THE JOURNAL OF NAVIGATION (2005), **58**, 181–189. © The Royal Institute of Navigation
doi:10.1017/S0373463305003267 Printed in the United Kingdom

AIS and Long Range Identification & Tracking

William R. Cairns
(*Maritime Domain Awareness Staff, US Coast Guard*)
(Email: wcairns@comdt.uscg.mil)

This paper describes the United States Coast Guard's efforts regarding Long Range Identification & Tracking (LRIT) of ships. Among those elements included in the LRIT plan, automatic identification systems (AIS), typically envisioned as a short-range system, may also play a long-range role. AIS vessel tracking may be accomplished through high elevation shore sites allowing reception of AIS signals to nominally 24 nm that loosely puts it in the category of a short-range sensor. Additionally, the US Coast Guard is conducting research and development efforts to determine the feasibility of using AIS receive capability on low earth orbit (LEO) satellites and high altitude, long endurance (HALE) airships or balloons. In parallel with the developing technical capabilities, the US approach with the International Maritime Organization (IMO), and domestic legislation and regulations are also addressed. Finally, a vision for the implementation of LRIT is offered. The paper was presented on 9 November 2004 at Church House, London during the Institute's NAV 04 Conference.

KEY WORDS

1. AIS. 2. Identification & Tracking.

1. OVERVIEW. The United States' 96-hour Notice of Arrival (NOA) data indicates that on an average day 1,040 vessels over 300 gt approach the US from foreign ports carrying goods and passengers while another 350 merchant ships are present in our ports. An additional unknown number of vessels approach the US, penetrate and traverse our Exclusive Economic Zone (EEZ) on coastwise courses bound for non-US ports. This group of vessels is not currently required to report their vessel course using the NOA since they do not plan to arrive at a US port, and, in general, are not currently tracked. Overall, an estimated 5000 of these large vessels are within 2000 nm of the US at any time.

The US Coast Guard is faced with the daunting responsibility of maintaining a persistent surveillance of the approaches to the United States in the interest of preserving the safety and security of the homeland. Multiple maritime threats from hostile government-sponsored and non-governmental organizations pose a significant threat. The economic impact resulting from an attack on West Coast ports, for instance, has been estimated to be $140M to $2B loss over 11 days. The economic loss to the country in general is incalculable, not to mention the impact on businesses that would have to close and lay off workers as a result. Ongoing migrant and drug law enforcement events occurring routinely demonstrate the limited ability of US civil government and military entities to clearly see and understand what is happening near our maritime borders, and best carry out an appropriate response.

Our goal is to expand surveillance capabilities outward from the coastline to enable sufficient time for identification and response and interdict potential attackers. However, standoff distance alone is not sufficient. Adequate time must also be part of the equation to allow for detection of potential threats, investigation to define threats, and appropriate response to mitigate the threat before the threat becomes an attack.

LRIT is designed to implement a reliable, persistent surveillance of ships along the US coastline out to 2,000 nm, for purposes of detecting, classifying, identifying and targetting vessels. This is the minimum distance required to ensure targets and threats are identified and targetted in time to mount an effective response. As a part of classifying vessels, there is a need to obtain and archive global vessel movement and port visit histories to document shipping patterns and to identify non-normal behaviour.

The US Coast Guard is preparing a vessel tracking plan to take advantage of existing and developing technologies to accomplish these tasks.

2. LONG RANGE IDENTIFICATION & TRACKING.

The US Coast Guard has a number of objectives for LRIT and other complementary approaches to attain maritime domain awareness.

LRIT will give the US Coast Guard a comprehensive surveillance capability through layered sensor arrays. Various sources of ship information bring different parts of the picture. Cooperative information, information that the ship volunteers about itself, will be reported or collected from broadcast technology such as AIS or through satellite communications polling. Non-cooperative information will be obtained from other sensors such as radar, imagery, and other sources. Layering of separate sources of tracking information will provide a desired level of redundant position reports on individual vessels. This will help maintain coverage requirements and ensure that deception or interference of any one sensor does not totally skew or disable the performance of the entire surveillance system. Layering of cooperative and non-cooperative sensors will assist in correlating specific ship and route data and identifying anomalies worthy of further investigation.

In the near term, the US Coast Guard may pursue voluntary participation in LRIT. Merchant vessels subject to the Safety of Life at Sea Convention (SOLAS) and transiting Sea Area A3 have the capability to regularly report position information via installed GMDSS equipment (i.e., Inmarsat-C). Many already use this capability or other satellite communications (e.g., Low Earth Orbit satellites) to report position and other information to shore-side agents and owners. Ship owners of SOLAS ships may be asked to voluntarily make their position information available to the US Coast Guard and permit polling. As an incentive for participation, port entry and departure requirements may be expedited.

The LRIT architecture design includes facilities, personnel, data resources, and reporting mechanisms. This system will require the management, movement and storage of significant amounts of data within very tight time constraints. The system will also require the necessary personnel and oversight to support this infrastructure. Automated review of database, track, and route information will return pertinent information to operators in near real-time. Through surveillance activities, contacts

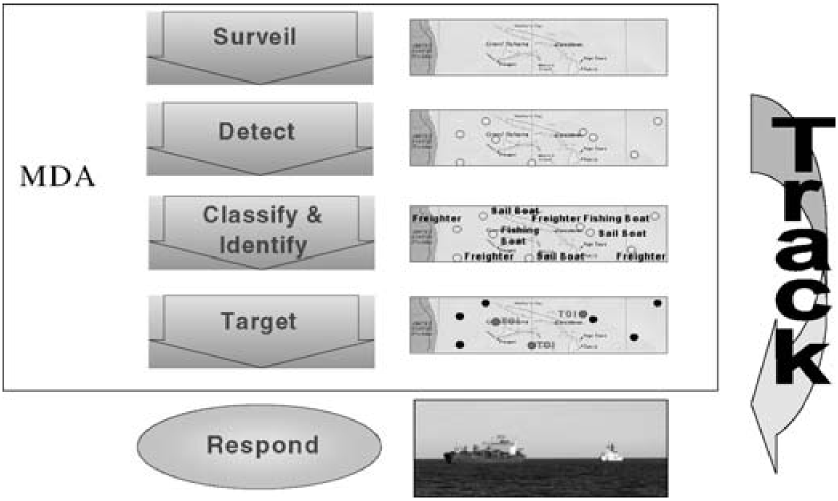

Figure 1. MDA Tracking.

are detected, classified and identified as shown in Figure 1. Intelligence obtained through human/machine mechanisms will return information to the Command Centre watch stander via the Common Operational Picture (COP). Historical activities, characteristics, and identifying features will be maintained for all ships greater than 65 feet in length. In order to enable anomaly detection and track correlation functions, the database must capture this information and be available for automated analysis. Predefined rule sets are imbedded in the system and applied by "intelligent" software that has the capability to alert the Command Centre watch stander to changes in vessel behaviour, discrepancies in multiple source information, and other circumstances worthy of further investigation.

LRIT management will be integrated into the COP and other national level information systems. The Coast Guard COP is integrated with other systems to enable the sharing and collaboration with Federal, State and Local officials. The Command and Control architecture includes all required nodes and sources of LRIT information. Figure 2 indicates the notional architecture for an LRIT system and those information sources and sinks with which it interacts.

3. LEGISLATION AND REGULATION.

The need for LRIT deployment was created under the auspices of Congressional legislation. This section looks into recent legislation relevant to maritime transportation security and its effect on regulations and the implementation of LRIT.

The Maritime Transportation Security Act (MTSA) of 2002 initiated legislation for long-range tracking to assist in maritime security:

> "*The Secretary may develop and implement a long-range automated vessel tracking system for all vessels in United States waters that are equipped with the Global Maritime Distress and Safety System or equivalent satellite technology. The system shall be designed to provide the Secretary the capability of receiving information on vessel positions at interval positions appropriate to deter transportation security incidents. The Secretary may use existing maritime organizations to collect and monitor tracking information under the system.*"

https://doi.org/10.1017/S0373463305003267 Published online by Cambridge University Press

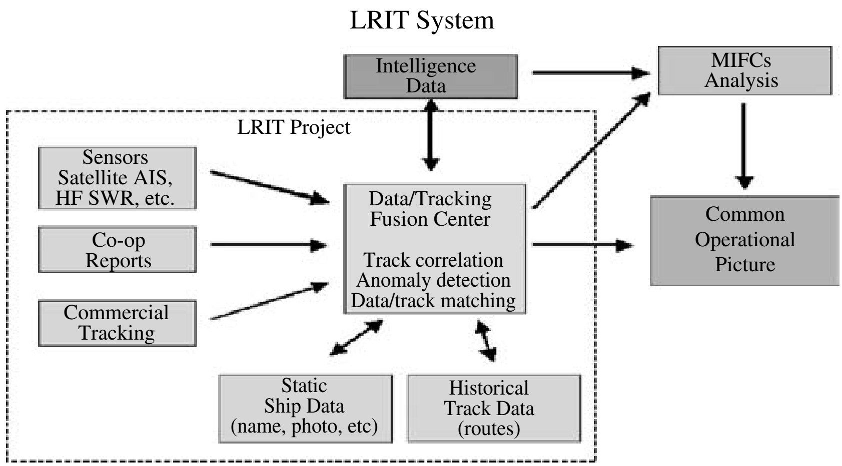

Figure 2. LRIT System Notional Architecture.

The Coast Guard and Maritime Transportation Act of 2004 amended this section of MTSA 2002 by requiring the Secretary of the Department Homeland Security to implement long-range tracking "*consistent with international treaties, conventions, and agreements to which the United States is a party*."

With MTSA as the underlying authority to implement long-range identification and tracking, the USCG is pursuing several regulatory initiatives at both the international and domestic levels.

3.1. *Proposed mandatory participation in LRIT for SOLAS ships*. The US is leading the effort at the International Maritime Organization (IMO) for adoption of mandatory vessel reporting which includes Flag, Port and Coastal State access to the reporting data. A US-proposed draft amendment to SOLAS Chapter XI (Special Measures to Enhance Maritime Security) was submitted to the Maritime Safety Committee 78th session (MSC 78) in May 2004. The draft amendment was discussed at the Radiocommunications and Search & Rescue Sub-Committee 8th session (COMSAR8) in February 2004. The draft amendment was revised and forwarded to MSC78. COMSAR9 is expected to finish its deliberations and forward its work to MSC80.

The US proposal seeks to have SOLAS ships carry LRIT equipment capable of automatically transmitting the identity of the ship, its position (latitude and longitude) and the date and time of position. As specified in the draft amendment, this information should be, at a minimum, current within 4 hours when the ship is 300 nm or more from the coast and 1 hour when the ship is less than 300 miles from the coast. Furthermore, the draft states that contracting governments, subject to certain restrictions, shall be able to receive identification and tracking information transmitted by ships as follows:

- Flag States – All Flag ships worldwide.
- Port States – All ships that have indicated to that Port State an intention to enter a port facility at a distance or time to be set by the Port State.
- Coastal States – All ships, regardless of the flag, navigating within a distance of 2,000 nautical miles of its coast.

https://doi.org/10.1017/S0373463305003267 Published online by Cambridge University Press

As revised at COMSAR8, the frequency of updates and the tracking distance from coastal states among other issues was yet to be resolved. Deliberations at COMSAR9 and the work it presents to MSC80 will have a significant impact on international maritime security. Future actions at IMO notwithstanding, existing legislation and regulations form a framework for LRIT in the US.

3.2. *US regulations.* Some position reporting requirements for US flag ships have been in place for many years. In 46 CFR 307, the US established a mandatory position reporting system. Under these regulations, operators of US flag oceangoing vessels in US foreign trade and certain foreign flag vessels must report their locations to enhance the safety of the vessel operations at sea and "provide a contingency for events of national emergency."

AMVER is a global ship reporting system that, since its inception in 1958, has been used exclusively to support search and rescue (SAR) operations. Ships voluntarily participate in AMVER by submitting sailing plans and updates. AMVER protects this data and maintains a global plot of ships so that the ship(s) best suited and least adversely impacted in the vicinity of a distress situation can be quickly identified and diverted to assist. Data collected by AMVER is protected as commercial proprietary information, and provided upon request to any recognized rescue coordination centre (RCC) worldwide coordinating response to a distress situation. In 2002, ships of over 140 flags voluntarily participated in AMVER.

AMVER exchanges data with other ship reporting systems used for SAR, such as CHILREP, JASREP and AUSREP, but only when the ship submitting the information so requests, as provided for in the IMO standard message format used by AMVER. Currently, AMVER's average daily plot includes about 3,000 ships. AMVER is sponsored by the US Coast Guard and is operated by the Coast Guard's Operations System Centre (OSC). AMVER collects, maintains and distributes ship position data worldwide by a variety of means, and has demonstrated that it can collect data via commercial companies that poll ships fitted with Inmarsat equipment. However, AMVER does not currently poll ships. While feedback is not always received from international Rescue Coordination Centres (RCCs) that use AMVER data in actual SAR cases, based on reports that are received, AMVER has been helping to save in the range of 150–400 lives annually, and with more participation these numbers would be expected to increase.

AMVER's concept of operation is to maintain a global plot based on voluntarily reported sailing plans and updates. An alternative, were the system authorized to use polling or some equivalent method of acquiring real-time data, would be to collect data for SAR only when and where needed, and to stop maintaining a global plot. This would minimize the shipboard effort, greatly reduce data collection for SAR, and make the system more accurate and cost-effective. For AMVER to work in this mode, participation would have to be mandated by IMO. This idea was introduced at COMSAR8 in February 2003 and could be further developed in concert with efforts to meet IMO requirements for long-range identification and tracking (LRIT) system.

3.3. *Develop regulations for domestic Port State LRIT reporting.* For SOLAS foreign vessels that intend to visit a U.S port, we are considering the requirement for vessels to self-report, at US expense, their identification, position, and time of position via Inmarsat, and otherwise allow the US to poll when within 2,000 nm of the US coast. It is anticipated such a regulation, if approved, would take effect

https://doi.org/10.1017/S0373463305003267 Published online by Cambridge University Press

in the 2006–2007 timeframe. This effort would be aligned with multi-lateral efforts at IMO.

- *Port State*. Regulation is in place for Notice of Arrival (NOA) of 96 hours for foreign flagged vessels intending to visit a US port. The regulation will be reviewed and could be revised or replaced by new requirements that may include:
  - Initiating the 96-hour NOA by electronic reporting means.
  - Once the NOA is initiated, automatic vessel position reporting could start, with 4-hour updates while outside of 300 nm and hourly within 300 nm.

3.4. *Develop regulations for domestic Flag State LRIT reporting*. For US Flag SOLAS class, regulations would be revised to require these vessels to report, at US government expense, their position globally and allow polling. Similar data is already required for SAR purposes only. It is anticipated that such a regulation, if approved, would take effect in the 2005–2006 timeframe.

- *Flag State*. Regulation is in place that requires US flagged ships to report to AMVER for safety purposes. A work plan would be developed that looks at incorporating LRIT requirements for ship reporting.

Prior to any regulation change, the US Coast Guard would publish a notice and comment period to allow the industry the opportunity to participate in the rulemaking process.

4. AUTOMATIC IDENTIFICATION SYSTEMS FOR MARITIME DOMAIN AWARENESS.

Along with the international focus on LRIT and US domestic legislation and regulations, AIS has also taken on a security role in the US. Perhaps it will surprise some that AIS may also have a long-range capability. Automatic Identification System (AIS) is based on an established standard of the International Telecommunications Union Radiocommunications Bureau (ITU-R) for a self-organized time division multiple access reporting scheme. AIS is required to be installed on all SOLAS class vessels (300 grt and greater) effective December 2004. Various AIS messages include a host of information sent via VHF broadcasts including Maritime Mobile Service Identity (MMSI), other ship identification, position, cargo (including hazardous cargo), crew and passenger information, speed, rate of turn and other data. The system was designed as a safety tool for collision avoidance by communicating this information between ships within VHF range of each other. However, AIS is now being investigated as a tool for maritime security.

4.1. *Nationwide AIS*. The US Coast Guard is developing a long-term major acquisition to deploy AIS nationwide. The AIS track information available from a nationwide infrastructure will provide AIS data to the COP. In the short term, the Coast Guard is working with the National Oceanographic and Atmospheric Administration (NOAA) to install AIS receivers on the National Data Buoys. Figure 3 represents the additional coverage that may be attained from these buoys. In September 2004, the Coast Guard established a contract with the Marine Information Service of North America (MISNA) to install AIS capability in 10 Alaska ports. Similar smaller scale efforts are being made in the Gulf of Mexico, Hawaii, and California.

https://doi.org/10.1017/S0373463305003267 Published online by Cambridge University Press

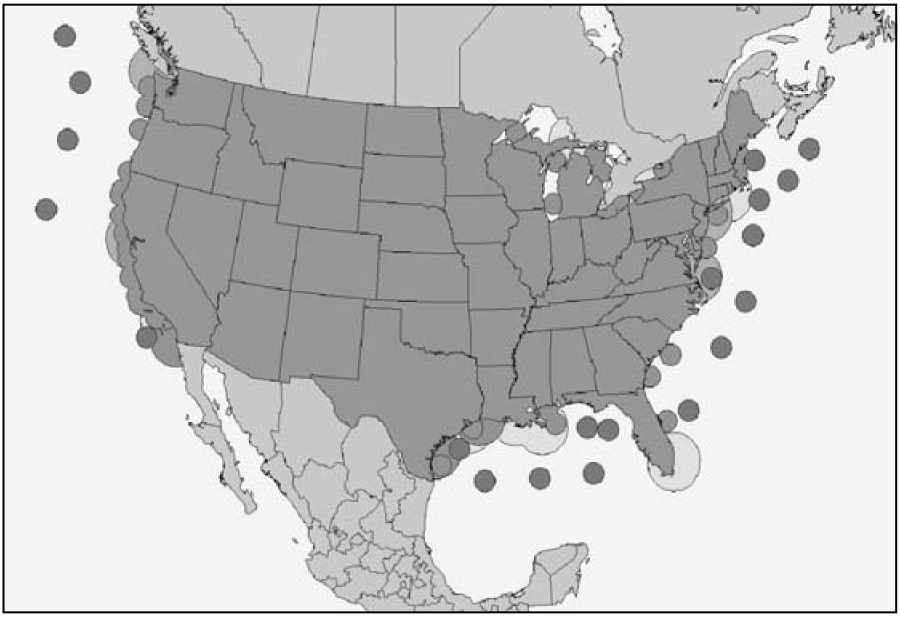

Figure 3. Potential AIS coverage offshore from NOAA Data Buoys.

A shipboard Automatic Identification System (AIS) is typically thought of as a line-of-sight system because it operates in the Very High Frequency (VHF) band. A good rule of thumb to use for line-of-sight analogue transmissions is:

$$d = \sqrt{[2\ (h_{antenna} + h_{ship})]}$$

where d is the line-of-sight distance (in miles) and h represents the respective heights of the shore side and ship antennas (in feet). This means an AIS receiver placed on a tower at 300 feet should receive signals from a ship's AIS placed 30 feet above the waterline out to 26 miles. Having said that, in practice digital transmissions usually have a longer reach than analogue. Recognizing this, the rule of thumb offers a conservative estimate of line-of-sight coverage of AIS. However, research has shown that, in practice, AIS may reach distances significantly longer than this rule of thumb predicts.

4.2. *Research and Development findings on the range of land-based AIS systems*. While the rule of thumb may come in handy for rapid, conservative estimates of AIS coverage, more comprehensive propagation models yield more accurate estimates, which indicate a broader coverage area. For example, in the ship-to-ship scenario, using the "Engineer's Refractive Effects Prediction System-PROPR" model, two ships with Class A AIS antennas at 100 ft, 12.5 W transmit power, 2.5 dB antenna gain, and receiver sensitivity of −107 dBm ought to receive each other at 40 nm. From a similarly Class A-equipped ship to a shore station with 100 ft, 9.5 dB antenna gain and −119 dBm receiver sensitivity, the shore station ought to "see" the Class A at 97 nm. The USCG Research & Development Centre (RDC) has established an experimental network that is used to study methods that can improve AIS

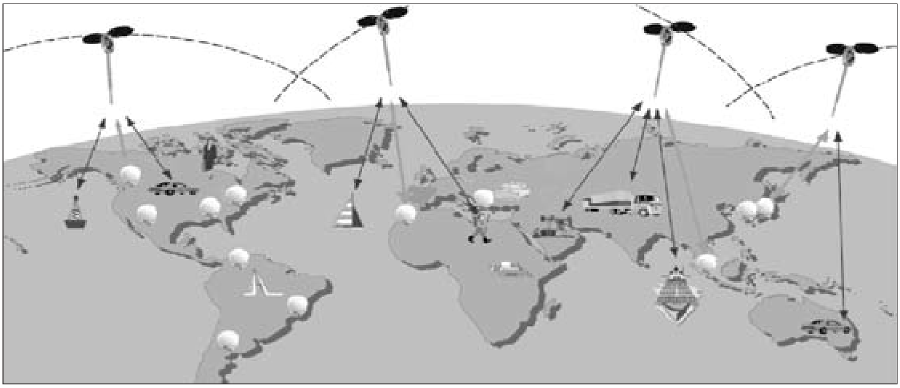

Figure 4. Space-based Automatic Identification System.

reception. RDC has conducted measurements on AIS shore site reception to determine the apparent coverage area. At one typical site, 50 percent of the time the maximum reception range was 140 nm; 10 percent of the time the maximum reception range was 220 nm. The important point here is that these distances are only achieved intermittently, but that may be good enough for some applications.

While it is apparent that tower-mounted AIS may reach well beyond typical VHF shore side coverage, it is still somewhat limited in range. By placing AIS receivers at heights not achievable with towers, the AIS receive capability expands to a significantly larger footprint.

4.3. *Satellite-Based AIS.* The Coast Guard contracted with Johns Hopkins University Applied Physics Lab to study AIS signals and determine if these could be captured from a high altitude platform. AIS transmissions are self-organizing time division multiple access. As such, vessels within the same horizon can broadcast their information in specific time slots without stepping on each other's signals. This study examined the feasibility of receiving and deciphering a large number of simultaneous signals with due regard to satellite receiver saturation. The report indicates that the ability to receive the signal was feasible from this type of platform and a significant number of signals could be received simultaneously without loss of message content. The next step following the APL study in developing a wide area, high altitude AIS receive capability is to put a receiver on a satellite for testing. This initial cost is approximately $7M. A contract with ORBCOMM was issued and, working with Johns Hopkins Applied Physics Lab, the design and installation details have been defined and the satellite assembled. Figure 4 shows the concept for AIS on the ORBCOMM satellite. The test satellite is due to be launched in late 2005 or early 2006 and will operate for up to 24 months. After validating the concept with a successful test, the US Coast Guard plans to deploy a follow-on constellation. If testing of a satellite with an AIS receiver is successful, deployment could begin for a five-year phase in period to launch up to 26 satellites. Many diverse maritime applications already use satellite communications services for fleet management to track, monitor and control mobile and fixed assets such as containers, barges, fishing vessels, pipelines and oil rigs, etc.

4.4. *High Altitude, Long Endurance (HALE) Airship-based AIS.* Working with other US government agencies and commercial vendors, the US Coast Guard is conducting evaluations on the use of high altitude balloons. These airships are capable of reaching about 65,000 feet in altitude and remaining on station in excess of 1 month. These new platforms could sustain a payload that could include AIS receivers, radars, cameras, and other sensors to detect surface ship tracks over a range of 400 nm radius.

4.5. *Test Broad Ocean Surveillance System* (*BOSS*) *concept*. The US Coast Guard plans to develop a proposal, seek funding and construct a test plan for a Broad Ocean Surveillance System (BOSS) concept that will yield surveillance capabilities for out to 2,000 nm from the US coast. The BOSS includes both Lighter Than Air vehicles such as HALE and also Heavier Than Air vehicles such as Unmanned Aerial Vehicles (UAVs). The BOSS airframes will support an LRIT sensor package. The test would define the supportability, sustainability, and performance data necessary to determine long term employment, particularly in areas where there is a higher than normal density of traffic, and resolution requirements to detect very small targets may be acute (e.g., Straits of Florida). The siting of individual BOSS LRIT sensors could provide high-resolution detection and tracking of migrant and law enforcement targets of interest over a sea area up to 800 nm in diameter.

5. CONCLUSION.

The US Coast Guard is pursuing a broad spectrum of long-range identification and tracking and other complementary technologies and applications to achieve Maritime Domain Awareness. A major system acquisition process is well underway to install a nationwide AIS capability. The US Coast Guard is leading the effort at IMO to adopt a SOLAS Amendment for LRIT carriage. In the interim, we are also looking to shipping interests to voluntarily report their ships' positions through GMDSS or other equipment as soon as we have that capability.