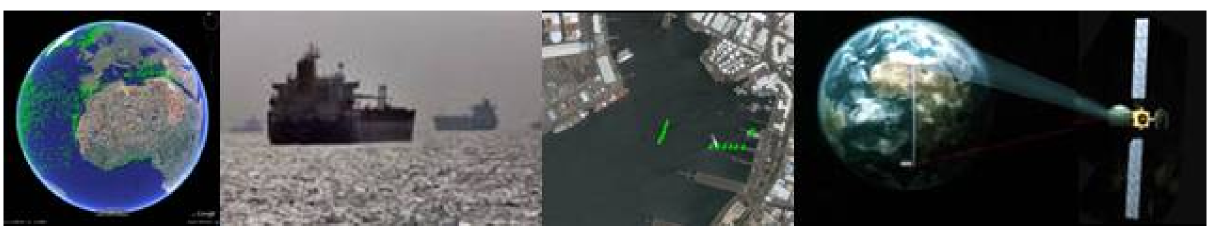
in cooperation with

Institute of Space Systems

Flight Operations



Technical Note TN-15-1:
Flight Trial Technical Report

Preparatory Action for Assessment of the Capacity of Space borne Automatic Identification System Receivers to Support EU Maritime Policy

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ISSUE	*DATE*	*CHANGE AUTHORITY*	*REASON FOR CHANGE AND AFFECTED SECTIONS*
1	27.09.2010	ComDev	Initial Release
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3	11.10.2010	ComDev	Final review

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1. INTRODUCTION

This report presents the results of the PASTA MARE AIS Flight Campaign and includes comparisons with terrestrial AIS data (t-AIS) from EMSA and satellite AIS data (s-AIS).

Section 6. Presents the summary of the flight trial, comparing the AIS message decoding of the airborne receiver with terrestrial (t-AIS) data supplied by EMSA and with satellite (s-AIS) data supplied by the AS3 satellite.

A COM DEV Europe (CDE) designed airborne payload was used to capture the data during the flight trial. The data was processed through an AIS data processing algorithm for the final results shown in the report. Both COM DEV and Luxspace processed the data and comparative processing results are presented in section 7.

Although not part of the original requirements of the flight trial, due to a recent agreement between exactEarth (the COM DEV AIS Service Company) and SpaceQuest (a US smallsat manufacturer), data from SpaceQuest's AS3 satellite was available for the regions covered by the aircraft trial (although not at exactly the same time). As this provides insight into the relative performance, this data is included here. However, the AS3 satellite uses on-board processing that is known to be not as good as the exactEarth post processing technique so the results should NOT be seen as representative of exactEarth s-AIS capability. To highlight this, comparative data of 'Onboard' processed data and 'Post' processed data for the Gulf of Mexico region has been included – see Annex 1.

Annex 2 includes a specially included summary of the AIS detection for the Baltic Sea region – an area that has been reported as problematic for s-AIS detection.

The table below presents the route of each flight trial and the date when the AIS receiver captured the data.

Table 1-1: Description of flight passes and captured AIS data

Flight Path	Date	Approximate Time, UTC
Amsterdam to Trondheim	15th July 2010	08.00 to 12.00
Trondheim to Cork	16th July 2010	11.00 to 15.00
Cork to Amsterdam	17th July 2010	11.00 – 13.00
Amsterdam to Malaga (Spain)	30th July 2010	10.00 - 15.00
Malaga to Amsterdam (Over land)	31st July 2010	11.00 - 13.00

The flight data was captured at up to 39,000 ft above sea level and the satellite data was captured along a typical Low Earth Orbit (LEO) of approximately 650 km above the ground.

2. APPLICABLE AND REFERENCE DOCUMENTS

Reference	Description	Issue
AD1	TNO 11-1 Receiver Hardware ICD	2
AD2	TNO 11-2 Receiver Software ICD	A

Table 2-1: List of Applicable Documents

Document	Description
[RD-1]	Preparatory Action for Assessment of the Capacity of Space borne Automatic Identification System Receivers to Support EU Maritime Policy – Pasta Mare Technical Proposal Call for Tenders No MARE/2008/06

Table 2-2: List of Reference Documents

3. ABBREVIATIONS

The following abbreviations are used in this document.

Abbreviation	Full
AIS	Automatic Identification System
FoV	Field of View
s-AIS	Satellite AIS data
t-AIS	Terrestrial AIS (EMSA) data
TBC	To Be Confirmed
TBD	To Be Defined

Table 3-1: List of Abbreviations.

4. THE AIS DATA COLLECTION PLATFORM

4.1 AIRCRAFT

In preparation for the flight trial there were two alternatives considered for the aircraft:

1. Hawker
2. Cessna Citation II.

From the installation point of view the Cessna provided a superior technical solution. The University of Delft prepared this Aircraft as a flight laboratory for different missions.

Figure 4-1: Cessna Citation II.

The aircraft provides a choice of external GPS Antennas, integrated power supplies for 230V 50Hz and 110V 400Hz, prepared access to the VHF antenna and prepared anchorage points for racks.

TU Delft supported the integration for the equipment on the aircraft from a technical point of view, and also managed the approval for the flight-worthiness of the installation.

4.2 INSTALLATION

For the aircraft installation, two plates were provided with assembled devices and an existing rack. The first plate includes the operator devices (Monitor, Keyboard, Display, Mouse) on top of the rack. The second plate includes the power supply, the DC power filter, the receiver, and the eInstrument PC.

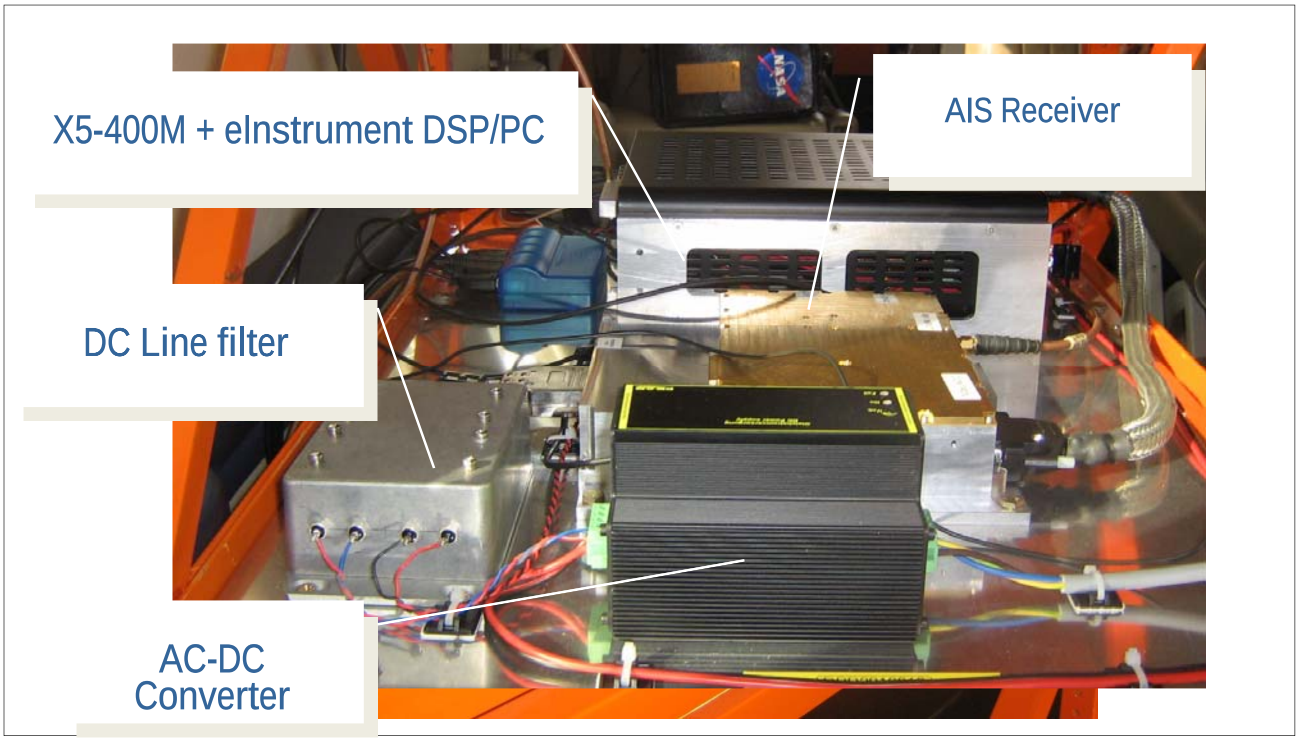


Figure 4-2: The AIS receiver system installed into the flight rack.

The following figure presents the system.

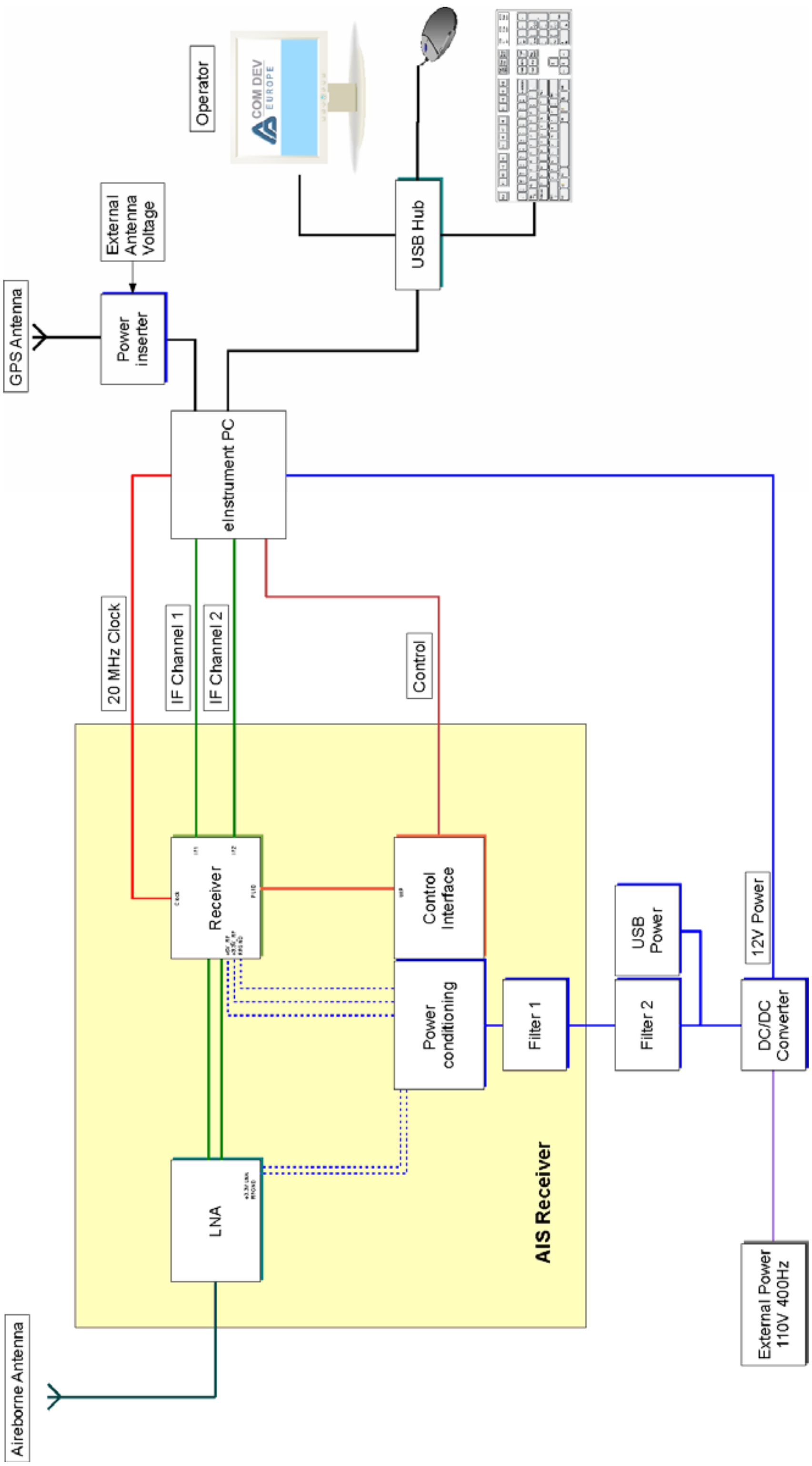


Figure 4-3 Flight trial AIS receiver system.

4.3 SOFTWARE

The Receiver was controlled by software running on the embedded PC. The software controlled the AIS receiver, the GPS timing reference (X3-TIMING) and Digital Signal Processor (X5-400M) in real-time. The data was stored onto a dedicated Hard Disk Drive (HDD). The software provides a user interface that enables the AIS channels to be monitored in real-time either in the time domain or frequency domain (power spectrum). The operator can also control the receiver's attenuator and local oscillator settings. Some adjustment to the gain was required especially shortly after take-off due to slight overloading of the receiver. However, this appears to have had little if any impact on the quality of the data. The following figure shows the real-time spectrum monitoring display.

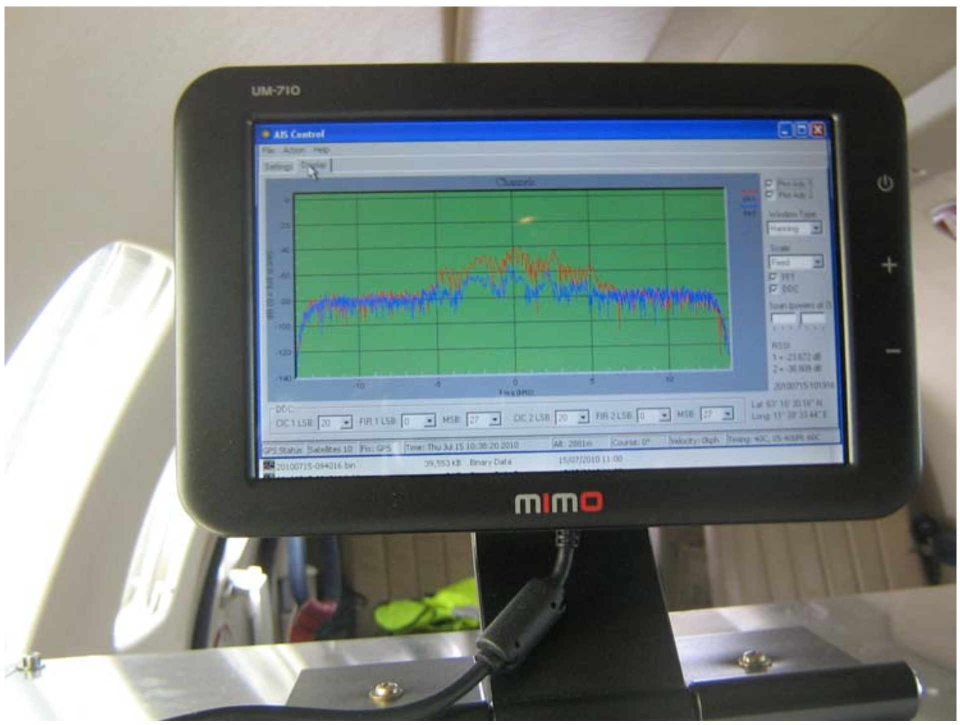


Figure 4-4: The real-time AIS channel monitoring display.

5. DATA PROCESSING

5.1 DATA SET

The signal data was captured by the receiver (sampled at 28.125 ksps) and stored in real-time to a hard disk drive using the format specified by the software ICD, AD2. The data was collected in nominally 3-minute chunks. Each 3-minute chunk was stored to a separate file. Every 10 seconds the GPS position report was inserted in NMEA 0183 format (GPGGA).

The table below summarises the data sets captured. It can be seen that a huge amount of data was collected.

Table 5-1: Summary of data sets produced from the flight trial.

Flight	Date	Data Set	Data length, mins	# files	Total size, bytes
Amsterdam-Trondheim	15/07/2010	AMS-Trond	224.5	74	2,871,489,506
Trondheim-Cork	16/07/2010	Trond-Cork	208.67	67	2,669,343,219
Cork-Amsterdam	17/07/2010	Cork-AMS	110.00	36	1,409,215,380
Amsterdam-Malaga	30/07/2010	AMS-Mala	331.00	110	4,232,357,246
Malaga-Amsterdam	31/07/2010	Mala-AMS	281.83	91	3,603,841,135
TOTAL			**1,156.00**	**378**	**14,786,246,486**

5.2 TYPICAL WAVEFORMS

Figure 5-1 shows a typical AIS power plot (10,000 samples) recorded on final approach to Amsterdam (Malaga-AMS). Figure 5-2 shows a typical spectral plot. Figure 5-3 shows a typical GMSK modulated AIS packet in the time domain (Real, I part).

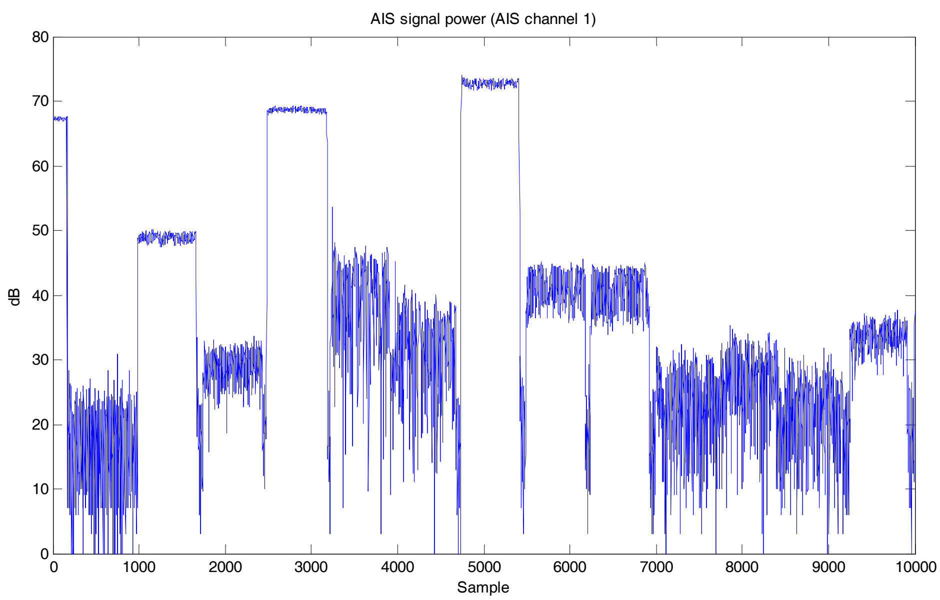


Figure 5-1: Typical AIS power versus time (Channel 1).

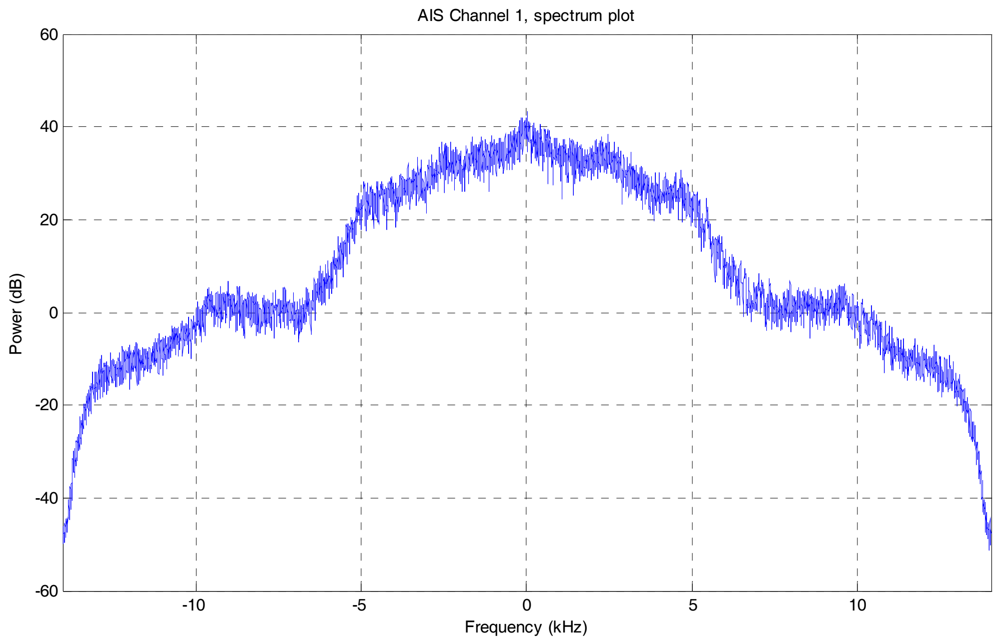


Figure 5-2: Spectral plot for a typical AIS channel (131072 samples).

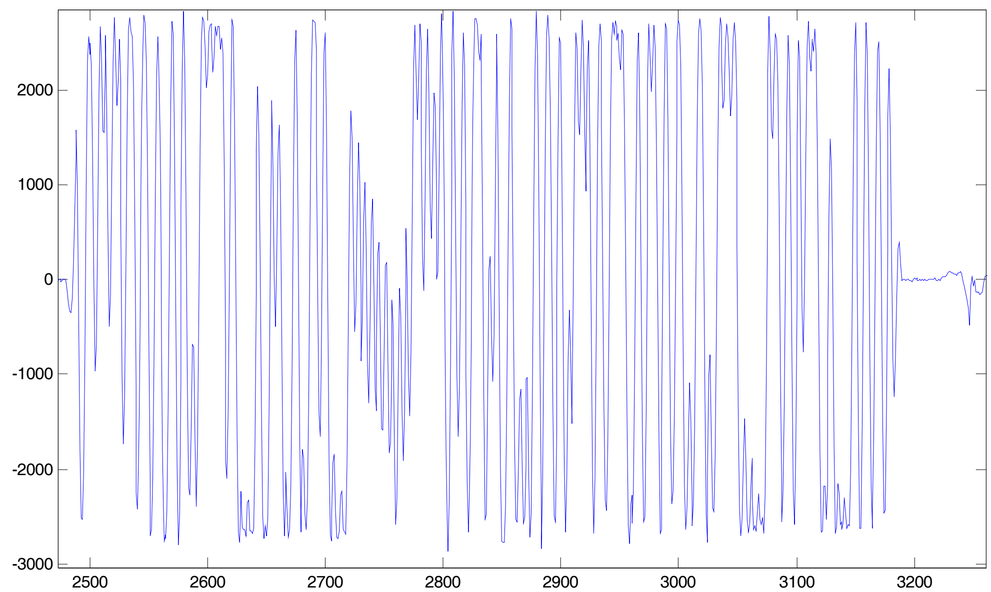


Figure 5-3: A typical AIS packet.

6. FLIGHT TRIAL REPORT

6.1 OVERVIEW

This section describes the comparison of Automatic Identification System (AIS) data captured on a receiver on-board an aircraft flown across five destinations with terrestrial AIS data (t-AIS) obtained from the European Maritime Safety Agency (EMSA) as well as actual satellite AIS data named AS3.

A COM DEV Europe (CDE) designed payload was used to capture the data during the flight trial. The data was then processed through an AIS data processing algorithm for the final results shown in the report. The data captured by the AS3 satellite used on-board processing to decode the AIS messages, before sending them via a downlink.

The table below summarises the flights used for the trial.

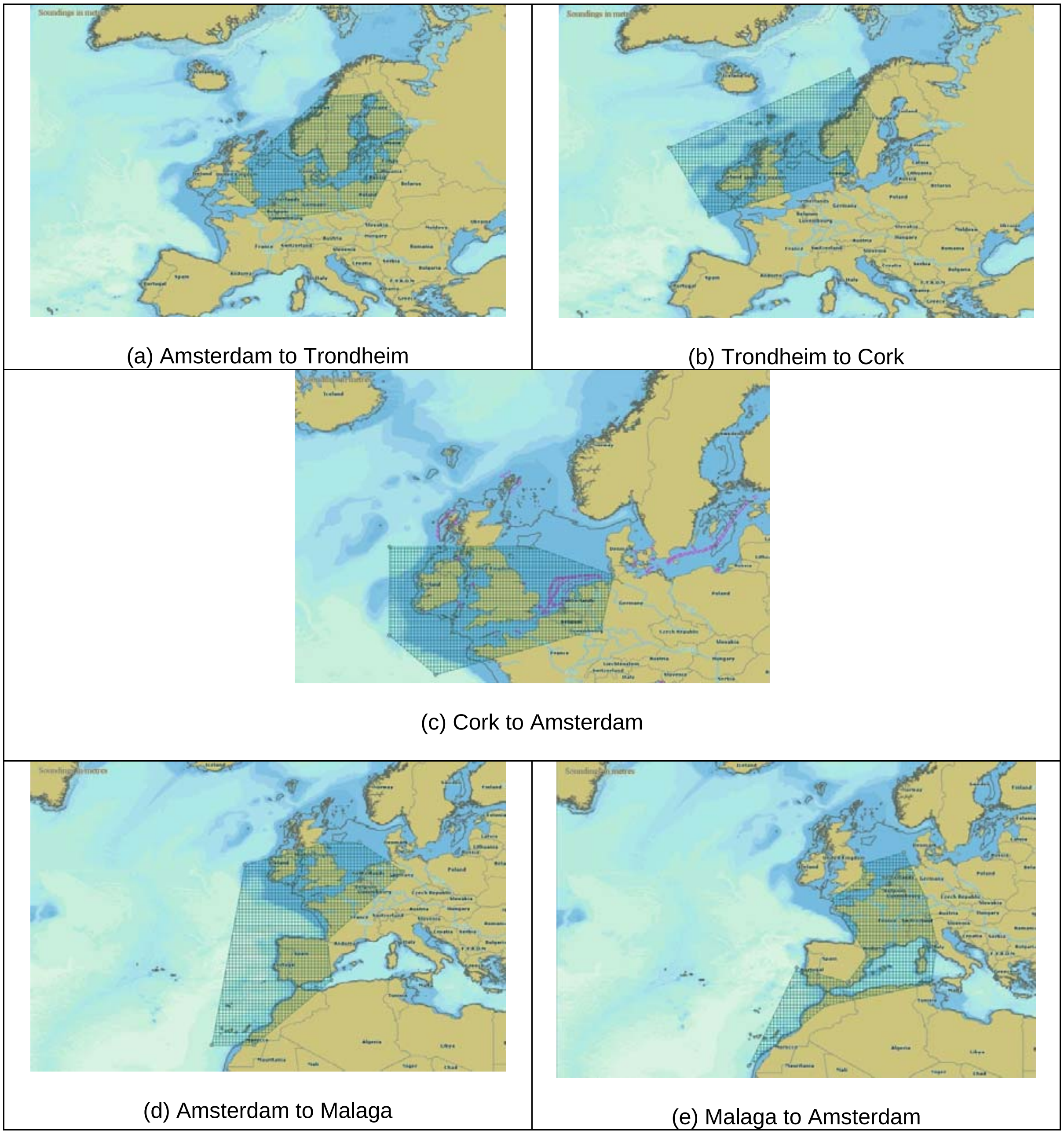
Table 6-1: Description of trial flight passes and captured AIS data

Date	Route	Time (UTC)	Area
15.07.2010	Amsterdam - Trondheim	7:19 – 10:51	North Sea and Baltic Sea
16.07.2010	Trondheim - Cork	11:45 – 15:01	North Sea
17.07.2010	Cork – Amsterdam	10:44 – 12:27	Atlantic - Channel
29.07.2010	Amsterdam - Amsterdam	8:39 – 10:09	North Sea - Channel
30.07.2010	Amsterdam - Malaga	10:25 – 15:19	Channel, Golf of Biscaya, Portuguese Coast
31.07.2010	Malaga - Amsterdam	11:56 – 16:08	Western Mediterranean Sea

The flight data was captured at 39,000 ft above sea level and the satellite data was captured along a typical Low Earth Orbit (LEO) of approximately 650 km above the ground.

The following section summarizes the comparison of results for five geographical areas (see Figure 6-1). The geographical areas representing the coverage of captured data were defined by polygons in Gate-House AIS Display (GAD) and each data set was geographically filtered by the polygon-bound. The actual area of the polygon was defined by the coverage of each data set obtained during the flight along the route described in the table above.

It should be made clear that in this case the polygon does not represent a common area of signal detection. In some cases the t-AIS data does not ‘see’ as far as the aircraft and in deed in some cases the Field of View of the aircraft antenna means that there isn’t common coverage with the t-AIS. In addition the t-AIS represent a restricted data set as it is down-graded to 6 minute time sequences. Also Portugal does not deliver any terrestrial data to EMSA so the data in that region only comes from Spain and this will artificially reduce the numbers of AIS signals in the Atlantic region.



(a) Amsterdam to Trondheim

(b) Trondheim to Cork

(c) Cork to Amsterdam

(d) Amsterdam to Malaga

(e) Malaga to Amsterdam

Figure 6-1: Plot of polygons used for ‘coarse’ analysis.

In addition to the filtered data, the flight data results also include statistics for *unfiltered* data (i.e. everything that could be successfully decoded from the captured files).

6.2 AMSTERDAM TO TRONDHEIM

6.2.1 FLIGHT DATA RESULTS

Figure 6-2 below shows the Amsterdam-Trondheim flight plan. Apart from the initial leg of the journey near the airport where the aircraft was directed by ATC, this was the path flown by the aircraft.

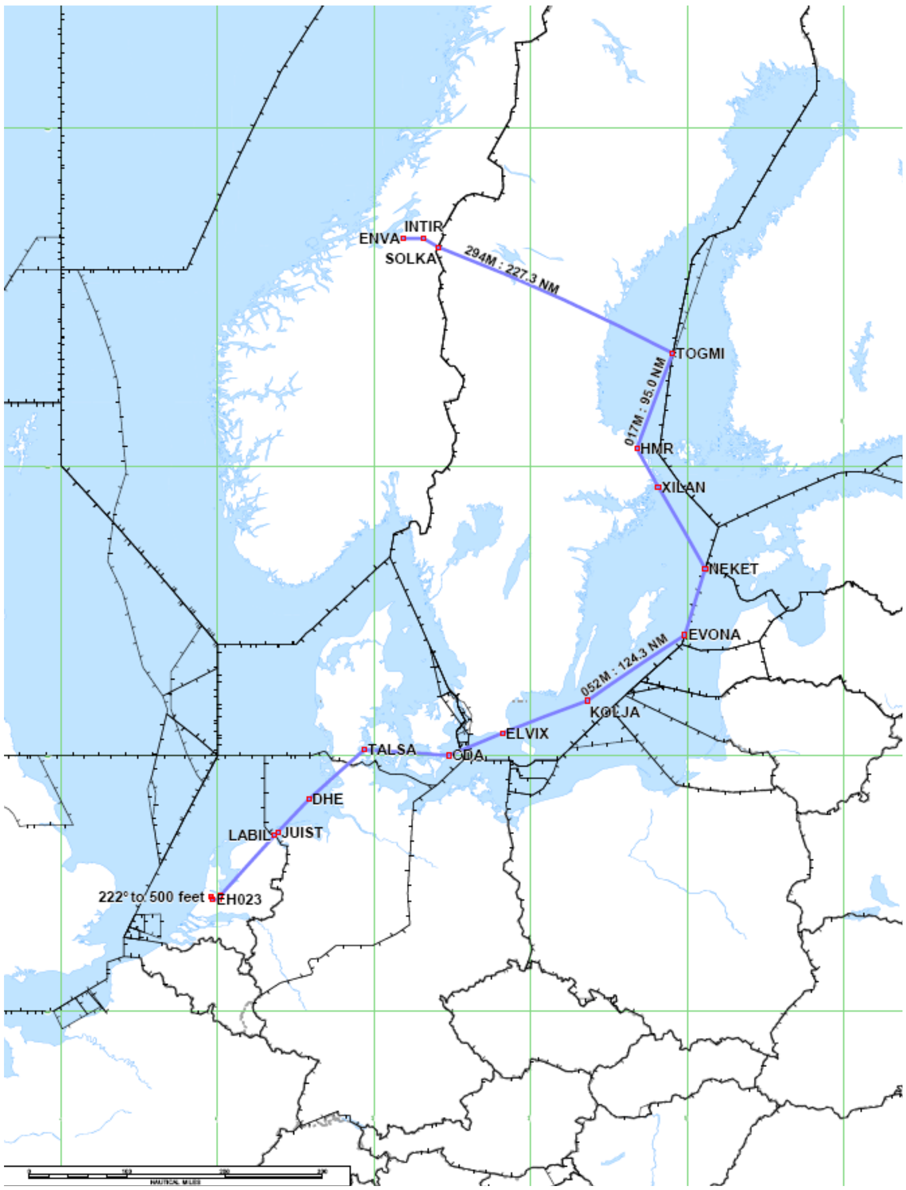


Figure 6-2: The Amsterdam-Trondheim flight showing waypoints (Courtesy of TU-Delft Flight Department)

The take-off from Amsterdam was at 0719 UTC, landing at Trondheim at 1051 UTC, a flight time of approximately 3 hours, 32 minutes.

This was the first trial flight for the receiver. Initially at low altitudes some manual adjustment of the receiver's gain was required, but generally the dynamic range of the receiver was such that very little subsequent manual intervention was required.

Table 6-2 below presents the unfiltered message decode results from the Amsterdam-Trondheim flight (i.e. all messages received with a correct FCS) as decoded by COM DEV.

Table 6-2: Unfiltered variable-length decoded results for the Amsterdam-Trondheim flight (COM DEV Results).

Number of Unique MMSI Detected	7,498
Total number of messages detected	389,742
Average detection rate over flight duration	1840 messages/min
Type 1,2,3 (Class-A Position Report)	352,631 (303,582 type 1, 717 type 2, 48332 type 3)
Type 4 (Basestation)	18,283
Type 18 (Class-B Position Report)	8,481
Other types	10,347

6.2.2 COMPARISON WITH TERRESTRIAL AND SATELLITE DATA

Figure 6-3 shows a plot of vessels detected from the AIS receiver on-board the aircraft during its journey from Amsterdam Airport (AMS) to Trondheim. Figure 6-4 and Figure 6-5 show the vessels detected in the same geographical area defined by the polygon shown in Figure 6-1(a), for both terrestrial AIS (t-AIS) data and satellite AIS (s-AIS) data respectively. It should be noted that this is not a 'like for like' comparison since the t-AIS data has limited range which is of a smaller area than the polygon and the Airborne AIS data will also be limited by the antenna FoV. These plots are to show in general the level of vessels seen by each system. Later in this report a more detailed analysis is performed with a limited area that is common to all three sensors (see section 7.)

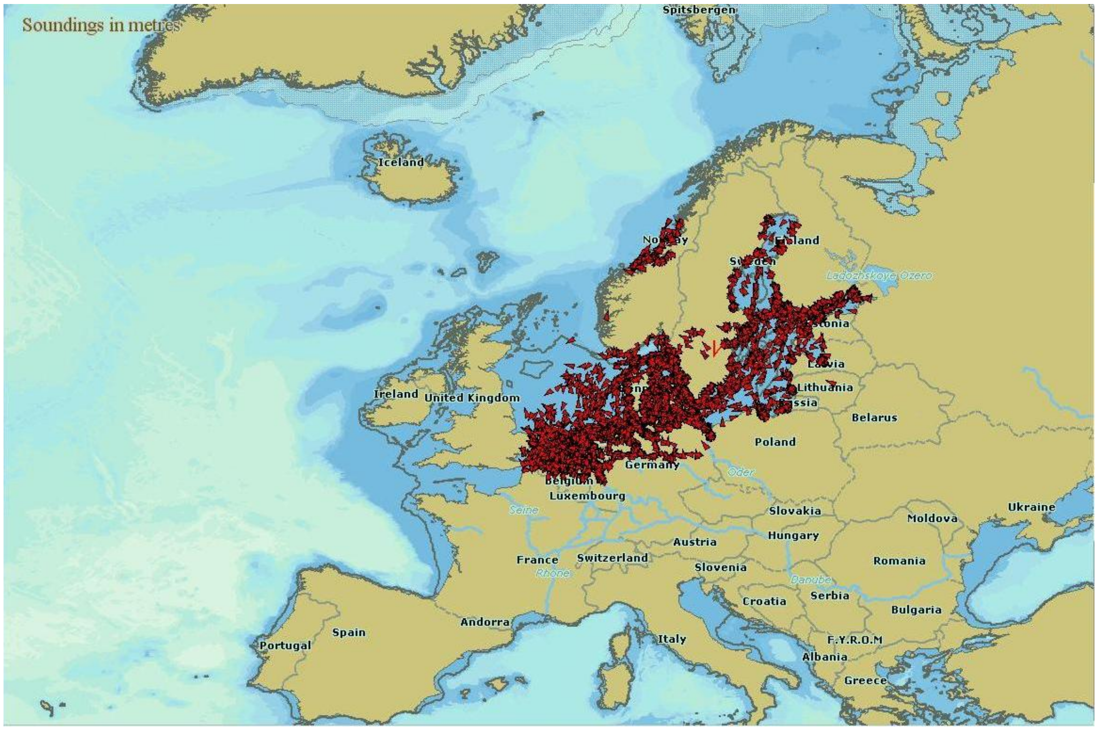


Figure 6-3: Plot of the vessels detected from the on-board receiver flown from Amsterdam to Trondheim.

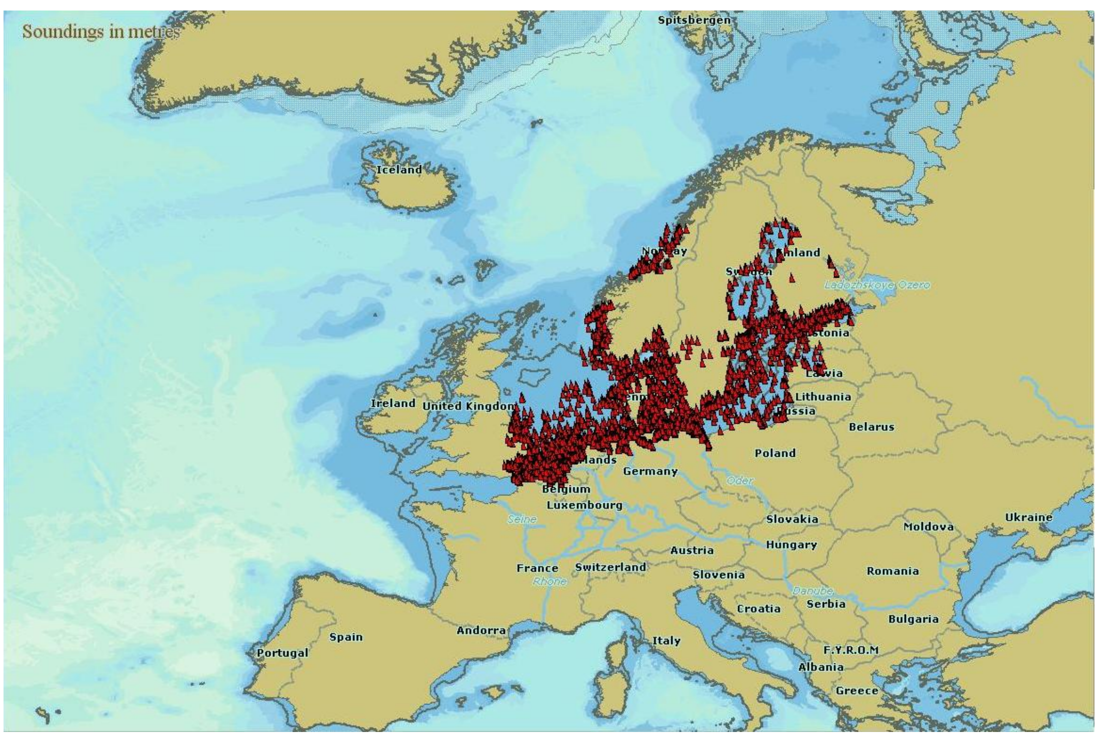


Figure 6-4: Plot of the vessels detected from terrestrial AIS, Amsterdam to Trondheim capture area.

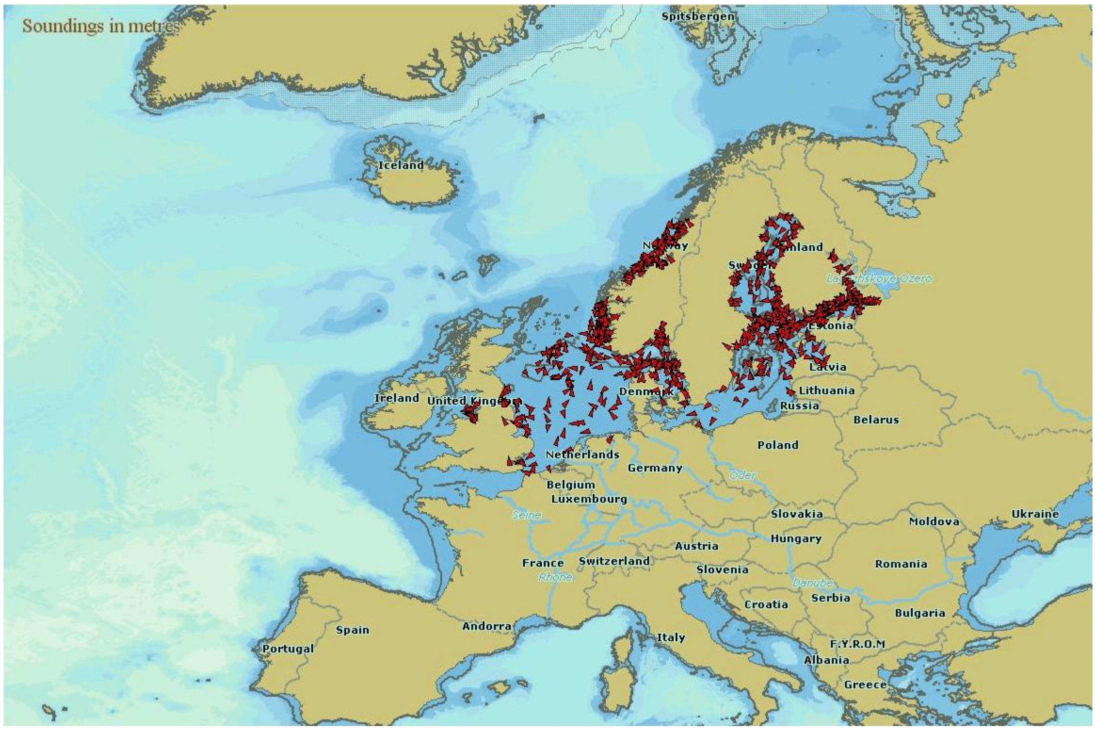


Figure 6-5: Plot of the vessels detected from satellite AIS with on-board processing, Amsterdam to Trondheim capture area.

Table 6-3 summarizes the vessel and message detection statistics for the three data sources within the geographical region defined for the Amsterdam to Trondheim flight. It is clear that the t-AIS data records the highest number of vessels, about 7% more compared to the airborne receiver. Note that a direct comparison of message detection rate between t-AIS and airborne is not valid because the t-AIS was sampled at 6 minute intervals, whereas all received messages (of class 1-4) for the airborne receiver within the specified geographical region have been included.

Table 6-3: Amsterdam to Trondheim vessel and message detection statistics for flight, t-AIS and s-AIS data.

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	347,941	5,923	58.7	299,387	697	47721	1
t-AIS	162,012	6,346	25.5	162,012	0	0	0
AS3	1,664	944	1.8	1,410	1	150	18

6.3 TRONDHEIM TO CORK

6.3.1 FLIGHT DATA RESULTS

Figure 6-6 below presents the flight plan for the Trondheim to Cork flight.

Take-off from Trondheim was at about 11:45 UTC and landing at Cork airport was at 15:01 UTC, a flight time of about 3 hours 16 minutes.

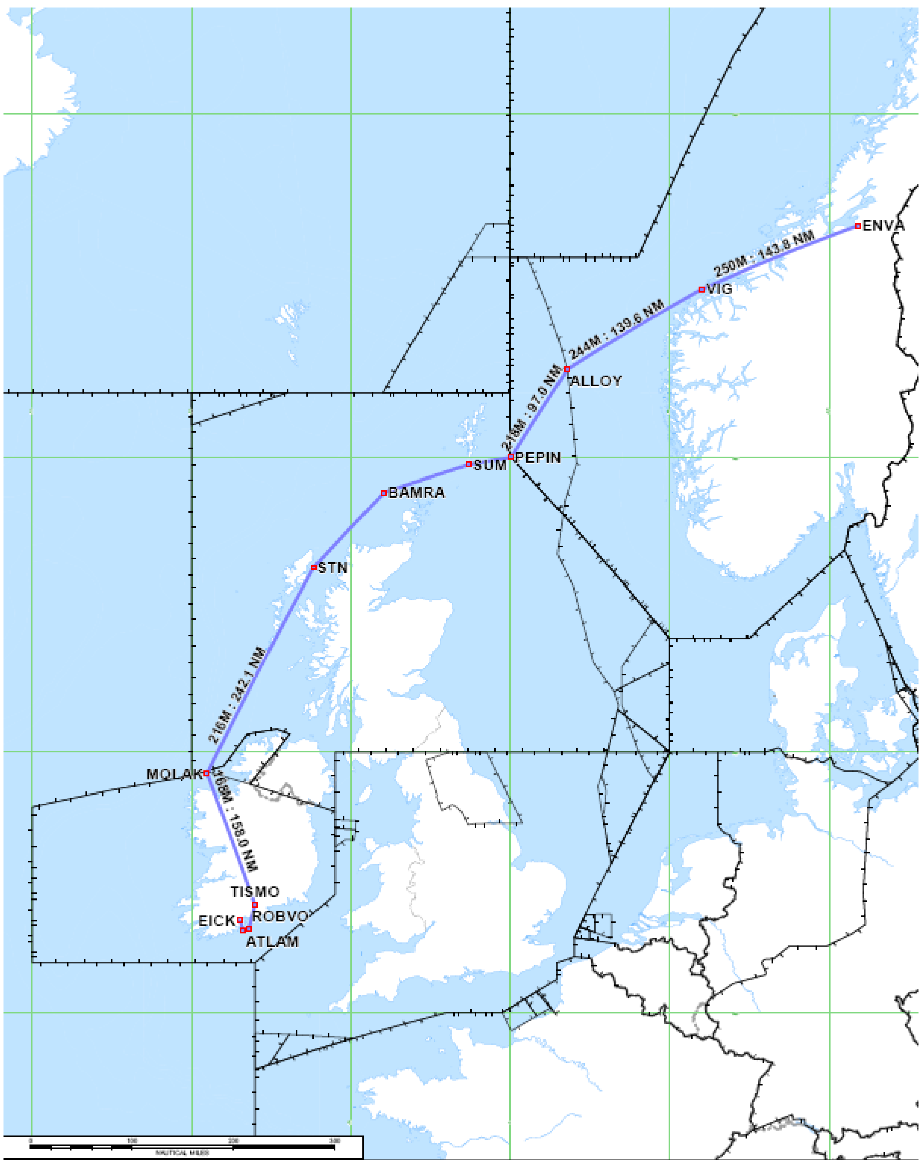


Figure 6-6: Flight plan for the Trondheim to Cork flight (Courtesy of TU-Delft Flight Department).

Table 6-4: Unfiltered variable-length decoded results for the Trondheim-Cork flight.

Number of Unique MMSI Detected	2768
Total number of messages detected	360,181
Average detection rate	1970 messages/min
Type 1,2,3 (Class-A Position Report)	324,747 (259,822 type 1, 220 type 2, 64705 type 3)
Type 4 (Basestation)	18,998
Type 18 (Class-B Position Report)	4955
Other types	11,841

Compared to the results for the Amsterdam-Trondheim flight (see Table 6-2), the number of ships is significantly less (only 2768 unique MMSI compared to 7,498). However, the message detection rate is greater (1970 compared to 1840). This may be due to the lower density of shipping resulting in fewer collided packets.

Figure 6-7 shows a plot of the number of vessels detected from the AIS receiver on-board the aircraft during its journey from Trondheim to Cork with the geographical filtering polygon applied.

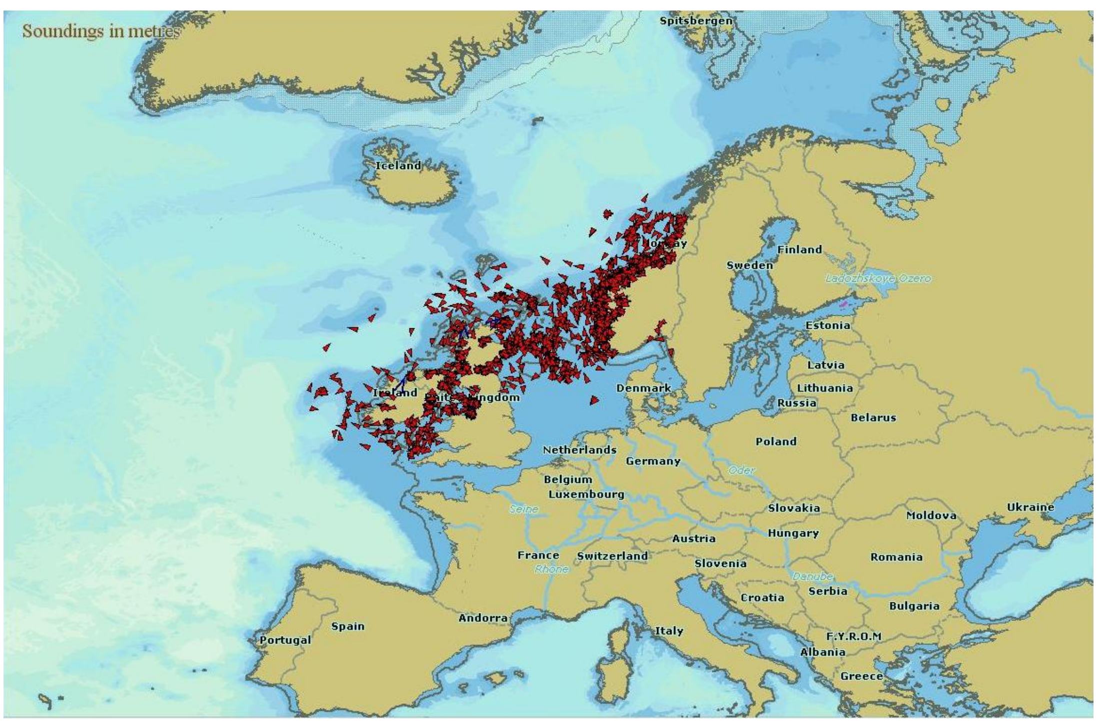


Figure 6-7: Plot of the vessels detected from the on-board receiver flown from Trondheim to Cork.

6.3.2 COMPARISON WITH TERRESTRIAL AND SATELLITE DATA

Figure 6-8 and Figure 6-9 show the number of vessels detected in the same geographical area defined by the polygon shown in Figure 6-1(b), for both terrestrial AIS data and satellite AIS data respectively. It should be noted that this is not a 'like for like' comparison since the t-AIS data has limited range which is of a smaller area than the polygon and the Airborne AIS data will also be limited by the antenna FoV. These plots are to show in general the level of vessels seen by each system. Later in this report a more detailed analysis is performed with a limited area that is common to all three sensors sensors (see section 7.)

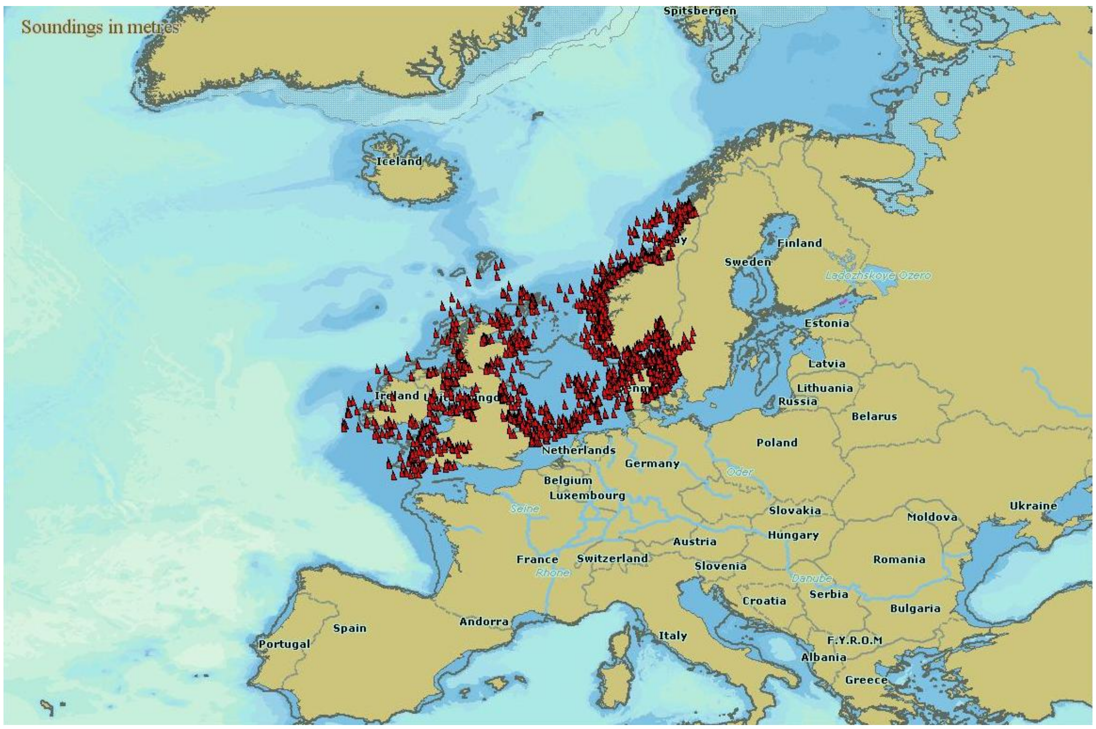


Figure 6-8: Plot of the vessels detected from terrestrial AIS, Trondheim to Cork capture area.

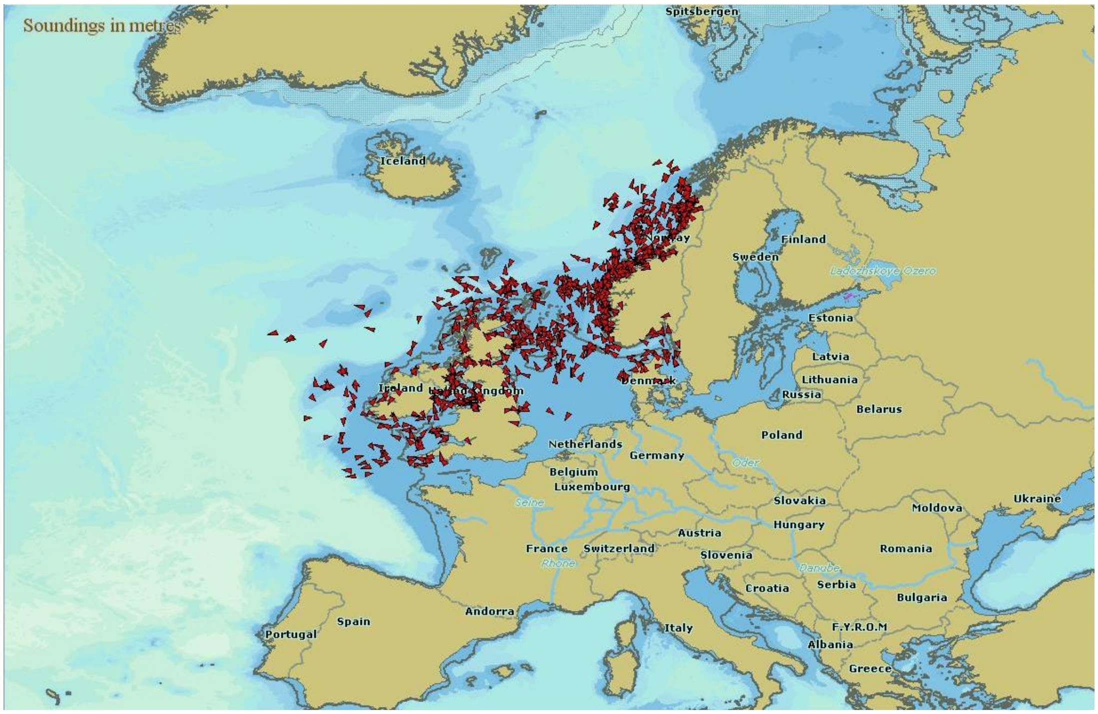


Figure 6-9: Plot of the vessels detected from satellite AIS with on-board processing, Trondheim to Cork capture area.

As an example of the detailed AIS data available from the flight, Figure 6-10 below shows a tacking yacht (Class-B vessel) plotted in Google Earth.

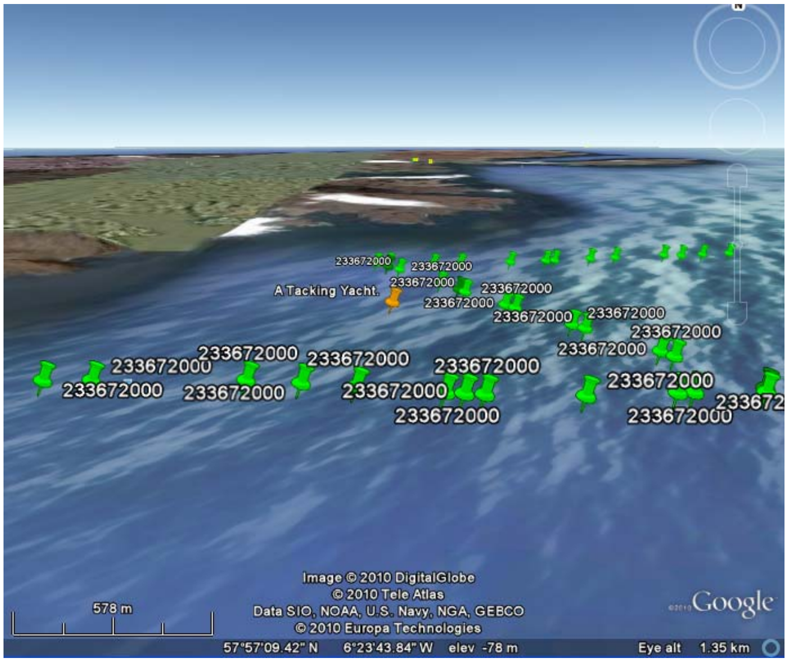


Figure 6-10: An example of a small vessel, probably a yacht performing tacking.

Another example shown below was the coming together of two vessels after which one of them switched its AIS transponder off.

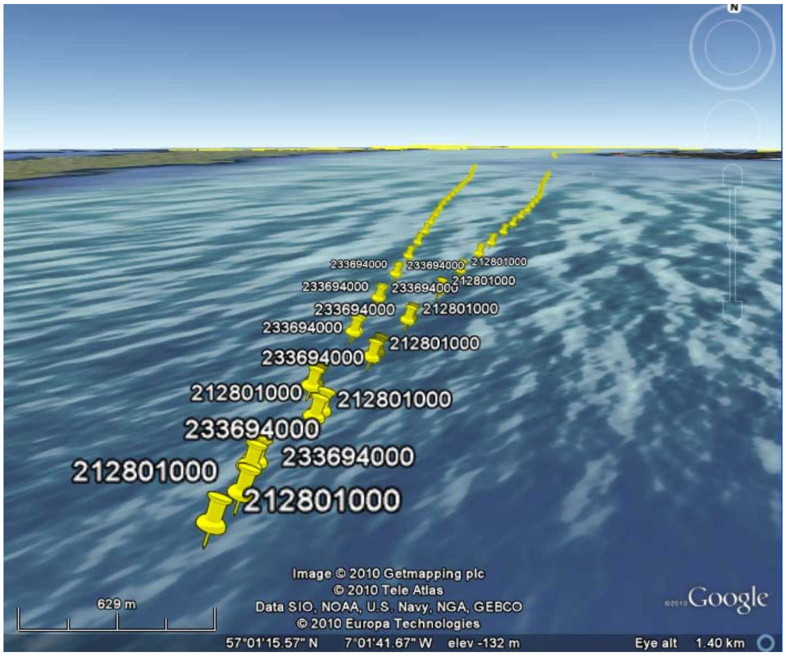


Figure 6-11: An interesting plot showing two ships on a convergent course. Possibly one of the ships is a pilot vessel.

Table 6-5 summarizes the vessel and message detection statistics for the three data sources within the geographical region defined for the Amsterdam to Trondheim flight. It is clear that the t-AIS data records the highest number of vessels, about 34% more compared to the airborne receiver. In this case, it is possible that the FoV of the airborne antenna limited the detection rate. Note that a direct comparison of message detection rate between t-AIS and airborne is not valid because the t-AIS was sampled at 6 minute intervals, whereas all received messages (of class 1-4) for the airborne receiver within the specified geographical region have been included. A vessel underway normally should report its position every 10s, therefore the true t-AIS message rate may be over 30 times greater than the 6 minute sampled rate in high density areas.

Table 6-5: Trondheim to Cork vessel and message detection statistics for flight, t-AIS and s-AIS data.

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	318,858	1,855	171.9	254,215	195	63,627	0
t-AIS	15,002	2,491	6.0	15,002	0	0	0
AS3	2,000	954	2.1	1,580	0	310	15

6.4 CORK TO AMSTERDAM

6.4.1 FLIGHT DATA RESULTS

Figure 6-12 below presents the flight plan for the Cork to Amsterdam flight of 17th July 2010. Take-off from Cork was at approximately 10:44 UTC, landing at Amsterdam at about 12:27 UTC, a flight duration of about 1 hour 43 minutes.

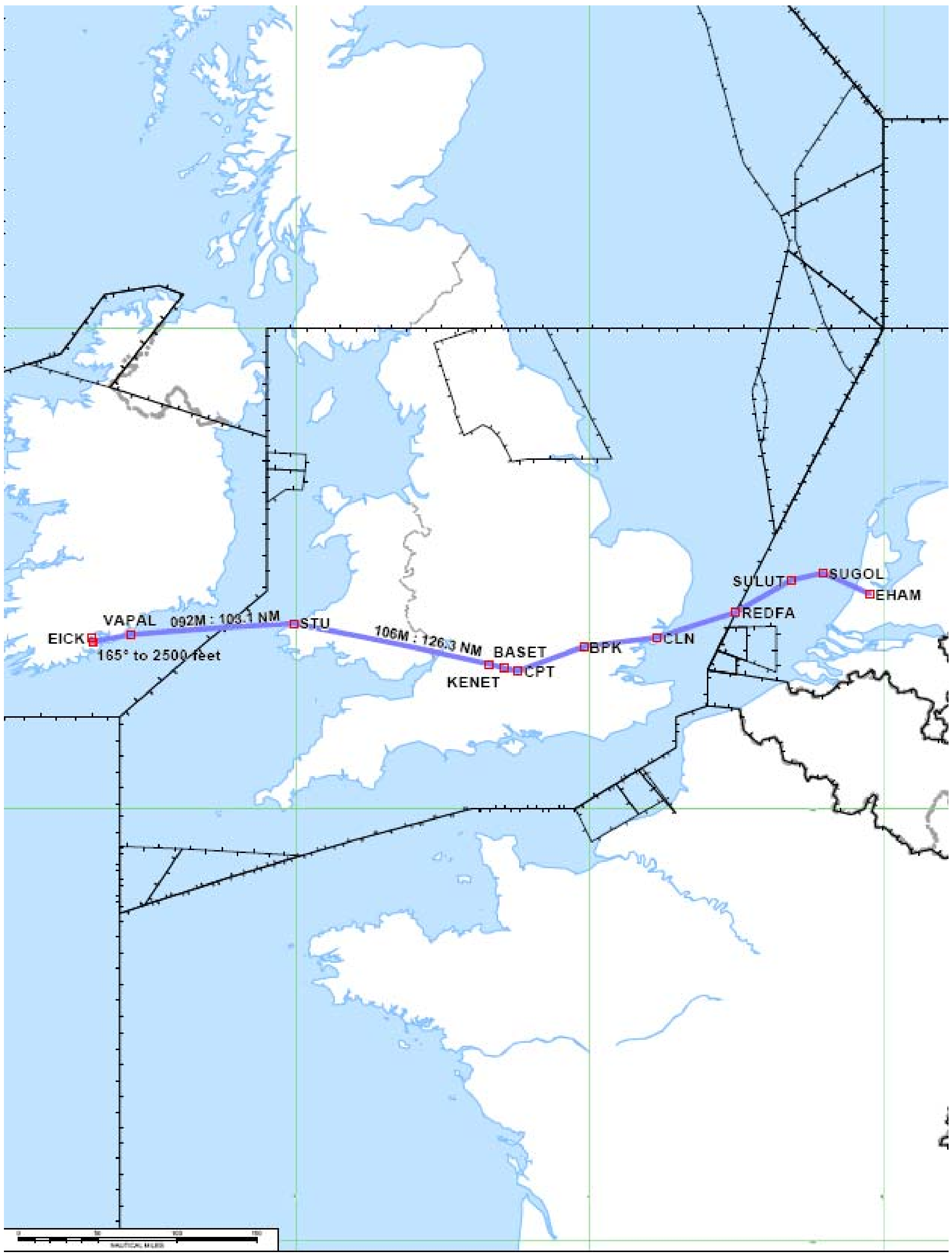


Figure 6-12: Flight plan for the Cork to Amsterdam flight, 17th July 2010.

The following table presents the un-filtered, fixed-length decoded messages decode statistics.

Table 6-6: Unfiltered fixed-length decoded results for the Cork-Amsterdam flight.

Number of Unique MMSI Detected	4328
Total number of messages detected	165,791
Average detection rate	1610 messages/min
Type 1,2,3 (Class-A Position Report)	156,257 (130,321 type 1, 3199 type 2, 22737 type 3)
Type 4 (Basestation)	6,026
Type 18 (Class-B Position Report)	1941
Other types	1,567

The number of messages detected was considerably less than for the other flights, and this is reflected in the average detection rate.

6.4.2 COMPARISON WITH TERRESTRIAL AND SATELLITE DATA

Figure 6-13 shows a plot of the number of vessels detected from the AIS receiver on-board the aircraft during its journey from Cork to Amsterdam. Figure 6-14 and Figure 6-15 show the number of vessels detected in the same geographical area defined by the polygon shown in Figure 6-1(c), for both terrestrial AIS data and satellite AIS data respectively. It should be noted that this is not a 'like for like' comparison since the t-AIS data has limited range which is of a smaller area than the polygon and the Airborne AIS data will also be limited by the antenna FoV. These plots are to show in general the level of vessels seen by each system. Later in this report a more detailed analysis is performed with a limited area that is common to all three sensors (see section 7.)

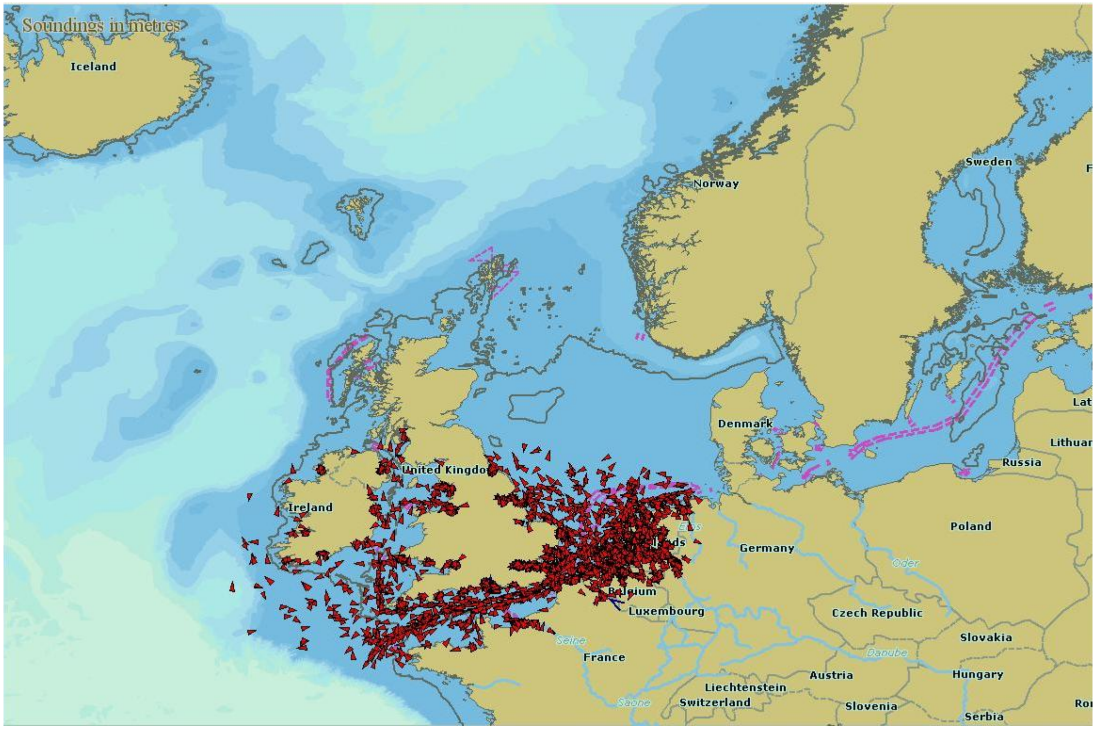


Figure 6-13: Plot of the vessels detected from the on-board receiver flown from Cork to Amsterdam.

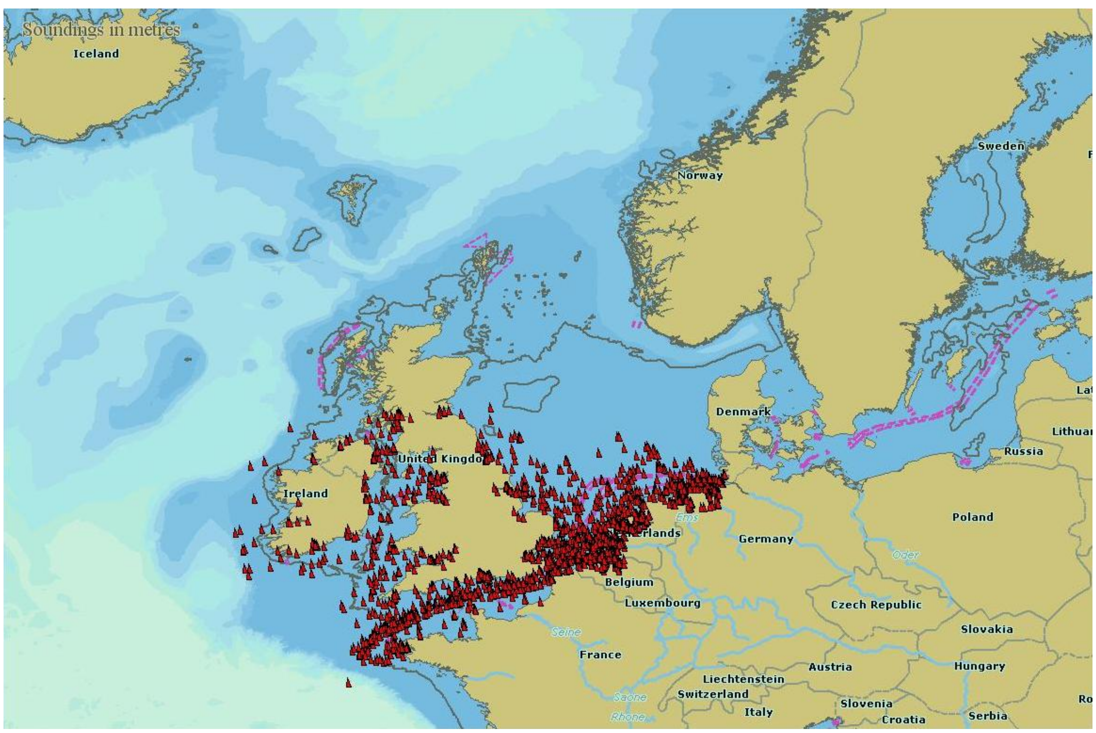


Figure 6-14: Plot of the vessels detected from terrestrial AIS, Cork to Amsterdam capture area.

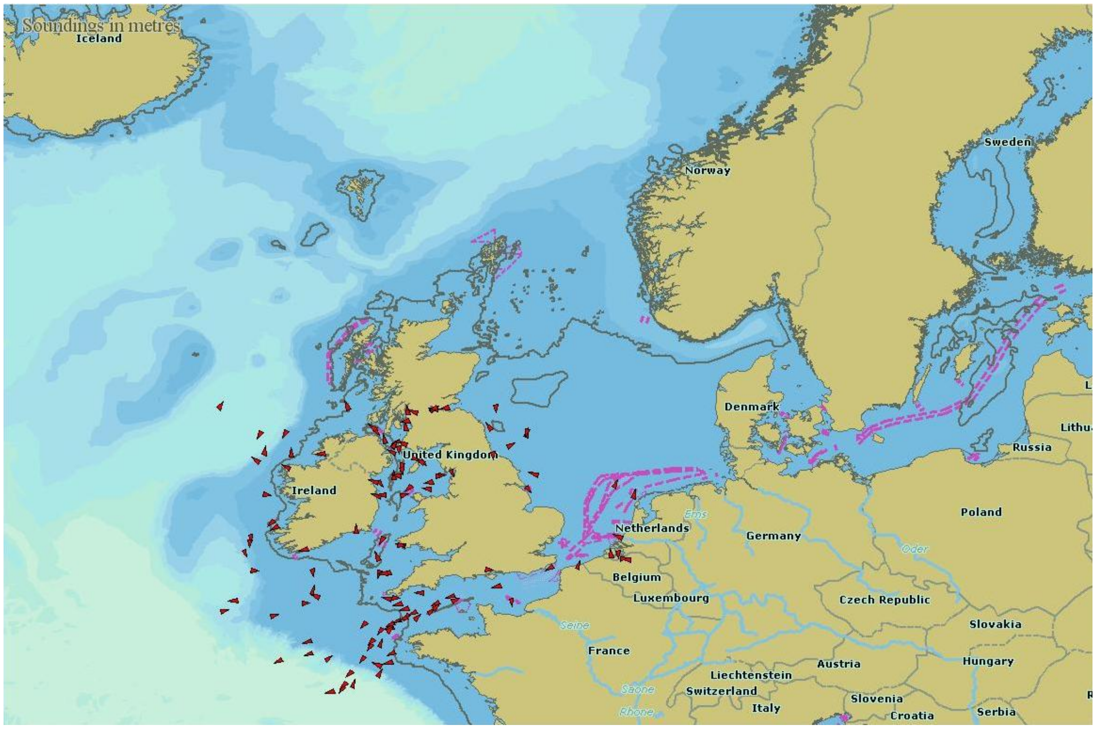


Figure 6-15: Plot of the vessels detected from satellite AIS with on-board processing, Cork to Amsterdam capture area.

Table 6-7 summarizes the vessel and message detection statistics for the three data sources within the geographical region defined for the Amsterdam to Trondheim flight. The results show that the number of vessels detected by the flight receiver was 11% greater compared with the number of vessels detected by the terrestrial AIS system. It must be emphasized that due to limitations in the FoV of the airborne receiver and availability of EMSA data within the large geographical region, it is not necessarily a like-for-like comparison. Note that a direct comparison of message detection rate between t-AIS and airborne is not valid because the t-AIS was sampled at 6 minute intervals, whereas all received messages (of class 1-4) for the airborne receiver within the specified geographical region have been included.

Table 6-7: Cork to Amsterdam vessel and message detection statistics for flight, t-AIS and s-AIS data.

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	159,365	3,748	42.5	132,843	3,300	23,185	2
t-AIS	52,119	3,363	15.5	52,015	0	0	0
AS3	172	147	1.2	127	0	14	3

6.5 AMSTERDAM TO MALAGA

6.5.1 FLIGHT DATA RESULTS

The flight plan for the Amsterdam to Malaga flight was unavailable at the time of writing. Figure 6-16 below presents the flight path as recorded by the GPS receiver for the Amsterdam to Malaga flight.

Figure 6-16: Google Earth plot of the GPS position data from the data file for the Amsterdam to Malaga flight on 30th July 2010.

Take-off from Amsterdam was at 10:25 UTC. The aircraft landed at Malaga airport at 15:19 UTC making the flight duration about 4 hours 54 minutes.

Table 6-8 below presents a summary of the unfiltered message decoding.

Table 6-8: Unfiltered variable-length decoded results for the Cork-Amsterdam flight.

Number of Unique MMSI Detected	6,970
Total number of messages detected	572,350
Average detection rate	1,950 messages/min
Type 1,2,3 (Class-A Position Report)	529,184 (473,062 type 1, 5,121 type 2, 51,001 type 3)
Type 4 (Basestation)	18,220
Type 18 (Class-B Position Report)	7,677
Other types	17,269

Since the flight path encompassed some of the busiest shipping lanes in the world, unsurprisingly the number of unique ship MMSIs and resulting messages is high. This can clearly be seen below in Figure 6-17 below.

6.5.2 COMPARISON WITH TERRESTRIAL AND SATELLITE DATA

Figure 6-17 shows a plot of the number of vessels detected from the AIS receiver on-board the aircraft during its journey from Malaga to Amsterdam. Figure 6-18 and Figure 6-19 show the number of vessels detected in the same geographical area defined by the polygon shown in Figure 6-1(d), for both terrestrial AIS data and satellite AIS data respectively. It should be noted that this is not a ‘like for like’ comparison since the t-AIS data has limited range which is of a smaller area than the polygon and the Airborne AIS data will also be limited by the antenna FoV. These plots are to show in general the level of vessels seen by each system. Later in this report a more detailed analysis is performed with a limited area that is common to all three sensors (see section 7.)

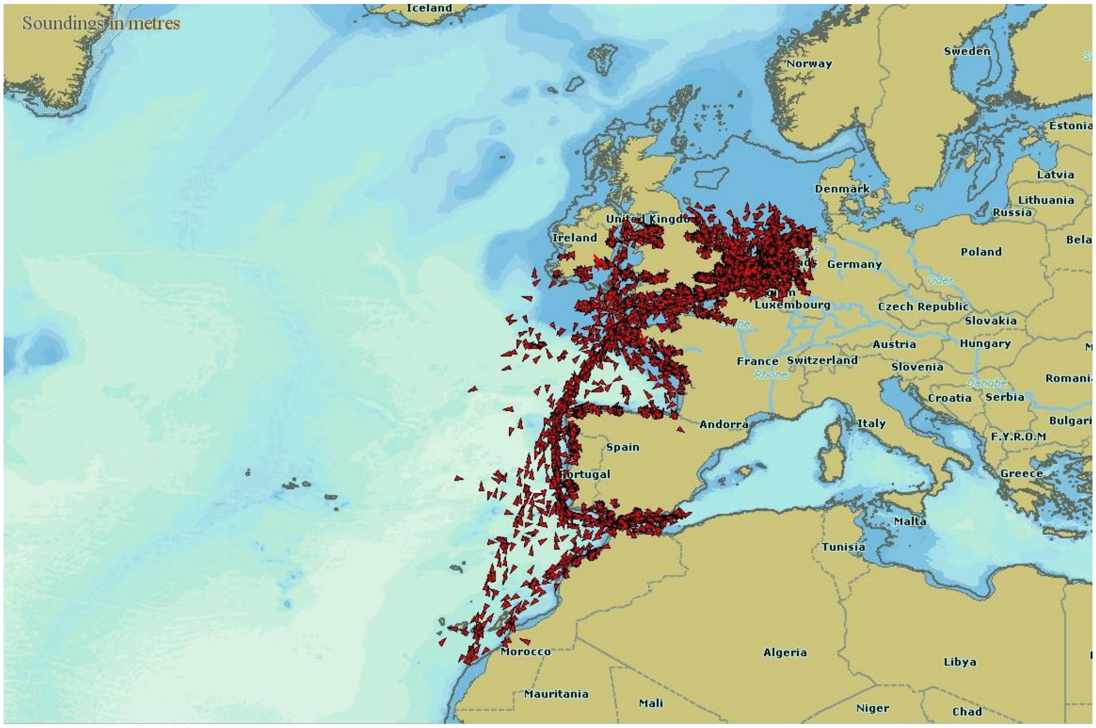


Figure 6-17: Plot of the vessels detected from the on-board receiver flown from Amsterdam to Malaga.

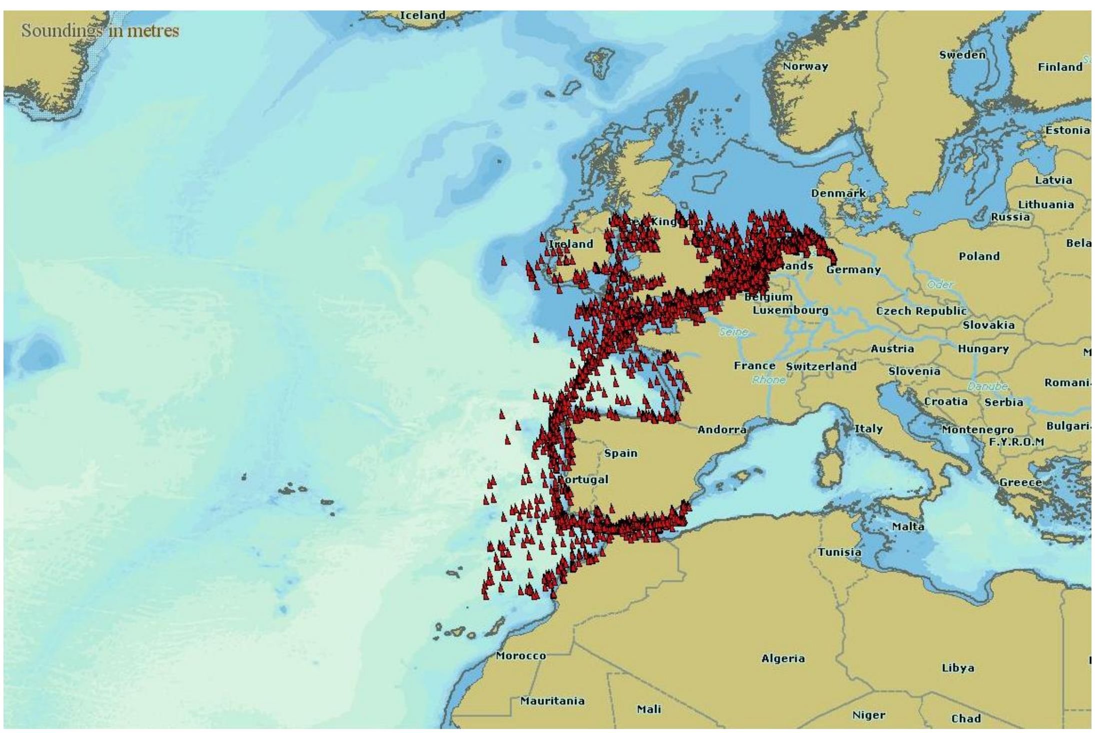


Figure 6-18: Plot of the vessels detected from terrestrial AIS, Amsterdam to Malaga capture area.

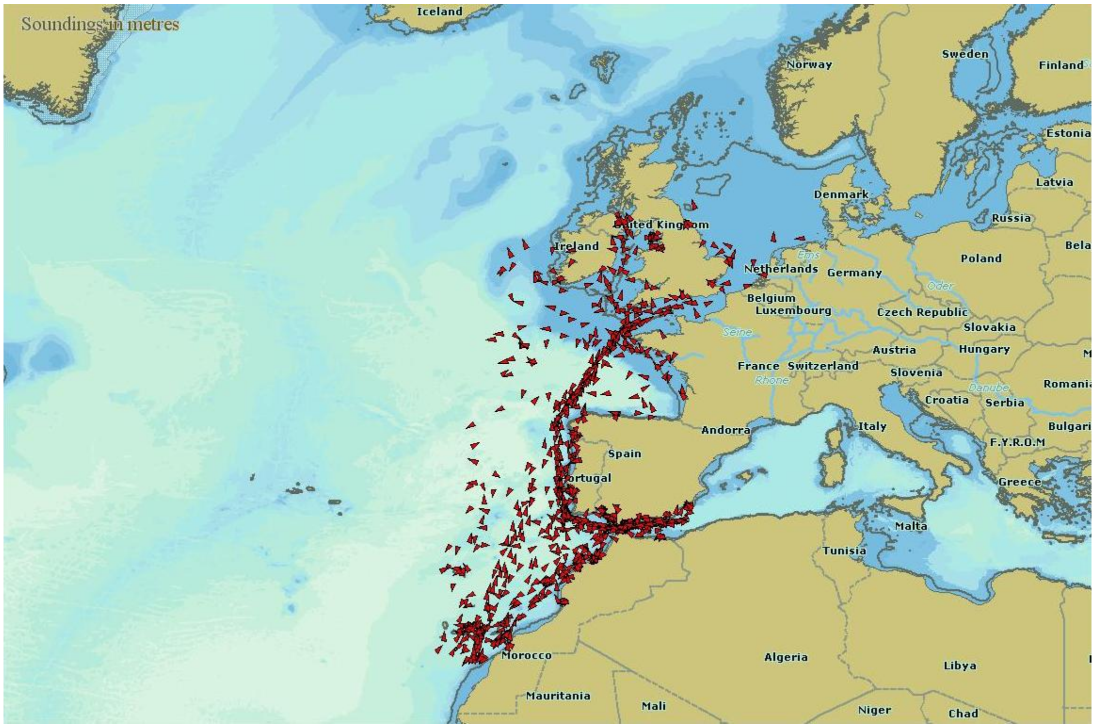


Figure 6-19: Plot of the vessels detected from satellite AIS with on-board processing, Amsterdam to Malaga capture area.

The figure below shows the Google Earth image of the Straights of Gibraltar. The yellow pins represent Class-A vessel position reports. The red pins represent basestation reports. The green pins represent Class-B vessel position reports.

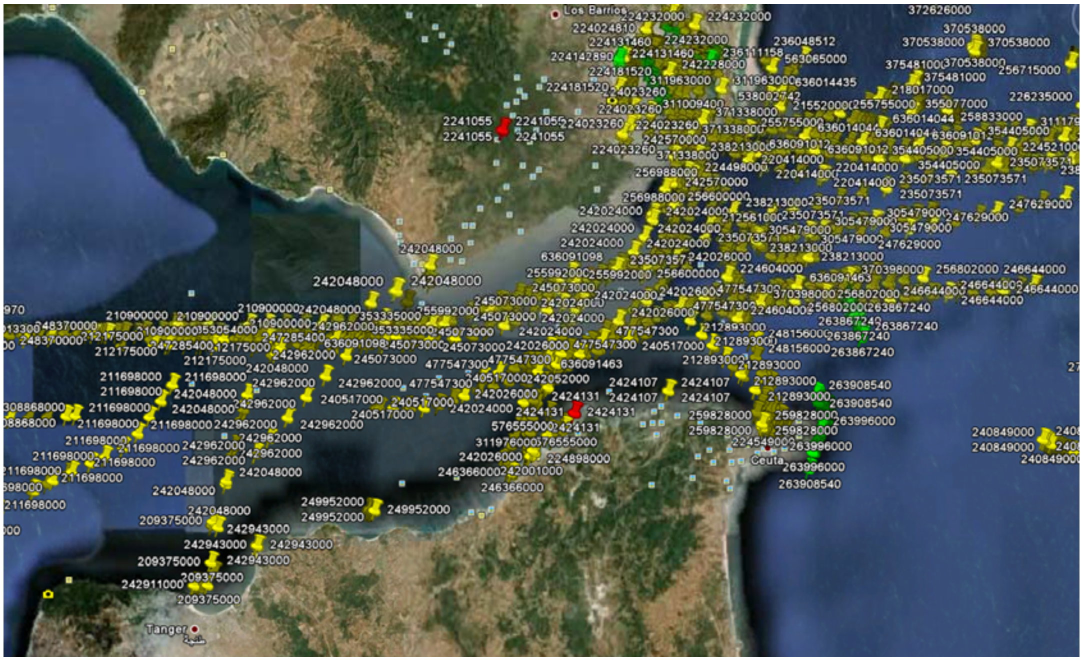


Figure 6-20: Shipping in the Strait of Gibraltar as decoded by COM DEV from the flight data (3 minute intervals).

Table 6-9 summarizes the vessel and message detection statistics for the three data sources within the geographical region defined for the Amsterdam to Malaga flight. The airborne receiver detected about 13% more vessels compared to t-AIS. Again, it must be emphasized that due to limitations in the FoV of the airborne receiver and availability of EMSA data within the large geographical region, it is not necessarily a like-for-like comparison. Note also that a direct comparison of message detection rate between t-AIS and airborne is not valid because the t-AIS was sampled at 6 minute intervals, whereas all received messages (of class 1-4) for the airborne receiver within the specified geographical region have been included. A vessel underway normally should report its position every 10s, therefore the true t-AIS message rate may be over 30 times greater than the 6 minute sampled rate in high density areas.

Table 6-9: Amsterdam to Malaga vessel and message detection statistics for flight, t-AIS and s-AIS data.

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	524,325	5,290	99.1	468,316	5,072	50,768	1
t-AIS	99,374	4,696	21.2	99,374	0	0	0
AS3	2,423	1,078	2.2	2,181	0	181	1

6.6 MALAGA TO AMSTERDAM

6.6.1 FLIGHT DATA RESULTS

The flight plan for the Malaga to Amsterdam was unavailable at the time of writing. Figure 6-21 below presents the flight path as recorded by the GPS receiver for the Malaga to Amsterdam flight.

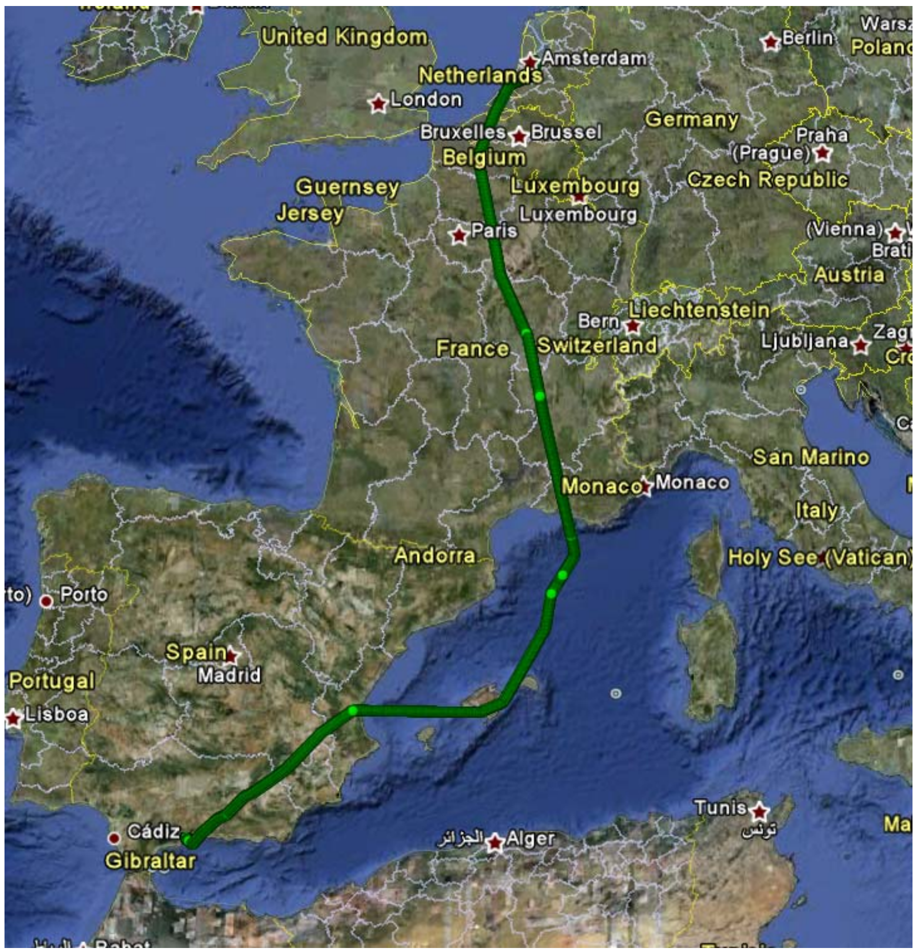


Figure 6-21: Google Earth plot of the GPS position data from the data file for the Malaga to Amsterdam flight on 31st July 2010.

Take-off from Malaga was at 11:56 UTC, landing at Amsterdam was at about 16:08 UTC, a flight duration of about 4 hours 12 minutes.

Table 6-10 below presents the unfiltered message decode results from the Malaga to Amsterdam flight on 31st July 2010.

Table 6-10: Unfiltered variable-length decoded results for the Malaga-Amsterdam flight.

Number of Unique MMSI Detected	6,234
Total number of messages detected	446,029
Average detection rate	1,770 messages/min
Type 1,2,3 (Class-A Position Report)	405,566 (347,232 type 1, 15,374 type 2, 42,960 type 3)
Type 4 (Basestation)	18,195
Type 18 (Class-B Position Report)	6,477
Other types	15,791

The results for this flight were somewhat surprising because a large section of the flight path was over land but yet a very large number of messages were decoded and the average message decode rate was similar to that for the other flights.

6.6.2 COMPARISON WITH TERRESTRIAL AND SATELLITE DATA

Figure 6-22 shows a plot of the number of vessels detected from the AIS receiver on-board the aircraft during its journey from Malaga to Amsterdam. Figure 6-23 and Figure 6-24 shows the number of vessels detected in the same geographical area defined by the polygon shown in Figure 6-1(e), for terrestrial and satellite AIS data respectively. It should be noted that this is not a 'like for like' comparison since the t-AIS data has limited range which is of a smaller area than the polygon and the Airborne AIS data will also be limited by the antenna FoV. These plots are to show in general the level of vessels seen by each system. Later in this report a more detailed analysis is performed with a limited area that is common to all three sensors (see section 7.)

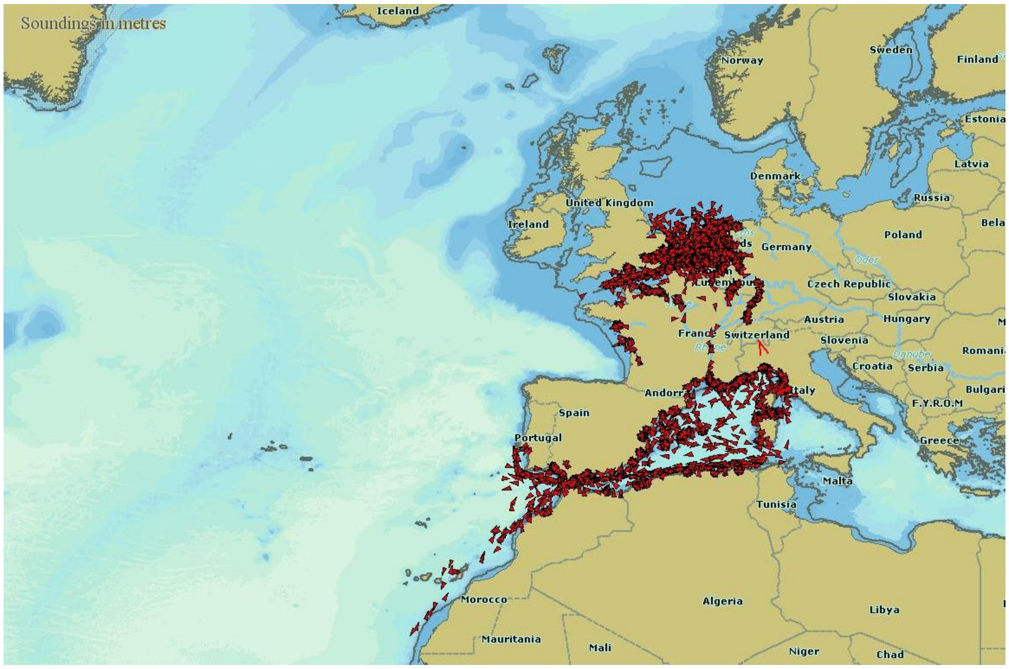


Figure 6-22: Plot of the vessels detected from the on-board receiver flown from Malaga to Amsterdam.

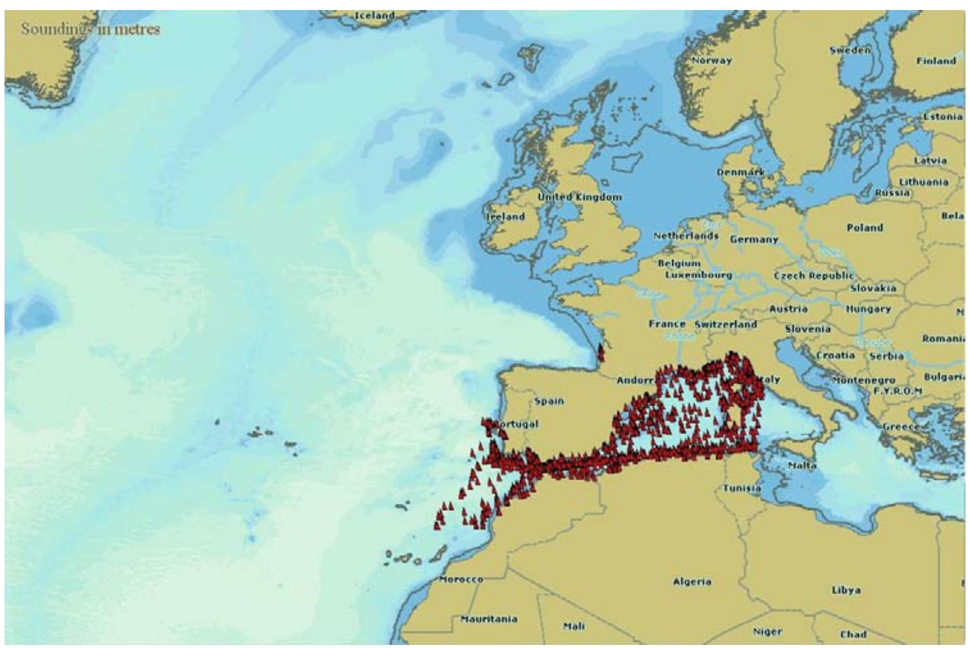


Figure 6-23: Plot of the vessels detected from the terrestrial AIS flown from Malaga to Amsterdam.

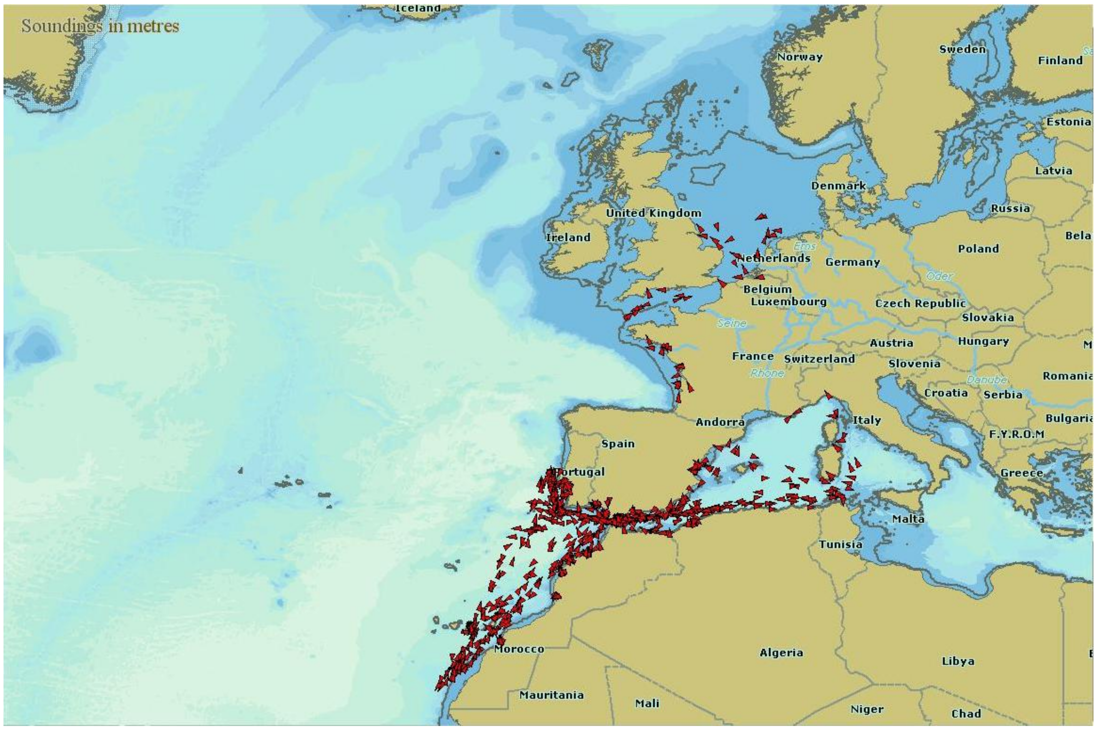


Figure 6-24: Plot of the vessels detected from satellite AIS with on-board processing, Malaga to Amsterdam capture area.

Table 6-11 below summarizes the vessel and message detection statistics for the three data sources within the geographical region defined for the Malaga to Amsterdam flight. The results show that the number of vessels detected by the flight receiver was 145% greater compared with the number of vessels detected by the terrestrial AIS system. It must be emphasized that due to limitations in the FoV of the airborne receiver and availability of EMSA data within the large geographical region, it is not necessarily a like-for-like comparison. Note that a direct comparison of message detection rate between t-AIS and airborne is not valid because the t-AIS was sampled at 6 minute intervals, whereas all received messages (of class 1-4) for the airborne receiver within the specified geographical region have been included.

Table 6-11: Malaga to Amsterdam vessel and message detection statistics for flight, t-AIS and s-AIS data

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	399,247	5,038	79.2	341,030	15,346	42,710	2
t-AIS	66,500	2,059	32.3	66,500	0	0	0
AS3	2,482	840	3.0	2,236	0	190	7

6.7 SUMMARY OF VESSEL DETECTION COMPARISON

Table 6-12 summarises the unique vessel and message class 1-4 detection statistics for the airborne receiver (from ComDev), t-AIS (from EMSA) and s-AIS (from AS3) data presented in the previous sections. The terrestrial messages were sampled at 6 minute intervals so therefore the number of messages reported below is less than for the airborne receiver for which all received messages (of classes 1-4) have been included. Moreover, data from the Portuguese terrestrial station network was not available, which obviously lowers the tital number of vessel reported, compared to the flight campaign.

Table 6-12: Summary of comparison vessel and message detection for airborne (ComDev), t-AIS (EMSA) and s-AIS data (AS3).

Date	Route	Capture	Messages	Vessels	Messages per vessel	AIS message type			
						Msg1	Msg2	Msg3	Msg4
7/15/10	AMS-Trond	Flight	347,941	5,923	58.7	299,387	697	47,721	1
		t-AIS	162,012	6,346	25.5	162,012	0	0	0
		AS3	1,664	944	1.8	1,410	1	150	18
7/16/10	Trond-Cork	Flight	318,858	1,855	171.9	254,215	195	63,627	0
		t-AIS	15,002	2,491	6.0	15,002	0	0	0
		AS3	2,000	954	2.1	1,580	0	310	15
7/17/10	Cork-AMS	Flight	159,365	3,748	42.5	132,843	3,300	23,185	2
		t-AIS	52,119	3,363	15.5	52,015	0	0	0
		AS3	172	147	1.2	127	0	14	3
7/30/10	AMS-Malaga	Flight	524,325	5,290	99.1	468,316	5,072	50,768	1
		t-AIS	99,374	4,696	21.2	99,374	0	0	0
		AS3	2,423	1,078	2.2	2,181	0	181	1
7/31/10	Malaga-AMS	Flight	399,247	5,038	79.2	341,030	15,346	42,710	2
		t-AIS	66,500	2,059	32.3	66,500	0	0	0
		AS3	2,482	840	3.0	2,236	0	190	7

6.8 LUXSPACE DEMODULATION AND DECODING RESULTS

The following tables include the messages correctly detected using the LuxSpace demodulation scheme for the regions previously mentioned of the different flights.

Table 6-13: Luxspace results for the Amsterdam-Trondheim flight.

Total number of messages detected	318,820
Number of Unique MMSI Detected	5,557
Average detection rate	1505 messages/min
Type 1,2,3 (Class-A Position Report)	278,455 (Type 1: 240,207; Type 2: 463; Type 3: 37,785)
Type 4 (Basestation)	14,392
Type 5 (Ship related data)	4,735
Type 18 (Class-B Position Report)	6,034
Other types	15,205

Table 6-15: Luxspace results for the Trondheim-Cork flight.

Total number of messages detected	306,985
Number of Unique MMSI Detected	1,766
Average detection rate	1679 messages/min
Type 1,2,3 (Class-A Position Report)	272,864 (Type 1: 217,808; Type 2: 183; Type 3: 54,873)
Type 4 (Basestation)	15,822
Type 5 (Ship related data)	5,246
Type 18 (Class-B Position Report)	3,884
Other types	9,169

Table 6-16: Luxspace results for the Cork-Amsterdam flight.

Total number of messages detected	143,337
Number of Unique MMSI Detected	3,520
Average detection rate	1392 messages/min
Type 1,2,3 (Class-A Position Report)	127,322 (Type 1: 106,611; Type 2: 2,253; Type 3: 18,458)
Type 4 (Basestation)	5,010
Type 5 (Ship related data)	1,932
Type 18 (Class-B Position Report)	1,485
Other types	7,588

Table 6-147: Luxspace results for the Amsterdam-Malaga flight.

Total number of messages detected	477,301
Number of Unique MMSI Detected	4968
Average detection rate	1626 messages/min
Type 1,2,3 (Class-A Position Report)	432,699 (Type 1: 388,096; Type 2: 3,340; Type 3: 41,263)
Type 4 (Basestation)	14,467
Type 5 (Ship related data)	8,283
Type 18 (Class-B Position Report)	5,518
Other types	16,334

Table 6-158: Luxspace results for the Malaga-Amsterdam flight.

Total number of messages detected	353,741
Number of Unique MMSI Detected	4,564
Average detection rate	1404 messages/min
Type 1,2,3 (Class-A Position Report)	312,519 (Type 1: 268,716; Type 2: 10,747; Type 3: 33,056)
Type 4 (Basestation)	14,034
Type 5 (Ship related data)	6,532
Type 18 (Class-B Position Report)	4,356
Other types	16,300

The comparison of these results with the ones presented above leads to the following conclusions. The receiver of LuxSpace was able to detect more ships than t-AIS and s-AIS in all flights. It can be also derived that the number of messages detected by COM DEV is larger than the ones obtained by LuxSpace. However, the number of ships detected by COM DEV is only slightly higher. This difference has its origin in the nature of the demodulator used for the post processing.

As far as our knowledge goes, the receiver implemented by COM DEV is a coherent demodulator while the approach selected by LuxSpace is a non-coherent demodulator based on an FM-discriminator. Both have advantages and disadvantages. The main advantage of the coherent demodulator is that it provides a good performance against noise but the price to pay is the complexity in the implementation. On the other side, the non-coherent demodulator is less complex because it does not need to recover exactly the carrier used in the transmitter but at the expense of performance.

Usually, the difference in performance between coherent and non-coherent is 3 dB but in the case of the modulation used for AIS, which is Gaussian Modulation Shift Keying (GMSK), is 4 dB. For that reason, the number of messages detected by LuxSpace is smaller than COM DEV's demodulation scheme. Nevertheless the number of ships detected is quite similar, despite of the theoretical difference in performance, due to the number of messages collected.

The selection of the mentioned demodulator by LuxSpace was done as a first approach to detected AIS messages from space. This receiver has proved to be extremely robust when tested under all kind of conditions with real signals. In addition to this, a coherent demodulator is currently being implemented as a second generation of spaceborne AIS receiver.

7. REGIONAL COMPARISON BETWEEN FLIGHT AND TERRESTRIAL MMSI COVERAGE

7.1 OVERVIEW

This section presents a comparison of detection of unique ship MMSIs between the flight data and the EMSA data for specified regions bounded in time and geographical areas.

The comparison uses the number of unique MMSIs within the region as the metric. The EMSA data (if available) should provide the true number of MMSIs within the region. Therefore, the true number of ships that were actually in the region at the observation time cannot be precisely known.

The tables present:

- MMSIs detected by both flight and EMSA
- MMSIs detected only by flight
- MMSIs detected only by EMSA.

The total number of MMSIs that could be detected is assumed to be the sum of all three cases, though obviously the true number may not be the total number of MMSIs recorded.

The probability of detection (PoD) is estimated for flight and for EMSA. It is based on the assumption that the true number of MMSIs is the sum total as described above and is calculated thus:

$$PoD_{FLIGHT} = \frac{N_{FLIGHT}}{N_{FLIGHT\_EMSA} + N_{FLIGHT\_ONLY} + N_{EMSA\_ONLY}}$$

$$PoD_{EMSA} = \frac{N_{EMSA}}{N_{FLIGHT\_EMSA} + N_{FLIGHT\_ONLY} + N_{EMSA\_ONLY}}$$

where N_x is the number of unique MMSIs detected within the region.

Since the total is itself based on observed data rather than a definitive “truth”, the PoD may not be an accurate guide to detection performance. For instance, if the N_{FLIGHT} of one flight detector is lower than the other, then the denominator of the above equations will tend to be reduced in line with N_{FLIGHT} making the PoD appear greater than it actually would be for an “independent” estimate of the number of ships in the region.

The following sections present the ratios of flight-to-total and EMSA-to-total for the geographical/time regions and present both Luxspace detection and COM DEV detection figures. The figures present the Luxspace data.

7.2 AMSTERDAM TO TRONDHEIM

Figure 7-1 shows the geographical rectangles, the associated flight transit times and the PoD for flight and terrestrial vessel detection.

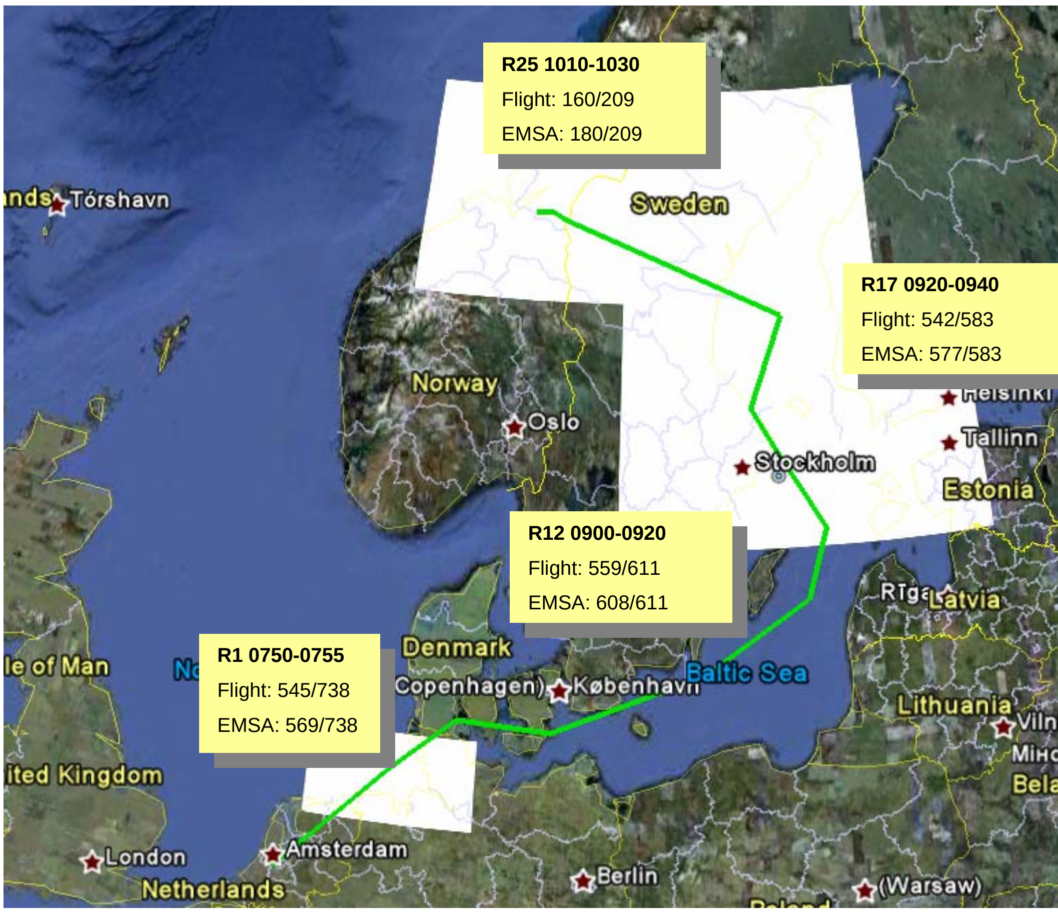


Figure 7-1: Geographical Regions and flight path for Amsterdam-Trondheim decoding comparison.

Table 7-1: Amsterdam to Trondheim regional comparison with Luxspace detection.

Amsterdam - Trondheim					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
1	10.31	5.57	54.75	53.22	545	569	376	169	193	738	73.8	77.1	07:50	5
12	25.8	14.2	62.2	58	559	608	556	3	52	611	91.5	99.5	09:00	20
17	25.8	14.2	62.2	58	542	577	536	6	41	583	93.0	99.0	09:40	20
25	23	6.9	65.5	62	160	180	131	29	49	209	76.6	86.1	10:10	20

Table 7-2: Amsterdam to Trondheim regional comparison with COM DEV detection.

Amsterdam - Trondheim					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
1	10.31	5.57	54.75	53.22	588	570	402	186	168	756	77.8	75.4	07:50	5
12	25.8	14.2	62.2	58	566	591	552	14	39	605	93.6	97.7	09:00	20
17	25.8	14.2	62.2	58	515	580	506	9	74	589	87.4	98.5	09:40	20
25	23	6.9	65.5	62	155	179	119	36	60	215	72.1	83.3	10:10	20

For this flight it can be seen that the EMSA 'PoD' is higher than the corresponding flight trial data. However, as will be seen in later sections this is not typical for the rest of the flights undertaken.

It can also be seen that the processing of the EMSA data by two different companies yielded slightly different results for the number of ships. We believe that this is due to the accuracy that each company deals with the ships that are on the edge of the polygon.

7.3 TRONDHEIM TO CORK

Figure 7-2 shows the geographical rectangles, the associated flight transit times and the PoD for flight and terrestrial vessel detection.

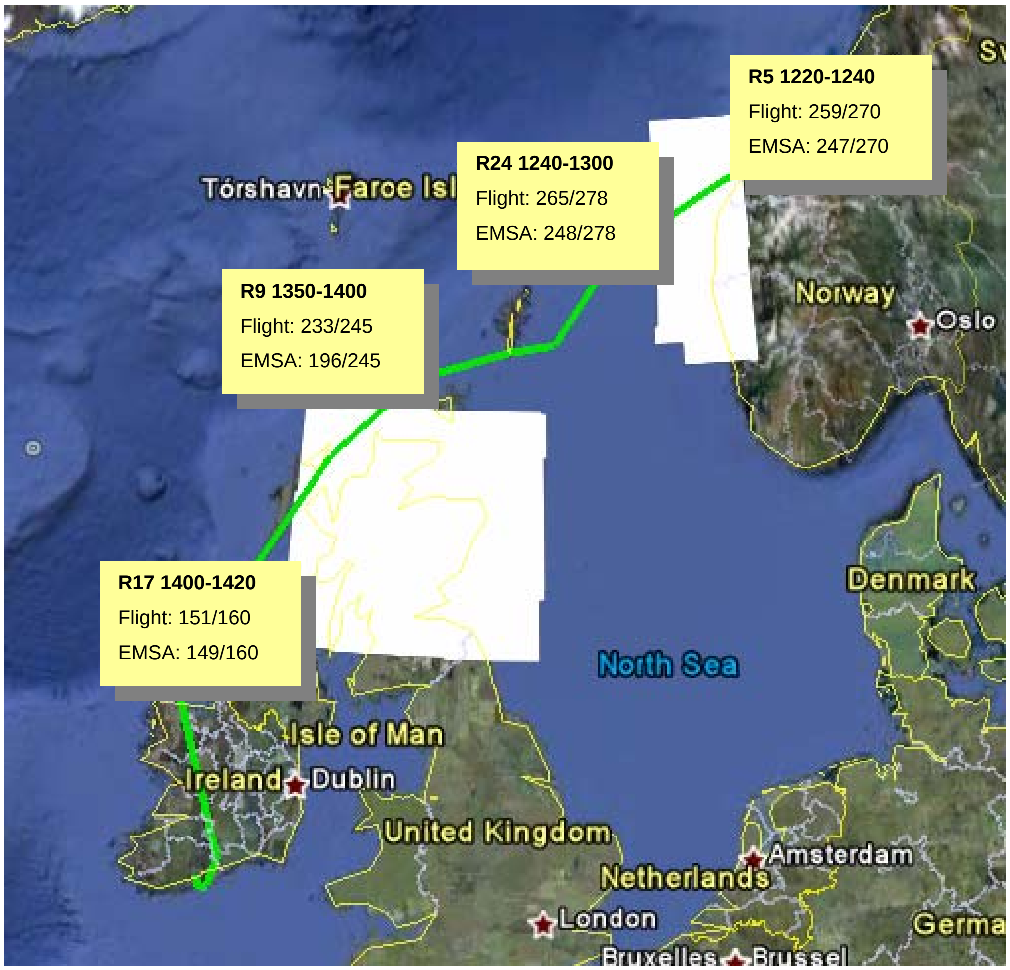


Figure 7-2: Geographical Regions and flight path for Trondheim to Cork decoding comparison.

Table 7-3: Trondheim to Cork, regional comparison with Luxspace detection.

Trondheim - Cork					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
5	5.8	3	63.3	60	259	247	236	23	11	270	95.9	91.5	12:20	20
9	-0.3	-7	59	55.4	233	196	184	49	12	245	95.1	80.0	13:50	10
17	-0.2	-4.5	59	56.3	151	149	140	11	9	160	94.4	93.1	14:00	20
24	5.9	3.77	63	59.7	265	248	235	30	13	278	95.3	89.2	12:40	20

Table 7-4: Trondheim to Cork, regional comparison, COM DEV detection.

Trondheim - Cork					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
5	5.8	3	63.3	60	220	247	203	17	44	264	83.3	93.6	12:20	20
9	-0.3	-7	59	55.4	249	196	191	58	5	254	98.0	77.2	13:50	10
17	-0.2	-4.5	59	56.3	160	149	147	13	2	162	98.8	92.0	14:00	20
24	5.9	3.77	63	59.7	279	240	233	46	7	286	97.6	83.9	12:40	20

It can be seen that for this flight trial the flight data shows a generally higher PoD compared with the Ground data.

7.4 AMSTERDAM TO MALAGA

Figure 7-3 shows the geographical rectangles, the associated flight transit times and the PoD for flight and terrestrial vessel detection.

Figure 7-3: Geographical Regions and flight path for Amsterdam to Malaga decoding comparison.

Table 7-5: Amsterdam to Malaga regional comparison with Luxspace detection.

Amsterdam - Malaga					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
2	-4.2	-8.4	36.2	33	263	261	251	12	10	273	96.3	95.6	14:50	10
9	1.5	-2.6	51	49.8	234	229	221	13	8	242	96.7	94.6	11:20	10
15	-4.7	-6.7	48.9	47.8	72	53	51	21	2	74	97.3	71.6	12:40	5
24	-6	-10	37	33	175	171	161	14	10	185	94.6	92.4	14:40	20
30	-3.7	-8.2	50.2	48	193	175	168	25	7	200	96.5	87.5	12:10	10
36	-8.3	-10.5	43.1	37	217	124	123	94	1	218	99.5	56.9	13:50	5

Table 7-6: Amsterdam to Malaga regional comparison with COM DEV detection.

Amsterdam - Malaga					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMSA	in common:	Flight	EMSA		Flight	EMSA	Time	Duration
2	-4.2	-8.4	36.2	33	274	268	259	15	9	283	96.8	94.7	14:50	10
9	1.5	-2.6	51	49.8	245	229	228	17	1	246	99.6	93.1	11:20	10
15	-4.7	-6.7	48.9	47.8	74	53	53	21	0	74	100.0	71.6	12:40	5
24	-6	-10	37	33	187	174	169	18	5	192	97.4	90.6	14:40	20
30	-3.7	-8.2	50.2	48	195	175	172	26	3	201	97.0	87.1	12:10	10
36	-8.3	-10.5	43.1	37	225	96	95	130	1	226	99.6	42.5	13:50	5

It can be seen that for this flight trial the flight data shows a consistently higher PoD compared with the Ground data. For some test regions the low PoD of the terrestrial AIS can be attributed to the non availability of the complete terrestrial AIS data along the Portuguese coastal area.

7.5 MALAGA TO AMSTERDAM

Figure 7-4 shows the geographical rectangles, the associated flight transit times and the PoD for flight and terrestrial vessel detection.

Figure 7-4: Geographical Regions and flight path for Malaga to Amsterdam decoding comparison.

Table 7-7: Malaga to Amsterdam regional comparison with Luxspace detection.

Malaga - Amsterdam					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMS A	in common:	Flight	EMS A		Flight	EMS A	Time	Duration
3	3	-1	42	36.6	312	319	310	2	9	321	97.2	99.4	12:50	20
10	-1	-7	36.9	35.5	275	239	208	67	31	306	89.9	78.1	12:00	5
19	9	3	44	41	339	190	156	183	34	373	90.9	50.9	14:00	5
28	8	2	43.6	37.7	316	281	183	133	98	414	76.3	67.9	13:40	5

Table 7-8: Malaga to Amsterdam regional comparison with COM DEV detection.

Malaga - Amsterdam					MMSI`s seen by:			only by		Total number of ships:	PoD			
Number	Longitude max	Longitude min	Latitude max	Latitude min	Flight	EMS A	in common:	Flight	EMS A		Flight	EMS A	Time	Duration
3	3	-1	42	36.6	327	324	319	8	5	332	98.5	97.6	12:50	20
10	-1	-7	36.9	35.5	295	244	219	76	22	317	93.1	77.0	12:00	5
19	9	3	44	41	364	192	166	198	26	390	93.3	49.2	14:00	5
28	8	2	43.6	37.7	375	281	219	156	65	440	85.2	63.9	13:40	5

It can be seen that for this flight trial the flight data shows a considerably higher PoD compared with the Ground data.

8. CONCLUSION

8.1 OVERVIEW

This report has presented the results of the Pasta Mare AIS flight trial. An overview of the flight receiver and its installation was presented in section 4.

Section 6. Presented unfiltered AIS detection (i.e. all message types with no geographical bounds) performed by COM DEV on the captured signal waveforms and coarse comparisons for defined geographical regions with EMSA data (where available) and satellite-acquired data for that region.

Section 7. Presented a comparison of unique MMSI detection within specified geographical and time regions between flight data and EMSA data. From these figures, a Probability of Detection (PoD) was derived. Results for COM DEV and Luxspace detection algorithms were presented.

8.2 PERFORMANCE OF FLIGHT AIS RECEPTION

The receiver implemented on board the aircraft performed extremely well and in some cases even appears to have detected more vessels than the corresponding ground based data. However, despite applying geographical filters that attempt to encompass the greatest common area, FoV (for the flight data) and data availability (for the satellite and terrestrial data) makes this at best a somewhat subjective comparison.

This raises some implications in terms of determining the true 'Probability of Detection' since by definition some absolute ground truth is required. This means that a suitable, quantitative measure still needs to be determined when looking at the performance of different AIS systems. This will be discussed in the final report.

Processing the same data with COM DEV algorithms and Luxspace algorithms produced generally similar results for the flight data with COM DEV processing showing slightly higher PoD values. Analysis of the ESA algorithm could not be conducted as part of this program but the raw data has been made available to ESA for analysis and then a comparison with Luxspace and COM DEV processed data could be undertaken.

The flight AIS data appears not to be excessively collided nor does it exhibit extreme Doppler shift as anticipated. Therefore, it is not especially challenging to detect compared to the satellite-derived data and not very representative of LEO satellite observation. The COM DEV ground-based de-collider was probably therefore a "sledgehammer to crack a nut" for the airborne data. The relatively poor performance of the satellite is largely attributed to the use of simple on-board AIS detection together with a much larger FoV (and hence more collisions). See Annex 1.

8.3 IMPLICATIONS FOR SATELLITE AIS RECEPTION AND FUTURE WORK

Whilst the performance of the SpaceQuest AS3 receiver was not as good as the aircraft trial or ground data this is not surprising given the experimental nature of the spacecraft. However, analysis (given in Annex 1) shows the benefit of post processing raw data in terms of increasing the number of ships detected (in dense shipping areas by up to a factor of x10). This is of course not the only possible solution or improvement that could be made to any satellite based AIS system. Given the increasing number of AIS satellites being launched and offering commercial services further flight trials in conjunction with satellite passes could show significant benefit in determining the true performance capabilities of the s-AIS systems.

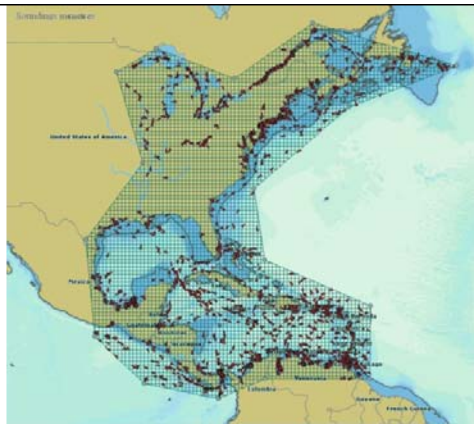
ANNEX 1. A COMPARISON OF SATELLITE ON-BOARD VERSUS GROUND-BASED PROCESSING

A comparison was performed to gauge the AIS message performance between on-board satellite processing using AS3 and ground base processing using a proprietary algorithm to process the raw AIS spectrum data down-linked via a separate satellite (AS4). The algorithm in general enhances the AIS signal detection, thus the number of messages detected.
The comparison was made for the data captured from both satellites over the east coast of America where the frequency spectrum of the AIS signals could be downloaded. Three regions were compared, these being:

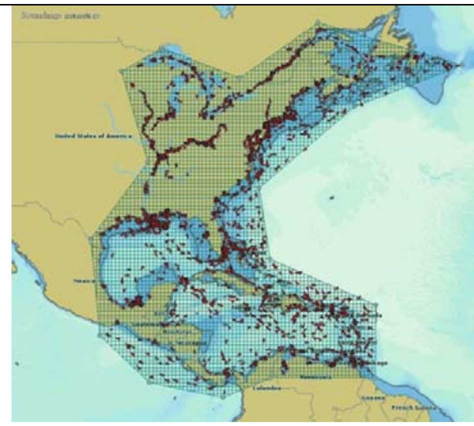
- Gulf of Mexico and the East Coast of America
- Gulf of Mexico
- Part of the North Coast of the Gulf of Mexico

Figure A1-1 shows the graphical comparisons of the decoded AIS messages from the on-board processing satellite (AS3) and the ground based processing algorithm via data down-linked from satellite AS4 for all three regions.

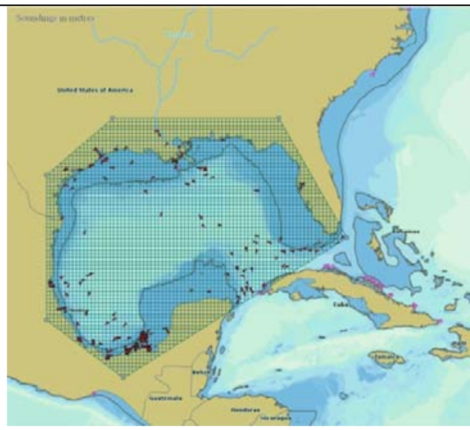
The plots show a similar count between AS3 and AS4 when comparing the Gulf of Mexico and the East Coast of America. The number of vessels detected by the ground processing method increases by approximately two fold for the Gulf of Mexico region compared with the on-board processing method and by nine-fold when comparing a specific region along the North Coast of the Gulf of Mexico (see Table A1-1).



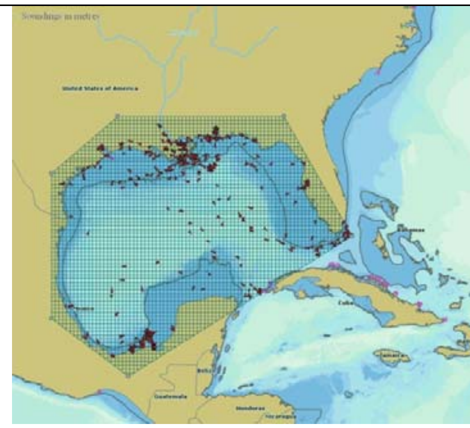
(a) On-board AIS message detection along Gulf of Mexico and the East Coast of America



(b) On-board AIS message detection along Gulf of Mexico and the East Coast of America

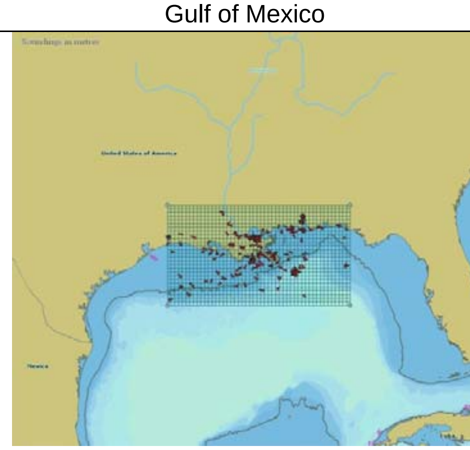


(c) On-board AIS message detection along Gulf of Mexico



(d) Ground based AIS message detection along Gulf of Mexico

(e) On-board AIS message detection along the North Coast of the Gulf of Mexico



(f) Ground based AIS message detection along the North Coast of the Gulf of Mexico

Figure A1-1: Comparison of on-board satellite processing and ground processing of AIS messages.

Table A1-1 Comparison of on-board satellite processing and ground processing of AIS messages.

Area	Satellite Capture	Messages	Vessels	Messages per vessel	Vessel detection ratio (AS4/AS3)
Gulf of Mexico and the East Coast of America	AS3	7573	2241	3.4	1.18
	AS4	11672	2648	4.4	
Gulf of Mexico	AS3	372	270	1.4	1.87
	AS4	746	506	1.5	
North Coast of the Gulf of Mexico	AS3	26	26	1.0	9.69
	AS4	311	252	1.2	

Thus, it can be concluded that ground based AIS message detection via the proprietary decoding algorithm can produce between 18 to 87 % more messages for large coastal areas such as the East Coast of America and the Gulf of Mexico compared with general on-board satellite processing. However, for specific narrow congested coastlines the ground processing method can potentially calculate nine to ten times more AIS messages compared with general on-board satellite processing.

ANNEX 2. A SPECIAL COMPARISON OF THE BALTIC SEA REGION

The Baltic Sea is of special interest because it has proved to be a challenge for s-AIS observation. This is thought to be due to land-borne interference possibly from such sources as high-latitude Ionospheric Sounding Radar or other Radar systems.

This Annex presents comparative statistics for the airborne, t-AIS and s-AIS AIS data filtered with a geographical polygon covering the Baltic Sea as shown below.

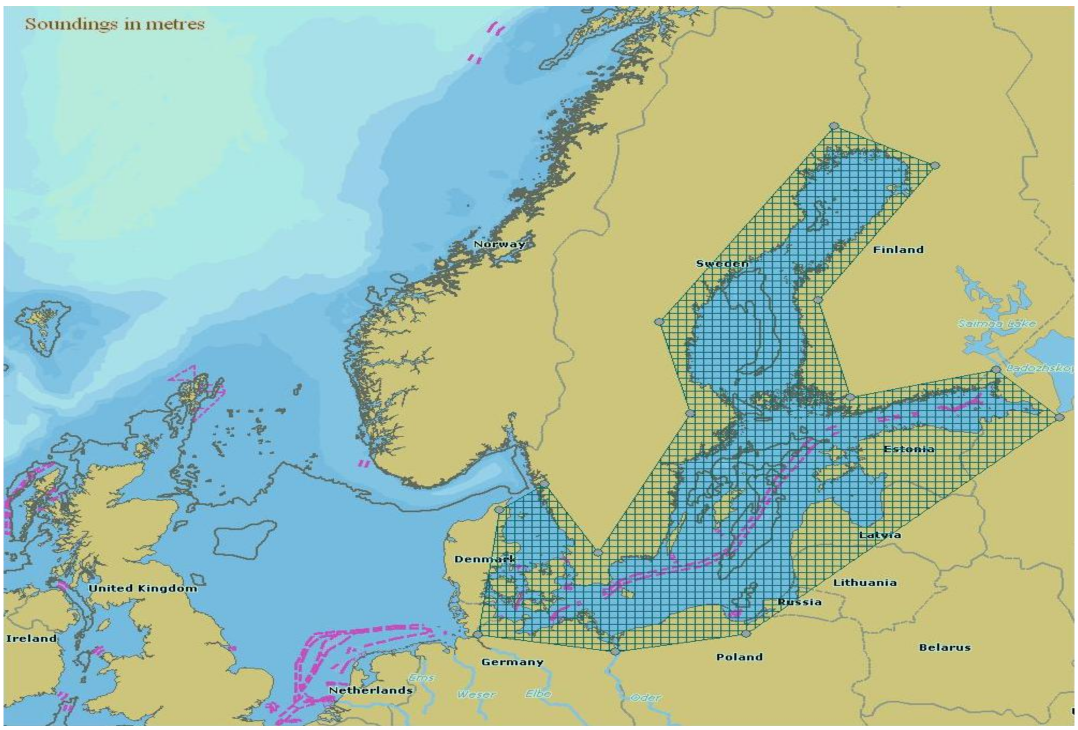


Figure A2-2: The geographical polygon in the Gatehouse AIS Display (GAD) used to filter the AIS data for the Baltic Sea region.

The following three figures present the GAD plots for the airborne, t-AIS and s-AIS AIS data.

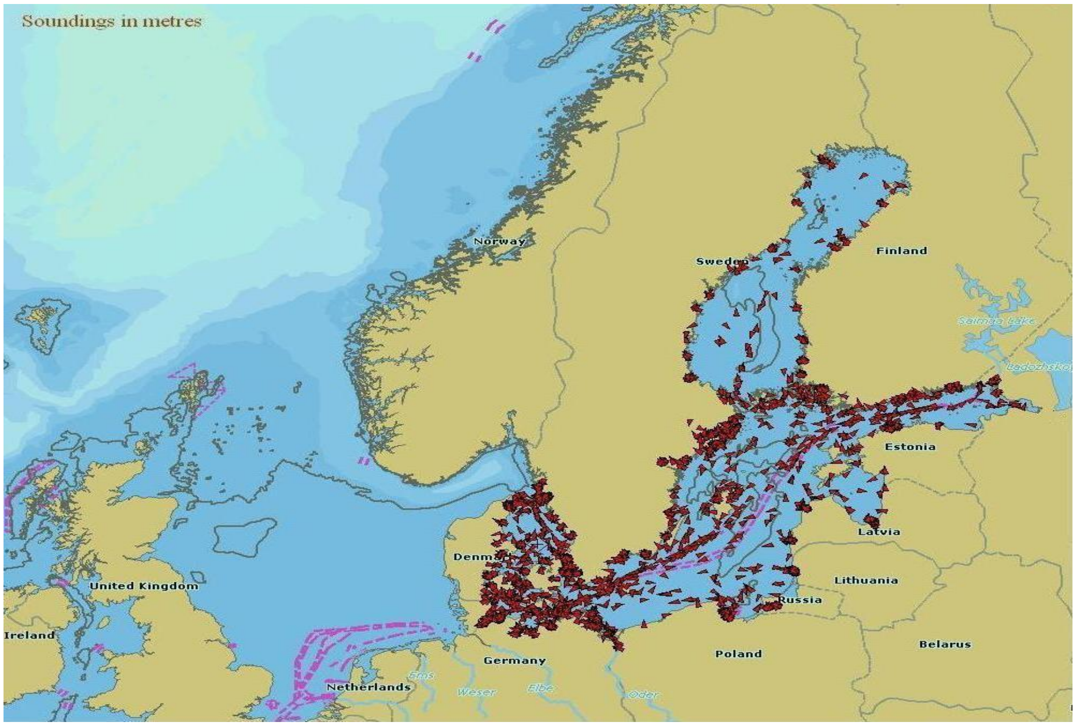


Figure A2-3: Plot of the vessels detected by the airborne receiver over the Baltic Sea region.

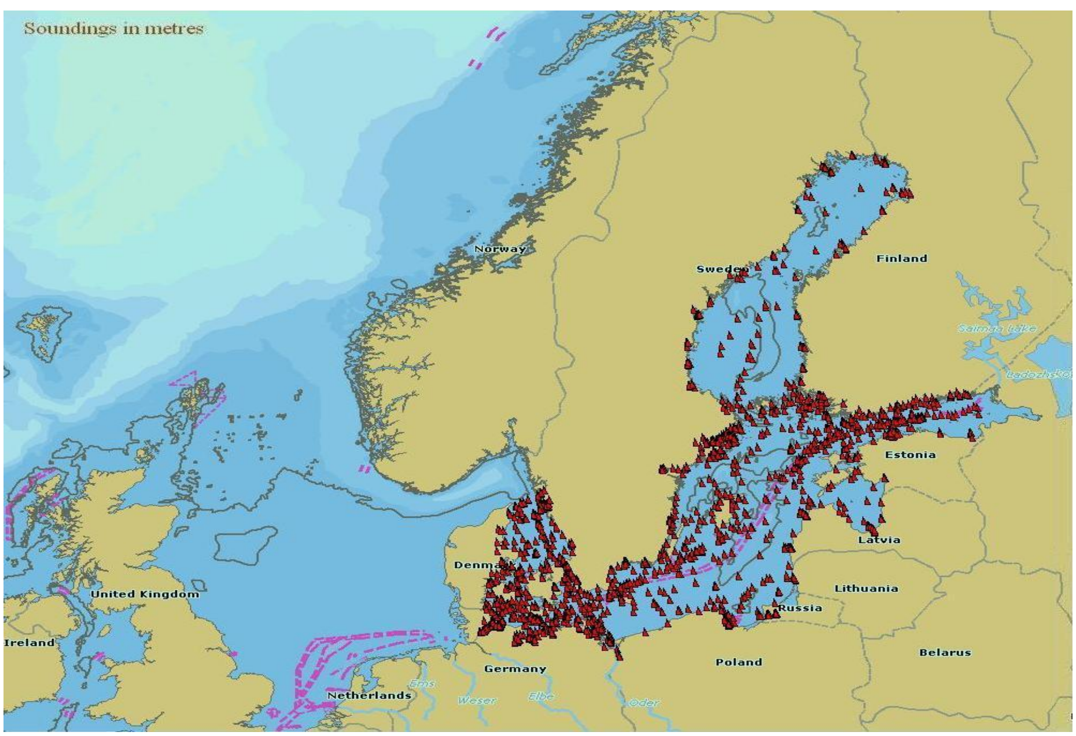


Figure A2-4: Plot of the vessels detected by the terrestrial AIS over the Baltic Sea region.

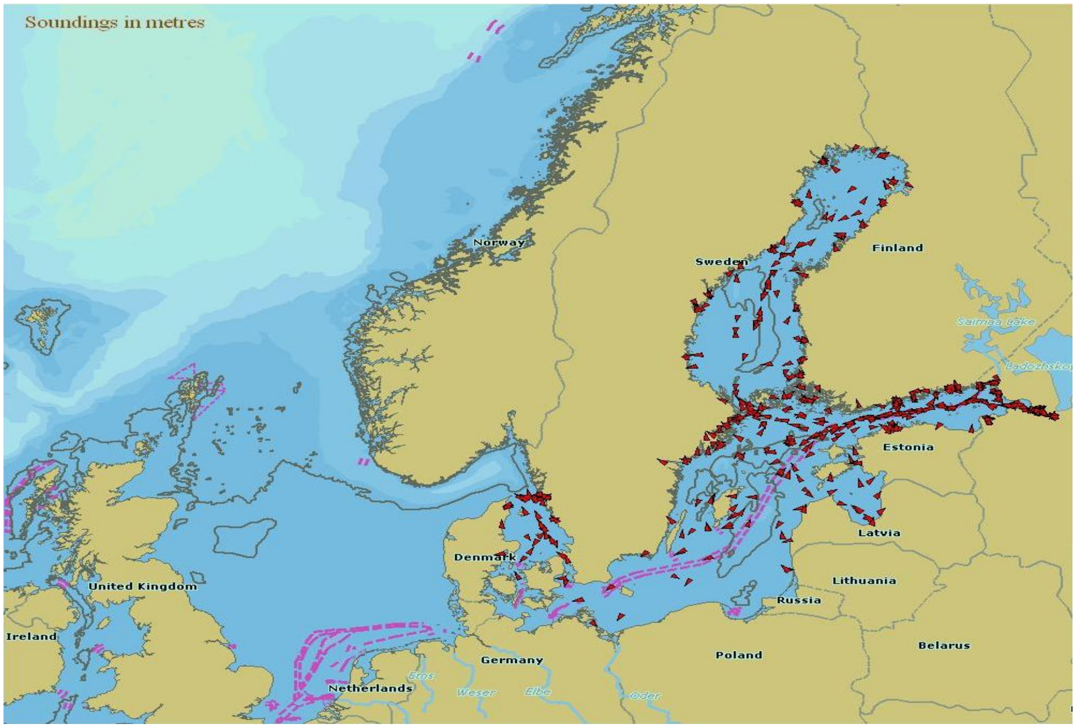


Figure A2-5: Plot of the vessels detected by the s-AIS receiver over the Baltic Sea region.

The following table summarises the unique vessel identification and message types 1,2,3 and 4 detections for the three sources of AIS data.

Table A2-1: Summary of statistics for captured flight trial AIS data, t-AIS data (EMSA) and satellite AS3 data for the Baltic Sea region.

Capture	Messages	Vessels	Messages per vessel	AIS message type			
				Msg1	Msg2	Msg3	Msg4
Flight	254302	2305	110.3	221255	0	33025	0
t-AIS	69648	2431	28.6	69648	0	0	0
AS3	934	510	1.8	832	0	83	9

These results show that the number of unique vessels identified by the flight and t-AIS (EMSA) are similar. The t-AIS message detection is lower than that of the flight because the messages were sampled in 6 minute steps, whereas every message type 1-4 that the flight data correctly decoded is included.

The AS3 s-AIS data is significantly less than either flight or t-AIS. This *may* be due to interference (though none was observed using the airborne receiver) but is much more likely to be due to the high density of shipping in the Baltic Sea region which when observed by a satellite results in numerous packet collisions. As shown in Annex 1, a simple on-board AIS detector does not perform as well as ground-based processing which actively attempts to de-collide the packets but increases of up to x10 can be possible with on ground processing of the raw data.