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Processing and Analysis of SAR and AIS Data for Ship Detection

Technical report to close out GEOINT Task 10

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1 INTRODUCTION

The "Research and development support for SAR-based GEOINT and terrain analysis" contract (W7714-091140/001/SV), initiated in December 2011, aims to provide research and development (R&D) technical support for the Space and ISR Applications (SIA) Section at Defence Research and Development (R&D) Canada – Ottawa (DRDC Ottawa).

The work for Task 10 was carried out between September 2012 and March 2013. The objectives for Task 10 were to upgrade DRDC Ottawa custom tools that process SAR and AIS data; and to process and analyze concurrent SAR and AIS data sets that have been acquired during trials. Task 10 consists of two subtasks:

- Upgrade DRDC Ottawa custom tools for processing and analysis of concurrent SAR and AIS data; and,
- Processing and analysis of concurrent SAR and AIS data using DRDC Ottawa Custom Tools.

Section 2.1 contains a list of items in Task 10's Statement of Work, and their completion status. Section 2.2 contains a list of Task 10 items that were completed, and a brief description of each item. Incomplete items are explained in Section 3.

2 TASK ITEMS, DESCRIPTIONS, AND THEIR STATUS

2.1 Task Items and Their Status

Table 1 lists all task items of Task 10 and their completion status. Further to this information, every completed item is described in greater detail in Section 2.2.

Table 1: List of Task 10 items and their completion status

Item Number	Item	Complete	Incomplete
Subtask 1: Upgrade DRDC Ottawa custom tools for processing and analysis of concurrent SAR and AIS data			
CSIAPS:			
1.1	• Investigate extension of CSIAPS archiving (data repository and metadata search) to support AIS sensors of interest and recommend way ahead	✓	
IA Pro:			
1.2	• Develop drivers for classified imagery	✓	
1.3	• Ingest vector files from CLG message stream		✓
1.4	• Generate locally convex hull to indicate expected spatial extent of an AIS data set	✓	
1.5	• Update GDAL drivers to read RADARSAT-2 and TerraSAR-X RPCs	✓	
1.6	• Correct and augment product.xml GCPs to account for RPCs and the Terrain Height parameter in two cases: a) ocean for which the height is zero; b) land for which the land height is obtained from a DEM	✓	
1.7	• Re-project third-party detector results (e.g., OceanSuite) to account for RPCs	✓	
1.8	• Investigate and implement, if feasible, the OceanSuite ship detection algorithm		✓
1.9	• Investigate and implement, if feasible, a ship wake analysis algorithm		✓

Item Number	Item	Complete	Incomplete
ADSS:			
1.10	• Carry out regression testing of modified modules	✓	
1.11	• Build all modules on RedHat 5.5 OS	✓	
1.12	• Integrate with DSTO capabilities	✓	
1.13	• Develop ability to run H1 demonstration		✓
SAR-AIS ADSS Pipeline:			
1.14	• Implement support for other imagery sources: o TerraSAR-X; o COSMO-SkyMed; o XWEAR; o Classified imagery		✓
1.15	• Implement support for other detection sources		✓
1.16	• Incorporate a database containing static vessel information (e.g., IHS-Fairplay, CANMARNET, Mensuration)	✓	
1.17	• Automatically declare a target based on comparison of signature RCS and published ship length (AIS or ISR)		✓
1.18	• Generalize RIMPAC-specific elements	✓	
1.19	• Ingest OceanSuite OTHGold messages	✓	
1.20	• Support distribution of pipeline and IA Pro via a single virtual machine	✓	
SAR-AIS ADSS Pipeline Automation:			
1.21	• Develop intelligent (i.e., using historical or archived) Internet Ships Register lookup of MMSI to extract static vessel information	✓	
Data Display:			
1.22	• Investigate and implement a dynamic real-time display for ADS1b data that includes recent, sensor footprint coverage, and ground stations (with the intent of using this setup for M3MSat once it has been launched)	✓	

Item Number	Item	Complete	Incomplete
Subtask 2: Processing and analysis of concurrent SAR and AIS data using DRDC Ottawa Custom Tools *Use DRDC Ottawa custom tools to analyze SAR and AIS data acquired during trials:*			
2.1	• Carry out SAR and AIS coverage analysis using CSIAPS and STK	✓	
2.2	• Run the SAR-AIS ADSS Pipeline and compile detection statistics for various SAR/AIS data sets	✓	

2.2 Descriptions of Completed Task Items

Table 2 contains brief description for each completed item of Task 10.

Table 2: Completed task items and descriptions

Item Number	Item Description
Subtask 1: Upgrade DRDC Ottawa custom tools for processing and analysis of concurrent SAR and AIS data	
CSIAPS:	
1.1	• Investigate extension of CSIAPS archiving (data repository and metadata search) to support AIS sensors of interest and recommend way ahead Various methods of extension were investigated and detailed to DRDC Ottawa, and the recommendation was made to pursue a direct database approach for archiving AIS data.
IA Pro:	
1.2	• Develop drivers for classified imagery The GDAL NITF driver was modified to support classified SAR I+Q complex products. In order to support these products (containing real and imaginary component), a modification to the NITF driver was made to convert the two bands into a single complex band. The standard complex SAR analysis routines in IA Pro are now able to be applied to NITF SAR I+Q products.
1.4	• Generate locally convex hull to indicate expected spatial extent of an AIS data set A locally convex hull (LoCoH) can be used to determine the coverage area for an AIS dataset. After thinning the data, AIS data must be decoded, extracted by desired spatial and temporal extents, and saved as a Shapefile. Data can then be used with a script that was originally written in R to perform LoCoH analysis. This entire process was streamlined in ADSS. ADSS already contains AIS drivers capable of extracting the AIS subset so a new module (called locoh) was written to generate the LoCoH. The algorithm was re-implemented in C++ for speed and for compatibility with ADSS. The Computational Geometry Algorithms Library (CGAL) (www.cgal.org) was used in the data thinning and the nearest neighbour search of the convex hull algorithm. The modified LoCoH tool demonstrated significantly improved performance over the R script. Note that CGAL must be installed and built into the Linux OS to run the locally convex hull tool.

Item Number	Item Description
1.5	• Update GDAL drivers to read RADARSAT-2 and TerraSAR-X RPCs An update was made to the RADARSAT-2 driver, in order to copy the RPC information from the product.xml file to the GDAL RPC-domain metadata. Unfortunately, TerraSAR-X metadata does not contain any RPCs. Note that this patch will be submitted to GDAL.
1.6	• Correct and augment product.xml GCPs to account for RPCs and the Terrain Height parameter in two cases: a) ocean for which the height is zero; b) land for which the land height is obtained from a DEM A new tool was developed in IA Pro to allow orthorectification of images that contain RPCs (see Figure 1), using the RPC-domain metadata provided by GDAL (its gdalwarp utility). This is a result of the RADARSAT-2 driver update that occurred for Item 1.5. Given a DEM or a constant terrain height, an orthorectified output image can be quickly generated.
1.7	• Re-project third-party detector results (e.g., OceanSuite) to account for RPCs RPC-based orthorectification for vectors has been implemented in IA Pro.
ADSS:	
1.10	• Carry out regression testing of modified modules Regression testing has been carried out for some, but not all, of the modified modules.
1.11	• Build all modules on RedHat 5.5 OS ADSS modules were built on RedHat 5.5 OS.
1.12	• Integrate with DSTO capabilities The DRDC development patch has been submitted to DSTO for integration with the main ADSS distribution.
SAR-AIS ADSS Pipeline:	
1.16	• Incorporate a database containing static vessel information (e.g., IHS-Fairplay, CANMARNET, Mensuration) A database containing static vessel information (ship length, etc.), as derived from the CANMARNET database and DRDC's own static AIS database (if unavailable from CANMARNET), was provided and integrated into the Polar Epsilon stream. Static vessel metadata was incorporated/provided as part of the detections parameters output by SAAS.
1.18	• Generalize RIMPAC-specific elements RIMPAC-specific elements in IA Pro, especially OTHGold outputs, were generalized.
1.19	• Ingest OceanSuite OTHGold messages The pipeline was extended to allow OceanSuite detections to be read in from OTHGold messages. This expands from the pre-existing ability to ingest OceanSuite detections as Shapefiles.

Item Number	Item Description
1.20	• Support distribution of pipeline and IA Pro via a single virtual machine A significant effort went into the distribution of the pipeline and IA Pro via a virtual machine. A number of bugs were fixed and new features were added to the system that was demonstrated at RIMPAC. The pipeline, via a single virtual machine, has been distributed within DRDC and to outside users.
SAR-AIS ADSS Pipeline Automation:	
1.21	• Develop intelligent (i.e., using historical or archived) Internet Ships Register lookup of MMSI to extract static vessel information Developed an intelligent Ships Register lookup using CANMARNET database, and integrated into the Polar Epsilon stream.
Data Display:	
1.22	• Investigate and implement a dynamic real-time display for ADS1b data that includes recent, sensor footprint coverage, and ground stations (with the intent of using this setup for M3MSat once it has been launched) STK is used to display the location of exactView-1 (also known as ADS1b) in its orbit (see Figure 2). It is set up in real-time animation mode, in order to show the currently predicted satellite location (see Figure 3). A Windows-based vessel tracking application TV32 was used to display AIS contacts in a dynamic and real-time manner (see Figure 3). In order to avoid displaying AIS contacts from all exactEarth satellites, a python script was written as a buffer; this script intercepts a live AIS feed and forwards only exactView-1 data to TV32. Note that this python script is also used for logging, so it acts as a replacement for the AIS decoder. Additionally, when M3MSat becomes operational, the python script can easily be modified to show M3MSat's AIS contacts in TV32.
Subtask 2: Processing and analysis of concurrent SAR and AIS data using DRDC Ottawa Custom Tools	
2.1	• Carry out SAR and AIS coverage analysis using CSIAPS and STK SAR and AIS concurrent coverage analysis using CSIAPS and STK was carried out to assist the RADARSAT-2 image acquisition.
2.2	• Run the SAR-AIS ADSS Pipeline and compile detection statistics for various SAR/AIS data sets Extensive RADARSAT-2 SAR/AIS analysis was carried out over Gibraltar, Canary Islands and Vancouver, under various beam mode configurations including MSSR modes. SAR-AIS detection statistics were compiled and reported.

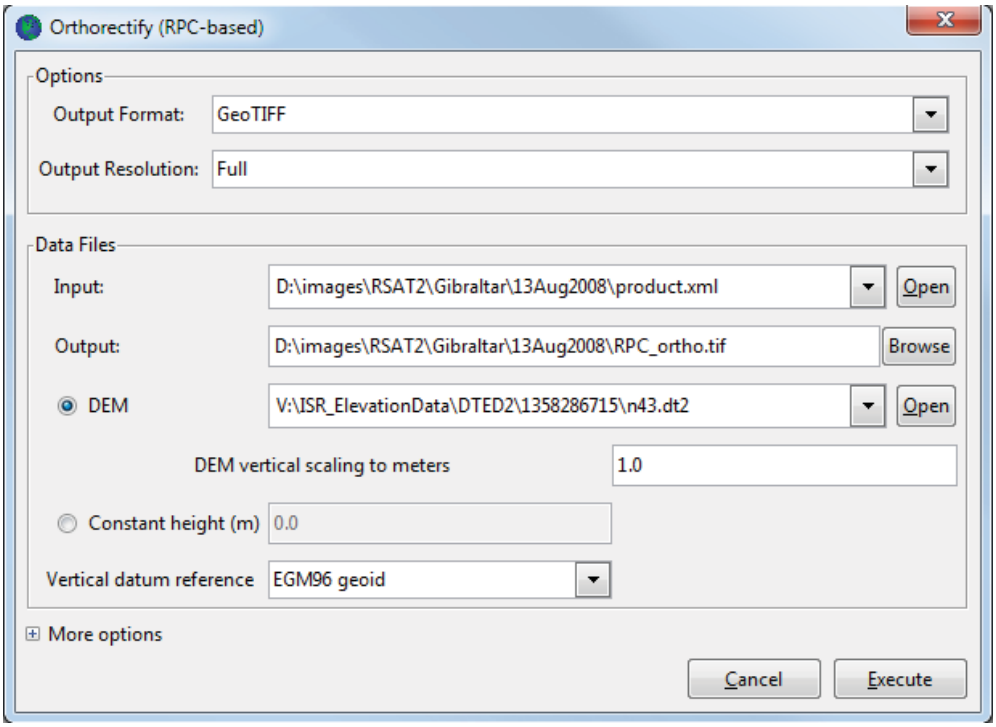

Figure 1: IA Pro's new RPC-based orthorectification tool

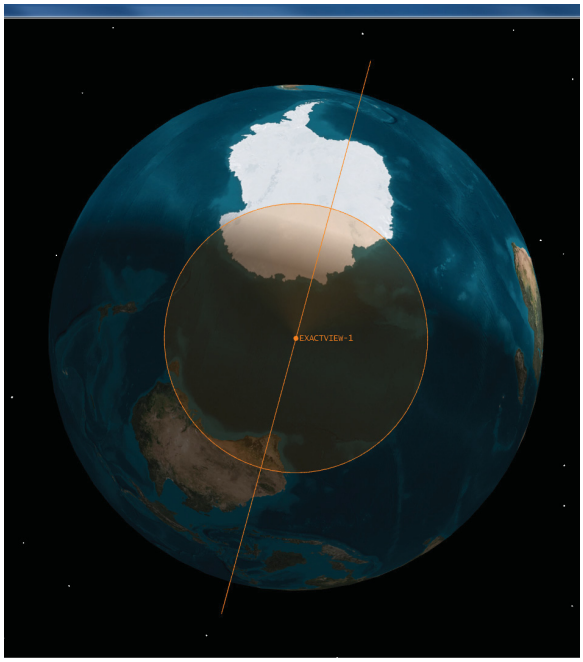

Figure 2: STK displays the exactView-1 orbit

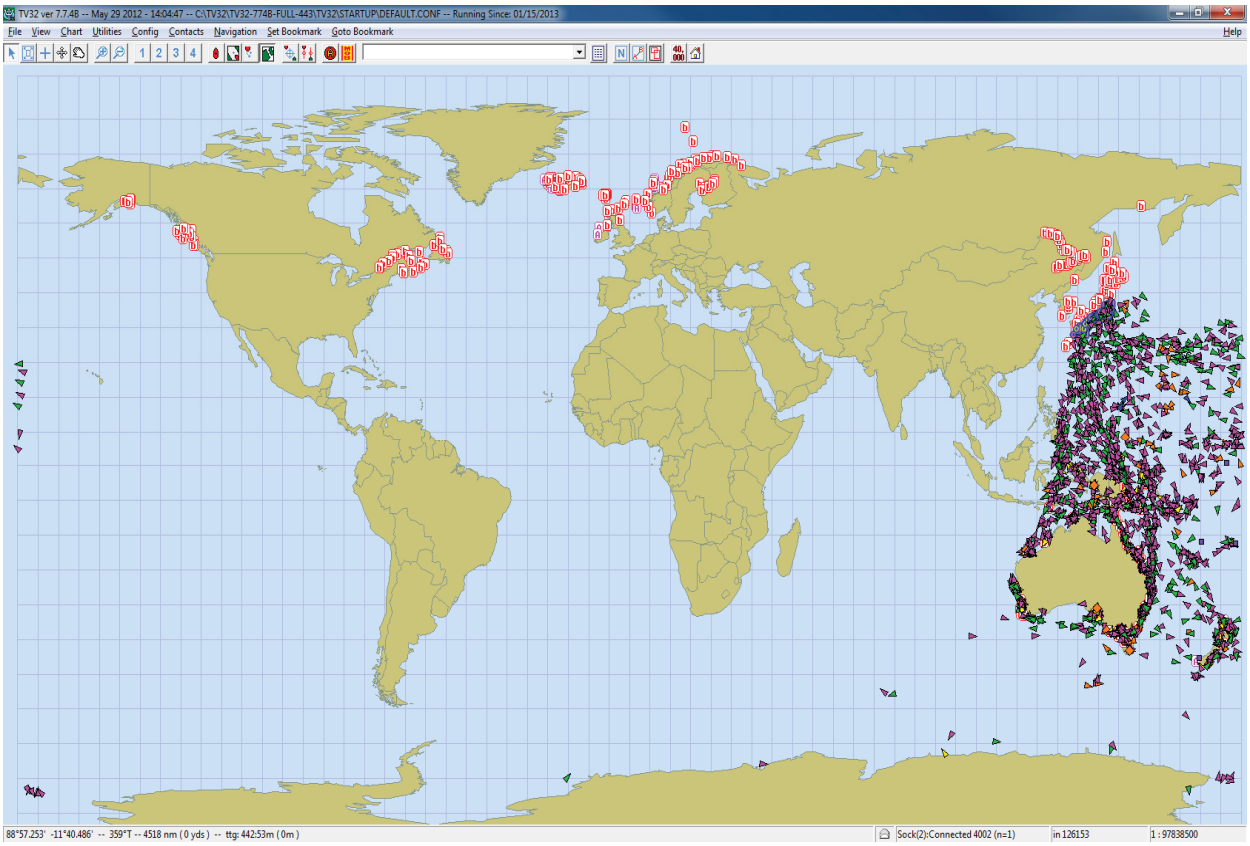

Figure 3: Dynamic display of AIS contacts from AIS sensor exactView-1

2.3 Descriptions of Completed Non-Task Items

In addition to the items originally appearing on Task 10, one additional item was completed for CSIAPS. This was a logical follow-up of Task 10 work, and is described in Table 3.

Table 3: Additional items completed and their description

Item	Description
SAR-AIS ADSS Pipeline	Pipeline work included greater support for OTHGold output, improved generation of KML, and further development of the python automation scripts. The python script development allows detection of zipped RADARSAT-2 imagery, AIS data, and OceanSuite files. Country codes and friendly status were moved into a configuration file, to allow future modifications without requiring a rebuild of ADSS. The validation tool in IA Pro underwent changes to better support the clustered target model of the pipeline.

3 EXPLANATIONS OF INCOMPLETE TASK ITEMS

There are seven items that were not completed in Task 10. They were a result of DRDC redirecting more resources to higher priority tasks than was originally planned. The status for each incomplete item is given in Table 4.

Table 4: Incomplete items' current status

Item Number	Item	Status
IA Pro:		
1.3	Ingest vector files from CLG message stream	This is viewed as a low priority item, and will be investigated in Task 13.
1.8	Investigate and implement if feasible the OceanSuite ship detection algorithm	This is viewed as a low priority item, and will be investigated in Task 20.
1.9	Investigate and implement if feasible a ship wake analysis algorithm	This is viewed as a low priority item, and will be investigated in Task 17.
ADSS:		
1.13	Develop ability to run H1 demonstration	Installed and configured DRDC's SAR-AIS pipeline and unclassified ADSS on RedHat 5.5 on the Virtual Lab (VL). The SAR-AIS RIMPAC and MARLANT demonstrations have been configured and successfully operated on VL. However the H1 was never installed on the VL.
1.14	Implement support for other imagery sources: o TerraSAR-X; o COSMO-SkyMed; o XWEAR; o Classified imagery	Preliminary support for TerraSAR-X imagery already exists in the pipeline, though this has yet to be extended to the automation component. Support for other imagery sources such as COSMO-SkyMed, and XWEAR are yet to be implemented.
1.15	Implement support for other detection sources	This is viewed as a low priority item, and will be investigated in Task 17.
SAR-AIS ADSS Pipeline:		
1.17	Automatically declare a target based on comparison of signature RCS and published ship length (AIS or ISR)	This is viewed as a low priority item, and will be investigated in the future.