The Second International Scientific Conference
المؤتمر العلمي الدولي الثاني لتكنولوجيا علوم البحار
For Marine Science Technology
لتكنولوجيا علوم البحار
Sabratha – Libya 09-10/03/2021 صبراتة - ليبيا

The Use of Vessel Monitoring System, Automatic Identification System and Long Range Identification and Tracking System to Enhance Maritime Security

Oussama Ibrahim Hassan
Coastguardian76@gmail.com
General Administration for Coast Security, Ministry of Interior, Libya

Abstract

Libya with its unique maritime features, geostrategic location, rich biological diversity; coupled with its heavy reliance on economic marine-based activities and its responsibility for many hundreds of thousands of square kilometers of EEZ, the continental shelf, sovereignty territorial sea, 1770 km long coastline, and tens of seaports spread along this coast; all this had made clear the irrefutable importance of the Libyan maritime domain at all levels.

Recently, this growing importance brought in parallel an increased number of asymmetric threats including, illegal immigration, transnational organized crime, trafficking, smuggling, IUUF, and intentional environment damage. These serious security concerns put the General Administration for Coast Security (GACS), as the first and foremost maritime law enforcement authority that should counter such diverse threats, under severe challenge.

In the other hand, it is well known that the cornerstone to effectively counter any threat is its early detection through persistent surveillance of the maritime domain. In fact, experienced maritime security approaches showed that many sensors technologies could provide true and timely detailed information in a given area, affording the effective knowledge of the maritime situation, and the comprehensive understanding of what could impact maritime security. Among these sensors systems are the VMS, AIS and LRIT.

This study identifies GACS missions and functions for which VMS, AIS and LRIT are suitable, so to link its needs and considerations with information provided by these systems, while also highlighting operational issues and technological requirements that should be considered to ensure that VMS, AIS and LRIT are effectively integrated into maritime security operations. As such, the main purpose of this paper is to analyse how, in what contexts and to what extent GACS can use VMS, AIS and LRIT.

Keywords

GACS, VMS, AIS, LRIT, Maritime surveillance, Maritime security

1. Introduction

The current maritime security situation in Libya is dominated by a combination of asymmetric threats of a varying nature. These threats include, of particular concern, illegal immigration, transnational organized crime, trafficking (human, weapons, munitions, narcotic, counterfeit goods), smuggling (subsidized goods, fuel), IUUF, encroachment by foreign fishermen or intrusion of foreign vessels and aircrafts (civil, military, research vessels); as well as intentional environment damage.

Tackling such threats requires a continuous and persistent surveillance through a robust maritime surveillance system in order to reach a level of situation awareness which allows the timely detection and prevention of events threatening maritime security, environment and ensure border control (Fisher and Bauer, 2010).

Factually, it is well known that activities happening at sea can be divided into legal and illegal activities, whereas the legal activities consist of normal background traffic including cooperative vessels, primarily associated to a given context of normal operations (where all the rules are obeyed), and the illegal activities basically consisting of non-cooperative vessels with an illegal intention and anomalous behaviour. To distinguish possible threats from legitimate shipping, fishing and other maritime activities is the core of any maritime surveillance system.

2. GACS need for maritime surveillance data

Serving as one of the 21 General Administrations of the Ministry of Interior under the official name of the *General Administration for Coast Security*, this administration is a civilian-uniformed authority by law, and regulated by Act No. (10) Of 3 September 1992 for matters relating to security and the police.

Ten main responsibilities are defined in the Ministerial Decree No. (145) issued on the 1st of April 2012 and specified within its institutional framework. These basic duties according to the Decree are the following:

1. Preparing and executing necessary plans that ensure protection, safe guarding and securing Libyan coasts;
2. Working on and supervising surveillance, safe guarding and protection of Libyan coasts;
3. Patrolling coasts and territorial waters to ensure reconnaissance and surveillance;
4. Enforcement of security control over movements on the beaches and the areas adjacent to the sea;
5. Coordination, cooperation and participation in Search and Rescue (SAR) operations with relevant authorities;
6. Monitoring, evaluating and taking security measures regarding the security situation of ports, harbours, recreational beaches and marine clubs;

7. Registering, documenting, licensing and certifying fishing vessels, fishing boats and leisure crafts;
8. Granting security clearances and sailing permits for fisheries operations and recreational boating in coordination with relevant authorities;
9. Performance of such other duties as may be assigned to it by the minister of interior without contrary to the legislations in force and to this Act;
10. Preparing periodical reports concerning the work of the administration.

As it can be clear, tasks and functions appointed to the GACS are mainly connected to security, safety and marine environment protection. However, from an operational perspective, six out of ten of the above mentioned tasks (1 to 6) rely primary on the availability of data about the past, current and expected situation in the maritime domain with the goal of having knowledge of all coastal and open sea activities relevant to national security.

In general, such data are provided by a variety of heterogeneous sensors that can be subdivided into: Cooperative and Non-cooperative systems as depicted in the following table.

Table 1: Sensors Technologies

SENSORS	
Cooperative	Non Cooperative
Cooperative sensors are those by which only participating vessels are monitored. These sensors are also sometimes referred to as voluntary, participatory or compliance sensors. Despite these terms, some vessels participate unwillingly and may interfere with onboard surveillance systems. Nonetheless, the levels of information they provide make them a valuable surveillance tool. •Automatic Identification System (AIS). •Long Range Identification and Tracking (LRIT). •Vessel Monitoring System (VMS).	Non cooperative sensors are those that can observe vessel activities without their participation or knowledge, not even their permission. The information they provide is generally less detailed than for the cooperative ones, but they can monitor the activity of all vessels, including suspicious and illegal activities. •Radar ◦Conventional radar (S-Band, X-Band) ◦Frequency Modulated Continuous Wave radar (FMCW) ◦Over The Horizon Radar (OTHR) ◦High Frequency Surface Radar (HFSWR) ◦Radar imaging system (SAR, ISAR, SLAR, FLAR) •Optical (camera, video) •Acoustic: Passive/Active (Sonar), Passive (Hydrophone) •Electronic Support Measures (ELINT, COMINT)

Source: Author based on (Brooke, 2011)

In fact, among the main shortcomings with regard to the current situation of the GACS in respect of maritime security is the lack of its own maritime surveillance system. Accordingly, it will be of the benefits of the GACS, as a starting point, to use data provided by other monitoring system developed for particular purposes other than maritime law enforcement – such as Vessel Monitoring System (for fisheries control), Automatic Identification Systems (for safety of navigation), Long Range Identification and Tracking system (for security, search and rescue and other purposes).

Hence, this paper will focus only on the three main non-cooperative technologies that have a marine surveillance and enforcement application: VMS, AIS and LRIT.

3. Vessel Monitoring System (VMS)

The Vessel Monitoring System (VMS) is one of the most widespread cooperative surveillance tools currently in use in the area of fisheries management. Both its units and operating costs are relatively low, coupled with the ease of operation; this has facilitated its widespread use.

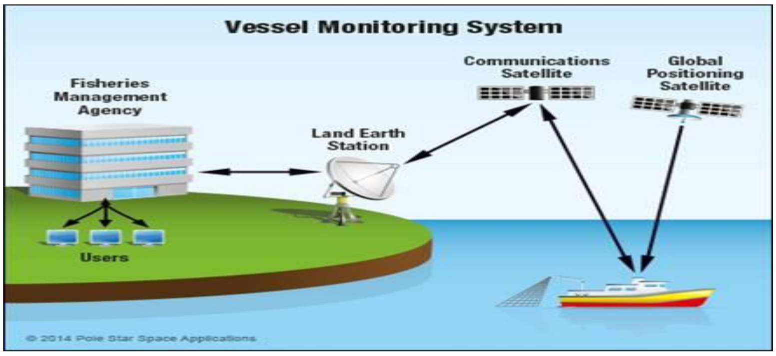

Figure 1: Vessel Monitoring System (AFMA, 2014)

Vessels using a VMS system carry a transceiver unit (transmits and receives signals) that transmits its GPS coordinates via a communications satellite (e.g. INMARSAT-C, ARGOS, ORBCOMM, IRIDIUM) to a monitoring station on shore (Figure 1). Currently VMS uses satellite GPS technology that provides position data within 10 m resolution from anywhere on the globe.

While there are currently no binding global agreements regarding the use of VMS, most Regional Fisheries Management Organizations (RFMOs) as well as many States have mandated its use on larger commercial fishing vessels (flagged to and/or fishing in the waters of the State). VMS is now a standard feature in the fisheries law of over 60 countries and 15 international organisations (Long et al., 2013).

However, the term of VMS is defined by IMO in “Performance standards and functional requirements for the long-range identification and tracking (LRIT) of ships” by Resolution MSC.263 (84) adopted on 16 May 2008 as “a system established by a Contracting Government or a group of Contracting Governments to monitor the movements of the ships entitled to fly its or their flag. A Vessel Monitoring System may also collect from the ships information specified by the Contracting Government(s) which has established it”.

The VMS data are usually only reported to the vessel’s flag State or the EEZ coastal State. In areas beyond national jurisdiction, enforcement of VMS regulations is the responsibility of flag states, though this may be administered through the RFMOs. VMS itself monitors the position, course, speed, and in some cases vessel activity.

Once positional reports are received at RFMO, the data is automatically displayed as plots on marine charts for the intended purpose of conducting appropriate geospatial analysis.

In fact, the VMS system is a vital tool in assisting fisheries managers to achieve compliance with fishery management arrangements, in particular where fishing activity needs to be restricted to certain areas or zones such as automatic alert notifications designed to raise awareness upon entering prohibited areas or protected areas. Additionally, the system has improved the quality of location derived data for research purposes.

VMS also offers many ancillary benefits not only to the fishing industry but also to the overall security. It is obviously part of fisheries enforcement, but along with other systems, it can be part of overall sea surveillance. When radar or other sensor detects a given vessel, VMS can confirm the radar centre whether the target is a known fishing vessel. There may be correlation between VMS and other sensors. Another benefit is that VMS has been considered by courts in various countries where VMS data were used as evidence in prosecuting fisheries offences by coastal States. In 1998, VMS technology applied in evidence for the first time in the United States with the successful prosecution of *F.V. Independence* (Long et al., 2013).

Despite its capabilities, VMS in itself is a cooperative system, and does not monitor non-cooperative vessels. Vessels can also evade VMS regulations by registering with States which do not require its use, are not members of RFMOs that require its use, or which require VMS use but lack the will or capacity to enforce regulations. Vessels may also tamper with their VMS and disable the equipment, jam signals, or broadcast false position data. In response, some States (such as the US and the EU) regulate the types of VMS unit permitted, allowing only "Tamper-resistant" models. For instance, to overcome the problems associated with false signal transmission, the EU's Galileo satellite navigation system (similar to the GPS) uses encrypted signals so that it is more difficult to intervene Galileo-based VMS.

Though GPS coverage is continuous, VMS units typically report vessel position to the RFMO every 1-2 hours. Limitation of the low reporting rate can complicate enforcement as a two hour window can be sufficient for fishing vessels to make quick illegal entries into restricted areas. A simple increase in reporting rate would greatly ameliorate this problem.

4. Automatic Identification System (AIS)

The Automatic Identification System (AIS) is an automatic tracking system used for identifying and locating vessels. This "shipboard broadcast system that acts like a transponder, operating in the VHF maritime band" (USCG, 2020) is commonly found on ships and used by vessel traffic services (VTS) around the world, also it could be installed on land in specific areas like choke points or along the coast, buoys, warships and any other place within line of sight range of a vessel.

Like VMS, AIS is a cooperative system, with all the difficulties that entails. However, AIS has the weight of an international body and convention behind it. Under regulation 19 of chapter V of the Safety of Life at Sea (SOLAS), the IMO mandated by an amendment in December, 2000 that AIS is to be fitted aboard all ships of 300 gross tonnage and upwards that are engaged on international voyages, cargo ships of 500 gross tonnage and upwards that are not engaged on international voyages and all passenger ships (that carry more than 12 passengers), irrespective of size, built on or after 1 July 2002.

There are two classes of AIS, Class A which is referred to in the SOLAS convention, and Class B, which provides less functionality than an AIS Class A and is intended for non-SOLAS vessels (vessels to which the SOLAS convention does not apply). There are also different types of non-shipborne AIS, including:

- AIS used for shore stations (AIS Base Stations).
- AIS Aids to Navigation (AIS AtoN).
- AIS Search and Rescue Transmitters (AIS SART).
- AIS fitted to Search and Rescue Aircraft (SAR aircraft).
- Man Overboard units (AIS MOB).

Each AIS Class A station consists of one VHF transmitter, two VHF TDMA receivers (AIS 1 and AIS 2), one VHF DSC receiver (Ch.70), a standard marine electronic communications link to shipboard display, and a sensor input from different onboard systems. Timing and positional information comes from a GNSS (global navigation satellite system such as GPS, GLONASS, DGPS/DGLONASS and GALILEO) that should comply, respectively, with IMO Resolution MSC.112 (73), MSC.113 (73), MSC.114 (73), MSC.233 (82) and IEC Test Standard 61108.

An AIS transponder normally works in an autonomous and continuous mode, regardless of whether it is operating in the open seas or coastal or inland areas. AIS transponders use two dedicated frequencies, VHF maritime channels 87B (161.975 MHz) for AIS 1 and 88B (162.025 MHz) for AIS2. TDMA (Time Division Multiple Access) is the technology used to allocate and share the available airwaves on the AIS frequency. The AIS standard states that there are a fixed number of time slots for each of the two AIS channels: 2,250 on each channel repeated every 60 seconds, so a total of 4,500 every 60 seconds across both channels. AIS sent information packets are transmitted on these slots. At the same time, AIS units in range by listening to the time slots can receive the information (Figure 2).

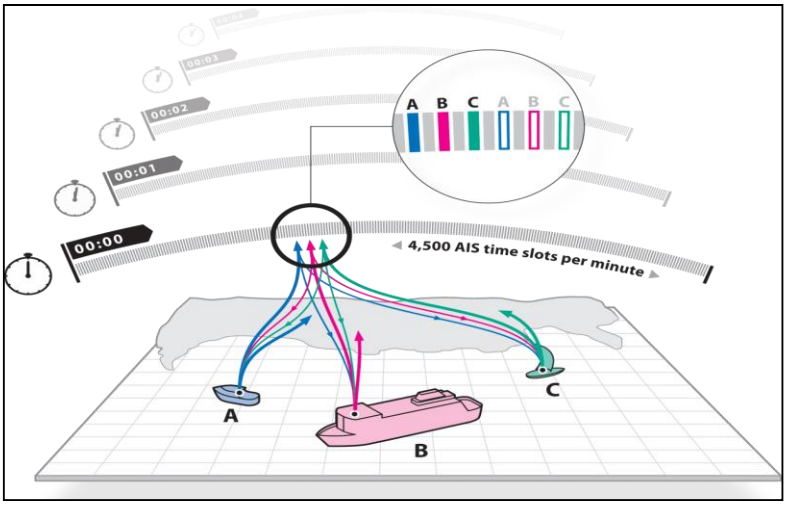

Figure 2 Time Division Multiple Access (TDMA) technology (allaboutais, 2012)

AIS-equipped ships broadcast automatically a wealth of information, including:

- Static information: such as IMO number, MMSI number, call-sign, name, dimensions, type of vessel.
- Dynamic information: such as time in UTC, lat/long (to GPS accuracy), course over ground, speed over ground, heading, rate of turn, navigational status.
- Voyage related information: such as draft, cargo type, route plan (waypoints), destination and estimated time to arrival.
- Short safety-related messages: Free format text message (approximately 158 characters of text) sent as required.

This information can be received by other ships, aircraft, or terrestrial base stations, and displayed on a computer or electronic chart plotter as it can be also overlaid onto a radar screen. AIS has a far higher reporting rate than other systems like VMS, from once every 6 minutes (static and voyage related information) down to every 2 seconds - 3 minutes (dynamic information) depending on speed and course alteration. The rate of data exchange increases as a ship gains speed.

However, AIS range is currently limited to ~20-60 nm, as the broadcast carries VHF range which is basically line of sight, except under certain atmospheric conditions as it sometimes can curve some distance over the horizon to reach 100 nm (for example in summer in the Libyan maritime domain). In addition, AIS messages that are received by a ship can be re-transmitted by AIS-base station, satellite, etc.; this relaying function can also extend the range.

As originally intended under SOLAS, the primary use of AIS is navigational safety and collision avoidance. However, the obvious power of AIS in monitoring maritime traffic can aid greatly in maritime security and provide a means to assist in maritime surveillance, which has attracted the attention of many navies and coast guards worldwide. AIS data from various sources (coastal stations, buoys, aircraft, etc.) is increasingly being used as surveillance tool in national defence and security applications.

Indeed, AIS enables authorities to identify specific vessels and their activity within or near a nation's Exclusive Economic Zone. When AIS data is fused with existing radar systems, authorities are able to differentiate between vessels more easily. While AIS broadcasts do not explicitly identify vessel activity, the navigational information provided is often sufficient to identify many types of activity, which involve distinctive vessel movement patterns. In other words, AIS data can be automatically processed to create normalized activity patterns for individual vessels, which when breached, create an alert, thus highlighting potential threats for more efficient use of security assets.

Hence, to achieve the full benefits of AIS, information better to be displayed graphically on radar, ECDIS or on its own dedicated display. Recognizing this, IMO has mandated in its revised radar performance standards (IMO Resolution MSC.192 (79) 2004) that from 1 July 2008 onwards, all new radar installations must be able to display AIS targets. The ability to display AIS information on radar or ECDIS depends entirely if the radar/ECDIS has been designed or modified for this purpose.

In addition to the information currently broadcast by AIS, the architecture of AIS transmission includes several currently unused data slots. These slots may be used to transmit additional information. Since, originally out of a possibility of 64 different types of messages that can be sent by AIS transceivers, only 27 are defined by the International Telecommunication Union (ITU). The rest of messages (28-63) are undefined and reserved for future use. In this context, in May 2004 the IMO Maritime Safety Committee approved SN.1/Circ.236 as guidance for the application of AIS binary messages. The purpose of this document was to define a provisional set of 7 digital messages for a trial period of 4 years with no change. The criteria for selecting the trial messages were to be a demonstrated operational need by a cross-section of users including ships, VTS, Pilots, Coastguard and port authorities. These 7 trial messages were reviewed during 2009 and published as 15 new messages within IMO SN.1/Circ.289, these new messages were defined and approved internationally from June 2010.

Regarding maritime security, many of the new messages could be very helpful such as: Extended ship static and voyage-related data, Number of persons on board, Clearance time to enter port, Area notice (broadcast & addressed) and Route information. For example, the "area notice" specification in the IMO circular SN.1/Circ.289 may solve a major problem with enforcing spatially-regulated marine zones, when some Vessels may not be aware of such areas and may violate regulations. The use of AIS could reduce this problem, since regulated areas could be automatically displayed on those vessels with

Electronic Chart Display and Information Systems (ECDIS). This may also help shifting the burden of proof in prosecuting violations.

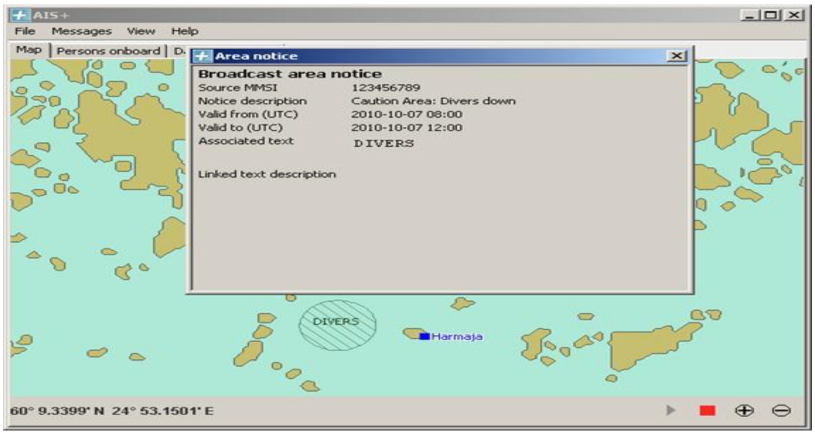

Figure 3: AIS Area notice message portrayal (Porthin et al, 2011)

Figure 3 above shows a graphic display in a chart indicating the area or position concerned by the Area notice message on a separate PC screen onboard a ship with an opened area notice information dialog. This example portrayal was application software developed in 2011 by Markus Porthin et al.

In the same context, AIS transceivers could be mounted on moored buoys or on land if within range, and AIS technology could be adapted to display area boundaries at considerably less cost to install and maintain than the radar beacon (RACON) systems currently used for marking navigational hazards. This potential application would be a powerful tool in enforcement of regulations, since all AIS equipped vessels would be aware of the boundaries (Brooke et al., 2010).

Thus far, there are two major limitations in the use of AIS for maritime surveillance. First, non-SOLAS vessels and small crafts are not required to carry AIS (AIS class B is not mandated by IMO). Second, the limited range of traditional AIS signals makes monitoring remote locations impractical; however to offset the first limitation, some countries reviewed the requirement of the AIS carriage for specific types of craft. For example, in April 2009 the EU passed legislation requiring all EU fishing vessels over 15 m length to be class A AIS-equipped by mid-2014, the US expanded the range of vessels required to carry AIS; a Federal Regulation was issued to reduce the AIS carriage requirements down to 65 feet (19 m) for vessels entering a US port, as well as towing vessels of 26 feet or more and over 600 horsepower and other specified vessels. In order to overcome the second limitation on the spatial coverage, it has been recently demonstrated that AIS signals can be well received using space-based systems.

To conclude, AIS may help in maritime surveillance by providing the tracking of ships. This function is acknowledged by IMO and IALA; in the same document on Performance Standards for AIS (MSC69/22/Add.1 ANNEX 12 Page 13), the IMO states: “AIS should be capable of providing to ships and to competent authorities, information from the ship, automatically and with the required accuracy and frequency, to facilitate accurate tracking”. AIS can therefore be used by Coastal States for maritime surveillance, in particular by:

- Monitoring restricted areas
- Monitoring mandatory routes
- Generating alerts in shore based monitoring centers
- Providing data for Port State Control, port authorities, coast guard centers and others authorities and services; and
- Monitoring vessels of particular interest (IALA, 2005).

5. Satellite-based AIS (S-AIS)

At the time, when AIS was developed in the 1990s, it was not anticipated to be detectable from space. After some years of investigating the possibility of mounting AIS receivers on microsatellites to achieve extended range, it was discovered that while Earth’s curvature limits horizontal range of VHF signals to about 40 nautical miles, these same signals extend much farther vertically into space, which enable satellites equipped with AIS receivers to capture this information and relay it to the ground.

As such, the primary weakness of AIS has been overcome and the detection of the AIS signal transmitted from a ship is possible in the entire radio visibility range of a satellite equipped with an AIS payload. For example, for a Low-Earth orbit (LEO) satellite at an altitude of 650 Km, the average field of view is above 20 million square kilometers (Iervolino, 2016). Nevertheless, the major problem was that a VHF antenna on a micro-satellite would receive AIS signals from thousands of ships. This would violate the TDMA limitations, resulting in message collisions which give major interference problems for the satellite. However an AIS receiver in low earth orbit work better in areas of low-density shipping. This work in a store and forward mode or by directly linking the AIS information to land or coast guard vessels.

The main difference between coastal and Satellite-based AIS is that the latter does not provide continuous coverage; satellite cannot transmit captured data to the earth for further processing and distribution, until it is above a fixed ground station, which is only periodically within range. The expected refresh rate for the full constellation of satellites is <30 minutes for pole ward regions and <90 minutes for equatorial regions (Brooke et al., 2010). This latency could be improved by operating more AIS-equipped satellites and installing additional ground stations.

The cost of S-AIS is considerable, with a yearly subscription fee on the order of a few million dollars. It is important to remember, though, that this fee is applicable at the level of national governments and organizations of similar scale. Many governments are attracted to space-based AIS for its national security and surveillance applications, and are willing to consider the subscription fees as a security and defence related expense. The AIS data from a government-level subscription, though, will typically be available to all relevant government agencies, including enforcement agencies (Brooke et al., 2010).

With regard to maritime surveillance, great strength of S-AIS is the ease with which it can be correlated with additional information from other sources such as radar, optical, and more SAR related tools such as GMDSS, SARSAT and AMVER. Satellite-based radar and other sources can contribute to maritime surveillance by detecting all vessels in specific maritime areas of interest.

6. Long Range Identification and Tracking (LRIT)

On 19 May 2006, the IMO adopted Resolutions of the 81st Maritime Safety Committee - MSC 202(81) and MSC 211(81) - which made an amendment to Chapter V of the International Convention of Safety of Life At Sea, 1974 (SOLAS) Regulation V/19-1 and introduced the establishment of the Long Range Identification and Tracking system (LRIT) for reasons related to national security. The SOLAS amendment came into force on 1 January 2008 with compliance by 31 December 2008.

The main purpose of the LRIT ship position reports is to enable a Contracting Government to obtain ship identity and location information in sufficient time to evaluate the security risk posed by a ship off its coast and to respond, if necessary, to reduce any risks. At the 83rd Maritime Safety Committee, the purpose and scope of LRIT was extended to include search and rescue (SAR), safety, and protection of the marine environment (MSC 242(83)).

The main components of the LRIT system, as illustrated in Figure 4, include: the ship-borne transmitting equipment, the Communication Service Provider(s) (CSPs), the Application Service Provider(s) (ASPs), the LRIT Data Centre(s) (DCs), including any related Vessel Monitoring System(s) (VMSs), the LRIT Data Distribution Plan (DDP), and the International LRIT Data Exchange (IDE).

In fact, LRIT works in essentially the same manner as VMS; an LRIT-equipped vessel uses its on-board equipment (e.g. ship security alert system (SSAS), global maritime distress and safety system (GMDSS) or any satellite communications terminal on board) to transmit automatic position report-including the shipborne equipment identifier, positional data latitude and longitude, and the date and time of the transmission- every 6 hours to a telecommunication satellite (INMARSAT, IRIDIUM, etc.) operated by a Communication Service Provider (CSP). Reporting rate can be increased from the usual 6 hours, down to 15 minutes if required by the vessel's flag State or coastal State authorities for example when a security incident occurs in a specific area and a more detailed surveillance picture is required. As mentioned on MSC.263 (84), this change in reporting frequency should be activated remotely without the vessel's knowledge (without human interaction on board the ship).

Once the message is received by the CSP, it is then transmitted to the Application Service Provider (ASP) which completes the LRIT information of the vessel by adding the ship identity (IMO and MMSI identification numbers) as well as the date and time when the position report is received and forwarded by the ASP. The new extended message generated by the ASP is then securely transferred to the LRIT Data Centre chosen by the vessel's national administration. LRIT Data Centres communicate with each other, collect, store and exchange information and data through the IDE, this latter exists to route the messages to the proper destination by using address information contained in the Data Distribution Plan (DDP), a document maintained by the Contracting Governments and made available by the DDP Server, hosted at IMO.

The IDE has been developed, hosted and operated on a temporary basis since 16 December 2008 by the United States Coast Guard agency (MSC.264 (84) of 2008). On 18 October 2011, the IDE has been transferred to the European Maritime Safety Agency (EMSA) in Lisbon, Portugal. 65 Data Centres worldwide (covering 117 Contracting Governments and Territories) currently use the IDE hosted at EMSA. The backup Disaster Recovery site remains with the US Coast Guard, which could be activated to ensure the continuous and uninterrupted operation of the LRIT system in the case of a critical failure (for example sustained power outage, sustained network connectivity degradation, etc.) at the primary site in Portugal (IMO, 2011).

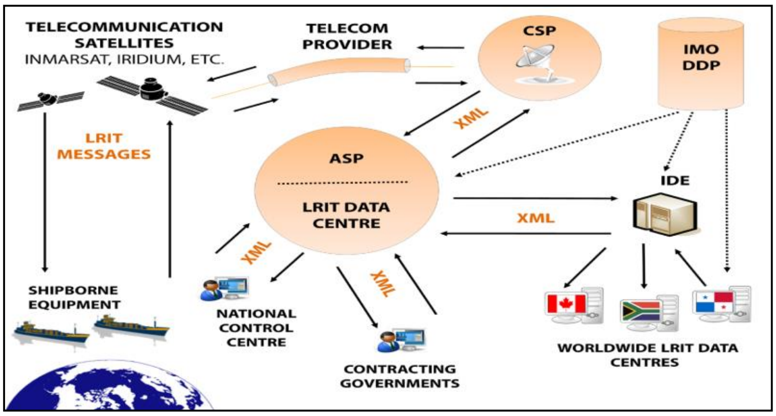

Figure 4: LRIT system (EMSA, 2021)

LRIT carriage is mandatory on three categories of ships making international voyages: passenger ships including high-speed passenger craft, cargo ships over 300 GT including high-speed craft, and mobile offshore drilling units. These categories largely overlap with the requirements for AIS Class A coverage. Despite this overlap, and the fact that both LRIT and AIS use are governed by the SOLAS convention, there is no interfacing between them; they function completely independently of each other. As such, ships operating exclusively in the sea area GMDSS A1 (Regulation 19.1 para. 4.2) and are fitted with AIS are not required to install LRIT equipment;

their coastal AIS coverage is deemed sufficient.

One important difference between LRIT and AIS, apart from the obvious one of range, is that whereas AIS is a broadcast system, LRIT data are very tightly controlled, transmitted to and processed by a limited number of national, regional or international Data Centres, which share and exchange information as necessary; LRIT data are available only to the recipients who are entitled to receive such information and safeguards concerning the confidentiality of those data have been built into the regulatory provisions. Under the terms of SOLAS Regulation V/19-1.8, only four parties are entitled to access vessel position information: Search and Rescue (SAR) authorities to support their daily salvage operations, Flag States, on a routine basis, to track vessels on their registers wherever they are, Port States requesting information about a vessel once it declares its intention to enter its control area as to have one of their ports as destination, irrespective of its location or flag (on receipt of the Notice of Arrival), and Coastal States (specifically, the SOLAS Contracting Governments of coastal States) which may track any LRIT-equipped vessels within 1000 nm of their coast providing that vessel is not within the territorial waters of another state.

As a surveillance system, LRIT combines some of the strengths of VMS and AIS, but unfortunately most of the weaknesses as well. LRIT, like AIS, also has the advantages of strong safety- and security-based international legal backing and with it an existing international architecture for data sharing and standardization; something that VMS sorely lacks. But LRIT carriage requirements are as limited as those of AIS, and so currently exclude the vast majority of vessels and so far it is small crafts used in illicit activities. In addition, like VMS, one of its main shortcomings is a low reporting rate, as low as once every 6 hours (compared to VMS once per 1-2 hours) providing near-real-time but non-continuous surveillance. The capacity for on-demand polling of LRIT systems, however, means that there is no reason why its reporting rate cannot be increased.

Despite these weaknesses, LRIT does complement VMS well; LRIT carriage generally excludes fishing vessels (which carry VMS instead), and many non VMS-equipped vessels are required to use LRIT. Combining the two systems therefore could allow for global tracking of most types of cooperative vessels. Efforts to integrate data from the two systems, or to extend LRIT carriage to fishing vessels, may prove worthwhile. The same goes for LRIT and AIS, where the information collected from the two systems are mutually complementary in term of the sea areas coverage.

7. Conclusion

This paper investigated the role of cooperative sensor systems: VMS, AIS and LRIT when used by GACS. It can be obviously concluded that although these technologies have been developed and implemented mainly for other purposes than maritime security and law enforcement; their effective application can contribute significantly in fostering maritime security.

As such, main finding of this paper was that VMS, AIS and LRIT systems can play a key role in the maritime security context according GACS tasked missions, since they can assist the day to day operations by providing timely and reliable information about activities in the Libyan maritime domain that would in turn provide early warning and quicker response time to possible maritime threats as well as optimizing GACS limited resources.

Summing up, specific main contributions of VMS, AIS and LRIT are:

- The possibility of establishing an electronic database of vessels identities and movements.
- Enhance reporting of incidents related to maritime security.
- Reveal anomalies and suspicious activities so to distinguish between legal and illegal activities within Libyan maritime domain and to prevent its impacts.
- Can guide GACS patrols directly to illicit targets so to avoid time and resources waste.
- Enhance the effectiveness of operations and more cost-efficient GACS maritime missions.
- Help achieving compliance with Libyan legislations and laws.
- Enhance the control of restricted and prohibited areas.

- Provide target identification when correlated with other non-cooperative sensors.
- Can be used by court as evidence.
- Enhance SAR operations.
- Provide data for marine accident investigation.
- Provide data for long term planning.

Finally, the first and foremost recommendation of this paper to the Libyan Ports and Maritime transport Authority (LPMTA), as the competent authority for Port State Control and Flag State Control, is to establish a developed Vessel Traffic Management System (VTMS) in which AIS and LRIT are integrated with other sensors. The same recommendation goes to the General Authority for Marine Wealth (GAMW) as the exclusive authority responsible for the fishing sector, to consider establishing an adequate Vessel Monitoring System (VMS).

Establishing both VMS and VTMS will accelerate and pave the way for GACS to establish its own Maritime Surveillance System. Moreover, this will support the GACS in exploiting to the maximum possible the advantages of VMS, AIS and LRIT technologies in the field of maritime security.

8. References

1- Australian Fisheries Management Authority (AFMA), (2014). *Satellite monitoring of fishing boats/Rules and Regulations/Domestic Compliance*[Online].Availableat:https://www.afma.gov.au/monitoring-enforcement/satellite-monitoring-fishing-boats[Accessed 10 Feb. 2021].

2- All About AIS, (2012). Technical fundamentals. [Online]. Available at:http://www.allaboutais.com/index.php/en/ais-technical-information-footer/109-ais-technicals/various-ais-technologies. [Accessed 10 Feb. 2021].

3- Brooke, S., (2011). REVIEW OF SURVEILLANCE AND ENFORCEMENT OF FEDERAL FISHERIES IN THE SOUTHEASTERN US. Marine Conservation Institute, USA. Available at: https://marine-conservation.org/media/filer_public/2012/03/23/safmc_serma_final_report.pdf [Accessed 13 Feb. 2021].

4- Brooke SD, Lim TY, and Ardron JA. (2010) Surveillance and enforcement of remote maritime areas.Paper 1: surveillance technical options. Marine Conservation Biology Institute, USA. Version 1.2; 39 Pages.Available at : https://www.openchannels. org/sites/default/ files/literature/surveillance_and_enforcement_of_remote_maritime_areas.pdf [Accessed 10 Feb. 2021].

5- European Maritime Safety Agency (EMSA), (2014). *Publications: Vessel Tracking Globally. Understanding LRIT.* [Online]. Lisboa, Portugal.Available at:http://www.emsa.europa.eu/publications /leaflets/item/256-vessel-traking-globally-understanding-lrit.html. [Accessed 10 Feb. 2021].

6- Fischer, Y. and Bauer, A., (2010, November). Object-oriented sensor data fusion for wide maritime surveillance. In *Waterside Security Conference (WSS), 2010 International* (pp. 1-6). IEEE. doi:10.1109/wssc.2010.5730244. Available at: http://dx.doi.org /10.1109/wssc .2010.5730244 [Accessed 10 Feb. 2021].

7- IMO. RESOLUTION MSC.322(89), (2011). Operation of the International LRIT Data Exchange. International Maritime Organization, London, 20 May.
8- International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), (2005, December). *IALA Guideline 1050 on the Management and Monitoring of AIS Information. Edition 1.0.* France: Author.
9- Lervolino, P., (2016). *Ship detection with SAR: modelling, designing and real data validation*. PhD dissertation, Faculty of Engineering & Physical Science University of Surrey, Guildford, U.K.
10- Long, R. And Monnet, J., (2013,June). EU REGULATION OF FISHING VESSELMONITORING SYSTEMS. In *Workshop on Information and Communications Technology for Environmental Regulation: Developing a Research Agenda*, June 20-21,2013. School of Law, NUI Galway.
11- Porthin, M., Berglund, R., and Seitsonen, L. (2011). AIS+ - facilitating on board use of AIS Application-Specific Messages. In *E-Navigation Underway: International conference on e-navigation*, Copenhagen, Denmark and Olso, Norway, 31 January – 2 February, 2011. (pp. 42-48). Available at: http://www.efficiensea.org/files/ conferenceproceedings.pdf [Accessed 10 Feb. 2021].
12- US Coast Guard, (2020). *AUTOMATIC IDENTIFICATION SYSTEM OVERVIEW*. [Online]. USCG Navigation Center , Alexandria,VA.Availableat:https://www.navcen.uscg.gov/?pageName =aismain#:~:text=The%20AIS%20is%20a%20shipboard,often%20as %20every%20two%20seconds. [Accessed 10 Feb. 2021].