around lighthouse equipment containing mercury is not well ventilated, the concentration levels can rise above recommended limits and there is potential for mercury poisoning. <ercury vapour is heavier than air and in still air will tend to concentrate in low parts of the work-space. Well designed ventilation will allow such concentrations to disperse.

Ingestion: This can lead to acute mercurial poisoning.

Skin Absorption: Mercury is not easily absorbed through the skin.

Precautions

It is essential for the Authority to have detailed and strictly managed working procedures for all personnel working with, or in close proximity to mercury.

Staff must be trained in these work procedures and regularly medically monitored to ensure that they do not become contaminated with mercury.

The working procedures must follow national health and safety regulations and should be written by an expert in this field.

For work on optics the procedure will cover emptying, cleaning and re-filling the optic bath. Clean-up procedures will detail methods to recover all visible particles of mercury and the use of chemicals to neutralise smaller spills.

Personal protective equipment must be supplied that is specifically designed for use with mercury. This will include overalls, gloves, overshoes, respirator and eye protection. Procedures for the safe storage and disposal of this equipment must be in place.

A mercury vapour meter must be available to monitor the working environment and procedures in place for regular testing and calibration.

Consignment

Mercury is a hazardous substance and the relevant national and international regulations must be followed with regard to the type of container to be used, the packaging of this container for transport and the marking of this packaging.

Both IMO and the International Air Transport Association (IATA) have regulations covering the transportation of mercury.

Paints

Aids to Navigation authorities use a significant quantity and variety of paints and related surfacing materials. There is potential for hazardous situations to arise and for environmental pollution. For example:

- storage of inflammable paints and solvents;
- during surface preparation and removal of paint prior to repainting;
- contact with vapours and solvents during application;
- clean-up and waste disposal.

Lead

Lead based paints have been widely used in the past, but are now restricted or prohibited in some countries. Authorities maintaining older lighthouses are likely to be faced, at some stage, with having to remove lead based paint and disposing of the waste.

Members are encouraged to assess the risks and to adopt appropriate measures to safeguard maintenance personnel and the environment.

Antifouling Coatings

Antifouling paints contain biocides and are applied to vessels and floating aids to navigation to reduce the accumulation of marine organisms. For service vessels the antifouling paint assists to minimise fuel consumption.

On buoys and lightvessels the build-up of marine growth is not particularly detrimental. In view of the concentration of these types of aids to navigation in port approaches and internal waterways, less toxic paint systems may be preferred to minimise environmental pollution.

A particular group of antifouling paints using Tributyltin (TBT) has been banned from use. For further information, consult the International Convention on the Control of Harmful Antifouling Systems on Ships, published by the International Maritime Organization (IMO).

8.11 Preservation of Historic Aids to Navigation

The IALA Advisory Panel on the Preservation of Lighthouses, Aids to Navigation, and Related Equipment of Historic Interest (PHL) was established by the IALA Council in 1996 in response to membership interest in the heritage value of lighthouses. In 2002, this Panel became part of the IALA Committee on Engineering, Environment, and Preservation (EEP). Objectives are to:

- promote a greater commitment by members to preserve the historic aspects of their service;
- encourage member countries to see the preservation of their own lighthouses in an international context;
- share information on the subject between both members and non-members, with particular attention being given to the complementary use of lighthouses;
- research and document strategies on the conservation of historic lighthouses, particularly in relation to changes in technology and working practices;
- foster member interaction with related industries in an effort to bring forward common projects in the interest of protecting historic lighthouses.

Examples of work accomplished to date:

- the creation of the format for an IALA database for recording details of historic lighthouses;
- a book, titled "Lighthouses of the World" was published in 1998 with English, French, German and Spanish versions, featuring over 180 historic lighthouses from around the world;
- a Workshop in Kristiansand, Norway on "The Alternative Use of Historic Lighthouses in 2000;
- a Seminar on the "Practical Aspects of Lighthouse Preservation" in 2005 in Gothenburg, Sweden;
- the IALA Conservation Manual was published in 2006 to provide guidance to members on many aspects of Historic Lighthouses Conservation;
- a Seminar on the "Heritage Issues of Introducing New Technologies in Aids to Navigation" in Santander, Spain in 2009. Some key conclusions and recommendations of the seminar were:
  - Change is inevitable. Ideally, changes made during the development of a historical aid to navigation site should be reversible and in all cases properly documented;
  - The preservation and documentation of aids to navigation should focus on whole sites and include historical developments and achievements in technical equipment and related human experiences. Documentation should include the experiences and recollections of those involved in operating aids to navigation, as well as those involved in their conservation.
  - Radionavigation aids were an important part of aids to navigation technology in the 20th century and there is a need to document and disseminate this aspect of aids to navigation heritage.
- a Seminar on the "Preservation of Lighthouse Heritage" in Athens, Greece in 2013 gathering high level professionals from different areas related to the Cultural Heritage.

8 PROVISION, DESIGN AND MANAGEMENT

One of the eighteen recommendations from the 17th IALA Conference held in Capetown, South Africa in March 2010, stating that "IALA should continue to provide guidance on the preservation and maintenance of historic equipment and artefacts"confirms that the work of IALA on guidelines and the exchange of information relating to the Conservation of Historic Lighthouses is still considered important by its members.

Restoring a Heritage Lighthouse -
Photo Courtesy of Instituto Hidrografico (Portugal)

Lighthouse Interpretative Display -
Photo Courtesy of IALA

Refer to IALA publications:

- *Lighthouse Conservation Manual;*
- *Guideline 1049 on the Use of Modern Light Sources in Traditional Lighthouse Optics;*
- *Guideline 1063 on Agreements for Complementary Use of Lighthouse Property;*
- *Guideline 1074 on Branding and Marketing of Historic Lighthouses;*
- *Guideline 1075 on a Business Plan for Complementary Use of a Historic Lighthouse;*
- *Guideline 1076 on Building Conditioning of Lighthouses;*
- *Guideline 1080 on the Selection and Display of Heritage Artefacts;*
- *Report from the IALA Seminar on Heritage Issues of Introducing New Technologies in Aids to Navigation Santander, Spain in June 2009;*
- *Report from the IALA Seminar on the Preservation of Lighthouse Heritage, Athens, Greece in June 2013.*

8.11.1 Lens Size and Terminology

Information on terminology for historical glass lens systems and the typical amount of mercury held in mercury float pedestals (for rotating lens systems) is provided in *Table 28*.

Description	Focal distance	Typical Quantity of Mercury for Mercury Float Pedestals	
	mm	kilograms	litres
Hyper-radial	1330		
Meso-radial	1125		
First Order	920	175	12.9
Second Order	700	126	9.3
Third Order	500	105	7.7
Small Third Order	375	96	7.0
Fourth Order	250		
Fifth Order	187.5		
Sixth Order	150		

Table 29 - Terminology for Historical Glass Lens Systems and Associated Quantities of Mercury

8.11.2 Third Party Access to Aids To Navigation Sites

In 1998, IALA conducted a survey to investigate the extent to which Authorities were permitting aids to navigation sites to be used for collecting "non-aids to navigation" data. This study was associated with investigations of the Advisory Panel on the Preservation of Historic Lighthouses into alternative uses of lighthouses and other aids to navigation.

The responses came from a wide range of IALA members and shared several common themes:

- predominant applications were for the collection of meteorological data (i.e. weather, wind speed and direction), tidal/ current data and for telecommunication installations;
- data collected for or by other governmental agencies generally did not attract a fee, but fees were often charged for data obtained for commercial purposes;
- data acquisition equipment had to have its own separate power supply unless that aids to navigation site had mains power available.

Where practical the complimentary use of existing structures or accommodation should be considered as an alternative to a new construction with its consequential environmental impact.

IALA acknowledges that Authorities face an increased demand to share aids to navigation sites with "third parties". While it is important to ensure that the integrity and security of aids to navigation are maintained, the presence of a third party may be beneficial:

- in reducing the risk of vandalism;
- as a source of revenue or sharing of operational costs (eg power, road maintenance etc);
- as a means of monitoring the operation of the aid.

If an Authority receives a request for a third party installation, it should first establish whether such involvement is permitted in the Authority's legislation. If there are no impediments, the Authority may consider negotiating an agreement with the potential third party to clearly establish the responsibilities and liabilities of each party. The agreement may also address:

- conditions to apply to the third party installation and operation to ensure that the equipment does not compromise the integrity and security of the aids to navigation and other property owned by the Authority;
- access to electrical power. At sites with mains power, it may be advisable for the Authority to require separate metering of the third party supply so that electricity costs can be recovered;
- if no mains power is available, it is reasonable to require that the third party provide its own power supply;
- where practical, the installation of the third party equipment should take into consideration and preserve the heritage value of the aid to navigation.

Authorities should reserve the right to cancel any third party agreement if continued use jeopardizes the performance or functionality of the aid to navigation.

8.12 Human Resources Challenges

One of the aims of IALA is to foster the safe and efficient movement of vessels through the harmonization of aids to navigation services worldwide. SOLAS (2004 edition) Chapter V, Regulation 13, states that, '*in order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing aids to navigation*'. Recommendations and Guidelines produced by IALA clearly identify the role that IALA has to play in ensuring harmonized delivery of AtoN services.

In addition, Resolution 10 of the Standards of Training & Certification for Watchkeepers (STCW) code states that the contribution of vessel traffic service personnel contributes to the safety of life and property at sea and the protection of the marine environment.

IALA addresses this aim in several ways, one of which is to recommend that Aids to Navigation and VTS Authorities ensure their staff receive a high standard of training. To assist with this approach, IALA Recommendation V-103, together with associated model courses and supporting Guidelines, were developed. This approach provides a means to ensure VTS Personnel are trained to an agreed, minimum, level. In addition, both the ANM and EEP Committees are currently developing the training requirements for AtoN Management and Engineering Personnel through the World Wide Academy (WWA).

8.12.1 Source of Skills

Competent Authorities should ensure that all employees have the knowledge, skills and training to perform their duties effectively, and with safety. The term 'employees' includes newly hired, part time and temporary employees.

The ISO 9001 Quality Management standard places considerable emphasis on competence, awareness and training. (See Section 8.7.1). An overview of the skill development process for aids to navigation work in *Table 30*

Skill	Process
Education	- school - tertiary institution
Experience	- work experience - related work experience
Training	- induction training - on-the-job training - apprenticeships - specific training programs - refresher courses

Table 30 - Skill Development Processes for Aids to Navigation Work

Photo Courtesy of
Australian Maritime Systems Ltd.

Photo Courtesy of
the United States Coast Guard

8.12.2 IALA World Wide Academy

The IALA World Wide Academy (The Academy) is an integral, but independently funded part of IALA. It commenced operations in January 2012.

The IALA World-Wide Academy is the vehicle by which IALA delivers training and capacity building

The Academy is dedicated to assist National Authorities in sustainable development and improvement in the provision of Marine Aids to Navigation, including VTS. While its training activities are intended for the benefit of all IALA Member States, Capacity Building is targeted at key developing States in specified regions. Capacity Building enables National Authorities to meet their States' respective obligations under the UNCLOS and SOLAS conventions, as detailed in recommendations of the International Maritime Organisation (IMO) and IALA.

Thanks to generous sponsorship from a number of agencies and organisations, The Academy is independently funded, but remains an integral division of IALA. Academy activities are achieved with targeted support from the IALA Secretariat. The Academy is governed by a Board of five members under the Chairmanship of its Dean. The IALA Secretary General is a standing Board Member. The three other Board Members are elected for a four year term. The Board reports to the IALA Council which approves its activities set out in a rolling annual Action Plan which forms part of the Master Plan covering the four year period during which Board Members are elected. The current Action and Master Plans are available on The Academy's website – www.iala-academy.com.

The Academy works closely with the IMO and other key Bodies such as the International Hydrographic Organisation (IHO) to develop Capacity Building in a coordinated manner as part of the United Nations "*Delivering as One*" initiative.

"Delivering as One"

World-Wide Academy Aims

- To develop IALA Recommendations and associated model courses on aids to navigation training;
- To establish and manage an accreditation system for organisations delivering VTS and AtoN management training in accordance with IALA Recommendations and associated model training courses; and
- To establish and manage systematic aids to navigation Capacity Building to enable National Authorities to meet their obligations under the UNCLOS and SOLAS Conventions

Academy Deliverables

Both existing and potential Member States are encouraged to contact The Academy for assistance with either training or capacity building.

Training and Accreditation

National (Competent) Authorities work with The Academy to **accredit** official Training Organisations (ATO). ATOs deliver IALA approved model training courses on VTS; AtoN management and specialist AtoN installation, servicing; maintenance and replacement for technicians. Academy training and international accreditation strategy is based primarily on work by IALA Committees with whom a strong liaison is maintained. Based on this liaison The Academy publishes a series of Council-endorsed model courses. The objective of The Academy is not necessarily to conduct training itself, but to develop and promote the use of these model training courses by Member States.

The Academy does deliver some training itself. These are Level 1+ "awareness" seminars; one-week seminars on the IALA Risk Management tool-box and periodic one month Level 1 courses for AtoN Managers.

Vessel Traffic Services Courses		Aids to Navigation Courses	
V-103/1	VTS Operator Training	E-141/1	Level 1 Manager Training
V-103/2	VTS Supervisor Training	E-141/2	Level 1+ Senior Manager Training
V-103/3	VTS On-The-Job Training	IALA WWA.L1/3	Level 1 Risk Management Tool-box
V-103/4	VTS OJT Instructor Training	IALA WWA L2.0	Level 2 Technician Training (30 specialist modules)

Table 31 - Academy Model Courses

Refer to IALA publications:

- *Recommendation V-103 on Standards for Training and Certification of VTS Personnel;*
- *Recommendation E-141 on Standards for Training and Certification of AtoN Personnel.*

Capacity Building

In common with the IHO, The Academy has a Capacity Building strategy based on the "4As" concept.

Stage 1: Raising the Awareness of Executives in Ministries and senior managers of aids to navigation service providers charged by Competent Authorities for such services. This is achieved through targeted "Level 1+" seminars. The intended outcome of such seminars is for some or all Competent Authorities to ask The Academy to conduct a specific or regional assessment on their behalf.

Stage 2: Conduct an Assessment of needs for that State or group of States based on a visit by Academy staff or sponsored experts using tailored Terms of Reference.

Stage 3: Produce an Analysis of requirements, based partly on available AIS data from several sources.

Stage 4: The intended deliverable for the four-stage process is to produce a list of Actions to meet the requirements identified during Stage 3 based on the principle of "SMART" objectives[42].

Region	Target States
East Asia	4
Eastern Atlantic	19
Meso-America and Caribbean	19
North Indian Ocean	10
ROPME (Arabian Gulf) Sea Area Region	4
Southern Africa and Islands	8
South-West Pacific	11

Table 32 - Capacity Building Regions

[42] Targets to be Specific; Measurable; Achievable; Realistic and Timely

A GLOSSARY OF ACRONYMS

A GLOSSARY OF ACRONYMS

AIS	Automatic Identification System
AISM	Association Internationale de Signalisation Maritime (Title of IALA in French)
AtoN	Aid(s) to Navigation
COLREGS	International Regulations for Preventing Collisions at Sea
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigation Chart
EEZ	Exclusive Economic Zone (Defined in UNCLOS)
GALILEO	Global Navigation Satellite System (EU)
GLONASS	Global Navigation Satellite System (Russia) GLOSS Global Sea Level Observing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (USA)
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IHO	International Hydrographic Organisation
IMO	International Maritime Organization
IMPA	International Maritime Pilots' Association
IMSO	International Mobile Satellite Organisation
INMARSAT	International Maritime Satellite Organisation
ISO	International Standards Organisation
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union – Radiocommunications Bureau
LRIT	Long Range Identification and Tracking
MRCP	IALA Maritime Radio Communications Plan
MTBF	Mean time between failures (in hours)
MTTR	Mean time to repair (in hours)
PIANC	The World Association for Waterborne Transport Infrastructure
PSSA	Particularly Sensitive Sea Area
RACON	Radar transponder beacon
RCDS	Raster chart display system
RNC	Raster navigation chart
SAR	Search and Rescue
SBAS	Satellite Based Augmentation System
SOLAS	IMO Convention on the Safety of Life at Sea 1974
SRS	Ship Reporting System
UNCLOS	United Nations Convention on the Law of the Sea
UTC	Universal Time Co-ordinated
VDES	VHF Data Exchange System
VHF	Very High Frequency (radio in the 30-300 MHz band)
VTM	Vessel Traffic Management
VTS	Vessel Traffic Service
VTSO	Vessel Traffic Service Officer
WWA	World Wide Academy

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MARITIME BUOYAGE SYSTEM

and Other Aids to Navigation

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AISM

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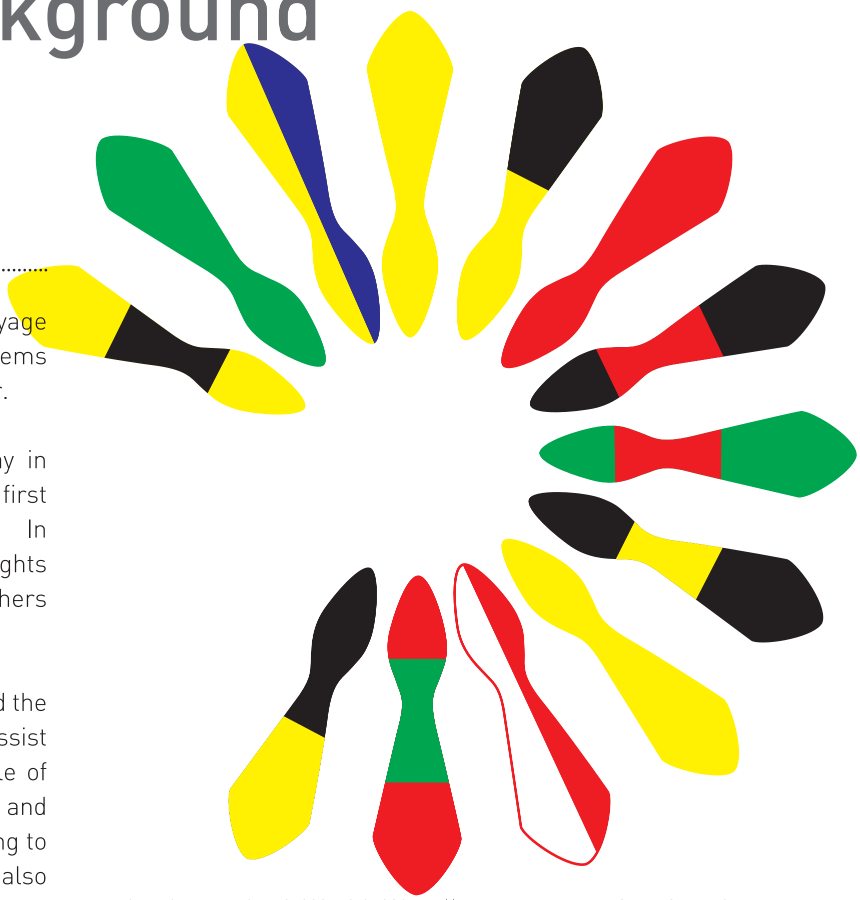
MARITIME BUOYAGE SYSTEM
and Other Aids to Navigation

Historical Background



PRIOR TO 1976

There was once more than thirty different buoyage systems in use world-wide, many of these systems having rules in complete conflict with one another.

There has long been disagreement over the way in which buoy lights should be used since they first appeared towards the end of the 19th century. In particular, some countries favoured using red lights to mark the port hand side of channels and others favoured them for marking the starboard hand.

Another major difference of opinion revolved around the principles to be applied when laying out marks to assist the mariner. Most countries adopted the principle of the Lateral system whereby marks indicate the port and starboard sides of the route to be followed according to some agreed direction. However, several countries also favoured using the principle of Cardinal marks whereby dangers are marked by one or more buoys or beacons laid out in the quadrants of the compass to indicate where the danger lies in relation to the mark, this system being particularly useful in the open sea where the Lateral buoyage direction may not be apparent.

The nearest approach to international agreement on a unified system of buoyage was reached at Geneva in 1936. This Agreement, drawn up under the auspices of the League of Nations, was never ratified due to the outbreak of World War II. The Agreement proposed the use of either Cardinal marks or Lateral marks but separated them into two different systems. It provided for the use of the colour red on port hand marks and largely reserved the colour green for wreck marking.

At the end of World War II many countries found their aids to navigation destroyed and the process of restoration had to be undertaken urgently. In the absence of anything better, the Geneva rules were adopted with or without variation to suit local conditions and the equipment available. This led to wide and sometimes conflicting differences particularly in the crowded waters of North Western Europe.

In 1957 the, then, International Association of Lighthouse Authorities (IALA) was formed in order to support the goals of the technical lighthouse conferences which had been convening since 1929.

Attempts to bring complete unity had little success. Fresh impetus was given to the task of the IALA

Technical Committee, by a series of disastrous wrecks in the Dover Strait area in 1971. These wrecks, situated in one lane of a traffic separation scheme, defied all attempts to mark them in a way that could be readily understood by mariners.

There were three basic issues to address:
i) the need to retain existing equipment as far as possible to avoid undue expense
ii) the need to define how the colours green and red were to be used when marking channels
iii) the need to combine Lateral and Cardinal rules.

To meet the conflicting requirements, it was thought necessary as a first step to formulate two systems, one using the colour red to mark the port hand side of the channels and the other using the colour red to mark the starboard hand side of channels. These were called System A and System B, respectively.

The rules for System A, which included both cardinal and lateral marks, were completed in 1976 and agreed by the International Maritime Organization (IMO). The System was introduced in 1977 and its use has gradually spread throughout Europe, Australia, New Zealand, Africa, the Gulf and some Asian Countries.

FROM 1980

The rules for System B were completed in early 1980. These were considered to be suitable for application in North, Central and South America, Japan, Republic of Korea and Philippines.

The rules for the two Systems were so similar that the IALA Executive Committee was able to combine the two sets of rules into one, known as "The IALA Maritime Buoyage System". This single set of rules allows Lighthouse Authorities the choice of using red to port or red to starboard, on a regional basis; the two regions being known as Region A and Region B.

At a Conference convened by IALA in November 1980 with the assistance of IMO and the International Hydrographic Organization (IHO), Lighthouse Authorities from 50 countries and the representatives of nine International Organisations concerned with aids to navigation met and agreed to adopt the rules of the new combined System. The boundaries of the buoyage regions were also decided and illustrated on a map annexed to the rules. The Conference underlined the need for cooperation between neighbouring countries and with Hydrographic Services in the introduction of the new System.

FROM 2010

Although the maritime buoyage system (MBS) has served the maritime community well since its inception in the 1970s, after the 2006 IALA Conference in Shanghai, China, it was decided to review the system in light of changes in the navigation environment and the further development of electronic aids to navigation.

Worldwide consultation revealed that the fundamental principles of the MBS should be retained. However, due to changes in navigation practices and patterns, as well as innovations and technological developments, some enhancements to the MBS were needed.

Ideally, a unified marking arrangement would, in principle, be desirable for Regions A and B. All IALA Members view this change as impractical, detrimental to safety, and probably unachievable. However, with the aim of improving navigational safety, advances towards a global unified system can be achieved through adoption of common characteristics, such as consistent lighting rhythms, on port and starboard hand marks regardless of region.

The most significant changes in the 2010 revision are the inclusion of aids to navigation used for marking recommended by IALA that are additional to the floating buoyage system previously included. This is aimed at providing a more complete description of aids to navigation that may be used. It includes the Emergency Wreck Marking Buoy, descriptions of other aids to navigation specifically excluded from the original MBS, and the integration of electronic marks via radio transmission. With regards to aids to navigation, the changes provided by this revision will allow the emerging e-Navigation concept to be based upon the marks provided by this booklet.

Thus, the IALA Maritime Buoyage System will continue to help all Mariners, navigating anywhere in the world, to fix their position and avoid dangers without fear of ambiguity, now and for the years to come.

Continuity and harmonization of Aids to Navigation Marking is to be encouraged by all competent maritime authorities.

General principles of the System

The responsibility for safe navigation resides with the mariner, through the appropriate use of aids to navigation in conjunction with official nautical documents and prudent seamanship, including voyage planning as defined in IMO Resolutions. This booklet provides guidance on the Maritime Buoyage System and other aids to navigation for all users.

The IALA Aids to Navigation system has two components: The Maritime Buoyage System and other aids to navigation comprised of fixed and floating devices. This is primarily a physical system, however all of the marks may be complemented by electronic means.

Within the Maritime Buoyage System there are six types of marks, which may be used alone or in combination. The mariner can distinguish between these marks by identifiable characteristics. Lateral marks differ between Buoyage Regions A and B, as described below, whereas the other five types of marks are common to both regions.

These marks are described below:

LATERAL MARKS

Following the sense of a 'conventional direction of buoyage', lateral marks in Region A utilize red and green colours (refer to section 2.4) by day and night to denote the port and starboard sides of channels respectively. However, in Region B (refer to section 2.5) these colours are reversed with red to starboard and green to port.

A modified lateral mark may be used at the point where a channel divides to distinguish the preferred channel, that is to say the primary route or channel that is so designated by the competent authority.

CARDINAL MARKS

Cardinal marks indicate that the deepest water in the area lies to the named side of the mark. This convention is necessary even though for example, a North mark may have navigable water not only to the North but also East and West of it. The mariner will know it is safe to the North, but shall consult the chart for further guidance.

Cardinal marks do not have a distinctive shape but are normally pillar or spar. They are always painted in yellow and black horizontal bands and their distinctive double cone top-marks are always black.

Cardinal Marks (continued)

An aide-memoire to their colouring is provided by regarding the top-marks as pointers to the positions of the black band(s):

- **North:**
  Top-marks pointing upward:
  black band above yellow band;
- **South:**
  Top-marks pointing downward:
  black band below yellow band;
- **East:**
  Top-marks pointing away from each other:
  black bands above and below a yellow band;
- **West:**
  Top-marks pointing towards each other:
  black band with yellow bands above and below.

Cardinal marks also have a special system of flashing white lights. The rhythms are basically all **"very quick"** (VQ) or **"quick"** (Q) flashing but broken into varying lengths of the flashing phase. **"Very quick flashing"** is defined as a light flashing at a rate of either 120 or 100 flashes per minute, **"quick flashing"** is a light flashing at either 60 or 50 flashes per minute.

The characters used for Cardinal marks will be seen to be as follows:

- **North:**
  Continuous very quick flashing or quick flashing;
- **East:**
  Three **"very quick"** or **"quick"** flashes followed by darkness;
- **South:**
  Six **"very quick"** or **"quick"** flashes followed immediately by a long flash, then darkness;
- **West:**
  Nine **"very quick"** or **"quick"** flashes followed by darkness.

The concept of three, six, nine is easily remembered when one associates it with a clock face. The long flash, defined as a light appearance of not less than 2 seconds, is merely a device to ensure that three or nine **"very quick"** or **"quick"** flashes cannot be mistaken for six.

It will be observed that two other marks use white lights; Isolated Danger marks and Safe Water marks. Each has a distinctive light rhythm that cannot be confused with the very quick or quick flashing light of the Cardinal marks.

ISOLATED DANGER MARK

The Isolated Danger mark is placed on, or near to a danger that has navigable water all around it. Because the extent of the danger and the safe passing distance cannot be specified for all circumstances in which this mark may be used, the mariner shall consult the chart and nautical publications for guidance. Distinctive double black spherical top-marks and Group flashing (2) white lights, serve to distinguish Isolated Danger marks from Cardinal marks.

SAFE WATER MARKS

The Safe Water mark has navigable water all around it, but does not mark a danger. Safe Water marks can be used, for example, as fairway, mid-channel or landfall marks.

Safe Water marks have an appearance different from danger marking buoys. They are spherical, or alternatively pillar or spar with red and white vertical stripes and a single red spherical top-mark. Their lights, if any, are white using isophase, occulting, one long flash or Morse **"A"** (• -) rhythms.

SPECIAL MARKS

Special marks are used to indicate a special area or feature whose nature may be apparent from reference to a chart or other nautical publication. They are not generally intended to mark channels or obstructions where the MBS provides suitable alternatives.

Special marks are yellow. They may carry a yellow **"X"** top-mark, and any light used is also yellow. To avoid the possibility of confusion between yellow and white in poor visibility, the yellow lights of Special marks do not have any of the rhythms used for white lights.

Their shape will not conflict with that of navigational marks. This means, for example, that a special buoy located on the port hand side of a channel may be cylindrical but will not be conical. Special marks may be lettered or numbered, and may also include the use of a pictogram to indicate their purpose using the IHO symbology where appropriate.

MARKING NEW DANGERS

"New Dangers" are newly discovered hazards, natural or man-made, that may not yet be shown in nautical documents and publications, and until the information is sufficiently promulgated, should be indicated by:

- marking a new danger using appropriate marks such as; Lateral, Cardinal, Isolated Danger marks, or equally
- using the Emergency Wreck Marking Buoy (EWMB)

If the competent authority considers the risk to navigation to be especially high at least one of the marks should be duplicated.

The Emergency Wreck Marking Buoy has blue and yellow vertical stripes in equal number, with a vertical/perpendicular yellow cross top-mark, and displays a blue and yellow alternating light.

Marking of a new danger may include use of a Racon coded Morse **"D"** (- ••) or other radio transmitting device such as automatic identification systems as an Aid to Navigation (AIS as an AtoN).

Marking of a new danger may be discontinued when the appropriate competent Authority is satisfied that information concerning the **"New Danger"** has been sufficiently promulgated or the danger has been resolved.

OTHER MARKS

Other Marks include lighthouses, beacons, sector lights, leading lines, major floating aids, and auxiliary marks. These visual marks are intended to aid navigation as information to mariners, not necessarily regarding channel limits or obstructions.

- Lighthouses, beacons and other aids of lesser ranges are fixed aids to navigation that may display different colours and/or rhythms over designated arcs. Beacons may also be unlighted.
- Sector lights display different colours and/or rhythms over designated arcs.

  The colour of the light provides directional information to the mariner.
- Leading lines / Ranges allow ships to be guided with precision along a portion of a straight route using the alignment of fixed lights (leading lights) or marks (leading marks), in some cases a single directional light may used.
- Major floating aids include lightvessels, light floats and large navigational buoys intended to mark approaches from off shore.
- Auxiliary Marks are those other marks used to assist navigation or provide information. These include aids of non-lateral significance that are usually of defined channels and otherwise do not indicate the port and starboard sides of the route to be followed as well as those used to convey information for navigational safety.
- Port or Harbour Marks such as breakwater, quay/jetty lights, traffic signals, bridge marking and inland waterways aids to navigation (further described in section 8.7).

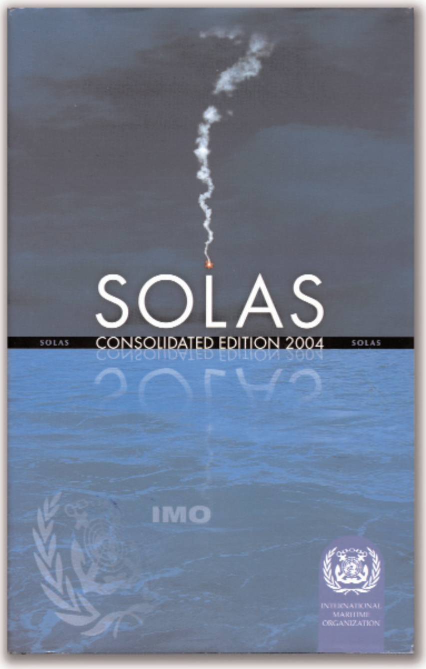
SOLAS CHAPTER V,
Regulation 13 – Consolidated edition 2004

Establishment and operation of aids to navigation

1. Each Contracting Government undertakes to provide, as it deems practical and necessary, either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.

2. In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines* when establishing such aids.

3. Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.



* *Refer to the appropriate Recommendations and guidelines of IALA and to SN/Circ.107, Maritime Buoyage System.*

RULES

1. GENERAL

1.1 Scope

The Maritime Buoyage System and other aids to navigation provide rules that apply to all fixed, floating and electronic marks serving to indicate:

1.1.1 The lateral limits of navigable channels.

1.1.2 Natural dangers and other obstructions such as wrecks.

1.1.3 Landfall, course to steer, and other areas or features of importance to the mariner.

1.1.4 New dangers.

1.2 Types of marks

A Mark is defined as a signal available to the Mariner to convey guidance in safe navigation. The Maritime Buoyage System and other aids to navigation provide the following types of marks that may be used in combination:

1.2.1 Lateral marks, used in conjunction with a **"conventional direction of buoyage"**, generally employed for well defined channels. These marks indicate the port and starboard sides of the route to be followed. Where a channel divides, a modified lateral mark may be used to indicate the preferred route. Lateral marks differ between Buoyage Regions A and B as described in MBS Sections 2 and 8.

1.2.2 Cardinal marks, used in conjunction with the mariner's compass, to indicate where the mariner may find navigable water.

1.2.3 Isolated Danger marks to indicate isolated dangers of limited size that have navigable water all around them.

1.2.4 Safe Water marks to indicate that there is navigable water all around their position, e.g. mid-channel marks.

1.2.5 Special marks to indicate an area or feature referred to in nautical documents, not generally intended to mark channels or obstructions.

1.2.6 Other marks used to provide information to assist navigation.

1.3 Method of characterising marks

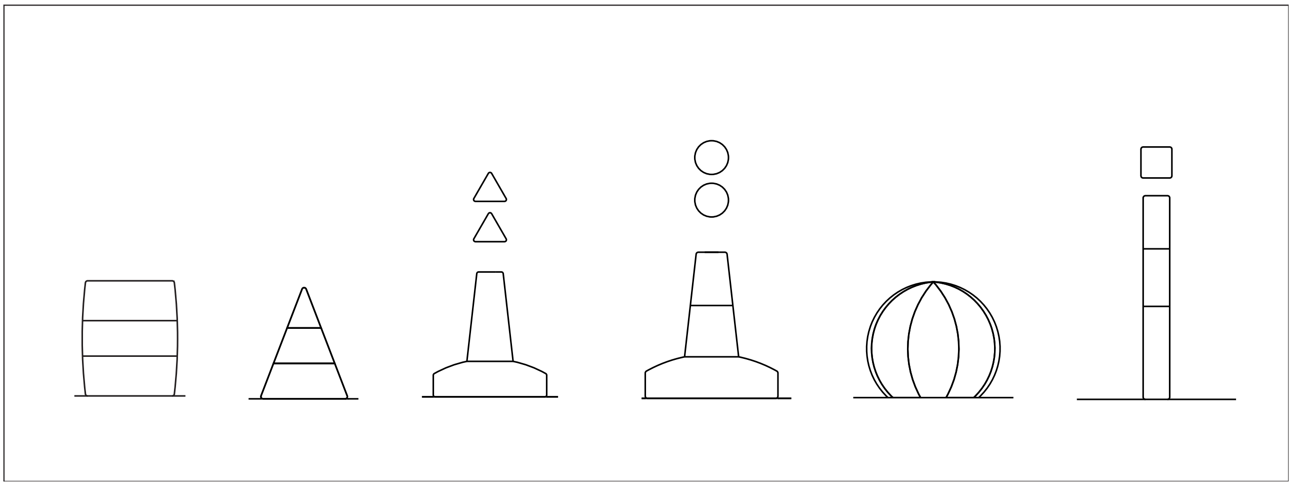
The significance of the mark depends upon one or more of the following features:

1.3.1 By night, colour and rhythm of light and/or illumination enhancement.

1.3.2 By day, colour, shape, top-mark, and/or light (including colour and rhythm).

1.3.3 By electronic (digital) symbology, e.g. as a complement to physical marks.

1.3.4 By electronic (digital) symbology solely.



2. LATERAL MARKS

2.1 Definition of 'conventional direction of buoyage'

The 'conventional direction of buoyage', which must be indicated in appropriate nautical charts and documents, may be either:

2.1.1 The general direction taken by the mariner when approaching a harbour, river, estuary or other waterway from seaward, or

2.1.2 The direction determined by the proper authority in consultation, where appropriate, with neighbouring countries. In principle, it should follow a clockwise direction around land masses.

2.2 Buoyage Regions

2.2.1 There are two international Buoyage Regions A and B, where lateral marks differ. The current geographical divisions of these two Regions are shown on the world map on the centrefold of this booklet.

2.3 General Rules for Lateral Marks

2.3.1 Colour

The colour of lateral marks must comply with the IALA MBS Regions as specified in Sections 2.4 and 2.5.

2.3.2 Shapes

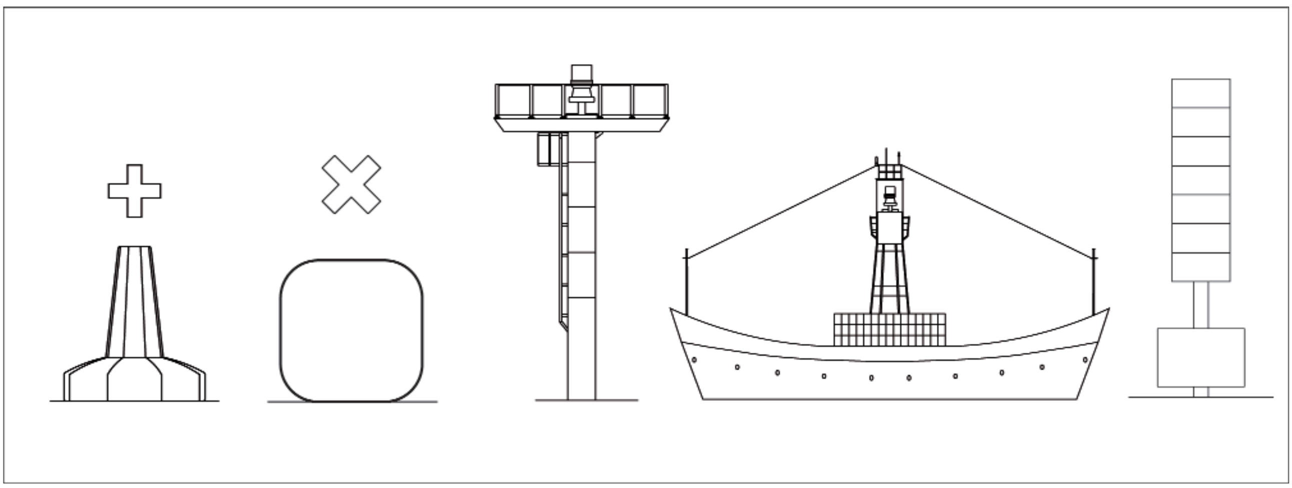
Lateral marks should be of cylindrical and conical shape. However, where they do not rely on a distinctive shape for identification, they should, where practicable, carry the appropriate topmark.

2.3.3 Numbering or lettering

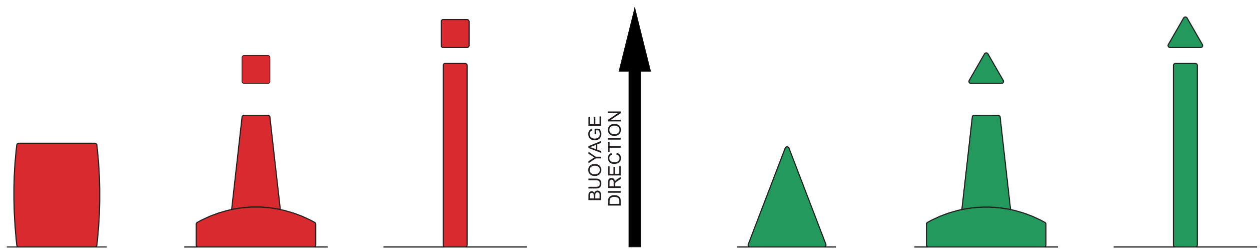
If marks at the sides of a channel are numbered or lettered, the numbering or lettering shall follow the 'conventional direction of buoyage' i.e. numbered from seaward. The protocol for numbering lateral marks, especially in confined waterways, should be 'even numbers on red ~ odd numbers on green'.

2.3.4 Synchronisation

If appropriate, synchronised lights (all flash at the same time) or sequential lights (flash one after another) or a combination of both may be utilized.

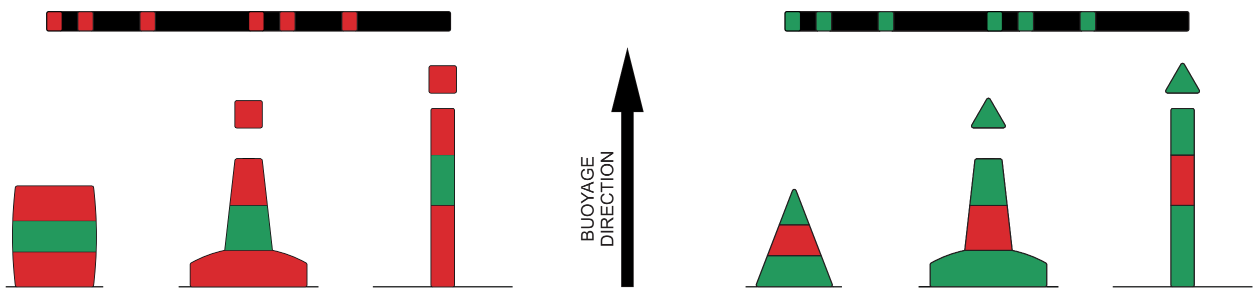


2.4 Description of Lateral Marks used in Region A



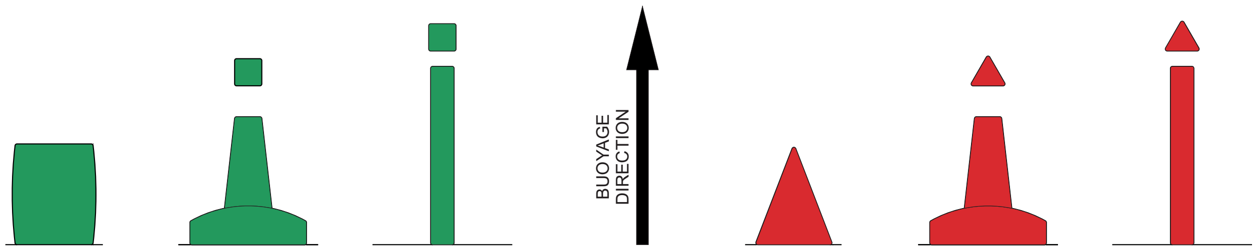
	2.4.1 Port hand Marks	2.4.2 Starboard hand Marks
Colour	Red	Green
Shape of buoy	Cylindrical (can), pillar or spar	Conical, pillar or spar
Topmark (if any)	Single red cylinder (can)	Single green cone, point upward
Light (when fitted)		
Colour	Red	Green
Rhythm	Any, other than that described in section 2.4.3.	Any, other than that described in section 2.4.3.

2.4.3 At the point where a channel divides, when proceeding in the "conventional direction of buoyage," a preferred channel may be indicated by a modified Port or Starboard lateral mark as follows:



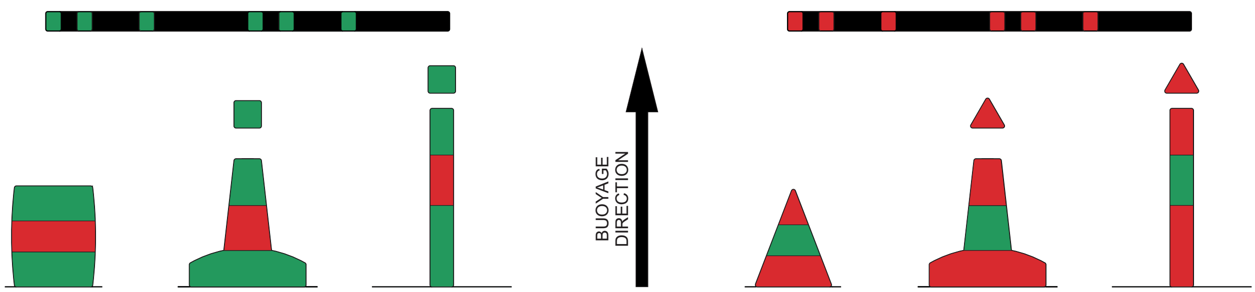
	2.4.3.1 Preferred channel to Starboard	2.4.3.2 Preferred channel to Port
Colour	Red with one broad green horizontal band	Green with one broad red horizontal band
Shape of buoy	Cylindrical (can), pillar or spar	Conical, pillar or spar
Topmark (if any)	Single red cylinder (can)	Single green cone, point upward
Light (when fitted)		
Colour	Red	Green
Rhythm	Composite group flashing (2 + 1)	Composite group flashing (2 + 1)

2.5 Description of Lateral Marks used in Region B



	2.5.1 Port hand Marks	2.5.2 Starboard hand Marks
Colour	Green	Red
Shape of buoy	Cylindrical (can), pillar or spar	Conical, pillar or spar
Topmark (if any)	Single green cylinder (can)	Single red cone, point upward
Light (when fitted)		
Colour	Green	Red
Rhythm	Any, other than that described in section 2.5.3.	Any, other than that described In section 2.5.3.

2.5.3 At the point where a channel divides, when proceeding in the "conventional direction of buoyage," a preferred channel may be indicated by a modified Port or Starboard lateral mark as follows:



	2.5.3.1 Preferred channel to Starboard	2.5.3.2 Preferred channel to Port
Colour	Green with one broad red horizontal band	Red with one broad green horizontal band
Shape of buoy	Cylindrical (can), pillar or spar	Conical, pillar or spar
Topmark (if any)	Single green cylinder (can)	Single red cone, point upward
Light (when fitted)		
Colour	Green	Red
Rhythm	Composite group flashing (2 + 1)	Composite group flashing (2 + 1)

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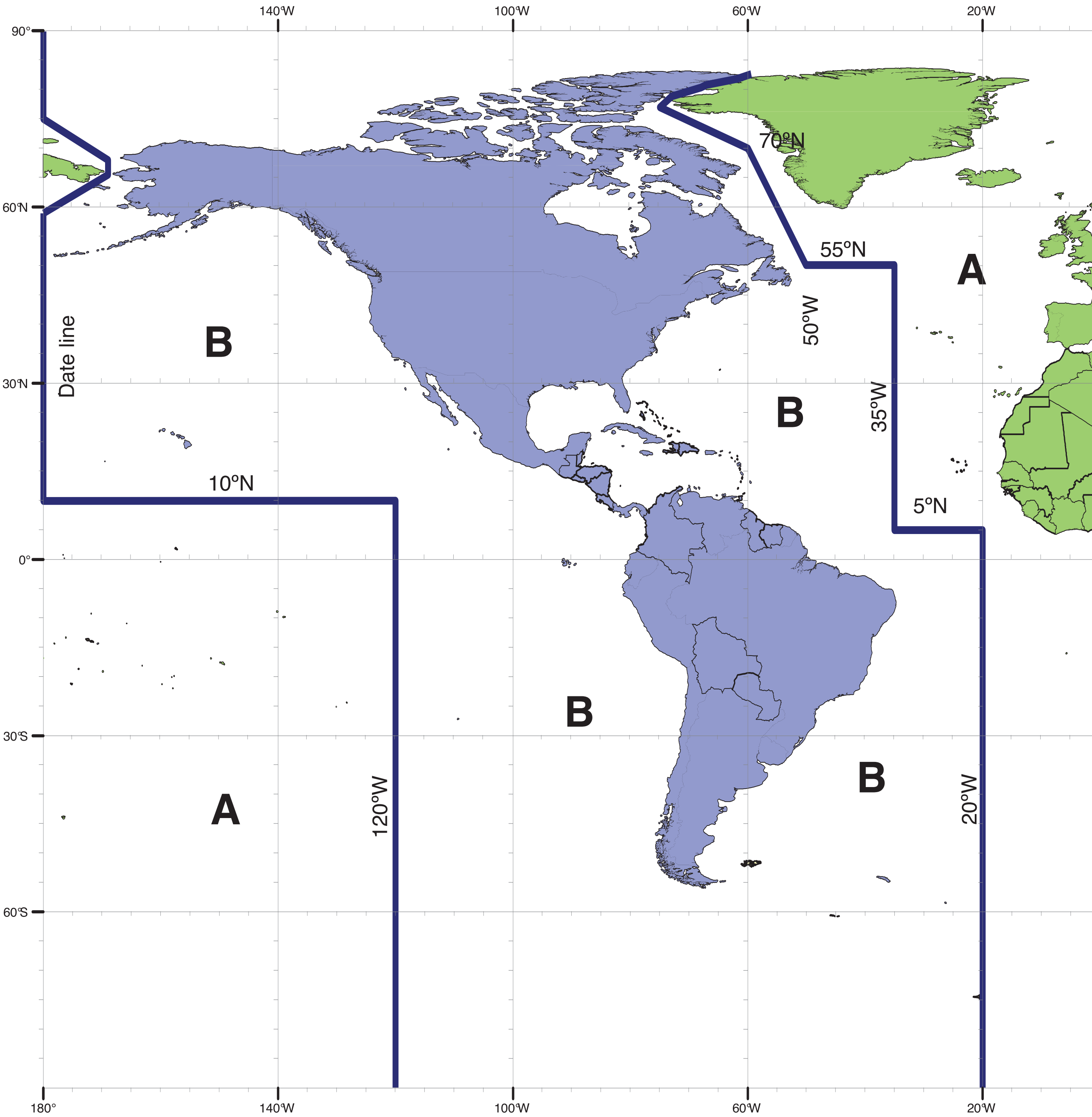
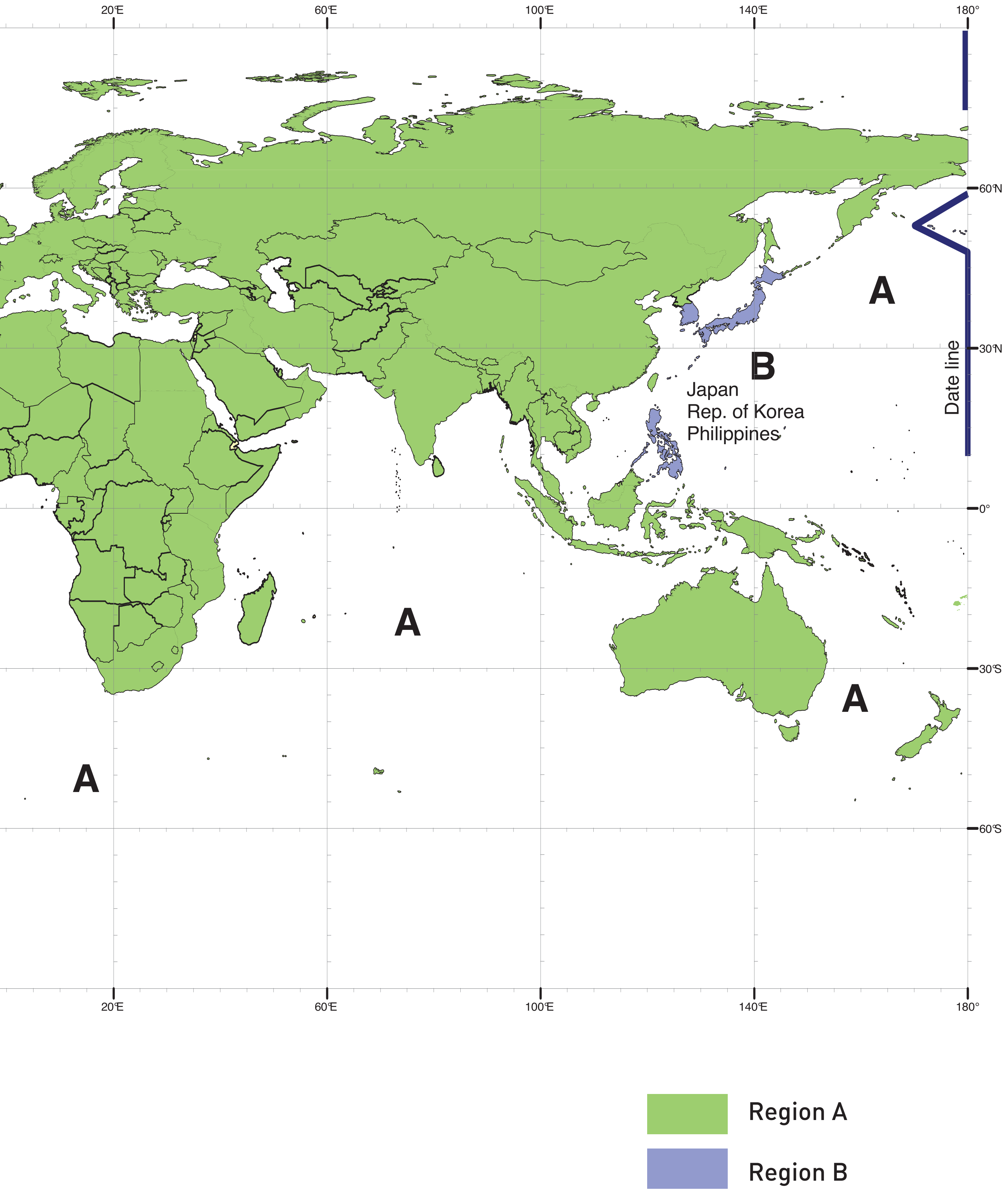


E BUOYAGE SYSTEM

egions A and B



3. CARDINAL MARKS

3.1 Definition of Cardinal quadrants and marks

The four quadrants (North, East, South and West) are bounded by the true bearings NW-NE, NE-SE, SE-SW, and SW-NW, taken from the point of interest.

3.1.1 A Cardinal mark is named after the quadrant in which it is placed

3.1.2 The name of a Cardinal mark indicates that it should be passed to the named side of the mark.

3.1.3 The Cardinal marks in Region A and Region B, and their use, are the same.

3.2 Use of Cardinal Marks

A Cardinal mark may be used, for example:

3.2.1 To indicate that the deepest water in that area is on the named side of the mark.

3.2.2 To indicate the safe side on which to pass a danger.

3.2.3 To draw attention to a feature in a channel such as a bend, a junction, a bifurcation or the end of a shoal.

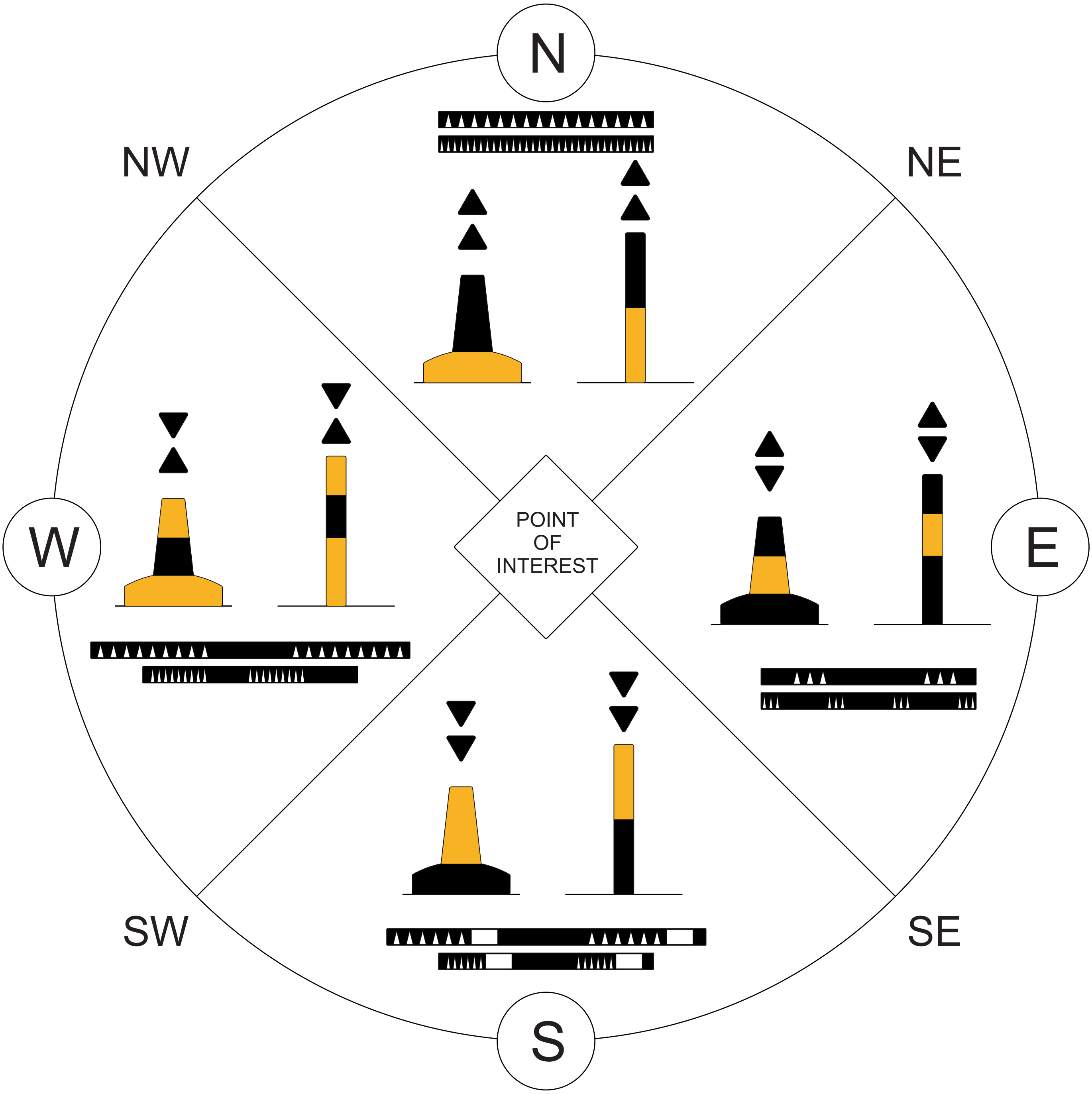
3.2.4 Competent authorities should consider carefully before establishing too many cardinal marks in a waterway or area as this can lead to confusion, given their white lights of similar characteristics.

3.3 Description of Cardinal Marks

	3.3.1 North Cardinal Mark	3.3.2 East Cardinal Mark
Topmark [a]	2 black cones, one above the other, points upward	2 black cones, one above the other, base to base
Colour	Black above yellow	Black with a single broad horizontal yellow band
Shape of buoys	Pillar or spar	Pillar or spar
Light (when fitted)		
Colour	White	White
Rhythm	VQ(3) or Q Long flash every 15s	VQ(3) every 10s or Q(3) every 15s

	3.3.3 South Cardinal Mark	3.3.4 West Cardinal Mark
Topmark [a]	2 black cones, one above the other, points downward	2 black cones, one above the other, point to point
Colour	Yellow above black	Yellow with a single broad horizontal black band
Shape of buoys	Pillar or spar	Pillar or spar
Light (when fitted)		
Colour	White	White
Rhythm	VQ(6) + Long flash every 10s or Q(6) + Long flash every 15s	VQ(9) every 10s or Q(9) every 15s

Note [a] **:** The double cone top-mark is a very important feature of every Cardinal mark by day, and should be used wherever practicable and be as large as possible with a clear separation between the cones.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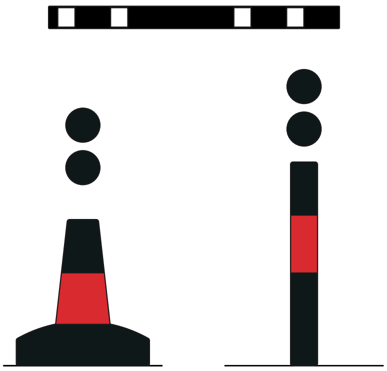
4. ISOLATED DANGER MARKS



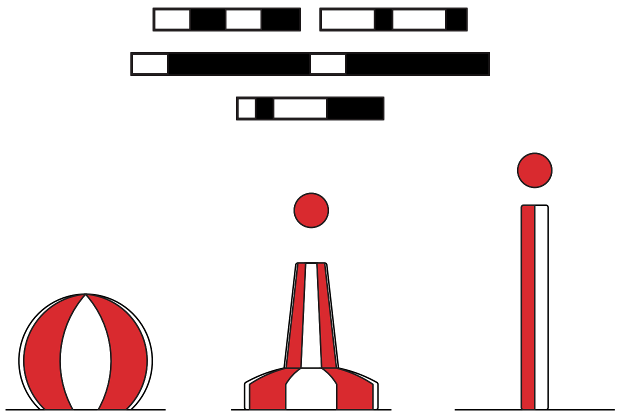
4.1 Definition of Isolated Danger Marks

An isolated Danger mark is a mark erected on, or moored on or above, an isolated danger which has navigable water all around it.

4.2 Description of Isolated Danger Marks

	Description
Top-mark [b]	Two black spheres, one above the other
Colour	Black with one or more broad horizontal red bands
Shape of buoy	Optional, but not conflicting with lateral marks; pillar or spar preferred
Light (when fitted)	
Colour	White
Rhythm	Group flashing (2)

5. SAFE WATER MARKS



5.1 Definition of Safe Water Marks

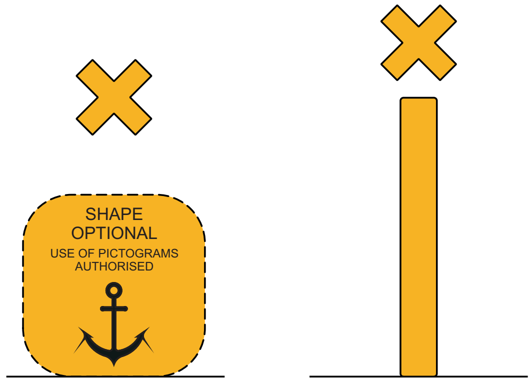
Safe Water marks serve to indicate that there is navigable water all round the mark. These include centre line marks and mid-channel marks. Such a mark may also be used to indicate channel entrance, port or estuary approach, or landfall. The light rhythm may also be used to indicate best point of passage under bridges.

5.2 Description of Safe Water Marks

	Description
Colour	Red and white vertical stripes
Shape of buoy	Spherical; pillar or spar with spherical topmark
Top-mark (if any)	Single red sphere
Light (when fitted)	
Colour	White
Rhythm	Isophase, occulting, one long flash every 10s or Morse "A"

Note [b] **:** The double sphere topmark is a very important feature of every Isolated Danger mark by day, and should be used wherever practicable and be as large as possible with a clear separation between the spheres.

6. SPECIAL MARKS



6.1 Definition of Special Marks

Marks used to indicate a special area or feature whose nature may be apparent from reference to a chart or other nautical publication. They are not generally intended to mark channels or obstructions where other marks are more suitable.

Some examples of uses of Special Marks

6.1.2 Ocean Data Acquisition Systems (ODAS) marks.

6.1.2 Traffic separation marks where use of conventional channel marking may cause confusion.

6.1.3 Spoil Ground marks.

6.1.4 Military exercise zone marks.

6.1.5 Cable or pipeline marks.

6.1.6 Recreation zone marks.

6.1.7 Boundaries of anchorage areas

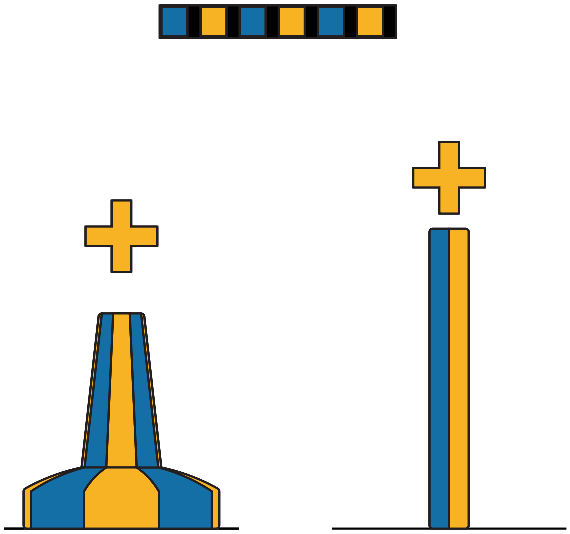
6.1.8 Structures such as offshore renewable energy installations

6.1.9 Aquaculture

6.2 Description of Special Marks

	Description
Colour	Yellow
Shape of buoy	Optional, but not conflicting with lateral marks
Top-mark (if any)	Single yellow "X" shape
Light (when fitted)	
Colour	Yellow
Rhythm	Any, other than those reserved for cardinal, isolated danger and safe water marks.
Pictogram	The use of pictograms is authorized, as defined by a competent authority.

7. MARKING NEW DANGERS



7.1 Definition of New Dangers

The term "New Danger" is used to describe newly discovered hazards not yet shown in nautical documents. 'New Dangers' include naturally occurring obstructions such as sandbanks or rocks or man-made dangers such as wrecks.

7.2 Marking of New Dangers

7.2.1 'New Dangers' should be appropriately marked using Lateral, Cardinal, Isolated Danger marks or by using the Emergency Wreck Marking Buoy. If the Authority considers the risk to navigation to be especially high, at least one of the marks should be duplicated.

7.2.2 If using a Lateral lighted mark for this purpose a VQ or Q light character shall be used.

7.2.3 Any duplicate mark shall be identical to its partner in all respects.

7.2.4 In addition it may be marked by a Racon, coded Morse "D"(- ••)

7.2.5 In addition it may be marked by other electronic means, such as automatic identification system (AIS as an AtoN).

7.2.6 Virtual Aids to Navigation may be deployed solely or in addition to physical Aids to Navigation.

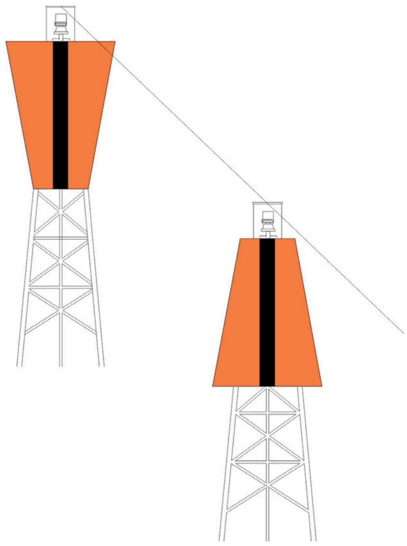
7.2.7 The marking of the new danger may be removed when the competent Authority is satisfied that information concerning the "New Danger" has been sufficiently promulgated or the danger otherwise resolved.

7.3 Description of New Dangers Marks

	Description
Colour	Blue/Yellow vertical stripes in equal number dimensions (minimum 4 stripes and maximum 8)
Shape of buoy	Pillar or spar
Top-mark (if any)	Vertical/perpendicular Yellow cross
Light	
Colour	Yellow/blue alternating
Rhythm	One second of blue light and one second of yellow light with 0.5 sec. of darkness between

8. OTHER MARKS

8.1 Leading Lines/Ranges



8.1.1 Definition of Leading Lines/Ranges

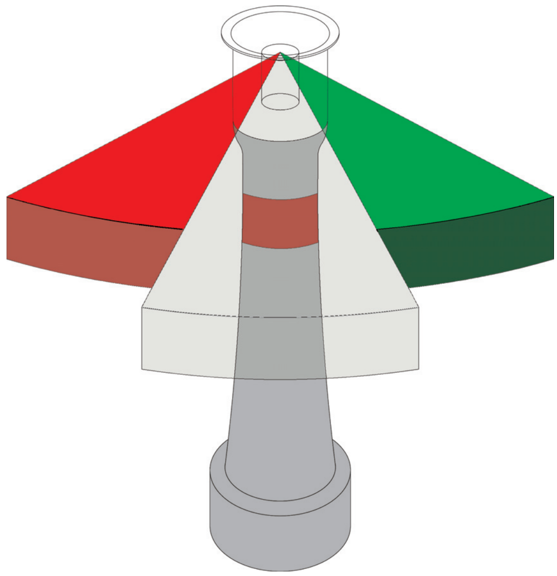
A group of two or more marks or lights, in the same vertical plane such that the navigator can follow the leading line on the same bearing.

8.1.2 Description of Leading Lines

Leading Line structures can be any colour or shape that provides a distinctive mark that cannot be confused with adjacent structures.

Description	
Colour	No colour significance. Competent authority determines the optimum colours to contrast with the dominant background colour at the location
Shape	No shape significance. Rectangular or triangular figures are recommended.
Light (when fitted)	
Colour	Any colour. Competent authority determines the optimum colour to contrast with the dominant back ground colour at the location.
Rhytm	Any, however fixed characteristics should be used sparingly and the use of synchronisation can assist in the overcoming background light.

8.2 Sector Lights



8.2.1 Definition of Sector Lights

A sector light is a fixed aid to navigation that displays a light of different colours and/or rhythms over designated arcs. The colour of the light provides directional information to the mariner.

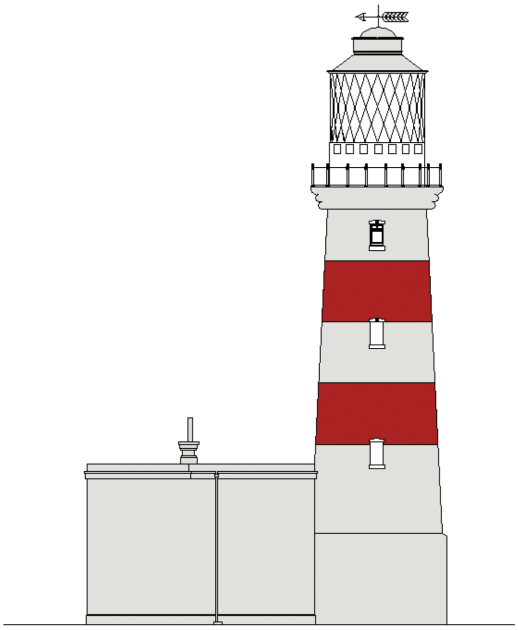
8.2.2 Description of Sector Lights

A sector light may be used:

- To provide directional information in a fairway;
- To indicate a turning point, a junction with other channels, a hazard or other items of navigational importance;
- To provide information on hazard areas that should be avoided;
- In some cases a single directional light may be used.

Description	
Colour	Not applicable
Shape	None, light only
Light	
Colour	If using to mark channel limits follow convention for IALA region indicated in Section 2. Lights may have oscillating boundaries
Rhythm	As appropriate

8.3 Lighthouses



8.3.1 Definition of a Lighthouse

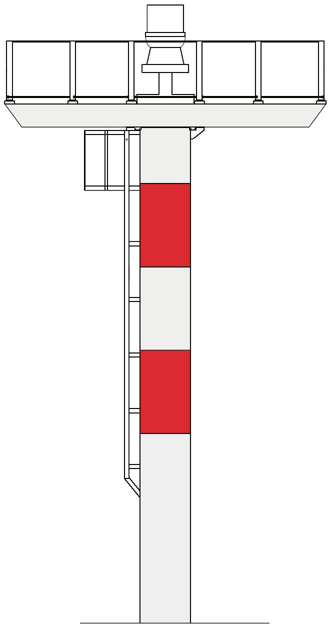
A lighthouse is a tower, or substantial building or structure, erected at a designated geographical location to carry a signal light and provides a significant daymark. It provides a long or medium range light for identification by night.

8.3.2 Description of a Lighthouse

It may provide a platform for other AtoN such as DGNSS, racon or AIS as an Aids to Navigation to assist marine navigation. A lighthouse is a structure that may provide a daymark for identification by day.
A sector light may also be incorporated into the structure.

Description	
Colour/Shape	Lighthouse structures can be of any colour, shape, or material generally designed to provide a distinctive daymark.
Light	
Colour	White, Red, or Green
Rhythm	Any number of flashes, isophase or occulting or as appropriate, to allow light to be readily identifiable.

8.4 Beacons



8.4.1 Definition of a Beacon

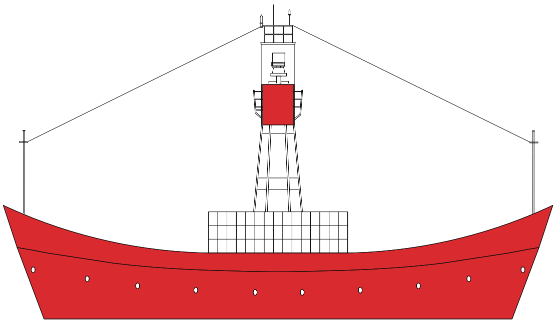
A fixed man-made navigation mark that can be recognised by its shape, colour, pattern, topmark, or light character, or a combination of these.

8.4.2 Description of a Beacon

- Can carry a signal light and in this case is termed a light beacon or lighted beacon;
- If not fitted with a light it is termed an unlighted or unlit beacon and provides only a day mark;
- As a leading line/range or conspicuous radar mark;
- It may also carry a topmark.

Description	
Colour	Any
Shape	As appropriate, including cardinal mark
Topmark (if any)	As appropriate
Light (when fitted)	
Colour	White, Red, or Green
Rhythm	As appropriate

8.5 Major Floating Aids



8.5.1 Definition of Major Floating Aids

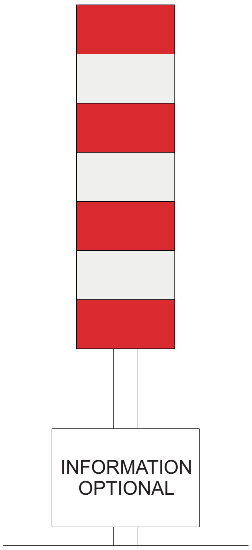
Major floating aids include lightvessels, light floats and large navigational buoys.

8.5.2 Description of Major Floating Aids

Major floating aids are generally deployed at critical locations, intended to mark approaches from offshore areas, where shipping traffic concentrations are high. It may provide a platform for other Aids to Navigation such as, racon or AIS as an Aids to Navigation to assist marine navigation.

Description	
Colour	As appropriate - predominantly red
Shape	Vessel or buoy shape with light tower
Light (when fitted) including off station lights	
Colour	As appropriate
Rhythm	As appropriate

8.6 Auxiliary Marks



8.6.1 Definition of Auxiliary Marks

Minor aids that have not been previously described.

8.6.2 Description of Auxiliary Marks

These marks are usually outside of defined channels and generally do not indicate the port and starboard sides of the route to be followed or obstructions to be avoided. They also include those marks used to convey information related to navigation safety. These marks shall not conflict with other navigational marks and shall be promulgated in appropriate nautical charts and documents. Should not generally be used if a more appropriate mark is available within the MBS.

8.7 Port or Harbour Marks

Mariners should be careful to take account of any local marking measures that may be in place and will often be covered by Local Regulations or by-laws. Before transiting an area for the first time, mariners should make themselves aware of local marking arrangements.

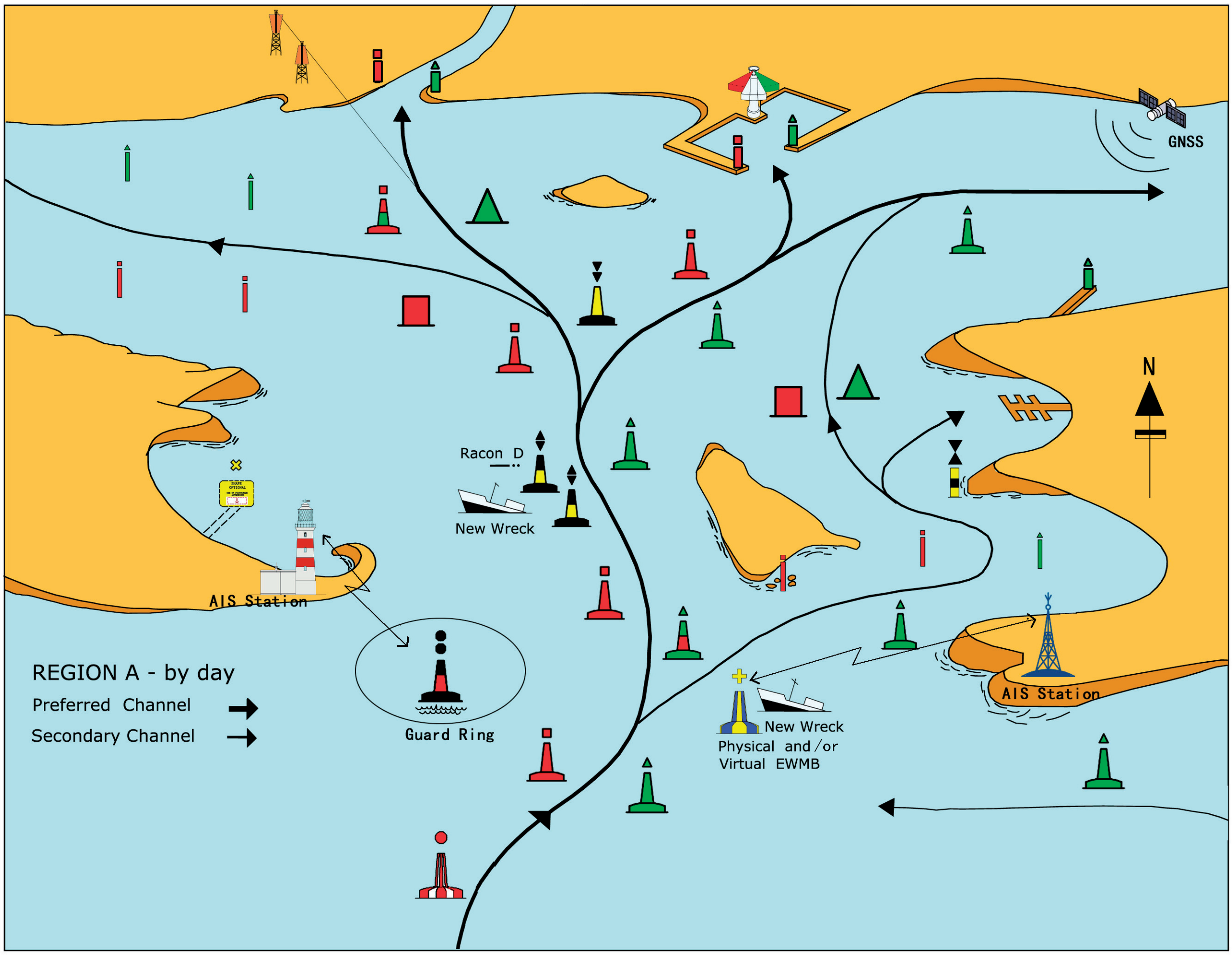
Local Aids to Navigation may include, but not be restricted to, marking of:

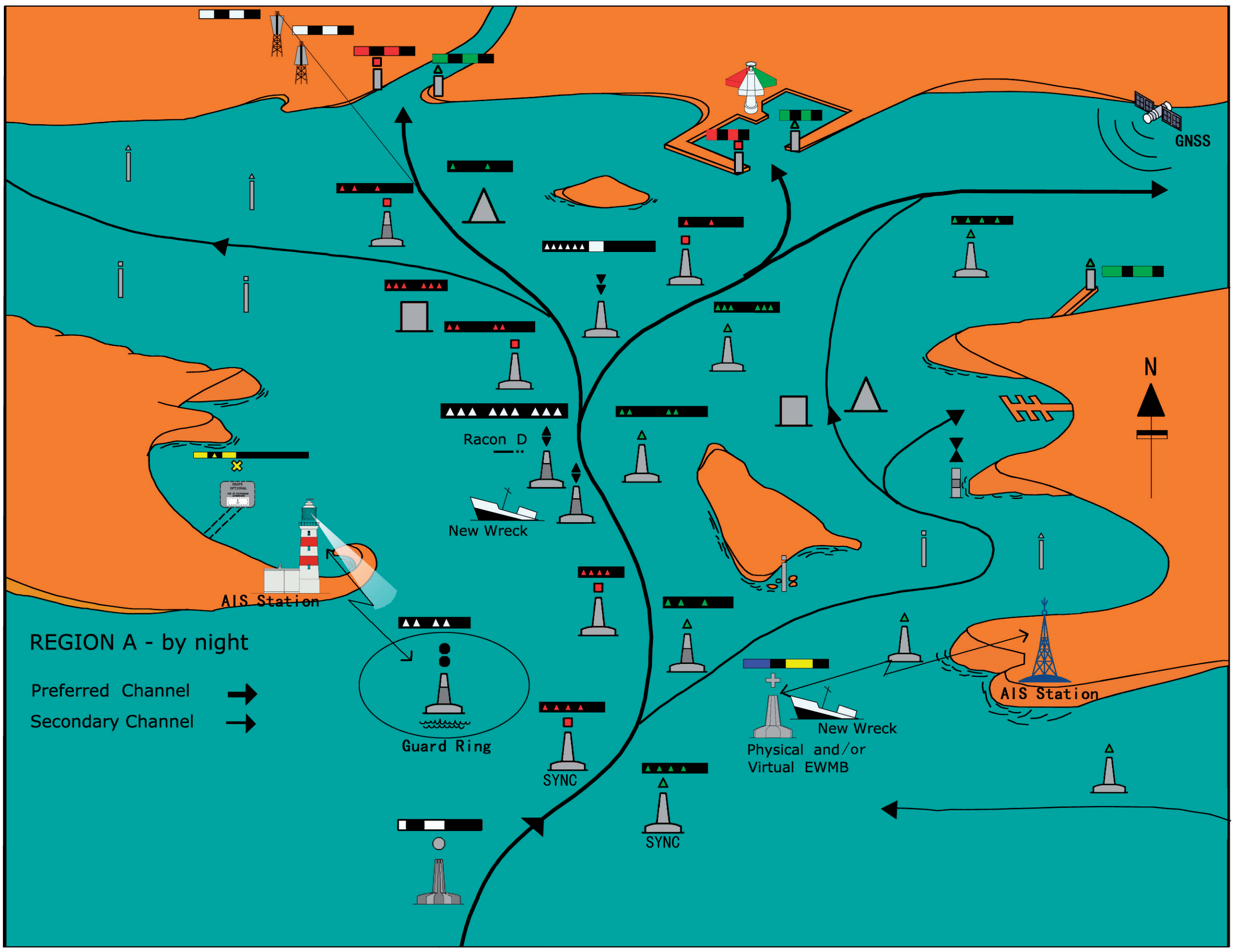
- breakwaters, quays and jetties;
- bridges and traffic signals;
- leisure areas.

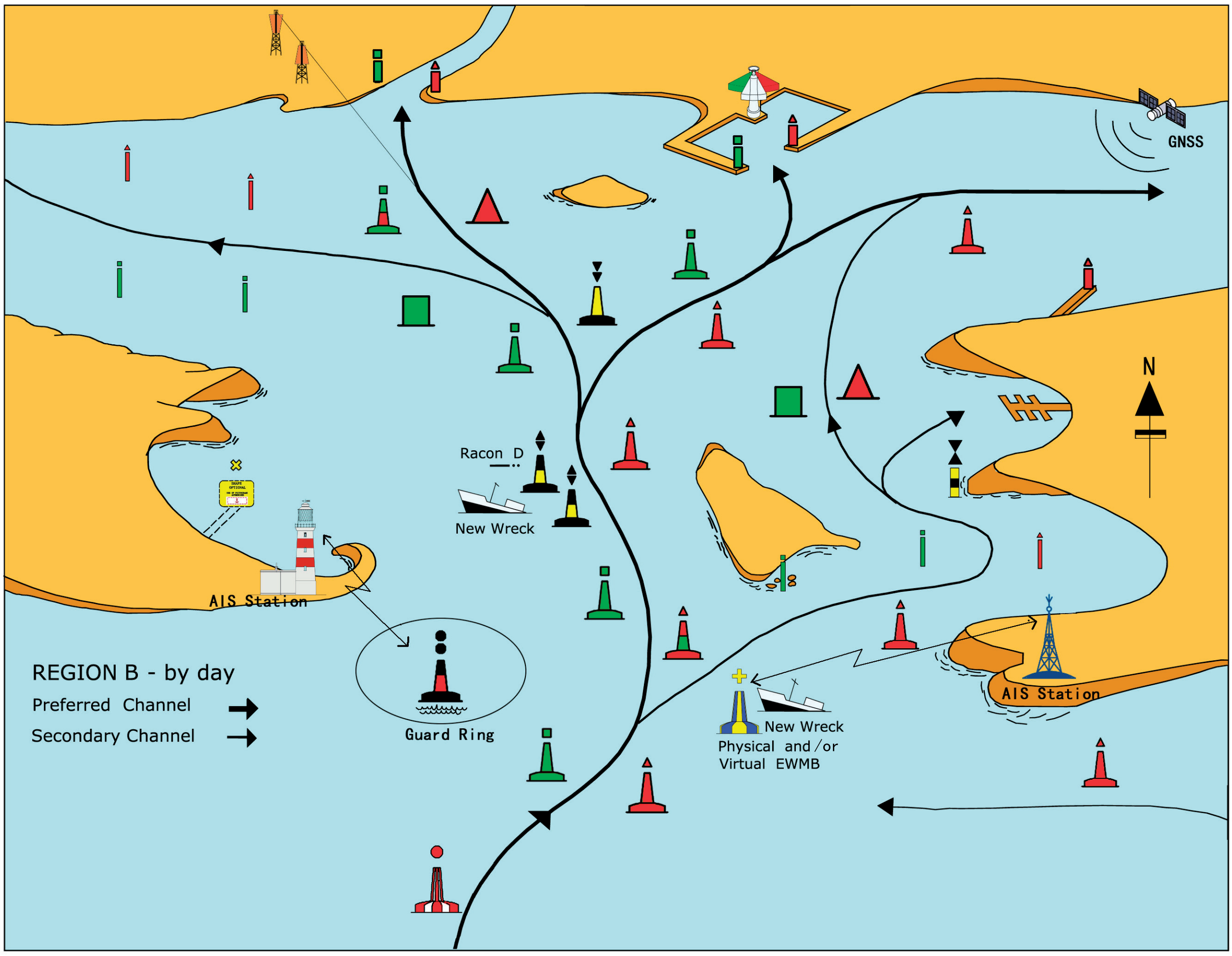
and other river, channel, canal, lock and waterways marked within the responsibilities of competent authorities.

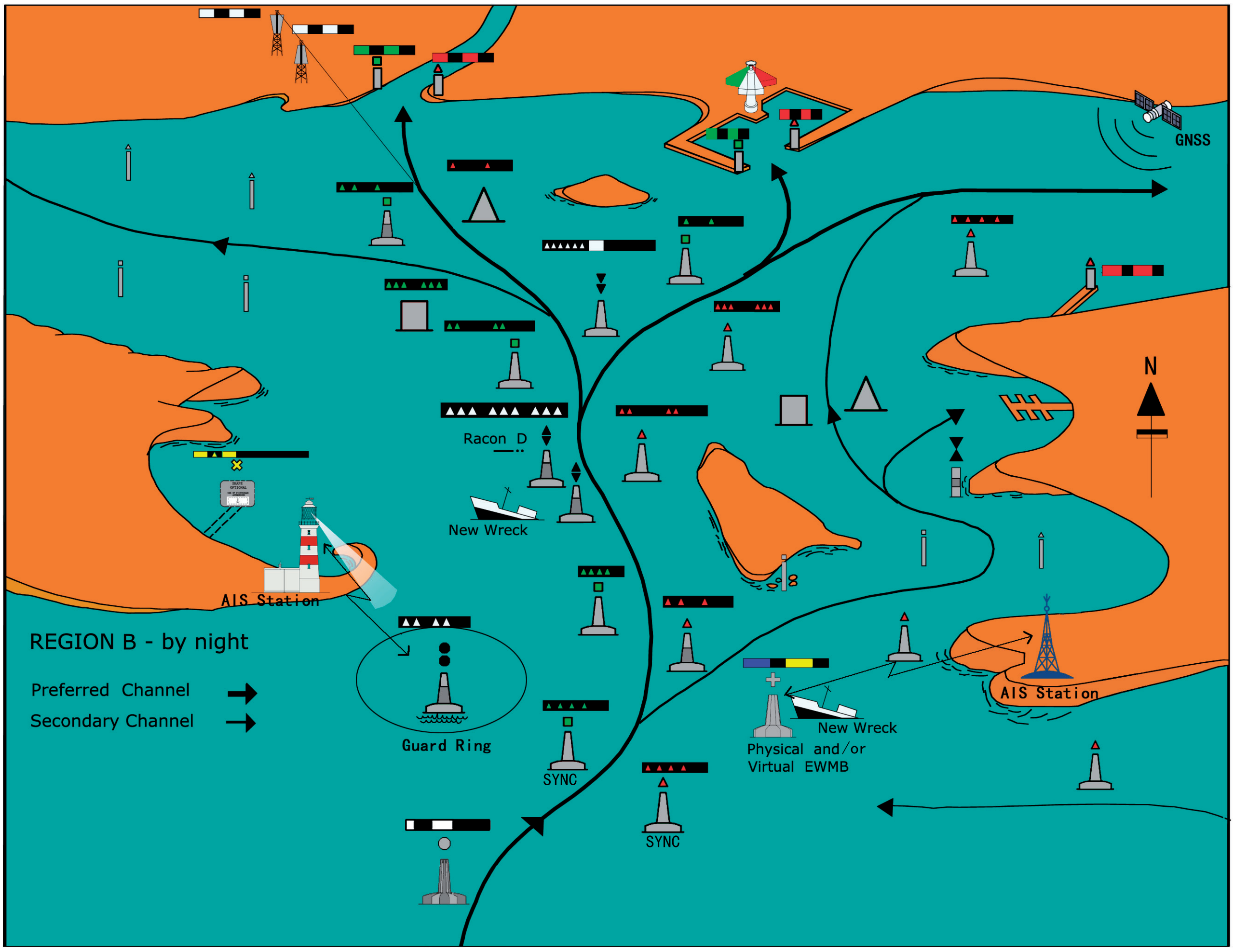
9. IALA RECOMMENDATIONS AND GUIDELINES

IALA Recommendations and Guidelines provide information on planning, operating, managing, and implementing the marks authorized by the MBS and can be found via the IALA website at: **www.iala-aism.org**.


GNSS
Racon D
New Wreck
AIS Station
REGION A - by day
Preferred Channel
Secondary Channel
Guard Ring
New Wreck
Physical and/or
Virtual EWMB
N


GNSS
Racon D
New Wreck
AIS Station
REGION A - by night
Preferred Channel
Secondary Channel
Guard Ring
SYNC
SYNC
New Wreck
Physical and/or
Virtual EWMB
N


GNSS
Racon D
New Wreck
AIS Station
N
REGION B - by day
Preferred Channel
Secondary Channel
Guard Ring
AIS Station
New Wreck
Physical and/or
Virtual EWMB


GNSS
N
Racon D
New Wreck
AIS Station
REGION B - by night
Preferred Channel
Secondary Channel
Guard Ring
SYNC
AIS Station
New Wreck
Physical and/or
Virtual EWMB
SYNC