

**Agenda item 9 – IALA TECHNICAL ACTIVITIES**

**9.7 EEP**

**9.7.1 Documents submitted for approval**

***9.7.1-1 Draft Guideline on Providing  
AtoN services in Polar Regions***

Note by the Secretariat

**1 SUMMARY**

This is a new Guideline emerging from the IALA Workshop on Challenges of Providing AtoN Services in Polar Regions and completed at EEP21.

In view of the increasing shipping traffic across the arctic and the increase in the number of voyages in Polar regions, it is clear there is a need to provide guidance on the special challenges of providing AtoN services in polar regions. This Guideline addresses these specific challenges and does not replicate the other aspects of AtoN provision which are covered by existing IALA documentation.

**2 ACTION REQUESTED**

The Council is requested to Approve the draft Guideline

# Draft IALA Guideline No. #####

On

## AtoN SERVICES IN POLAR REGIONS

Draft v10.1

Edition 1

**[December 2013]**

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## Document Revisions

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

Date	Page / Section Revised	Requirement for Revision

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## **IALA Guideline No. #####**

### **THE CHALLENGES OF PROVIDING ATON SERVICES IN POLAR REGIONS**

#### **3 INTRODUCTION**

In February 2010 the five Arctic coastal Member States (Canada, Denmark, Norway, Russian Federation and The United States) met at the IALA offices in Paris to evaluate and discuss the future marking of Polar routes.

The meeting was seen as a first step towards the development of a common approach to addressing the risks inherent in the expansion of maritime traffic in Polar waters. The five countries concerned adopted a Resolution dated 12 February 2010 and requested IALA to forward it to IMO and to the Arctic Council. It was also agreed that IALA will provide a forum for subsequent discussions relevant to safety of navigation issues in Polar waters.

In view of the recent opening of shipping routes and the increase in number of voyages in Polar Regions, it is clear there is a need to provide guidance on the special challenges of providing AtoN services in Polar Regions. This Guideline addresses these specific challenges and it is assumed that all other aspects of AtoN provision are dealt with in existing IALA documentation.

#### **4 BACKGROUND**

The conditions for maritime navigation in the Polar areas are changing fast and can be expected to lead to new seasonal shipping routes opening due to the reduction in the area covered by ice during the summer months.

IMO produced Guidelines for ships operating in Polar Waters in 2010, and is working to develop a mandatory Polar Code.

In Polar waters, maritime infrastructure and services for prevention of incidents and accidents are especially important due to the potential serious consequences of an incident in remote waters with limited infrastructure for SAR operations and combating of oil spills.

However, in Polar areas it is difficult to maintain reliable systems based on traditional Aids to Navigation due to the extreme distances, sea ice and climate. Buoys and other installations may be damaged and/or moved by ice. Furthermore, shipping routes have to be flexible and able to be moved at short notice to take into account the shifting weather and ice conditions and local hydrographical conditions.

To establish safe and efficient maritime transport corridors in Polar waters there is, therefore, a need to develop and implement electronic maritime navigation, communication and traffic monitoring infrastructure, including inter alia, radio-navigation aids, GNSS, AIS satellite. Development of virtual aids to navigation is one solution that should be given strong consideration.

Whatever solutions will be adopted, it is of utmost importance that new methods to mark safe waterways are internationally coordinated and agreed in order for mariners to experience one single internationally agreed system.

##### **4.1 Navigation in Polar Regions**

Navigation in Polar Regions is particularly challenging for a number of reasons:

- The potential for collision with ice
- Restricted manoeuvrability in ice conditions
- Extreme and dynamic weather conditions
- Visibility often limited by fog, snow or low cloud
- Limited weather forecasting over wide areas
- Limited availability of survey reports to modern standards

- Differences in chart datum
- Use of different chart projections
- Limitations on usability of navigation and communications equipment
- Limited shore infrastructure, salvage and SAR facilities
- Response times (to incidents or AtoN failures) measured in days or non-existent

#### 4.1.1 Navigation in Ice

The basic principle of navigation in the Polar Regions is to avoid ice whenever possible, even if this requires a substantial deviation, as navigation in ice is much slower than in open water.

In planning a voyage in polar waters the open water voyage plan is adjusted, based on currently known ice conditions, which may be based on satellite, aerial or visual observations.

If it is necessary to enter ice, the ship's progress is continually re-assessed in view of prevailing local ice conditions. These considerations include the age and thickness of ice, movement of and changes in pressure on the ice floes, the identification of potentially dangerous floes and the effects of weather and tide.

#### 4.2 Emerging routes in Polar Regions

There has been a longstanding interest in routing ships via the Polar Regions, as there is scope for significantly shortening trade routes between Pacific and Atlantic ports, with consequential savings in transit times and fuel use. The widely reported reduction of the Polar ice pack in recent years has increased the likelihood of ice-free routes in summer.

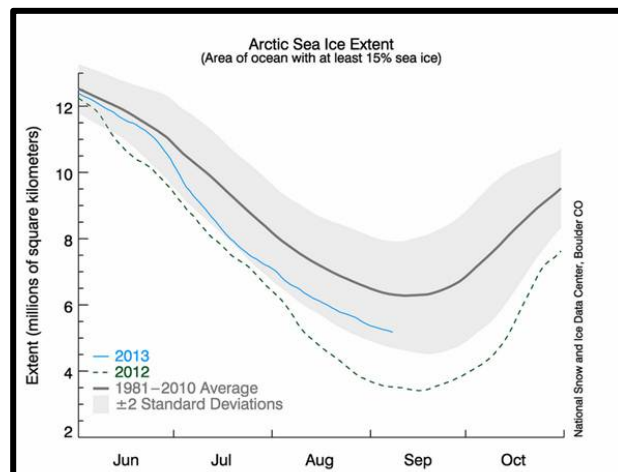


Figure 1 Arctic sea ice extent in 2012 and 2013 compared with 1981

This has led to increases in transit traffic, and also in more localised traffic focussed on the exploitation of minerals, hydrocarbons and logging.

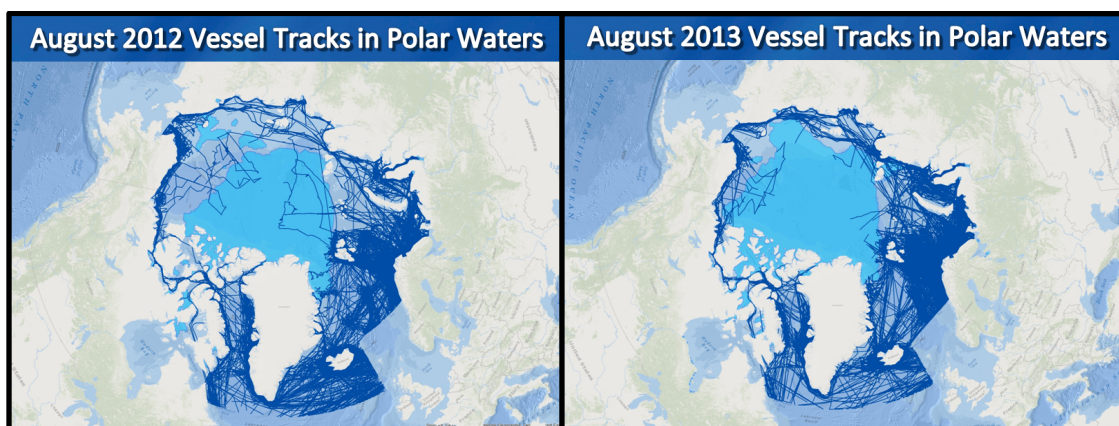


Figure 2 Vessel Tracks in Polar Waters in August 2012 and August 2013 (Courtesy ExactEarth)

#### 4.2.1 Northern Sea Route

The Northern Sea Route (North East Passage) stretches approximately 2,800 kilometres along the Russian Arctic coast from Novaya Zemlya to the Bering Strait. It has been used intermittently for shipping, depending on shipping requirements and the degree of ice on the route, and peaked at 6.6 million tons in 1987. The route was closed by ice in 2007, but reopened the following year. Six ships transited the route in 2010, followed by 34 in 2011 and 46 in 2012. Most of these vessels are high capacity oil or gas tankers, benefiting from fuel savings as voyages from Korea to Rotterdam are reduced by some 4,000 nautical miles<sup>1</sup>.

#### 4.2.2 Northwest Passage

*The Northwest Passage* is the sea route connecting the Atlantic and Pacific Oceans through the archipelago of Canada. The islands of the archipelago are separated from each other and the Canadian mainland by several waterways. The Canadian Arctic is mostly an area of destination for traffic calling at ports there. Shipping is nevertheless expected to increase in the years to come, not least since oil and gas activity in the Beaufort Sea is likely to expand. The Northwest Passage has also experienced intermittent use by cruise liners, and increased leisure usage.

#### 4.2.3 Antarctic routes

Although Antarctic waters are not generally used for transit by vessels, there are various vessels operating in the Antarctic, mostly offering cruises from South America to the Antarctic Peninsula.

### 4.3 Environmental considerations

#### 4.3.1 Visibility

At high latitudes it is dark for all or most of the day for half the year. Conversely, it is light for all or most of the day during the summer months. Both of these conditions impact on visual navigation.

#### 4.3.2 Temperature

Extremely low temperatures can affect the performance of external equipment. Icing on antennas and snow build-up can cause problems for many different systems.

Consistent cold temperatures can reduce the expected life of equipment, and can make some materials brittle. Also, consideration should be given to selection of lubricants used on moving parts.

#### 4.3.3 Sudden severe weather events

Weather events in the Arctic often develop very quickly and are dependent upon barometric pressure changes, temperature differentials, and land/ice topography. Wind storms often include hurricane force winds, hail, and large amounts of precipitation. All of these things combined with a dearth of weather stations make weather prediction extremely difficult.

For this reason, investments may need to be made to increase the number and density of fixed weather stations throughout the polar waters and ships transiting would greatly assist in this effort if they were able or required to report periodically on their local weather.

#### 4.3.4 Moving landscape

Ice sheets grow and shrink with the seasons and ice-charts may need to be updated frequently. Consideration should be given as to how this information can be managed in an efficient and cost-effective manner to ensure the mariner uses the most up to date information.

The growth and reduction of the ice sheet can also result in land based systems having to be installed on permanently stable, high ground which may potentially be at sub-optimal locations, distant from the area of navigable waterway being served.

#### 4.3.5 Natural resources

It is expected that the Polar Regions will observe a growth in offshore industry, with associated increase in marine traffic and subsequent risk, as approximately 25% of undiscovered oil and gas resources are believed to be within this region.

#### 4.3.6 Hydrography

Given the rapid changes expected to navigable areas due to moving ice and the ice shelf, the mariner will need up to date charts, referenced to an appropriate datum.

### 4.4 Special features of AtoN in cold regions

Given the great distances and limited resources available in the Polar Regions, it is not practical to provide Aids to navigation with the same density and coverage as is possible in more temperate climates.

It is therefore necessary to focus resources on providing maximum benefit for minimum cost, particularly in terms of maintenance requirements.

The potential for ice and animal damage, the limitations of power supplies and structures operating at very low temperatures, the difficulty of maintenance access and working, the logistics of getting personnel and materials to site all pose unique challenges when providing AtoN in Polar Regions. These issues are considered further in this Guideline.

Provision of appropriate AtoN needs to be balanced against the high cost of provision, and the personnel risks inherent in maintaining such sites.

## 5 PURPOSE

The purpose of this document is to provide guidance to IALA members on aspects related to the definition, installation, operation and maintenance of Aids to Navigation in Polar Regions, in the context of promoting safety of navigation, security, protection of the maritime environment and efficiency of maritime traffic.

## 6 DEFINITIONS / ACRONYMS

Definitions of terms used in the guideline are contained in the IALA Dictionary which is available on the IALA web site. Polar AtoN e-Navigation definitions are shown in ANNEX A.

### 6.1 Glossary of Terms

AIS	Automatic Identification System
ASM	Application Specific Messages
AtoN	Aid(s) to Navigation
DSC	Digital Selective Calling
GEO	Geo-stationary Orbit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (USA)
HEO	Highly Elliptical Orbit / High Earth Orbit
HF	High frequency (3 – 30 MHz)
IMO	International Maritime Organization
LEO	Low Earth Orbit
MEO	Medium Earth orbit
MSI	Maritime Safety Information
NAVTEX	Navigational Telex

PNT	Position, Navigation and Timing
SAR	Search and Rescue
SOC	State of Charge
VDES	VHF Data Exchange System

## **7 THE NEED FOR ATON IN POLAR REGIONS**

AtoN are required to provide mariners with a means of confirming their ground-referenced position.

There are a number of issues which add to the benefit of AtoN at known locations. These include the sometimes poor correlation between charts and electronic position fixing, and the difficulties of distinguishing between ice-covered sea and shoreline.

### **7.1 Regulatory requirements**

SOLAS Chapter V requires each Contracting Government to provide such aids to navigation as the volume of traffic justifies and the degree of risk requires. Although volumes of traffic are low in the Polar Regions, the degree of risk is often high, with lack of salvage and SAR facilities an additional consideration.

### **7.2 User requirements for AtoN in polar seas**

Physical AtoN provision should be such that the mariner is able to periodically confirm their position, rather than attempting to mark every hazard or turning point.

One approach is to identify offshore routes where the standard of hydrography can be of a higher quality than over the wider area, and chart and mark these routes to clearly identify the preferred routing. These routes can be used to identify areas where ice is less of an issue. A further benefit of this approach is that the routes can be selected to minimise the possibility of vessels drifting ashore, if beset by ice or loss of power or steering.

## **8 SPECIAL FEATURES OF WORKING IN REMOTE POLAR REGIONS**

### **8.1 Life Cycle considerations**

A project in the Polar Regions normally takes longer to develop and implement than it takes in more densely populated areas. The remoteness, the rarity of specialized resources, the lack of support infrastructure, the complexity of transportation, dangers from wildlife and the environmental conditions are many elements that need to be seriously considered for the successful delivery of a project.

In many cases, a project that can be delivered within a year in populated areas may take up to two or three years before being finalized, depending on its complexity, location and size. Completion dates are vulnerable to postponement due to extreme weather or ice conditions.

For this reason, it is important to analyse each activity required in the delivery of the project and ensure its feasibility in remote areas. Care should be taken especially with regard to the following elements:

- AtoN System selection
- Land and soil survey
- Authorizations and permits
- System design (Structure, power system, AtoN equipment...)
- Material acquisition
- Quality control
- Material Transportation
- Staff transportation & welfare
- Construction period
- Equipment suitability for cold regions

- Lodging facilities
- Local material and resources availability
- Operation and maintenance requirements
- Health and Safety
- Hazardous material

## **8.2 Type of service that would meet the requirements**

As mentioned earlier, it is essential to determine the requirements for each specific site. Due to the remoteness of those sites, simple equipment should be used as much as possible. For example, unlighted leading lines, radar reflectors, daymarks are simple and economic solutions to guide vessels and should be considered first in areas where the cost and difficulty of access is significant.

The use of active aids to navigation brings more challenges, increases the initial cost and brings additional requirements in terms of maintenance and site visits. Active aids might be lighted leading lines, shore light, radar target enhancers, AIS, Racons and other e-navigation solutions that need communication systems. Due to the facility of access and the availability of contractors to proceed with maintenance, it might be decided to restrict the use of active aids to near villages or communities.

## **8.3 Project planning**

Implementing projects in Polar Regions is a challenge that requires a lot of planning. It is important to secure resources for critical activities well in advance of work. The solutions when something is not working as planned are either limited, or extremely expensive to implement. For this reason, it is recommended to refer to experienced people in that type of projects in remote locations for assistance in project planning. This includes personnel from the AtoN authority and also consulting firms and contractors when appropriate.

Using those resources does not guarantee that everything will go well but brings a higher level of confidence. The involvement of the people of the local communities is another way to improve the project outcome, considering their knowledge of the conditions that may affect the delivery of a project. They can normally help regarding the best construction period, the availability of local resources and the possibilities and challenges concerning transportation.

## **8.4 Equipment redundancy requirements for remote regions**

Due to the difficulty of accessing sites for a very long period each year, the implementation of redundant equipment needs to be considered for any active system. Many factors should be considered before making the decision to install redundancy, noting that each additional item of equipment, or electrical connection, introduces another potential point of failure. The importance of the aid to navigation in the AtoN system, the reliability of the planned equipment under normal conditions, the level of knowledge in terms of performance of this equipment in cold climate, the required/ expected availability, the capital and maintenance cost, and the impact of a failure are many elements to consider before making a decision to duplicate equipment or not.

## **8.5 Co-ordination with local communities**

In order to maintain good relationship with the local communities, the importance of communication cannot be understated. They should be informed of the goal of the project, the planned work, the immediate and long-term impact on their community and of any commitment the organization is willing to make (e.g. paying a rent for the use of the land or acquire the land).

Normally, permits are required before proceeding with any project on native lands. All required permissions should be received before starting the work in order to ensure good collaboration and prevent confrontation. Explaining how this project will be beneficial to the navigation and indirectly to the communities should help getting the go ahead.

Consideration should also be made to ensure the project doesn't affect the lifestyle of those communities by affecting negatively the wildlife habits that may affect the subsistence of the local people. Examples may be blocking the passage of grazing animals or diverting the flow of a river affecting the fish habitat.

In many cases, being able to demonstrate that the implementation of aids to navigation will generate work for local people will help the discussions. Adding local acquisition to the project may also influence the time required to get the expected permits.

#### **8.6 Contribution of indigenous residents (employment, local knowledge)**

The local knowledge of the indigenous population may be an important success factor in the delivery of a project in the Polar Regions. Involving the officials of the communities, local contractors or local engineering firms may facilitate the planning and construction of a project. In many cases, the local people know who has material, machinery and transportation capabilities in the area. Local acquisitions should be utilised wherever possible; this may reduce the need to import equipment and material at high cost.

This would also increase the employment in the local villages, which could affect positively the perception of a project in the community.

#### **8.7 Secure storage of material**

Depending of the timing and the method selected, it may be necessary to ship and store the material in advance to a close local community. It is important to ensure it is stored in a secure place. Sensitive equipment (e.g. lights, power systems, electronics...) may need to be protected from the environment and should not be stored outside without appropriate protection.

If there is a need to store petroleum or any other chemical product, consideration should be given to the protection of the environment. Fuel drums for example should be stored on special pallets or in special containers to prevent any leak. National, regional and local regulations concerning the storage of petroleum products must be followed to prevent any possible litigation.

Another element to consider is the possibility that your material attracts large animals and be damaged before you return to the site. Additional physical protection may be required in that case.

#### **8.8 Limited availability of fuel, material, equipment and manpower.**

In the preparation of any project in Polar Regions, one should consider the limited availability of fuel. It is always important to consider the requirements and determine the best solutions to limit the quantity of fuel required during and after construction.

Depending of the conditions, transportation of fuel can easily cost 8 to 10 times the cost of the fuel itself. This factor may influence the way the project will be planned and implemented.

It is sometimes possible to find raw material that would be suitable for construction not too far from the construction site. For example, gravel pits close to the work site might be identified during the initial soil investigation. However, permission to operate a gravel pit is normally required and remediation methods may be necessary. It should be noted that excavating gravel from the sea shore is prohibited in some countries.

It is also good to investigate the availability of equipment in the area to limit the need to bring the heavy machinery from outside. Municipalities, local contractors and sometimes large contractors from outside doing work in the area during the summer season may already have what is needed and reduce your need to bring everything with you. They may also supply local manpower and reduce your need to bring your own workers.

One other possibility to reduce the need for fossil fuels is the pre-fabrication of the material. This way of working will limit the time required on-site thus the need for fuel for equipment and accommodation. However, this may increase the need for lifting equipment of higher capacity and require more space on board shipping vessels.

#### **8.9 Backup equipment and spare parts**

Working in remote locations brings challenges that are not even considered in densely populated areas. Authorities should make sure the organisation responsible for the site construction has brought sufficient spare parts and equipment should something go wrong. The lack of a spare part or tool may cost thousands of dollars to source spare equipment and cause delays in the delivery of the work. The presence of an unexpected water source may require more pumps than planned, also causing delays and additional cost to a project.

Experience has also shown regular issues with the quality of the fuel in remote locations, so filtering the fuel prior to filling the vehicle tanks and having spare fuel filters for the machinery is advisable.

Consideration should also be given to the effects of extreme low temperatures on batteries, particularly lead-acid cells.

In order to reduce the level of risk associated with the lack of spare parts, a risk analysis of the equipment on-site, the work methods, the soil conditions, the various resources available in the area and the remoteness of the work should be done to determine what spare parts should be brought to the work site.

### **8.10 Considerations for scheduling work in cold regions**

When work needs to be done on permafrost, it is important to take some precautions to prevent it from melting. Removing vegetation will immediately cause the soil to melt, especially if the work is conducted in summer where the sun shines almost 24 hours a day. This may impact the areas where roads need to be built as well as the work site. If the permafrost melts, the possibility of landslides increases drastically.

As the number of ships travelling in Polar Regions is limited, it is important to schedule and reserve ships to carry material early in advance. The shipping season in some areas is quite limited, so the lack of planning may mean a long delay in the project.

In some cases, winter transportation may be the only solution to reach some sites. Ice roads built on lakes and frozen ground may sometimes be the only solution to bring heavy machinery to construction sites.

A disadvantage of working in a Polar region is the short construction period which is sometimes limited to a few summer months. However, as the sun never goes below the horizon during that period, it is possible to plan the work on 2 or 3 shifts a day, giving more time to complete the work.

During the planning of the project, consideration should be given to the possibility of delays due to weather conditions. It is particularly true if the project requires the use of air transportation.

### **8.11 Communication with the site during construction**

During a project in Polar Regions, it is important to consider the availability of communications. It is generally required to stay in contact with the support team of engineers who may not be on-site, especially if something goes wrong. Voice communication is essential for safety reasons, however it may also be necessary to transfer data and satellite communications may offer a solution.

In the event the main communication system fails, there should be a back-up strategy to keep the site team in contact with the outside world, especially in the case of an emergency on site.

### **8.12 Quality control**

It is important to ensure the material brought on-site is compliant with the requirements and fully operational. It is also required to have quality control on the site to ensure proper construction, and document and approve any change done during construction.

## **9 SITE DESIGN AND EQUIPMENT SELECTION**

### **9.1 Aids to Navigation for Polar Regions**

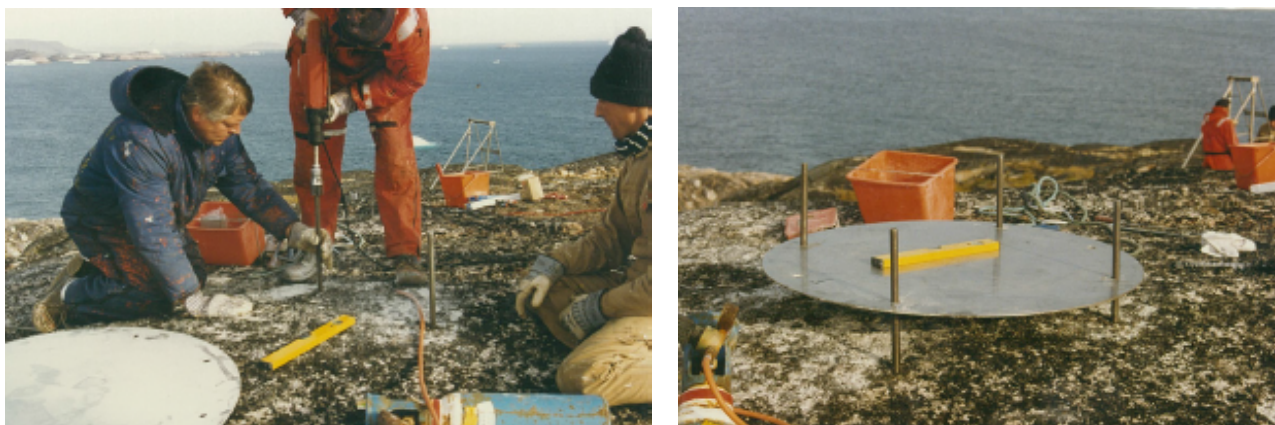
Given the poor survivability of buoys in winter ice conditions, it is unlikely that these are suitable in most circumstances, and fixed AtoN should be utilised wherever necessary. Where buoyage is used this should be either seasonal, or designed for all-season survivability; both these options are expensive and do not guarantee good reliability.

Unlit beacons and passive radar reflectors are particularly beneficial owing to their high reliability and low maintenance requirements, as opposed to powered AtoN, and are utilisable during polar summers where there is nearly three months of sunlight without a sunset. Electronic AtoN are also of high value owing to their usability in fog or poor visibility conditions, and power requirements for racons are minimised due to the low traffic volumes.

Development of virtual aids to navigation should be given strong consideration as an adjunct to conventional aids to navigation for use in Polar waters; however provision of an effective virtual aids to navigation system depends on adequate hydrographic services as well as the provision of appropriate Maritime Safety Information systems and communications infrastructure.

## 9.2 Foundations and structures

Standard civil engineering best practices should be applied. Special considerations should be given to polar factors such as the presence of permafrost and seasonal ice conditions. To obtain the necessary information the design team should collect data from all available sources, notably local knowledge. Where data is not available it should be collected, for example, land and soil surveys or wind and ice measurements.



*Figure 3 Examples of a simple foundation which is preferred in Polar Regions to ensure a swift installation and to reduce the use of heavy equipment and large quantities of materials.*

Refer to <http://www.pws.gov.nt.ca/pdf/publications/GeotechnicalGuidelines.pdf> for more information on Soil Investigation in Permafrost.

## 9.3 Aids to Navigation equipment

The design of aid to navigation equipment for use in Polar Regions is a relatively new industry for commercial producers. The various desired performance characteristics may or may not be available for a particular type of equipment on the market today, therefore special care should be taken with respect to defining the equipment requirements. Some of the more prominent issues to consider include, but are not limited to:

- i. **Ruggedness:** The equipment must be able to withstand harsh weather conditions, including extreme cold, ice and snow accumulation, and severe wind. If the available equipment cannot withstand the local conditions, the site design should include the provision of a protective structure or housing.



*Figure 4 Examples of housings in Greenland*

- ii. Power consumption: Although this is always a consideration, it is particularly important in the Polar Regions due to the impact of cold weather on power system requirements. This is discussed further in Section 9.7
- iii. Reliability: Due to the cost of maintenance and the elevated risks associated with navigation in the Polar Regions. If the reliability of the equipment cannot be guaranteed, an alternative maintenance strategy could/should be considered, such as local contracts to verify the equipment on a regular interval. Further information on outsourcing is provided in maintenance section 10.1.4



*Figure 5 Examples of structures suitable for Polar Regions (Koksoak River in Canada, Lincoln Island in Alaska)*

Simple land based AtoN unlit structures have been successfully designed to the following requirements

- Few components
- Easy to repair – single man operation (possible for one individual to carrying spare parts and repair the day mark)
- Wind speed up to 60 m/s without damage
- Deformation of +7% on the top mark in wind speed of 60 m/s is accepted but not on the post.



*Figure 6 Simple land based unlit structure*

For locations where a solution is not achievable with equipment presently available, industry engagement may be required.

### 9.3.1 Potential for Ice damage

Dynamic ice flow has the potential to cause catastrophic failure of structures. Although not limited to floating AtoN, these are particularly susceptible to mooring damage or forced submersion. Static ice build-up on structures may also cause damage due to overloading and wind damage as a result of increased surface area.

## 9.4 Energy sources

Provision of power supplies for electrical AtoN is particularly challenging, as the polar winter features long periods of darkness, when the AtoN may be required to be functional but the potential for solar-electric charging is negligible. This requires either large power reserves, although battery efficiency is reduced in cold conditions; or the potential for sourcing power from other means.

The remoteness of the location and cold climate impact the possible energy sources. Different kinds of energy sources are evaluated for use with AtoNs in Polar Regions below.

- i. Public power supply: This is the ideal technology, based on reliability, however it is rarely available at planned AtoN sites.
- ii. Solar: This is a proven reliable and robust technology. There are two main challenges. First ice and snow accumulation, which needs to be addressed when designing the site layout, capacity and redundancy. Second, the need for sunlight. Solar systems in Polar Regions must therefore be designed with much larger energy reserve to pass the long period of darkness.
- iii. Wind: Each type has its own environmental (wind, ice) capabilities and limitations that need to be considered. The technology also has specific maintenance requirements that must be completed to ensure performance. Maintenance should be available locally to consider this technology a feasible option.
- iv. Diesel: Is not suitable for small AtoN due to the maintenance frequency requirement, and the high cost of fuel transportation.
- v. Fuel Cells: Is a new unproven technology for use in Polar Regions, and is therefore not currently recommended.
- vi. Primary batteries: These are a proven and reliable power source with predictable capacity but require a robust maintenance programme to assure AtoN performance.
- vii. Isotope nuclear thermoelectric generators have been used to provide heat and electric power. These generators use Strontium 90 as a fuel source and can operate unattended for long periods. However, they have not been totally reliable with risks of radiation contamination and susceptibility to theft. The environmental impact following an in-service failure, and disposal issues at the end of life, no longer make these units a recommended power source.

Solar power systems are probably the most suitable energy source for stand-alone AtoN applications in Polar Regions due to the simplicity, reliability and low maintenance requirements. Hybrid solutions may be an alternative where more energy is required.

## 9.5 Solar energy systems

Use of a Solar Model spreadsheet that has been tailored to suit Polar latitudes is required. The Danish Maritime Authority (DMA) has provided their spreadsheet for capacity assessment to IALA for members to use.

In general and as a rule of thumb the battery must be fully charged by the end of March (September in the Antarctic).

## 9.6 Energy storage

The cold climate limits the number of possible energy storage technologies. Currently the most widely used solution is based upon Ni-Cd battery technology because of its well documented performance in extremely low temperatures. The reduced usable capacity in low temperatures has to be considered when calculating the battery size. Other criteria to consider include service intervals and expected lifespan.

It has been found that fibre plate Ni-Cd batteries perform much better in Polar Regions than tubular plate Ni-Cd. “Arctic Electrolyte” with a crystallization point of - 40°Celsius should be used. Stronger electrolyte is available, but will reduce the life time of the battery.

Successful battery sizing has been carried out applying the following criteria.

- After the 3 winter months without charging (autonomy period) the remaining capacity of the battery must not be reduced to less than 35 % of the total battery capacity.
- Deeper discharge (to 10% SOC) of Ni-Cd batteries is accepted for keeping nominal system voltage (the 35% limit is addressed for variations in solar radiation and less optimal geographic orientation of the panels).
- Example of energy loss and calculation of de-rating factors for sizing Fibre Structured Ni-Cd batteries:
  - 7% loss of total capacity caused by no charging to 100%
  - 20 % loss of total capacity caused by low temperature
  - 20 % loss of total capacity caused by degradation and memory effect
  - 7 % very low self discharge – compensates for 7 % loss due to lack in 100 % topping up
  - Total loss: 40 % of total battery capacity

Compensation factor for calculation of actual battery capacity is therefore 1.40. Using pocket plate Ni-Cd batteries the required compensation factor is 1.67.

It is essential to refer to the battery manufacturer's data for the correct assessment of capacity and performance in sub zero temperatures.

It has been found that fibre plate Ni-Cd batteries have the following characteristics.

- During operation no carbonising at the anode is found.
- Trials on charging a totally discharged battery has shown that it is possible in less than 8 days to charge a totally discharged 240 Ah battery up to nominal capacity using 1 solar panel of 40 W rating.

Present generation lithium batteries do not operate well at temperatures of less than -10°C.

## 9.7 Energy consumption

Energy consumption of AtoN is a critical factor in AtoN in all areas and this applies equally in Polar Regions. Because of the long period of three months darkness in winter and three months daylight in summer, all equipment needs to be rated for continuous operation on a 24 hour basis for three month periods.

## 9.8 Physical protection devices

### 9.8.1 Vandalism / theft

A major cause of vandalism against AtoN in Polar Regions is shooting. As the people in remote regions depend on the sea to a much greater extent than those in more temperate regions, signs reminding of the value of the AtoN to local users have been found to be a great deterrent against vandalism.

Stealing of power systems is a further risk and the usual precautions against intrusion are usually effective.



*Figure 7 Example of cable protection against wild animals & notices to deter vandalism*

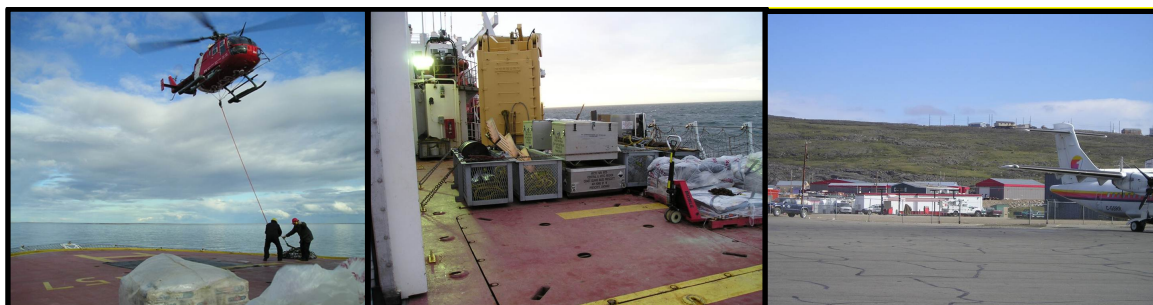
#### 9.8.2 Animals

The curiosity of animals should never be underestimated. Bears have smashed battery cabinets and the batteries inside them. Sea lions, seals, and bears have a penchant for chewing the insulation off unprotected electrical wires. Whenever possible an AtoN should be enclosed and the wires run within its construction or adequately protected.

## 10 INSTALLATION AND CONSTRUCTION IN REMOTE REGIONS

### 10.1 Logistics

The remoteness of Polar Regions requires more planning than other areas. Construction crews should ensure they understand the issues they may encounter. Typical non-polar sites may be accessed by road, small boat or helicopter with contractors readily available and material and equipment easily sourced locally. In Polar Regions, options are rather limited and in many locations only seasonal access is possible. Many areas can have access restrictions due to local environmental protection regulations such as species at risk, among other challenges.



*Figure 8 Methods of transportation to Polar Regions*

#### 10.1.1 Transportation

Polar Region sites are difficult to access with few roads and airports. There are a limited number of local service providers. In order to access and construct an AtoN site, various means of transportation can be used; commercial service providers when available and more likely your internal organization's resources: ships, helicopters, small vessels, etc.

#### 10.1.2 Availability of resources

One cannot rely on sourcing the equipment or materiel locally. Supplies are limited in Polar Regions, and generally can only support the local community needs. The logistics plan should make allowances for the resources needed and contingency on each of these items. With respect to equipment, you should carry repair kits and spare parts to be able to perform repairs on site.

#### 10.1.3 Personnel

Personnel should be suitably trained and competent to work in remote areas and be physically fit.

Minimalist crew numbers are not recommended. Insufficient staff numbers could compromise the task whilst one too many will not – the task is too important and expensive to be put at risk by short staffing

Accommodation will generally need to be provided for staff welfare, this may be on a ship or purpose built for the duration of the works

#### 10.1.4 Outsourcing

This option can be explored. Outsourcing transport should ensure companies are qualified to operate in Polar Regions. The dangers and complexities need to be well understood. To make this option feasible, the requirements of the job must be very well understood and described in advance of tendering the job. This option is not generally recommended due to the shortage of local site information.

### 10.2 Safety considerations

#### 10.2.1 Safety plan

The development and implementation of a Health and Safety Plan will ensure efficient and safe activities during all phases of the project, from concept, development through to construction, operations and abandonment.

A Project safety Plan should be developed initially that will cover activities during the design and construction phases, through to the “ready-for-operations” stage of the project.

The Project Safety Plan should specify the resources and measures needed to plan, schedule, control and monitor implementation of the day-to-day work activities. It should incorporate risk prevention and mitigation measures identified in formal risk assessment and safety engineering studies undertaken during the design phase.

Major contractors should be required to develop Safety Plans for their installations and operations and those plans should be integrated in the Project Safety Plan.

An Environment, Health and Safety Management Plan should also be developed. The elements identified below could be considered during the development of this plan:

- Leadership/responsibilities/accountability
- Managing risk
- Emergency preparedness
- Assuring competency
- Conducting business responsibly
- Ensuring contractor and supplier performance
- Managing incidents
- Documentation management
- Reporting Health and Safety performance, and
- Evaluating system effectiveness.
- Medical/First Aid services on-site
- Medical evacuation
- Communications with emergency services
- Fuel transfer and storage

- Garbage disposal
- Leaks from machinery
- Emergency response in case of fuel spill
- Risk plan for wild animals

## **11 OPERATION AND MAINTENANCE**

### **11.1 Operation and safety plan**

An Operation and Safety Plan that documents all the hazards and effects associated with the facility and the corresponding control measures should be developed. Management during the operational phase should focus on procedural and administrative aspects. Hazard management techniques such as an effective permit to work system, job hazard analysis, Environment, Health and Safety performance monitoring system and contingency planning should be implemented to address operation-specific hazards.

Production operations manuals should be developed for routine activities. Formal maintenance management systems should be established to ensure safe and environmentally sound operations of the facilities.

In the event that an external contractor performs the operation/maintenance activities, it is recommended that the contractor develops an Operation and Safety Plan for his activities.

### **11.2 Repair & Maintenance strategies**

Repair by replacement – Due to the extreme conditions at the AtoN, consideration should be given in the design and installation to allow ease of component or module replacement to reduce the time required to spend on site.

Planned maintenance - The cost of repairs will be high due to the difficulties in access to the AtoN, therefore the cost of any planned maintenance can be offset by the reduction in the likelihood of a failure. Schedules to replace entire components more frequently than on an easily accessible AtoN should be considered.

### **11.3 Safety considerations - Safety plan**

The implementation of a Health and Safety Plan system will ensure efficient and safe maintenance activities.

The Safety Plan should specify the resources and measures needed to plan, schedule, control and monitor implementation of the day-to-day work activities. It should incorporate risk prevention and mitigation measures identified in a formal risk assessment

An Environment, Health and Safety Management Plan should also be developed. The elements identified below could be considered during the development of this plan:

- Leadership/responsibilities/accountability
- Managing risk
- Emergency preparedness
- Assuring competency
- Conducting business responsibly
- Ensuring contractor and supplier performance
- Managing incidents
- Documentation management
- Reporting Health and Safety performance, and
- Evaluating system effectiveness.

For the activities in remote areas, emphasis should be placed on the Medical and First Aid services available on-site, the communications with medical services as well as medical evacuation from the work site.

- Medical/First Aid services on-site

- Medical evacuation
- Communications with emergency services

#### **11.4 Environmental precautions**

- Fuel transfer and storage
- Garbage disposal
- Leaks from machinery
- Emergency response in case of fuel spill

## **12 E-NAVIGATION AND POTENTIAL FUTURE DEVELOPMENTS IN POLAR REGIONS**

### **12.1 Introduction to e-navigation in Polar Regions**

e-Navigation is a concept for the future of maritime navigation, which would make the relevant information available to the user, on board and ashore, in a coherent and efficient way (see 1.2 for definition). It is particularly applicable to Polar Regions because many e-Navigation services can be made available remotely without additional infrastructure on the ground. However, whilst positioning is currently in place, it is lacking in resiliency which needs enhancing. In addition adequate communications and information services have yet to be established.

The problems of Polar Regions that make operations there difficult, such as the environment – low temperatures, ice, storms, space weather effects; sparse or inaccurate surveys; lack of infrastructure – SAR/pollution control resources, can all be addressed to some extent by e-Navigation services.

The pressure to implement solutions is increasing with the effects on traffic and routes of more offshore exploration/onshore mining, with greater economic expectations and the severity of consequences of an accident.

The increasing number of ships using Northern routes brings an increasing requirement for services, to which is added the growth of tourism and cruises in these regions. However the overall low density of general users affects the viability of services and the standards of vessels can be very variable.

The flexibility of providing e-Navigation services, using a range of information, communications and positioning systems has the potential to meet requirements more cost-effectively than with conventional, fixed infrastructure. However, it should be emphasised that e-Navigation will not replace physical aids to navigation and a mix of systems is always likely to be needed.

Some e-Navigation services could have applications in Polar Regions in the immediate future and so the subject has been treated in some detail here.

### **10.2 Information systems**

#### **10.2.1 Existing situation**

Conventionally Maritime Safety Information (MSI) is delivered via SafetyNet, NAVTEX, local NavWarnings and Notices to Mariners, using a range of frequency bands from MF, through HF and VHF to L Band satellites.

#### **10.2.2 Digital MSI – ASM**

Digital information systems are a core part of e-navigation. However, currently there is only one general purpose digital communication means universally available – AIS ASM. It is likely, that other systems will be developed to provide e-navigation solutions in the future. However, it is essential that these systems be standardised by the relevant bodies (IMO, ITU, IHO etc).

#### **10.2.3 The Maritime Cloud**

Maritime Cloud is a concept being developed to connect all maritime actors in a communication framework with the aim of providing a single platform for all information exchange between all actors in maritime traffic. Its key components are:

1. Geo-messaging: how to exchange data
2. Maritime Identity Register: how to identify actors and solve security concerns
3. Maritime Service Portfolio Register: how to locate providers of services

In development of Maritime Cloud it is anticipated that Internet will become an important communication channel in e-navigation. For realising the targets set for the Maritime Cloud, a new geo-aware messaging protocol is proposed, a private overlay network to the Internet. Geo-awareness makes it possible to send and receive messages that are relevant to the exact location of the vessel.

Maritime Identity Register gives each vessel a unique identity code, similar to call-sign or MMSI, tied to the “ship keel” for the lifetime of the vessel, not fixed to a specific role or technology.

In essence Maritime Service Portfolio Register is an electronic meeting place where providers and users of services meet. Service providers maintain updated information of services and areas where the services are provided. Service users then make queries of services that they see relevant and valuable for them.

As a summary, Maritime Cloud is based on the notion of e-navigation as an infrastructure and services as “apps”. Services can be developed dynamically by any actor. Maritime Cloud is built on existing proven technology and can therefore be cost effective.

Maritime Cloud is currently used as the testbed infrastructure in the ACCSEAS project. The concept has also been submitted to the IMO e-navigation process as a proposed infrastructure supporting e-navigation.

#### 10.2.4 Arctic Web

Arctic Web is a web based approach to providing e-navigation services and solutions. As such it is not limited to any specific equipment or carriage technology. It focuses specifically on the Arctic region, aiming at gathering all relevant information and services for the Arctic. This includes e.g. provisioning of AIS data, allowing for coordinated passage/voyage or location of emergency support in distant areas as well as information on ice conditions (thickness, concentration, type etc.).

Both Maritime Cloud and Arctic Web take advantage of not just the latest technologies but also latest development methods and tools. They are based on open source code and are available for anyone for further development of the platform itself and additional services.

### 10.3 Information services

#### 10.3.1 Introduction

The lack of traditional Aids to Navigation in the polar regions, makes up to date maritime safety information imperative to safe navigation. Maritime Safety Information (MSI) means navigational and meteorological warnings, meteorological forecasts other urgent safety-related messages, (IHO definition). A system should be developed to reliably deliver all of this information to the navigator in near real time. Methods of delivery are limited by the vast geographical distances and limited bandwidth available. Study should begin on methods to increase transmission distance and interoperability of systems to display the information.

Other examples of information services to be developed could be Sea Traffic Management – dynamic route planning, QA for hydrographic data, global sharing of maritime information, for example user-shared ice-routing (it's almost always easier to break up refrozen brash than to open a new channel.)

Content of services – ice forecasts/warnings, met/hydro, space weather - all can be delivered in depth or detail tailored to and by the end user. Space should be made for user-created content i.e. a bulletin board of useful marine information.

Virtual AtoN – The IALA-organised Meeting on the Marking of Arctic Routes resolved that to 'establish safe and efficient maritime transport corridors in Arctic waters there is a need to develop and implement electronic maritime navigation, communication and traffic monitoring

infrastructure, including i.e. radio-navigation aids, GNSS, AIS satellite. Development of virtual aids to navigation is one solution that should be given strong consideration.’ It was recommended that IALA would support ‘the marking of polar routes and development of virtual aids to navigation’.

The Report to IMO NAV 59 on ‘Policy & Symbols for AIS AtoN’ noted that a ‘Virtual AIS AtoN is transmitted as a Message 21 representing an AtoN that does not physically exist. The competent AtoN authority should take every precaution to avoid confusion to the mariners. The AIS message should clearly identify this as Virtual AIS AtoN. Virtual AIS AtoN should not be used for permanently marking an object for which Physical AtoN would be possible, but, may be considered for marking an object or feature where it is difficult to establish a Physical AtoN due to environmental or economic constraints e.g. deep water, harsh sea conditions.

There needs to be further study and standardisation by IALA before moving forward with full implementation in the Arctic. Possibilities include terrestrial AIS via relays and satellite delivery. Issues include areas where charts are offset by a constant distance, or the incorrect datum is applied. In these cases, where does one put the virtual AtoN? Virtual AtoNs need not be limited to marking points. Lines could be used to delineate channels or, dynamically, the limits of ice sheets.

Integrity monitoring of the information broadcast is essential as no acknowledgement is built in.

## **10.4 Communications systems**

### **10.4.1 Introduction**

This section looks at the existing systems as required by SOLAS for sea area A4 (see ANNEX A). It then goes on to consider improved communication and dissemination of MSI (*Maritime Safety Information*) with ships operating in polar areas, through enhanced communication systems. These could be introduced over the next few years as part of e-Navigation.

### **10.4.2 Existing systems**

According to SOLAS Chapter IV, the systems required for operation in Sea Area A4 are:

- *VHF with DSC and distress alerting*
- *MF/HF radio installation*
- *SAR locating device,*
- *MSI through HF direct-printing telegraphy,*
- *Satellite EPIRB,*

And SOLAS Chapter IV *reg. 19-1*

- *LRIT Long-Range Identification and Tracking of ships*

For ships operating in Sea Area A4, HF radio remains the only viable system for communicating distress and safety information and MSI, because of limited coverage by recognized satellite systems. In spite of this and the fact that SOLAS requires that *each Contracting Government undertakes to make available appropriate shore-based facilities for space and terrestrial radiocommunication services, including services in the bands between 4,000 kHz and 27,500 kHz* (SOLAS chapter IV, regulation 5), many Administrations have closed down their HF radio stations, because of low traffic.

### **10.4.3 Future infrastructure needs**

Convention ships are not permitted to operate beyond the coverage of systems in which continuous alerting is available. Beyond the coverage of satellites in the Inmarsat system only HF is capable of fulfilling this obligation today. There is therefore a need to re-establish reliable communication to and from ships operating in polar areas for safety reasons.

Efficient, seamless and automated delivery of MSI should be a key objective of such communication in order to minimize distress situations. It should be noted that some urgent safety situations may require higher bandwidth solutions than available using AIS.

It is imperative to monitor all shipping traffic in polar areas to ensure its optimum safety.

#### 10.4.4 VDES (VHF data exchange system)

The future VDE (VHF Data Exchange) may become an efficient tool for communication and navigational safety in Polar Regions as well as other areas.

#### 10.4.5 HF Data

A new data communication system using 10-20 kHz bandwidth for data rates up to 51 kbps, has been incorporated in the Recommendation ITU-R M. 1798-1. Appendix 17 to the Radio Regulations as revised at the World Radiocommunication Conference 2012 (WRC-12). The revision of AP17 will implement new digital bands for 3 kHz systems as well as wideband systems.

#### 10.4.6 NAV DAT

NAV DAT is an MF radio system, for use in the maritime mobile service, operating in the 500 kHz band for digital broadcasting of maritime safety and security related information from shore-to-ship. It has the potential to transmit any type of text, graphs, pictures, data etc. with encryption if required, and automatic reception. The global architecture of NAV DAT is similar to NAVTEX and the coverage is approximately 250/350 NM from coast stations.

#### 10.4.7 eLoran

The enhanced Loran (eLoran) system is an experimental system that provides a data channel modulated onto the 100 kHz signals. The formats for this data channel currently available offer data rates below 100 bps although higher rate concepts have been proposed and the system has very long range (1000 km).

#### 10.4.8 Satellite AIS

Satellite AIS may provide part of the solution to the monitoring problem, but the ground infrastructure has still to be fully developed.

#### 10.4.9 Polar orbiting communications satellites

As an alternative to HF, AIS, VHF and Inmarsat, which are required to be carried on SOLAS convention ships, polar orbiting satellite systems could be used as a tool for enhanced safety in polar areas.

Though there are no recognized satellite services defined for Sea area A4, non-GMDSS satellites are available (or planned), some of which are described in ANNEX A.

#### 10.4.10 WiFi/WiMax/IMT/LTE

Private and public networks could be used for communications in local port areas and other inhabited areas, but would have limited coverage in polar regions and would not generally be available out of sight of land.

#### 10.4.11 Need for generic SD receiver

In future it should be possible to provide a software defined receiver that will operate with various systems across several bands. Such a concept would need to be standardised in the normal way, but could have operational and commercial advantages.

#### 10.4.12 LRIT

The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships of 300 GT or more. General requirements are contained in resolution A.694(17) for ship borne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids. In addition, the ship borne equipment should be capable of automatically and without human intervention on board the ship transmit the ship's LRIT information at 6-hour intervals to an LRIT Data Centre, Ref.: Resolution MSC.263(84), MSC.1/Circ.1307 and 1309

The LRIT system is only accessible to nominated authorities.

## **10.5 Positioning systems**

Reliable positioning is essential to almost all e-Navigation services and reliance on electronic positioning could be greater in Polar Regions than in other parts of the world, simply because physical AtoN are few and far between. This section looks at the possible limitations of GNSS in Polar Regions and the possible alternatives or backups that might be available.

### **10.5.1 Limitations of GNSS in Polar Regions**

Global Navigation Satellite Systems, in particular GPS, have become the primary means of maritime navigation. However, GNSS are known to be vulnerable to interference, both deliberate and accidental. The inclined Medium Earth Orbits of the present GNSS can also result in poor geometry at high latitudes. The extent of these problems has been investigated and it can be concluded that accuracy is unlikely to be a problem for users in high latitudes. However, integrity (the ability of a system to warn of a malfunction) can only be provided by Receiver Autonomous Integrity Monitoring (RAIM) and this is not available on many maritime GNSS receivers currently installed. Space Based Augmentation System, such as WAAS and EGNOS rely on Geo-stationary orbit satellites, which are not generally visible above 75 degrees of latitude at sea level. There are some ground-based, medium frequency DGPS stations in Northern latitudes, but coverage is very limited.

The problem of interference to GNSS is not likely to be any worse at high latitudes, although solar storms can cause occasional scintillation, loss of lock and increased errors. Interference from faulty equipment is a general problem, but of course the consequences could be more serious if there are no alternatives available.

### **10.5.2 Receiver standards**

Existing maritime receiver standards are more than ten years old and do not reflect current technology. In particular they were formulated for individual, standalone systems, whereas modern receivers generally employ two or more position sources. For these reasons and to support the concept of resiliency essential for e-Navigation, development of a multi-system receiver performance standard is underway at IMO. This should lead to a generic, 'required navigation performance' approach that will meet the integrity requirements that are lacking in present day receivers.

### **10.5.3 Racons**

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.

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 that highlights the range and bearing of the racon and uses a Morse character for identification. Range is dependent on mounting height, but is typically 20 NM.

It is likely that Racons will be able to operate in low temperatures and their shape will help prevent snow build up, however some additional protection may be needed.

Racons are used in the vicinity of Greenland and Svalbard and have operated there with no problems for many years. These Racons are powered via solar panels and battery banks; the power consumption is very low due to the limited number of passing vessels.

### **10.5.4 DGNSS**

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, navigation and time data (PNT). 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.

Ranges of stations are generally 100-200 NM. There are a few stations operational in Northern Norway and some in Northern Russia, but not sufficient to provide complete coverage of Northern routes.

#### 10.5.5 eLoran

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

eLoran is independent of 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. Ranges of individual stations are in the region of 1000km.

None of the currently operating Loran-C stations covering Arctic waters has been converted to eLoran and their future is uncertain. However, in combination with the existing Chayka infrastructure in Northern Russia, there is the potential to cover substantial parts of the Northern routes.

#### 10.5.6 Need to define requirements

The level of provision of radio-navigation systems in Polar Regions should be related to identified requirements – accuracy, availability, integrity, level of resilience. ANNEX B provides a suggested method of assessing those requirements.

### 10.6 Human Element – training

The Human Element is an essential consideration in e-Navigation. Introduction of new services and new ways of operating requires training and familiarisation and this will need to be tailored to the special conditions in Polar Regions.

10.6.1 Special features – ice, stormy weather, darkness, lack of coastal infrastructure, need for self-sufficiency, all require specialised training.

10.6.2 Ice navigation – need for sufficient knowledge of the area, weather, local communications, ice pilots – local knowledge, local competent person needed if not available among crew.

10.6.3 How should e-Navigation systems be adapted to local/regional needs? Location Based Services, such as the Arctic Web, can provide the information relevant to the user's needs for a particular area.

## 13 REFERENCE

### 13.1 Strategy and information references

- Resolution of the meeting between Canada, Denmark, Norway, the Russian Federation, the United States of America and IALA on 10-12 February 2010
- Wikipedia

### **13.2 Manuals on construction in cold regions**

- Construction in Cold Regions: A Guide for Planners, Engineers, Contractors and Managers by Terry T. McFadden, Editor John Wiley & Sons
- Geotechnical Engineering For Cold Regions by Andersland, O and Anderson, D, Editor McGraw Hill
- Effectiveness Of Geosynthetics For Roadway Construction In Cold Regions: Results Of A Multi-Use Test Section, by Hayden, Sara A, Humphrey, D N, Christopher, B R, Henry, K S and Fetten, C: Corporate Author: Industrial Fabrics Association International

### **13.3 Foundation manuals**

- Reference for the Canadian Foundation Engineering Manual

<http://www.cgs.ca/engineering-manual.php?lang=en>

### **13.4 Structural design codes**

- CSA-S37 (Canada) Reference for the CSA standard: S37-01 (R2011) - Antennas, Towers, and Antenna-Supporting Structures

<http://shop.csa.ca/en/canada/structures/s37-01-r2011/inv/27013452001>

### **13.5 Applicable IALA Guidelines and Recommendations**

### **13.6 e-Navigation references**

- Ice Navigation and the Electronic Age, Captain Patrick R. M. Toomey, Canadian Coast Guard (retired), 21 June 2012.
- Presentation on the Maritime Cloud and the Arctic WEB, Omar Frits Eriksson, the Challenges of Providing AtoN Services in Polar Regions, Ilulissat, Greenland, 30 September and 4 October 2013.

## **ANNEX A DEFINITIONS OF GNSS TERMS WITH REFERENCE TO POLAR ATON**

### **1.1 Sea Areas**

*Sea area A1* means an area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government.

*Sea area A2* means an area, excluding sea area A1, within the radiotelephone coverage of at least one MF coast station in which continuous DSC alerting is available, as may be defined by a Contracting Government.

*Sea area A3* means an area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite in which continuous alerting is available.

*Sea area A4* means an area outside sea areas A1, A2 and A3.

### **1.2 e-Navigation**

“E-Navigation is the *harmonized* 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.”

### **1.3 Geostationary Earth Orbit (GEO)**

Geostationary Earth Orbit (GEO) is in a circular orbit 35,786 km (22,236 mi) above the Earth's equator and rotates at the same speed as the earth's rotation. Because the Geostationary Earth Orbit satellite is over the equator, the typical communications coverage extends from approximately 70 degrees South to 70 degrees North. Depending on geographic location, the satellite coverage may extend further north and south. The only GEO satellites accepted by IMO as meeting the GMDSS requirements is the Inmarsat system.

### **1.4 Geocentric orbit**

Geocentric orbit is an orbit around the Earth and are usually classified by the satellite's altitude (i.e., Low Earth Orbit (LEO), Medium Earth orbit (MEO) and High Earth orbit (HEO)); the shape of the orbit (e.g., highly elliptical); and the area the orbit crosses (e.g., Polar orbit).

To provide effective, full-time communications over any given area, any LEO or MEO system requires a constellation of satellites. Some orbits, such as the Highly Elliptical Orbit (HEO) can be designed so that the satellite covers a region of the earth for a large fraction of its orbital period. For example, two HEO satellites could provide polar coverage.

### **1.5 Polar Coverage**

Two general types of satellite orbits that will provide Polar coverage: A constellation of satellites in low or medium earth orbit with sufficient number of satellites such that a satellite is in view at all times (e.g., Iridium) or a smaller number of satellites in a highly elliptical orbit (e.g., Molniya satellites used by Russia).

Note: Definitions of terms used in the guideline are contained in the IALA Dictionary which is available on the IALA web site.

## ANNEX B REQUIREMENTS FOR RESILIENT PNT

### 1.1 Background

At the 59<sup>th</sup> Session of the IMO Sub Committee on Safety of Navigation (NAV 59), there was consensus in the e-navigation Working Group on the need for Resilient Positioning Navigation and Timing (PNT). It was also agreed that requirements for Resilient PNT should be prepared as part of the Strategy Implementation Plan for e-navigation.

### 1.2 Approach

IMO Resolution A.1046(27) World Wide Radio Navigation System sets out the requirements for recognition of systems under the WWRNS. This Resolution does not distinguish between single systems that might meet the requirements by themselves and combinations of systems that might meet them together. This paper proposes that in addition to the parameters of availability, accuracy, integrity and continuity set out in A.1046, the limitations of each system should be assessed, such as vulnerability to interference, or coverage. By this means complementary systems could be selected to ensure overall resiliency is provided. This approach of considering the WWRNS as a compendium of systems fits in with the planned development by IMO of a Multi-system Receiver Performance Standard, a generic standard that will cover different systems and combinations of systems – specifying what is required, not how it should be done.

### 1.3 Requirements

The following table summarises the requirements set out in Resolution A.1046:

Region	Accuracy	Availability	Integrity	Continuity	Update rate
Ocean waters	100 m 95%	99.8 %	broadcast by MSI	-	2 sec
Harbours, harbour approaches, coastal waters	10 m 95%	99.8 %	broadcast within 10 s	99.97% in 15 minutes	2 sec

**Table 1** Requirements set out in Resolution A.1046

### 1.4 Assessments

It is proposed that the following table would be completed during system analysis and used to assess single systems and combinations of systems against the requirements, with the additional column recording limitations, so that these can be mitigated by combining with other systems:

Region	Accuracy	Availability	Integrity	Continuity	Update rate	Limitations
Ocean waters						
Harbours, harbour approaches, coastal waters						

**Table 2** System analysis and table to assess single systems and combinations of systems against the requirements

<sup>i</sup> IMO MSC 87/INF.15 –

<sup>ii</sup> Source: Wikipedia