AIS SART Vs Radar SART Trials

Over five years ago tests were performed on the airborne and detectability of various locating devices, including AIS SARTs as a GMDSS-certified device, as a man-overboard device and as an EPIRB homer; a GMDSS-certified radar SART; a 121.5 MHz locating signal and a 406 MHz signal. The following is a summary of results.

Key West Florida, January 2009

On 14 January 2009 the US Coast Guard performed airborne tests in Key West Florida in seas 1-2 ft, Winds 040 at 10 kts of the following equipment:

- AIS-SART prototypes according to the then draft IEC61097-14, mounted at various heights at the test position, 0, 0.1, 1.0, 1.5 and 3.0 meter above sea surface.
- EPIRB (406 and 121.5): Deployed in water and floating in its normal operating position.
- 9 GHz radar SART: Mounted at a height at 1m above sea surface.

RESULTS

The results obtained for the AIS-SARTs deployed in the water, is comparable with the range obtained from the 406 MHz EPIRB towards an aircraft.
See table below for complete range measurements versus altitude.

The results obtained at the various altitudes were:

ALTITUDE	Range obtained
20000 ft:	119 – 132 Nm[1]
10000 ft:	84 – 97 Nm

[1] AIS software limit of 200 contact display. AIS contacts detected exceeded 200 contact limits for all flight altitudes except 1000 ft. This very likely limited AIS detection ranges recorded. An open ocean environment with fewer AIS transmitters may produce higher detection ranges.

5000 ft: 59 – 79 Nm
1000 ft: 28 – 65 Nm

The lowest range is at all altitudes with the AIS-SART floating in water, and is comparable with what would be obtained from a small float free EPIRB.

For the AIS-SART mounted at 1m above sea level, the results were among the highest at all altitudes.

The results obtained at 1000 ft for two of the units; 970000003 and 970000007 was remarkably high and well beyond line of sight. For these units it might have been abnormal conditions, such as tropo scatter or aircraft scatter, i.e. messages being reflected by the body of another aircraft that lead to this range. All the details from the airborne AIS would have been needed to do a more complete analysis on this. The results from the other units at 1000ft were more in line with what would be expected from a theoretical point of view.

CONCLUSION

The range performance are according to, or exceeding the expectations. Together with previous tests done in Oban Bay, Scotland this shows that the IEC draft specification 60097-14 fulfils all range performance requirements for the AIS-SART mounted at 1m antenna height.

An EPIRB with an AIS-SART transmitter would have an antenna height comparable with the antenna height of the unit with ID code 9700000008. The detailed results shows that this performed very well and it was only at the lowest altitude that the range was significant lower than the higher units. This is because many of the transmissions from this unit were sent while the antenna was below the water surface; therefore the likelihood of getting transmissions through is lower.

The AIS-SART with ID code 970000003 was mounted on “Oscar”, a simulated person floating in the water. The results obtained from this unit shows that AIS-SART used as a man over board alert has a good potential as a life saving device. The test from this unit can also be seen as the result that could have been obtained from an EPIRB or PLB that is raised from the sea level.

Table 1 Key West Airborne Test Results

Unit type	ID	Height a.s.l.(m)	20000ft	10000ft	5000ft	1000ft	Notes
AIS-SART	970000002	3.0	**119 nm**	**94 nm**	**70 nm**	**30 nm**	Mounted on aux vessel Discovery at 3.0 m antenna height
AIS-SART	970000003	0.1	**132**	**94**	**65**	**53**	Floating on a simulated person in the water, height 0.1 m above water surface.
AIS-SART	970000005	1.5	**127**	**97**	**67**	**31**	Mounted on aux vessel Discovery at 1.5 m antenna height
AIS-SART	970000007	1.0	**129**	**95**	**79**	**65**	Floating, mounted on a pole 1m height
AIS-SART	970000008	0.0	**129**	**84**	**59**	**28**	Floating, mounted in the water surface, in and out of water
EPIRB	406 MHz	0.0	**126**	**115**	**68**	**52**	Floating in the water, attached to the boat with the integral line
EPIRB	121.5 MHz	0.0	**8**	**7**	**5**	**4**	Homer on the 406 MHz EPIRB
Radar SART 9 GHz		1.0	**23**	**22**	**30**	**33**	Floating in the water for the 2 first passes, at the two last passes a second radar transponder where switched on, this improved the results on the lowest altitudes.
Radio - line of sight		**1.0**	**176**	**125**	**89**	**41**	

Hawaii, January 2010

The US Coast Guard conducted tests on 20-21 January 2010 using a long range search and rescue aircraft of three AIS SARTs, a radar SART, a 406 EPIRB, and an EPIRB fitted with a 121.5 MHz beacon and with an AIS beacon. The aircraft was capable of homing on 121.5 and 406 MHz, detecting and displaying AIS targets, and carried a x-band radar having a SART mode. Satellite detection of the AIS devices was also performed during these trials and results presented in the annex courtesy of and with the permission of ExactEarth.

Table 2 Hawaii Airborne Test Results

Unit Type	Altitude (ft)				Notes
	20 K	10 K	5K	1 K	Ranges are Approximate in Nautical Miles
Line of Sight	174	123	87	39	Calculated
AIS EPIRB	145	102	70	33.5	Inbound Only
EPIRB 406 MHz	155 156	117 115	76 76	32 37	Outbound Inbound
121.5 MHz	**0	*X	*X	1.2	Outbound Inbound
AIS SART (1)	140	94	70	30	Inbound
AIS SART (2)	145	Inop	Inop	Inop	Inbound
AIS SART (3)	137	96	68	19.5	Inbound
RADAR SART	90	*X	*X	38	Inbound

**Aircraft Did not try to detect 121.5 and RADAR SART on 5 K and 10 K passes.*

*** Aircraft did not detect 121.5 MHz on the 20 K pass.*

Tested results were results were only slightly less than line of sight of the EPIRB, AIS SART, and AIS EPIRB. Line of Sight Calculations: 20 K = 174 nm, 10 K = 123 nm, 5 K = 87 nm, 1 K = 39 nm.

Annex: Report on ExactEarth Satellite AIS-SART-EPIRB Sea Trials

Annex

Report on ExactEarth Satellite AIS-SART-EPIRB Sea Trials conducted in Hawaii on 20-21 January 2010

1. Summary:

COM DEV's experimental AIS satellite, called NTS (Nano-satellite for Tracking of Ships), successfully collected AIS data from all 5 of the AIS test units deployed by the USCG / IALA team in Hawaii in January 2010, as illustrated in the satellite footprint in Figure 1.

The test units that were activated for sea trials on 20-21 Jan 2010 were:

- 1 AIS-EPIRB at 1 Watt
- 3 AIS-SARTs at 1 Watt
- 1 AIS Class A at 12.5 Watt, that incremented its MMSI number every 2 sec

The probability of broadcast detection by the satellite system was:

- 25% for the AIS-EPIRB,
- 37 to 87 % for the various AIS-SART units
- 75 % for the Class A unit

In addition, AIS transmissions from about 270 different ships were also detected by the satellite each day in that region of the Pacific Ocean.

Because NTS is a nano-satellite demonstrator, it has a limited storage capacity and downlink rate. NTS is only able to capture 90 seconds of AIS data and must downlink this data before capturing additional data. During the first day of trials NTS captured 90 seconds over Hawaii and managed to download the full 90 seconds. During the second day, NTS also captured 90 seconds over Hawaii, however, due to limitations in the pass over our ground station, we were only able to download 60 seconds of that data.

The future operational micro-satellites, unlike the demo nano-satellite, will have no restrictions on the amount of data that can be captured and downlinked.

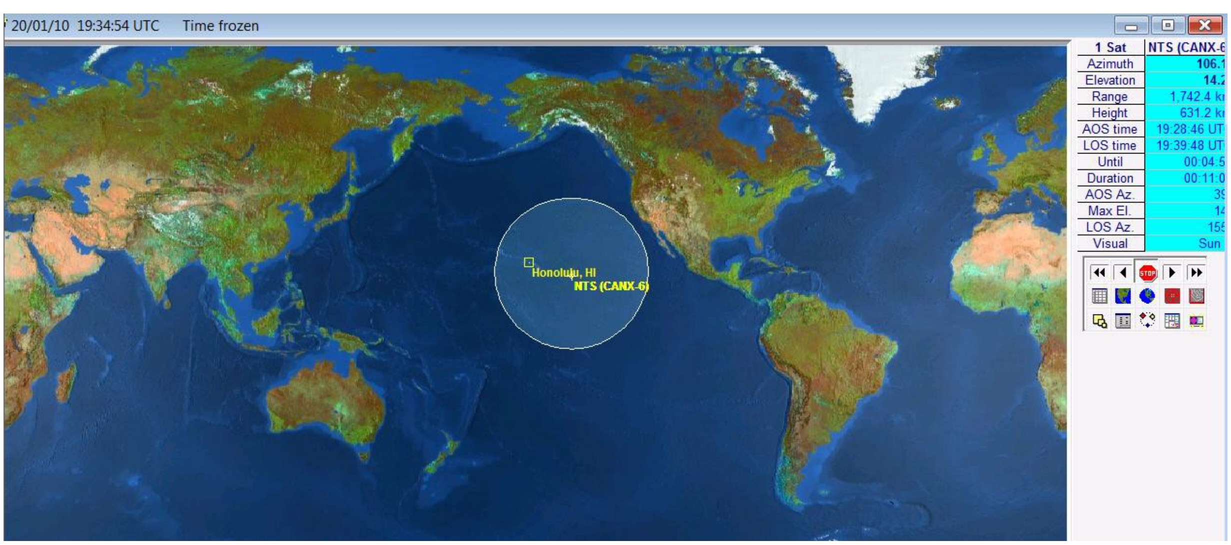

Figure 1: Footprint of COM DEV satellite passing over Hawaii area-21 Jan 10

2. Test Signals

All the AIS test units, as well as the AIS units on ships, transmitted on the regular AIS channels, alternating between AIS Channel 1 and AIS Channel 2, and bursts were received by the satellite on both channels. The test team deployed the test units in various configurations.

The 12.5 Watt Class-A unit was programmed to transmit a burst every 2 seconds and for the MMSI number to automatically increment on each burst. It was noted that this unit transmitted only an 8-digit MMSI number, rather than the normal 9-digits.

All the 1-Watt units (i.e. three AIS-SARTs and one AIS-EPIRB) are programmed to transmit 8 quick bursts about each minute, alternating on Ch 1 and 2, as defined by ITU and illustrated in Figure 2.

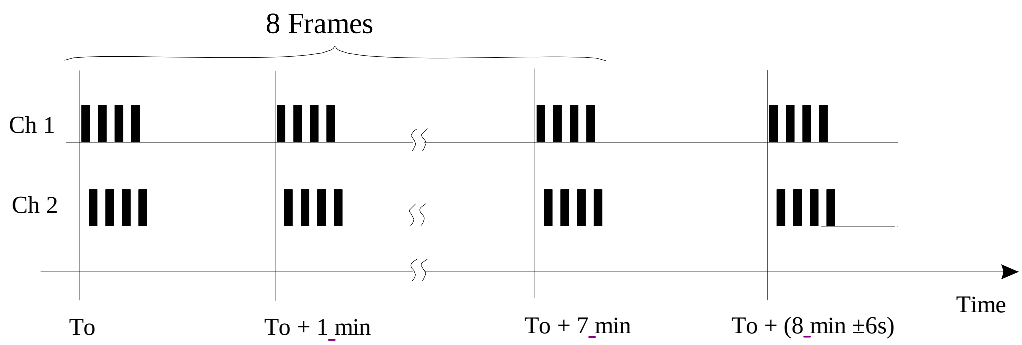

Figure 2: Illustration of timing of 8 quick bursts per minute from the 1-Watt test units

3. Test Results

<u>3.1 Day 1: (20 Jan 2010)</u>

The satellite was scheduled to record AIS signals starting on day 1 on 20 Jan 2010 at 19:34:54 UTC (09:34:54 local time in Hawaii) for about 90 seconds (limited due to satellite memory) as it passed over the Hawaii area. The elevation angle to the satellite was about 14 degrees and the distance to the satellite was about 1,800 km.

During the 90 seconds of data collection, about 270 unique AIS signals were detected, primarily from ships at sea as illustrated in Figures 3 & 4 and from two AIS test units as illustrated in Figure 5 and listed in Table 2.

AIS signals were detected from two test units that day, transmitting at 1 Watt, but one of the test units (MMSI 970010119) did not have a valid lat/long encoded in it, so it transmitted the default value of 91 deg Lat and 181 deg Long, but it could not be plotted on the map as these default values do not actually exist.

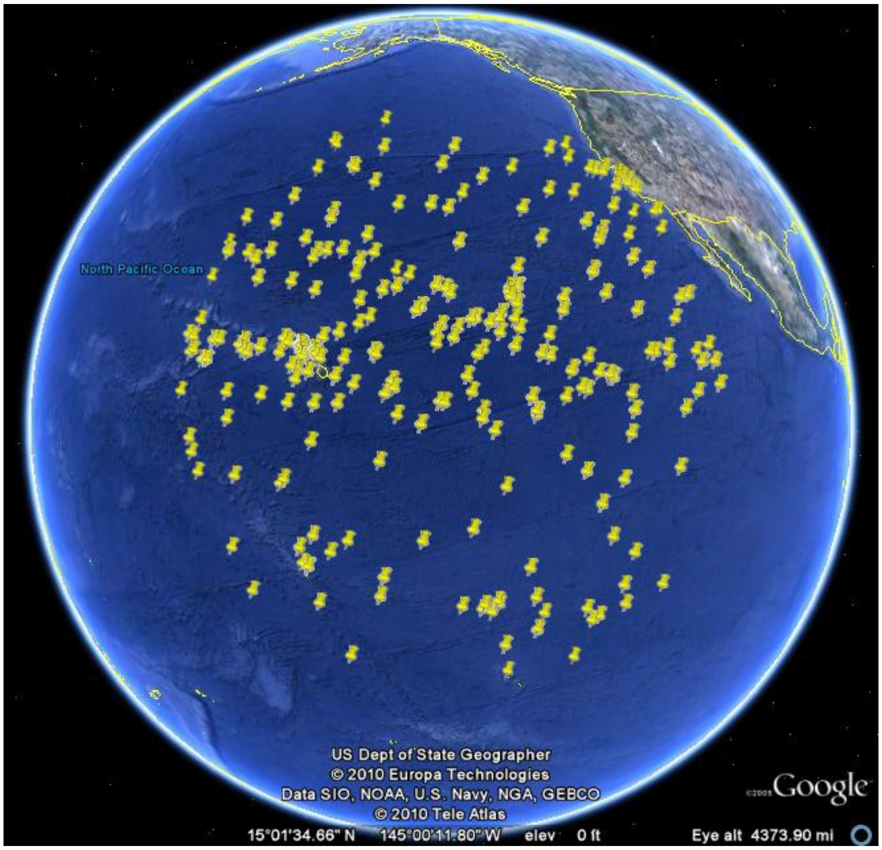

Figure 3: Locations of AIS signals from about 270 ships detected in the satellite footprint in that region of the Pacific Ocean, and the two test units deployed near Hawaii

Figure 4: Zoom in shows the MMSI numbers of the ships in that region of the Pacific Ocean

Figure 5: Zooming in further shows that 3 AIS transmissions were detected at a single location from the AIS-SART test unit MMSI 970010118 deployed 1.8 km off the coast of Hawaii. (AIS-SART test unit MMSI 970010119 was also detected but its location could not be plotted due to its default lat/long)

3.2 Day 2: (21 Jan 2010)

The NTS satellite made a similar pass over the Hawaii area, slightly later on day 2, on 21 Jan 2010 at 19:53:54 UTC (09:53:54 local Hawaii time) and collected AIS data for ~60 seconds (limited due to downlink time to ground station). The elevation angle to the satellite was about 25 degrees and the distance to the satellite was about 1,300 km.

The ~270 ships were detected again and so were all 5 of the AIS test units: 3 AIS-SARTs at 1 Watt, 1 AIS-EPIRB at 1 Watt and 1 Class-A at 12.5 Watts that incremented its MMSI number every 2 seconds. These are all illustrated in Figures 6, 7 and 8 and listed in Table 3.

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Figure 6: Zooming in shows the various AIS transmissions detected from the test unit AIS-SARTs (numbers …118, 119 & 120), the AIS-EPIRB (….117) and the Class-A (…1520...)

Figure 7: Zooming in further shows the various AIS transmissions detected from the test unit AIS-EPIRB (….117), AIS-SARTs (numbers …118, 119 & 120) and the cluster of detections from the Class-A unit (…1515 and incrementing to 1544)

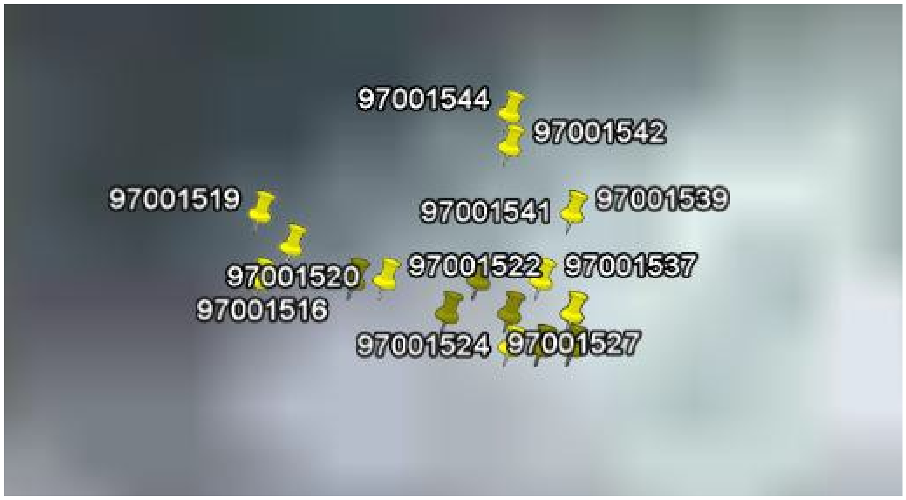

Figure 8: Zooming in further shows the cluster of various AIS transmissions detected from the Class-A unit that incremented its MMSI value every 2 sec (…1515, ..1516 etc.)

3.3 Probability of Broadcast Detection

The "probability of broadcast detection" is ratio of the number of bursts successfully received and decoded by the satellite system relative to the number of AIS bursts transmitted during the detection time interval.

Table 1: Probability of Broadcast Detection based on results in Tables 2 & 3

AIS test unit	Last 3 digits of MMSI number	Power	Test Date	Detection Time Interval (sec)	Number of bursts received & decoded	Number of Bursts Transmitted during detection time period	Probability of Broadcast Detection
AIS-SART	118	1 Watt	20 Jan	90	3	8	37.5 %
AIS-SART	119	1 Watt	20 Jan	90	1	Unknown*	--
AIS-EPIRB	117	1 Watt	21 Jan	60	2	8	25 %
AIS-SART	118	1 Watt	21 Jan	60	3	8	37.5 %
AIS-SART	119	1 Watt	21 Jan	60	5	8	62.5 %
AIS-SART	120	1 Watt	21 Jan	60	7 **	8	87.5 %
Class A	515-544	12.5 Watt	21 Jan	60	22	29	75.8 %

* test unit number 119 was faulty on that day and transmitted default lat/long values
** 7 bursts received from first cycle of 8, and 1 burst from start of next cycle a minute later

Table 2: 20 Jan 2010: NTS satellite data collected for two AIS-SARTs
Data capture begins at T = 19:34:54 UTC = 09:34:54 local Hawaii time (for ~90 seconds)

MMSI	TRANSMIT POWER	LAT	LONG	TIME = seconds since 19:34:54 UTC or 09:34:54 Hawaii time on 20 Jan 2010
970010119	*1 Watt*	*91 **	*181 **	*43.8 ***
970010118	1 Watt	21.32	-158.139	47.3
970010118	*1 Watt*	*21.32*	*-158.139*	*49.3*
970010118	*1 Watt*	*21.32*	*-158.139*	*57.4*

* default value of 91 & 181 indicates Lat/Long not set or is incorrect
***Red italics* is AIS Channel 1, normal text is AIS Channel 2

Table 3: 21 Jan 2010: NTS data collected for AIS-SARTs, AIS-EPIRB and Class A unit
Data capture begins at T = 19:53:54 UTC = 09:53:54 local Hawaii time (for ~60 seconds)

MMSI	TRANSMIT POWER	LAT	LONG	TIME = seconds since 19:53:54 UTC or 09:53:54 Hawaii time on 21 Jan 2010
Class A				
97001515	12.5 Watt	21.32856	-158.12	1.788532376
97001516	*12.5 Watt*	*21.32856*	*-158.12*	*3.630556583 ***
97001519	12.5 Watt	21.32856	-158.12	9.610480309
97001520	*12.5 Watt*	*21.32856*	*-158.12*	*11.79956341*
97001521	12.5 Watt	21.32856	-158.12	13.58819962
97001522	*12.5 Watt*	*21.32856*	*-158.12*	*15.59040165*
97001523	12.5 Watt	21.32856	-158.12	17.69940376
97001524	*12.5 Watt*	*21.32856*	*-158.12*	*19.83509254*
97001526	*12.5 Watt*	*21.32856*	*-158.12*	*23.83950996*
97001527	12.5 Watt	21.32856	-158.12	25.54806519
97001529	12.5 Watt	21.32856	-158.12	29.68597221
97001530	*12.5 Watt*	*21.32856*	*-158.12*	*31.58140945*
97001531	12.5 Watt	21.32856	-158.12	33.53022385
97001532	*12.5 Watt*	*21.32856*	*-158.12*	*35.57394409*
97001533	12.5 Watt	21.32856	-158.12	37.57614899
97001535	12.5 Watt	21.32856	-158.12	41.63398361
97001536	*12.5 Watt*	*21.32856*	*-158.12*	*43.87646103*
97001537	12.5 Watt	21.32856	-158.12	45.55831909
97001539	12.5 Watt	21.32856	-158.12	49.61614609
97001541	12.5 Watt	21.32856	-158.12	53.70066833
97001542	*12.5 Watt*	*21.32857*	*-158.12*	*55.59609985*
97001544	*12.5 Watt*	*21.32857*	*-158.12*	*59.57384872*

MMSI	TRANSMIT POWER	LAT	LONG	TIME = seconds since 19:53:54 UTC or 09:53:54 Hawaii time on 21 Jan 2010
AIS-EPIRB				
970010117	1 Watt	21.32853	-158.12	52.07223511
970010117	1 Watt	21.32853	-158.12	60.08110809
AIS-SARTs				
970010118	*1 Watt*	*21.32857*	*-158.12*	*54.66178131*
970010118	*1 Watt*	*21.32857*	*-158.12*	*58.66616821*
970010118	1 Watt	21.32852	-158.12	8.622756958
970010119	*1 Watt*	*21.32849*	*-158.12*	*13.26786423*
970010119	*1 Watt*	*21.32849*	*-158.12*	*17.27233315*
970010119	1 Watt	21.32849	-158.12	11.26568985
970010119	1 Watt	21.32849	-158.12	15.27004147
970010119	1 Watt	21.32849	-158.12	23.27888489
970010120	*1 Watt*	*21.32859*	*-158.12*	*3.016579628*
970010120	*1 Watt*	*21.32859*	*-158.12*	*7.020924091*
970010120	*1 Watt*	*21.32859*	*-158.12*	*11.02540588*
970010120	*1 Watt*	*21.32859*	*-158.12*	*15.02977276*
970010120	1 Watt	21.32859	-158.12	5.018756866
970010120	1 Watt	21.32859	-158.12	9.023121834
970010120	1 Watt	21.32859	-158.12	13.02759171
970010120	1 Watt	21.32859	-158.12	59.3069458

***Red italics* is AIS Channel 1, normal text is AIS Channel 2