NovaSAR: Next Generation Developments

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NovaSAR is a spaceborne Synthetic Aperture Radar (SAR) programme conceived by Surrey Satellite Technology Ltd (SSTL) and Airbus Defence and Space (Airbus DS), with support from the UK Government, employing a novel small satellite design capable of supporting the requirements of a high performance SAR payload [1].The current system operates in S-Band and focuses on maritime and forestry applications. The NovaSAR-S mission will demonstrate a highly capable system provided at a significantly lower cost than traditional spaceborne SAR systems. This first satellite, due for launch in 2016, will demonstrate the approach and technology adopted. In parallel a number of enhancements and developments have been identified which will not only extend the capability offered by the first mission but will also expand the utility of the NovaSAR programme - once again pushing the boundaries of small satellite system performance pioneered by SSTL. This paper discusses some of the potential modifications to the NovaSAR payload and platform design.

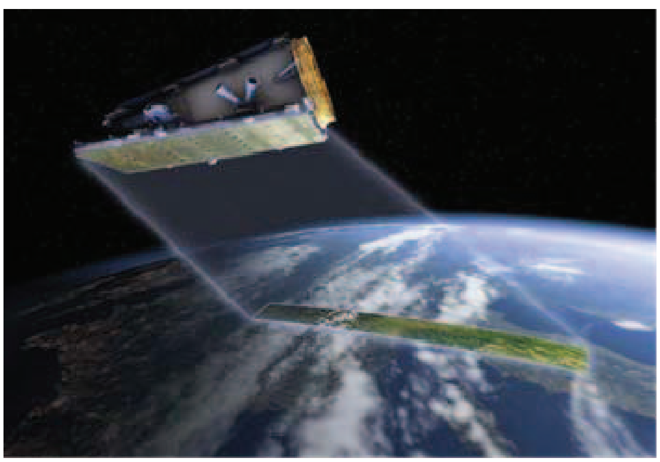

Fig 1: NovaSAR-S

I. THE NOVASAR PROGRAMME

NovaSAR is a spaceborne Synthetic Aperture Radar (SAR) programme conceived by Surrey Satellite Technology Ltd (SSTL) and Airbus Defence and Space (Airbus DS), with support from the UK Government, employing a novel small satellite design capable of supporting the requirements of a high performance SAR payload [1].

The first spacecraft, NovaSAR-S, is in manufacture in the clean rooms in SSTL and Airbus DS with the flight readiness review scheduled for 2016. This mission, planned with a seven year lifetime, will operate in S-band and provide imagery to meet a wide range of application needs, particularly forestry monitoring and maritime situational awareness.

Fig 2: Top: NovaSAR-S platform in the SSTL cleanroom, Bottom: Payload antenna at Airbus UK

The antenna and payload design offers a range of modes including a 6 m resolution Stripmap imaging mode and a novel 400 km wide area Maritime mode operating with high along-track ambiguity specifically to spot bright targets, such as ships and oil rigs, on the surface of the ocean [2]. Up to 5 million km^2 of imagery can be collected per day with areas revisited every 3 days on average.

In addition NovaSAR-S will carry an Automatic Identification Systems (AIS) receiver. This payload collects and processes ship identification messages from AIS transmitters which are required under maritime regulations to be carried by all ships over 300 gross tonnes. This ship detection data, when used to collect data simultaneously with SAR imagery of the same area, will provide additional information on the identification, location and track of ships and highlight non-AIS transmitting vessels located in restricted areas.

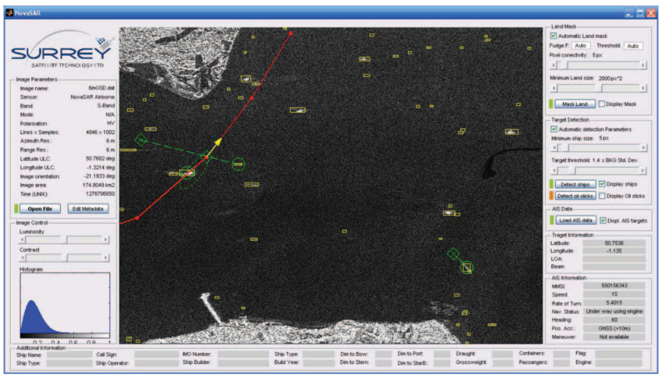

Fig 3: SSTL Demonstration Maritime Services Tool displaying an S-band airborne SAR image with simulated AIS data

II. Potential developments for future NovaSAR missions

The NovaSAR-S mission will demonstrate a highly capable system provided at a significantly lower cost than traditional spaceborne SAR systems. However, such cost savings require some compromise in performance. A number of enhancements and developments have therefore been identified which will not only address some of the limitations of the first mission but will also expand the utility of the NovaSAR programme - once again pushing the boundaries of small satellite system performance pioneered by SSTL. A subset of the proposed modifications to the NovaSAR payload and platform designs are discussed below.

A. Increased Antenna Area

Increasing the size of the NovaSAR antenna would enable access to higher incidence angles and reduce the power needed during imaging, reducing the peak power requirement of the mission and hence increasing the imaging time capability per orbit.

The current NovaSAR-S SAR payload antenna design is for a fixed non-deployable antenna sized to allow at least two satellites to be accommodated in a Dnepr, Vega or PSLV fairing or similar. The antenna is made up of an array of 6x3 phase centres. This configuration results in a total antenna area of 3x1 m with the required element spacing.

One of the simpler antenna modifications would be to add an additional two rows of phase centres, resulting in an 8x3 phase centre array, which would allow for enhanced performance but could limit options for accommodating more than one satellite in a launcher. Increasing the antenna size through the use of deployable panels can also be considered. This would preserve the current launch envelope but would add to the mission complexity.

The addition of the two rows of phase centres would enable a reduced pulse duty cycle from 25%, for the existing configuration, to approximately 14%. Although the standby power consumption of the payload would increase, due to the higher number of phase centres, the allowable reduction in pulse duty cycle would result in a reduction in the payload imaging power requirement from ~2.2 kW to ~1.3 kW; a reduction of ~40%. This, in turn, could be employed to either reduce the orbit average power consumption if maintaining the current payload duty cycle, or allow an increase in the total imaging time per orbit from approximately 3 to 4 minutes. Other impacts on the payload and platform however would need to be considered, for example data storage and the ability to downlink the acquired data in the required timeframe.

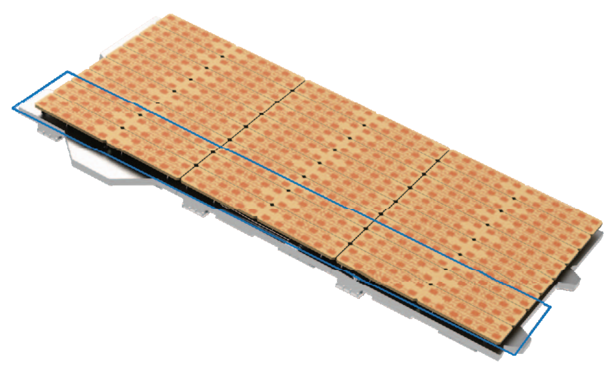

Fig 4: Increase in antenna area by the addition of two rows of phase centres

B. Increased Orbit Control

The ability to tightly control the orbit of a SAR satellite provides a number of benefits. An obvious benefit of precise orbit control is the enabling of operational interferometry such that the critical baseline is maintained over the lifetime of the mission allowing both short term and long term changes to be monitored. Other benefits include the ability to maintain lower orbits, hence improving the radiometric performance of the SAR due to the increased received RF power at the sensor array.

The current propulsion capability of NovaSAR allows for orbital injection error correction and altitude maintenance, consistent with a small satellite approach. An additional dV allowance (~10 m/s dV) has been made to enable InSAR experiments or to allow for a less accurate launch capability.

To maintain the orbit path to within a few hundred metres for successive orbit repeat cycles, required to maintain the critical baseline for interferometric operation, would require between 1 and 3 m/s dV per year depending on atmospheric conditions.

Currently, therefore, opportunities for inteferometric measurements on the first mission are limited to either controlling the orbit over a short section of the satellite's total lifetime to provide a demonstration interferometric capability, or ad hoc opportunities using archive image pairs with the appropriate interferometric baseline.

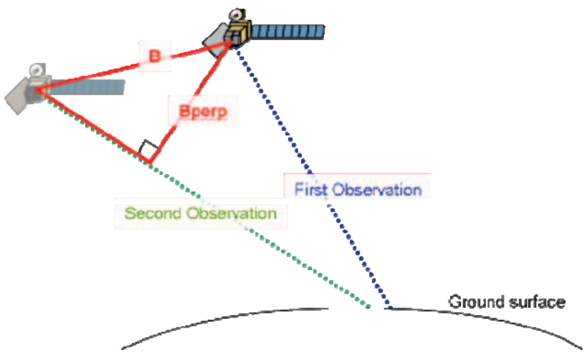

Fig 5: Interferometric geometry

Options for improving the orbit control include modifying the spacecraft design to allow a greater propellant volume to be accommodated, using alternative higher performance propellants and including an electric propulsion system, with modifications to the structure and power generation capabilities as appropriate.

In addition to SSTL's heritage propulsion system the first NovaSAR mission will also fly the QCT-200 electric propulsion system, currently under development by SSTL, Surrey Space Centre (University of Surrey) and Airbus UK. As well as providing a technology development flight opportunity, flying the QCT-200 on NovaSAR will improve the dV capability by almost an order of magnitude which could potentially allow the requirements for Interferometry to be met over an extended period of time and pave the way for an operational interferometry capability to be offered by future NovaSAR missions.

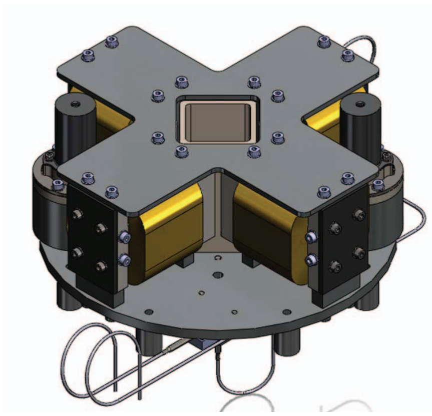

Fig 6: QCT-200

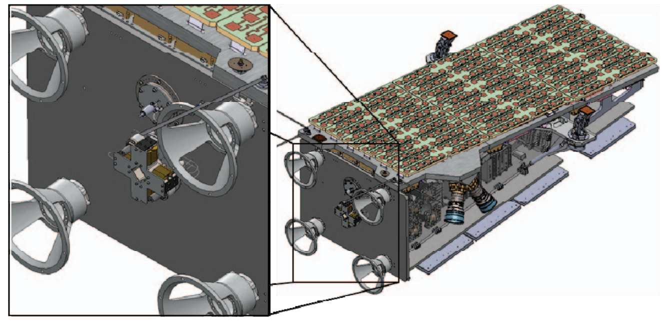

Fig 7: QCT-200 located on the NovaSAR platform

C. X-Band Variant

X-Band is a widely used waveband for SAR systems as it allows finer imaging resolutions to be achieved, due to the broader available imaging bandwidth, and the ability to image out to larger incidence angles with the same antenna area. It also provides more antenna gain for the same antenna area than for longer wavelengths. An X-band variant of NovaSAR would, like its S-band precursor, be able to address a wide range of applications. However the shorter wavelength would provide complementary information to that provided by the S-band system and be of particular benefit for applications such as security and urban mapping. With both NovaSAR-S and NovaSAR-X in orbit at the same time synergistic observations between the two wavebands would be possible on a regular basis.

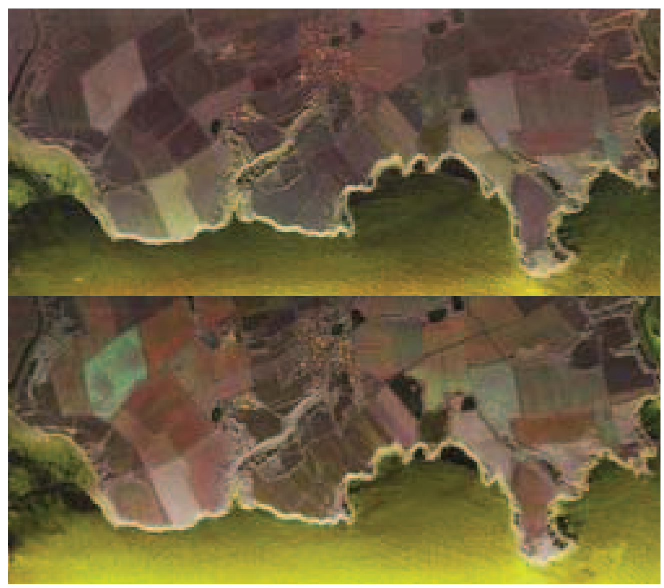

Fig 8: Comparison of X-band (top) and S-band (bottom) imagery of S Wales agricultural area (from Airbus UK airborne SAR demonstrator)

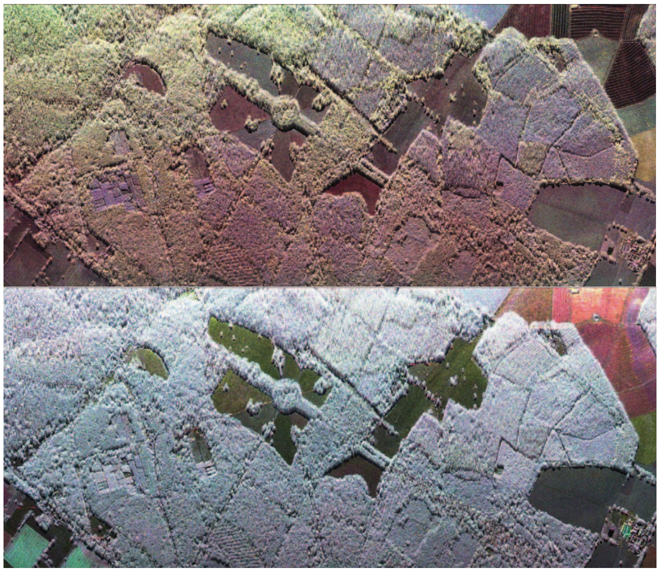

Fig 9: Comparison of X-band (top) and S-band (bottom) imagery of Southern England forestry area (from Airbus UK airborne SAR demonstrator)

Gallium Nitride Solid State Power Amplifiers (SSPAs), which have been the enabling technology for the low cost NovaSAR-S system, are now available in X-Band with good levels of efficiency hence a low cost X-band SAR satellite is now realisable.

The short wavelength of X-band compared to S-band enables a much higher maximum incidence angle (>50°) from the same antenna area resulting in significantly wider access and, hence, reduced revisit times. Due to ships having a higher radar cross section at X-band than at S-band the swath width for Maritime mode would also be significantly larger (potentially up to 600 km).

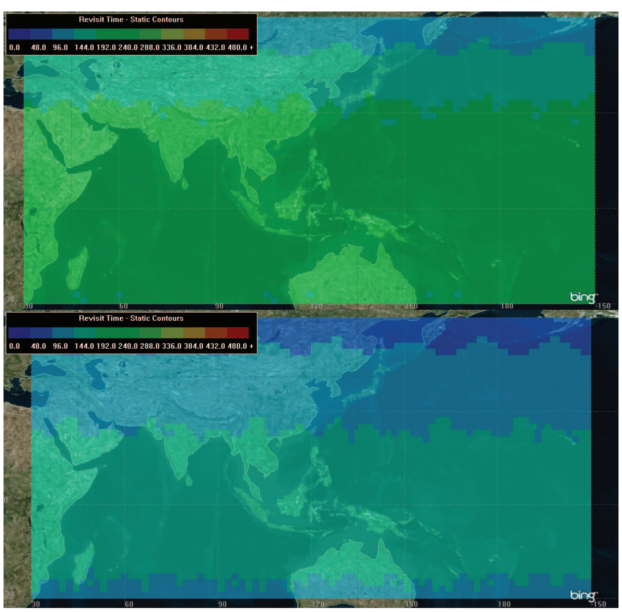

Fig 10: Average revisit time: Top – Maritime mode S-band (4-10 days); Bottom Maritime mode X-band (2-8 days)

ITU regulations allow a wider bandwidth at X-band (600 MHz vs 200MHz at S-band). A Stripmap mode with a resolution of 2m over a swath width of 20 km could be achieved with acceptable sensitivity and ambiguity performance.

Implementation of an X-band variant of NovaSAR could utilize the same antenna area (3x1 m) but would require an increase in the number of phase centres (to around 32-48) with correspondingly smaller electronics. The existing control electronics design could also be utilized with only a few modifications required to implement the change from S-band to X-band. The higher resolution will have an impact on antenna design as the higher transmit bandwidth requires shorter radiator sub arrays. In addition the tolerances on the planarity of the antenna are more critical for X-band than at longer wavelengths.

D. Increased Payload Duty Cycle

Improving the orbital duty cycle of the SAR payload will allow a greater volume of imagery to be collected and hence provide the ability to meet a greater proportion of users' requirements, albeit with the obvious consequence of adding pressure to the data storage and downlink functions.

As discussed previously two additional rows of phase centres to the S-band SAR payload will allow an increase in payload duty cycle by more than 30%. An alternative option for increasing the duty cycle is to improve the power generation capability by increasing the solar panel area either through the use of deployable solar panels or with an additional lateral solar panel which was originally baselined for a dawn-dusk design of NovaSAR. Employing both the current and lateral solar panels has the potential to increase the payload duty cycle by up to 50%. Impacts on the platform would include changes to the thermal design as a lateral solar panel would cover the current radiator panel, mechanical changes in order to incorporate changes to the thermal design, and accommodate the additional power modules, and an increase in the mass budget due to the extra panel and the associated electronics and harness.

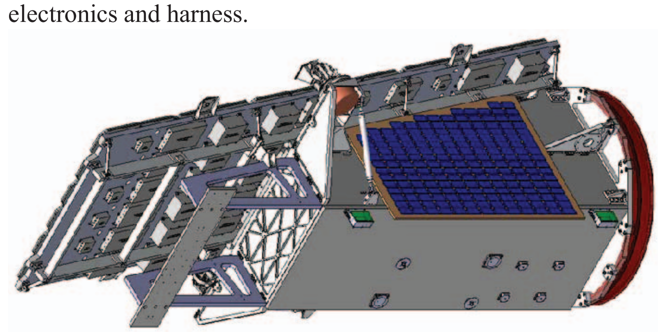

Fig 11: Lateral solar array originally baselined for dawn-dusk variant

E. Other Enhancements

Along with the SAR specific enhancements SSTL is continually improving the capability of its platforms and sub-systems, including avionics, data downlink, on-board data storage and computing capabilities through a combination of mission programs and technology development activities.

The SSTL avionics suite has been improved, along with data storage and on board computing. Within the timescale of the next NovaSAR mission these improvements may help realise mass reductions of the order of 10% on this platform type with corresponding launch cost savings.

Parallel activities include the modification of the X-Band downlink chain currently on board NovaSAR-S to a Ka band variant [3]. While using Ka band results in increased platform stability and control requirements, the narrower beam allows for higher power and much higher data downlink rates.

Figure 12: 'Selfie' of the SSTL high gain antenna pointing mechanism on board TechDemoSat-1

III. SUMMARY

The first NovaSAR-S mission will demonstrate a highly capable system provided at a significantly lower cost than traditional spaceborne SAR missions. A number of enhancements and developments have been presented which will expand the utility of the NovaSAR programme by pushing the boundaries of small satellite system performance.

REFERENCES

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[2] P. Iervolino, R. Guida, P. Whittaker. "NovaSAR-S and Maritime Surveillance". IEEE Geoscience and Remote Sensing Symposium, 2013-07-21 - 2013-07-26, Melbourne, Australia. 2013.

[3] Ferris, M., & Phillips, N. (2011). The use and advancement of an affordable, adaptable antenna pointing mechanism. In *Proc. 14th Eur. Space Mech. Tribol. Symp* (pp. 227-234)