PERFORMANCE EVALUATION OF AN OPERATIONAL SPACE-BASED AIS SYSTEM

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Abstract

An important system in the field of global maritime surveillance is the Automatic Identification System (AIS), which is responsible for communicating ship- and voyage-related data of surface vessels. In order to improve the performance of the existing land-based AIS system, a consortium led by OHB has been responsible for the development of a full-fledged European space-based AIS system.
The main challenge in space-based AIS is the collision of multiple AIS messages in a single slot. Several innovative technologies have been applied to the payload to maximize its detection performance.
The constellation has been optimized for high performance, sufficient coverage and low timeliness, resulting in 4 orbital planes consisting of 3 satellites each. Orbital parameters are 550 km altitude at 88° inclination.
Assessment of the AIS constellation performance is done by using a dedicated AIS simulator applying either present-day or future traffic models. After definition of the use cases, including so-called of High Traffic Zones, which contain exceptionally dense traffic, the performance per use case has been evaluated.
Considering all vessels, the user requirements of 1 hour update interval with 80% detection probability for non-HTZ and 3 hour update interval with 80% detection probability for HTZ, can be met for most use cases. For critical use cases, such as North Atlantic or Mediterranean, these requirements will be met for open sea traffic. Such a situation is representative of space-based AIS complementing the already existing infrastructure of coastal stations.

1 INTRODUCTION

An important system in the field of global maritime surveillance is the Automatic Identification System (AIS), which is responsible for communicating ship- and voyage-related data of surface vessels. Primarily intended as an anti-collision system, many entities use land-based AIS for monitoring and guidance of maritime traffic, which requires ships to be equipped with an AIS transceiver that transmits relevant data about this vessel in the very high frequency (VHF) range.

In order to perceive the maritime traffic situation beyond the land-based AIS range, introduction of a space-based AIS system is proposed, which primary figure-of-merit consists of the probability of detection of a ship's AIS message in case the satellite receives a multitude of AIS messages. Because of mutual overlap and interference of the AIS signals, which will not occur at land-based receivers, the challenge is to filter out and decode individual AIS messages.

In Europe, several activities have been initiated by ESA and EC to validate AIS receivers, design first operational missions and to develop complete space-based AIS constellations. A consortium led by OHB has been responsible for the development of a full-fledged European space-based AIS system.

This paper will give a presentation of the preliminary results from an ESA-TIA feasibility study, ESA contract No. 21959. It will start with a summary of user requirements, which were obtained by interviewing relevant users, including coast guards, port authorities, and national customs, and which were consequently consolidated and approved by EMSA.

Based on these requirements, two general scenarios have been considered in evaluating the feasibility of the European space-based AIS system. In scenario 1, only the areas with low and medium traffic will be considered, enabling the use of simple technology. Scenario 2 also considers the high traffic zones, which consequently requires the application of more complex technology.

Next, a short overview of available technologies relevant to space-based AIS will be presented, which will include antennas, space-based receivers and digital processing algorithms.

For every scenario, a trade-off of the available technologies has been made leading to a baseline spacecraft. These spacecraft have to be deployed in a constellation in order to meet the user requirements. By simulating a constellation in a dedicated AIS simulator, its detection performance can be evaluated. The preliminary simulation results of the selected constellations will be presented and will be accompanied by a thorough discussion.

2 REQUIREMENTS ANALYSIS

2.1 User Requirements Definition

As a starting activity of the European space-based AIS system study, the collection and formatting of user requirements was performed, which involved application of the results of recent studies for ESA and EC concerning space-based maritime surveillance and space-based AIS. In addition, several entities in the field of maritime surveillance were contacted. These included coast guards, military bodies, commercial operators and port authorities. In total, 110 user entities from 16 European nations have provided input to the user requirements.

By refining the set of user requirements, a comprehensible set of mission requirements was obtained, which will provide the primary guidelines for accomplishing the development of the European space-based AIS system.

Key mission requirements include:

- System shall be able to track surface vessels carrying Class-A AIS transmitters
- System shall be able to geographically cover all global areas
- System shall allow for updates of the AIS data within intervals of at maximum 3 hours (1 hour goal)
- AIS data shall be available on ground maximum 1 hour after being received by a spacecraft (0.5 hours goal)
- System shall have a minimum ship detection probability of 80% (95% goal)

These requirements were presented to, and consequently endorsed by, ESA, EMSA and the EC Steering Committee.

2.2 Maritime Traffic Model

For simulating the performance of the European space-based AIS system, a ship traffic model is used that is based on several different sources, which contain maritime data on the east coasts of US and Canada, Gulf of Mexico, Greenland, Iceland, European waters, North Africa, Red Sea and the Gulf of Persia.

In the traffic model representing present-day shipping traffic, the total amount of active vessels equals 55,500. Only surface vessels carrying Class-A AIS transmitters are included in this value. A plot of this traffic distribution is presented in Figure 1.

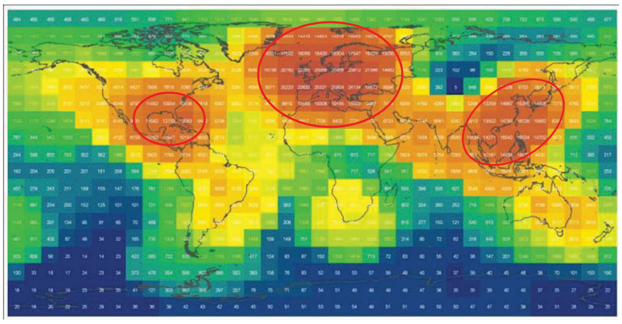

Figure 1: Plot of maritime traffic distribution

In the traffic model, the growth in ship traffic during the coming years due to economic conditions is taken into account. After all, the space-based AIS system has to be capable to deliver satisfactory performance during the next coming years. Although predictions show a high amount of uncertainty, it has been calculated that global shipping traffic will grow to 94,200 vessels in 2024. Additionally, a regulations change will add up to 20,000 vessels. Because they act as weak interference sources, an extra 50,000 vessels carrying Class-B AIS are added. In addition, land-based emitters operating in the maritime band have to be added as interference sources, as ITU regulations have not prohibited those from transmitting in the AIS frequency bands.

By investigating Figure 1, it is seen that the global maritime traffic is concentrated in a limited amount of hot-spots. These areas will be called High Traffic Zones (HTZ) in the further discussion. The following areas are considered the most critical HTZ:

- Europe, i.e. North Sea, Mediterranean, Channel Coast
- Caribbean, Gulf of Mexico
- East Asia, i.e. Chinese Sea, Yellow Sea

2.3 System Scenarios

In order to guide the design of the European space-based AIS system, a set of different system scenarios has been defined, which is based on the mission requirements and a first analysis of the detection of ship traffic from space. These scenarios discriminate between performance goals in different geographical areas, thereby yielding a range between low and high performance architectures. In Table 1, the candidate scenarios are listed.

Table 1: System scenario overview

Scenario Number	Geographical Area	Update Interval
#1	Global minus HTZ HTZ (North Sea, Caribbean)	3 hr N/A
#2	Global minus HTZ HTZ (North Sea, Caribbean)	1 hr 3 hr

<u>Scenario #1</u> is considered the minimum scenario, which has to be met by the space-based AIS system. It demands an update interval of 3 hours for all global areas, except for the High Traffic Zones (HTZ). No requirement is set for the HTZ, such that they will not drive the design.

Scenario #2 is considered a realistic, but still demanding scenario for offering a good coverage for all global areas. As a consequence, the update interval for general global waters is equal to 1 hour and 3 hours for the High Traffic Zones.

In any scenario, it is required to achieve a probability of vessel detection of at least 80% within every stated update interval, while a value of 95% is aimed at. In addition, the timeliness (i.e. interval between AIS message reception by the system and delivery to the user) cannot be more than 1 hour, with a desired value of 30 minutes.

In this paper, **scenario #2** will be further considered for the purposes of constellation lay-out and result presentation. A lifetime interval of 7.5 years considered, which infers that the performance is considered for 2021, coinciding with 84,800 vessels travelling in global waters.

3 CHALLENGES & DESIGN OPTIONS

3.1 Message Collision Problem

Several fundamental difficulties accompany the attempts to receive signals with a space-based platform, which are largely related to the fact that the AIS system was developed for the terrestrial application of ship collision prevention. The main principle behind AIS functionality is the SOTDMA (Self Organizing TDMA) protocol, which ensures that AIS transmitters are organized into cells, in which every transmitter is assigned a time slot for message transmission. By operating a space-based platform for AIS message reception, so-called message collision will take place, which is illustrated in Figure 2. This phenomenon is caused by two types of collisions:

- Type I: AIS transmitters in different SOTDMA cells transmitting in the same time slot
- Type II: AIS transmitters emitting in different time slots, which overlap due to distance caused time delays

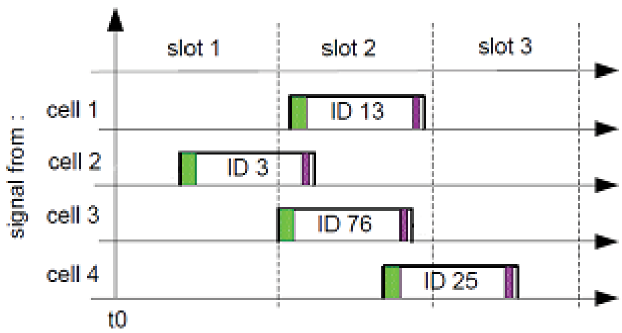

Figure 2: Illustration of the message collision problem [2]

In the so-called high traffic zones, these problems will have severe consequences for the AIS reception performance, because the antenna can have up to 20,000 different vessels in its field-of-view. However, the problem of message collision can be mitigated by applying innovative technologies.

3.2 Receiver Architecture

As the main building block of the AIS payload, the AIS receiver is responsible for receiving and demodulating the AIS messages. Therefore, application of an SDR (Software Defined Radio) is proposed, which allows for the implementation of powerful signal detection algorithms.

Two types of receiver architecture can be used for the overall demodulation of AIS messages:

- On-board processing

  In an on-board processing architecture, the separation and demodulation of the AIS messages out of the corrupted input signal is performed on-board the satellite. This requires significant processing power in order to implement the required decoding algorithms, but reduces the needed downlink bandwidth as the transmitted data is equal to the original AIS information.

- Digital bent-pipe / digital sampling

  In a digital bent-pipe architecture, the downlinked data package consists of a sample package of all AIS channels mentioned in the protocol. By reconstructing the AIS signal on-ground, high performance decoding algorithms can be used for separation and demodulation of the AIS messages. This saves much processing power on-board the satellite, but requires a wideband downlink channel for transmission of the sampled AIS signals.

As a side remark, the exploitation of a third AIS frequency dedicated to space-based AIS is considered in the design of all receivers. By using this third frequency, the mutual interference of the AIS messages is drastically decreased in areas. After all, the third frequency will also be used for AIS transmission on the open seas, but will most likely be ordered to switched off when the vessel is in range of a coastal station. Hence, no interference by vessels in coastal areas will be present on the third frequency. Although the third frequency is seriously considered for future application, it is not implemented in practice yet.

3.3 Digital Signal Processing

Digital signal processing algorithms have the task to separate the multiple AIS messages in a particular time slot, so that they can be successfully decoded. These include:

- Core GMSK demodulation algorithm
- Multi-user detection algorithms
- Multi-receiver combination algorithms

A core GMSK demodulation algorithm is used for demodulation of the AIS GMSK modulated message. Coherent demodulation provides the best performance, but is most complex. Slightly less performance is gained with a non-coherent demodulation algorithm, which is simpler though.

A multi-user detection algorithm is used to separate multiple AIS messages occupying a single slot. This will be done in an iterative way by subtracting previously demodulated messages from the original noisy signal containing multiple AIS messages. Although these algorithms are capable of decoding a low amount of messages (between 2 and 5), their performance quickly diminishes when large amount of messages are present in a single slot. Performance will significantly increase by introducing a large amount of discrimination between the signals.

A multi-receiver algorithm can be used when multiple receivers are flown on a single satellite. This algorithm combines the received AIS signals from all receivers in an attempt to increase the probability to demodulate individual AIS messages.

3.4 Antenna

Every spacecraft in the AIS constellation has to be equipped with one or more antennas to enable reception of AIS messages. The choice of antenna technology can positively influence the probability of detecting an AIS message in a signal band with interference. This is accomplished by exploiting the following phenomena, which are related to the choice of antenna technology:

- Polarization diversity
- Frequency diversity (i.e. Doppler shift)
- Power diversity
- Geometric diversity (radiation pattern)

For the choice of antenna, various technology options are available. These include:

- Monopole /dipole
- Helix
- Patch

The monopole /dipole antenna and the patch antenna offer linear polarization, and are therefore able to introduce polarization diversity. The helix antenna suffers from a 3 dB gain loss due to polarization mismatch in addition to losing the benefit of polarization discrimination. Nevertheless, a helix offers a steep gain slope in its antenna pattern, which improves the power diversity in the received signals.

4 CHALLENGES & DESIGN OPTIONS

4.1 Constellation Lay-out

The design of the spacecraft constellation has a significant impact on the performance of the space-based AIS system. After all, the probability to detect a particular ship (i.e. to demodulate at least one message sent by this ship) is directly related to the cumulative contact time. In the end, the selected orbit is dependent on several parameters, which will be treated in the following subsections.

4.1.1 Orbit

One may be inclined to think that a high orbital altitude would be favourable to detection performance, because it gives rise to a wide coverage, which in turn leads to a long contact time. However, this will also lead to an increasing number of ships in the field-of-view, which consequently results in a higher amount of message collisions. Hence, the altitude has to be selected by striking a careful balance between an increase performance resulting from a larger covered area and a decreased performance resulting from more message collisions.

4.1.2 Inclination

Because global coverage is defined as a prime user demand, a high inclination is necessary. Hence, the inclination is limited to a range between 80° and SSO. Although it was not further pursued in this analysis, it would be possible to have orbital planes with lower inclination in the constellation.

4.1.3 Ground stations

The ground stations have to be selected in conjunction with the orbit to meet the requirement on data timeliness. Although this requirement seems challenging, because it sets a very low value for timeliness (< 1 hour), it can be easily met if two polar ground stations are used. In case timeliness value of 30 minutes is pursued, it is necessary to include a low-latitude ring of ground stations or apply use a GEO intersatellite link.

It has been decided to design a symmetrical constellation of 4 orbital planes with 3 satellites each. Every orbital plane is located at 550 km altitude with an inclination of 88°. As a baseline, 2 polar ground stations have been selected for data downlink and satellite control. In Figure 3, this constellation is shown.

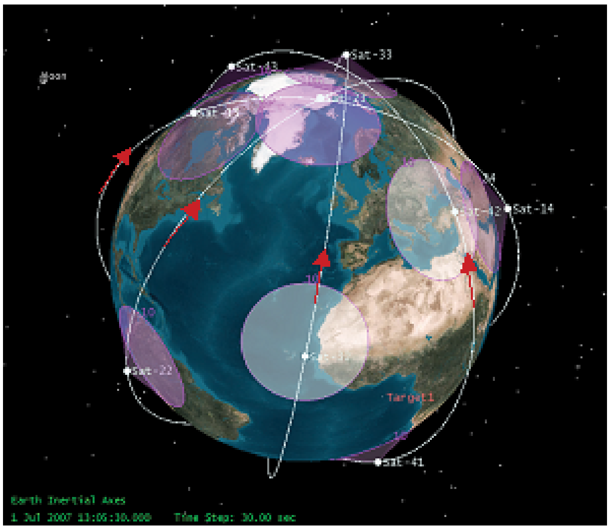

Figure 3: Preliminary constellation lay-out for European space-based AIS

4.2 Spacecraft Configuration

Each satellite in the constellation proposed in the previous section has the same lay-out. All will make use of a high performance payload allowing a high detection probability even in areas with dense traffic density. Main characteristics are:

- Software Defined Radio operating in full hybrid mode
- 4 Patch antennas joined into a phased array
- High performance digital processing algorithm exploiting Doppler shift and relative power differences

The satellite platform has consequently been optimized for supporting this payload by providing:

- Structural support to te relatively large and heavy patch antennas
- Medium pointing accuracy in nadir direction
- Sufficient power generation for any possible local time value due to non-SSO orbit
- High data rate downlink
- Orbit maintenance for 7.5 years

In Table 2, the main technical characteristics of the proposed spacecraft are presented.

Table 2: Main technical parameters of Space-Based AIS spacecraft

Parameter	Value
Dry Mass	315.0 kg
Wet Mass	327.5 kg
Payload Mass	108.5 kg
Delta V	78.9 m/s
Average Power Consumption	248.5 W
Average Payload Power	80.6 W
Power Generation Threshold (EOL, 1 SC)	579.6 W
Data Storage	9,250 Mb
Downlink Data Rate	42,400 kbps

An impression of the proposed European Space-Based AIS spacecraft is shown in Figure 4.

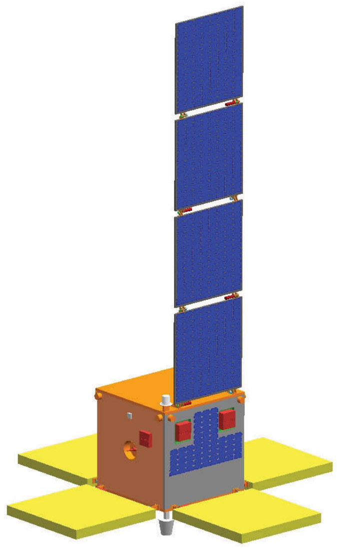

Figure 4: Impression of Space-Based AIS Spacecraft

5 PERFORMANCE SIMULATIONS

5.1 Simulator Description

In order to assess the performance of the European space based AIS system, FFI's dedicated simulation environment is used. This simulator, AISDET, uses the maritime vessel distribution model to simulate reception of AIS messages using the LEO constellation [3]. Each vessel transmits according to the SOTDMA scheme on two channels. The signal strength at the receiver of each message is computed to check whether it can be decoded according to receiver performance parameters. In case of message collision, the received power ratio between the desired and undesired signal (D/U) at the receiver input determines whether a particular message can be decoded or not.

The software model has the following features:

- Each vessel transmits according to the SOTDMA scheme
- Received signal strength and Doppler shift are calculated for each message
- Travel time is computed for each message to check for message collisions
- Output from antenna simulation software is used for computing antenna gain patterns
- A detailed ionosphere model is used to take Faraday rotation into account

In addition, the simulator makes use of mathematical models of the digital signal processing algorithms in order to define the detection threshold of the receiver.

5.2 Presentation and Discussion of Results

By using the unique algorithms of the AISDET simulator, it has been possible to estimate the performance of the designed space-based AIS system. It has to be recalled that all figures in this section are given for 2021.

In its raw form, the detection performance is expressed as a database showing the message detection instances of all involved vessels. By using this data, the detection interval for single vessels can be easily determined.

Post-processing of the data involves pooling the data of all ships in a particular geographical area and combining the detection intervals of all individual ships to arrive at a statistical distribution of the update interval in this respective area.

As a general performance measurement, the considered areas are taken to be 1° x 1° cells. In this way, a global map of the system's detection performance can be generated. In Figure 5, this map is presented.

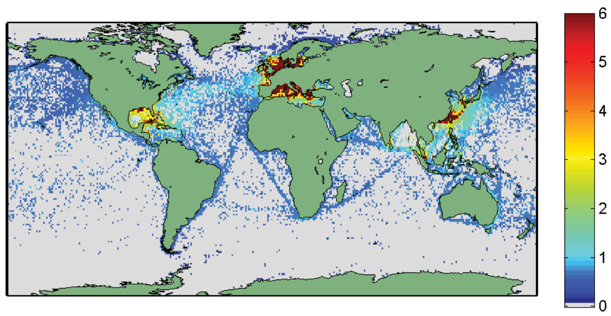

Figure 5: Global detection performance of the space-based AIS system

When investigating Figure 5, it has to be noticed that the color scale refers to the 80% confidence mark of the Cumulative Density Function of a particular 1° x 1° cell. For instance, yellow coloring indicates that the update interval of a random vessel in this 1° x 1° cell is equal to, or lower than, 3 hrs with 80% certainty.

It is easily seen in Figure 5 that the performance of the space-based AIS system is the lowest in the High Traffic Zones identified in Figure 1. This supports the theory that a high traffic density leads to many message collisions, which reduces the performances of the system. Aside from the High Traffic Zones, the overall performance is very good, because the update interval does not rise above below 1 hour.

For a more detailed performance assessment, multiple areas of interest have been defined, which have been called use cases. These use cases represent those areas, which are especially interesting for the space-based AIS system and thus deserve a more detailed investigation.

For the purposes of this paper, three different use cases are being presented. These are:

- North Atlantic
- Gulf of Mexico
- Mediterranean

Figure 6 shows the exact geometrical definition of these use cases.

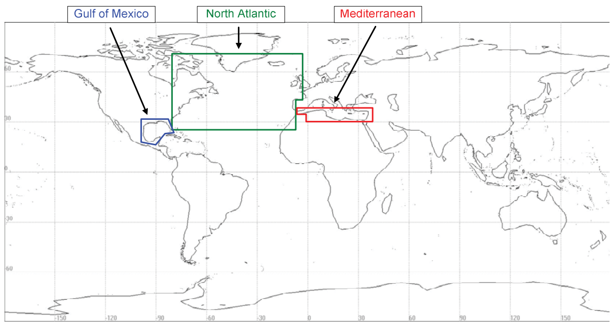

Figure 6: Earth map showing location of selected use cases

For every single use case, the Cumulative Density Function (CDF) will be shown. In Figure 7, the update interval CDF of the North Atlantic use case is presented. Similarly, the update interval CDF of the Gulf of Mexico use case is shown in Figure 8, while Figure 9 shows the update interval CDF of the Mediterranean use case.

Note that every CDF shows the cumulative distribution that a particular update interval (UI) is reached, i.e. that the update interval is equal to, or less than, the corresponding value.

Each graph of the update interval CDF shows the behavior of the update interval for every possible repetition time. These graphs show a general trend that the lower the repetition time, the lower the update interval. This can be easily explained by realizing that a low repetition time (i.e. high repetition rate) infers a high probability that at least a single message will be detected.

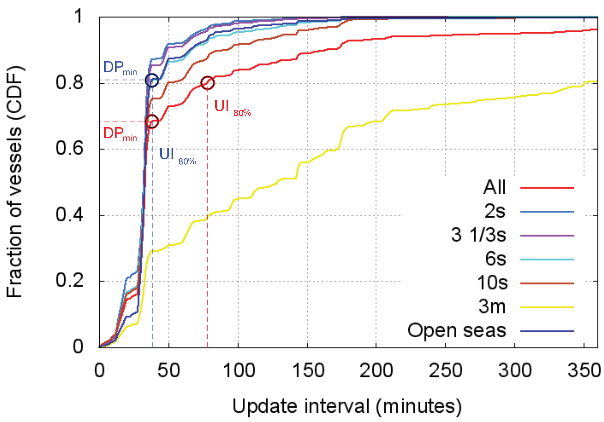

Figure 7: Update interval CDF of North Atlantic use case

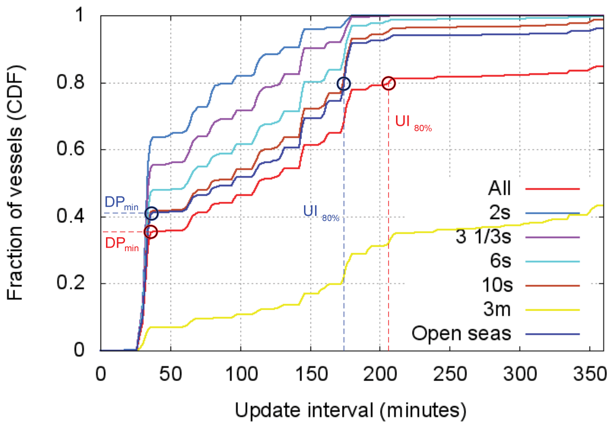

Figure 8: Update interval CDF of Gulf of Mexico use case

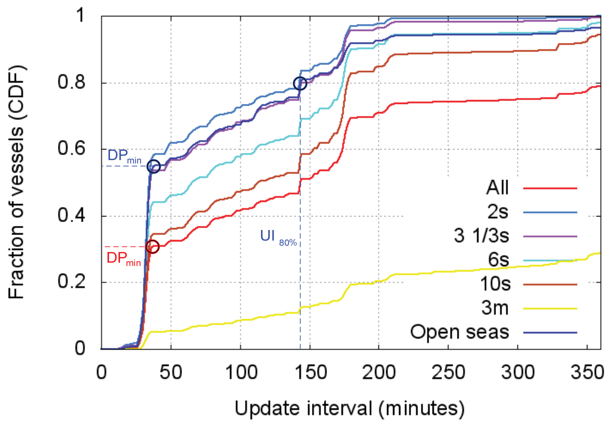

Figure 9: Update interval CDF of Mediterranean use case

As the main reference, the graph labeled *All* will be used. This graph is an average of all individual repetition times, weighted according to the amount of ships transmitting with a particular refresh time. Hence, this graph gives an accurate representation of the probability that a particular update interval is achieved.

Additionally, the graph labeled *Open seas* shows the behaviour of the update interval CDF of all ships outside coastal zones. In other words, ships within 40 NM of the coast are excluded in the determination of this graph. Therefore, it represents the situation, in which a combined system of coastal AIS stations with satellite-based AIS is applied for maritime monitoring.

It is easily noticed from Figure 7 to 9 that the overall update interval is heavily influenced by the 3 minute graph. Realizing that ships, which transmit with a 3minute repetition time, are either anchored or moored, the inclusion of the 3 minute graph in the calculation of the overall update interval may be questioned. In this sense, the *Open seas* graph may be more representative, as it excludes ships in port, which are anchored or moored.

In all three use cases, the first step in the CDF is observed at about 30 minutes. This is easily explained, because it is equal to the time between two successive passes of a satellite in the constellation, being the orbital period divided by number of spacecraft in a plane. After this first step, the update interval increases gradually until it converges to an asymptotic value.

Focusing on Figure 7, it is recalled that the North Atlantic is not defined as a High Traffic Zone. Thus, the requirement is a 1 hour update interval with 80% detection probability (DP). It is seen that the initial step after 30 minutes already results in a rather high detection probability (~68%). After 60 minutes the detection probability equals about 74%, so the requirement is not completely met when all vessels are considered. However, by excluding coastal vessels, compliance is easily ensured. The asymptote of the detection probability for all vessels lies at about 97%, so almost all vessels in this use case can be detected. Considering these observations, the North Atlantic can be considered an area with medium traffic density. On a global scale, similar areas are found in the Persian Gulf and the US Atlantic Coast.

Shifting the attention to Figure 8, it has to be remembered that the Gulf of Mexico is considered a High Traffic Zone. Hence, the requirement on update interval is 3 hours with 80% detection probability. It is easily noticed that the performance in this use case is significantly lower than in the North Atlantic use case. After all, the initial step after 30 minutes yields only a detection probability of 36%. A gradual increase finally results in a detection probability of about 78% after 3 hours when all vessels are considered, which does not meet the requirement. By excluding all coastal vessels, this value can be increased to about 92%, which complies with the requirement. The asymptote of detection probability lies at about 84%. All these observations lead to the conclusion that the Gulf of Mexico can be considered an area with high traffic density. Similar areas are found in the Black Sea, the Bay of Biscay and near Singapore.

As a final use case, the Mediterranean, which is considered a High Traffic Zone, is investigated in Figure 9. Thus, the requirement on update interval is 3 hours with 80 % detection probability. Comparing Figure 8 and 9, it is noticed that the Mediterranean yields lower performance than the Gulf of Mexico. The initial step after 30 minutes results in about 30% detection probability. After 3 hours, this detection probability has gradually increased to 68%, which does not comply with the requirement. Excluding all coastal vessels leads to a significant improvement, raising the detection probability to about 91%. The asymptote of detection probability lies at about 79%. All these observations lead to the conclusion that the Mediterranean can be considered an area with very high traffic density. Similar areas are found in the North Sea and Chinese Sea.

5.3 Intermediate Conclusion

Reflecting on the results of the performance assessment, it is seen that it is very challenging to meet all requirements laid down by the users. But with a constellation of 12 satellites equipped with high performance receiver architecture, phased array antennas and intricate digital processing algorithms, the requirements can be complied with in most use cases.

As has already been addressed, excluding vessels in the coastal zones, which also includes vessels in ports, already reduces the problem significantly. In this open sea case, the overall performance of the constellation is compliant with the user requirements.

Considering all global water surfaces, the system is able to provide a detection probability of 66.1% within an update interval of 1 hour. With an update interval of 3 hours, this performance increases to 80.2%.

6 FUTURE PROSPECTS

6.1 Role of SB-AIS in Maritime Security

Space-based AIS provides a convenient means of monitoring the global maritime traffic. However, it comes with several drawbacks. Most notably, it does not provide a way to detect non-cooperating vessels, i.e. vessels, which do not have their AIS transmitters turn on, either deliberately or by accident. Another drawback is the fact that AIS is not obligatory for small ships, which are below 45 m in length.

Because of these drawbacks, space-based AIS will have limited use as a stand-alone system. However, it will offer a large benefit when it is integrated with other remote sensing systems. A proposed system of systems working together to yield high performance monitoring of maritime traffic would involve:

- Space-based AIS
- Low-resolution, large swath remote sensing systems, e.g. SAR or low-res optical
- High-resolution remote sensing systems, e.g. high-res optical

The corresponding work flow would then be:

1. Large area coverage of global waters with low-res remote sensing
2. Correlation of AIS messages with vessels detected with remote sensing
3. Identification and monitoring of suspicious vessels with high-res remote sensing or in-situ systems (e.g. aircraft or coast guard)

With this workflow, space-based AIS plays a crucial role in reliable and rapid detection of non-cooperating and/or suspicious vessels.

6.2 Next Steps

As the first step in the implementation of a European space-based AIS system, a so-called First Space Node (FSN) will be deployed, which is foreseen to supplement EMSA's Coastal AIS Network. This FSN comprises one or two spacecraft optimized for the monitoring of selected use cases. These spacecraft will be optionally complemented by an optical IR payload for detection of non-cooperating vessels. It is foreseen to start Phase-B activities in the second half of 2010.

A first design iteration of the optical IR payload has already been performed. It has been chosen to implement a camera operating in medium-wave infrared (MWIR: 3.7 – 4.5 µm) for optional integration on the FSN spacecraft. By operating in this band, the payload is capable of detecting the wakes of moving ships. Furthermore, it is capable to function both in day and night conditions.

In Figure 10, the configuration and performance characteristics of the IR payload are shown.

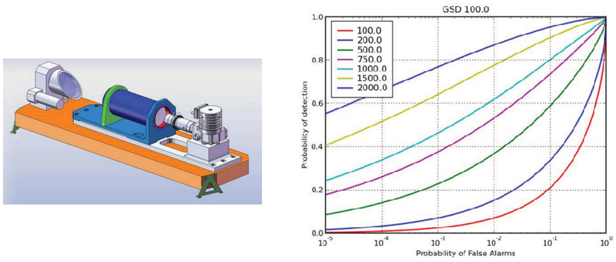

Figure 10: Configuration and performance characteristics of proposed IR payload

The IR payload will be a low resolution system with a ground sampling distance (GSD) of 100 m. This makes it possible to achieve a large swath width of up to 1000 km after integration of a scanning mirror.

Table 3: Technical characteristics of proposed IR payload

Parameter	Value	
Mass	25.0	kg
Power Consumption	38.0	W
Data Rate	1.9	Mbps
Dimensions (Envelope)	540 x 140 x 100	mm

In Table 3, the primary technical characteristics of the proposed IR payload are shown. By comparing these values with those in Table 2, it is easily noticed that this IR payload does not pose a heavy burden on the available satellite resources. This infers that a low-resolution IR payload can be easily integrated on the baseline space-based AIS spacecraft. Other systems, such as SAR or high-res optical, do not have these advantages and highly likely require a dedicated system.

7 STUDY TEAM AIS EXPERIENCE

The study team responsible for performing the European space-based AIS study has much experience in the field of maritime surveillance and AIS. For example, team prime OHB-System has fully constructed the Rubin–7 and –8 satellites [4].

Rubin–7 was the first spacecraft used for successful validation of space-based AIS, while Rubin–8 was a highly successful spacecraft flying 2 AIS receivers, which were responsible for the reception of over 600,000 messages during its first week of operation. Rubin–9, which is equipped with two newly developed types of spaceborne AIS receivers, was launched with a PSLV launcher on 23rd September 2009.

FFI has worked on studies related to space-based AIS for more than 6 years. On a national level, FFI is responsible for the Norwegian AIS satellite AISSat-1, which will be launched with a PSLV launcher in Spring 2010.

Kongsberg Seatex has been in the AIS market since its beginning and has a strong position on AIS infrastructure, base stations and mobile units. They have been responsible for designing and delivering the AIS receiver on the International Space Station (ISS) and the AIS payload aboard AISSat-1.

TAS (Thales Alenia Space) has a strong experience in Mission Segment & on-board satellite receiver for Satellite Based Data Collection & Navigation systems including SARSAT3, ARGOS3, ARGOS4, GALILEO and EGNOS. TAS is currently leading several projects on space-based maritime surveillance at national and European level.

On the application side, OHB is supporting the Promotion Centre for Communication, Earth Observation and Navigation integrated Applications (CEON) in Bremen, which will exploit AIS data for data fusion and service products.

8 CONCLUSION

In order to improve the performance of the existing land-based AIS system, a European space-based AIS system is proposed. For this purpose, relevant users have been interviewed yielding a requirement specification for the system. Furthermore, a maritime traffic model has been generated, which takes into account growth in the global shipping traffic over the next years. Two scenarios have been defined, which describe various levels of attainable performance of the system.

The main challenge in space-based AIS is the collision of multiple AIS messages in a single slot. In order to mitigate this problem, several innovative design options are available. A main design choice is the applied receiver architecture, being either on-board processing or digital bent-pipe. Smart solutions in digital signal processing and spacecraft antennas enable discrimination of the received AIS messages, leading to an improvement in detection performance.

The constellation has been optimized for high performance, sufficient coverage and low timeliness, resulting in 4 orbital planes consisting of 3 satellites each. Orbital parameters are 550 km altitude at 88° inclination. Assessment of the AIS constellation performance is done by using a dedicated AIS simulator applying either present-day or future traffic models. After definition of the use cases, including identification of so-called High Traffic Zones, which contain exceptionally dense traffic, the performance per use case has been evaluated.

Considering all vessels, the user requirements of 1 hour update interval with 80% detection probability for non-HTZ and 3 hour update interval with 80% detection probability for HTZ, can be met for most use cases. For critical use cases, such as North Atlantic or Mediterranean, these requirements will be met if open sea traffic is taken into account. Such a situation is representative of space-based AIS complementing the already existing infrastructure of coastal stations.

Considering all global water surfaces, the system is able to provide a detection probability of 97.0% within an update interval of 1 hour. With an update interval of 3 hours, this performance increases to 98.7%.

Although a space-based AIS system might offer limited benefit to maritime security as a stand-alone system, it has much potential added value when used in conjunction with other remote sensing systems, such as SAR or optical. Implementation of the space-based AIS system is initiated by the deployment of a First Space Node, of which Phase-B will start in the second half of 2010.

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