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ASTROSAR-LITE – A RADAR SYSTEM FOR THE TROPICS

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Abstract. The Earth's low latitude zones are arguably those most able to benefit from Earth observation systems, which,access remote regions over a wide area requiring little ground infrastructure, delivering timely, accurate and independent data to whole communities. Existing systems have been deployed into high inclination orbits – optimised for northern hemisphere coverage but with very poor service to the equatorial and tropical regions, as until now there has been no suitable low cost launcher or compatible satellites available. That is changing - EADS Astrium and its partners have developed a unique low-cost SAR satellite system 'AstroSAR-Lite' providing high performance radar imagery with unprecedented capability in terms of all-weather, day/night, high resolution, and wide area imagery. With up to 15 revisits per day, whole nations can be imaged within a 1-2 weeks and a 1 million sq km of exclusive economic zone can be imaged each pass for maritime use. Astrium is further enhancing operational utility by facilitating an AstroSAR Lite 'Constellation Club'.

Keywords: EARTH OBSERVATION, RADAR SATELLITE, MARINE MONITORING HIGH REVISIT.
OBSERVAÇÃO TERRESTRE, SATÉLITE DE RADAR, ALTA REVISITA MARÍTIMA QUE CONTROLA.

1. INTRODUCTION

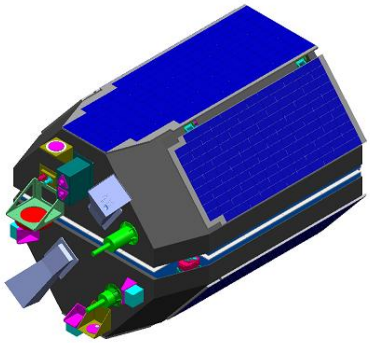
The AstroSAR-Lite X-band radar satellite presents an innovative system solution to meet the needs of Earth Observation in all regions of the world but with specific emphasis on providing unparalleled service to users in and around the tropical regions.

With a wide range of available imaging modes, the AstroSAR-Lite satellites are equally adept at meeting both the requirements for high sensitivity, high resolution land imaging and the wide swath modes favoured in the detection of offshore shipping. AstroSAR-Lite's unique 900km swath maritime mode allows up to 1million km^2 of exclusive economic zone to be imaged on each pass. Spotlight mode and interferometric imaging is also possible.

Through the use of qualified, existing and proven hardware, together with highly efficient system design and integration techniques, EADS Astrium are offering a low risk, low cost route to ownership of an imaging Earth observation system with an unmatched price / performance combination. Unlike optical systems, it is independent of Earth illumination and prevailing weather conditions, resulting in a significant increase in operational effectiveness.

In recognition of the fact that the various users will have a range of differing priorities and requirements the AstroSAR-Lite satellite has been designed in a modular fashion around a robust and fixed architecture. This allows a high degree of tailoring of the performance without loss of heritage or qualification status.

This paper provides an insight into the overall system design, the heritage and performance of the AstroSAR-Lite satellite.



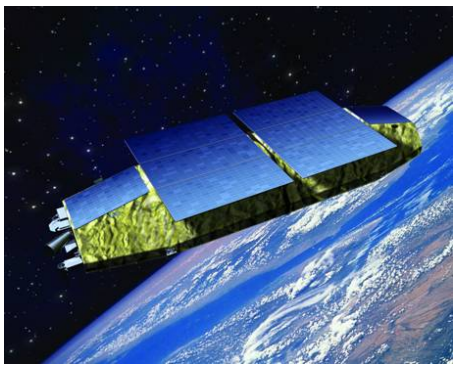


Figure 1 & 2 The AstroSAR-Lite Spacecraft in its Operational and Launch Configurations

2. SYSTEM OVERVIEW

AstroSAR-Lite is a satellite system comprising a number of components specifically designed or selected to optimise its overall performance:

- Snapdragon physical configuration
- Qualified and existing platform equipments
- Qualified and existing radar equipments
- Falcon 1 launcher (or back-up vehicle)

The satellite is designed to operate in any orbit from polar through to near equatorial, with no change in hardware. This has been of paramount importance, since it is recognised that customers will request orbit inclinations most suited to their region but would not wish to incur additional costs for this tailoring of the satellite.

The design provides for a baseline minimum imaging window of ~1,000km per orbit: every day of every year for the satellite lifetime. This may be extended to three such imaging durations within each orbit enabling out-of-region or constellation 'shared resource' operations.

The patented mechanical configuration is unique in the field of satellite design. The design recognises the SAR antenna as the most important part of the radar system. It is configured as two equal halves along the centre plane of the stowed satellite. This provides the largest possible antenna area to be fitted into the launch vehicle with only a single hinge line and mechanism. The antenna support structure, like the overall satellite structure, is fabricated from carbon fibre providing high mechanical stiffness, low roll inertia and thermo-elastic stability.

For the baseline configuration the solar arrays are body-mounted. When not imaging or down linking the whole satellite rolls about the velocity vector to point the arrays at the sun so as to enhance the power generating capability.

With its smallest cross-section facing the in-orbit velocity vector the long, thin, deployed profile results in a very low coefficient of drag and hence a low requirement for orbit maintenance propellant. The low mechanical inertias associated with this design enable rapid transitions from right to left looking for imaging even with the standard attitude control sensors.

The overall satellite is designed to fit within the Falcon 1 launch vehicle. As well as providing the lowest cost single launch this vehicle offers direct injection into all orbits from

polar to near equatorial. Clearly, since the satellite is compatible with the Falcon 1 fairing it is also compatible with all the larger launch available launch vehicles.

3. ACCESS & REVISITS

Injection into low inclination orbits is of paramount importance in providing maximum access and revisits to the equatorial and tropical regions. Traditionally Earth observation satellites have been launched into sun-synchronous polar or high inclination orbits. Whilst this does provide global access the revisit rates at the equator are typically less than one per day. Even at 50 degree inclination orbit (optimised for Southern Chile) revisit is typically 4 times greater than with a polar orbit

A single AstroSAR-Lite, operating from a 7 degree orbit provides up to 13 revisits per day with a minimum revisit interval of only 90 minutes. A constellation of 3 reduces this to 30 mins.

The figure below demonstrates how, with only a single satellite, the orbit inclination can be selected to maximise the revisit rate at any latitude from equatorial through to polar. For the equatorial and tropical regions this vastly improved access will enable applications where near real-time imaging is essential. It can also be seen from this figure that even a very small constellation of AstroSAR-Lites can be deployed to bring high and near equal revisit rates to wide areas of the globe.

When the access and revisit performance is augmented by another spacecraft the revisit performance is enhanced. With a constellation of at least three such spacecraft it can be shown that by using a near equatorial orbit a user can expect to see one or more satellites every orbit period, or 90 minutes. The precession of the orbit results in each member of the constellation being visible for one third of the mission's lifetime, so with three satellites there is always a spacecraft to be tasked with providing imagery. This architecture provides an excellent system for monitoring a region and applications such as change detection are well served.

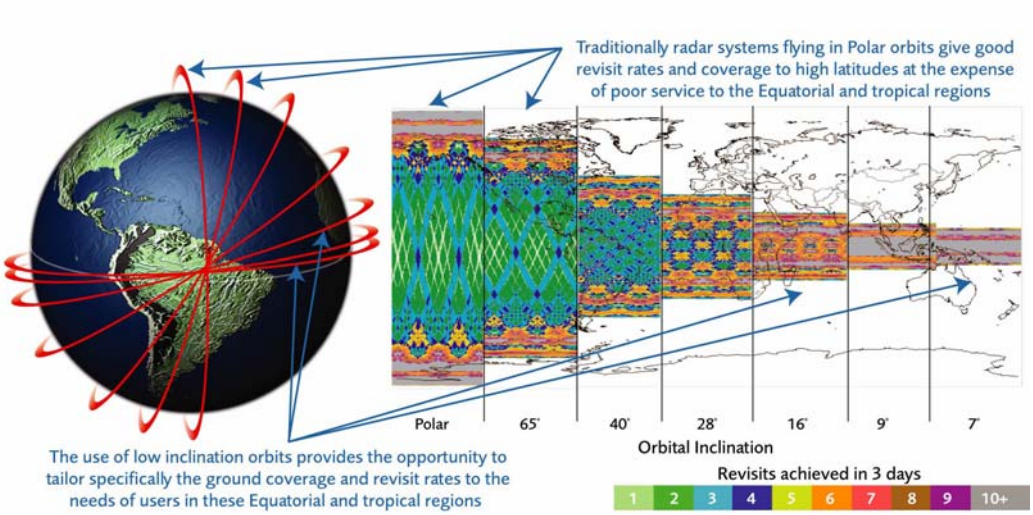


Figure 3 Effect of orbit inclination on access

4. 'CLUB' CONSTELLATION

The already revolutionary performance afforded to tropical nations by the AstroSAR-Lite system is improved by a further order of magnitude if even a small constellation of satellites can be accessed. Yet the cost of a constellation is prohibitive for many users. Astrium have therefore facilitated the formation of a 'Constellation Club' amongst AstroSAR-Lite owners.

Whilst retaining autonomous control of their own satellite owners have the option to access a growing constellation for the price of only one satellite, trading their excess capacity outside region for secure access to other club satellites over their own region. This concept has proved attractive to the majority of AstroSAR-Lite customers and it is likely that at least 3 of the first 4 satellites, scheduled for launch in 2010, will opt to join the constellation with several more joining later.

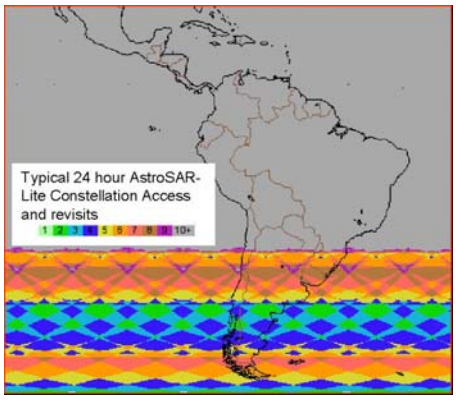


Figure 4 High revisits across South America

5. HERITAGE

With its background as a major supplier of satellite systems for over 40 years and the European leader in SAR satellite systems EADS Astrium is extremely familiar with the need to clearly demonstrate the maximum possible heritage for its products prior to the first launch. With this in mind the AstroSAR-Lite satellite has been specifically designed for low risk as well as low cost. In the broadest terms this has been achieved through the use of existing hardware and terrestrial-based demonstrations of the instrument.

The instrument can be considered as having two major parts – the phased array antenna together with its transmit and receive amplifiers, and the central electronics that is responsible for generating the transmit radar signal and collecting and formatting the received echoes. The central electronics is virtually identical to that produced by EADS Astrium for the RadarSAT-2 programme.

The antenna consists of 180 simple and robust identical phase centres, each with its own transmit and receive amplifiers and rechargeable battery power supply. This antenna architecture and the central electronics have been configured within an airborne programme and flown successfully around the UK. This radar has acquired imagery to both demonstrate the instrument operation and to provide real data to exercise the synthetic aperture radar on-ground processor, and the results are representative of the quality that will be available from the AstroSAR-Lite satellites.

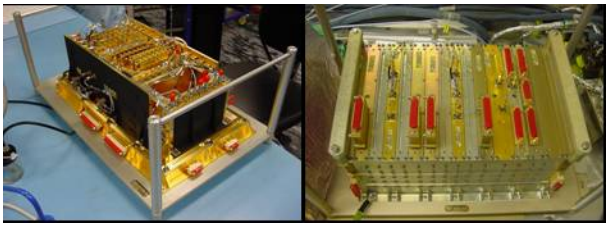


Figure 5 Radarsat 2 Electronics

Figure 6 X-Band AstroSAR airbone demonstrator

In addition to providing representative flight data for the current AstroSAR-Lite satellites this airborne asset is being continually updated to demonstrate, for example, the ability to create digital elevation models from a pair of orbiting satellites. Meanwhile Astrium are launching Europe's most advanced SAR satellite to date in late 2006. TerraSAR-X is twice the size of AstroSAR-Lite and designed for global coverage from polar orbit for commercial exploitation by Astrium's applications company Infoterra. It can produce commercial imagery almost identical to that which will be available (but with much higher revisit) from AstroSAR-Lite in 2010. This allows customers to trial AstroSAR-Lite applications and ground infrastructure from 2006 using TerraSAR-X data ensuring a fully operational end-to-end system from day one.

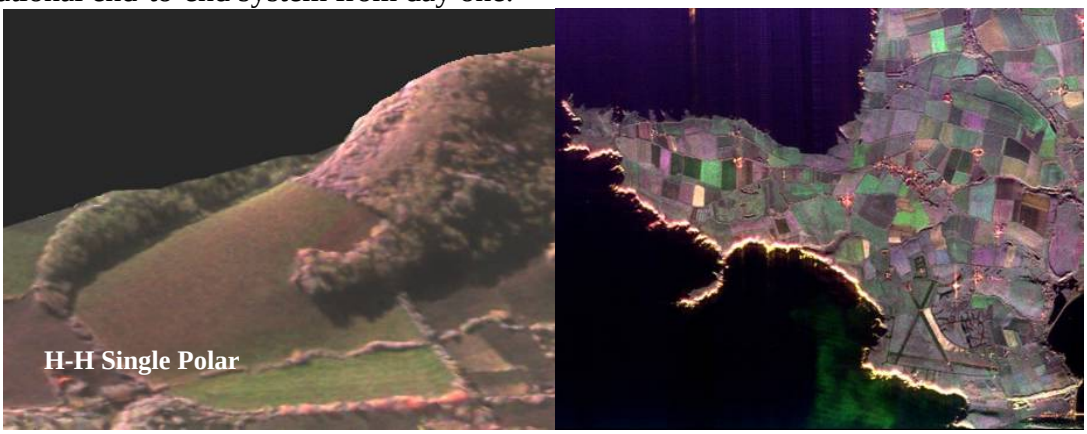


Figure 7 AstroSAR Demonstrator SAR Imagery

The AstroSAR-Lite platform is also based on proven, qualified, elements. The structure is a simple single-skinned filament wound carbon fibre hexagon cut in half to form the two linked parts of the satellite.

All the detailed processes and representative hardware have already been qualified. This structure design has also been selected for ESA's Swarm mission.

The mechanisms responsible for restraining the two halves during launch and then deploying to the on-orbit configuration come directly from EADS Astrium's telecom programmes where they have been used extensively in securing and deploying antennas on all EUROSTAR programmes.

Similarly the platform electronics and attitude control sensors and actuators are existing units that have been flown on previous Earth observation missions.

6. PERFORMANCE

Through its very modular design AstroSAR-Lite offers a range of instrument modes that will be tailored to the needs of individual Customers. All performances quoted provide a minimum sensitivity of –19 dB. The range of performances for the baseline satellites is outlined in the following:

Orbit

The orbital height is between 500km and 525km. This has been selected as the optimum between the need to minimise aerodynamic drag and the desire to minimise the power requirements of the instrument. The orbit inclination can be selected at any value between 98 degrees and near Equatorial.

Operational Instrument Modes

The detailed performance in each mode depends upon the required resolution. The quoted performances are all at the highest resolution. The radar sensor is capable of being operated in any, and all, of the following modes:

- Strip map
- Scan SAR
- Wide Swath Maritime
- Spotlight
- Single polar
- Dual Polar
- Quad polar

An interferometric data product can be provided by returning the spacecraft to a prescribed location after each orbit repeat interval. In the absence of extremes of space weather the spacecraft then covers the same ground track over each repeat interval, allowing new and earlier images to be combined.

Imaging Duration

The satellite is designed to collect contiguous imagery for up to 1000km each and every orbit throughout its lifetime in the best resolution mode. It also has the flexibility to complete such imagery three times in a single orbit. Longer swaths can be imaged at lower resolutions.

Image resolution

The instrument has been proven to sub-metric resolution but as the instrument is modular it can be set at any value. Best resolution at export is regulated by the prevailing export legislation. This is currently set at 3m for most of the world.

Swath Widths

The nominal modes provide:

Stripmap 1 – 3m resolution with 20km swath
Stripmap 2 – 10m resolution with 40km swath
ScanSAR 1 – 30m resolution with 100km swath
ScanSAR 2 – 60m resolution with 200km swath
Spotlight – 1m x 1m over 10km x 10 km
Maritime – Ship detection over swaths up to 900km

Data Storage and Downlink

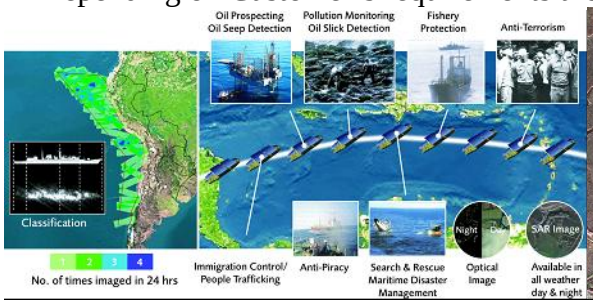
The minimum data storage (64Gbits) is compatible with storing 1000km of imagery at 3m resolution. Down linking is provided through a dedicated X-band link at 105Mbits per sec. The memory is expandable in blocks of 64 Gbits up to 256 Gbits, and the down link can be increased to 300Mbits/sec as an option.

Lifetime

The design lifetime is 5 years with optional extensions to 7 years.

Mass

Depending on Customer's requirements the launch mass is between 400-500kg.



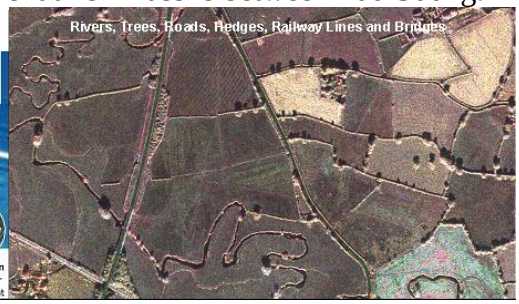


Figure 8 Maritime & EEZ Applications **Figure 9 Surface Features**

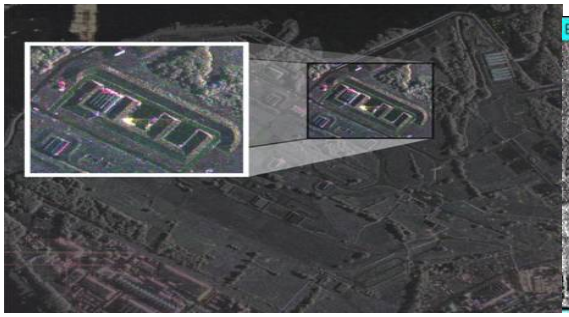


Figure 10 Security Monitoring

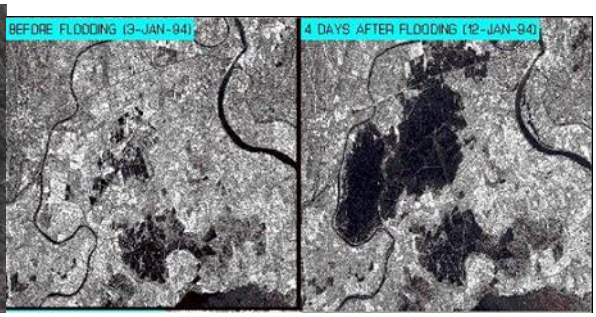


Figure 11 Flood Monitoring

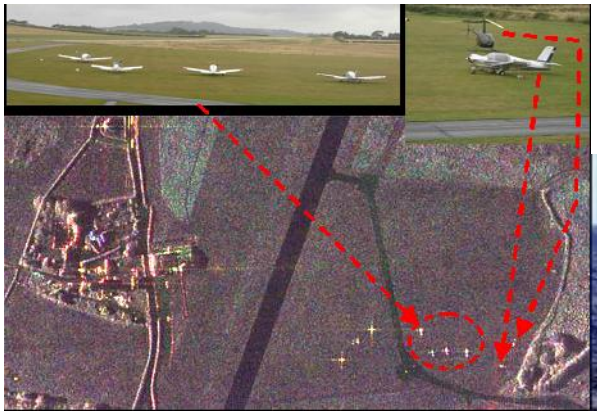


Figure 12 Aircraft Detection

Figure 13 Environmental Monitoring

7. CONCLUSION

In conclusion it is seen the AstroSAR-Lite System provides a near-continuous Earth observation system with an all weather night and day imaging performance that is comparable with larger and much more costly spacecraft. Using a combination of features available only from Astrium, namely the Snapdragon architecture, a high-performance antenna design and low mass and power space-qualified SAR central electronics, together with compatibility with the low-cost Falcon-1 launcher, then AstroSAR-Lite can out-perform any other system over the regions below 50 degrees of latitude. Astrium's unique very wide swath Maritime mode enables unprecedented levels of maritime monitoring, updating total maritime picture over 1 million sq km of sea per pass up to 15 times per day for equatorial nations. A single AstroSAR-lite already provides an order of magnitude advantage over other systems to tropical users, mapping whole countries in a week or two, but when used in a small constellation in terms of revisit, access and coverage performance further orders of magnitude are added – this remarkable breakthrough in persistent reliable space based monitoring will revolutionise our capability to manage the tropical environment and urban and infrastructure development, respond to regional disasters - whether natural or man made, ensure the security of food, fisheries, shipping, oil fields and oil transportation, and borders whilst helping to fight illegal logging, trafficking, immigration and corruption. Through the constellation club AstroSAR-Lite also provides a medium for international collaboration amongst the regions new and established space players. A role Astrium is proud to support and appropriate with our unequalled experience in international collaborations and technology transfer.