

# Marine GPS

THE COMPLETE GUIDE TO

# AIS

Automatic Identification System



# The Complete Guide to Automatic Identification Systems

Leica Geosystems Inc.





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# introduction

It's a dark night. The officer of the watch is tracking a dozen or more targets on the radar. One of the blips on the radar screen seems to be turning to the right. The OOW picks up the VHF microphone.

*"Vessel on my starboard bow, this is MV Eversail. It appears you may be making a turn to starboard. Do you intend to cross my bow, over?"*

*"Eversail, this is MV Seafarer. Are you the ship in the inbound lane near buoy 23, over?"*

*"Seafarer, this is Eversail. That's negative, I am at the junction buoy near Deadman's Reef, over."*

*"This is Seafarer, Roger, out."*

s i l e n c e

*"Eversail, this is MV Oceanbreeze, I think I am the vessel off your starboard bow. I am outbound in the auxiliary channel from the tanker berth. I am slowing to disembark the pilot, over."*

*"Oceanbreeze, this is Eversail. I have you on my radar. You are not the ship I was calling, over."*

s i l e n c e

*"Vessel five miles off my starboard bow, this is MV Eversail in the outbound channel passing Deadman's Reef junction buoy. What are your intentions, over?"*

*"Eversail, this is MV John Brown. I think I am the vessel off your starboard bow, over."*

*"John Brown, this is MV Seafarer. I believe I am astern of you. Are you the ship that's just passing Buoy 23, over?"*

a n d s o f o r t h . . .

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Radio exchanges like the above are a commonplace occurrence on ships at sea, especially in busy waterways. The weak link in the current generation of collision-avoidance electronics is the inability to identify any given radar target when multiple contacts are being tracked, especially at night or in reduced visibility, when it is impossible to verify a ship's identity visually. This inevitably leads to confusion, and has been cited as a contributing factor to many collisions and near-collisions at sea.

A new technology, called Automatic Identification Systems (AIS), will help to resolve this difficulty by providing a means for ships to exchange ID, position, course, speed and other vital data, with all other nearby ships and shore stations through a standardized transponder system. The data exchange will be totally automatic and transparent to the users. The result will be a dramatic improvement in situational awareness for officers of the watch, who will have a clear and unambiguous identification, as well as other vital information, from all other AIS-equipped ships.

AIS will have a far-reaching impact on safety at sea. It will be required on most ocean-going commercial ships, and will also be integrated into shoreside surveillance and vessel traffic control systems.

In this booklet, Leica Geosystems presents an overview of this important new technology, including a simplified explanation of system functionality, carriage requirements, equipment specifications and references. Leica has been deeply involved in AIS technology from its inception more than 20 years ago, and is a leading supplier of high-precision GPS and DGPS equipment for the maritime industry worldwide.

# what is AIS?

**AIS** is a shipboard broadcast transponder system in which ships continually transmit their ID, position, course, speed and other data to all other nearby ships and shoreside authorities on a common VHF radio channel. The concept is derived from the pioneering work of a Swedish inventor named Håkan Lans, who developed in the mid 1980s an ingenious technique for spontaneous, masterless communication, which permits a large number of transmitters to send data bursts over a single narrowband radio channel by synchronizing their data transmissions to a very precise timing standard. This data communications scheme is described in the next chapter.

AIS is designed to operate in one of the following modes:

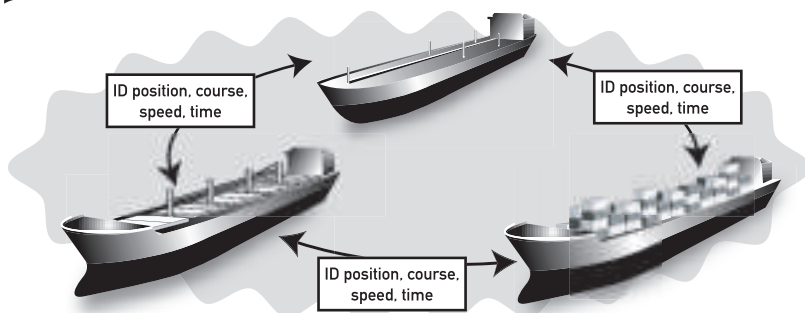
- In a ship-to-ship mode for collision avoidance
- As a means for coastal states to obtain information about a ship and its cargo
- As a traffic management tool when integrated with a Vessel Traffic System (VTS)

## ship-to-ship data exchange

The primary operating mode for AIS will be autonomous ship-to-ship reporting. In this mode, each ship transmits its data to all other AIS-equipped ships within VHF range. The unique communications scheme permits these data transmissions to take place independently without the need for a master control station.

### Autonomous Ship-to-Ship Reporting

Figure 1



Ships transmit AIS reports automatically on a common VHF channel. Timeslots for each data transmission are synchronized by the precise GPS time standard.

Position and other data are fed automatically from the ship's sensors into the AIS system, where the data is formatted and transmitted in a short data burst on a dedicated VHF channel. When received on the other ships, the data is decoded and displayed for the officer of the watch, who can view AIS reports from all other AIS-equipped ships within range in graphic and text format. The AIS data may optionally be fed to the ship's integrated navigation systems and radar plotting systems to provide AIS "tags" for radar targets. The AIS data can also be logged to the ship's Voyage Data Recorder (VDR) for playback and future analysis.

Updated AIS messages are transmitted every few seconds, to keep the information up to date. Note that the ship-to-ship data exchange takes place automatically without any action required by the watch officer on either ship.

In pilotage waters, a pilot can plug a laptop computer, loaded with his own navigation program, directly into the ship's AIS system. In this way, the pilot can monitor the position and movement of all other vessels in the area independent of the ship's installed navigation systems.

Typical AIS Display

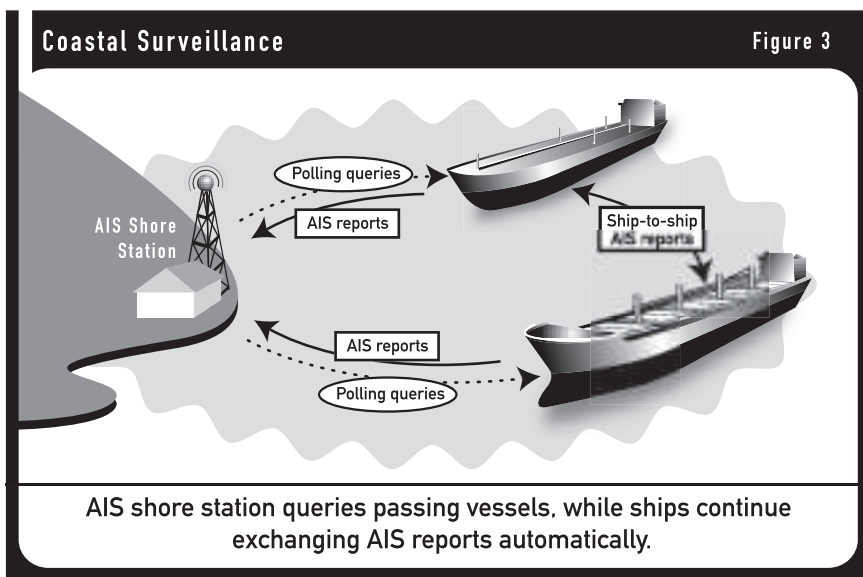
Figure 2





## coastal surveillance

In coastal waters, shoreside authorities may establish automated AIS stations to monitor the movement of vessels through the area. These stations may simply monitor AIS transmissions from passing ships, or may actively poll vessels via the AIS channels, requesting data such as identification, destination, ETA, type of cargo and other information. Coast stations can also use the AIS channels for shore-to-ship transmissions, to send information on tides, notices to mariners and local weather forecasts. Multiple AIS coast stations and repeaters may be tied together into Wide Area Networks (WAN) for extended coverage.



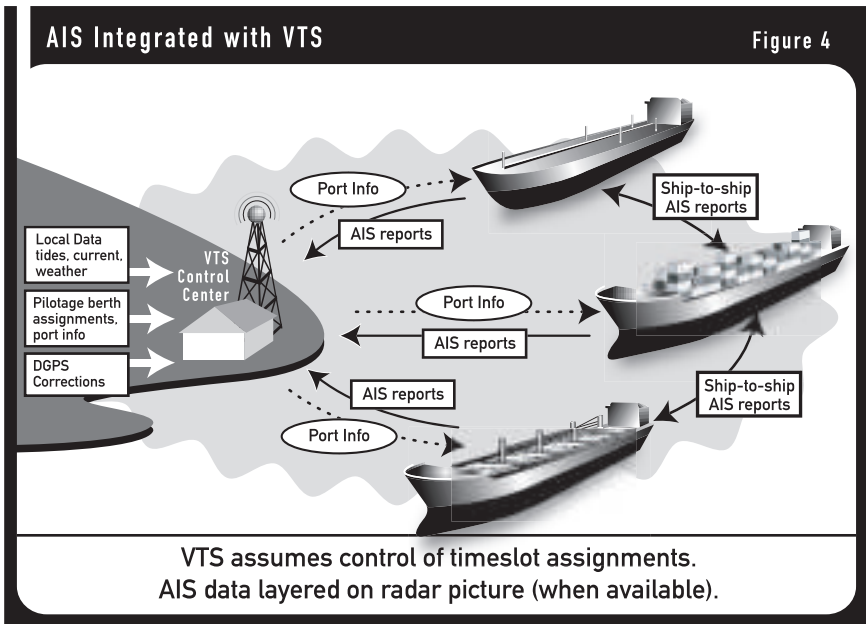
Coastal nations may use AIS to monitor the movement of hazardous cargoes and control commercial fishing operations in their territorial waters. AIS data can be logged automatically for playback in investigating an accident, oil spill or other event. AIS will also be a useful tool in search and rescue (SAR) operations, allowing SAR coordinators to monitor the movements of all surface ships, aircraft and helicopters involved in the rescue effort.

## vessel traffic systems

When integrated with shore-based vessel traffic systems (VTS), AIS provides a powerful tool for monitoring and controlling the movement of vessels through restricted harbors and waterways. The AIS can augment traditional radar-based VTS installations, providing an AIS “overlay” on the radar picture, or can provide a cost-effective alternative in areas where it is not feasible to establish radar-based systems. When integrated with radar, the AIS can ensure continuous coverage, even when the radar picture is degraded by heavy precipitation or other interference.

The AIS channels can be used to transmit port data, pilotage, berth assignments, shipping agency information, tides and currents, notices to mariners and other information from shore to ship, as well as ship-to-ship and ship-to-shore AIS reports. It is also possible for the VTS to broadcast the complete harbor picture to all ships in the area, so the masters and pilots all share the same “big picture.”

The VTS center can assume control over the assignment of timeslots for AIS messages to ensure optimum data exchange within the coverage area. Special dedicated channels may be designated for local-area AIS operations. The shipboard AIS equipment will have the ability to shift to different channels automatically when directed by the shoreside VTS controller.



# potential benefits of AIS

## For the Officer of the Watch

- Improved situational awareness
- Unambiguous identification of radar targets
- Overcome problem of “target swapping” when two contacts pass close together on the radar screen
- Ability to “see” around bends or behind a landmass, to detect and identify other ships
- Predict the place and time of CPA with other vessels
- Detect a change in another ship’s heading almost in real time without waiting for ARPA calculations
- Detect vessels that might otherwise be hidden in another vessel’s radar shadow
- Real time information about other ship’s movements (e.g., accelerating or decelerating, rate of turn)
- Automatically swap information on destination, ETA, loading condition and other data with nearby ships
- Reduce VHF voice traffic, since data is exchanged automatically

## For the VTS Center Watchstander

- Automatic identification of radar targets
- Overcome target swapping of radar contacts
- Constant coverage even when radar picture is degraded by weather and interference
- Tracking of vessels behind islands and obstacles
- Ability to send port data, weather forecasts and safety messages automatically to all ships in the area
- Decrease need for manual input of static data, such as vessel name, size, draft and cargo
- Automatic logging of all data

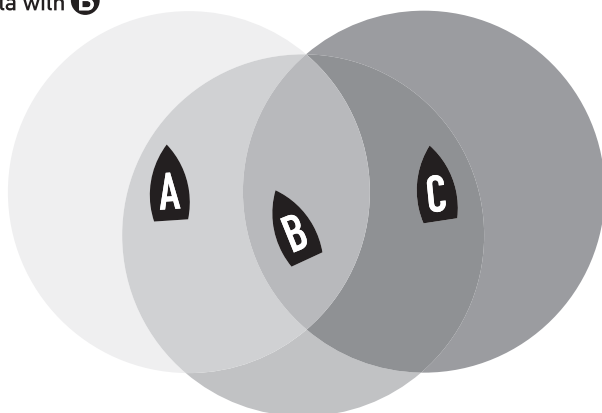
# AIS communications scheme

**AIS** messages must be updated and retransmitted every few seconds at a minimum, since the usefulness of the data decays rapidly as a function of time. To accommodate this high update requirement, AIS utilizes a unique self-organizing time-division multiple access (STDMA) data communications scheme, which uses the precise timing data in the GPS signals to synchronize multiple data transmissions from many users on a single narrowband channel.

**AIS Communication Cells**

**Figure 5**

- A** exchanges data with **B**
- B** exchanges data with **A** and **C**
- C** exchanges data with **B**



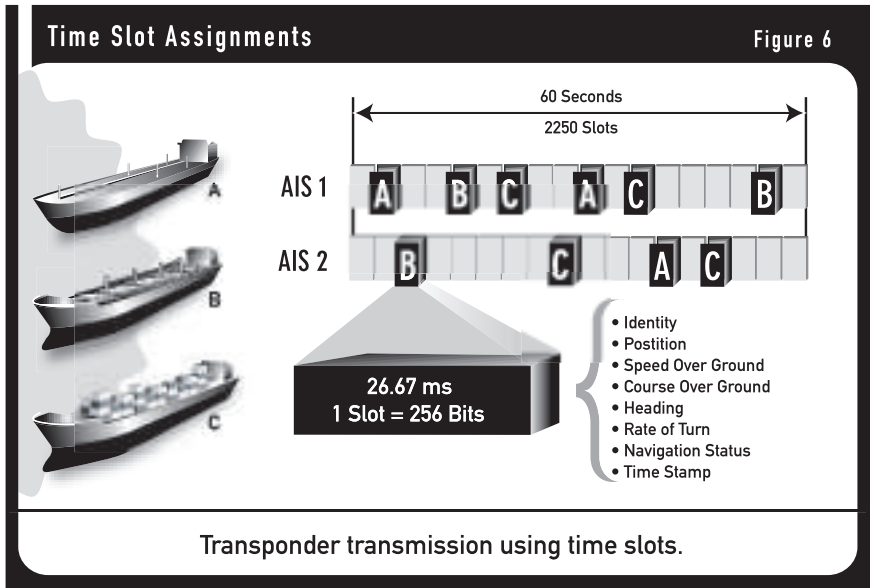
Each ship broadcasts its AIS messages and receives messages from all ships within VHF radio range. The area in which AIS messages can be received is called the ship's "cell". Each ship is in this way in the center of its own communication cell.

The practical size of the cell can be varied according to the traffic density on the AIS channel. If the number of AIS messages begins to overload the network, the ship's AIS system can automatically shrink its cell by ignoring weaker stations further away in favor of those nearby.

Under the STDMA protocol, each minute of time is divided into 2,250 timeslots. An AIS report fits into one or several of these 2,250 timeslots, which are selected automatically based on data link traffic and projections of future actions by other stations currently on the network. When a ship first enters the cell of another ship, it takes an unoccupied timeslot. The AIS stations continually synchronize their slot selections with each other.

Timeslots and timeout periods are selected on a randomized basis. When a station changes its slot assignment, it announces to all other stations on the channel its new location and timeout for that location. Each station continually updates its internal “slot map” to reflect changes in occupied slots and timeouts. Special provisions are made for automatic conflict resolution in the event two stations end up in the same timeslot, to ensure that stations always choose unoccupied slots. In situations of high traffic density it may be necessary to reduce the number of ships in a communication cell, as described above. This enables time slots used by weak stations far away, to be used also by a station nearby. The AIS system applies very specific rules on how this reoccupation of timeslots is done.

The key to the STDMA scheme is the availability of a highly accurate standard time reference, to which all of the stations can synchronize their timeslot assignments, in order to avoid overlap. This time reference is supplied by the precise timing signal in the GPS satellite message. Thus, GPS plays a critical role in AIS, providing the universal time reference as well as positioning data for each ship.



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AIS data transmissions utilize a robust 9.6 kbps FM /GMSK (Gaussian Minimum Shift Keying) modulation technique, which is specified in ITU Recommendation M.1371.1. The International Telecommunications Union (ITU) has designated two dedicated frequencies for AIS. They are 161.975 MHz (marine band channel 87B) and 162.025 MHz (channel 88B). In some parts of the world, such as the United States, where these frequencies may not be available for AIS, other channels may be designated.

The ship's AIS station has two independent VHF receivers, which are normally tuned to the two AIS frequencies, as well as one transmitter, which alternates its transmissions back and forth between the two. The shipborne system can also be retuned to other frequencies, for instance when operating under the control of a shore-based VTS. This can be done either manually or remotely by the AIS shore station.

# AIS messages

**AIS** is designed to work autonomously and continuously in a ship-to-ship mode, but the specifications provide for switchover to an “assigned mode” for operation in an area subject to a competent authority responsible for traffic monitoring, with the data transmission intervals and timeslots set remotely by the shoreside authority. Alternatively, the AIS can work in a “polling mode” in which the data transfer occurs in response to interrogation from another ship or shore station.

## **Information provided by the AIS falls into several categories:**

### *Static data*

- IMO number (where available)
- Call sign and name
- Length and beam
- Type of ship
- Location of position-fixing antenna on the ship  
(aft of bow and port or starboard of centerline)

### *Dynamic data*

- Ship's position with accuracy indication and integrity status
- Time in UTC
- Course over ground
- Speed over ground
- Heading
- Navigational status (e.g., “at anchor,” “not under command,” manually entered)
- Rate of turn (where available)

### *Voyage related data*

- Ship's draft
- Hazardous cargo (type)
- Destination and ETA (at master's discretion)

### *Safety-related messages*

- As needed

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Dynamic information is derived from interfaces with the ship's GPS and other sensors. Static information is programmed into the unit at commissioning. Voyage-related data is entered manually by the master through a password-protected routine. Safety messages can be inserted at any time by the ship or shore station.

The static and voyage-related data are transmitted every six minutes, when amended or on request (for instance, when interrogated by a Vessel Traffic System operator). Safety messages are sent as needed. The update rates for dynamic information will depend on the ship's status and speed, according to the following schedule:

At anchor	3 minutes
0-14 knots	10 seconds
0-14 knots and changing course	3 <sup>1</sup> / <sub>3</sub> seconds
14-23 knots	6 seconds
14-23 knots and changing course	2 seconds
23+ knots	2 seconds
23+ knots and changing course	2 seconds

The AIS specifications also allow for insertion of brief binary messages from ships or shore stations. Such messages might include notices to mariners, navigational warnings, tides and currents, weather forecasts, SAR communications and ship-specific instructions from a VTS operator. The AIS standard also includes formats for transmission of differential GPS error correction data. This can provide valuable redundancy to existing beacon DGPS systems in critical navigation areas.



# AIS shipboard equipment

IMO Resolution MSC.74(69), Annex 3 (see Chapter 6) states that an approved shipboard AIS system shall be able to perform the following functions:

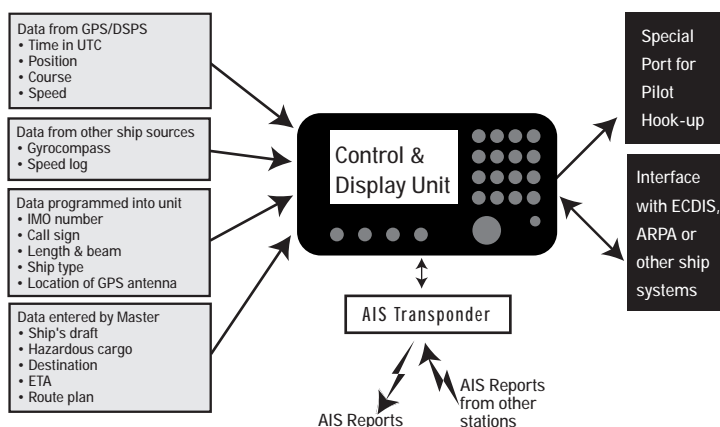
- Automatically provide information on the ship's identity, type, position, course, speed, navigational status and other safety-related matters to appropriately equipped shore stations, other ships and aircraft.
- Receive automatically such information from similarly fitted ships.
- Monitor and track ships.
- Exchange data with shore-based facilities.

A shipboard AIS system consists of the following elements:

- An STDMA radio transponder with two VHF receivers and one transmitter (it is also possible that the transponder have a Digital Selective Calling {DSC} receiver tuned to Channel 70).
- A control and display unit, which includes the communications processor and interfaces for taking inputs from the ship's navigation sensors and sending outputs to external systems, such as ECDIS, ARPA, VDR or Inmarsat terminal.
- One or more GPS/DGPS receivers that provide position information as well as the precise time base needed to synchronize the STDMA data transmissions.

Shipboard AIS System

Figure 7



Ship's position and precise timing data are derived from the GPS receiver, augmented by differential corrections when available. Other data is fed into the AIS from shipboard sensors, such as gyrocompass and speed log, via a standard NMEA-0183/2000 interface. Static and voyage-related data are operator-entered through a keyboard. The AIS communications processor organizes the data for transmission and handles all STDMA communications functions. The shipboard transponder system receives AIS reports from other ships and shore stations and displays the AIS data for each target in text or graphic format. Serial data ports are used to output AIS data for display on an external device, such as ECDIS, ARPA or remote PC.

## total shipboard GPS/DGPS/AIS solution

Leica's MX420 Navigation System was introduced to provide an integrated solution for marine GPS, DGPS and AIS. The MX 420 incorporates:

- a combined Control and Display Unit for GPS, DGPS and AIS, incorporating the most widely accepted standard man machine interface (MMI) for marine GPS
- the world's most accurate GPS receiver (MX 421), based on new-generation Silicon Germanium (SiGe) chip technology, sealed in a "smart antenna" radome
- a differential GPS beacon receiver that meets all projected IMO carriage requirements
- an IMO-compliant AIS transponder developed by industry pioneer SAAB TransponderTech

The MX420 Navigation System is built to meet all existing applicable international marine standards, and it is designed to be compliant also to future standards through software upgrades.

The MX 420 Control and Display Unit (CDU) collects and decodes AIS reports from other stations and provides a readout of information from all AIS-equipped ships and shore stations. Data can be viewed in text or graphic form. The MX 420 CDU gathers inputs from ship's sensors and organizes the data for transmission via AIS. The CDU is also used for entering AIS static and voyage-related information for AIS broadcasts, as well as system setup functions. High-speed serial data ports are provided for outputs to the ECDIS, ARPA or other shipboard systems. An extra port has been provided for a ship's pilot to plug into the AIS system.

The MX420 CDU comes either as an AIS-only CDU, called MX420/AIS Basic, or as a combined DGPS and AIS Control and Display unit, called MX420/AIS. The MX420/AIS Basic connects to an existing GPS or DGPS receiver on board, while the MX420/AIS interfaces to the new MX421 or MX421B smart antenna and includes all GPS navigation functions.

The MX 421 "smart antenna" incorporates the new SiGe-based GPS receiver developed jointly by Leica and IBM. The results are astounding. The MX 421 delivers RMS (root mean square) accuracy of better than 3 meters using autonomous GPS signals in a non-differential mode. The dual-channel DGPS beacon receiver, with H-field antenna, provides position solutions of better than 1 meter RMS, as well as the inherent reliability and integrity monitoring provided by the DGPS beacon broadcasts. The MX421 is a type approved commercial marine GPS or DGPS sensor that is designed to meet all existing and projected IMO carriage requirements.

# carriage requirements

The IMO has established mandatory carriage requirements for approved AIS equipment under the Safety of Life at Sea (SOLAS) Convention. The AIS carriage requirements will apply to:

- all ships of 300 gross tonnage and upwards engaged on international voyages
- cargo ships of 500 gross tonnage and upwards not engaged on international voyages
- all passenger ships irrespective of size

All newbuilds must be fitted with an approved AIS after July 1, 2002. Existing ships engaged in international voyages constructed before July 1, 2002, must be fitted according to the following timetable:

- In the case of passenger ships, not later than July 1, 2003
- In the case of tankers, not later than the first safety equipment survey after July 1, 2003
- In the case of ships other than passenger ships and tankers of 50,000 gross tonnage and upwards, not later than July 1, 2004.
- In the case of ships other than passenger ships and tankers of 10,000 to 50,000 gross tonnage, not later than July 1, 2005.
- In the case of ships other than passenger ships and tankers of 3,000 to 10,000 gross tonnage, not later than July 1, 2006.
- In the case of ships other than passenger ships and tankers of 300 to 3,000 gross tonnage, not later than July 1, 2007.

Existing ships not engaged on international voyages constructed before July 1, 2002, must be fitted not later than July 1, 2008.

A flag state may exempt ships from complying with the carriage requirements if the ships will be removed permanently from service within two years of the implementation date.

# what about non-solas vessels?

The AIS carriage requirements apply only to commercial vessels subject to the Safety of Life at Sea (SOLAS) convention. What about smaller vessels, such as tugs, workboats, fishing vessels and pleasure yachts, which will not be equipped with AIS? Will they be invisible to shipboard and AIS shore stations?

In some areas, such as inland rivers, which carry heavy commercial traffic, it is likely that port states will expand the AIS carriage requirements to include other craft, such as tug-barge combinations. Likewise, some nations may decide to use AIS technology to monitor fishing in their littoral waters by requiring commercial fishing vessels to be equipped with AIS.

There is considerable discussion in maritime circles about developing a sort of "mini-AIS" — simplified transponders that could be installed on non-SOLAS vessels. These devices might be shorter-range combined transmit/receive devices transmitting limited information at a reduced update rate, or in some cases "receive-only" terminals — receiving and displaying AIS data from other vessels, but not transmitting STDMA data. Specifications are yet to be determined for these types of equipment.

# AIS standards

There are three primary international standards for AIS equipment. They were developed jointly by the International Maritime Organization (IMO), International Telecommunications Union (ITU) and International Electrotechnical Commission (IEC). The shipboard AIS equipment must meet the provisions of all three documents.

*IMO Resolution MSC.74(69), Annex 3, "Recommendations on Performance Standards for a Universal Shipborne Automatic Identification System (AIS)"*

This document establishes carriage requirements for AIS and performance requirements for the shipboard equipment. The IMO standard was used by the ITU and IEC in developing technical and test standards. It was approved by the IMO Subcommittee on Safety of Navigation at its 45th session in late 2000.

*ITU-R Recommendation M.1371-1, "Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the Maritime Mobile Band"*

This document defines in detail how AIS and STDMA technology works. The original standard, adopted by the International Telecommunications Union (ITU) in 1998, was revised in 2001 to clarify design requirements.

*IEC Standard 61993-2, "Universal Shipborne Automatic Identification System (AIS)"*

This standard specifies the minimum operational and performance requirements, methods of testing and required test results conforming to the performance standards contained in IMO Resolution MSC.74(69), Annex 3. It incorporates the technical characteristics contained in ITU-R M.1371-1 and takes into account the ITU Radio Regulations where appropriate. This draft standard is expected to be approved for publication by December 2001.

Other organizations involved in AIS standards development include the following.

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*International Association of Lighthouse Authorities (IALA/AISM).*

IALA has been the primary organization spearheading the development and adoption of universal AIS transponder technology in the marine industry. IALA prepared the first recommended performance standards in 1996, which became the basis for the ITU standard. The IALA AIS Committee meets four times each year to support continued development of the technology.

*Radio-Technical Commission for Maritime Services (RTCM)*

RTCM Special Committee 101 is concerned with Digital Selective Calling (DSC) and AIS issues. It meets to prepare proposals to international standard-making bodies.

*National Marine Electronics Association (NMEA)*

The latest version of the NMEA 0183 standard for marine electronics interfacing includes provisions for data exchange with an AIS transponder. NMEA 0183 will be superseded and supplemented by a new standard, NMEA 2000, which also provides AIS data formats.

Other standards that relate to the AIS application are:

*IEC 61108-1 for marine GPS receivers.*

This standard is currently being reworked in order to enhance the reliability and integrity of marine GPS navigation.

*IEC 61108-4 for beacon DGPS receivers.*

There is a new draft of this standard that is intended to provide higher robustness and integrity in DGPS navigation.

*IMO MSC 64(67), Annex 2, Recommendations for DGPS Performance Standards*

This standard was amended by the Marine Safety Committee in November 2000. It will establish carriage requirements and performance characteristics for DGPS beacon receivers.

These standards will enhance the performance of shipboard GPS and DGPS equipment to fully support the AIS functions.



# appendix

## useful links

U.S. Coast Guard Navigation Center – [www.navcen.uscg.gov](http://www.navcen.uscg.gov)

G.P.&C. Systems International – [www.gpc.se](http://www.gpc.se)

Universal AIS Website – [www.uais.org](http://www.uais.org)

SAAB Transponder Tech – [www.transpondertech.se](http://www.transpondertech.se)

Swedish Maritime Authority – [www.sjofartsverket.se](http://www.sjofartsverket.se)

International Maritime Organization – [www.imo.org](http://www.imo.org)

International Telecommunications Union – [www.itu.ch](http://www.itu.ch)

International Electrotechnical Commission – [www.iec.ch](http://www.iec.ch)

International Association of Lighthouse Authorities – [www.iala-aism.com](http://www.iala-aism.com)

Leica Geosystems – [www.leica-geosystems.com](http://www.leica-geosystems.com)





Contact Leica Geosystems: +1 310 791 5300 (USA - Canada),  
+45 4454 0300 (Denmark),  
+65 776 9318 (Singapore)  
or [www.leica-geosystems.com/marine](http://www.leica-geosystems.com/marine)

*Leica*