Addressing the gaps

Maerospace Corp discuss the dangerous gaps that remain in global maritime domain awareness technology

'Since 2010, satellite-automatic identification systems (S-AIS) and AIS national deployments have finally made global Maritime Domain Awareness (MDA) a reality'. That's the story often presented today. However, serious gaps exist in the capabilities of these incredibly valuable technologies. This article focuses on some of the inherent aspects of satellite and coastal AIS that create misleading information and that can cost lives and increase risk for any MDA stakeholder, namely:

- Data is old, wrong and incomplete;
- Doppelgangers;
- Dark targets; and
- Ineffective anomaly alerting.

At the end of this article we will introduce a capability that directly addresses these inherent challenges in MDA.

Fig. 1 shows a typical wide area MDA display. The screen shows 14,109 vessels from both S-AIS and coastal AIS with ships colour coded by type. Without S-AIS only a tiny number of ships clustered around ports would be shown. Despite being a vast improvement in MDA, the display is not what it seems.

Any user might reasonably assume that this screen shows where all the ships are in this region of interest – but it doesn't. More experienced users might understand that there is a latency delay from when the ships are detected to when the data appears on the screen, so the screen should show the maritime domain as it was a short time ago – but it doesn't.

Old, wrong, and incomplete

Rather than the current position, each dot represents the most recently received position report for the vessel. That position was accurate only at the time of transmission. However, there is more than latency involved in the age of the data.

When a satellite passes over an ocean area, it 'sees' a field of view (FoV) of about 3,000 miles in diameter. If there are more than 1,000 ships anywhere in that field of view, then the probability of the satellite detecting signals from a ship during its approximately ten minute pass will be limited. The probability ranges from 15% to 85% depending on the satellite technology used. A large majority of the satellites in orbit today (regardless of the operator) are at the low end of this range.

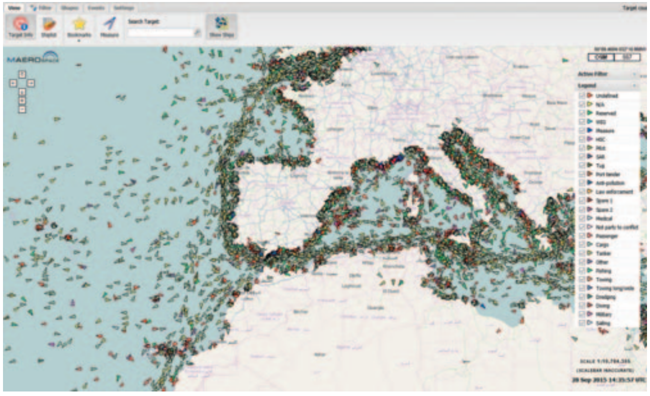

Fig. 1 A typical wide area AIS display

All S-AIS operators today use a mix of technologies in their constellations. Thus, what the user sees, regardless of the provider, is a system output that contains a mix of detection rates. When a satellite does not detect a ship on a pass, the dot representing that ship stays in the last detected position on the map, while dots for each newly detected ship are moved on the map. With low probability of detection, some ships can go days between detections. So, a display as shown in Fig. 1 contains ship positions spread out over many hours, or even days. Fig. 2 shows the same map colour coded by the age of the data. Fig. 3 shows the global distribution of the age of messages for a sample data set of satellite and coastal data at one moment in time in mid-2014.

The time spread is the problem. The position reports are indeed old, but the more important issue is that every ship position is old by a different amount.

Current displays are misleading.

The dots for any two ships shown near each other often represent position reports separated in time by many hours. The ships shown in the displays have never been in the relative positions shown. Unless users are trained to understand these fundamental facts, current displays will result in bad decisions regarding interdiction (wasting resources), and search and rescue operations will contact the wrong vessels to lend assistance (costing lives).

Displays are missing ships

A second effect of time spreads is that most displays are configured to delete a dot from the map after a ship has not been seen for more than a certain period (usually 24 hours). Our analysis indicates that approximately 15% of vessels in a large region go undetected for more than 24 hours (for example: over 800 vessels in the Gulf of Mexico are typically not displayed). This means that about 15% of the ships actually present are completely missing from current MDA displays. Ships can go undetected for both innocuous and nefarious reasons but the extent of this problem surprises many people.

Key takeaways

- Position reports are not just delayed but are spread in time;
- Any two ships shown close together may never have been next to other; and
- Users must be trained to understand time spreads.

These effects are not limited to S-AIS. Coastal AIS is often assumed to be completely accurate but the range for higher probabilities of detection is only within about 30 miles from a base station. As the distance from a base station increases, the probability of detecting the ship decreases and all the problems described above emerge.

Bigger constellations won't solve the problem

Every S-AIS operator is expanding its constellation and network. However, the inherent problem of signal collisions will always result in numerous passes (and many hours) being required to build up a complete set of position reports for all vessels. A predictive process must be applied to obtain an accurate representation of the maritime situation.

Doppelgangers

Doppelgangers are ships that use the same Maritime Mobile Service Identity (MMSI) as another ship. The MMSI is the only identifier for a ship used in AIS. The International Maritime Organization (IMO) number in Type 5 AIS messages is much more rarely detected by S-AIS. The MMSI number is manually entered by the user upon installation of the AIS transponder and can be changed relatively easily at any time.

Key takeaways

- Doppelgangers are a far bigger problem than most people realise;
- Doppelgangers can hide ships from your display; and
- Doppelgangers must be tracked separately.

Any AIS display can show that multiple ships transmit the same MMSI – intentionally or unintentionally – for one of many reasons:

- Improper initial setup;
- Temporary numbers used for testing that were not reset on deployment;
- Failure of power to the unit can sometimes reset the unit to factory defaults;
- Improper training or laziness on the part of installer or crew;
- False positive reports; bit errors in transmission that garble the MMSI number; and
- Deliberate spoofing of the MMSI to avoid detection.

As you can see, an incorrect MMSI number does not imply nefarious intent, contrary to some recent reports. However, it can and should alert authorities to demand proper configuration of the equipment.

The extent of the doppelganger problem surprises many people. In a one-week period, we detected 24,899 MMSI numbers used by more than one vessel. Another firm we met had detected over 39,000 MMSI numbers used by more than one ship over a period of one month.

The effect of doppelgangers can be dramatic. A vessel of interest will suddenly disappear from a user's screen if a doppelganger (new position report using the same MMSI) is detected anywhere on the Earth outside of the visible region. Tracks will display outrageous and unusual behaviour (e.g. see Fig. 4 for the track of MMSI 123456789).

The solution to this problem is to identify and track doppelgangers separately. Each version of the doppelganger may be, in fact, a separate ship.

Dark targets

What if the ship turns off its AIS? Providers have often focused on the idea that AIS tells you where the good guys are; everyone else is suspicious. This is a decent starting point but does not get to the heart of the matter. In fact, all ships are dark between detections. If a ship typically goes six or ten hours between detections, then it is dark for that long. How do you tell if a ship turned off its AIS (suspicious indeed) four hours ago of if the ship was detected four hours ago but is typically only seen every six hours?

In addition to the dot for a ship disappearing from a display because a doppelganger was detected elsewhere, there are four classes of dark ships at any point in time:

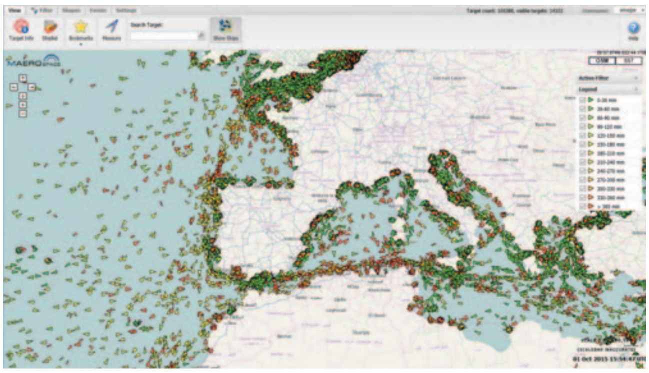

Fig. 2 AIS display colour-coded by age of data

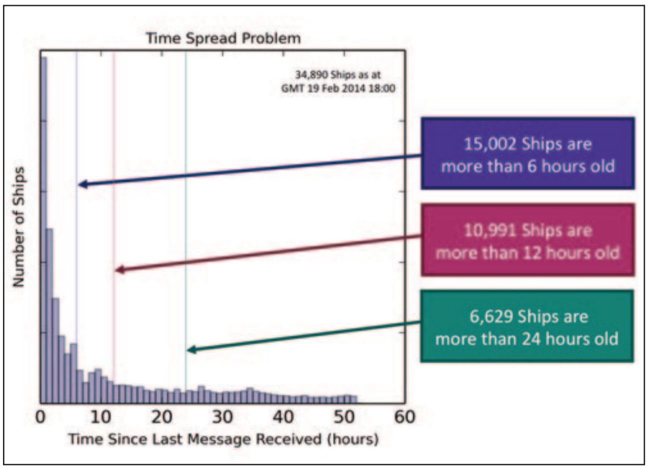

Fig. 3 Distribution of time spreads

- Ships that are between detections;
- Ships that have stopped transmitting recently;
- Ships that begin transmitting false positions (spoofing); and
- Ships that are always dark (or have not transmitted for a long time).

By using predictive tracking (such as with Maerospace's TimeCaster) ships that are simply between detections, but behaving normally, can be shown in reasonably accurate locations, so long as the predictions account for more than simple dead reckoning.

If a ship stops transmitting, that fact can be detected by keeping track of the typical time between messages for the ship. A ferry in a harbor will often be detected every minute whereas a ship far from shore may only be detected once in many hours due to the probabilistic nature of S-AIS detection resulting from signal collisions as well as onboard factors such as damaged antennas. Thus, the transmission signatures must be tracked for each and every ship individually. Statistical inferences can then be made to determine if a ship should have been detected and raise an alert if appropriate.

For ships trying to spoof their position, if the vessel was being tracked normally (as it most likely was when it last departed from a port), then the sudden shift of position when spoofing begins will generate a (virtual) doppelganger that can and should be tracked separately. The original ship's track will then appear to be a ship that stopped transmitting and can be detected using the method described above.

Another method used by some S-AIS providers is 'position validation' (PV). This method uses knowledge of the satellite's position and signal analysis to verify that a ship's reported position is consistent with the FoV of the satellite, and the smaller region where the signal might have originated. This is a valuable tool, especially if the PV calculation is applied to every vessel every time. While this can detect a vessel spoofing its position, it cannot precisely locate the vessel.

Over the next few years, a massive increase in optical satellite constellations is being deployed. Euroconsult has predicted that more than 400 new such satellites will be launched in the near future. In addition, several radar satellites are being launched from Canada, Spain and elsewhere to expand the availability of imagery through clouds and at night. The satellites can easily detect the ships present in a single image – if it is looking in the right place. Satellite images tend to be small compared with the AIS location errors described earlier in this article. For example, if a 25x25 mile image is taken of the most recently reported position of a ship, the ship can easily be more than 100 nautical miles away and no ships (or worse, a different ship) may be shown in the image near the reported position. Imagery of the ocean, and the ship identity and position must be correlated both geospatially and temporally in order to be useful. Only after a picture is obtained for the right location and the right time, can one make an assessment of whether the displayed position of the identified ship is correct or not. If it is, then all is normal. If not, then the ship is truly dark, possibly behaving unpredictably and deserves attention.

Key takeaways

- All ships are dark between detections;
- Not all missed messages represent dubious intent; and
- Robust analytics can track many dark targets.

Finally, we come to the most difficult challenge. A ship that is always dark. This can be a ship that was never tracked or has not been operated with AIS for a long time and thus does not appear in any current displays – even in the wrong location. In this case, users must rely on radar and optical data rather than AIS. The challenge here is that shore and shipboard radar are typically line-of-sight with ranges limited to a few tens of miles or less. For these situations, MDA stakeholders must rely on a combination of traditional surveillance (vessels and aircraft) and human intelligence. The use of the analytic methods described here can, however, allow much more efficient use of those very expensive surveillance assets so that key resources are not wasted locating and verifying ships that are behaving as expected.

Ineffective anomaly detection

Few people are interested in all the ships behaving normally. Everyone wants to see anomalies – who is behaving unexpectedly and why?

Geofences (simple mapped polygons) can be used to generate an alert when a ship enters an area of interest; usually, a restricted area. With current reporting systems, a ship must enter the defined area and be transmitting, then a satellite must fly over and the ship must be detected (see limited probability of detection discussion above); finally, an alert can be raised after the latency period of the data. All of these factors can make current AIS-based alerting ineffective except close to coastal stations.

To be effective, alerting must be predictive. Alerts should be raised based on a reasonable prediction of boundary crossing in order to allow time to make an appropriate response. Such predictions must work even if doppelgangers are showing up on the other side of the globe. Predictive alerting will not capture every nefarious ship but it can make a dramatic improvement in the usefulness of anomaly detection tied to ship movements.

Future developments

In the coming years, all S-AIS providers and most coastal systems will be expanding their constellations and ground networks to improve revisit times and reduce latency. These important enhancements won't solve the problems identified in the foregoing discussions. Better quality raw data will help and the problem of old, wrong and incomplete data will be reduced, but not eliminated. Many ships will still be detected only after many satellite passes. Even if the time between passes is reduced dramatically, there will always be a substantial variance in detection times, resulting in the misleading screens and all of the problems described above.

TimeCaster™ - today's solution

Maerospace has developed a service product that addresses all of the gaps described in this article. It can easily add to existing AIS, S-AIS and LRIT data sources or raw data can be provided. TimeCaster uses patent pending robust analytics to 'NowCast'™ the location of every ship in the world every ten minutes. Near future positions are also available. Automatic detection and separate tracking of doppelgangers is built-in. Dark targets are addressed both by tracking detections and predicting the expected next message for every ship, as well as providing accurate locations for optical/radar image tasking. In 2016, we will offer users the ability to acquire recent or near future optical imagery as an overlay. As a service, TimeCaster can be implemented in a matter of days with onsite capabilities when needed.

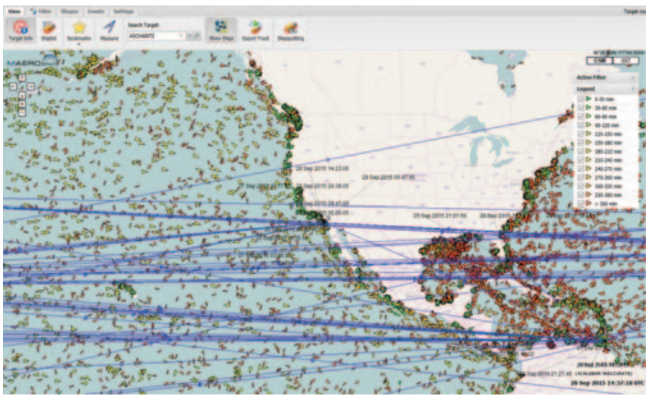

Fig. 4 A 24-hour track of MMSI 123456789

About the author

Eric Meger, CEO of Maerospace, has worked in Satellite AIS since 2007 and was a founding executive at exactEarth. He sits on the Board of Directors at the Association of Strategic Alliance Professionals-Ontario. Eric's Alliance work at exactEarth won the ASAP Int'l Excellence award in 2014. He is also a recipient of the Space Foundation's National Excellence Recognition award and co-authored an IEEE paper on ship tracking algorithms. Eric holds an MBA from the Harvard Business School and an AB degree in Physics from Washington University in St Louis.

About Maerospace

Maerospace Corporation, based in Canada, is a global supplier of maritime information including the TimeCaster™ service for maritime authorities and commercial ship and cargo tracking products based on the world's most accurate and complete view of global AIS-equipped ships through their patent-pending NowCast™ technology.

With these capabilities, TimeCaster provides the most accurate, complete and useful picture of the maritime domain available.

Conclusion

While AIS and S-AIS have made a dramatic improvement in maritime domain awareness, several critically important challenges must be addressed to make these tools useful:

- Inherent time spreads in ship detection drastically mislead users;
- Doppelgangers are a far worse problem than previously thought;
- Dark targets are a ubiquitous challenge but can be addressed analytically; and
- Anomaly detection requires predictive alerting.

By understanding both the limitations and the opportunities created by satellite and coastal AIS systems, users can be trained to understand the issues described here and additional tools can be applied to capture the tremendous potential for improved security, better outcomes and more efficient maritime operations.

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