NovaSAR-S SAR Payload

Session 5 : Innovative Radar Development

CEOI EMERGING TECHNOLOGIES WORKSHOP
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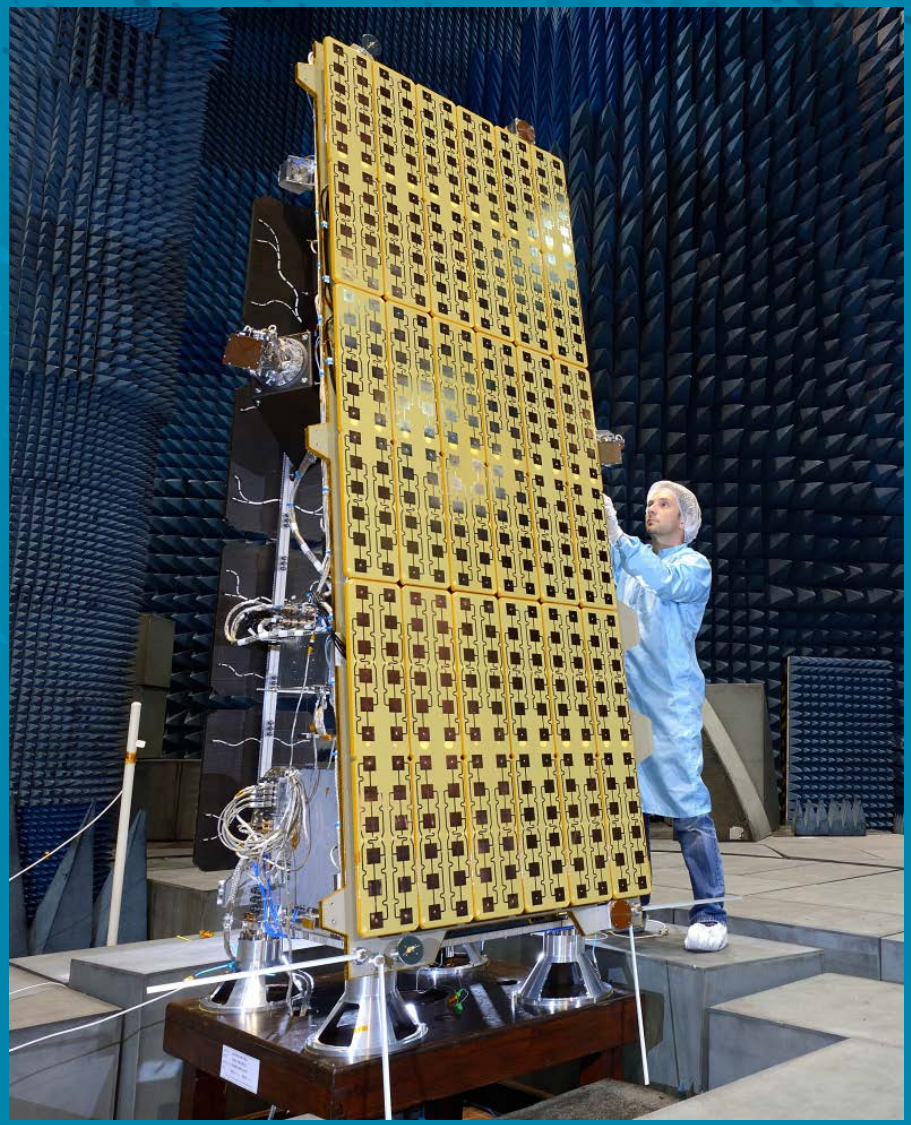

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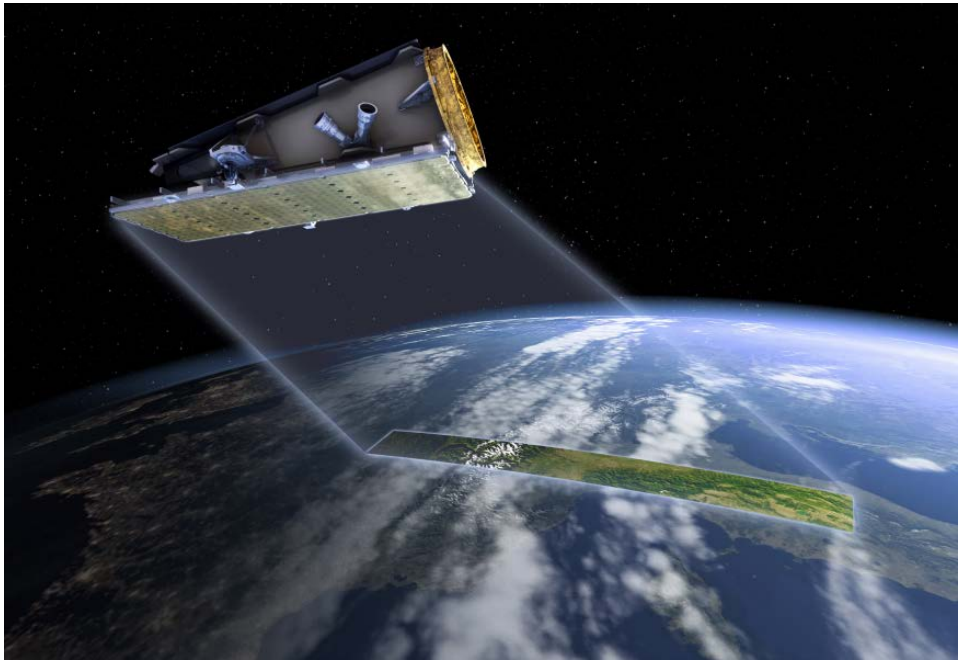
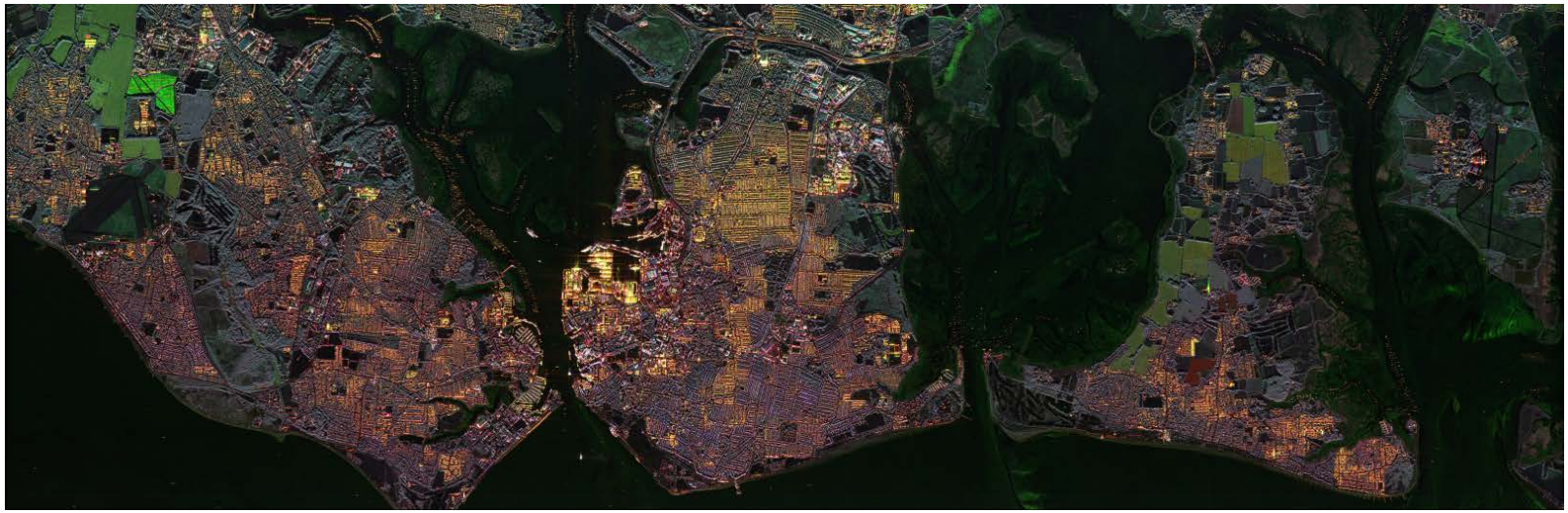
Introduction to NovaSAR-S



The NovaSAR-S payload is an S-band Synthetic Aperture Radar developed with low cost in mind, while maintaining performance and offering attractive applications.

Key enabling technology is exploited in an innovative design to disrupt the normal performance-to-cost ratio. The mission is a partnership between Surrey Satellites Technologies Ltd. (SSTL) and Airbus Defence & Space (Portsmouth), funded by the UK Government via the UK Space Agency.



S-Band Airborne SAR Image of Portsmouth

Acquired by AirSAR Demonstrator June 2014

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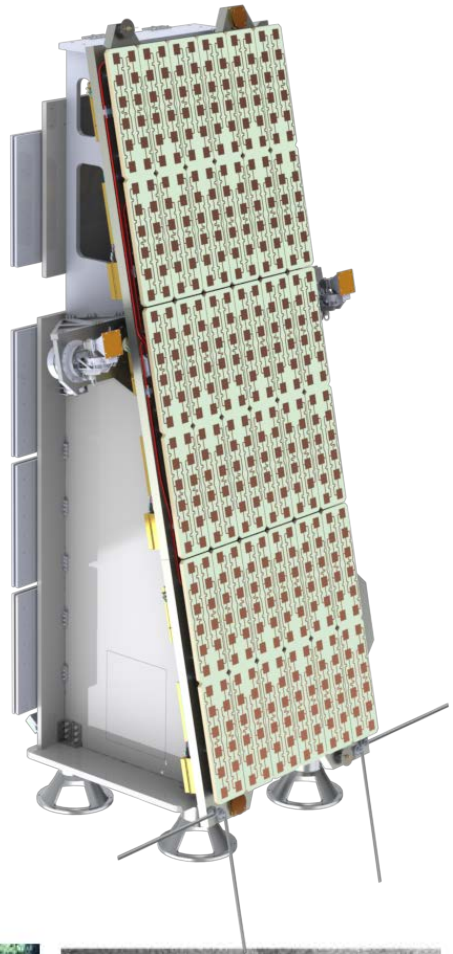
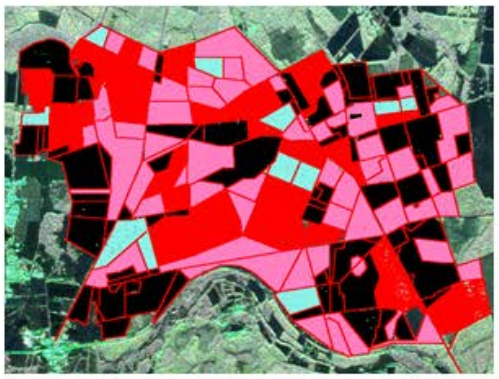
Why a low-cost SAR Mission?

- Space-borne SAR is traditionally an expensive undertaking and many potential customers are currently unable to afford such systems;
- Lower cost per satellite opens the door to constellations of SAR instruments and the possibility of rapid revisit applications;
- Lower cost per mission means lower cost per image product, enabling new products and applications available to a expanded customer base;

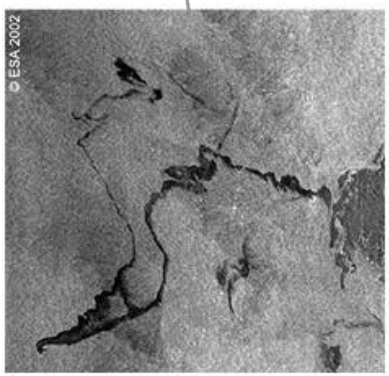


CARTOGRAPHY

COASTAL MONITORING



LAND USE CLASSIFICATION



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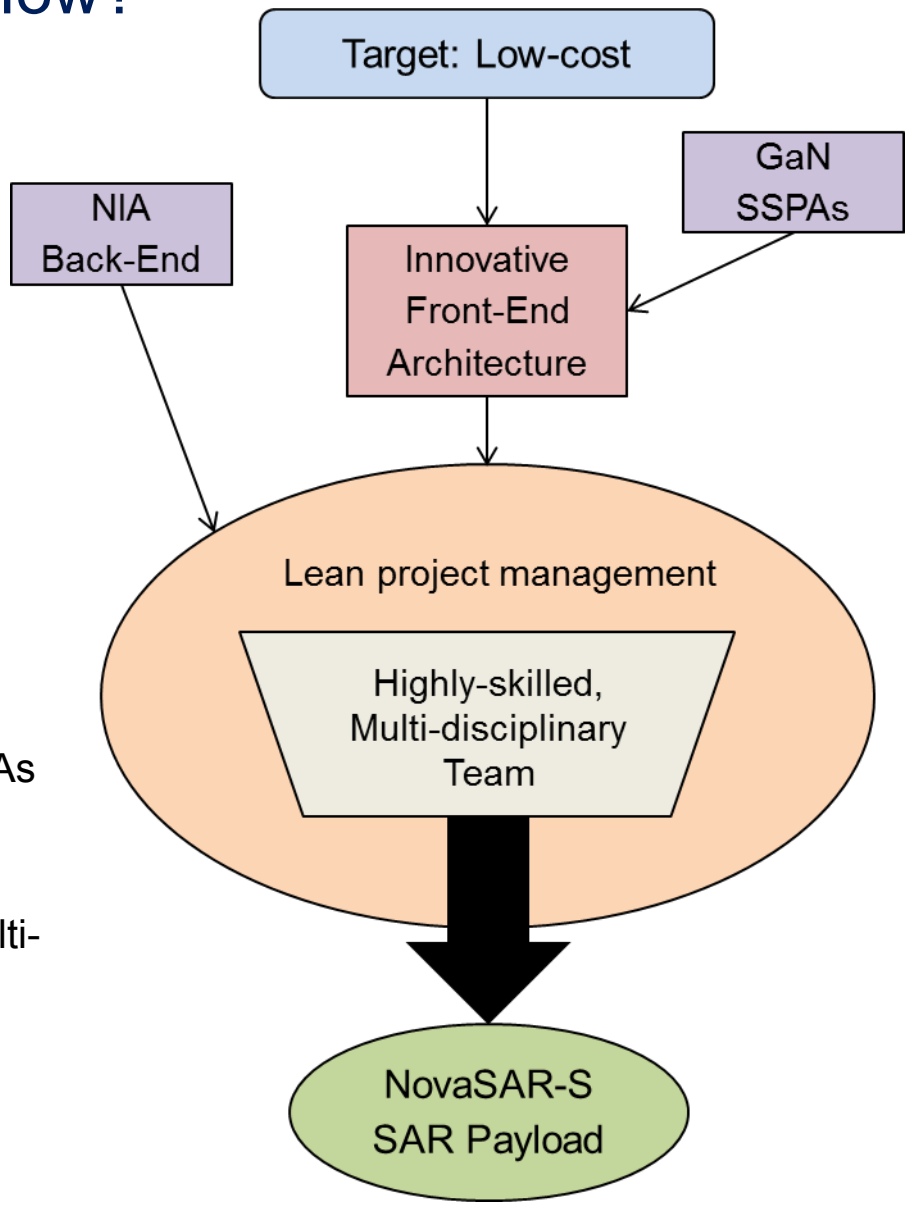
Developing a Low Cost SAR Payload: How?

Drivers

- Total mission cost of £50M in-orbit (including NRE);
- Capable instrument;
- Small enough to fit in low-cost launcher fairing – 3x1m

Enablers

- Innovative Front-End Architecture (Low phase centre count);
- Reduction of instrument complexity (No CPU / software);
- Low-cost, high-flexibility Back-End : Re-programmable FPGAs
- Intelligent parts selection and screening philosophy;
- Reduced number of subcontractors;
- Lean project management and a compact, highly skilled, multi-disciplinary team.



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Front-End Trade-off

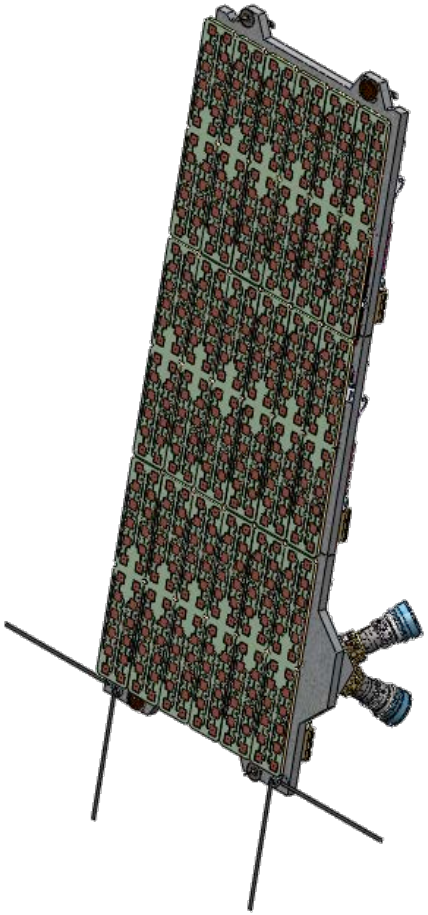
Traditional TWTA+Reflector was initially considered:

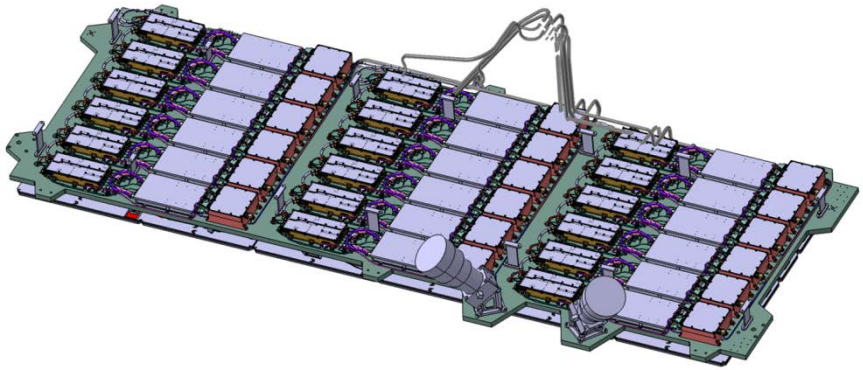
- Suitable solution for high frequency (X-Band);
- Simple Front-End architecture;
- Efficient use of antenna area;
- High-cost of TWTA units (dual redundancy is essential);
- Limited mode flexibility without complex feed array.

The advent of high-efficiency Gallium Nitride-based Solid State Power Amplifiers at S-Band facilitates:

- Approximately 10x more peak RF power per phase centre than normal;
- Approximately 10x less phase centres on antenna.

Detailed trade-off analyses were performed to ascertain performance of an S-Band Phased-Array Antenna of this architecture, with many phase-centre configurations considered.





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Front-End

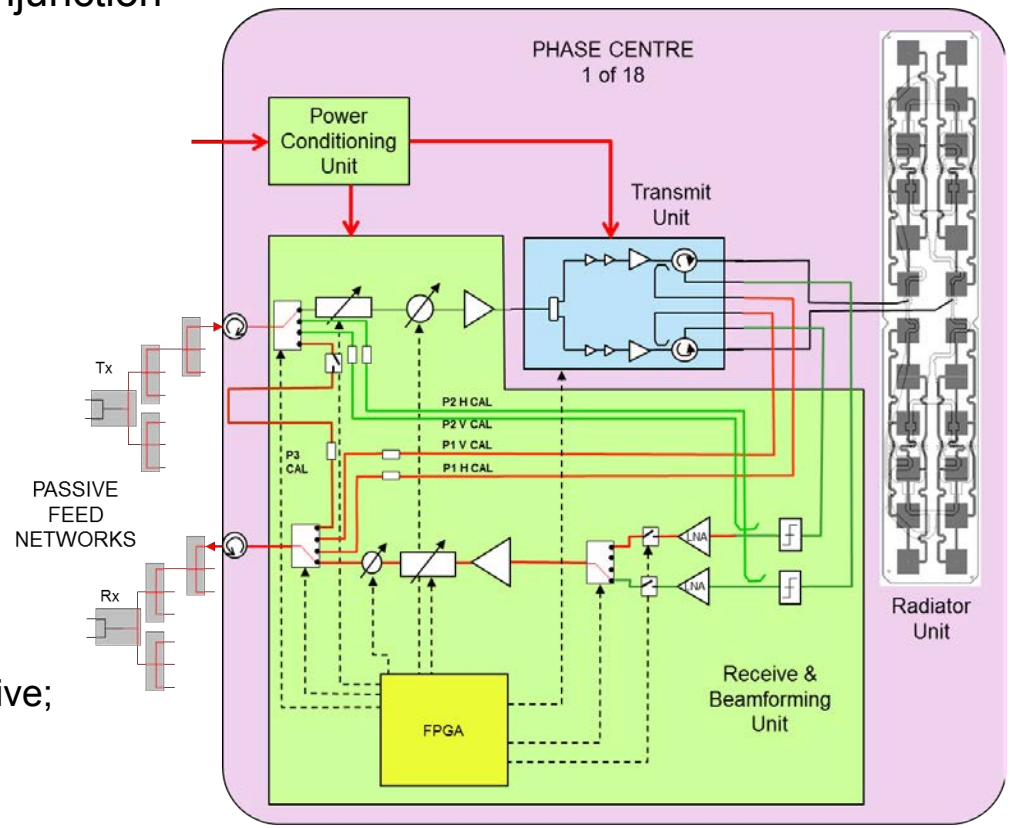
The result is a 18 phase-centre antenna, with 100 Watts of peak power delivered per phase centre, in a 3-column / 6-row configuration, all accommodated in a 3 x 1m panel.

An antenna area of 3m^2 presents its limitations but, in conjunction with careful tuning, delivers very attractive performance:

- 125 km access width for 20-31° incidence;
- 165 km access with incidence down to 16°;
- Down to 6m resolution with 15-20 km swath width;
- 20-30m resolution ScanSAR with 100-140 km swath width.

Key features of the NovaSAR-S Front-End:

- Low cost;
- Phased Array Antenna – Flexible operating modes;
- 'Graceful degradation';
- Up to 200 MHz of available Bandwidth (ITU regs.);
- 'P1, P2, P3' Calibration Scheme;
- Polarimetric Capability – H or V polarised transmit, H or V receive;
- Fully scalable.



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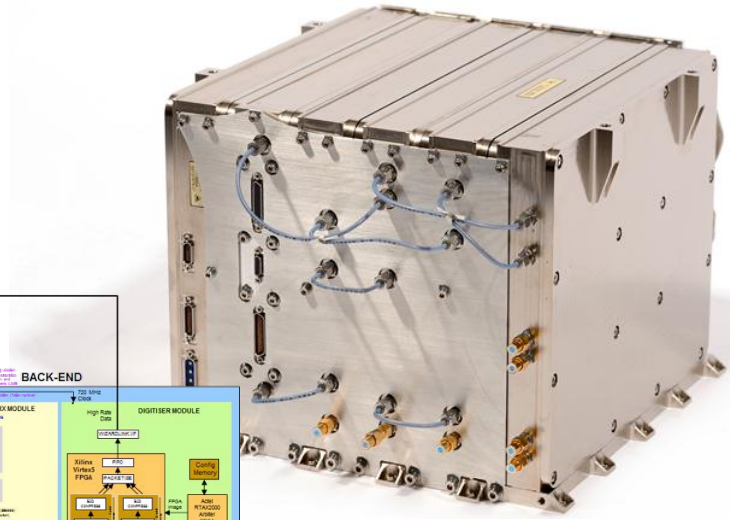
Back-End: The NIA Generic Central Electronics at work

The NovaSAR-S Payload uses Airbus Defence & Space's New Instrument Architecture (NIA) Generic Central Electronics for it's Back-End equipment, leveraging NIA's simplicity, flexibility, low mass, low power consumption and compact size.

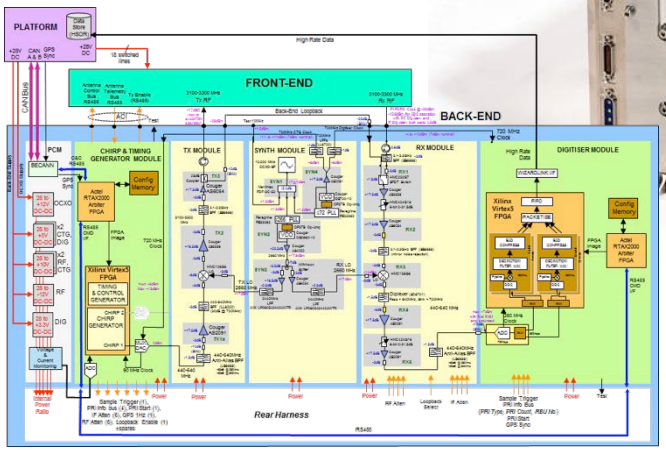
The NIA Generic Central Electronics (subject of another paper in this conference [2]), exploits the power and flexibility of Space-Grade Xilinx Virtex 5 Field-Programmable Gate Arrays (FPGAs), in tandem with high-speed data converters (ADC & DAC), providing a generic and modular Central Electronics solution for space radar payloads (SAR, Altimeters, etc..) that requires no CPU and is reprogrammable in-orbit.

NIA gives NovaSAR-S the flexibility needed to control the Front-End efficiently, exploiting its limited area to the fullest, and allows the implementation of complex and novel operation modes.



Key features of the NovaSAR-S Back-End:

- Simple - No payload software or CPU;
- Flexible and reprogrammable;
- Low-power: 46W;
- Low-mass: 10.9 Kg;
- Small size: approx. 209mm H x 265mm W x 272 mm D.



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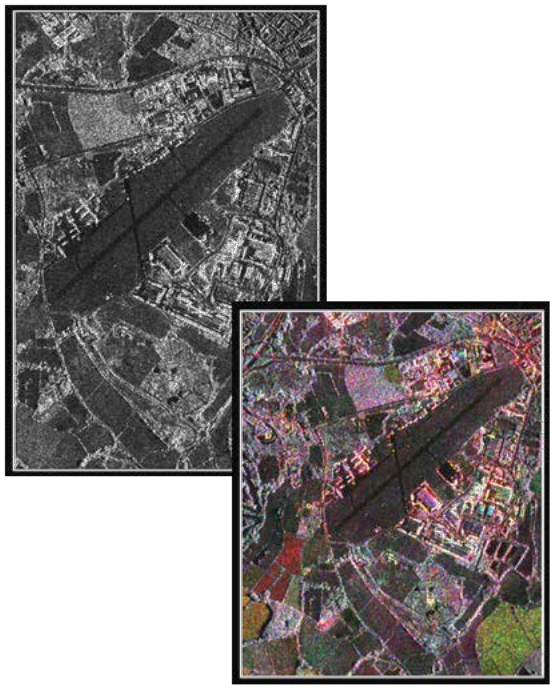
Baseline Modes and Performance

A set of baseline, single-polar operating modes were developed based on the selected antenna configuration. These are summarised as :

Mode Type	Spatial Resolution	No. of Looks	Swath Width
Stripmap	6m	3 (az.)	15-20km
ScanSAR	20m	4 (2 Rg, 2 Az)	100km
ScanSAR	30m	4 (2 Rg, 2 Az)	140km



Simulated NovaSAR-S Imagery

All modes:
Sensitivity: better than -20 dB;
Distributed Target Range Ambiguity better than -17 dB;
Distributed Target Azimuth Ambiguity better than -17 dB.

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Maritime Mode

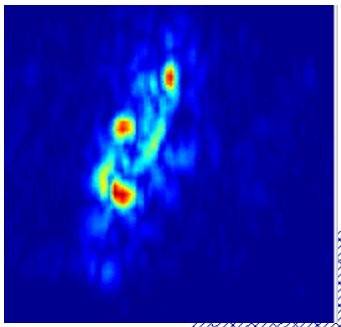
NovaSAR-S also delivers an innovative experimental Maritime Mode that is intended to enable open sea surveillance in a globalised world were the growing volume of shipping links is being threatened by piracy, extreme weather events and congestion.

This mode implements a novel low PRF timeline for wide-area ship detection in the open ocean, with the following characteristics:

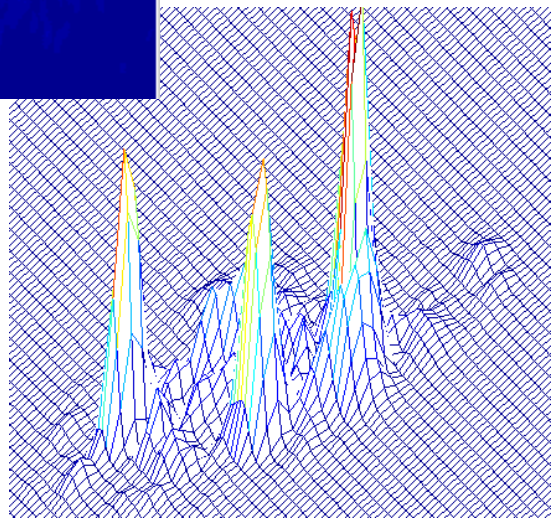
- Deliberately azimuth ambiguous ScanSAR;
- More than 400 km Swath width;
- ~34-57° incidence angle;

Analysis of S-Band airborne imagery of ships using the Airbus Defence & Space Airborne SAR Demonstrator enabled tuning of the baseline Maritime Mode design in order to balance detection probability, swath width, and false alarm rate (< 1 image pixel in 10^7)

Visual



SAR Image



Mesh Plot

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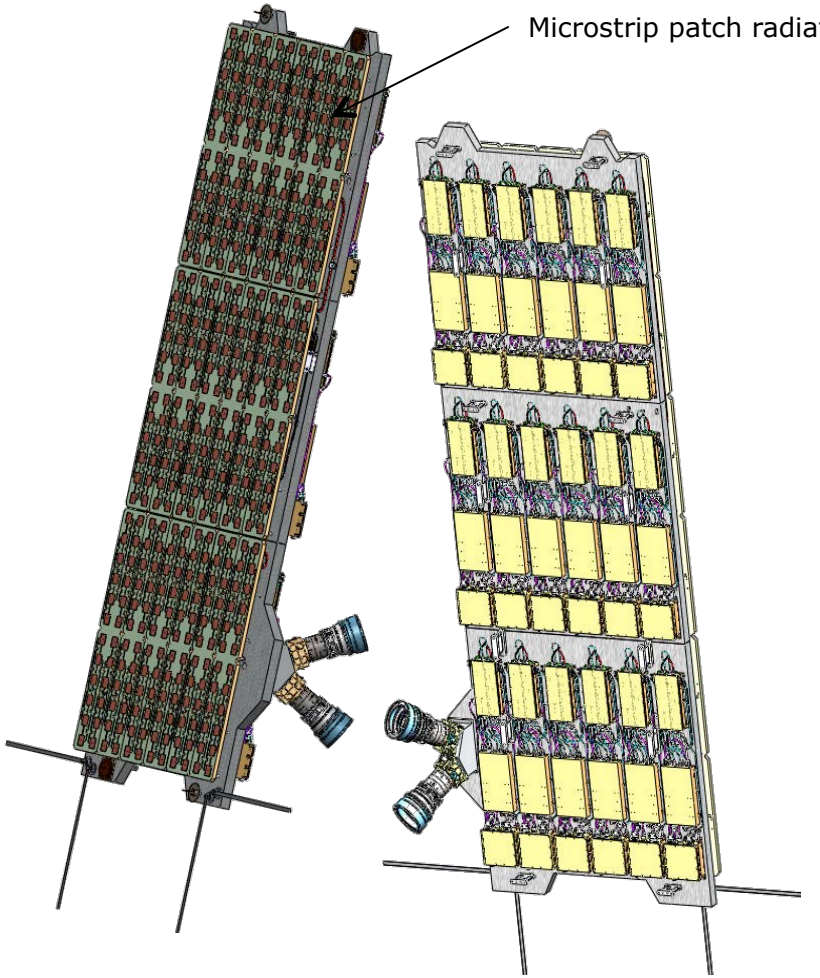
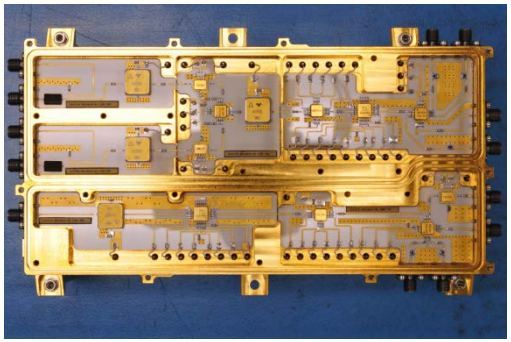
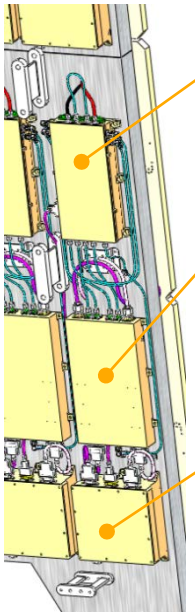
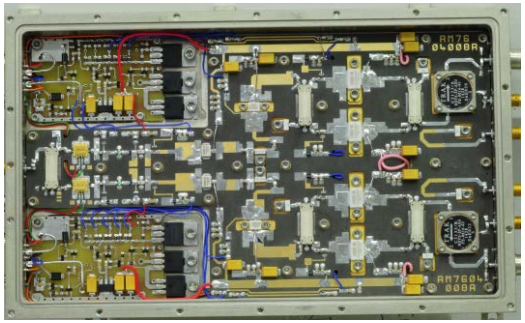
Payload Implementation – Front End









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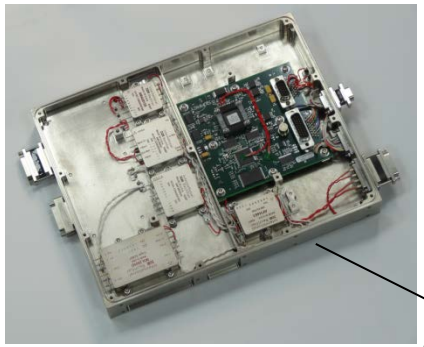
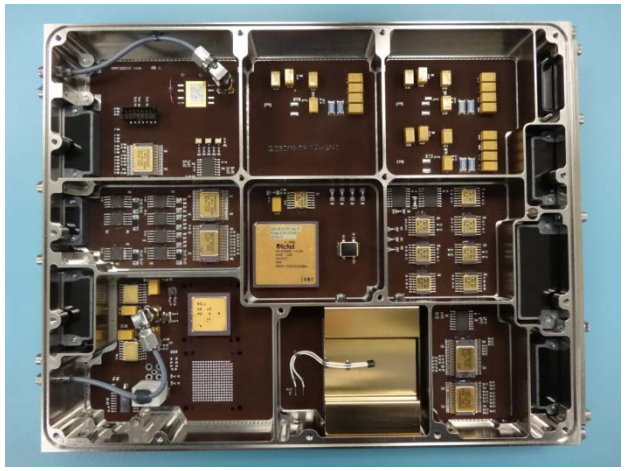
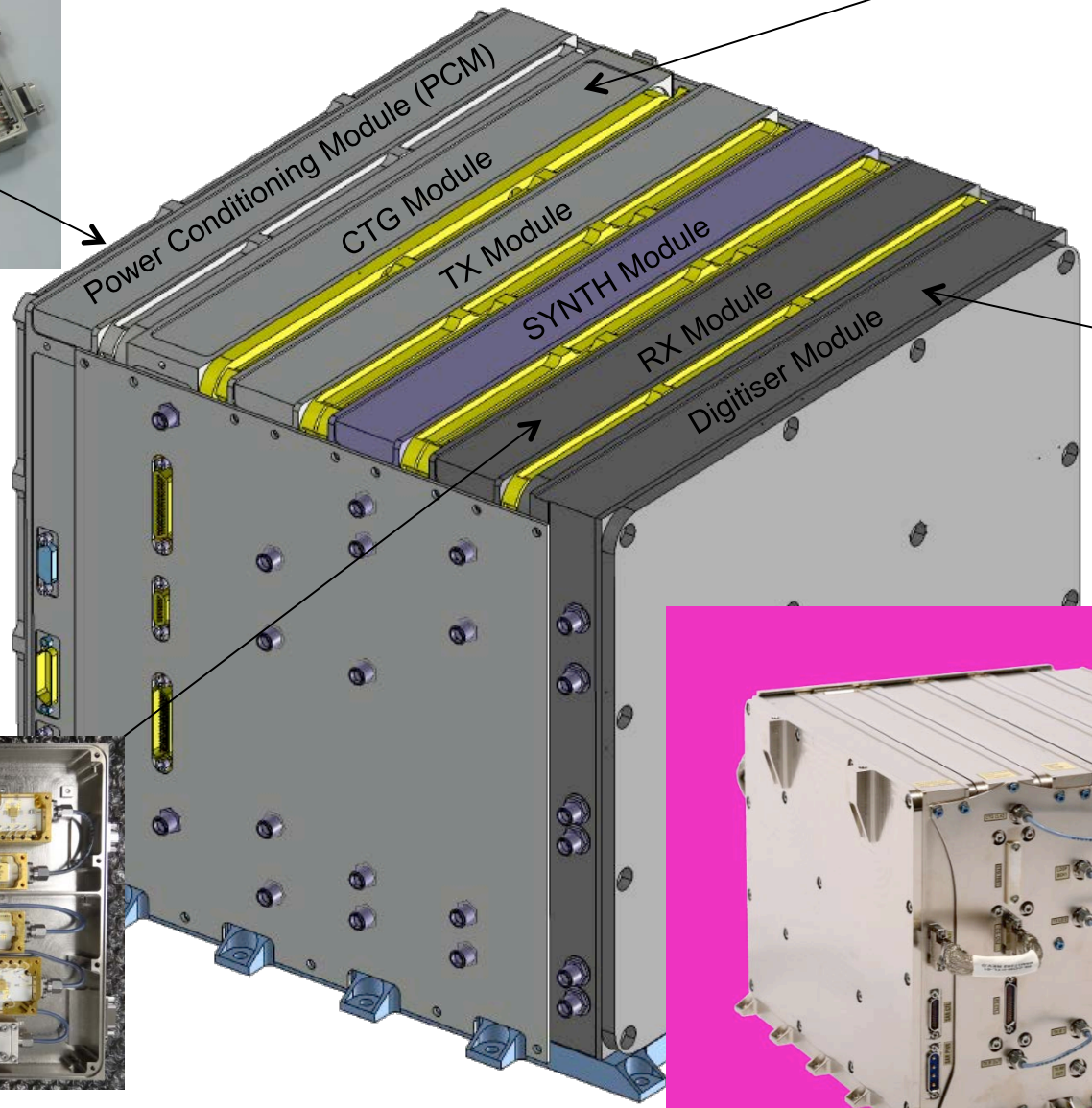
Payload Implementation – Back-End







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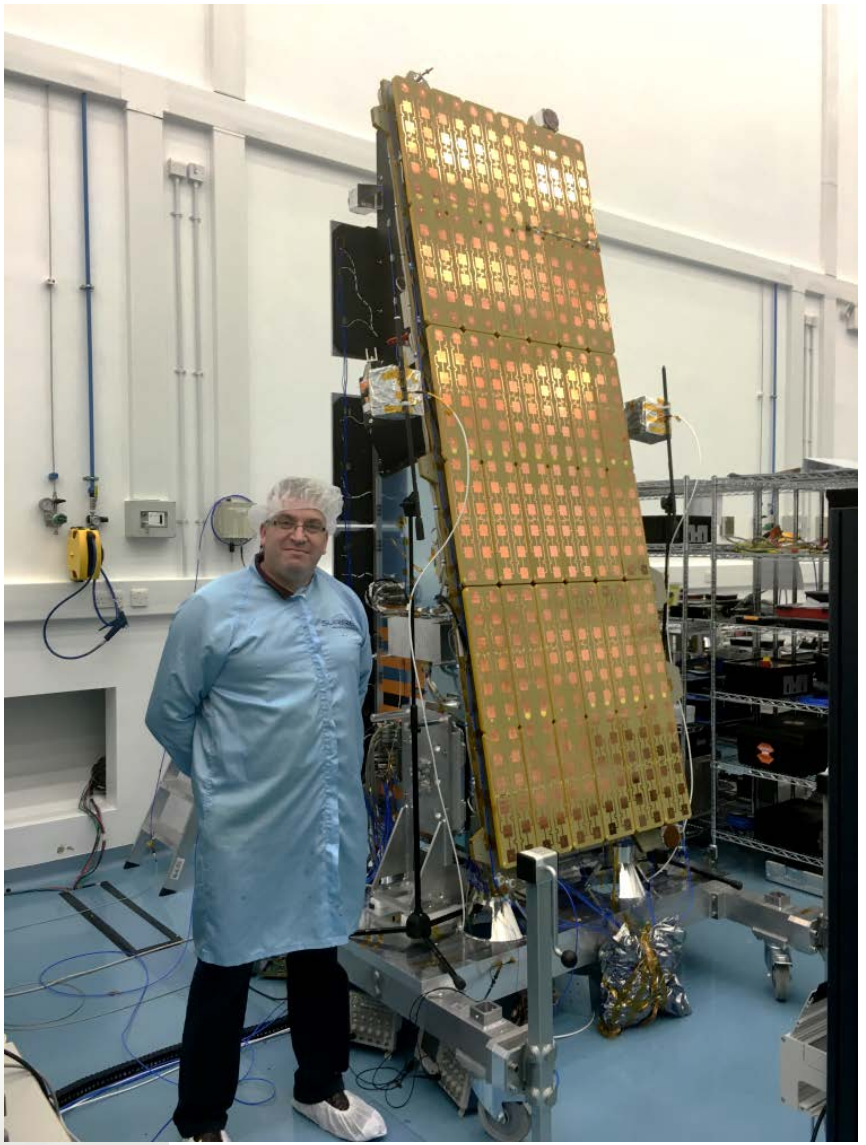
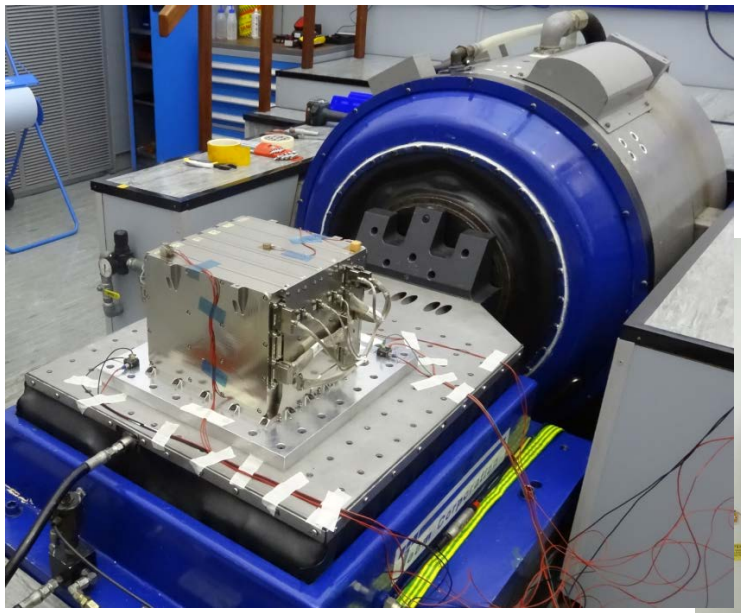
Project Status

The NovaSAR-S Payload successfully completed formal Engineering Qualification Programme of the Central Electronics and a Single Phase Centre (1/18th of Front-End) in March 2014.

The flight payload build and test is complete.

NovaSAR-S launch is due ~Q3 this year





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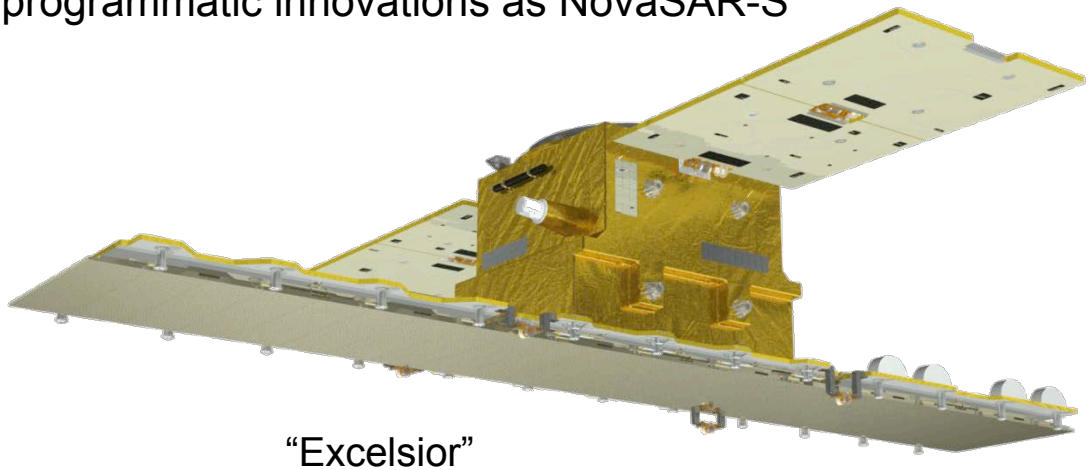
Future Developments

GaN technology is now available at higher frequencies, including X-Band (9-10GHz)

This presents he opportunity to evolve the NovaSAR-S innovations to X-Band, yielding significant performance benefits, in particular :

- Greater access
- Finer spatial resolution

Airbus Defence & Space are currently developing a new low cost X-Band SAR Payload - “Excelsior” using X-Band GaN and the same architectural and programmatic innovations as NovaSAR-S



“Excelsior”

Mode Name	Ground Range Spatial Resolution	Swath Width	Sensitivity	No. of Looks	Access Range (each side)
Spotlight (VV)	1m	10km	< -18dB	1	192-595km (20-50°)
Stripmap (VV)	3m	25km (18 swaths, 1 of 3 platform roll angles)	< -18dB	1	184-600km (19.2-50°)
ScanSAR_20 (VV)	20m	120km (4 swaths with 4 different platform roll angles)	< -19dB	4 (Rg)	192-595km (20-50°)
ScanSAR_30 (VV)	30m	200km (2 swaths with 2 different platform roll angles)	< -19dB	4 (Rg)	192-595km (20-50°)
Maritime Ship Detection (VV)	30 x 6m 30 x 6m 30 x 6m 50 x 6m	400km 675km 750km 1020km	N/A	1	456-856km (41-60°) 852-1527km (60-77°) 983-1733km (65-80°) 529-1549km (46-77°)

Excelsior Performance

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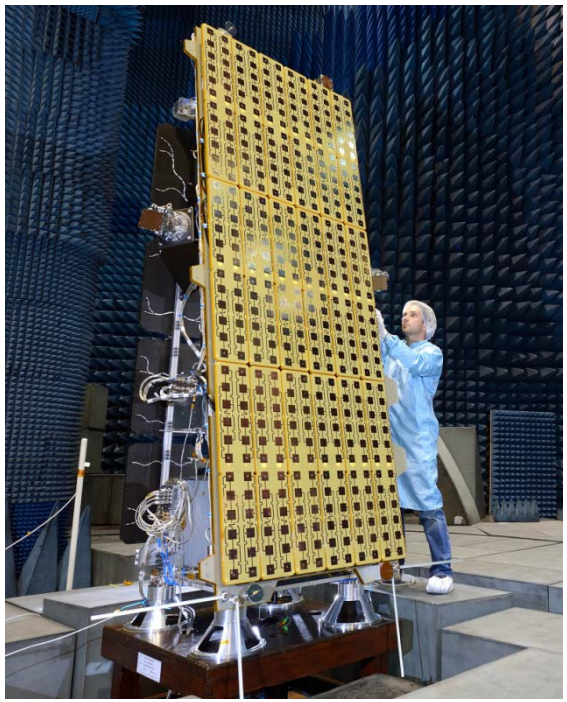
Conclusion

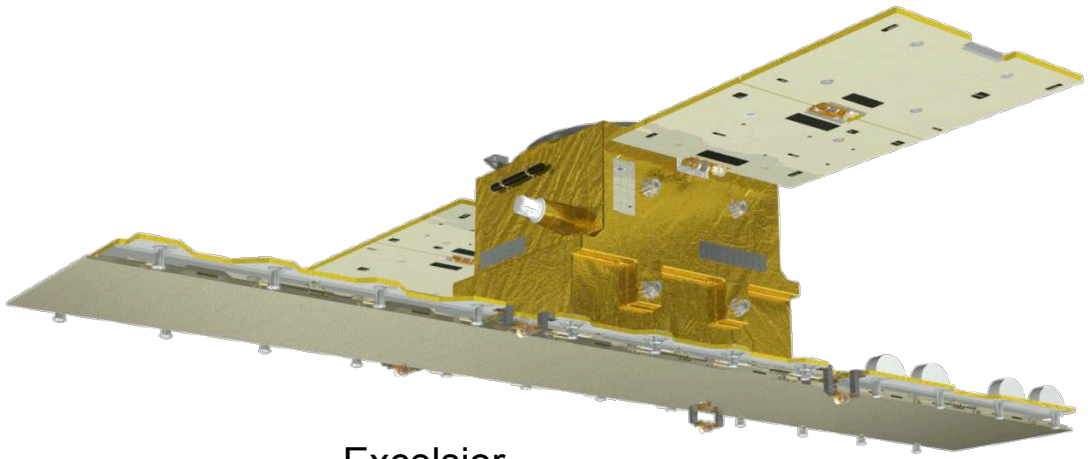
The NovaSAR-S SAR Payload development programme has produced an innovative, flexible, scalable payload design that delivers a range of operating modes over a moderate incidence angle range.

Combining key technologies such as GaN and re-programmable FPGAs, with architectural innovations such as a low phase centre count phased array and a CPU and software free central electronics, and then applying an efficient programmatic approach such as reduced subcontractor hierarchy and a compact multi-disciplinary engineering team, has yielded a truly low cost payload, compatible with a target first spacecraft cost of < £50M in-orbit.

Recent X-Band GaN developments have enabled Airbus to also begin development of a low cost X-Band SAR payload, 'Excelsior' that further enhances performance to cost ratio, providing finer resolution and greater access.



NovaSAR-S



Excelsior

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