# IN-ORBIT VALIDATION OF OXFORD SPACE SYSTEMS DEPLOYABLE WRAPPED RIB ANTENNA (WRA)

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*Abstract* – **Oxford Space Systems (OSS) has achieved significant advancements in space deployable antennas, enabling small-satellite constellations through their low mass, low launch volume and high RF performance. Launched in January 2026 on a Falcon 9 rocket, OSS have collaborated with SSTL on the CarbSAR mission to successfully demonstrate and validate the technology of the innovative deployable Wrapped Rib Antenna (WRA) in-orbit.**

**The CarbSAR mission has been jointly funded by Oxford Space Systems, SSTL, Airbus Defence and Space, Dstl and the National Security Strategic Investment Fund (NSSIF), within a long-term programme that also includes support from the UK Space Agency, InnovateUK and the Defence and Security Accelerator (DASA). This represents an important milestone for UK-developed Synthetic aperture radar (SAR) satellite technology, with clear relevance to future defence, security and Earth Observation applications for UK and international partners.**

**The WRA is uniquely deployable in diameter and length resulting in a compact stowed configuration, achieved through the innovative use of space compatible wrappable high strain composite materials, foldable knitted technical textiles and novel deployment mechanisms. This results in a lightweight, volume efficient, reliable and high RF performance product.**

**The WRA is highly modular, scalable in diameter and frequency and reconfigurable with larger variants of the X-Band SAR product undergoing qualification and alternative configurations in development spanning from multi-mode SAR to wideband and multi-band telecommunications, showcasing the critical role it can play as an enabling technology for a broad range of small satellite constellations.**

**This paper describes the successful in-orbit validation of Oxford Space Systems Wrapped Rib Antenna as part of the CarbSAR mission highlighting the technological innovations, product industrialisation, In-orbit deployment operations, and the critical and diverse applications it enables.**

## I. INTRODUCTION

In 2023, OSS and SSTL entered into a partnership to build and launch a CarbSAR In-Orbit Demonstration (IoD) mission, with Oxford Space Systems delivering a 3m WRA Protoflight (PFM) X-Band antenna to demonstrate and validate the technology on-orbit. The work was jointly funded by OSS, SSTL, Airbus Defence and Space, the National Security Strategic Investment Fund (NSSIF, HM Government's corporate venturing arm for national security and defence technologies, www.nssif.co.uk) and the UK MoD [1], with launch and antenna deployment successfully achieved in January 2026 (see Fig.1).

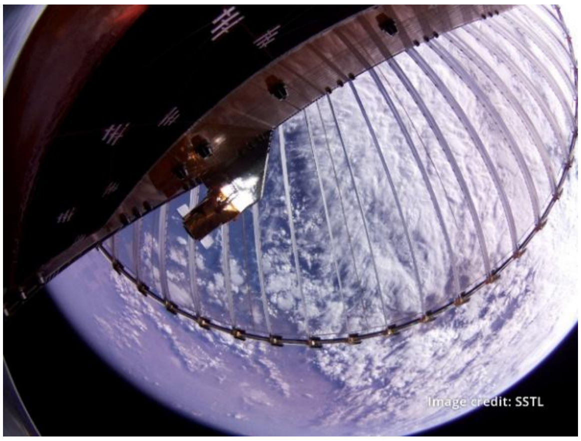



Fig. 1. Deployed 3m X-SAR Wrapped Rib antenna captured on-orbit by S/C video cameras (credit:SSTL)

The In-orbit-demonstrator mission had the following goals which will be discussed throughout the paper;

- Validate the WRA deployment & operations in flight conditions (microgravity, vacuum, thermal) & achieve flight heritage for the product (raise Technology readiness Level)
- Prove out the industrialisation & constellation readiness of the WRA product to accelerate production for future missions (raise Manufacturing Readiness Level)
- Strengthen the UK's role in secure and resilient, next-generation Earth observation capabilities through collaboration with mission partners.

## II. WRA PRODUCT DESIGN AND USE-CASES

The trend to small satellites and rideshare launches looks to increase as proliferated constellations of small satellites provides advantages of performance, resilience and agility over legacy approaches. One use-case is Synthetic aperture radar (SAR). SAR imaging offers advantages in terms of being able to image during the day and night, and in all weather conditions, therefore increasing imaging opportunities for security, defense or environmental related earth observation. In addition, SAR can be integrated into multi-sensor constellations alongside electro-optical and RF monitoring sensors to provide a complementary monitoring capability. Smallsat SAR constellations offer a cost-effective solution providing high temporal and spatial resolution.

A key enabling technology for smallsat SAR constellations is a lightweight and stowage efficient deployable antenna that can be accommodated on small satellites and rideshare launch vehicles. Once deployed large aperture reflector antennas enable high resolution SAR imaging performance.

For the IoD mission and X-Band SAR application a 3m dual reflector Cassegrain architecture was selected (see Fig. 2). This architecture positions the feed close to the vertex (lower focus) of a parabolic primary reflector and utilises a hyperbolic secondary reflector located within the (upper) focus of the primary reflector. This achieves a large aperture in a compact & lightweight design, supporting high gain, stowage efficiency and high deployed stiffness. To increase antenna aperture efficiency and reduce sidelobes critical for SAR applications, the effects of secondary reflector blockage and reflections back to the feed were mitigated using an axially displaced Cassegrain (ADC) architecture.

The metal mesh primary reflector surface and carbon fibre reinforced plastic (CFRP) secondary reflector are supported by lightweight high strain composite structures which are able to be wrapped and coiled for launch, providing stored strain energy, which when commanded, is released allowing the structures to unfurl into geometrically accurate and stiff deployed structures needed for RF performance and agile spacecraft slewing manoeuvres. This provides a simple and reliable deployment mechanism.

For the IoD mission the WRA is used to download data through an X-band downlink channel, and to collect Synthetic Aperture Radar data. The WRA also hosts S-Band TT&C antennas on the deployable secondary reflector, pointed directly at earth for the spacecraft telemetry, tracking and telecommand link (see Fig.3). This highlights the capability of the WRA reflector to have multiple antennas sharing the same aperture and accommodate secondary antennas or equipment in support of wider mission operations. The design is also robust and standardised allowing it to be used across more types of missions, orbits and environments.

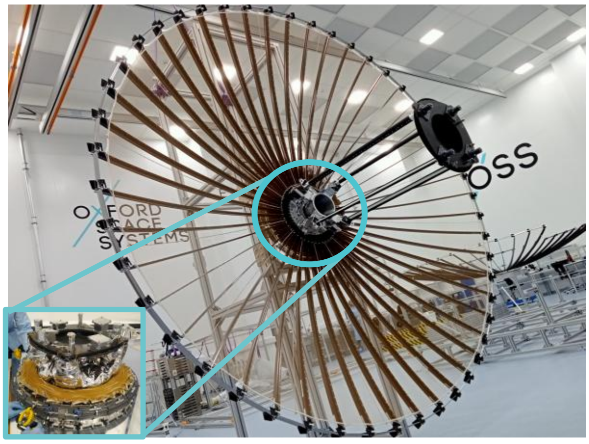



Fig. 2. Deployed 3m X-Band SAR Wrapped Rib antenna (stowed inset)

Fig. 3. CarbSAR spacecraft with stowed 3m WRA PFM mounted on earth facing panel (credit SSTL)

The WRA design is highly scalable and modular, with larger diameter reflectors going through qualification programmes and reflector configurations being developed for multi-mode SAR, wideband and multi-band telecommunication applications from L-Band to Ka-Band frequencies. This is supported by OSS in-house metal mesh which demonstrates 98% reflectivity in X-band (Fig.4).

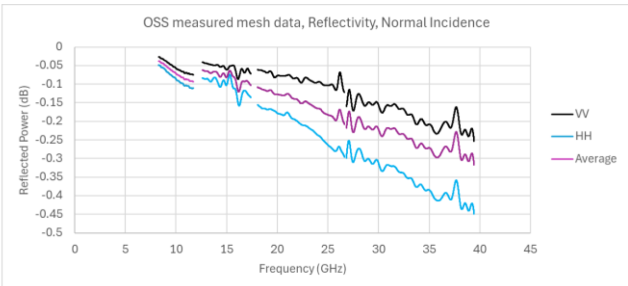



Fig. 4. OSS Mesh RF Reflectivity test results

## III. WRA PRODUCT INDUSTRIALISATION

The IoD mission had the goal to validate industrialised batch production, qualification, acceptance and verification approaches critical for smallsat constellations in order to raise manufacturing readiness level (MRL) and meet constellation delivery schedules. The IoD mission took the following approaches in support of this;

- OSS manufactured, assembled and integrated the PFM antenna metal mesh and composite parts in-house to demonstrate industrialisation of production processes necessary for constellations.
- Adopting a novel RF verification approach – scans of the as-built PFM antenna have been imported into validated RF analysis models to verify performance, rather than conduct RF pattern testing, to demonstrate batch production, constellation verification approaches.
- Qualification and acceptance philosophy using a pyramid approach where the modular design is broken down into lower levels of assembly, allowing parallel production, qualification & acceptance test activities at subsystem level, critical for constellation delivery schedules.

The WRA design features a foldable and wrappable pre-tensioned metal mesh surface to provide the required RF surface accuracy and reflectivity at X-band and above, & support the low mass, low inertia and stowage efficient design goals. Backed by the ESA Artes programme, OSS successfully developed an industrial scale in-house knitting manufacturing facility, shown in Fig.5 [2]. Using expertise from the technical textiles industry, OSS have developed their own proprietary metal mesh knitting architecture, and the capability to knit, process, assemble, integrate and verify the metal mesh surface in-house bringing greater control of quality, cost and schedule. Challenges overcome included the joining methods for the individual gores that form the full parabolic surface, edge stiffening to retain the tension and shape at the reflector circumference and composite rib attachment methods with the latter being solved using innovative ultrasonic welding techniques used in the electronics industry.

The WRA design features novel wrappable & rollable high strain composites that unfurl to provide the supporting stiff and accurate structure to the RF reflective surfaces. OSS successfully developed an industrial scale in-house composite manufacturing facility, using expertise from the Formula One industry (Fig. 6). Challenges overcome included the reliable bonding method for composite skins that form the parabolic lenticular ribs, and incorporation of thermal control surfaces with the latter being solved using innovative co-curing lamination techniques.


Fig. 5. Metal Mesh production at OSS

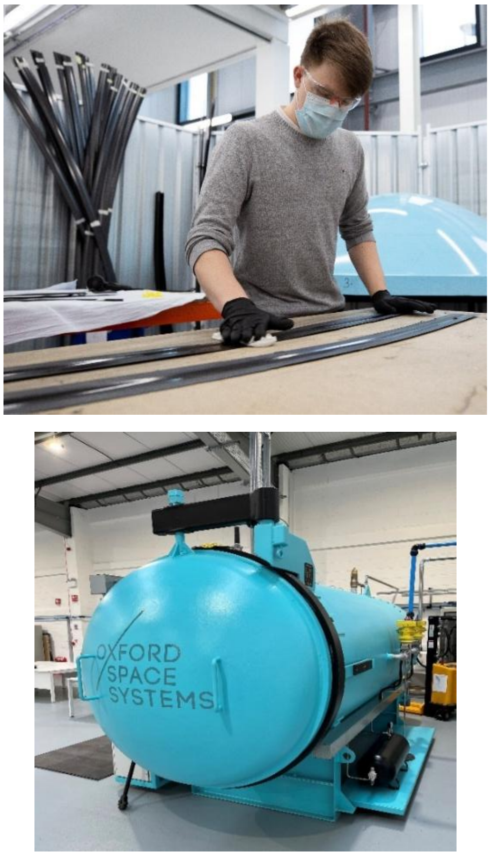



Fig. 6. Composite production at OSS

Due to the large electrical dimensions and the relatively flexible nature of the deployable design, RF measurements for this type of antenna pose challenges with relatively few antenna test ranges capable of conducting the test. Due to gravitational & dynamic effects on antenna geometry the preference was to test the antenna in a static configuration with the boresight aligned vertically. In this way the antenna can be kept stationary, reducing dynamic disturbances, and gravitational effects are more evenly distributed across the aperture and can be compensated for either directly through relatively simple ground support equipment or through analytical post processing.

Therefore in 2023, OSS collaborated with Airbus Defence and Space Germany (ADS GmbH) in Ottobrunn to use their innovative indoor Portable antenna measurement system (PAMS) Nearfield Test facility to conduct a further RF test on the 3m WRA EM, Fig.7, supported by funding from ADS UK. The PAMS measurement facility was developed specifically to enable pattern measurements for large deployable antennas in a stable configuration. The system employs a standard overhead crane-based gondola probe as a near-field scanner. The gondola is positioned by a controller to sample the near-field data on an arbitrary acquisition surface around the AUT. The antenna and probe location information is accurately obtained in up to six dimensions from a laser tracking system for each measurement point [3]. Results from the PAMS test are shown in Fig.8.

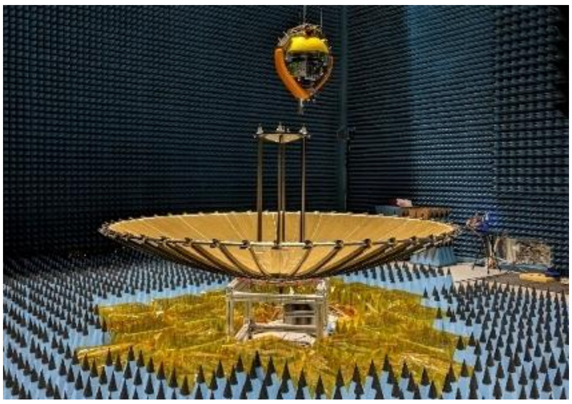
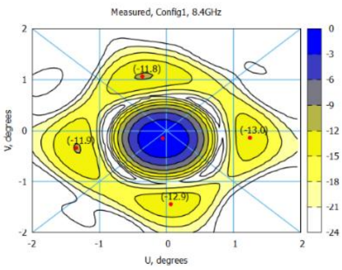


Fig. 7. 3m WRA EM PAMS-based test configuration



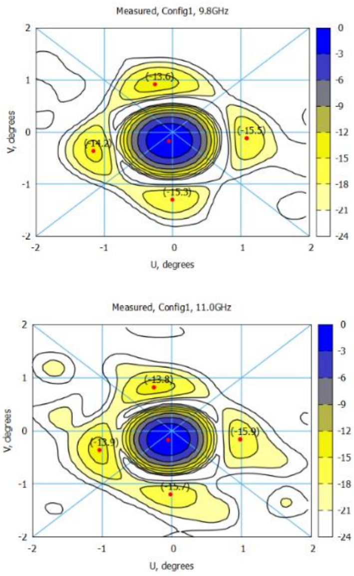




Fig. 8. 3m WRA EM PAMS-based measured result

OSS used the PAMS based testing to provide data to correlate RF analysis models and validate an innovative RF verification method for flight model batch builds. The RF verification method uses laser tracker scans of the as-built reflector surfaces (primary and secondary) (Fig.9) and imports them into RF analysis models (Fig.10) to predict the radiation pattern parameters and state compliance, rather than carry out RF range testing. This has the potential to save a large recurring cost and schedule impact for constellation batch builds. It also reduces the risk of additional handling and transportation on the integrity of flight antennas due to the use of overseas test facilities.

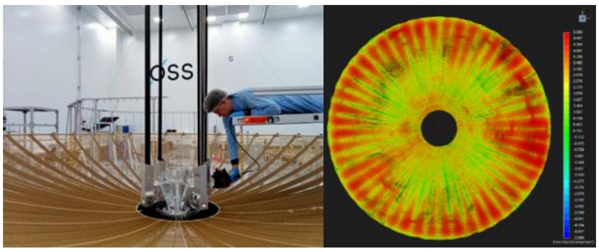


Fig. 9. 3m WRA scanning of primary reflector (LHS) and resulting scanned surface (RHS)

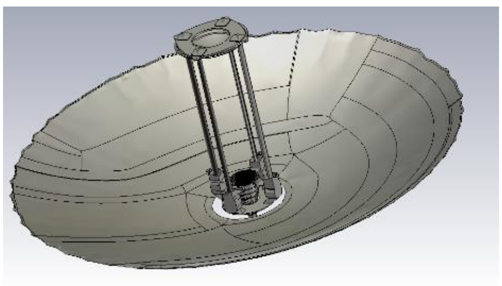


Fig. 10. 3m WRA RF analysis model incorporating scanned surface

Using this method, the average level of agreement between analysis prediction and test measurement was found to be very good, validating the verification approach. For example, the measured peak realised gain was within 0.2dB of analysis prediction. In addition, the level of agreement was found to be good over a range of frequencies, configurations and antenna performance parameters (Fig.11). This gives a high level of confidence that if OSS follow a similar process of surface scanning, import into analysis models and analysis modelling approach then we should obtain similar levels of agreement across the WRA production line. This method of RF verification was successfully adopted for the In-orbit demonstrator (IoD) 3m WRA Protoflight model (PFM).

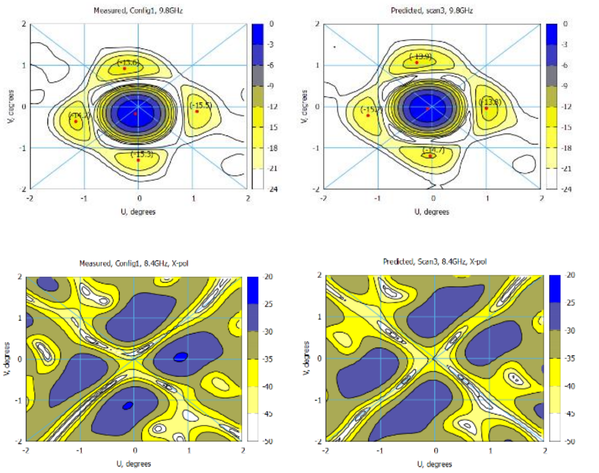



Fig. 11. 3m WRA EM RF measurement to analysis correlation (Co-pol pattern contour top and Cross-polar contour bottom)

The WRA is uniquely deployable in diameter and length through separate deployments for the primary reflector and deployable mast that can support a secondary reflector or feed depending on the antenna architecture. This results in a modular design with primary and secondary subsystems with simple interfaces (mechanical, thermal, electrical), independent function and low coupling that is intended to allow parallel production, verification, qualification and acceptance test approaches. The approach to qualification and acceptance testing is illustrated in Fig.12 and Fig.13, showing the primary and secondary reflector subsystems going through separate parallel testing regimes (deployment, thermal cycling, initial motion at hot and cold), and then being combined for system level testing (Bakeout, Vibration, Deployment).

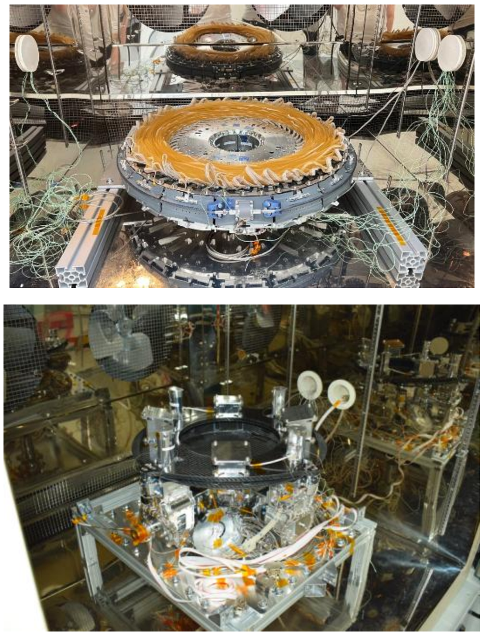


Fig. 12. WRA subsystem level testing approach, primary reflector subsystem top and secondary reflector subsystem bottom.

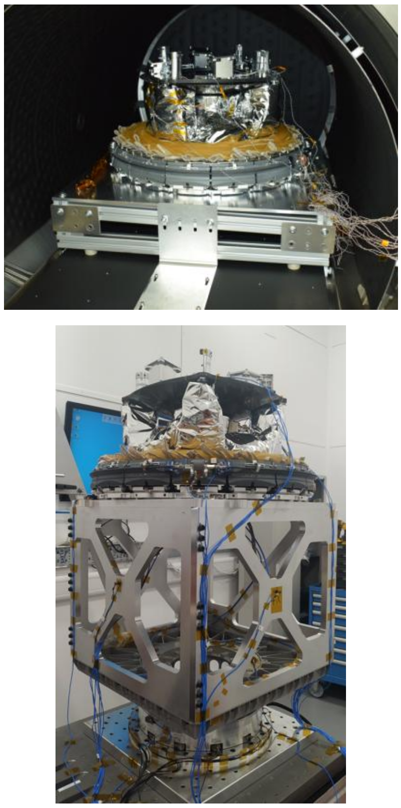


Fig. 13. WRA system level testing approach (TVAC testing top and vibration testing bottom)

## IV. IN-ORBIT-DEPLOYMENT & OPERATIONS

The CarbSAR spacecraft was successfully launched and separated from the SpaceX Falcon 9 rideshare launch vehicle on January 11th 2026 with antenna deployment occurring shortly afterwards. Deployment was successfully performed in two stages with Primary and secondary reflector deployments conducted on separate ground station passes with OSS staff supporting operations at SSTL's facility in Guildford. The deployment was captured by video cameras onboard the spacecraft providing vital telemetry and feedback on the success of the deployment and the dynamic behaviour in on-orbit conditions [4]. Further telemetry was provided through the attitude and orbit control system (AOCS) with the gyro's onboard picking up the angular momentum exchange between the spacecraft and the WRA during deployment (Fig.14).

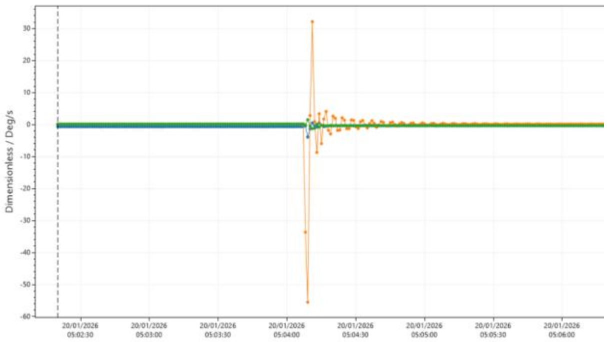



Fig. 14. Spacecraft gyro data showing angular momentum exchange between WRA and spacecraft during deployment (credit:SSTL)

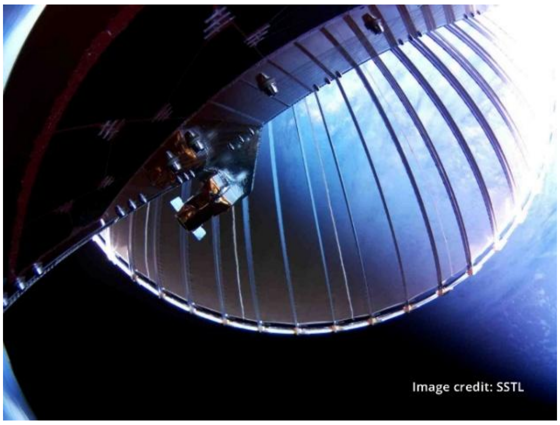



Fig. 15. Image captured post deployment from the on-board video camera (credit:SSTL)

The successful WRA deployment [5] marked a major milestone for the mission, OSS and UK developed space radar technology and is testament to the collaboration between the mission partners over many years. The CarbSAR mission now moves into validating the delivery of high-resolution X-Band SAR imagery from a compact small satellite, enabling day and night all weather observation of the Earth to support secure and resilient UK and international partner capabilities.

## V. CONCLUSION

Oxford Space Systems have successfully validated a modular and scalable metal mesh wrapped rib deployable reflector antenna through on-orbit deployment and operations. Through collaborative and innovative approaches, OSS has advanced its capability in novel metal mesh & composite materials, batch production, qualification, acceptance and RF verification approaches to produce a reliable, high gain, lightweight, and stowage efficient antenna industrialised for smallsat constellations.

Leveraging this capability, OSS continues to develop the WRA product as larger diameter X-SAR WRA's are currently going through qualification programmes and alternative WRA architectures are being developed for multi-mode SAR, wideband and multi-band telecommunication applications from L-Band to Ka-Band. This approach, supported by collaborative and strategic partnerships, will ensure OSS will continue to enable large mission capability for its UK and international customers.

## VI. ACKNOWLEDGEMENT

The authors wish to thank all the OSS employees past and present who contributed to the 3m X-Band SAR WRA antenna development. OSS would like to thank key partners and customers SSTL, ADS and NSSIF for their collaboration and funding. Finally, the authors extend their gratitude to the UKSA, ESA Artes and GSTP programmes and its technical officers for the funding support and technical guidance over the years.

## VII. REFERENCES

[1] https://oxford.space/post/?permalink=oxford-space-systems-and-sstl-to-launch-carbsar-in-orbit-demonstration-mission-to-showcase-innovative-wrapped-rib-antenna

[2] https://connectivity.esa.int/projects/oxford-space-systems-metal-mesh-industrialisation

[3] A. Geise, O. Neitz, J. Migl, H. Steiner, T. Fritzel, C. Hunscher, T. Eibert "A Crane Based Portable Antenna Measurement system – System description and Validation". *IEEE Transactions on antennas and propagation.* vol. 67, no. 5, pp. 3346-3357, May 2019

[4] https://www.linkedin.com/posts/oxford-space-systems_wrappedribantenna-sar-earthobservation-activity-7422595246930182145-U7tD?utm_source=share&utm_medium=member_desktop&rcm=ACoAAAYjljoBxC2le9U77McpOOb7Y1PhphVHU9w

[5] https://oxford.space/post/?permalink=oxford-space-systems-and-sstl-announce-successful-in-orbit-deployment-of-wrapped-rib-antenna-on-carbsar-mission