IMPACT ASSESSMENT OF ESA EARLY R&D ACTIVITIES

Advanced techniques for mesh reflector with improved radiation pattern performance (AMPER)

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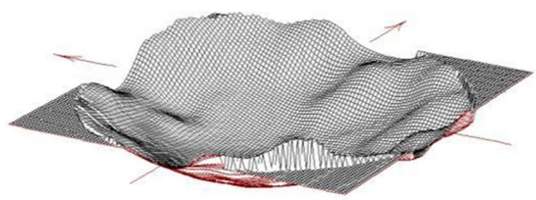
Effective satellite-based communication and observation is often hindered by coverage issues…

The need for large reflector antennas has existed since the start of space communication and Earth Observation (EO). The demand for bigger apertures[1] remains constant across the electromagnetic spectrum, including for optical[2] and high-energy devices[3]. For communications missions, this demand stems from larger apertures being able to help detect faint signals, reduce power consumption, and focus energy precisely, thereby minimising interference with surrounding areas.[i] For EO, larger antennas enable higher spatial resolution on the ground, facilitating more accurate observation and detailed images.[ii]

Figure 1: Profile of the shaped surface reflector antenna



Source: L. Datashvili, et. al (2023)[iii]

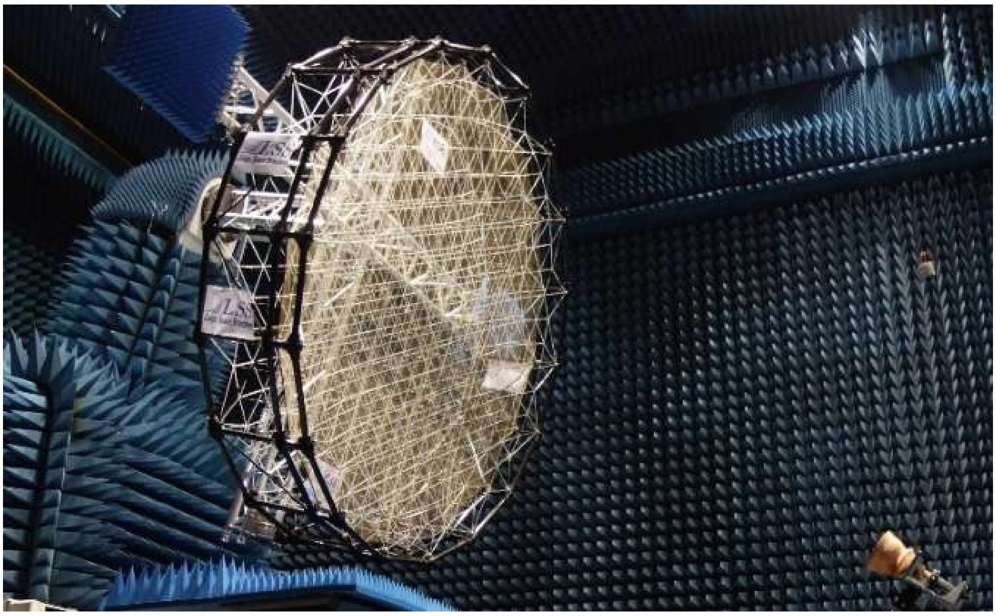
Traditional large reflector antennas with parabolic surfaces offer only limited radiofrequency (RF) performances when generating multiple RF beams to illuminate a specific region on Earth. Beyond this performance barrier, traditional large reflector antennas also require multiple feeds to cover irregularly shaped regions, which can increase the cost of a mission. An additional limitation with traditional antennas is that, when they are applied to large RF apertures, the antennas produce unwanted grating lobes, i.e. unwanted signals that can cause interference.[iv] This can have significant impact on applications, such as defence and military communications, where spatial isolation over a certain area is required and RF interferences must be mitigated.[v] Therefore, these limitations highlighted the need for a lighter and more efficient alternative solution, which offers better coverage and performance.

[1] Diameter of the reflector antenna.
[2] Devices that operate in visible light such as cameras and sensors used in remote sensing and communications.
[3] Instruments that detect or generate X-rays and gamma rays such as space telescopes used in astrophysics.

… however, interferences can be mitigated through the shaped surface reflector antenna, developed with ESA funding…

The Advanced Techniques for Mesh Reflector with Improved Radiation Pattern Performance (AMPER), funded by ESA's Technology Development Element (TDE)[4] programme (€600,000 total), is a technology development activity aimed at improving the reflector antenna radiation pattern. The two key objectives of this project were to optimise the way the reflector antenna shapes and focuses its signal (radiofrequency beams) through – (a) surface shaping and (b) grating lobes reduction (GLR). Surface shaping enables the mesh reflector to generate contoured beams that can be shaped to the irregular perimeters of regions on Earth, whereas the inclusion of a large aperture size facilitates the reduction of grating lobes. The contractors successfully designed and developed a breadboard prototype of a large, 2.6m shaped metal-mesh reflector antenna and 1m reflector breadboard with GLR, achieving both of the AMPER project objectives – the first one of its kind in Europe.

Figure 2: Prototype of the 2.6m metal-mesh reflector antenna



Source: ESA[vi]

[4] ESA's Technology Development Element (TDE) is a mandatory programme which explores innovative, 'blue-sky' concepts. It supports all ESA fields of activity across various technical disciplines, serving as the foundation for future technological advancements. All ESA Member States contribute to the TDE on a mandatory basis.

AMPER is part of the European large deployable reflector (LDR) roadmap, which aims to fill a gap in European capability in this domain. Positioned within this broader effort, AMPER builds on predecessor activities, such as ESA's TALDES[5] and SCALABLE[6], addressing a specific limitation in large, shaped mesh reflectors with reduced grating lobes. This ESA-funded project thus plays an important role in ensuring European non-dependence and leadership in the domain.

Figure 3: AMPER project team

The AMPER project was carried out by the prime contractor – Large Space Structures (LSS) GmbH (DE) and their subcontractor – TICRA (DK). LSS are key European suppliers of large deployable reflectors and deployable reflector systems, and possess distinct expertise in this field. They were responsible for the design and assembly of the shaped mesh reflector antenna and the GLR breadboarding. TICRA focuses on the provision of reflector antenna modelling software, and were responsible for the analysis of the designs within the AMPER activity.

… through optimised coverage and enhanced signal strength …

Specific EO and telecommunications applications require distinct design specifications on a reflector antenna. Traditional parabolic reflectors struggle with producing multiple RF beams without any spillover, which causes RF interferences and reduces the spatial performance of the reflector as a whole. Due to the requirement for large apertures and precise illumination of wide areas with beams pointing towards the desired angle, the shaped mesh reflector antenna is a suitable solution for applications in EO and telecommunications.

In the domain of telecommunications, the shaped mesh reflector and reduced grating lobes capabilities can provide an efficient gateway between satellite and ground-station

[5] As part of the ESA TALDES project, LSS demonstrated a 6m LDR based on a conical ring structure, 1.6m, 4m and 6m LDRs based on double pantograph rings. Available at: https://www.largespace.de/about-lss/completed-projects/#1513675887748-c63b981d-fb27

[6] As part of the ESA SCALABLE project, LSS, in cooperation with HPS GmbH developed a 5m deployable metal mesh reflecting surface supported by a cable network. Available at: https://www.largespace.de/about-lss/completed-projects/#1513677132339-8096a06d-5695

communications and can facilitate secure military and defence communications. In the EO domain, it can be used to monitor climate change-induced phenomena. The sensitivity of the antenna also plays a significant role in increasing the accuracy of measurements and enhancing the spatial resolution of images.

… delivering potentially valuable socio-economic benefits.

The shaped mesh reflector antenna and GLR capability still needs further technology maturation through follow-on projects / missions, as well as adoption from commercial and institutional organisations. However, ESA TDE funding has already led to some important benefits being realised, including strengthening European technological non-dependence, enhancing reputation and visibility, and skill development.

Strengthening European non-dependence and technological leadership

Strategic ESA investment into developing capability for the shaped mesh reflector antenna and GLR has helped progress the European LDR roadmap and contributed to building Europe's non-dependence in the domain.

A key area of cooperation between the European Space Agency, the European Defence Agency and the European Commission has been around enhancing technological sovereignty, including promoting European non-dependence on key space technologies.

ESA TDE funding for the AMPER project has enabled the development of this first-of-its-kind satellite technology in Europe. The shaped mesh reflector antenna and the GLR capability are enabling technologies with wide-ranging applications, notably in telecommunications and EO missions, but also in satellite navigation, military and defence satellites, as well as planetary communication for space exploration. Currently, only the United States and China have demonstrated capabilities and long-term flight heritage in this area. Therefore, strategic ESA investment in developing this technology has significantly reduced European reliance on external suppliers for its procurement.

Additionally, this activity plays a key role in developing the European LDR along ESA's roadmap, by enhancing knowledge and experience in the domain (while the shaping technology developed on AMPER has not been directly leveraged for the LDR, its building blocks do). Progressing capabilities in LDR helps fill an important technological gap in Europe, strengthening non-dependence.

ESA TDE funding has enabled the development of a European shaped mesh reflector antenna from early R&D up to demonstration on a 3m LDR class breadboard prototype.

LSS effectively leveraged expertise and advancements gained from previous ESA-funded projects (e.g., TALDES and SCALABLE) to enable further technology progression. The shaped mesh reflector antenna evolved from early R&D to breadboarding the mesh reflector antenna, and proving the concept at C band. The breadboard prototype consisted of a 2.6m diameter shaped reflector, where a supporting network was used in 3 layers to facilitate metal-mesh surface shaping (as seen in **Figure 2**). Furthermore, within the AMPER project, grating lobes reduction (GLR) was demonstrated on a 1m breadboard prototype at Ka-band.

LSS reported the progression of AMPER project technologies from Technology Readiness Level[7] (TRL) 1 to TRL 4, with some components leveraged from the SCALABLE project reaching TRL 5. These prototypes achieved AMPER project objectives by generating contoured beams that can be shaped to a region (i.e. irregular service area), as well as reducing grating lobes such that there is minimal loss where the beam is focused. Furthermore, the lightweight (<10kg) and stowable nature of the mesh reflector is particularly beneficial, as it reduces launch constraints. It is also acoustically insensitive, meaning it is resistant to damages from pressures during launch. The AMPER technology is compatible with both deployable and fixed mesh reflectors of any size, for frequencies ranging from P-band to Ka-band.

As it stands, the shaped mesh reflector and GLR technology requires further funding to progress technological maturation, depending on the companies' self-financing abilities, support from the ESA Member States' national space agencies, and ESA (e.g. through GSTP or ARTES routes). Although the technology from the AMPER project has not led to specific follow-on projects, it has noticeably influenced LSS' reflector contributions including (as part of a consortium with companies from across 6 European countries) design and development of the European LDR on ESA-funded activities, such as the LEOB project[8] and the CIMR mission[9].

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[7] Technology Readiness Level (TRL) is a standardised system used to assess the maturity of a technology before it is deployed in operational missions. It ranges from TRL 1 (basic principles observed) to TRL 9 (actual system flight-proven in space). For space applications, TRL progression typically involves rigorous analytical studies, laboratory testing, validation in relevant environments, and demonstration in orbit to ensure reliability under extreme conditions.

[8] As part of the LEOB project, ESA selected the 'WeLEA' consortium (of which LSS and TICRA are a part) to build a full-size engineering model of the reflector for the CIMR microwave instrument. Available at: https://www.esa.int/European_Large_Deployable_Reflector

[9] The successful demonstration of the CIMR-aligned engineering model of the LDR on the LEOB project enabled it to be chosen for further technological maturation and to be integrated into ESA's CIMR mission. Available at: https://www.esa.int/European_Large_Deployable_Reflector

Upskilling and supporting the workforce

ESA funding for AMPER has fostered advanced technical and project management skills, whilst supporting approximately 4.5 FTEs.

LSS' involvement in the AMPER project provided direct support for 6 individuals, including both employees and doctoral students, equalling around 4.5 FTEs (full-time equivalent). The activities undertaken by the project team served as a catalyst for advanced skill development within the company, especially for those with early-career profiles.

In particular, the project facilitated the upgrade of specialised expertise in 3 layers network topology optimisation, as well as shaped reflector construction and assembly across the team. Notably, two doctoral students who were involved in AMPER have remained at LSS at present, continuing to advance critical work in developing European LDR technologies. One of them, as a lead systems engineer, is working on overall LDR technology qualification including HDRMs and deployment simulation, reinforcing the company's innovation capacity. Furthermore, LSS' involvement in AMPER facilitated valuable technical knowledge exchange with ESA's experts, contributing to the advancement of technological know-how within the team.

Since completing the AMPER project, LSS has expanded from 3 to over 60 employees. As one of their earliest ESA projects, technical knowledge gained by employees working on AMPER was systematically disseminated to newer employees, ensuring a transfer of expertise across the organisation. This growing knowledge base not only strengthened internal capabilities but also became a key driver of innovation. LSS reported that knowledge developed on AMPER was useful on successive European LDR technology advancement projects, such as ESA's LEOB project and on the ongoing work on LDRs for the CIMR mission. The team at LSS also reported that technical knowledge from the AMPER project will be leveraged on their work for the Earth Explorer 12 candidate missions, if a mission with an LDR is selected to be next Earth Explorer and they are successful in securing the contract.

Working with ESA has also enhanced LSS' project management skills, as it provided insight into the expectations and processes associated with partnering with such a key organisation. This translated into greater efficiency in delivering subsequent projects / missions with Agency, including but not limited to the DRAC[10] and LEOB projects and the CIMR mission.

[10] DRAC (Deployable Reflector Antenna for CubeSat) is an ESA-funded project whose objective is to develop and demonstrate 1m to 3m deployable reflector antennas for CubeSat applications. Available at: https://www.largespace.de/new-esa-project-drac/

Furthermore, ESA funding has strengthened the European space industry's talent pipeline, with doctoral students who worked on the AMPER project having secured positions at leading organisations such as Rolls Royce, OHB, IRPG and ESA. This has not only supported career progression for early-career professionals but also contributed to a transfer of expertise across the sector.

Enhancing reputation and visibility

LSS' involvement in AMPER has enabled them to strengthen their position in the European space industry as having unique expertise in the shaped mesh reflector antenna and GLR technology, further solidified by the dissemination of research at reputable conferences.

Thanks in part to the success of the AMPER project, LSS has strengthened its reputation in the niche domain of shaped mesh reflector antennas and GLR capabilities, solidifying their position as a key player within the European space industry. The AMPER project enabled LSS to build on their previous contracts with ESA, showcasing their reliability and expertise. This reinforced the company's credibility, positioning them as a strong candidate for larger future contracts as part of consortia for successive ESA projects / missions (e.g., LEOB, CIMR).

LSS have engaged in discussions with multiple stakeholders regarding the applications of the shaped mesh reflector antenna and GLR technology, though these have not yet led to a follow-on project. However, when looking for solutions to shaped antenna surfaces and reduced grating lobes, LSS are recognised as the sole European provider of a cost-effective, mechanical solution. This recognition further solidifies its standing as a trusted and reliable company.

Having published at least 3 scientific articles[vii,viii,ix,x], LSS, along with TICRA and ESA, have enriched the collective knowledge base of the European space industry through research, providing valuable expertise that will drive further innovation and progress of the shaped mesh reflector antenna and GLR capability. LSS have also presented this research at reputable conferences, such as the 41st ESA Antenna Workshop on Large Deployable Antennas and the 9th European Conference on Antennas and Propagation (EuCAP) among others. This has allowed them to expand valuable networks and demonstrate their expertise, significantly enhancing their visibility and influence within and outside Europe. The final breadboard prototype of the shaped mesh reflector antenna is displayed at the European Space Research and Technology Centre (ESTEC), offering significant visibility for LSS. This exposure helps demonstrate its capabilities, serving as a clear representation of the company's expertise and credibility.

Strengthening market position and competitiveness

The development of innovative mechanical solutions to shaped mesh reflector antennas and GLR on AMPER has enabled LSS to secure a competitive advantage in the satellite antenna market.

As highlighted earlier, the competitive advantage of LSS lies in being the sole European provider capable of delivering a mechanical solution to the shaped mesh reflector antenna and GLR. This is significantly more cost-effective compared to the predominant electronic solution on the market, i.e., beam forming network offered by the contractors' competitors.

Offering this European solution has allowed LSS to strengthen their market position, enabling them to potentially capture a greater share in the global satellite antenna market – which is currently growing at a CAGR of 11.8% and is expected to be valued at €11.27bn ($11.78bn) by 2032[xi].

LSS prioritised publishing research articles on the technology rather than patenting them, strategically balancing knowledge-sharing with demonstrating their competitive advantage. This approach not only contributed to the broader scientific community but also served to safeguard the company's technical expertise, ensuring they maintained a leading edge in the industry.

Positioning for potential follow-on missions and commercial interest

The demonstrated success of the AMPER project has strengthened LSS' position in securing follow-on opportunities within the European LDR roadmap, as part of ESA's LEOB project and CIMR mission.

The success of the TDE-funded AMPER project has strengthened LSS' position within the European space industry, fostering valuable connections and attracting commercial interest through actively engaging with key stakeholders. For example, they have been able to present the AMPER-developed shaped mesh reflector antenna and GLR technologies to leading organisations such as Eutelsat, Airbus, Thales Alenia Space and OHB, showcasing their capabilities and potential applications in both EO and communications. This could, in the future, lead to commercial contracts for the supply of shaped mesh reflector antennas (or related technologies), as well as large deployable mesh reflector antennas more generally.

Growing recognition within the European industry and from ESA has positioned LSS as a strong contender for larger projects / missions, which continue to mature or leverage knowledge and technology developed as part of the AMPER activity. Indeed, ESA offers various funding streams (e.g. Discovery & Preparation Programme, Technology

Development Element (TDE), General Support Technology Programme (GSTP)[11], Advanced Research in Telecommunications Systems (ARTES)[12], FutureEO[13], Navigation Innovation and Support Program (NAVISP)[14]) that enable the progression of technology maturity from early R&D to flight demonstration.

Building on the success of the TDE-funded AMPER project, alongside past achievements in predecessor activities, LSS (as part of a wider consortium) have received several contracts from ESA under various funding streams. For example, the company received a share in the €6m FutureEO contract to develop integrated European LDR technologies as part of the LEOB project. LSS will also play a role in the high-value Copernicus CIMR mission, for maturation and provision of an LDR, where the LDR element is funded at around €125m within the larger €500m CIMR budget.

These contracts illustrate LSS's technical expertise and reliability, but also open doors for future opportunities, reinforcing confidence among key stakeholders. For example, LSS is already leading a commercial mission project on multiple smaller deployable antennas for satellite communication. Additionally, LSS will soonfly its first LDR in an EU/ESA in-orbit demonstration project. Beyond immediate financial gains, these projects/missions have already, and will continue, to contribute to advancements in European non-dependence of LDR technologies.

Sustaining small organisations and catalysing business growth

> ESA funding for AMPER has allowed LSS to not only sustain themselves as an organisation but also grow in capacity through catalysing further internal investment.

LSS serves as a prime example of how ESA funding can play a pivotal role in catalysing business growth and development. The Agency's support for AMPER was instrumental in helping LSS build their heritage, advance their technology, solidify their expertise, and enhance their standing within the European space sector. Beyond fostering innovation, ESA funding also provided essential financial stability, ensuring LSS could survive and grow until their product was more mature, helping them overcome the 'innovation of valley of death'.

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[11] ESA's General Support Technology Programme (GSTP) advances cutting-edge technologies from early development to space-ready status by creating engineering models or 'breadboards' for testing.
[12] ESA's Advanced Research in Telecommunications Systems ARTES programme supports the transformation of R&D into commercial products and services by providing tailored support based on different levels of operational and commercial maturity.
[13] The ESA FutureEO programme is a long-term initiative aimed at developing innovative EO technologies, missions, and applications. It focuses on developing research, including promoting the use of new observation techniques. By supporting early-stage research and development projects, and exploring novel mission ideas, FutureEO seeks to maintain European leadership in EO.
[14] ESA's Navigation Innovation and Support Program (NAVISP) drives innovation and competitiveness in Europe's positioning, navigation, and timing (PNT) sector by advancing novel technologies. It explores enhancements to PNT systems through local augmentation, sensor fusion, multi-constellation integration, and the combination of satellite and terrestrial technologies.

This support has allowed LSS to streamline processes, increase their organisational efficiency, and enhance operational capacity by investing in key resources. This includes purchasing advanced software such as MATLAB[15], as well as financing essential infrastructure, including renting a small room for production of reflector parts, and contracting final assembly of the reflector with the Technical University of Munich. As a result, LSS has not only strengthened its competitive position but also paved the way for sustained growth and long-term success, as seen in their successive projects / mission involvement (e.g. LEA, LEOB and CIMR).

Would these benefits have been realised without ESA?

ESA's role is crucial in providing strategic investment to help develop technologies that will ensure Europe's non-dependence and technological leadership. ESA funding has helped de-risk and develop the shaped mesh reflector antenna and GLR technology, and contribute to the incremental maturation of the European LDR technology through the knowledge developed. AMPER has thus played an essential role in fostering technology development as part of the broader European LDR roadmap, enabling technological sovereignty in this domain.

"If the AMPER project had not happened, the company would not have survived. This project helped us prove ourselves and showcase that we are the right company to be trusted for LDRs. AMPER also helped us be a part of the big consortiums on the LEOB, CIMR but also to lead many other commercial and research projects." – Dr. Leri Datashvili, CEO & Chief Designer, Founder, LSS GmbH

ESA TDE funding for the AMPER project was pivotal in ensuring the survival and fostering the growth of LSS as an SME during its early days of operations. This financial support provided the necessary resources to continue expanding operations, allowing LSS to progress and refine the shaped mesh reflector antenna and GLR technology and remain competitive as a business. This, in turn, enhanced their ability to produce innovate technology within the European LDR roadmap, as demonstrated by their successive projects (e.g. participation in LEOB and CIMR). Through AMPER, LSS contributed to the upskilling of the European space industry in this unique capability. By publishing research and presenting at reputable conferences, they also solidified their reputation and gained increased visibility. Overall, AMPER helped strengthen LSS' position in the market, enabling the company to attract and retain top talent, and grow their business.

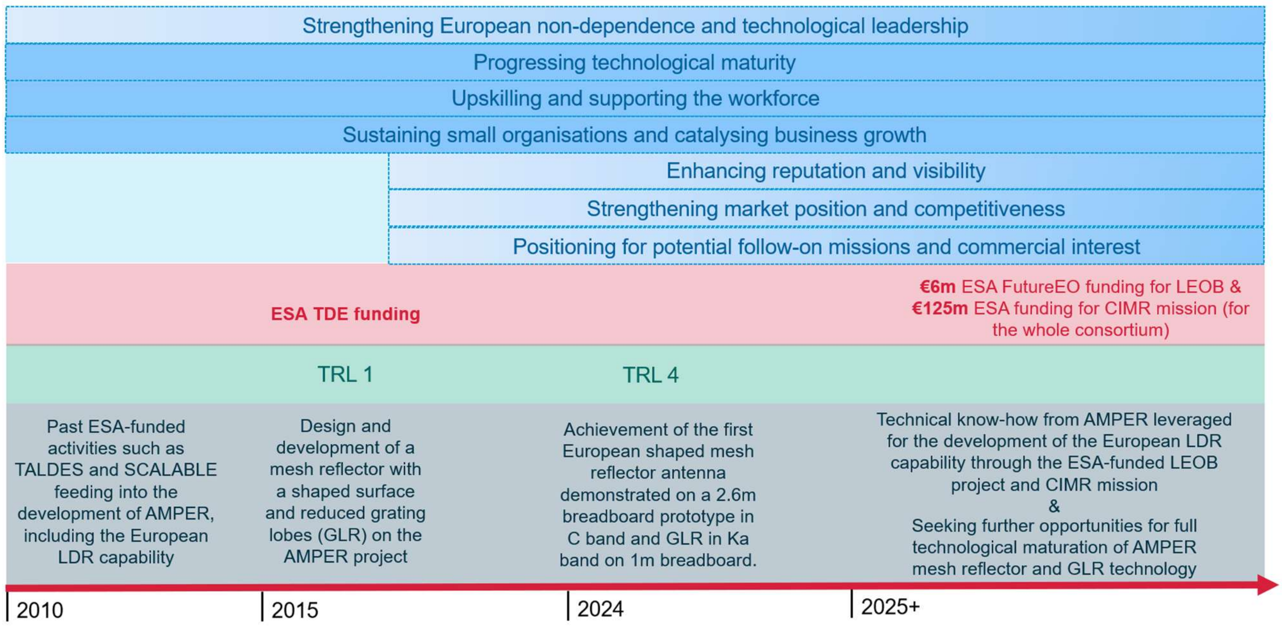
[15] MATLAB is a programming language that enables numerical computing, data analysing, creating simulations and more.

Next steps: Further development, further benefits

The next steps for the contractors include identifying opportunities for further technological maturation of the shaped mesh reflector antenna and GLR technology and capitalising on the key networks built through AMPER. Having also successfully achieved ESA's LEOB project objectives, both LSS and TICRA, as part of a consortium, aim to establish European non-dependence in the domain through the flight demonstration of the first European LDR on the CIMR mission.

A preliminary timeline overview of the TDE-funded 'Advanced Techniques for Mesh Reflector with Improved Radiation Pattern Performance (AMPER)' project and associated potential benefits are provided below.

Figure 4: Overview of the timeline of the progress, and subsequent benefit realisation, of the AMPER project



Source: know.space based on LSS and ESA data

Key priority indicators

Programme	TDE
Country	Germany, Denmark
Duration	9 years; Main contract: (2015 to 2020) CCN 3 for GLR: (2019 to 2024)
Prime contractor	Large Space Structures GmbH, DE (LSSS)
Sub-contractors	TICRA (DK)
TRL progression	From TRL 1 up to TRL 4
Spin-in into the space sector	-
Jobs supported	~4.5 FTE (on average).
New/further collaboration with ESA	LSS is leading several ESA projects following AMPER: DRAC, RAST, Milliwave and more.
Partnerships created	-
Follow-on funding applied/secured	-

[i] ESA (2017). ESA/ESTEC: D3P5 - TRP - Innovative Scalable Large Deployable Antenna Reflector - HPS (Germany) & LSS GmbH (Germany). Available at: https://indico.esa.int/event/170/contributions/1254/
[ii] The European Space Agency (2021). Automatic unfurling of European Large Deployable Reflector successfully demonstrated. Available at: https://www.esa.int/European_Large_Deployable_Reflector
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[iv] L. Datashvili, et. al (2023). Design and Performance of the First European Shaped Mesh Reflector Antenna. Available at: https://www.researchgate.net/publication/374263748_Design_and_performance
[v] L. Datashvili, et. al (2023). Design and Performance of the First European Shaped Mesh Reflector Antenna. Available at: https://www.researchgate.net/publication/374263748_Design_and_performance
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[vii] L. Datashvili, et. al (2023). Design and Performance of the First European Shaped Mesh Reflector Antenna – Presented at 41st ESA Antenna Workshop on Large Deployable Antennas. Available at: https://www.researchgate.net/first_European_shaped_mesh_reflector_antenna
[viii] L. Datashvili, et.al (2018). Large Deployable Reflectors: Enhancing the Mesh Reflector RF Performances – Presented at the 3rd International Conference "Advanced Lightweight Structures and Reflector Antennas". Available at: https://www.ticra.com/Large-deployable-reflectors-enhancing-the-mesh-reflector
[ix] J.C Angevain, L. Datashvili, et. al (2015). Phyllotactic arrangements of reflector mesh facets to decrease grating lobes – Presented at the 9th European Conference on Antennas and Propagation (EuCAP). Available at: https://ieeexplore.ieee.org/document/7228775
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[xi] Fortune Business Insights (2025). Satellite Antenna Market Size, Share and Industry Analysis. Available at: https://www.fortunebusinessinsights.com/satellite-antenna-market-110333