NovaSAR-S: A Low Cost Approach to SAR Applications

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Abstract – NovaSAR-S is SSTL's revolutionary small Synthetic Aperture Radar (SAR) satellite designed for low cost missions. The instrument specification and mission characteristics of the NovaSAR satellite have been designed to provide benefit to a range of applications - the key ones being maritime surveillance (including ship and oil slick detection), forestry, disaster monitoring (particularly flooding) and agriculture. The paper will present an assessment of the ability of NovaSAR to address these key applications and provide examples of products that could be derived from NovaSAR imagery to support these applications.

I. Introduction

This paper presents an overview of SSTL's NovaSAR-S SAR satellite and the applications that it has been designed to address.

II. Overview of the NovaSAR-S Programme

NovaSAR-S is SSTL's revolutionary small Synthetic Aperture Radar (SAR) satellite designed for low cost missions. SSTL has teamed with SAR payload experts at Astrium UK to design a system for approximately 20% of the cost of a conventional radar mission using a combination of the latest commercial off-the-shelf technologies and SSTL's tried and tested approach in delivering low cost small satellite missions. Drawing on the success of SSTL's Disaster Monitoring Constellation of small optical satellites, NovaSAR-S is designed to be operated as a stand alone system or as a collaborative constellation, where each satellite is owned and controlled by individual partners who gain the additional benefits of operating within a constellation.

The UK government is providing seed funding to develop and build the first NovaSAR-S demonstration satellite which is due for launch in early 2015 and is currently under construction at SSTL's state of the art satellite manufacturing facility in Guildford, UK.

NovaSAR-S will operate at an altitude of 580 km and is compatible with a variety of orbits including a Sun-synchronous orbit (SSO), with a 10.30 LTAN, and an Equatorial (minimum inclination 15 degrees) orbit. The sun-synchronous orbit offers several options for shared launches and the potential for phasing with optical satellites in the same orbital plane while the near equatorial orbit provides maximum imaging and downlinking opportunities for customers with imaging requirements based in equatorial regions. Both of these orbit options make the NovaSAR-S system unique since, with the failure of Envisat in 2012, most current operational civilian SAR satellites operate in a sun-synchronous dawn-dusk orbit. This makes NovaSAR-S complementary to other SAR systems by extending the range of daily imaging opportunities or improving coverage over equatorial regions. Table I presents an overview of the performance of NovaSAR-S's baseline modes.

TABLE 1
NOVASAR-S BASELINE MODES

Mode	Resolution	Incidence angles	Swath	No. of looks
1 ScanSAR	20 m	15.8-25.4°	100 km	4
		25.0-29.4°	50 km	4
2 Maritime	30 m	48.1-73.1°	750 km	1
3 Stripmap	6 m	16.0-25.4°	20 km	4
		21.8-31.2°	13-20 km	4
4 ScanSAR Wide	30 m	14.0-27.4°	140 km	4
		27.4-32.0°	55 km	4

III. NovaSAR-S Applications Overview

NovaSAR-S has been developed using an applications focused approach based on meeting the users need in the most cost-effective way and thus focusing on medium resolution applications. SAR imagery from NovaSAR-S will be suitable for a large and varied range of applications from wide area environmental monitoring to more detailed assessment of specific target areas. Operating between the SAR frequencies of C-band and L-band, an S-band system (around 3.2 GHz) can be reasonably expected to serve a similarly wide range of applications to those demonstrated by systems in these more traditional bands e.g. Envisat ASAR, Radarsat-1 & 2 and ALOS PALSAR.

Although wavelength is a key factor, the ability of NovaSAR-S to support specific applications is also dictated by other factors including resolution, coverage, imaging geometry, revisit time to an area of interest and the delay between image acquisition and information delivery to a user. The instrument specification and mission characteristics of the NovaSAR-S satellite have been designed to provide benefit to a range of applications - the key ones being maritime surveillance (including ship and oil slick detection), forestry, disaster monitoring (particularly flooding) and agriculture.

The following sections discuss the key applications in turn and show examples of the types of information and products, derived from NovaSAR-S data that could be provided to potential users. The SAR data displayed is S-band SAR imagery acquired by the Astrium airborne SAR demonstrator system during an imaging campaign over southern England and Wales in 2010. In order to acquire representative imagery the system parameters of the airborne SAR demonstrator were selected to represent those likely to be exhibited by a low cost spaceborne SAR system, and then post-processed by Surrey Space Centre, University of Surrey, to most closely match the specification of the NovaSAR-S baseline modes. An extensive amount of imagery was collected over areas specifically selected to provide a variety of landscape type and hence encompass a wide range of potential applications, including those associated with agriculture, forestry, urban, cartography, coastal and maritime.

IV. Maritime Applications

NovaSAR-S can address maritime applications by providing input to the situational awareness of activities at sea which impact on maritime safety and security. NovaSAR-S's wide area ScanSAR mode and, in particular, its innovative Maritime detection mode which offers a swath of 750 km, are able to cover wide areas with frequent updates hence providing an invaluable source of reliable ship data. In maritime mode a single sun-synchronous satellite can provide daily access revisits to any area of interest (see Figure 1).

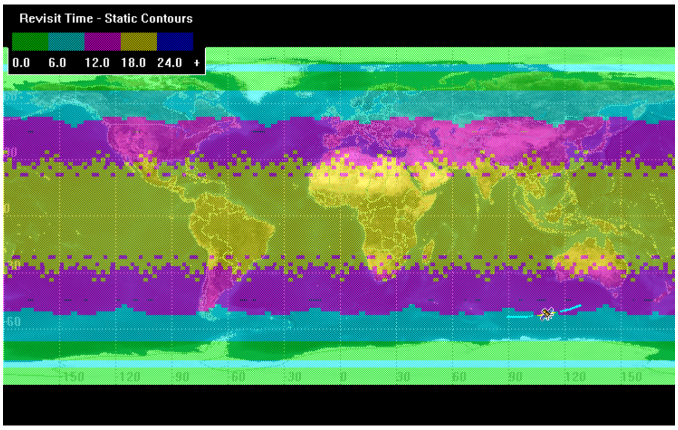

Fig 1. Average revisit time for 1 SSO NovaSAR-S operating in Mode 2.

In addition NovaSAR-S will carry an Automatic Identification System (AIS) receiver which, when used to collect data simultaneously with SAR imagery of the same area, will provide additional information on the identification of detected ships and highlight non-AIS transmitting vessels located in restricted areas. AIS is required to be carried for any ship over 300 tons, or for any passenger carrying ship, and the transmitted messages include unique identification, position, course, and speed data.

When operating in the more traditional ScanSAR and Stripmap modes the NovaSAR-S system will also be a useful tool for oil slick detection. The detection of oil slicks on the sea surface is useful for many applications including enforcement of maritime pollution laws and identification of offenders, support to clean-up and control activities, oil spill detection from remote pipelines and the detection of oil seepage from ocean floors indicating possible new oil fields.

The use of the NovaSAR-S wide area ScanSAR modes for initial slick detection combined with the high resolution Stripmap mode for detailed assessment, and AIS data for the potential identification of vessels at the source of the oil spill, will prove an invaluable data source for mitigating the environmental and economic impact of oil spills.

The following figures, which have been produced using SSTL's demonstration Maritime Applications Tool, show examples of the types of information and products that could be provided for maritime users.

Figure 2 shows the detection of ships within example S-band SAR imagery alone using edge detection and thresholding techniques. Position data, and approximate size of the detected vessels, can be derived and output as a list or on the displayed image. Ship detection algorithms optimized for S-band SAR are currently under development by the Surrey Space Centre, University of Surrey, UK [1], and EADS Innovation Works Singapore.

Figure 3 also displays simulated AIS ship detections, and an example ship track, based on the data contained in the AIS messages. The AIS receiver has a horizon to horizon field of regard and hence AIS data is collected from the area of interest for several minutes compared to the few seconds that is takes to acquire the SAR image of the same area. An error ellipse around the matched SAR response for a given AIS track is therefore drawn based on the potential time gap between the SAR and AIS detections, thus representing the uncertainty over the distance and direction in which the ship may have moved. This figure shows an area around the Isle of Wight in the English Channel (the world's busiest seaway) and highlights the number of non-AIS detected vessels some of which may be legitimate, due to the small size of the vessel, but some of which may deliberately not be transmitting AIS data. It is these vessels which may be of particular interest to certain users.

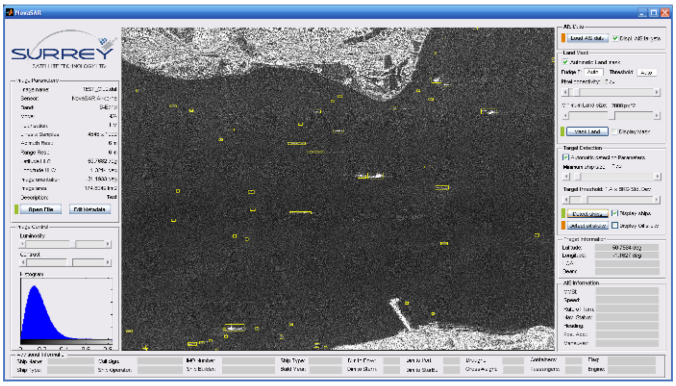

Fig 2. Ship detection in S-band SAR imagery.

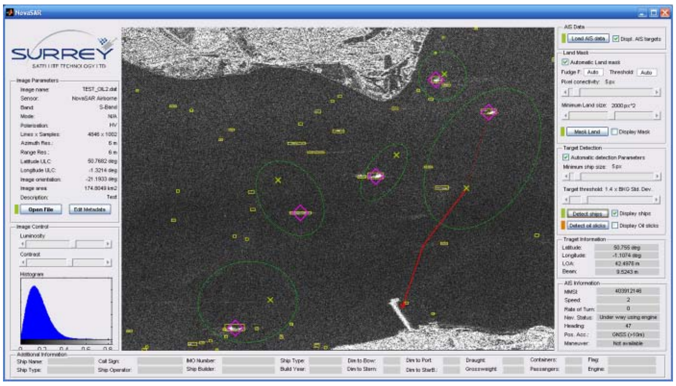

Fig 3. Ship detection using SAR imagery and AIS data.

Figure 4 shows the detection of a simulated oil spill in the SAR image. Again ship detections from SAR imagery and AIS data have been displayed. The ship tracks derived from the AIS data have been displayed to assess which ship may have been the cause of the incident.

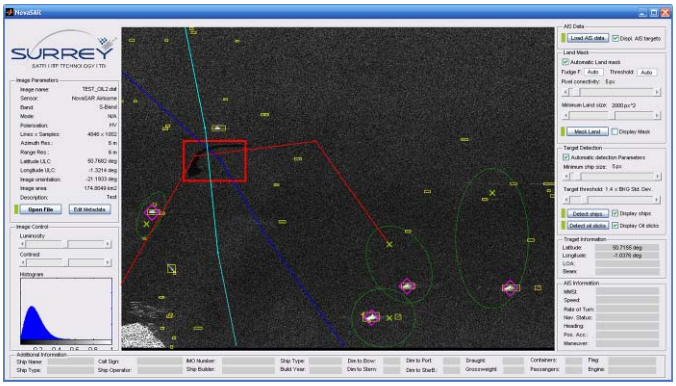

Fig 4. Oil slick detection combined with AIS data.

V. FORESTRY APPLICATIONS

Forestry is one of the main driver applications for the NovaSAR-S mission. Forestry management is becoming progressively more important as rates of deforestation and forest degradation continue to grow and as carbon taxing is implemented. Optical satellite imaging has been used for these purposes but unfortunately much of the forested areas under threat across the globe are in regions of high cloud cover. An advantage of SAR is its ability to see through cloud and S band is less prone to attenuation by cloud and rain than X band. Three NovaSAR-S satellites operating in ScanSAR mode can provide imagery of the entire Amazon Rainforest in approximately 11 days (Figure 5) with a maximum revisit time of less than 3 days to any area.

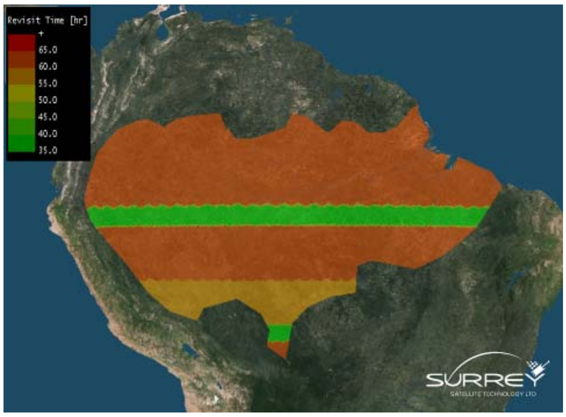

Fig 5. Maximum revisit for a constellation of 3 NovaSAR-S satellites over the Amazon Rainforest.

The NovaSAR-S ScanSAR modes will be able to support large area assessments and mapping activities while the high resolution Stripmap mode can support more detailed assessments of specific areas. S-band SAR has been shown to have some ability to penetrate the forest canopy to distinguish between forested and non-forested areas and to separate forest types [2].

Figure 6 shows a multipolarimetric S-band image of an area in the UK. A great deal of structure can be seen in the SAR image with forested and non-forested areas easily distinguishable and major routes through the trees clearly visible. S-band imagery therefore shows good potential for mapping of forest extent and, through change detection techniques, detection of deforestation. Figure 7 shows an image of the same area collected by the airborne demonstrator simultaneously in X-band. This comparison shows that S band provides similar but if anything better discrimination between forest and non-forest areas than X-band.

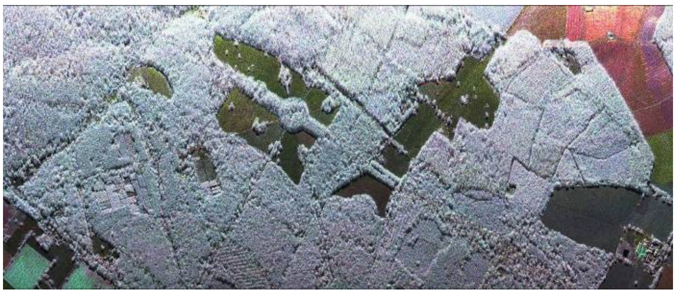

Fig 6. Multipolarimetric airborne S-band image of a forestry area in the UK

Fig 7. Comparison multipolarimetric airborne X-band image

Potential products include forest maps and identification of deforestation or degradation.

VI. AGRICULTURE AND RICE MAPPING

SAR imagery is a useful tool for land use mapping applications including cartography, land use monitoring, ecological monitoring, conservation, and management and planning activities.

Agricultural monitoring tasks that SAR can support include classification of different crop types, mapping of agricultural areas and soil moisture estimation. S-band has been proved to be successful in crop classification [3]. Multi-polarisation imagery from NovaSAR-S will also improve the ability to distinguish different crops (see Figure 8)

Fig 8: Multipolarimetric airborne S-band image of an agricultural area in the UK

Rice monitoring is of particular interest in the leading rice producing countries as it provides production estimates and assessments of the impacts of damage from natural disasters such as floods or droughts.

Rice mapping has been demonstrated using C-band (Radarsat/Envisat) and L-band SAR data hence the potential for NovaSAR-S to provide useful information for rice monitoring is high. When the rice is first planted the paddies are under water hence the fields appear dark due to low radar backscatter. The backscatter increases as the rice grows and the heads develop but decreases again as the crops mature. Hence several data acquisitions are required throughout the growing season. The use of multipolarisation also increases the ability to distinguish rice from other crop types. S-band will be able to penetrate the canopy hence providing more structural information. Simulations of rice backscatter at S-band have demonstrated the temporal variation of backscatter with HH exhibiting higher backscatter once the rice plant enters the transplanting stage [4].

VII. FLOOD MAPPING

For flood management applications NovaSAR-S's high resolution Stripmap mode will allow detailed assessment of flood extent and damage evaluation for specific areas of interest, particularly in urban areas. The ScanSAR modes will allow mapping of flood extent over wide areas. S-band penetrates through cloud and rain significantly better than higher frequencies and hence will provide a more reliable source of imagery in high rainfall areas.

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