



## Precise positioning services in the maritime sector

An estimate of the economic and social benefits of the  
use of augmented positioning services in the maritime  
sector

Prepared for the Department of Industry, Innovation,  
Climate Change, Science, Research and Tertiary  
Education

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## Executive summary

The maritime sector relies on accurate positioning for safe navigation and operation of ships in confined waters, in environmentally sensitive areas and for operations in the offshore oil and gas sector.

Position accuracy requirements vary according to the specific circumstances. In general position accuracy required is:

- 10 metre horizontal accuracy for general navigation
- 2.5 metres in ports
- 10 cm for marine engineering, dredging and hydrographic mapping
- 1 metre for tugs, cable, pipe laying and aids to navigation
- 1 cm for automatic docking.

Integrity is as important as position. Navigation standards specify a time to alarm of 10 seconds.

Positioning information from Global Navigation Satellite System (GNSS) is used in the current generation of shipboard devices such as the Automatic Identification System (AIS) and in Electronic Chart Display and Information Systems (ECDIS). GNSS is also used in many cases as the sole accurate timing reference on board a ship. These systems will be key elements of an e-navigation concept that international and national regulatory authorities are developing to further improve the safety of marine navigation.

The International Maritime Organization issued minimum maritime user requirements for positioning for marine navigation. To meet these requirements, augmented GNSS is required in ports and port operations, for dredging and cable laying, construction works and for marine aids to navigation (IMO, 2001). It is used by marine pilots for navigation in ports, docking activities and in under keel clearance systems. It is also used in the conduct of hydrographic and geophysical surveys. The offshore oil and gas sector uses GNSS for positioning work vessels and mobile drilling rigs.

Given the regulatory requirements for positional accuracy and time-to-alarm (integrity monitoring) it is difficult to envisage marine navigation without augmented GNSS for the above operations.

The economic and social benefits of navigation technologies relying on augmented GNSS include:

- Reducing the frequency of groundings in Torres Strait saving between \$0.6 million and \$0.8 million per year on average in clean up and salvage costs.
- Under keel clearance management systems to be introduced in 2013 which could deliver benefits of between \$10 million and \$13 million per year to the shipping industry by 2020.

- Savings in port infrastructure from improved channel tolerances reducing the cost of buoys and dredging by around \$1.8 million in 2012 and \$2 million in 2020.
- reduced environmental risks from oil spills estimated of around \$1.9 million in 2012 and \$3.4 million in 2020.
- Around 10 per cent saving in lost down time for geophysical surveys worth around \$5 million in 2012 and \$10 million in 2020.

The total amount attributable to the maritime sector total to around \$4.2 million in 2012 and 16.2 million by 2020. These amounts represent around 0.07 per cent and 0.30 per cent of total output from the maritime sector. The savings in seismic surveying have been attributed to the mining sector for the economic analysis.

### Key findings

- GNSS has become a component of position fixing for ships and will improve, replace or supplement existing position fixing systems some of which have shortcomings in regard to integrity, availability, control and system life expectancy.
- Augmented GNSS is used in many operations including navigation in ports and environmentally sensitive areas, operation of tugs, dredging and construction works, hydrographic geotechnical surveys and for offshore oil and gas operations.
- The maritime sector draws on all types of augmentation systems including the Differential GPS service provided by the Australian Maritime Safety Authority, RTK stand-alone, CORS networks where available and wide area space based services.
- There are a wide range of economic and social benefits that arise from the use of augmented GNSS in the maritime sector. The value of safety of life at sea and the protection of the marine environment against oil spills is very significant.
- The shipping industry is moving towards an e-navigation concept where a range of electronic and radio navigation technologies will provide safe and secure support for navigation by mariners. Augmented GNSS is one of the supporting technologies for e-navigation.

# 1 Introduction

ACIL Allen Consulting, in partnership with SKM and Lester Franks Surveyors and Planners, has been commissioned by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to assess the value of augmented positioning services in Australia. This report addresses the aviation sector.

The purpose of this report is to provide an understanding of the economic and social benefits of precise positioning information within the aviation sector. This information is to allow better informed decision-making and assist in identifying areas for growth and investment from both the private sector and government. It will also provide context to the National Positioning Infrastructure Plan being developed by Geoscience Australia.

## 2 The maritime sector

The maritime sector includes commercial ocean and coastal shipping (including the cruise ship sector, which is seeing growth in many parts of the world, including Australia), stevedoring, port and water transport operations, offshore construction and maintenance, and marine activities associated with geophysics, oil and gas extraction<sup>1</sup>.

The sector makes a significant contribution to the Australian economy through carriage of Australian trade. In 2010-12 Australia's exports by sea were worth \$222.6 billion and grew at an annual average growth of 10.7 per cent over the previous five years. Australia's imports by sea were worth \$160.9 billion and increased at an annual average rate of 5.5 per cent over the previous five years (BITRE, 2012).

Important sub-sectors of the shipping industry also operate in areas of high environmental value. The Great Barrier Reef Marine Park and Torres Strait are important sea lanes for transport of bulk commodities, petroleum, containerised goods and for tourism. Safety of navigation in the environmentally sensitive and navigationally challenging waters of the Great Barrier Reef and Torres Strait is critical.

## 3 Positioning requirements in the maritime sector

The maritime industry is truly an international one and where requirements for the safety of navigation are established by the International Maritime Organization (IMO) of which Australia is a founding member. Member States

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<sup>1</sup> The maritime sector as described above is captured in Divisions B (Mining) and I (transport) in the Australian and New Zealand Standard Industry Classification.

of the IMO have recognised the need for a civil and internationally controlled global navigational satellite system (GNSS) provision of navigational position-fixing for maritime purposes throughout the world for general navigation and for navigation in restricted waters such as ports and passages (International Maritime Organization, 2001).

The IMO has recognised that GNSS will improve, replace or supplement existing position fixing systems some of which have shortcomings in regard to integrity, availability, control and system life expectancy.

The requirements for position accuracy, integrity and service levels vary according to the type of marine activity involved. Reliability and integrity are also important criteria for safety of navigation. Integrity is the ability to provide users with warnings within a specified time when the system should not be used for navigation<sup>2</sup>. Alert limit is the magnitude of positional error before a warning is issued. A summary of these requirements set by the IMO is outlined below and a full description is provided in section Appendix C.

The IMO requirements for general maritime navigation are 10 metre horizontal accuracy and 1 metre in ports. A more important criterion is integrity where the time to alarm for an outage is 10 seconds and the alert limit is 25 metres for general navigation and 2.5 metres for ports. Accuracy for activities such as docking is generally more demanding. The horizontal accuracy required for automatic docking is 1 cm. Accuracy requirements for tugs and icebreakers is 1 metre. In each of these cases the integrity requirements are a time to alarm of 10 seconds and an alert limit of 2.5 metres.

Horizontal accuracy for marine engineering is 10 cm for dredging and construction works and 1 metre for cable and pipeline laying and for management of aids to navigation. Integrity requirements for these activities are 10 seconds time to alarm with alert limits of 25 cm for dredging and construction works and 2.5 metres for cable laying and management of aids to navigation.

Hydrographic mapping also requires accuracies of around 10 cm.

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<sup>2</sup> Integrity monitoring is the process of determining whether the system performance allow use for navigation purposes. Overall GNSS system integrity is described by three parameters: the threshold value or alert limit, the time to alarm and the integrity risk. The output of integrity monitoring is that individual (erroneous) observations or the overall GNSS system cannot be used for navigation (International Maritime Organization, 2001).



## 4 The value of applications in general shipping

### 4.1 Economic Benefits

Augmented GNSS supports a range of technologies, service and systems that deliver benefits in the maritime sector. This includes reducing maritime accidents and groundings, lowering environmental risk factors, reducing the incidents and risks of oil spills and reducing the infrastructure costs for ports.

Safety of navigation depends on the reliability of human decision making supported by aids to navigation. Accidents and groundings potentially endanger the environment and also create costs for administrations and the industry in clean-up of any resultant pollution (e.g. oil spills) or management of incidents when they arise.

The cost of oil spills varies. Recent evidence in Australia demonstrated that a significant oil spill could cause costs in salvage and clean-up of around \$30 million<sup>3</sup>. A serious oil spill would be catastrophic if it occurred in the Great Barrier Reef Marine Park.

The Great Barrier Reef region supports a variety of commercial and recreational activities including fishing, tourism and recreation worth in excess of \$5 billion per annum to the Australian economy. The shipping of bulk cargoes and petroleum transport through the reef accounts for some \$17 billion of Australia's export trade. (Access Economics, 2005). With the commencement of LNG shipping from Gladstone in 2014 this value will increase significantly.

This economic activity depends on safe shipping operations in the Great Barrier Reef Marine Park as well as Torres Strait. Augmented GNSS contributes to safer shipping operations in these waters and plays an important supporting role underpinning these economic activities. It does so in many ways.

For example, a study Under Keel Clearance (UKC) commissioned by the Australian Maritime Safety Authority in 2008 examined the use of UKC management systems in the Torres Strait and Great Barrier Reef. UKC systems in this area also rely on augmented GNSS. This was shown to deliver potential savings to the bulk shipping sector of between \$10 million and \$13 million per year (Thomson Clarke, March 2007). Augmented GNSS plays a supporting role with portable pilot units for UKC management systems in these areas.

Augmented GNSS can in some cases deliver lower costs for port operations. An unpublished study prepared for the Queensland Department of Natural

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<sup>3</sup> See later discussion in section 5.3.

Resources and Water in 2007 reported that augmented GNSS pilotage systems and improved channel tolerances had reduced the need for buoys in a major Queensland coal port, saving around \$4 million in capital costs. It would be reasonable to assume that other similar ports are also realising benefits. Assuming similar savings are possible in around 5 similar ports in Australia this could save around \$1.8 million per annum in depreciation and maintenance.

## 4.2 Navigation and GNSS

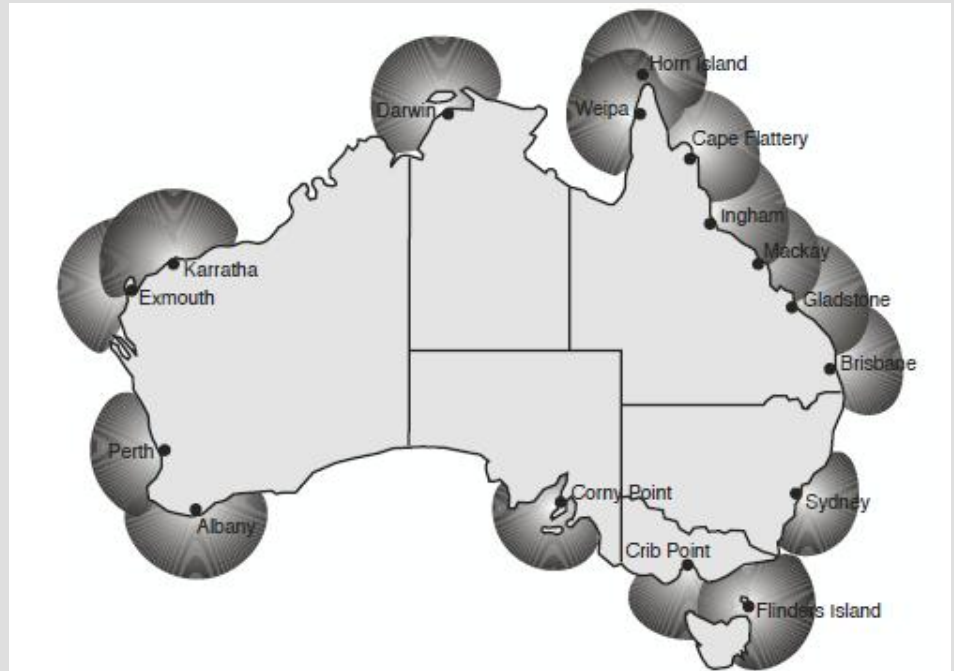
The task of marine navigation has been subject to considerable technological change over the past decades. Mariners rely on several sources of information to locate their position. This includes celestial navigation, light houses, radar and radar enhancers, radionavigation systems and GNSS. Celestial navigation has more or less been replaced by GNSS. The shipping industry has become increasingly dependent on GNSS over the past decade with GNSS becoming the primary means of position determination (AMSA, March 2012).

Positioning and timing from GNSS are used in the current generation of shipboard devices such as Automatic Identification Systems (AIS) and Electronic Chart Display and Information Systems (ECDIS). Augmented GNSS is also used in many cases as the sole, accurate timing reference on board ships. Augmented GNSS is required in any area discussed above where position accuracy of 1 metre or less are required.

The Australian Maritime Safety Authority manages a system of sixteen Differential GPS (DGPS) beacons around the Australian coast to provide augmented GNSS signals (see Box 1). Commercial services are also used by marine pilots as discussed in Section 4.3 below.

### Box 1 **AMSA's DGPS service**

AMSA's DGPS service provides a network of radio beacons that improve the accuracy and integrity of the GPS signal around selected areas of the Australian coast. The service is primarily intended for levy-paying commercial shipping.



The service has been proven to provide accuracy of between 2 to 4 metres for most circumstances compared with stand-alone GPS accuracy of between 13 to 22 metres. Integrity monitoring is an important feature of DGPS. The stations test for GPS signals that are out of specification and immediately notify users to disregard the signal. With DGPS the signal out warning occurs within a few seconds of a satellite becoming faulty. This could take up to 12 hours with stand-alone GPS.

*Source:* (AMSA, 2012)

The AMSA GNSS provides coverage of major ports and the Great Barrier Reef and Torres Strait. RTK and CORS services are also sometimes used in coastal applications for specialist surveying activities. These services, in conjunction with other navigation and vessel tracking systems, underpin safer navigation, lower risks of groundings and collisions and facilitate more efficient port operations. Economic benefits accrue from lower operating costs in ports, improved productivity in the ship operations and lower environmental damage costs.

To understand how these benefits arise, it is first necessary to first consider the framework within augmented GNSS relates to other navigation and monitoring systems in the maritime sector.

#### **4.2.1 Electronic Chart Display Information Systems (ECDIS)**

ECDIS represents one of the most significant changes in maritime navigation in recent years. The IMO has mandated carriage of EDCIS on larger passenger ships, tankers and cargo ships engaged on international voyages. The provision

of accurate and reliable position, navigation and timing (PNT) is a core requirement for the operation of ECDIS.

Precise positioning provided by augmented GNSS signals is particularly important for use of ECDIS in marine sensitive areas such as the Great Barrier Reef and for port approaches and navigation in restricted areas. ECDIS systems can incorporate warning signals that are activated if a vessel ventures into dangerous waters. Such systems require reliable position accuracy and high levels of integrity that only augmented GNSS.

#### **4.2.2 AIS**

AIS is a ship-to-ship and ship-to-shore data exchange system that exchanges information on identity, position, course, speed and other ship information, automatically and continuously between mobile and fixed AIS stations. The IMO requires the majority of the international fleet to carry AIS and it is also increasingly being used by smaller commercial and recreational vessels.

AIS is being used for other applications as well including vessel tracking systems, as a further aid to navigation, for management of under keel clearance, assisting in responding to oil spills and for search and rescue operations. It is a framework that contributes to lowering the risk of maritime accidents and environmental damage.

AIS depends on reliable PNT<sup>4</sup> information for which the most cost effective technology is augmented GNSS<sup>5</sup>.

### **4.3 Pilots**

The most hazardous part of any ship's voyage is the transit through a port or an environmentally sensitive area. Within port limits, where the margins of safety are greatly reduced, the chances of collateral damage costs are very high. The added precision and integrity monitoring that DGPS provides is considered critical for the provision of safe pilotage with the use of PPU technology.

A growing trend is for pilots to use Portable Pilot Units (PPU) which increasingly use augmented (GNSS) (see Box 2). The increased accuracy is not necessarily used in a direct sense, (most pilots are looking out the window or over the side for the last few metres of positioning accuracy), but the biggest benefit for increased positional accuracy is through the consequent improvement in velocity, being a derivation of position changes over time. The more accurate the knowledge of position each second, the more accurate the knowledge of velocity will be.

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<sup>4</sup> PNT stands for Position Navigation and Timing

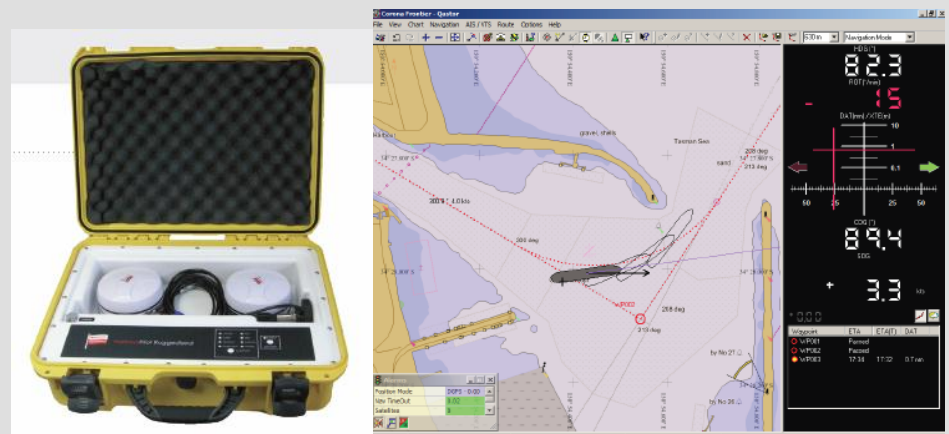
<sup>5</sup> The alternative to augmented GNSS is highly accurate but expensive atomic clocks.

According to a survey of the Australian Marine Pilots Association and Marine Ports Australia, augmented GNSS is used by pilots in ports in Queensland, Port Philip Bay, Fremantle, Dampier, Port Headland, Flinders Ports, Albany and ports in Northern Tasmania. Some use the AMSA DGPS service while others use commercial services or establish their own reference stations<sup>66</sup>.

This use is likely to increase as the technology of portable pilot systems improves and the requirement for safer navigation and applications such as under keel clearance management systems are introduced.

#### Box 2 **Portable pilot units**

Portable pilot units incorporating augmented GNSS capability are increasingly being used by marine pilots for navigation in ports and constrained waters and in the Great Barrier Reef Marine Park



Source: (Navicom Dynamics, 2013)

Economic value is created when accurate position information is added to the information in portable pilot units which supports better decision making in port manoeuvres, in environmentally sensitive areas and when docking.

<sup>66</sup> Personal communication

## 4.4 Under keel clearance

The economic benefits of under keel clearance were discussed previously. To ensure sufficient under keel clearances (UKC) of ships transiting Torres Strait, the current maximum draught for piloted ships is 12.2 metres. Ships with a draught of 12.2 metres are able to pass through Torres Strait within a tidal window on any day of the year whilst maintaining the required UKC. Tidal windows are restricted to periods around times of high water.

UKC management systems have been developed that provide more accurate information on under keel clearances that allow mariners to operate with smaller under keel clearances whilst at the same time maintaining an adequate safety margin. UKC systems require precise positioning and high levels of reliability. Augmented GNSS is used in the Portable Pilot Units that support UKC systems.

AMSA has introduced a UKC management system for use by coastal pilots on board ships transiting Torres Strait. The economic benefits have been outlined earlier in this report.

# 5 Monitoring and control

## 5.1 Benefits

Vessel Tracking Services (VTS) and Automated Ship Reporting have been important in improving the safety and reliability of ships sailing in Australian waters. This has delivered economic benefits to the shipping industry by reducing the risk of maritime accidents and groundings and reducing the risk of environmental damage from oil spills. They rely on augmented GNSS for sailing in most parts of Australian Coastal waters.

Since the introduction of the REEFVTS the average number of groundings in the Great Barrier Reef and Torres Strait has fallen from 1.42 per 10,000 transits to 0.15 groundings per 10,000 transits. This reduction is attributed to REEFVTS providing timely and accurate information to assist on-board decision making by the officers on the bridge (see Figure 1).

**Box 3 REEFVTS**

The Queensland and Australian Governments established REEFVTS in 2004. Its purpose is to:

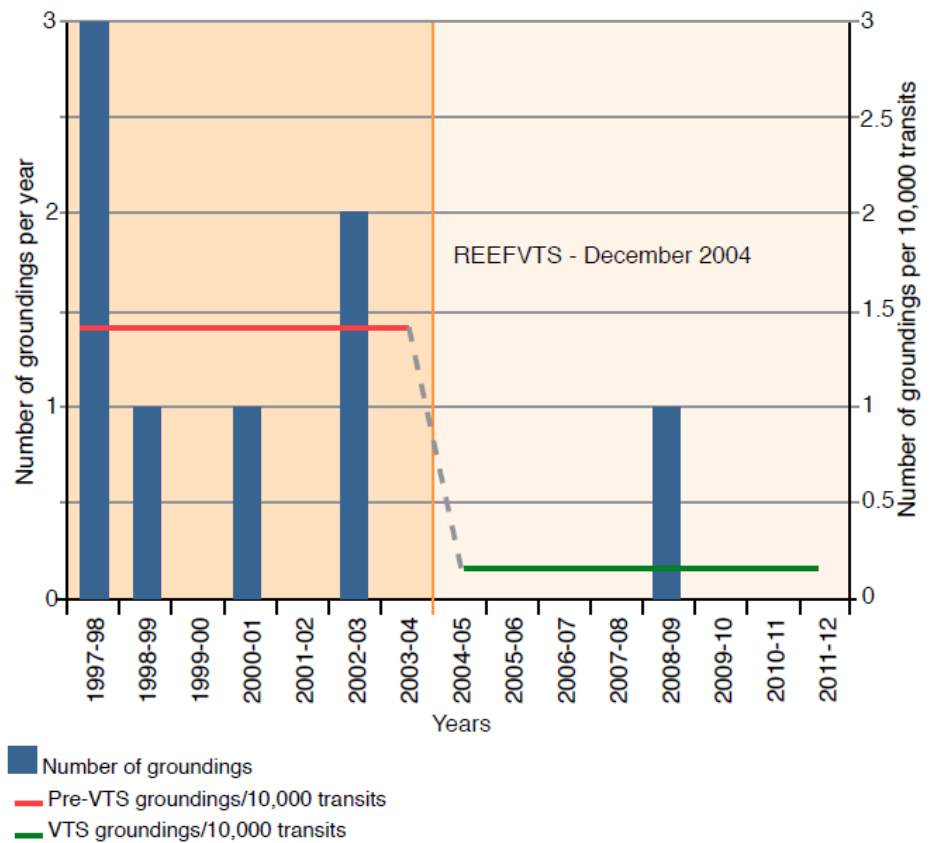
- make navigation in Torres Strait and the inner route of the Great Barrier Reef safer by working with shipping to give better information on possible traffic conflicts and other navigational information
- minimise the risk of maritime accidents, and therefore avoid the pollution and damage which such accidents can cause to the marine environment in the Great Barrier Reef and Torres Strait
- respond quickly if a safety or pollution incident does occur.

REEFVTS is operated jointly by the Australian Maritime Safety Authority (AMSA) and Maritime Safety Queensland (MSQ). AMSA is an agency of the Commonwealth Government; MSQ is an agency of the Queensland State Government. REEFVTS operates 24 hours a day from the VTS Centre, situated at Townsville on the Queensland coast.



Source: (AMSA, July 2011)

Figure 1 **Groundings since the introduction of REEFVTS**

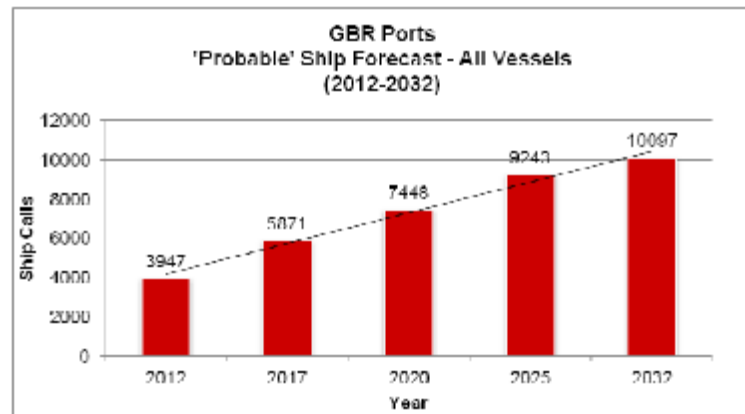


Data source: (AMSA, 2012)

In 2009-10, there were approximately 10,000 ship movements in the Great Barrier Reef involving some 3,500 ships<sup>7</sup>. The number of ships transiting the area is expected to increase at around 4 per cent per year as shown in Figure 2.

<sup>7</sup> Movement' meaning the passage of a ship to, from or between GBR ports, or on passage through the GBR region en route to or from ports outside of the GBR region.



Figure 2 **Estimates of vessel calling in regional ports.**

Data source: (PGM Environment, 2012)

The cost of groundings varies depending on the extent of damage. At a minimum costs are incurred by the shipping company in lost days and by the authorities who arrange towing and any clean-up. Charter rates for large bulk carriers are around \$50,000 to 100,000 per day (HANSA, 2013).

The seriousness of groundings varies widely but if it is assumed that on average grounding might take a vessel out of action for between 3 and 10 days per grounding the introduction of the REEFVTS would have reduced the average annual cost of groundings by between \$200,000 to \$800,000 as a result of the introduction of REEFVTS. As mentioned earlier, REEFVTS is supported by the GNSS augmentation signal broadcast from the AMSA beacons in the Torres Strait.

A grounding or accident which involved an oil spill would have far more serious consequences.

## 5.2 Vessel Traffic Services (VTS)

Vessel Traffic Services (VTS) are shore-based systems which range from the provision of simple information messages to ships, such as the position of other traffic or meteorological hazard warnings, to extensive management of traffic within a port or waterway. They require accurate position information with high reliability. Generally, ships entering a VTS area report to the authorities, usually by radio, and may be tracked by the VTS using radar, Automated Identification System (AIS) and other technologies, most of which are supported by augmented GNSS.

The benefits VTS derive from the fact that it allows identification and monitoring of vessels, strategic planning of vessel movements and provision of navigational information and assistance. VTS can also assist in prevention of pollution and co-ordination of pollution/emergency response. VTS has the capability to interact and influence the decision-making processes on board ships. As such it reduces the potential for errors in navigation leading to incidents and accidents and helps manage the environmental risk associated

with oil spills. As approximately 80% of maritime accidents can be attributed to the human factor, there is considerable benefit from interaction between the ship and VTS as an additional safeguard for safe navigation. (AMSA, July 2011) (IMO, 2009)

### **5.3 Automated ship reporting**

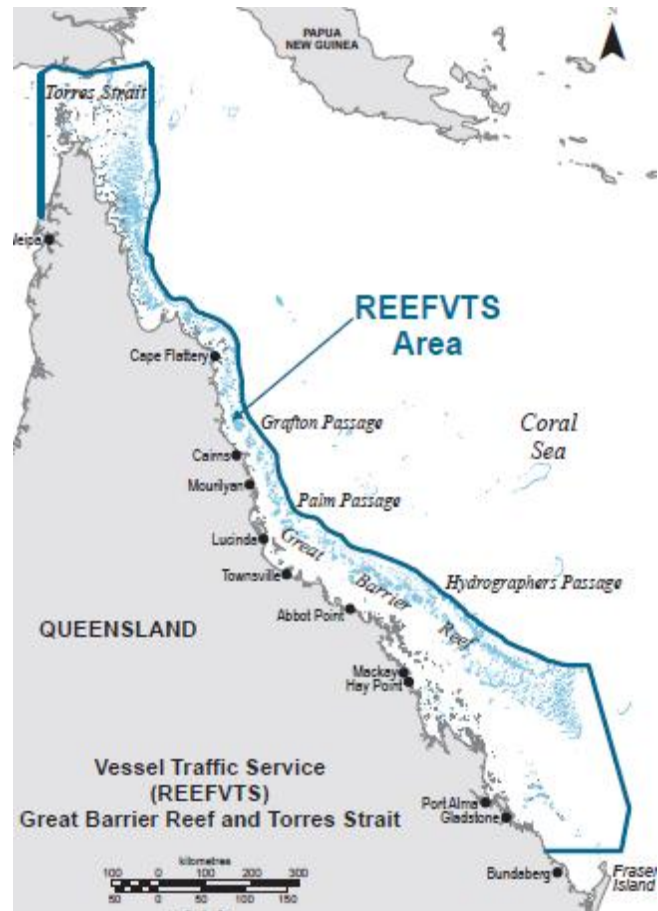
Automatic ship report (AIS) systems Australia produce significant economic benefits through safer shipping, lower numbers of groundings and lower risk of environmental damage from oil spills.

Automated ship reporting operates around the Australian coast providing AMSA with periodic updated reports of a vessels track and speed. The MASTREP system provides reports around the coast while the REEFREP monitors vessels travelling through the Great Barrier Reef and Torres Strait.

The AMSA DGPS service provides enhanced position accuracy and most importantly integrity monitoring of the GPS signal in the REEFVTS area to ensure that the ships are notified if the GPS signal is out of specification and should be disregarded. With the DGPS service these warnings are generated within a few seconds of a satellite becoming unhealthy.

The higher level of positional accuracy and performance integrity is critical for monitoring movements of ships through constrained shipping lanes and environmentally sensitive areas such as the Torres Strait and the Great Barrier Reef. Groundings and potential oil spills in the Great Barrier Reef area would have significant environmental and clean-up costs. Minimising the possibility of such events minimises related clean-up and compensation costs to industry and government and minimises environmental damage in a world heritage area which also supports an important tourism industry.

Figure 3 REEFVTS area



Data source: (AMSA, July 2011)

As discussed previously, the environmental costs of oil spills are extremely high in any area of Australia's coastal seas. Costs involve downtime of ships, the cost of clean-up, and the cost of towing if necessary. In addition there are significant environmental damage costs.

The grounding of the Shen Neng 1 in 2010 resulted in loss of about four metric tonnes of oil into the sea. The Shen Neng 1 did not break up and the spill was dispersed with chemicals. The incident MV Pacific Adventurer in Moreton Bay in 2009 however resulted in a more significant oil spill (around 270 tonnes) and clean-up costs of over \$ 30 million. If such an event occurred in the Great Barrier Reef, the clean-up costs would have been significantly higher.

An assessment of the costs of oil spill risk in the Great Barrier Reef Marine Park was undertaken in 2011 by DNV. The assessment took into account the use of VTS, traffic separation schemes, double hull protection and compulsory pilotage (see section Appendix B). The net risk was assessed as \$9.1 million per year and to increase to \$17 million by 2020. The assessment assumed a 79 per cent growth in national traffic between 2011 and 2020 but did not include growth in shipments of LNG through the GBR Marine Park.

It would not be unreasonable to assume that this assessment would have been around 20 per cent higher without systems supported by augmented GNSS. This would imply a value of around \$1.8 million in 2012 and \$3.4 million in 2020.

## **6 Offshore oil and gas operations**

### **6.1 Benefits**

The use of augmented GNSS in bathymetry and in offshore oil and gas operations has multiple benefits. More accurate bathymetry improves marine charts and safety of navigation. Augmented GNSS enables more efficient and lower cost bathymetry compared to other methods.

Augmented GNSS also increases the efficiency of some offshore oil and gas operations. One large offshore as producer estimated that the use of augmented GNSS in survey operations saves around 10 per cent in lost downtime. This would be equivalent to annual savings of between \$5 million and \$10 million in savings per years.

Other benefits derive from the use of augmented GNSS in dynamic position of vessels and in positioning mobile oil drilling platforms.

#### **6.1.1 GNSS in offshore oil and gas operations**

Offshore oil and gas operations require positional accuracy for exploration, drilling, construction, production and operations. The operating environment is high risk and is generally in remote waters. The cost of accidents is high both in financial and environmental terms.

They also require precise positioning to locate mobile drilling rigs, to support survey and geotechnical vessels and to dynamically position vessels during construction and maintenance operations. This requires accuracy at the sub metre level and high levels of reliability and integrity.

Augmented GNSS has become an enabling technology in conjunction with electronic and radio navigation systems and control systems for dynamic positioning of vessels, mobile drilling rigs and survey and geotechnical vessels.

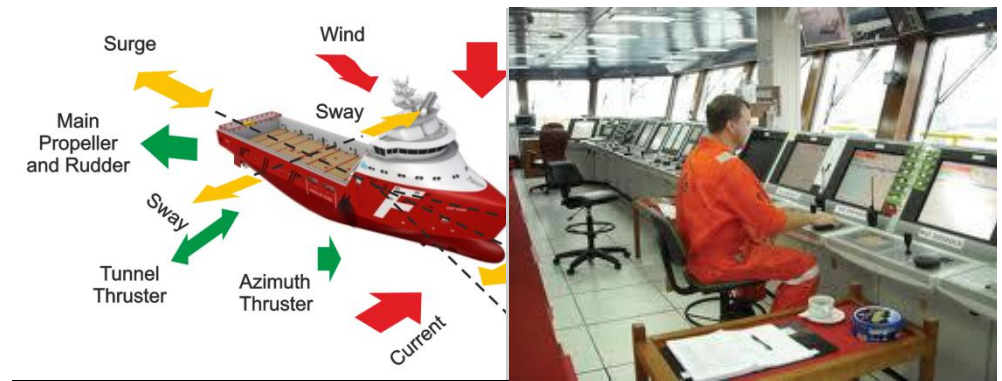
### **6.2 Dynamic Positioning**

Dynamic Positioning (DP) is a method for the station-keeping or precise positioning of special purpose marine vessels. A DP system seeks to maintain the vessel's position and orientation at a level of specified accuracy and reliability by compensating for the dynamic effect on the vessel of displacing forces such as wind, wave, and current (refer to figure 4). The core DP positioning technologies of augmented GNSS and inertial measurement units (IMU) are integrated with other sensors in a real-time navigation computer to

provide precise and automated commands to the vessel's multi-directional thrusters.

In general, a DP-capable vessel can complete a work program more efficiently than a conventionally positioned vessel. It also minimises the potential for damage to the environment or sub-sea infrastructure from the use of anchors.

Figure 4 **Dynamic positioning**



Data source: Wordpress

A typical scenario where DP is used is a Diving Support Vessel that has to work on sub-sea infrastructure installed adjacent to an oil platform. The DP system allows the vessels to move efficiently around the platform, and any other exclusion zone, safely and efficiently and without the use of anchors and trailing mooring lines that increase the risk of entanglement. DP may also eliminate the need to install acoustic positioning units on the sea floor. The installation of anchors and acoustic systems is time consuming and has significant logistic and safety risks, and so in these situations DP has both cost and risk management benefits.

DP systems are increasingly used in offshore oil and gas operations off the Australian coast for the positioning of mobile drill rigs, survey and geotechnical vessels, tugs and platform service vessels where the ability to control the position and orientation of the vessel is mission critical.

## 6.3 Survey and geotechnical

### 6.3.1 Hydrographic surveys

Hydrographic surveys depend on augmented GNSS for coastal/port areas. The majority of the work uses RTK GNSS or post-processing, where infrastructure is available, to support this work to the required accuracy. Wide Area DGPS is used for offshore work<sup>8</sup>.

With LIDAR (both for bathymetric and land) now being used extensively for coastal work, environmental modelling for climate change and flood

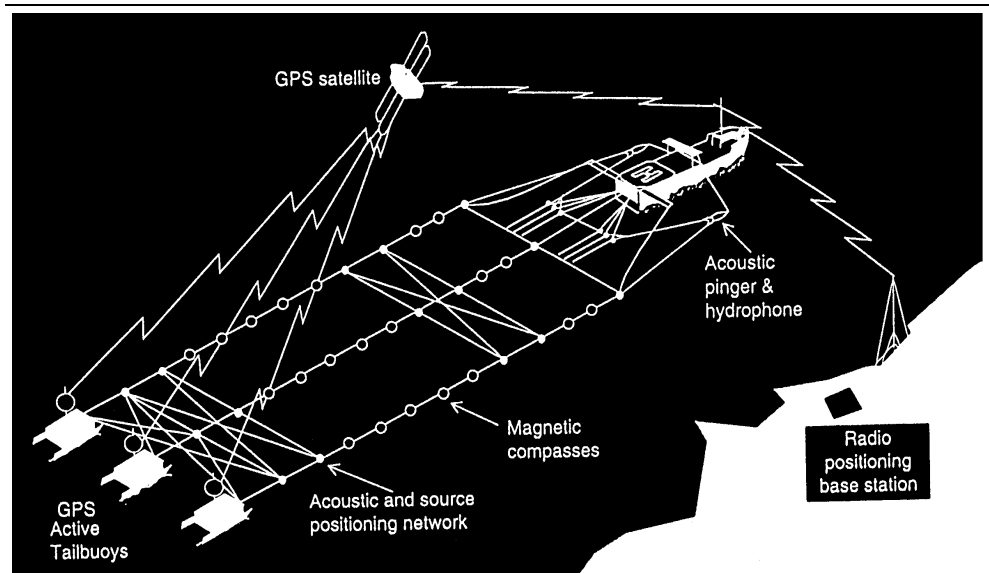
<sup>8</sup> Personal communication from the Australian Hydrographic Service.

management, there is an emerging need for a tool to allow better merging of bathymetry with land information in the intertidal zone. The key linking factor between these two is augmented GNSS. It is a common vertical reference datum that is used for both land and marine mapping. This is a future development requirement (Keysers, 2013).

### 6.3.2 Geotechnical surveys

The early stages of exploration for offshore oil and gas involve surveys run from specially equipped seismic survey vessels. These vessels broadcast sound waves that when reflected back from sedimentary layers beneath the seabed provide data that assists geologists interpret the sub-seabed geological structures (see Figure 5).

Figure 5 **Seismic survey**



Data source: Woodside

The track of the survey vessel must be known with high accuracy and reliability in order to map the results for subsequent analysis. If the survey vessel's position is not recorded correctly the resulting analysis can be degraded.

Augmented GNSS is used by these vessels to provide an accurate record of the survey tracks. Industry consultations indicated that the greater precision with augmented GNSS resulted in more accurate outcomes and better results than with stand-alone GNSS.

## 6.4 Mobile drilling rigs

Deepwater exploration for oil and gas is undertaken by mobile drilling rigs. These are large floating pontoons that can be towed from location to location. Once in position the drilling platform is anchored in place while drilling operations proceed.

Mobile drilling rigs require high levels of positioning precision both in terms of horizontal accuracy and reliability. Their location is important as drilling operations are directed from their platforms and high levels of certainty and precision are required to direct the drill lines and accurately record the location for analysis of results.

Stand-alone GNSS does not provide the level of positional accuracy or reliability and integrity for location of mobile drilling rigs. The alternative approach would involve additional set up costs to position the drilling rig prior to anchoring to the sea bed.

## 7 Future directions – e-navigation

The most recent developments under consideration by the Maritime Safety Committee of the IMO in its work on navigation, radio communications and search and rescue is the development of an e-navigation strategy. The aim of the e-navigation strategy is to integrate the existing and emerging navigation tools and in particular electronic tools including GNSS and augmented GNSS to enhance future navigation safety. ( IMO, July 2007).

This development recognises that the majority of collisions or groundings are caused by human error and the cost of these (to both companies and administrations) is rising each year (Lemon, 2010).

E-navigation has the potential to deliver improvements through the integration of ECDIS, GNSS, AIS and radar, along with improved links between ship and shore. Precise GNSS is a basic component of this technology mix in the areas identified earlier in this report.

### 7.1 Benefits

Augmented GNSS is an enabling technology that has a place in future e-navigation solutions. E-navigation systems in turn are an aid to navigation decision making by officers on the bridge. A search of literature did not identify any economic studies of the possible economic benefits of e-navigation. However one paper suggests e-navigation could improve the reliability of human decisions on the bridge by a factor of 10 (IMO, 2009). Better decisions reduce the risk of marine accidents, and oil spills. As discussed earlier the economic and environmental costs of oil spills can be extremely high.

## 8 Economic and social impacts

It is also difficult to envisage a maritime sector without augmented GNSS. The regulatory requirements for the use of augmented GNSS in navigation aids and with systems such as ECDIS, VTS and AIS, are established under an international framework. These requirements were introduced over the years in

recognition of the economic and social values associated with safety of navigation.

Attribution of benefits arising from augmented GNSS must take into account the fact that it is an enabling technology in most cases incorporated into other navigation systems. The economic and social benefits include intangible but significant benefits from safety of life at sea, protection of the marine environment and in particular reducing the risk of maritime accidents and oil spills.

Direct economic benefits include reduced costs for the shipping industry from more efficient pilotage in ports and harbours, lower average annual cost of downtime from accidents, lower average costs of oil spills and support for trade conveyed by shipping through environmentally sensitive areas.

A list of potential economic and environmental benefits of applications in the maritime sector is provided in Table 1. These estimates represent only benefits that we have been able to quantify. They are therefore considered to be conservative.

Table 1 **Estimates of the benefits derived from navigation technologies dependent on augmented GNSS**

Sector	Application and benefit	2012	2020
Shipping industry	Reduced costs of maritime accidents.	Reduced costs of groundings. <b>\$0.6 million</b> savings in lost time reported in Section 5.1.	Reduced costs of groundings. <b>\$0.8 million</b> based on savings reported in section 5.1 Full development of e navigation is estimated to have the potential to improve decision making on the bridge by a factor of 10. (Section 7.1).
	Greater shipping capacity through the Torres Strait with under keel clearance technologies	Not applicable in 2012.	<b>Between \$10 million and \$13 million per year</b> (Thomson Clarke, March 2007). Section 4.1.
Ports	More precise pilotage and improved channel tolerances reducing the cost of buoys and dredging.	Savings of around <b>\$1.8 million</b> per year. (Section 4.1)	Benefits likely to grow slowly as demand on major ports increases with LNG and other minerals exports increase. Savings of <b>\$2 million</b> per year assumed. (Section 4.1)
Offshore oil and gas industry	Lower costs in seismic surveys, positioning mobile drilling platforms and from dynamic positioning	<b>Savings of \$5 million per year.</b>	<b>Savings of \$10 million per year.</b>



Sector	Application and benefit	2012	2020
Fishing, tourism and resources industries	Improved safety in the Torres Strait and GBR marine park reduces risk of loss of income from maritime accidents, groundings and oil pollution and spills.	The value of augmented GNSS as a navigation support service for vessel track and VTS is in part in ensuring that this trade can continue.	Value of trade in the Torres Strait is likely to grow by at least 70 per cent by 2020 based on studies (Thomson Clarke, March 2007) (BITRE, 2012)
The environment	National Plan to Combat Pollution of the Sea by Oil and other Hazardous Materials. Established in 1975. (AMSA, October 2012)	Oil spill risk of <b>\$1.8 million</b> (ACIL Allen estimate based on impact of VTS on groundings). Section 5.3.	Oil spill risk of <b>\$3.4 million</b> (ACIL Allen estimate based on impact of VTS on groundings). Section 5.3.
Total quantifiable benefits to shipping industry	All benefits apart from offshore geophysical surveys are attributable to the shipping industry. Geophysical surveys are reported in the mining sector.	Total quantifiable benefits identified above total around <b>\$4.2 million</b> . This equivalent to around 0.07% of sector output.	Total quantifiable benefits identified above total around <b>\$16.2 million</b> . This equivalent to around 0.30% of sector output.

*Note:* Estimates are based on studies and consultations with industry and government.

*Data source:* Data in the table is compiled from information included in the report.

The last row shows the benefits from applications of augmented GNSS that we consider can be attributed to the maritime sector. The last row shows that the total benefits are estimated to be around \$4.2 million in 2012 and 16.2 million by 2020. These amounts represent around 0.07 per cent and 0.30 per cent of total output from the maritime sector.

The most value of augmented GNSS in the maritime sector is its contribution to safer navigation, improved safety of life at sea and protection of the marine environment. The value of the latter is difficult to estimate with certainty. However the potential social and environmental benefits are likely to be significantly higher than the direct economic benefits.

## Appendix A Glossary of terms

Term	Meaning
AIS	Automatic Identification System
AMSA	Australian Maritime Safety Authority
AUSVTS	Australian Vessel Traffic System
ECDIS	Electronic Charting and Display Information System
GBR	Great Barrier Reef
GNSS	Global Navigational Satellite System
GPS	Global Positioning System – originally the term for the US Navstar GNSS
IMO	International Maritime Organisation
PNT	Position Navigation and Timing
PPU	Portable Pilot Unit
REEFVTS	Vessel Traffic System in the Torres Strait and Great Barrier Reef Marine Park
UKC	Under Keel Clearance
VTS	Vessel Traffic System

## Appendix B National Plan for Combat of Oil Pollution at Sea

### B.1 Background

The National Plan was established in 1973 as a national integrated Government and Industry organisation framework enabling an effective response to marine pollution incidents. The plan provides a national framework for responding promptly to marine pollution incidents by maintaining:

- National Marine Oil and Chemical Spill Contingency Plans
- Detailed state and industry contingency plans
- Strategically placed response equipment
- National training programs (AMSA, October 2012).

### B.2 History of oil spills in Australia

Table 2 History of oil spills

Date	Source of Spill	Location	Spill volume
28/06/1999	Mobile Refinery	Port Stanvac, SA	230 tonnes
26/07/1999	MV Torungen	Varanus Island, WA	25 tonnes
03/08/1999	Laura D'Amato	Sydney, NSW	250 tonnes
18/12/1999	Sylvan Arrow	Wilson's Promontory, VIC	<2 tonnes
02/09/2001	Pax Phoenix	Holbourne Island, QLD	<1 tonne
25/12/2002	Pacific Quest	Border Island, QLD	Volumetric estimate unavailable but >70 km slick reported
24/01/2006	Global Peace	Gladstone, QLD	25 tonnes
08/06/2007	Pasha Bulker	Newcastle, NSW	Nil spill volume. Significant bunkers and lubricant oil held onboard posing a threat during vessel salvage
11/03/2009	Pacific Adventurer	Moreton Island, QLD	270 tonnes
21/08/2009	Montara Wellhead	NW Australian coast	~4,750 tonnes
03/04/2010	Shen Neng 1	Near Great Keppel Island, QLD	4 tonnes

Source: (AMSA, October 2012)

### B.3 Risk assessment

A risk assessment Commissioned by AMSA was carried out by DNV in 2011 taking into account safety measures, including:

- Requirements for doubled hull protection
- Traffic separation schemes
- Vessel Traffic Services
- Compulsory pilotage
- Emergency towage vessels.

The estimate also reviewed 2020 taking into account

- 79 per cent growth in national port traffic by 2020
- 81 per cent growth in national traffic by sea by 2020
- Offshore oil production would reduce by 89 per cent while condensate production would increase by 73 per cent (AMSA, October 2012)

The study did not take into account the impact of LNG shipping that is also expected to grow significantly in the coming 7 years.

Oil spill risk for 2011 and 2020 is summarised in the following tables.

Table 3 **Oil spill risk assessment 2011**

Source	ERI (million A\$ per year)	%
Trading ships at sea	2.6	29.1%
Trading ships in port	4.5	49.7%
Small commercial vessels	0.1	1.2%
Offshore production	0.6	6.2%
Offshore drilling	0.2	2.3%
Shore based	1.1	11.5%
Total	9.1	100.0%

Source: (AMSA, October 2012)

Table 4 **Oil spill risk assessment 2020**

Source	ERI (million A\$ per year)	% of 2020	% Increase from 2010
Trading ships at sea	5.0	28.3%	91%
Trading ships in port	10.9	60.9%	141%
Small commercial vessels	0.1	0.6%	7%
Offshore production	0.4	2.3%	-28%
Offshore drilling	0.2	1.2%	0%
Shore based	1.2	6.7%	14%
Total	17	100.0%	96%

Source: (AMSA, October 2012)

## Appendix C Minimum maritime user requirements

**Table of the minimum maritime user requirements for general navigation**

	System level parameters				Service level parameters			Fix interval <sup>2</sup> (seconds)
	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	
	Horizontal (metres)	Alert limit (metres)	Time to alarm <sup>2</sup> (seconds)	Integrity risk (per 3 hours)				
<b>Ocean</b>	10	25	10	10 <sup>-5</sup>	99.8	N/A <sup>1</sup>	Global	1
<b>Coastal</b>	10	25	10	10 <sup>-5</sup>	99.8	N/A <sup>1</sup>	Global	1
<b>Port approach and restricted waters</b>	10	25	10	10 <sup>-5</sup>	99.8	99.97	Regional	1
<b>Port</b>	1	2.5	10	10 <sup>-5</sup>	99.8	99.97	Local	1
<b>Inland waterways</b>	10	25	10	10 <sup>-5</sup>	99.8	99.97	Regional	1

*Notes:* 1: Continuity is not relevant to ocean and coastal navigation.  
2: More stringent requirements may be necessary for ships operating above 30 knots.

**Tables showing the minimum maritime user requirements for positioning**

	System level parameters					Service level parameters			Fix interval <sup>2</sup> (seconds)
	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	
	Horizontal (metres)	Vertical <sup>1</sup> (metres)	Alert limit (metres)	Time to alarm <sup>2</sup> (seconds)	Integrity risk (per 3 hours)				
<b>Operations</b>	Relative accuracy								
• tugs and pushers	1		2.5	10	10 <sup>-5</sup>	99.8	99.97	Local	1
• icebreakers	1		2.5	10	10 <sup>-5</sup>	99.8	99.97	Local	1
• automatic collision avoidance	10		25	10	10 <sup>-5</sup>	99.8	99.97	Global	1
	Absolute accuracy								
• track control	10	N/A	25	10	10 <sup>-5</sup>	99.8	99.97	Global	1
• automatic docking	0.1		0.25	10	10 <sup>-5</sup>	99.8	99.97	Local	1
<b>Traffic management<sup>3</sup></b>	Absolute accuracy								
• ship-to-ship co-ordination	10		25	10	10 <sup>-5</sup>	99.8	99.97	Global	1
• ship-to-shore co-ordination	10		25	10	10 <sup>-5</sup>	99.8	99.97	Regional	1
• shore-to-ship traffic management	10		25	10	10 <sup>-5</sup>	99.8	99.97	Regional	1

- Notes:*
- 1: There may be a requirement for accuracy in the vertical plane for some port and restricted water operations.
  - 2: More stringent requirements may be necessary for ships operating above 30 knots.
  - 3: Traffic management applications in some areas, e.g. the Baltic, may require higher accuracy.

**Table 1: Manoeuvring and traffic management applications.**

	System level parameters					Service level parameters			Fix interval (seconds)
	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	
	Horizontal (metres)	Vertical (metres)	Alert limit (metres)	Time to alarm (seconds)	Integrity risk (per 3 hours)				
Search and rescue	10	N/A	25	10	$10^{-5}$	99.8	N/A	Global	1
Hydrography	1 - 2	0.1	2.5 - 5	10	$10^{-5}$	99.8	N/A	Regional	1
Oceanography	10	10	25	10	$10^{-5}$	99.8	N/A	Global	1
<b>Marine engineering, construction, maintenance and management</b>									
• dredging	0.1	0.1	0.25	10	$10^{-5}$	99.8	N/A	Local	1
• cable and pipeline laying	1	N/A	2.5	10	$10^{-5}$	99.8	N/A	Regional	1
• construction works	0.1	0.1	0.25	10	$10^{-5}$	99.8	N/A	Local	1
Aids to navigation management	1	N/A	2.5	10	$10^{-5}$	99.8	N/A	Regional	1

**Table 2: Search and rescue, hydrography, oceanography, marine engineering, construction, maintenance and management and aids to navigation management**

	System level parameters					Service level parameters			Fix interval <sup>1</sup> (seconds)
	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	
	Horizontal (metres)	Vertical (metres)	Alert limit (metres)	Time to alarm <sup>1</sup> (seconds)	Integrity risk (per 3 hours)				
<b>Port operations</b>	<b>Absolute accuracy</b>								
• local VTS	1	N/A	2.5	10	10 <sup>-5</sup>	99.8	N/A	Local	1
• container/cargo management	1	1	2.5	10	10 <sup>-5</sup>	99.8	N/A	Local	1
• law enforcement	1	1	2.5	10	10 <sup>-5</sup>	99.8	N/A	Local	1
• cargo handling	0.1	0.1	0.25	1	10 <sup>-5</sup>	99.8	N/A	Local	1
<b>Casualty analysis</b>	<b>Predictable accuracy</b>								
• ocean	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• coastal	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• port approach and restricted waters	1	N/A	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1
<b>Offshore exploration and exploitation</b>	<b>Absolute accuracy</b>								
• exploration	1	N/A	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1
• appraisal drilling	1	N/A	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1
• field development	1	N/A	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1
• support to production	1	N/A <sup>2</sup>	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1
• post-production	1	N/A <sup>2</sup>	2.5	10	10 <sup>-5</sup>	99.8	N/A	Regional	1

Notes: 1: More stringent requirements may be necessary for ships operating above 30 knots.  
2: A vertical accuracy of a few cm (less than 10) is necessary to monitor platform subsidence.

**Table 3: Port operations, casualty analysis, and offshore exploration and exploitation**



	System level parameters					Service level parameters			Fix interval <sup>1</sup> (seconds)
	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	
	Horizontal (metres)	Vertical (metres)	Alert limit (metres)	Time to alarm <sup>1</sup> (seconds)	Integrity risk (per 3 hours)				
<b>Fisheries</b>	<b>Absolute accuracy</b>								
• location of fishing grounds	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• positioning during fishing <sup>2</sup>	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• yield analysis	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• fisheries monitoring	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
<b>Recreation and leisure</b>	<b>Absolute Accuracy</b>								
• ocean	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• coastal	10	N/A	25	10	10 <sup>-5</sup>	99.8	N/A	Global	1
• port approach and restricted waters	10	N/A	25	10	10 <sup>-5</sup>	99.8	99.97	Regional	1

Notes: 1: More stringent requirements may be necessary for ships operating above 30 knots.  
2: Positioning during fishing in local areas may have more stringent requirements.

**Table 4: Fisheries, recreation and leisure applications**

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