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Agenda item 6

ICAO/IMO JOINT WORKING GROUP ON HARMONIZATION OF AERONAUTICAL AND MARITIME SEARCH AND RESCUE (ICAO/IMO JWG-SAR)

SEVENTEENTH MEETING

Bremen, Germany, 27 September to 1 October 2010

SAR COMMUNICATIONS

Report on satellite detection of AIS-SART-EPIRB sea trials in HAWAII, 20-21 January 2010

(Submitted by exactEarth Ltd., Canada, in conjunction with USCG, IALA and WSV Germany)

SUMMARY

Executive summary: This document provides information on satellite detection of prototype AIS-SART-EPIRB signals during sea trials conducted by the USCG, IALA and WSV Germany, in Hawaii in January 2010

Action to be taken: Paragraph 18

SATELLITE DETECTION OF AIS-SART-EPIRB SIGNALS

1 In January 2010, exactEarth Ltd, and its parent company COM DEV International Ltd, participated in sea trials by using its Satellite-AIS system to detect and decode signals from prototype AIS-SARTs and AIS-EPIRBs deployed in Hawaii. These sea trials were organized by: the USCG (United States Coast Guard), IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) and WSV (German Federal Waterways and Shipping Administration).

2 The satellite was a small demonstration satellite, called NTS - Nanosatellite for Tracking of Ships, in a polar orbit at an altitude of about 630 km. The satellite received and stored the signals in its onboard memory, and later downloaded the signals as it passed over an earth station in Canada, where they were then forwarded to a sophisticated data processing centre in Toronto which extracted the AIS data.

3 Several prototype AIS test units were deployed and were transmitting while the satellite passed over the Hawaii area, as illustrated in the satellite footprint in Figure 1. In addition to these test signals, AIS transmissions from about 270 different ships in that region of the Pacific Ocean were also detected and decoded by the satellite during each test, as illustrated in Figure 4. Multiple bursts from all five AIS test units were successfully received and decoded, comprising:

- 1 AIS-EPIRB transmitting at 1 Watt (i.e. AIS-SART electronics installed inside an EPIRB case)
- 3 AIS-SARTs transmitting at 1 Watt
- 1 AIS Class A transmitting at 12.5 Watt (incrementing its MMSI number every 2 sec)

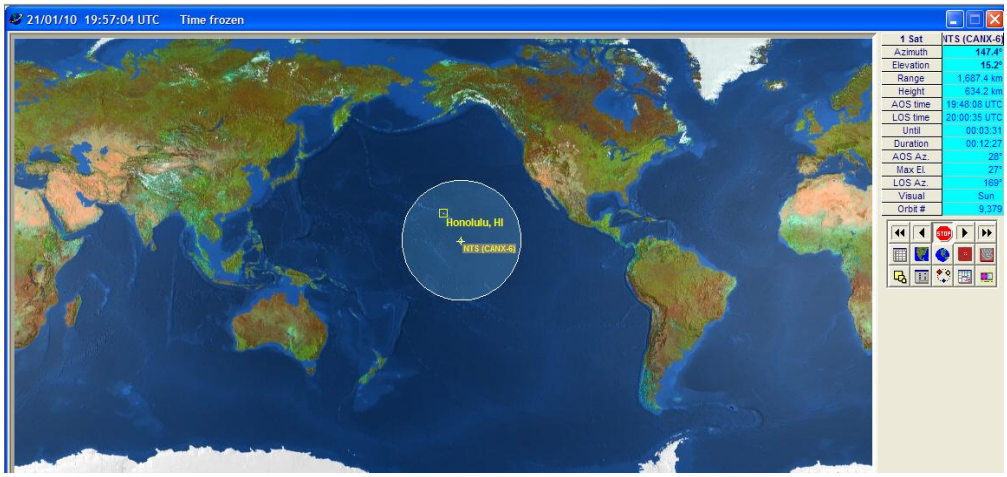

Figure 1: Footprint of low-Earth orbiting NTS satellite passing over Hawaii area-21 Jan 10

TEST SIGNALS

4 All the AIS test units, as well as all AIS units operating on ships at sea, transmit on the two regular AIS channels, alternating between AIS 1 (161.975 MHz) and AIS 2 (162.025 MHz), and AIS bursts were received by the satellite on both channels. The team deployed the test units in various configurations in the water and on deck, as shown in Figure 2.

Figure 2: The AIS Test Units were deployed in various configurations in water and on deck

5. 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 ID number, rather than the normal 9-digit MMSI.

6. All the 1-Watt units (i.e. 3 AIS-SARTs and an AIS-EPIRB) are programmed to transmit 8 quick bursts in about a 14-sec period, alternating on AIS 1 and AIS 2, and repeat that each minute, as defined by ITU in Recommendation ITU-R M.1371-4 and illustrated in Figure 3.

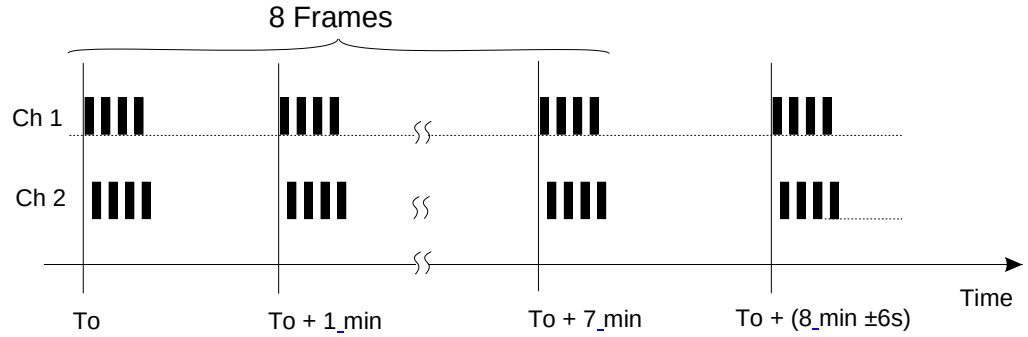

Figure 3: Illustration of timing of 8 quick bursts per minute from the 1-Watt AIS test units

TEST RESULTS

7 Day 1: (20 Jan 2010)

On day 1 (20 Jan 2010), the NTS satellite was scheduled to record AIS signals starting at 19:34:54 UTC (09:34:54 Hawaii time), for a duration of 90 seconds as it passed over the Hawaii area. The elevation angle to the satellite was 14 degrees and the distance to the satellite was 1,800 km, as listed in Table 1.

On this day, two AIS-SARTs (1 Watt) were deployed at sea, floating on a pole 1 metre above the water. Both AIS-SARTs were detected by the satellite system, as well as the AIS signals from about 270 ships at sea, as illustrated below.

One of the test units (MMSI 970010119) had an intermittent fault so could not be plotted on the map, as it did not have a valid lat/long encoded in it, so it transmitted the standard default values of 91 deg Lat and 181 deg Long, which do not actually exist.

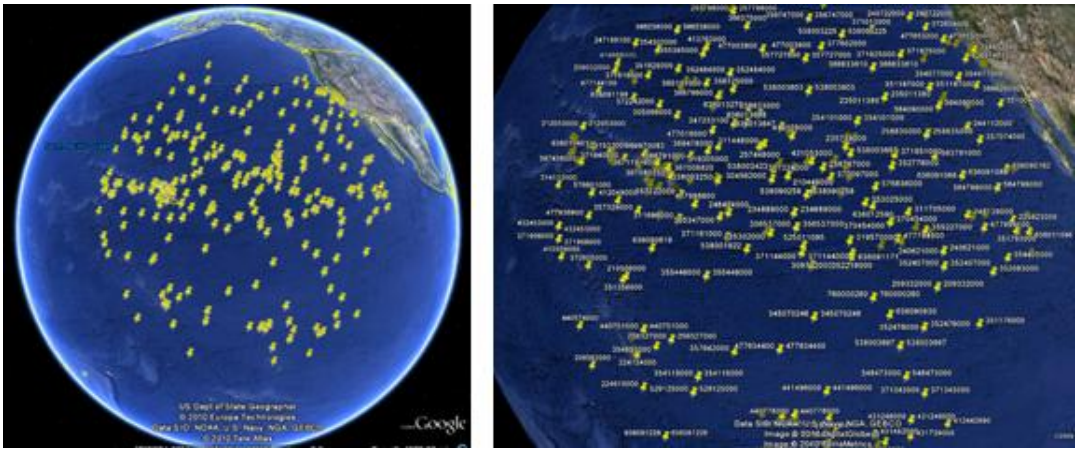

Figure 4: Locations and MMSI numbers of AIS signals from about 270 ships detected in the satellite footprint in that region of the Pacific Ocean, and the test units deployed near Hawaii

Figure 5: Zooming in shows 3 bursts detected from the AIS-SART at the deployed location 1.8 km, or ~1 nm, off the coast of Hawaii (test unit MMSI 970010118)
(Unit 119 was also detected but its location could not be plotted due to its default lat/long)

8 Day 2: (21 Jan 2010)

On day 2 (21 Jan 2010), the satellite made a similar pass over the Hawaii area, and starting at 19:53:54 UTC (09:53:54 Hawaii time) AIS data was again collected for 90 seconds. On this pass, the elevation angle to the satellite was about 25 degrees and the distance to the satellite was about 1,300 km, as shown in Table 1.

On this day, 5 separate AIS test units were deployed and activated in the marina and all 5 of the AIS test units were detected by the satellite system, comprising:

- 2 AIS-SARTs mounted 3m above the water on the rails of the vessel;
- 1 AIS-SART on a life vest floating in the water;
- 1 AIS-EPIRB floating in the water; and
- 1 Class-A mounted on the vessel, that intentionally incremented its MMSI number every 2 sec.

The satellite data received from these 5 AIS test units are shown in the following figures and tables. Again, about 270 ships were also detected on Day 2.

Figure 6: On Day 2 (left picture), several AIS transmissions were received from the AIS-EPIRB (...117), the AIS-SARTs (…118, 119 & 120) and the Class-A (…1520...) and zoomed in (right picture) shows the multiple incrementing numbers from the Class-A unit on the vessel

Table 1: Summary of NTS Satellite Pass Geometry for the Sea Trials

Test Day:	Day 1 (20 Jan 10)	Day 2 (21 Jan 10)
Data Collected for:	90 sec	60 sec
Elevation Angle to Sat:	14 deg	25 deg
Distance to Sat:	1,800 km	1,300 km
Power Transmitted from AIS-SART or AIS-EPIRB	1 Watt	1 Watt

9 Only 60 seconds of satellite AIS data was processed on day 2, because the subsequent satellite pass over the earth station was too short a duration to download the entire onboard memory data. However, exactEarth's new operational AIS satellites do not have the 90-second recording limitation that NTS has on the amount of data that can be stored and downloaded each orbit, as the new satellites have larger memories and faster download speeds, so can record and download signals for the entire orbit.

ANALYSIS OF TEST RESULTS

10 Probability of Burst Broadcast Detection

The "probability of burst broadcast detection" is ratio of the number of AIS bursts received over the number of AIS bursts transmitted during the same time interval. Table 2 summarizes the burst broadcast detection the AIS satellite system for the various test units in their deployed configurations. Since only a few bursts were emitted during the short satellite recording period, these rates are only indicative and are not statistically valid. Details of the individual bursts received are given in Tables 3 to 5. Multiple bursts were received, but only one burst needs to be received and decoded by the satellite system to detect the distress location, so the burst detection rates measured in these sea trials shows good performance.

In future, during a full 10-minute pass of an operational satellite, about 80 bursts would be emitted (i.e. at 8 per minute) by an AIS-SART, further improving the likelihood of detection.

Table 2: Summary of Burst Detections of Results in Tables 3 to 5

AIS test unit	Last 3 digits of MMSI number	Power (Watts)	Test Date (2010)	Time Interval (sec)	# of bursts rec'd	# of bursts emitted	Burst Detections	Test Unit Deployed Configuration
AIS-SART	118	1	20 Jan	90	3	8	3 of 8	1 m above water
AIS-SART	119*	1	20 Jan	90	1	Unknown intermittent	1 of ?	1 m above water
AIS-EPIRB	117	1	21 Jan	60	2	8	2 of 8	Floating in water
AIS-SART	118	1	21 Jan	60	3	8	3 of 8	3 m above water
AIS-SART	119	1	21 Jan	60	5	8	5 of 8	3 m above water
AIS-SART	120**	1	21 Jan	60	8	9	8 of 9	Oscar's life vest floating in water
Class A	515-544	12.5	21 Jan	60	22	29	22 of 29	On deck

* Test unit number 119 was intermittent /faulty on Day 1, so transmitted default lat/long values
** 7 bursts were received from first cycle of 8, plus 1 burst from start of next cycle

Table 3: Day 1 (20 Jan 2010): NTS satellite data received from two AIS-SARTs 1 m above water
Data capture begins at T = 19:34:54 UTC = 09:34:54 local Hawaii time (for ~90 seconds)

MMSI ID= 970010+	**TRANSMIT POWER****	**LAT**	**LONG**	**TIME = seconds since 19:34:54 UTC, 20 Jan 10**	**Comments**
118	*1 Watt*	*21.32*	*-158.139*	*47.3*	Floating 1 m
118	1 Watt	21.32	-158.139	49.3	above water
`118	1 Watt	21.32	-158.139	57.4	
119	1 Watt	91 *	181 *	43.8	Floating 1 m above water

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

Table 4: Day 2 (21 Jan 2010): NTS satellite data collected from special Class-A unit on the vessel

Data capture begins at T = 19:53:54 UTC = 09:53:54 local Hawaii time (for ~60 seconds)

MMSI ID= 97001+	TRANSMIT POWER**	LAT	LONG	TIME = seconds since 19:53:54, on 21 Jan 10	Comments
515	*12.5 Watt*	*21.32*	*-158.12*	*1.79*	AIS on deck
516	12.5 Watt	21.32	-158.12	3.63	
519	*12.5 Watt*	*21.32*	*-158.12*	*9.61*	
520	12.5 Watt	21.32	-158.12	11.80	¾ of the
521	*12.5 Watt*	*21.32*	*-158.12*	*13.59*	bursts were
522	12.5 Watt	21.32	-158.12	15.59	received
523	*12.5 Watt*	*21.32*	*-158.12*	*17.70*	during this
524	12.5 Watt	21.32	-158.12	19.84	one-minute
526	12.5 Watt	21.32	-158.12	23.84	period, mostly
527	*12.5 Watt*	*21.32*	*-158.12*	*25.55*	alternating
529	*12.5 Watt*	*21.32*	*-158.12*	*29.69*	between the 2
530	12.5 Watt	21.32	-158.12	31.58	AIS Channels
531	*12.5 Watt*	*21.32*	*-158.12*	*33.53*	
532	12.5 Watt	21.32	-158.12	35.57	
533	*12.5 Watt*	*21.32*	*-158.12*	*37.58*	
535	*12.5 Watt*	*21.32*	*-158.12*	*41.63*	
536	12.5 Watt	21.32	-158.12	43.88	
537	*12.5 Watt*	*21.32*	*-158.12*	*45.56*	
539	*12.5 Watt*	*21.32*	*-158.12*	*49.62*	
541	*12.5 Watt*	*21.32*	*-158.12*	*53.70*	
542	12.5 Watt	21.32	-158.12	55.60	
544	12.5 Watt	21.32	-158.12	59.57	

** Normal text is AIS Channel 1, and *Red italics* is AIS Channel 2

Table 5: Day 2 (21 Jan 2010): NTS satellite data received from AIS-EPIRB & 3 AIS-SARTs
Data capture begins at T = 19:53:54 UTC = 09:53:54 local Hawaii time (for ~60 seconds)

MMSI ID= 97001+	TRANSMIT POWER**	LAT	LONG	TIME = seconds since 19:53:54, 21 Jan 10	Comments
AIS-EPIRB					Floating in water
0117	*1 Watt*	*21.32853*	*-158.12*	*52.07*	Only part of a
0117	*1 Watt*	*21.32853*	*-158.12*	*60.08*	burst set rec'd
AIS-SARTs					
0118	*1 Watt*	*21.32852*	*-158.12*	*8.62*	3 m above water
0118	1 Watt	21.32857	-158.12	54.66	46 sec gap
0118	1 Watt	21.32857	-158.12	58.67	between burst set
0119	*1 Watt*	*21.32849*	*-158.12*	*11.27*	3 m above water
0119	1 Watt	21.32849	-158.12	13.27	
0119	*1 Watt*	*21.32849*	*-158.12*	*15.27*	Most bursts
0119	1 Watt	21.32849	-158.12	17.27	were received in
0119	*1 Watt*	*21.32849*	*-158.12*	*23.28*	this burst set
0120	1 Watt	21.32859	-158.12	3.02	On 'Oscar'
0120	*1 Watt*	*21.32859*	*-158.12*	*5.02*	floating in water
0120	1 Watt	21.32859	-158.12	7.02	
0120	*1 Watt*	*21.32859*	*-158.12*	*9.02*	7 of 8 bursts
0120	1 Watt	21.32859	-158.12	11.03	were received in
0120	*1 Watt*	*21.32859*	*-158.12*	*13.03*	this burst set,
0120	1 Watt	21.32859	-158.12	15.03	then 44 sec gap
0120	*1 Watt*	*21.32859*	*-158.12*	*59.31*	to next burst

** Normal text is AIS Channel 1, and *Red italics* is AIS Channel 2

DISCUSSION ON AIS DEVICES FOR SEARCH AND RESCUE (SAR)

11 The operational and technical characteristics of AIS-SARTs are defined by IMO and ITU. Since 1 Jan 2010, AIS-SARTs are part of the IMO GMDSS (Global Maritime Distress and Safety System), for carriage in life rafts and survival craft as an alternative to the older 9 GHz Radar Transponder SARTs.

12 Each AIS-SART is programmed with a unique 9-digit ID number, similar in length to an MMSI number, except they all start with 970, rather than a specific country code. The AIS SART should transmit Message 1 and Message 14 using the burst transmissions described by ITU. The Messages 1 and 14 should use a user ID 970xxyyyy (where xx = manufacturer ID 01 to 99; yyyy = the sequence number 0000 to 9999) and Navigational Status 14. Allocation of manufacturer ID numbers is managed by the CIRM organization, and the manufacturer then inserts a unique sequence number in each device. Several models are now made, as shown in Figure 7, and to date, six manufacturers have been allocated ID numbers, as listed on the CIRM website (www.cirm.org).

Figure 7: Several models of AIS-SARTs are now produced by various manufacturers

13 A different type of AIS station can also be carried by SAR aircraft in order to receive AIS signals in the search area and to broadcast their position and flight data while involved in SAR operations. The Satellite-AIS system has detected a number of these SAR aircraft AIS transmissions in various parts of the world.

14 Studies are underway to consider including AIS-SARTs inside 406 MHz EPIRBs, either as an addition to, in or place of, the 121.5 MHz homing signal currently transmitted by all EPIRBs. There may be merit to this, since conventional 'homing' would not be required, as SAR forces could simply 'navigate to' the position broadcast by the AIS-SART. Furthermore, most merchant vessels in the vicinity of an EPIRB alert are not equipped to receive a 121.5 MHz signal (since it is in the middle of the aeronautical frequency band), but could receive and locate an AIS-SART signal, and possibly render assistance.

15 During these and previous sea trials, USCG SAR aircraft flew search patterns at four different altitudes (1, 5, 10 & 20 thousand feet) to measure the detection range of the various test signals transmitted from the AIS-SARTs, a 9 GHz Radar Transponder SART and a 406 MHz EPIRB having a 121.5 MHz homer. They were able to detect the 406 MHz EPIRB signal and all the AIS signals from the SART and EPIRB in the water or on deck at a long range (typically 60 to 120 nm) compared to the 9 GHz SART (typically 20 to 40nm) and the 121.5 MHz homer (about 10 nm).

CONCLUSIONS

16 These sea trials demonstrated that exactEarth's Satellite-AIS system successfully detected and decoded all the low-power (1 Watt) AIS-SART and AIS-EPIRB test units deployed in these sea trials. Having a Satellite-AIS system receive such signals in distress situations could improve the likelihood of detecting distress events, particularly in remote regions, and such a secondary means of distress alerting might be useful now that satellite detection of 121.5 MHz signals has ceased.

17 Furthermore, the Satellite-AIS system routinely receives and tracks Class A transmissions from vessels on the high seas, so if a vessel is suddenly in a distress situation and the Class A stops and an AIS-SART signal appears, the satellite picture could help SAR forces plan their mission more effectively.

ACTION REQUIRED

18 The ICAO/IMO JWG SAR is invited to:

- note the information provided;
- note that further satellite detection of AIS-SART-EPIRB sea trials are planned for 2011;
- consider what other parameters could be tested in future Satellite-AIS sea trials; and
- provide guidance and suggestions to the sea trials organizers.

For further information please contact exactEarth at:

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www.exactEarth.com