The Automatic Identification System

Then, now, and in the future.

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After the *Exxon Valdez* oil spill in 1989, Congress enacted the Oil Pollution Act of 1990, which changed how we deal with oil pollution prevention and response and made participation in Coast Guard vessel traffic services (VTS) mandatory. One other important provision in the law was the mandate to create a dependent surveillance system to monitor tankers navigating to and from Valdez, Alaska.

Room for Improvement

Prior to this incident, vessel traffic services typically provided vessel information by inquiring about vessels' intentions and tracking their movement within the system via some manual plotting board or similar device. Though the inclusion of radar greatly enhanced the ability to track and monitor vessel movements, its range is limited, so the cost of providing full radar coverage throughout an entire VTS area and its approaches was prohibitive. Further, radar does not provide the ability to positively identify a vessel among other vessels or physical objects, such as ice. This limitation was always known, but became more evident after the *Exxon Valdez* disaster.

The U.S. Coast Guard Office of Vessel Traffic Management researched various means to improve vessel tracking, opting to modify the digital selective calling (DSC) communications protocol relied upon for Global Marine Distress Safety System alerts. DSC allows for scheduled broadcasts and the ability to poll for information, which led to a shipboard system that would allow specific very high frequency (VHF) DSC messages composed of vessel identity and position for tracking purposes. This technology eventually became automated dependent surveillance shipboard equipment.

As we ventured to track tankers, other countries and authorities also sought ways to track and monitor vessels transiting unique waterways, such as the Panama Canal, the Dover Straits, and the fjords of Sweden. In each of these areas, authorities came up with their own unique method. The British used DSC messaging similar to us, the Panamanians opted for a system using ultra-high frequency, and the Swedes used a system similar to cell phone technology, but via a VHF frequency. While all these systems quickly showed the value of automated vessel tracking, they were not interoperable.

Mandating Universal Standards

To avoid an even further proliferation of disparate systems, an effort arose to develop a universal, world-wide means to automatically identify vessels, and in 2000, the International Maritime Organization mandated universal automatic identification system use on all tankers, passenger vessels of 150 gross tonnage or greater, and other ships of 300 gross tonnage or greater (500 gross tonnage or greater in domestic voyages).

This system was designed to:

- improve navigation safety through automatic use,
- be used in a ship-to-ship mode for collision avoidance,
- be used as a means for littoral states to obtain information about a ship and its cargo,
- be used as a VTS tool for traffic management.

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Frequency Information

AIS primarily operates on two world-wide designated radio channels—VHF-FM channel 87B and 88B—but to ensure its universality, the system also operates on any channel in the VHF-FM band for areas where the designated frequencies may be unavailable.

To further provide robustness, AIS communicates using a time-division multiple access scheme, which allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, each using his own time slot.

Timing Scheme

During development, each AIS station reserved specific slots for its use to ensure it didn't use a slot reserved by another station. This prevents communications from "stepping on" each other, as is common in voice or DSC communications. Further, this schema was designed so those vessels in closer proximity would prevail over weaker signals, so vessels that could pose a greater risk for collision would be heard above those farther away.

INTERNATIONAL TELECOMMUNICATION UNION RECOMMENDATION

Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile band.

M = Mobile
B = Base Station

Message Library

Message ID	Message Name	Description	Transmit Priority	Purpose	Station Type
1	Position report	Scheduled position report; (Class A shipboard mobile equipment)	1	Position report from mobile stations output periodically, according to the current speed over ground (SOG), rate of turn (ROT), and navigational status setting, unless specified otherwise by reception of a message 16 or 23.	M
2	Position report	Assigned scheduled position report; (Class A shipboard mobile equipment)			
3	Position report	Special position report, response to interrogation; (Class A shipboard mobile equipment)			
4	Base station report	Position, UTC, date, and current slot number of base station	1	Used for reporting UTC time, date, and position. A base station should use message 4 in its periodical transmissions. A mobile station should output message 11 only in response to interrogation by message 10.	B
5	Static and voyage related data	Scheduled static and voyage-related vessel data report; (Class A shipboard mobile equipment)	4	Used by Class A shipboard and SAR aircraft AIS stations when reporting static or voyage-related data.	M
6	Binary addressed message	Binary data for addressed communication	4	An addressed binary message variable in length, based on the amount of binary data. The length will vary between one and five slots.	M/B
7	Binary acknowledgement	Acknowledgement of received addressed binary data	1	Used as an acknowledgement of up to four message 6 messages received, and transmitted on the channel, where the addressed message to be acknowledged was received.	M/B
8	Binary broadcast message	Binary data for broadcast communication	4	A message of variable length, based on the amount of binary data. The length should vary between one and five slots.	M/B
9	Standard SAR aircraft position report	Position report for airborne stations involved in SAR operations, only	1	Used as a standard position report for aircraft involved in SAR operations. Stations other than aircraft involved in SAR operations should not transmit this message. The default reporting interval for this message is 10 seconds.	M

Message ID	Message Name	Description	Transmit Priority	Purpose	Station Type
10	UTC/date inquiry	Request UTC and date	3	Used when a station is requesting universal time coordinated and date from another station.	M/B
11	UTC/date response	Current UTC and date if available	3	Same as message 4.	M
12	Addressed safety-related message	Safety-related data for addressed communication	2	An addressed safety-related message of variable length, based on the amount of safety related text. The length will vary between one and five slots.	M/B
13	Safety-related acknowledgement	Acknowledgement of received addressed safety-related message	1	Same as message 7.	M/B
14	Safety-related broadcast message	Safety-related data for broadcast communication	2	A safety-related broadcast message variable in length, based on the amount of safety-related text. The length will vary between one and five slots (up to 156 characters).	M/B
15	Interrogation	Request for a specific message type (can result in multiple responses from one or several stations)	3	Used for interrogations via the AIS VHF data link other than requests for UTC and date. The response should be transmitted on the channel where the interrogation was received.	M/B
16	Assignment mode command	Assignment of a specific report behavior by competent authority using a base station	1	Used by a base station when operating as a controlling entity. Other stations can be assigned a transmission schedule other than the currently used one. If a station is assigned a schedule, it will also enter assigned mode. Two stations can be assigned simultaneously.	B
17	Differential broadcast binary message	Differential position corrections provided by a base station	2	Used by a base station connected to a GPS reference source and configured to provide differential GPS data to receiving stations.	B
18	Standard Class B equipment position report	Standard position report for Class B shipboard mobile equipment to be used instead of messages 1, 2, 3	1	Used by Class B shipboard mobile equipment to report position periodically and autonomously instead of messages 1, 2, or 3 at a 30-second reporting interval, unless otherwise specified by reception of a message 16 or 23, and depending on the current SOG and navigational status flag setting.	M
19	Extended Class B equipment position report	Extended position report for class B shipboard mobile equipment; contains additional static information	1	Used by Class B shipboard mobile equipment; transmitted once every six minutes in two slots allocated by the use of message 18 in the communication state or after the following parameter values change: dimension of ship/reference for position or type of electronic position fixing device.	M
20	Data link management message	Reserve slots for base station(s)	1	Used by base station(s) to pre-announce the fixed allocation schedule for one or more base station(s) and it should be repeated as often as required; thus ensures a high level of integrity for base station(s) transmissions. This is especially important in regions where several base stations are located adjacent to each other and mobile station(s) move between these different regions. These reserved slots cannot be used by mobile stations.	B

Message ID	Message Name	Description	Transmit Priority	Purpose	Station Type
21	Aids-to-navigation (AtoN) report	Position and status report for aids to navigation	1	Used by an AtoN AIS station mounted on an aid-to-navigation or a fixed station; when the functionality of an AtoN station is integrated into the fixed station. It is nominally transmitted autonomously once every three minutes or may be assigned by an assigned mode command (message 16) via the VHF data link, or by an external propriety command. This message is limited to no more than two slots.	M/B
22	Channel management	Management of channels and transceiver modes by a base station	1	Used by a base station (as a broadcast message) to command the VHF data link parameters for the geographical area designated in this message. Alternatively, this message may be used by a base station (as an addressed message) to command individual AIS mobile stations to adopt the specified VHF data link parameters (frequency and/or output power). When interrogated and no channel management performed by the interrogated base station, the not available and/or international default settings (AIS 1 and AIS 2) should be transmitted.	B
23	Group assignment command	Assignment of a specific report behavior by competent authority using a base station to a specific group of mobiles	1	Used by a base station when operating as a controlling entity to control mobile station's: –transmit/receive mode; –reporting interval; or –the duration of a quiet time by "ship and cargo type" or by "station type."	B
24	Static data report	Additional data assigned to an MMSI Part A: Name Part B: Static Data	4	May be used by any AIS station to associate a MMSI with a name. Message 24 Part A and Part B is used by Class B "CS" shipboard mobile equipment. When doing so the message consists of two parts. Message 24B should be transmitted within one minute following message 24A. In case of an interrogation for a Class B "CS" on a message 24, the response includes part A and part B data.	M/B
25	Single slot binary message	Short unscheduled binary data transmission (broadcast or addressed)	4	Use for short infrequent data transmissions. The single-slot binary message can contain up to 128 data-bits depending on the coding method used for the contents, and the destination indication of broadcast or addressed. Its length is limited to one slot. This message will not be acknowledged by either message 7 or 13.	M/B
26	Multiple slot binary message with communications state	Scheduled binary data transmission (broadcast or addressed)	4	Primarily intended for scheduled binary data transmissions per its respective VHF data link access scheme. This multiple-slot binary message can contain up to 1,004 data-bits (up to 5 slots) depending on the coding method used for the contents, and the destination indication of broadcast or addressed. This message will not be acknowledged by either message 7 or 13.	M/B
27	Position report for long-range applications	Scheduled position report; (Class A shipboard mobile equipment outside base station coverage)	1	Primarily intended for long-range detection of AIS Class A equipped vessels (typically by satellite). This message has a similar content to messages 1, 2 and 3, but the total number of bits has been compressed to allow for increased propagation delays associated with long-range detection.	M

Technical Standards

The International Telecommunication Union adopted this schema into the AIS technical standard, which defines a finite library of fixed-length messages particular to each AIS station type, including:

- shipboard Class A units,
- less capable shipboard Class B stations,
- search and rescue aircraft,
- AIS aid to navigation stations,
- base stations.

The library also provides for short safety-related text messages, including a common message used by most AIS stations to interrogate and poll other AIS stations for their specific message or for time. In addition, the library provides a subset of messages that are to be used solely by the base station to control the behavior of other stations or the VHF data link, each assigning a different reporting rate, operation frequency, output level, and segment of the data link.

That Was Then

Today we track more than 7,000 vessels a day via a shore-side network of Coast Guard VTS transceivers and AIS receiver stations through our nationwide automatic identification system. In addition to our land network, we have also received AIS reports from what was initially a Coast Guard project to receive and decode AIS from commercial satellites. Most nations are doing the same, monitoring their waters with similar land-based networks, and efforts are underway to share this information.[1]

What does the future hold for AIS? Recent developments promise to reap great rewards for decades to come.

AIS SART. Most commercial ships are required to have lifeboats equipped with radar search and rescue transponders. Responders rely on these transponders to "home in" on deployed lifeboats. As such, they have been instrumental in saving many lives, but as mentioned previously, radar has limitations. Enter AIS.

Just as AIS was seen as another effective means to allow for the positive tracking of vessels, why not use its capability to home in on vessels such as lifeboats? Thus began an effort to develop an AIS-based search and rescue transmitter (AIS SART).

The U.S. Coast Guard conducted trials with prototype AIS search and rescue transmitters designed to broadcast in eight-second bursts to ensure the equipment broadcasts at least once on the crest of a wave. In all trials AIS SART performance far exceeded the radar counterpart. Aircraft flying at 20,000 feet were able to detect an AIS SART from more than 120 nautical miles, while radar search and rescue transponders only came within range at one-half to one-third the distance. Additionally, the new technology sends a GPS-derived position report, which promises to reduce the "search" in search and rescue operations.

Following various successful trials conducted by the U.S. Coast Guard, the Northern Light Board of Scotland, U.K. maritime authorities, and the Federal Waterways Administration in January 2010, the IMO allowed AIS SART use in lieu of the previous technology.

AIS ASM. Also in the technological forefront, the IMO has adopted a compendium of application-specific messages (ASM) that promise to greatly enhance AIS users' navigation safety. These applications will provide for the exchange of:

- environmental, meteorological, and hydrological data;
- reporting dangerous cargo and/or persons;
- port clearance and berthing information;
- mandatory and recommended routes;
- amplifying vessel static and voyage-related data;
- VTS or synthetic targets (vessels without AIS);
- pertinent time-critical dynamic navigation information concerning a specified geographic area, poly-line, or position.

AIS SAT. Finally, the latest change to the AIS technical standard includes a message specifically designed for AIS reception from satellite (AIS SAT). To enhance AIS satellite reception, the U.S. developed a new automatic identification service message in which the number of bits has been compressed to improve long-range detection.

However, another large challenge remains. The self-organizing nature of AIS, which is optimal for ship-to-ship communications, poses a unique dilemma to satellite receivers and their much larger reception area or footprint, given their altitude. Thus, satellite providers must devise ways to decipher multiple AIS messages using the same time slot.

The most effective way to avoid these "slot collisions" is to reduce AIS congestion. This is not possible on the existing AIS channels, given the ever-increasing number of AIS users, but could be accomplished if other channels were used for this new message. To that end, the U.S. is leading an effort to designate two additional VHF-FM channels for long-range AIS reporting.

About the author:

Mr. Arroyo is a program and management analyst in the Office of Navigation Systems at USCG headquarters and the USCG's regulatory project officer and subject matter expert for the Automatic Identification System (AIS). Since 1980 he has worked various assignments and duties in recreational boating safety, search and rescue, vessel traffic management, polar icebreaking, and ship and shore-side operations. He also currently serves as the U.S. delegate to the International Maritime Organization Navigation Sub-Committee, is a member of various working groups of the International Electrotechnical Committee (IEC) and Radio Technical Committee for Maritime Services (RTCM), and is vice-chair of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) AIS working group.

He obtained his Bachelor of Science from the University of Illinois, his Juris Doctor from DePaul Law School in Chicago, Illinois, and has sailed the seven seas and made landfall on every continent.

Endnote:

1. *Proceedings of the Marine Safety & Security Council*; Summer 2010, Vol. 67, No.2; p. 18.

Internationally adopted AIS Application-Specific Messages

Application Name	Purpose
Number of persons on board	Used by a ship to report the number of persons on board (e.g., on request by a competent authority).
VTS-generated/synthetic targets	Used to transmit known VTS or other types of synthetic targets. It can be variable in length, based on the amount of targets; up to four targets.
Clearance time to enter port	Used to provide specific ships with information on the granted port to call and time to enter; including the berth's location code (UNLOCODE) and position.
Marine traffic signal	Used to provide information on a signal station and status of the control signal at the entrance of a harbor or channel where the shipping direction controlled so that the traffic flow be kept in order. It provides the name of signal or station, position of station, status of signal, signal in service, time of next signal shift, expected next signal.
Berthing data	Used to provide information on the ship's berth. If sent from a ship it is a berthing request; if it is transmitted by a competent authority it is a berthing assignment, which includes: berth length, water depth at berth, mooring position, available berth date and time, services availability, type of services available, name of berth, centre position of berth.
Weather observation report from ship	Used to provide weather information as observed on a ship in navigation. Two different messages can be transmitted: Weather observation report from ship or World Meteorological Organization (WMO) weather observation reports from ship.
Area notice – broadcast – addressed	Used to provide pertinent time-critical dynamic navigation information concerning a specified geographic area, poly-line or positions, but not as a means to convey information already provided by current official nautical charts or publications. It can also be used to convey advisory lines or tracks. It is time-dependent (i.e. has start date and time and duration). It can be sent as either an addressed or broadcast message.
Extended ship static and voyage-related data	Used to provide additional extended and static voyage-related data from a ship, such as: air draught, last port of call, next port of call, second port of call, SOLAS equipment status, hull ice class, shaft horse power, VHF working channel, Lloyd's ship type, gross tonnage, laden or ballast status, type of bunker oil on board, total amount of bunker oil in tonnes, number of persons on board.
Dangerous cargo indication	Used in response to a request for a summary of the dangerous cargo information from a competent authority. It is intended to provide a non-verbal method of transfer of information on the general categories on dangerous cargoes, i.e. as an outline assessment of the categories of ships and their cargoes to facilitate in their participation in ship reporting systems and as initial information supporting search and rescue (SAR), anti-pollution, fire/chemical response or other incident/accident response operations. The data is intended for use by the shore-based authority with the ability to relay this information on a selective and secure basis to the relevant national authorities responsible for receiving reports (i.e. Maritime Reporting System) and for VTS, SAR, pollution response, fire-fighting, and other shore-based activities in response to accidents or incidents.
Environmental	Used to provide environmental information from one to eight environmental sensors (e.g., one sensor report uses two slots while a message with eight sensor reports can use up to five slots). Each sensor report carries the dynamic or static information relating to a specific sensor, such as: wind, water level, current flow (2D), current flow (3D), horizontal current flow, sea state, salinity, weather, air gap/air draft, etc.
Route information – broadcast – addressed	Used to communicate pertinent vessel routing information; when important route information [e.g., mandatory or recommended route(s)] – not already provided by current official nautical charts or publications – needs to be relayed by authorities or vessels. It can be broadcast or addressed, depending on which alternative is more appropriate.
Text description – broadcast – addressed	Used to provide a text description in combination with other AIS application-specific message (e.g., area notice or route information). It can be broadcast or addressed, however, the same source MMSI must be used to send both the main message and a text description message.
Meteorological and hydrographic data	Used to allow the distribution of meteorological and hydrographic information directly from the sensor source, e.g. current velocity.
Tidal window	Used to inform vessels about tidal windows which allow a vessel the safe passage of a fairway or waterway. It includes predictions of current speed and current direction. Up to three points of tidal information can be provided. (IMO SN.1/Circular 289)

AIS-SAT graphic courtesy of exactEarth Ltd. and the Environmental Systems Research Institute, Inc.

Automatic Identification System Broadcast Information

Mobile Stations (Class A and Class B shipboard equipment)

- Dynamic data every two to 10 seconds per speed and course change (Class B, 30s only).
- Position and accuracy (+/-10m)
- Position integrity via receiver autonomous integrity monitoring
- Course over ground
- Speed over ground
- Heading
- Rate of turn*
- Universal time-coordinated time stamp via GPS
- Vessel IMO number *
- Navigation status *
- Communication state (slot usage)

Static and voyage-related data every six minutes or upon change.

- Type of positioning source
- Vessel dimensions (derived from AIS reference point)
- Vessel name
- Vessel call sign
- Vessel type
- Static draft*
- Hazardous cargo flag*
- Destination and ETA*
- Data terminal (external AIS display) availability

* Unavailable from Class B equipment

Search and Rescue Aircraft

- Universal time-coordinated time stamp via GPS
- Position and accuracy (+/-10m)
  - Position integrity via receiver autonomous integrity monitoring
- Altitude sensor
- Course over ground
- Speed over ground
  - Communication state (slot usage)
  - Data terminal (external AIS display) availability

Search and Rescue Transmitter

- Universal time-coordinated time stamp via GPS
- Navigation status that indicates it is an active SART
- Associated text message that states either SART "active" or SART "test"
- Position and accuracy (+/-10m)
  - Position integrity via receiver autonomous integrity monitoring
- Course over ground
- Speed over ground
  - Communication state (slot usage)

Base (Shore) Stations

- Universal time-coordinated
- Position and accuracy (+/-10m)
- Position integrity via receiver autonomous integrity monitoring
- Type of positioning source
- Communication state (slot usage)

Aid to Navigation Station

- ATON name
- Type of ATON
- ATON dimension (reference point)
- ATON status
- Off-position indicator
- Position and accuracy (+/-10m)
  - Position integrity via receiver autonomous integrity monitoring
- Universal time-coordinated time stamp via GPS
- Virtual ATON indication
- Broadcast mode (autonomous or assigned)

Most stations can also perform safety-related and application-specific messaging

- Short text messaging < 156 characters
  - Addressed (and acknowledgement) or general broadcast
- Data messaging and binary applications