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AIS Implementation – Success or Failure?

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AIS is the most recent example of a major globally-introduced maritime navigation system. During its evolution, introduction and early in-service life, it has aroused a lot of negative comment. The basis for this negativity is examined, particularly in the light of the real experience that is now being gained by users of the system. The evolution of the AIS concept through the relevant international bodies – IMO, ITU, IALA and IEC – is discussed, together with the type of problems encountered during its introduction. Many of the problems would have been ameliorated if there had been better communication to users of the system. It is argued that the complexity of the system really required mandatory training to be undertaken, in parallel with the installation of the new equipment.

KEY WORDS

1. AIS. 2. VTS. 3. IMO. 4. Collision avoidance.

1. INTRODUCTION. In 1997 a meeting was held at the International Association of Lighthouse Authorities (IALA) in Paris concluding that the preferred option for a new identification system for ships should be based on a Self Organising Time Domain Multiple Access (SOTDMA) transmission protocol operating within the VHF marine band. Initially, the Automatic Identification System (AIS) was envisaged as providing a ship-to-shore data system that would enhance the operation of Vessel Traffic Services (VTS), giving two-way automatic data communication between ships and port authorities. This had evolved to allow VTS operators to display detailed positional and velocity information from ships at a data rate comparable to radar. The Swedish-advocated SOTDMA[1] system was chosen from a number of other competitive systems, after a number of trials and analysis programmes. Using just two 25 kHz VHF marine channels, it offered a reliable system that could operate satisfactorily in the busiest foreseen situations.

IALA, as a Non-Governmental Organization (NGO) with close links to the International Maritime Organization (IMO), presented its findings to IMO later in 1997. IMO is an agency of the United Nations that continues to have great success in agreeing globally enforced maritime standards enhancing safety, environmental protection and security. IMO members agreed to adopt the SOTDMA system for AIS in preference to a system based on VHF marine-band Digital Selective Calling (DSC). DSC equipment was already mandatorily carried by ships as part of the Global Maritime Distress and Safety System (GMDSS). The relatively small amount of data required for the originally envisaged VTS AIS could be adequately accommodated by DSC. It had the advantage that since it was an existing system it would be a low cost option to implement. However, DSC could not cope with the data rates required for real-time positional purposes. IMO recognised the potential of real-time AIS positional and velocity data to supplement radar information for collision avoidance purposes. In particular, it did not suffer from the long latency inherent with radar-tracked data. The new system was termed Universal AIS (UAIS) in recognition that the chosen solution also embodied a parallel DSC receiver to allow the original mode of use. (Today the 'Universal' prefix has generally become unused). IMO asked the International Telecommunications Union (ITU), a sister UN agency, to develop radiocommunications standards for AIS. These would ensure that systems designed to the standard would be compatible; that they would operate satisfactorily in the maritime electromagnetic environment; and that other services using the electromagnetic spectrum would not suffer from interference.

2. IMO AIS REQUIREMENTS. Recommendations on performance standards for AIS were published by IMO in 1998[2]. Within the scope of the standards it is stated that:

> *The AIS should improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS), by satisfying the following functional requirements:*
>
> 1. *in a ship-to-ship mode for collision avoidance;*
> 2. *as a means for littoral States to obtain information about a ship and its cargo; and*
> 3. *as a VTS tool, i.e. ship-to-shore (traffic management).*

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It is interesting that collision avoidance and security are now mentioned ahead of VTS, although AIS started off life as a potential tool aimed at aiding VTS.

The data to be transmitted by AIS is defined within the IMO performance standards, together with the update rates applicable to each data group. Positional and velocity data is required to be transmitted at rates up to once every two seconds, depending on the immediate dynamics of the ship; static information such as ship's name, length and beam is only transmitted once every six minutes. The IMO performance standards make it clear that the equipment should conform to ITU Radio Regulations and their applicable recommendations. These include M.1371[3], which was specifically developed for AIS. The general requirements of IMO Resolution A.694 (17)[4] have also been mandated. This resolution has requirements on meeting environmental conditions, power supply variations and human element aspects, including safety. Perhaps surprisingly, for performance standards that covered collision avoidance, there is no definition of what the user interface should be, except that data from an AIS *should be provided with an interface conforming to an appropriate international marine interface standard*. This implies the use of a digital link based on the international marine standards issued by the International Electrotechnical Commission (IEC), such as IEC 61162-1[5]. In principle, such an interface allows AIS data to be displayed on standard navigational displays such as radar or ECDIS. (ECDIS is the approved equipment for displaying official electronic chart data). Within IMO it has been assumed that AIS data would normally be displayed graphically on radar or ECDIS. However, in the performance standards this is not explicitly stated. This perhaps contributed to a great deal of confusion, which is discussed here in later sections.

In 2000, the carriage requirements for AIS were agreed and inserted into a revision of the International Convention for the Safety of Life at Sea (SOLAS)[6] in the form of a phased introduction, dependent on ship type and size, and terminating on 1 July 2008. It applied to all passenger ships and all ships above 300 gt, although non-passenger ships between 300 and 500 gt not engaged on international voyages were exempted. After the terrorist attacks in the United States in September 2001, SOLAS was revised such that the dates for the introduction of AIS were brought forward to be fully completed by the end of 2004. This underlined the importance that governments gave to the security aspects of AIS.

In parallel with ITU developing M.1371, which defined the 'Technical Characteristics' for AIS, the IEC was developing an equipment level standard, IEC 61993-2[7], which included standard tests intended to be used by national administrations for type approval. This follows conventional interaction between IMO, ITU and IEC when new marine radiocommunication equipment is being mandated. In this instance IALA also provided a major contribution to the standards. The lack of any IMO mandated display and data entry facility prompted IEC to incorporate into its AIS standard the concept of a 'Minimum Keyboard and Display' (MKD). The facility was intended for no more than checking that the AIS was operational and to allow input of static and voyage related data. The minimum requirement was for three lines of data, such that each line would allow the display of at least the bearing, range and name of ship, without the need for scrolling.

In November 2001 IMO issued guidelines for the operational use of shipborne AIS[8]. The minimum display devised by IEC had a mention within the guidelines,

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although with no additional cautions as to its intended use. The guidelines modified the purposes of AIS to the following:

- To help identify vessels;
- To assist in target tracking;
- To simplify information exchange (e.g. reduce verbal mandatory ship reporting)
- To provide additional information to assist situation awareness

It can be seen that the term 'collision avoidance' was not used in the purposes and that identification, which embraces security, now heads the list. However the use of AIS in collision avoidance situations was still acknowledged and a section in the guidelines was devoted to its use for assisting this function, together with appropriate cautions. There was also a description of how AIS is displayed on a graphical display, such as a radar. In July 2001, IMO issued interim guidelines for the graphical presentation and display of AIS target information[9]. These were subsequently incorporated into an IEC standard for the use and display of AIS information on radar[10]. They were not seen as being applicable to be included within the IEC 'MKD' AIS equipment standard.

3. AIS IMPLEMENTATION PROBLEMS. In general, the scene was set for an orderly introduction of AIS, mainly concentrating on its VTS and newly acquired security uses. Unfortunately, the end user was not really being adequately informed about the evolving situation, even though the marine press carried articles (of varying accuracy) on AIS. Although some shipping companies explained what was going on, the first realisation on many ships was when an installation engineer came on-board with the unit to be fitted. There was often a hurried and ill-informed debate between the master and the engineer as to where it should be installed. After completing the installation the engineer would normally briefly review the fundamentals of operation with any staff who happened to be on the bridge and that was it – AIS was installed and ready to go. The engineer had to get rapidly to the next installation – time was short to meet the IMO installation schedule.

Many ship owners were under the impression that this was 'fit-and-forget' equipment. Perhaps this was because of misinterpretation of what was meant by the clause in the IMO AIS performance standards stating: *The AIS should be capable of providing information automatically and continuously to a competent authority and other ships, without involvement of ship's personnel*, which is at least ambiguous. It was therefore perceived by many that no training was required for users. In any case the practical impetus was on getting equipment fitted to meet the accelerated requirements defined within SOLAS. In fact, compared to other mandatory ship fits of new navigation equipment, the fitting schedule went well – in terms of meeting timescales. The security issues gave administrations a 'big stick' to ensure compliance. In fact ships were fitted before many ports and coastal stations had their own AIS facilities. In some areas of the world these have still to be implemented.

AIS equipment manufacturers recognised that most radars and ECDIS fitted on ships would not be able to accept AIS data through their digital interface. In most cases, particularly with radar, the display equipment would have to be replaced at great expense. In an attempt to maximise the benefits to users of AIS in an affordable manner, many AIS manufacturers saw there was apparent sense in providing a graphical display capable of presenting AIS data in plan view. However, to be price

competitive and easily installable in tight positions, AIS 'MKD' displays are small (typically 120×90 mm) and monochrome. They quickly become confusing if there are many targets in range and are therefore not able to enhance the situational awareness of a ship in an adequate manner. Since a graphical display function was seen as a low-cost enhancement to a basic MKD, type approval bodies did not consider it to be necessary for them to meet the IMO recommendations on AIS graphical displays. A more useful enhancement, made by many manufacturers and much appreciated by users, is an increased length of the target list (above the minimum of three) and in ordering the list by range and bearing. Some units also calculate closest point of approach (CPA) and time to closest point of approach (TCPA). Filters and alarms can be set to user-defined CPA and TCPA limits. A competent type approval authority would check the accuracy of the additional functionality to that required in IEC 61993-2.

Once AIS equipment was fitted to ships certain problems started to emerge. These included:

- Many masters and officers of the watch (OOWs) had not been informed on their responsibilities to ensure that the equipment was properly set-up, neither had they been instructed on how to use the specific AIS equipment fitted to the vessel. Instruction manuals included with the equipment are often not suitable as training aids. This meant that static data (ship specific data) had not necessarily been correctly entered. Voyage related data such as navigation status, (for example anchored or underway), next port and estimated time of arrival, were not being entered. Also, the proper use of navigational related messages was not understood. Faulty equipment, which can lose static data if poorly designed, can start broadcasting incorrect data, which should be readily noticed if proper once-per-day checks were made on own-ship transmitted data.
- Non-compliant GPS units had been connected to the AIS. These did not necessarily have all the messages required for correct AIS operation causing data to be missing. More problematic, as it was less obvious, was that these systems did not give a datum message and therefore, if set to other than WGS84, would give an incorrect position to the AIS. These issues should have been checked and resolved by installation engineers.
- AIS antennas had been poorly sited giving interference to AIS from other systems resulting in data corruption. Interference could also come through the use of incorrectly specified antenna cable. This caused many systems to have a poor transmit and receive performance. On receive, this could result in the static and voyage related data of some targets never being demodulated. (For such data the update rate is only once every 6 minutes and, on occasions, all such broadcasts could be lost from specific targets). AIS test sets, which could have identified these problems on installation, were not available for the earlier installations. A significant number of poorly installed systems still appear to be unrectified.
- There were problems with heading information. Not all ships had a heading indicator with a digital interface. These had to be retro-fitted with an 'add-on' interface. Bridge staff were often not informed on how these should be checked and adjusted, resulting in transmitted headings having possible offsets of up to 180°. On some systems, when the heading indicator is switched off, the offset is lost and has to be manually reinserted when it is switched back on. This was not understood by users.

In many instances the bridge staff of ships with such anomalies remained unaware of the problems for a substantial length of time. They had not been told of the necessity for regular checks on transmitted data and, because port and coastal authorities did not necessarily have AIS facilities, defects were not being routinely communicated to errant ships. The large number of received anomalies greatly damaged the credibility of the system to competent users, many of whom were initially keen to use AIS for improving situation awareness. As a result there remains a great distrust of any AIS data, even though in many circumstances it can be more accurate than radar-derived data. Many maritime authorities are now properly policing the situation and because of this there are far fewer problems. However, residual problems with data transmission still remain and therefore the distrust continues.

4. AIS TRAINING. A significant number of the total problems experienced with the implementation of AIS would have been averted if users had been given proper training in the use of AIS, including the need to check regularly own-ship transmitted data. As already mentioned, there was a belief among many ship owners that training was not actually needed. However, the IMO International Safety Management (ISM) Code[11] is a statutory requirement on ship owners to have a safety management system in force, covering a number of specified items. In Section 6 of the Code it makes it clear that staff who have duties that relate to safety and the protection of the environment must be given proper familiarisation with their duties and have an adequate understanding of relevant rules, regulations, Codes and guidelines. At the very least, owners and ship management companies should have made users aware of the IMO guidelines on the use of AIS and given clear instructions on the use of AIS fitted to a particular vessel.

In the introduction to the IMO AIS Model Course[12] it is stated that "*AIS is a complex communications/navigation sub-system that is neither self-evident in concept nor in use*", underlining the hidden complexity of AIS, especially when used to enhance situation awareness. In Reference 14, written by two senior sea-going officers concerning the use of AIS, it is stated "*There are many aspects to an AIS system that the observer must understand: training is necessary and the benefits of training are numerous*". Model Courses are intended to assist the setting up of suitable training courses in nautical colleges. The AIS Model Course recommends a minimum of eight hours of tuition and practical exercises for bridge staff who are already familiar with radar. The course emphasises the limitations of AIS data being displayed on MKDs and concentrates on using AIS displayed on radar. Unfortunately, it is only becoming available now, after having been approved by the IMO Standards in Training and Watchkeeping Sub-Committee (STW) in January 2006. Even so, many training colleges and distance learning institutions independently evolved AIS training courses. These have been available for a number of years but there is still concern that most bridge officers have apparently not been properly trained. In March 2006 an experienced and busy UK pilot made the following observation to the author concerning AIS:

> "*Unfortunately I have yet to come across any Master or Watch Keeper who has attended any structured course from a college or elsewhere. In fact the situation is now possibly worse than when the systems were first installed. At that time the installation engineer at least provided a brief training of the key functions. Now, as vessels change crews, we have an increasing number*

of Officers serving on board who are totally unfamiliar with how the on-board equipment functions and if something goes wrong they have no idea how to deal with it. As with most equipment the instruction manuals are not user friendly".

5. AIS MISCONCEPTIONS. It should be beyond doubt that AIS, when properly used with radar, has the ability to aid situation awareness and potentially contribute to collision avoidance decisions. However, many users do not share this view for a number of valid reasons:

- They have had a bad experience of seeing much inaccurate data, including position and velocity, being transmitted by many targets.
- They have made their judgements based solely on viewing AIS data displayed on an MKD rather than on a radar display with approved AIS facilities.
- They are themselves untrained and many do not understand the benefits and weakness of both AIS and radar and how they can be jointly used to enhance situational awareness, without incurring information overload.

IMO thinking assumed that AIS data used to aid collision avoidance would normally be displayed with radar data on a radar display. Demonstrations of radars with such facilities were given to IMO delegates when the performance standard was under discussion, showing the ability of AIS. It was probably not realised by many that in order for this to happen radars had to be specifically designed for this purpose. In general radar displays already in use on ships could not be modified to display AIS data. As already noted, AIS equipment manufacturers recognised this problem and many incorporated a simple graphical display as part of the MKD. This was not anticipated in the original IMO thinking, as can be gauged from the AIS performance standards. Some maritime authorities attempted to clarify the situation concerning the use of MKDs. For instance, in 2004 the UK Maritime and Coastguard Agency stated that "*Many shipowners have opted for the least cost AIS installation to meet the mandatory carriage requirement. By doing so, many of the benefits offered by graphic display* (*especially AIS on radar*) *are not realised with the 3-line* '*Minimum Keyboard Display*' (*MKD*)"[13].

The use of an MKD-based AIS is often further compromised as they are often fitted in unsuitable positions, such as at the back of the bridge, well away from the radar. In the race to meet IMO deadlines little thought was given at installation as to where they should be situated. Furthermore, on smaller ships, it can actually be difficult to find a suitable place, without an expensive re-layout to at least part of the bridge. Compared to a radar image, an AIS-only display is a very incomplete representation of the surrounding situation. Having to view radar and AIS data on separate displays adds to the tasks of the user, creating additional possibilities of error and also increasing fatigue. Despite this, a small graphical AIS display is capable of giving essential information that may prevent an accident. It is currently unknown whether having an AIS with such a small display enhances or depletes overall safety.

6. THE FUTURE. A number of ships have been fitted with radars type approved to the IEC standard for the use and display of AIS information on radar, incorporating the IMO guidelines for AIS graphical displays to this standard. Some

good user experiences have been reported from their use[14]. From 1 July 2008 IMO is requiring all new radars to have an AIS display capability. This is to a revised performance standard from IMO[15], which is currently being incorporated into a new IEC standard[16]. There are no plans at present to make such radars compulsory and so it could be beyond 2018 before virtually all ships have such a system, unless there is an earlier decision to make them mandatory. IMO calls the tracking facilities of these new radars 'Target Tracking (TT)'. The term ARPA, automatic radar plotting aid, becomes inappropriate when AIS is an additional contributor to the tracking process.

The increased use of AIS data on radar will enhance target detection. Ship targets invisible to radar, such as those behind a (reasonably sized) headland or within heavy clutter become visible. In particular, AIS enabled radar systems can greatly enhance the detection of small vessels such as leisure craft, as these will become increasingly fitted with AIS. Systems designed for such craft follow the AIS Class B standard, which is compatible with shipborne (Class A) AIS systems but are of lower cost and have features that limit degradation of Class A systems in dense AIS traffic areas. Class B target data suffers from a number of deficiencies compared to shipborne AIS data[17]. However, when displayed on an AIS-compatible radar these deficiencies are minimised, greatly enhancing the possibility of detecting small AIS-fitted targets, particularly when their radar returns are obscured by clutter.

7. LESSONS. AIS would have had a smoother and more positive impact if the effective training of users had had equal emphasis to that applied to the installation programme. As well as explaining how AIS should be appropriately used with radar to enhance situational awareness it would have substantially reduced the number of inaccurate transmissions. Training should therefore be given more emphasis on future comparable programmes.

It is significant that the IMO Correspondence Group currently developing the performance standards for integrated navigation systems (INS) has been asked to include requirements and guidance within the performance standard for manufacturers and shipowners to ensure that suitable familiarisation training material is available on-board. This will prevent users of INS equipment being totally ignorant in its use from the day of installation, but is mainly intended for all newly joining bridge staff to become rapidly acquainted with the specific equipment on the bridge; it being assumed that shore-based training, conforming to the relevant IMO Model Course, having been previously undertaken. To be effective it means that IMO STW needs to construct the Model Course immediately after the acceptance of the performance standard, with timescales for completion which match the installation programme. If this structure had been implemented for AIS, it would have prevented many of the actually experienced problems.

During the development of the standards the intentions of IMO regarding AIS became unclear. It was originally viewed as an aid to VTS operation, then collision avoidance became first listed (within the performance standard) and finally AIS was rapidly introduced to enhance security. This vacillation led to unclear messages concerning AIS to be communicated within the marine community. However, if proper training had been part of the programme it would have removed any developing misconceptions.

In good faith manufacturers added graphical displays to AIS MKDs. This gave uninformed users the impression that these displays were suitable to enhance situational awareness and even could be used to assist collision avoidance. (In fact some manufacturers even mentioned their use for collision avoidance in early equipment manuals). Perhaps there should have been a greater clarity on the required user interface coming from IMO. IMO did not originally anticipate 'enhanced MKD' displays, and expected AIS data to be mainly shown on radar. However, it is impossible to foresee and prevent all well-intentioned actions like these. It is also perhaps unwise to prohibit manufacturers from developing new ideas in data presentation, as long as mandated presentation options are also available, otherwise development would be stifled and equipment standards could stagnate. Good shore-based generic training allows users to make informed decisions on how to best display and use the data.

8. CONCLUSIONS. This paper indicates that an increased emphasis on training would have alleviated the misconceptions and many of the problems that have arisen with the introduction of AIS. It would be prudent to examine the possibility of mandatory training when a future introduction of navigation equipment with similar complexity is made. It is left to others to decide whether the costs associated with such training would be justified from an overall economic viewpoint. However, the ISM Code already makes it clear that there is a requirement for proper familiarising of users before operating such equipment but it was apparently ignored by ship managers or considered to be not applicable to AIS.

This paper has concentrated on the ship-to-ship use of AIS. It is too early to claim success for this application but, with the increased use of AIS on radar displays, the future looks very promising. AIS data is becoming increasingly important to VTS operators and security forces. Accident analysis is already benefiting from AIS data. It is suspected that for these applications AIS can already be considered to be at least a qualified success.

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