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AISSat-1 Early Results

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ABSTRACT

AISSat-1 was launched on July 12, 2010 and is believed to be the first high performance nano-satellite to provide an observational service to governmental authorities. The primary mission objective is to perform maritime observation in the Norwegian High North and High South, thereby making a considerable contribution to the maritime situational awareness (MSA) of these areas.

The satellite is built, tested and prepared for flight by the Space Flight Laboratory at the University of Toronto Institute for Aerospace Studies (UTIAS/SFL), and is based on the 20 cm cube Generic Nano-satellite Bus (GNB). UTIAS/SFL also handled the launch of AISSat-1 by an Indian Polar Satellite Launch Vehicle (PSLV) from southern India. The payload is an AIS receiver developed and manufactured by Kongsberg Seatex AS, Trondheim Norway. The Norwegian Defence Research Establishment (FFI), Kjeller Norway developed the AISSat-1 mission concept and has been responsible for managing the project and for testing and preparing the AIS payload for flight.

The Automatic Identification System (AIS) for maritime vessels was introduced by the International Maritime Organization (IMO) to enhance the safety of life at sea (SOLAS). Vessels greater than 300 gt or carrying 12 or more passengers are broadcasting AIS messages on two channels in the maritime VHF band on regular basis to neighboring vessels for collision avoidance, and also to shore stations for vessel traffic services (VTS). AISSat-1 is designed to receive these AIS messages in space, and to forward the messages to the Norwegian Coastal Administration (NCA), with the aim to extend the range of the Norwegian ground based AIS network to also cover ocean areas at the high seas.

Some early results from AISSat-1 presented here clearly demonstrate that a low cost high performance nano-satellite can provide excellent and much needed maritime observation information to government authorities.

INTRODUCTION

The ocean areas under Norwegian jurisdiction shown in blue in Figure 1, amount in total to more than 2 million square kilometers. New developments in these areas impose new challenges on control and management of maritime activities. The arctic region is an important fish habitat, and is rich on oil and natural gas. If the current rate of ice melting persists, increased maritime activity in these fragile Arctic areas can also be expected. Monitoring current and future maritime activities is therefore of imperative importance. In a strategy document for the development of the Norwegian High North presented at the end of 2006, the Norwegian government clearly recognized this and stated that it will be a national responsibility and priority to strengthen the monitoring of maritime activities in the High North.

Maritime surveillance has traditionally been performed by maritime patrol aircraft, Coast Guard and Navy vessels, coastal radars, and later also Synthetic Aperture Radar (SAR) imagery. Introduction of the Automatic Identification System (AIS) by the International Maritime Organization (IMO) has provided an additional source of maritime traffic information. AIS is a ship-to-ship and ship-to-shore reporting system intended to increase the safety of life at sea (SOLAS) and to improve control and monitoring of maritime traffic. AIS equipped ships broadcast their identity, position, speed, heading, cargo, destination, etc. to vessels and shore stations within range of the VHF transmission. Norway has close to 50 AIS stations along the coast receiving AIS messages out to about 40-50 nautical miles off shore.

The Norwegian Defence Research Establishment (FFI) has examined both technical and organizational aspects of monitoring AIS signals from space. A comprehensive observation model for estimating the AIS signal environment in low Earth orbit has been developed, making it possible to evaluate various concepts for AIS satellite missions to meet both Norwegian and global requirements.

Figure 1: Ocean areas under Norwegian jurisdiction (light blue).

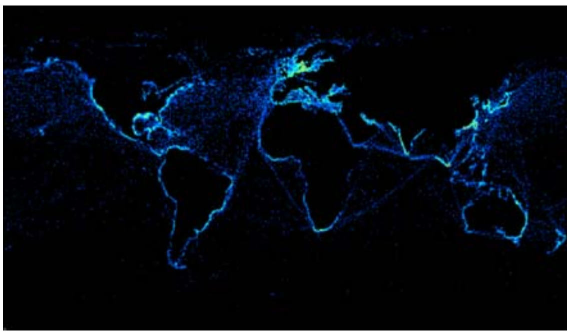

Figure 2: Global vessel distribution map.

VESSEL DENSITY MAP

An estimate of the global vessel distribution was necessary for the modeling. A base estimate was derived from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). This estimate was later updated by information from new and relevant sources. Figure 2 shows the most recent global vessel distribution map. There are more than 50 000 moving vessels in this map sending “dynamic” AIS messages containing ID, position, speed and heading, thereby allowing these vessel parameters to be plotted on a map.

AIS DETECTION PROBABILITY

A simulation tool, AISDET, developed by FFI performed vessel detection probability analyses for AISSat-1. AISDET uses the vessel density map in Figure 2 and other parameters to estimate the probability for detecting maritime vessels carrying AIS. The most resent global detection probability map generated for AISSat-1 is shown in Figure 3. This simulation is made for a 630 km circular sun-synchronous orbit. The detection probability varies over the globe. The most difficult areas are the Gulf of Mexico, the North Sea and the Far East, while the High North and the High South is easier to observe.

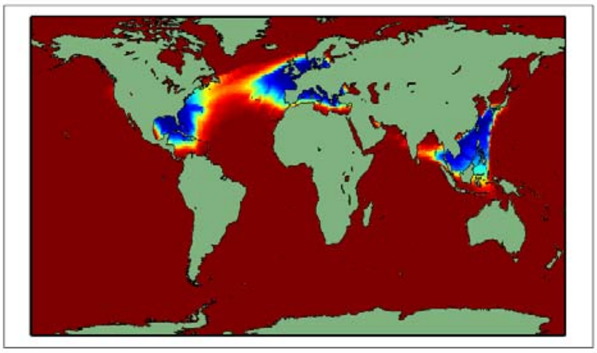

Figure 3: 24 hour global detection probability map for AISSat-1 orbiting at 630 km altitude.

AISSAT-1 MISSION ARCHITECTURE

The overall AISSat-1 mission architecture and main ground site locations are shown in Figure 4. AISSat-1 receives AIS messages from vessels at seas and forwards the messages to the Svalbard ground station (GS). The Svalbard location permits contact with the satellite in all of the 15 daily orbits. The AIS messages are then forwarded to the Norwegian Coastal Administration (NCA) in Haugesund, and finally to the Mission Control Centre (MCC) at FFI, Kjeller. Commands for tasking and operation of AISSat-1 are sent in the opposite direction.

AISSat-1 will observe part of the Norwegian ocean areas (Figure 1) every orbit, and provides a daily overview to various national authorities of the maritime activity in the area.

Figure 4: AISSat-1 mission architecture.

AISSAT-1 DESIGN

The AIS receiver shown in Figure 5 is a software defined radio (SDR). The AIS signal is sampled and forwarded to a field programmable array (FPGA) for further hardware processing. The radio covers the entire maritime VHF band, but is normally tuned to the two AIS channels (161.975 and 162.025 MHz). The FPGA enables in-flight fine tuning of the AIS sensor based on analyses of received AIS data.

Figure 5: AIS Sensor for AISSat-1.

The satellite being based on the 20 cm cube Generic Nanosatellite Bus (GNB), was designed, manufactured, integrated and tested at UTIAS/SFL. The GNB was considered an ideal platform for an AIS demonstration missions.

Figure 6 shows the internal structure of AISSat-1 with the two system trays and AIS sensor. The two trays contain all the system components for a basic satellite mission, including data processors, communications, attitude determination and control, power and thermal/structural components.

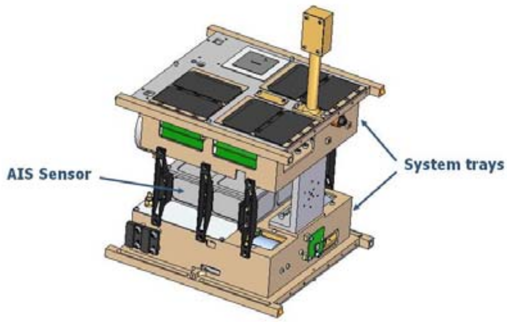

Figure 6: AISSat-1 system trays and AIS Sensor.

The flight ready AISSat-1 and its custom designed VHF monopole AIS antenna is shown in Figure 7.

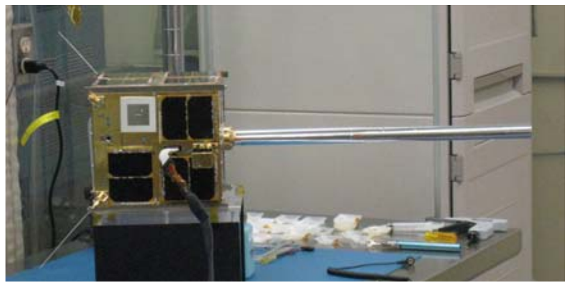

Figure 7: The flight ready AISSat-1.

LAUNCH AND EARLY RESULTS

AISSat-1 was launched 03:52 UTC on July 12, 2010. The launch was very successful and put the satellite into the expected 635km sun-synchronous orbit. Contact was established with the satellite during the second orbit and the first AIS messages were received in the afternoon. Figure 8 shows the very first AIS data received from AISSat-1. The green icons show the observation capability of the coastal AIS network, while the yellow and pink icons show the contribution made by AISSat-1 to the maritime overview of the High North. This successful acquisition of AIS messages was a very pleasant moment for the whole AISSat-1 team.

AISSat-1 is designed to have two basic observation modes. When the satellite is in contact with the Svalbard ground station AIS messages from vessels within the satellite's field of view are forwarded to the NCA and MCC in real time (< 1sec latency). This mode basically makes a maritime situational picture available to Norwegian authorities in real time.

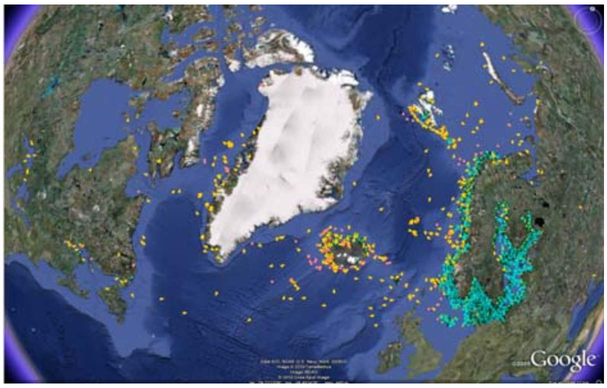

Figure 8: First AIS data from AISSat-1.

The ocean areas covered by the real time mode are shown in Figure 9. As this is a plot lot of the summer activities in the High North over a few weeks it shows that AISSat-1 also observes quite well the maritime activities in the North West and North East passage. This will soon be of significant importance when the ice situation allows for increased traffic in these environmentally fragile areas. More than 3000 vessels are observed in these areas daily.

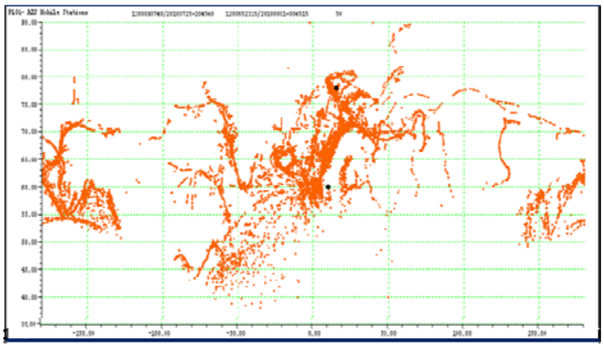

Figure 9: Ocean areas covered in real time mode.

AISSat-1 also has a store and forward mode that enables the satellite to map AIS vessels around the globe several times a day. AIS messages observed and stored during each orbit is sent to ground as soon as contact is established with the Svalbard ground station. Figure 10 shows a plot of daily global vessel observations. The color coding indicates in how many passes a vessel is observed during the 24 hour period. It must be remembered here that there are 15 daily satellite passes in the High North and South, while there are only 4 passes at the Equator. In this mode AISSat-1 is observing around 25000 moving vessels daily. The probability of detecting AIS messages based on traffic density etc. will also affect this number as discussed above. A comparison with the simulated detection probability map in Figure 3 shows an interestingly good match between the two.

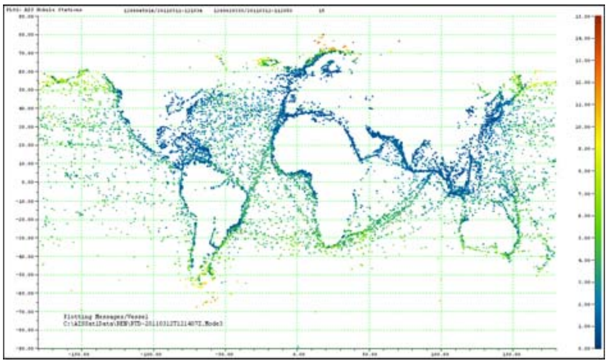

Figure 10: Global map of AIS data from AISSat-1.

Figure 11 shows observations made over Japan during the catastrophic tsunami in March 2011. This data was shared with the Japanese Coast Guard in order to provide a wider picture of the vessel distribution around Japan.

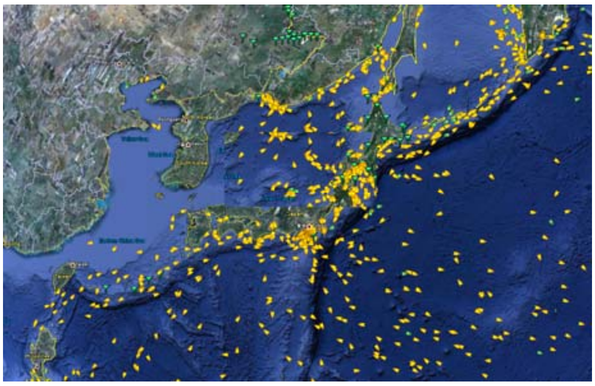

Figure 11: Vessel situation around Japan during the catastrophic tsunami.

CONCLUSIONS

AISSat-1 has by now operated for more than a year, and has provided a new and valuable maritime observation tool to Norwegian authorities for improved maritime situational awareness of Norwegian and international waters. AIS information has also been distributed to international authorities.

The up-time for AISSat-1 has been better than 95%. A copy of AISSat-1, named AISSat-2, has been ordered from UTIAS/SFL. The two satellites will in 2012 together form the first Norwegian observational asset in space with an up-time close to 100%.