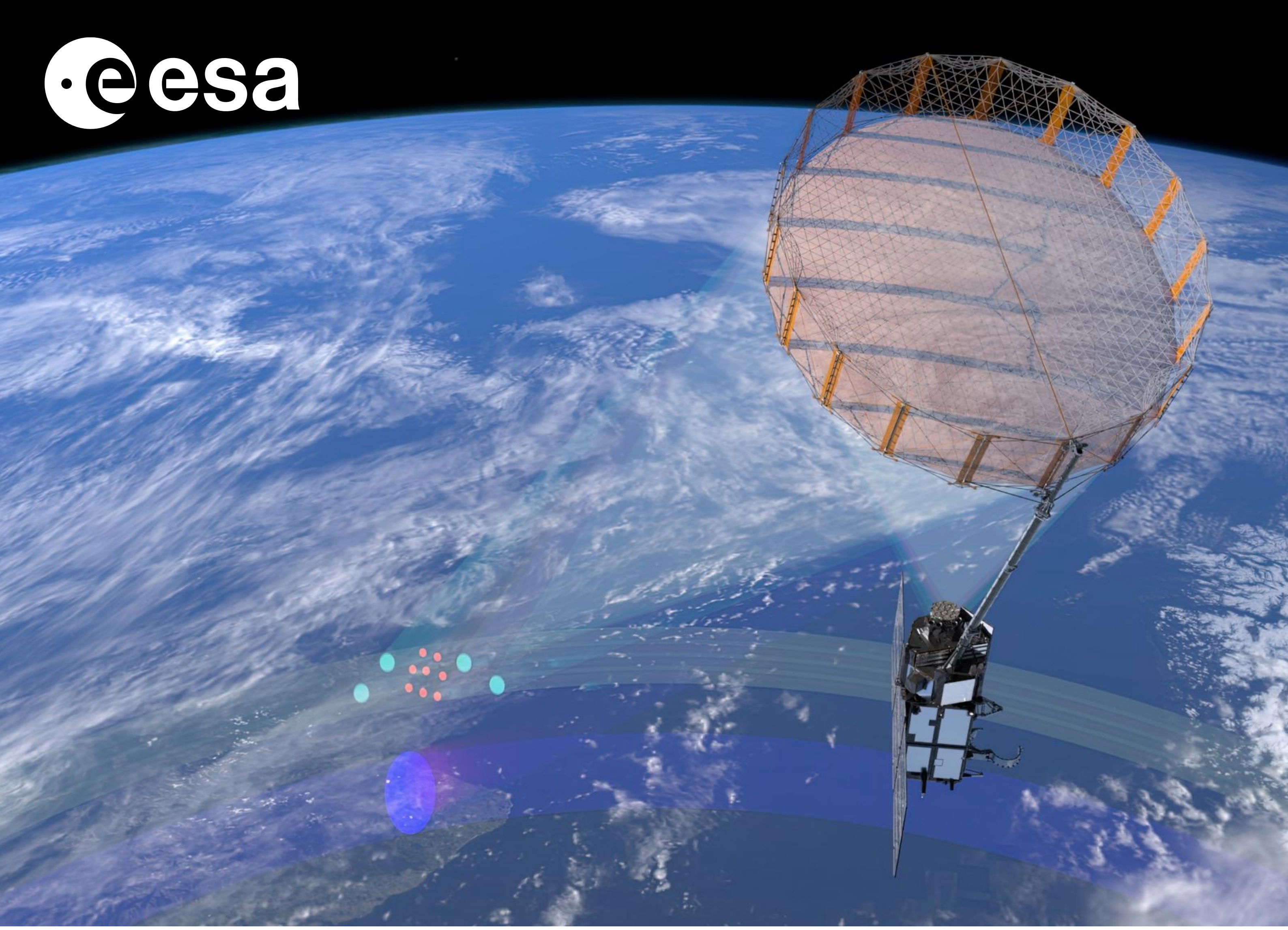

IMPACT ASSESSMENT OF ESA EARTH OBSERVATION EARLY R&D ACTIVITIES

LEOB: Large Deployable Reflector for Earth Observation

know.space

March 2025

High resolution imagery and detailed data is a cornerstone of Earth Observation solutions…

Reflectors are key structures that have been utilised in a wide array of satellites for decades, from ESA's ERS-1 to Biomass (scheduled for launch in 2025). They are used to increase accuracy by focusing and directing radar signals and are crucial for systems such as Synthetic Aperture Radar (SAR). This enables high-resolution imaging of the Earth's surface, helping capture detailed data regardless of weather conditions or time of day, and enhancing the capability of satellites to gather valuable data for various scientific, practical and dual-use applications. Earth Observation (EO) satellites use the reflectors alongside radar to monitor environmental changes, track land movements, and support disaster management and maritime surveillance.

Figure 1: ESA Biomass satellite over forest with 12m mesh reflector unfurled[1]

Source: ESA[2]

The increasing complexity and diversity of space-based applications for civil and defence purposes are driving the need for larger reflectors that enable higher spatial resolution and greater coverage of the Earth's surface. At the same time, the trend toward miniaturisation to optimise launch and manufacturing costs demands smaller satellites and components. Large deployable reflectors offer a practical solution for these requirements, enabling high performance while maintaining compact stowage volumes.[3]

[1] Reflector subsystem procured in 2015 from a non-European source.
[2] The European Space Agency (2023). ESA's forest satellite robust for launch. Available at: https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Biomass/ESA_s_forest_satellite_robust_for_launch
[3] HPS (n.d). Large Deployable Reflector Subsystems. Available at: https://www.hps-gmbh.com/en/portfolio/subsystems/large-deployable-reflector-subsystems/

… made possible through the development of large deployable reflectors funded by ESA …

The Large Deployable Reflector for Earth Observation (LEOB), funded by ESA's FutureEO programme[4], is a technology advancement project to accelerate the European development of such kind of space antennas/reflectors. This project received €6m for 5 years (2019 – 2024), with a focus on designing and testing an engineering model (EM) of the large deployable reflector (LDR) and assessing the impact on Large Deployable Reflector Subsystems (LDRS) - including deployable arm, hold-down-release-mechanisms, thermal hardware and deployment electronics. This activity enabled the design of the engineering model to be specifically tailored to CIMR (Copernicus Imaging Microwave Radiometer) mission requirements, as well as complete design concept and analysis for a reflector partially aligned with ROSE-L (Radar Observing System for Europe at L-band) mission objectives, which are both part of ESA's Copernicus Sentinel Expansion missions.[5] Upon internal discussions, ESA and the consortium chose only to advance the CIMR-aligned LDR capability up to the engineering model level, due to its highly-complex yet scalable nature, enabling technological transfer to the reflector that ROSE-L could use if required. More detail on scoping can be found in Annex A: Scoping and roles.

Spaceborne deployable reflectors are a key technology for enabling challenging missions in Earth remote sensing and science, and space telecommunications. The uniqueness of this technology is in its ability to compactly stow a deployable RF (radiofrequency) reflecting surface[6], reconciling the conflicting requirements of large aperture sizes.[7] Satellite missions rely on specialised technologies, often provided by a limited number of non-European suppliers, mainly located in the USA. One such technology is the LDRS, where if it cannot be sourced within Europe, dependence issues could arise for essential data on which critical services rely. ESA are consequently seeking to ensure European non-dependence by developing European LDRS technologies.[8]

[4] ESA's Future Earth Observation (FutureEO) programme aims to maintain leadership in Earth observation by fostering innovation and advancing satellite missions that address global challenges, including climate change and societal issues. It focuses on delivering scientific excellence to enhance societal and economic resilience through cutting-edge research and data-driven solutions.
[5] The data from ESA's Copernicus Sentinels supports Copernicus Services in tackling challenges like urbanisation, food security, climate change, and natural disasters. Six new Sentinel Expansion missions are currently being developed.
[6] The parabolic mesh on the LDR is an RF reflecting surface that is used to direct and capture microwave signals, enabling high-resolution imaging of the Earth's surface, including through clouds and darkness.
[7] A large aperture size enables finer resolution imaging (allowing detailed Earth surface mapping) and is correlated to the size of the antenna/reflecting surface.
[8] J. Angevain, et. al (2020). Spaceborne Unfurlable Reflector Antenna Technologies in Europe: Current Status and Future Outlook. Available at: https://www.researchgate.net/publication/344783886

Figure 2: European Large Deployable Reflector fully deployed

Source: ESA & LSS[9]

There has been considerable effort in the past decade through ESA's TDE (e.g. TALDES[10], AMPER[11] and SCALABLE[12] contracts), Discovery (e.g. RESTEO contract)[13] and ARTES (e.g. MSURA[14] and MESNET[15] contracts) programmes, as well as the European Commission's Horizon 2020 programme (Large European Antenna – LEA – project) to progress the development of various aspects of the Large Deployable Reflector Subsystems. These activities culminated in the ESA-funded LEOB project, a comprehensive integration project combining all the systems developed through previous programmes.

The LEOB project was carried out by the 'WeLEA' consortium, including contractors from various European nations. The selection of this consortium is rooted in their success on Horizon 2020's LEA[16] project. Concurrently, WeLEA was also contracted under ESA's FutureEO programme to carry out the LADEA project, which complemented LEOB's LDRS development with an arm technology focus. WeLEA is led by prime contractor High Performance Space Structures GmbH (HPS), a specialist company in space-based antenna-, reflector- and structure-subsystems, with Large Space Structures GmbH (LSS), a leading provider of large deployable reflectors in Europe, as a key subcontractor and lead on the LDR.

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[9] The European LDR is designed, built and deployed by/at LSS Gmb. Image supplied by LSS to ESA. The European Space Agency (2021). Automatic unfurling of European Large Deployable Reflector successfully demonstrated. Available at: https://www.esa.int/Applications/
[10] LSS (n.d). Completed Projects. Available at: https://www.largespace.de/about-lss/completed-projects
[11] The European Space Agency (2020). Mesh reflector for shaped radio beams. Available at: https://www.esa.int/Mesh_reflector
[12] ESA/ESTEC (2017). D3P5 - TRP - Innovative Scalable Large Deployable Antenna Reflector - HPS (Germany) & LSS GmbH (Germany). Available at: https://indico.esa.int/event/170/contributions/1254/
[13] Nebula Public Library, ESA (n.d). RESTEO Reflector Synergy between Telecom and Earth Observation. Available at: https://nebula.esa.int/reflector-synergy
[14] ESA CSC (2018). MSURA. Available at: https://connectivity.esa.int/projects/msura
[15] ESA CSC (2024). MESNET. Available at: https://connectivity.esa.int/projects/mesnet
[16] The Horizon 2020 LEA project (which received €5m in grant funding), was dedicated for the first time in Europe on subsystem-level activities, combining all required building blocks and mechanical and RF-test facilities

HPS (DE) oversaw the arm assembly (known as the deployable boom), reflective mesh delivery and surface accuracy measurements (to and at LSS) and product assurance, including coordinating deployment, electronics, hinges, HDRM, CFRP tubes and MGSE subcontractors. LSS (DE) was responsible for overall large deployable reflector assembly with RF Surface Mesh Assembly, RF Surface Network Assembly, Deployable Support Ring Assembly with Pantographs' and Posts' subassemblies, and Deployment Electro-Mechanical system. They oversaw these elements' concept, design, analysis, and development[17], as well as manufacturing, assembly, integration and testing of the engineering model[18]. More detail on roles can be found in Annex A: Scoping and roles.

Figure 3: Organisations part of the consortium

Source: Project documentation provided by LEOB contractors[19]

… enhancing environmental monitoring and resource management …

The CIMR mission imposed unique and challenging design requirements on the large deployable reflector developed under the LEOB project – mainly scalability in frequency range going from L-band to Ka-band, surface shape precision related to the RF aperture size, and rotation around the satellite axis. This required the LDR's surface be accurately shaped to ensure a stable RF surface even with the rotational and thermal loads. The beam spot size[20] and beam efficiency[21] also required the RF aperture to be between 7m and 8m. The

[17] Listed activities also done for ROSE-L
[18] Activities only done for CIMR, not ROSE-L
[19] Note: This is not an exhaustive diagram.
[20] The size of the beam at a specific distance: a smaller spot size offers greater precision, while a larger spot size covers a larger area.
[21] The proportion of the beam's power that reaches the target. Higher efficiency means that less energy is wasted or scattered.

successful validation of the engineering model developed under the LEOB project has proven the LDR's maturity for application in Earth Observation missions (from TRL 4 to 6, including LSS-invested developments).[22]

The LDR will enable the CIMR satellite (once launched) to facilitate frequent observations of sea-ice concentration at a resolution of 5 km or better, and sea-surface temperature at 15 km or better across a wide 1900 km swath. The CIMR instrument will measure Earth's brightness temperature at multiple RF frequencies (1.4, 6.9, 10.6, 18.7, and 36.5 GHz) and from different angles, allowing for more accurate tracking of ice loss, ocean warming, and shifting weather patterns.[23] Therefore, the whole LDR-Subsystem, with its significant impact on satellite level architecture, structure and mechanical loads, is central to the CIMR mission.

… and delivering potentially valuable socio-economic benefits

The flight verification of the LDRS on the CIMR mission and its potential commercialisation will unlock the most significant benefits for both the organisations involved and wider society. However, some important strategic and technological benefits have already been realised at an early stage through this ESA-funded technology advancement project.

Enhancing European non-dependence and technological leadership

Strategic and sustained ESA investment over the past decade has enabled the development of a first-of-its-kind large deployable reflector capability in Europe, enhancing European technological sovereignty and expertise.

ESA funding is a pivotal enabler of European technological leadership and strategic independence in the development of large deployable reflector subsystems. European EO and telecommunication missions have long been dependent on outsourcing the acquisition of LDRS from external suppliers. Currently, only a few countries in the world (mainly China, India, Russia, Japan, Israel and the US) have successful, long-term flight heritage of this capability.[24] Therefore, the contractors highlighted how ESA's investment in consistent and

[22] M. Loesch, et. al. (2023). LDRS – The Scalable European Solution of Large Deployable Reflector Subsystems for Earth Observation and Telecommunication. Available at: https://iafastro.directory/iac/archive/browse/IAC-22/B1/3/69331/
[23] The European Space Agency (2021). Automatic unfurling of European Large Deployable Reflector successfully demonstrated. Available at: https://www.esa.int/Applications/Observing_the_Earth
[24] J. Angevain, et. al (2020). Spaceborne Unfurlable Reflector Antenna Technologies in Europe: Current Status and Future Outlook. Available at: https://www.researchgate.net/publication/344783886_Spaceborne_Unfurlable_Reflector_Antenna_Technologies_in_Europe_Current_Status_and_Future_Outlook

credible development of this capability will reduce reliance on external providers, ensuring that the value generated from this strategic capability remains within Europe.

The LDRS is a vital technology in executing complex EO and telecommunications missions. Therefore in 2010, ESA's Large Antenna Working Group set out the objective of achieving European non-dependence and leadership through the development of technologies for reflectors with scalability and/or modularity features, to cover a) sizes above 4m and up to 25m and b) for frequency bands ranging from P to Ka.[25] Currently, satellites such as ESA's Biomass and SMOS use P and L band reflectors for EO purposes, and Eutelsat Hotbird and ESA's Alphasat use Ku and Ka band reflectors for television and broadband services.[26]

ESA's decade-long investment has culminated in the successful demonstration of the engineering model of the CIMR-aligned LDRS on the LEOB project. The demonstration showcases the highly scalable and enabling nature of the LDR. This flexibility will also facilitate future LDRS-enabled missions that require large aperture and/or high frequency operation. The European LDRS will achieve 'flight verified' status when the CIMR mission launches in 2029.

Progressing technology maturity

ESA funding has enabled the progression of European LDRS capability on the LEOB project successfully beyond the innovation 'valley of death'.[27]

Strategic ESA investment in the development of the LDRS capability, as well as in lower-tier building block/component capabilities, has been facilitated over the past decade mainly through the TDE and ARTES programmes – and now, through FutureEO. The LEOB project is a pivotal enabler in advancing the technological maturity of the European LDR, effectively bridging critical gaps in development, particularly the innovation 'valley of death'. This has ensured technology maturity progression from early R&D to an engineering model demonstration.

The contractors reported progression of LDRS technology from TRL 4 to TRL 5, successfully demonstrating an engineering model aligned for the CIMR mission requirements, with further TRL raising to TRL 6 thanks to LSS investment. This CIMR-aligned LDRS consisted of a 7.5m diameter foldable reflector surface with a deployable arm (developed under ESA's LADEA project), which enables compact stowaway on a launch vehicle of any size and

[25] T.K. Henriksen & C. Mangenot (2013). CEAS Space Journal: Large deployable antennas. Available at: https://link.springer.com/article/10.1007/s12567-013-0055-4
[26] To note, reflector providers for Eutelsat's Hotbird and ESA's Alphasat are outside of Europe.
[27] The 'valley of death' in R&D refers to the gap where innovative technologies often fail to secure enough funding to continue essential R&D, leading to their abandonment.

seamless unfurling once deployed in space. The large surface area ensures efficient signal capture and makes the system scalable for use with multiple RF bands all the way up to 36.5 GHz in the Ka band. The consortium also achieved design and analysis of a 12m diameter LDRS aligned with ROSE-L mission requirements.

The foldable/deployable feature of this LDRS was achieved without compromising on the large RF aperture needed for enhanced and more accurate imaging of the Earth. The successful demonstration of the engineering model under the LEOB project validates its scalability and reliability for other operational missions, expanding possible applications.

Securing the ESA CIMR mission contract

The successful demonstration of the CIMR-aligned LDRS engineering model on LEOB, along with other successful projects such as LADEA, has enabled the consortium to secure a follow-on contract to further mature and 'flight verify' the European LDRS technology.

Building upon the accomplishments of the LEOB project, alongside their other contracts, enabled the consortium to win a ~€125m opportunity to further advance the LDR-subsystem capability to full technological maturation. This could potentially achieve Europe's first 'flight verification' of the technology as part of ESA's CIMR mission.

The mission is scheduled to launch in 2029 and will include the CIMR-aligned parabolic large reflector antenna, with a projected aperture diameter of 7.4 m that rotates at 7.8 revolutions per minute. Equipped with this reflector, the CIMR satellite will provide exceptional spatial resolution and coverage, with the ability to observe sea-ice concentration at ≤ 5 km and sea-surface temperature at ≤ 15 km. This capability will enable continuous, operational monitoring of climate change in the Arctic's cryosphere, oceans, surrounding land, and atmosphere, particularly at low frequencies, which are essential for accurate assessments.

Ongoing successful completion of projects such as LEOB has also helped the consortium gain increased visibility and trust within ESA, across a variety of different programmes (e.g. TDE, ARTES, FutureEO). This enables them to maintain a competitive advantage in securing follow-on/future ESA missions.

Promoting job creation and workforce development

Continued ESA funding on LEOB has contributed to the growth of the European workforce, evidenced by at least 56 jobs created and/or supported – which rises even further within the follow-on CIMR activity. It has also fostered the development of young and early-career professionals.

ESA funding plays a significant role in creating and supporting jobs in the European space sector in general. SMEs such as HPS and LSS have benefited greatly; for example, this ESA FutureEO funding has allowed them to overcome financial barriers for technology advancement, hiring additional staff and scaling up their operations. Across the consortium, 56 jobs were created and/or supported on the LEOB activity, contributing to immediate employment opportunities and fostering the next generation of skilled professionals in the European workforce.

In particular, LSS reported that their involvement in LEOB supported a team of 36 staff members, including 20 full-time equivalents, 10 of which came from newly hired employees to meet the growing operational requirements. Meanwhile, HPS leveraged ESA-funding on the LEOB project to preserve 6 full-time existing jobs that were at risk, mitigating potential workforce reductions and ensuring continuity in critical roles. Further subcontractors of the consortium have reported a total of 14 jobs supported. Additionally, the follow-on acquisition of the CIMR-LDRS-contract has enabled a further 80 jobs created / supported within the consortium, which can be indirectly traced back to the LEOB (and LADEA) projects.

ESA funding for LEOB has also facilitated considerable impact on the development of young and early career-professionals. For example, several university students interned with HPS, enabling them to be trained in practical applications, with 2 becoming employees after their studies. Similarly, LSS employed at least 3 interns throughout the course of the LEOB project, and facilitated practical learning of 6 high-school students, who also returned as interns when they went to university.

By investing in talent development, the contractors are ensuring a robust pipeline of skilled professionals capable of driving innovation and adaptability, positioning Europe to maintain a competitive edge in this technological area of EO.

Developing new technical and project management skills

ESA funding has facilitated the development of unique technical skills in advancing the European LDRS capability (e.g. reflector folding, reflector assembly, deployment, vibration and TVAC testing at LSS) and furthered the contractors' project management abilities.

The technical skills developed as part of the LEOB activity reflect the novel demands and challenges. LSS developed complex technical skills in CAD (Computer-Aided Design) designing, as well as FEM analysis with NASTRAN. But most importantly, the team built expertise in reflector folding – as successful deployment is critically dependent on seamless folding and deploying of the delicate reflector components. Furthermore, the team increased expertise in final assembly and integration of the reflector, performing thermal and environment testing, conducting deployment tests, fine tuning components, identifying areas of potential instrument errors, flight knowledge and ensuring all uncertainties are resolved through measurements. Similarly, HPS noted that an experienced systems engineer led the team's training and enhanced company expertise in aspects of systems integration specific to the LDRS capability, with the team also collectively refining their skills on developing designs using CAD, structural analysis, configuration control and test engineering.

The contractors' involvement in LEOB as part of a larger consortium contributed to the growth of project management capabilities. HPS gained, in addition to its existing flight hardware management skills, further experience in managing a very large multinational consortium. LSS opted to employ a Project Manager with experience in the aerospace industry to effectively manage the demands of this project but also more importantly the CIMR activity, in combination with the organisation's other active projects.

The contractors also gained invaluable knowledge through their interactions with ESA. For example, experience on LEOB enabled HPS to gain an improved understanding of ESA's robust technology development processes and strategic priorities. Furthermore, LSS reported an exchange of technical knowledge between the company and ESA on LDR technology development, which was mutually beneficial in advancing the capability to the fullest extent. The exposure to ESA's operational framework has enabled both HPS and LSS to solidify their expertise and contribute more effectively to potential future ESA missions.

Publishing at least 5 journal articles[28] (see Annex B: Publications and conferences) and having disseminated their research through at least 8 key conferences has greatly enhanced the contractors' technical expertise by promoting rigorous research, critical analysis, and

[28] LSS noted that the scope of publication remains limited to safeguarding the company's proprietary knowledge.

effective communication of the unique LDRS technology developed on the LEOB project. This has also helped enrich the knowledge base in the field of large deployable reflector subsystems in Europe.

Enhancing business development by catalysing internal investment

To successfully deliver the objectives of the LEOB and CIMR LDRS activities, the contractors were required to scale up their operations. ESA funding thus facilitated business growth and catalysed significant internal investment.

ESA funding has enhanced business development for many SMEs on the LEOB project, including HPS, LSS and many of their subcontractors, but catalysing internal investment. This support has enabled contractors to scale their businesses, which in turn has strengthened their ability to innovate and compete in European and global markets.

In addition to ESA funding, the WeLEA consortium noted that the LEOB contract catalysed an in-kind internal investment in manpower, facilities and equipment, reflecting the project's limited scale and scope. LSS reported a modest investment in the expansion of personnel and equipment required for the design and manufacture of the LDR. Similarly, HPS also reported marginal investment in supporting existing staff and scoping of potential facilities.

However, the success of the LEOB project proved instrumental in securing the CIMR LDRS contract, a significantly larger and more complex activity. This, in turn, required a substantial escalation in investments of both personnel and facilities. LSS reported a sizable expansion of their team, as well as investment in enhancing their existing facilities (e.g., MAI/T, engineering, testing and production, and assembly and integration facilities). They also set up a clean room with deployment and gravity compensation systems for LDRs up to 10m in size. They noted that reflectors require more than 50,000 parts, with a high number of assemblies and subassemblies, which are all produced in-house. Similarly, HPS also reported a significant investment in manpower and an expenditure of €1m for the acquisition, installation and certification of a very large clean room for assembly and functional testing.

These strategic internal investments not only demonstrate the companies' ability to adapt and scale up their resources as necessitated by the needs of LEOB and CIMR, but they have also positioned them for sustained growth on future projects and missions.

Enhancing reputation, credibility and visibility

The successful achievement of LEOB project objectives has helped improve the contractors' reputation and visibility, positioning them well for future opportunities. This includes enabling HPS and LSS to submit competitive proposals to develop LDRS' for two Earth Explorer 12 candidate missions and receive 4 Phase 0&A projects for EE12

The contractors' participation in the development of a first-of-its-kind LDRS capability in Europe, as part of LEOB, has significantly elevated their position within the European space industry. Their demonstrated ability to deliver solutions not readily available in the market has enabled them to position themselves as leaders of LDRS and related building block capabilities, strengthening their reputation and enhanced visibility in an increasingly dynamic European market. This has also improved trust and visibility within ESA for the contractors, evidenced by the consortium's selection for the further advancement of the LDR capability and provision of the same reflector as part of ESA's CIMR mission.

An important result of the enhanced reputation and visibility has been the acquisition of additional follow-on and commercial opportunities by the contractor-chain, allowing them to broaden their operations and increase their reach within the European space industry. Examples include requests to HPS from countries such as India and South Korea, whilst several commercial contracts on building block level components have been placed, such as the reflective mesh (contractor: HPtex), mainly to the US and Asia, and the CFRP tubes (contractor: FHP).

The demonstrated success of the LEOB project has also positioned the contractors (HPS and LSS) well for seeking further follow-on mission contracts to advance their LDRS capabilities. For example, they have already submitted competitive proposals for the provision of large deployable reflectors for two ESA Earth Explorer 12 (EE12) candidate missions. In the meantime, HPS and LSS have received 4 early Phase 0&A projects for EE12.

The CryoRad mission – complementing Copernicus' CIMR mission, aims to bridge the gap in observation of the cryosphere and improve our understanding of key processes in the polar regions through novel measurements of key parameters such as the temperature profile of ice shelves, sea-ice thickness and sea-surface salinity in cold waters. Meanwhile the Hydroterra+ mission aims to deliver data over Europe, the Mediterranean and northern Africa to understand rapid processes tied to the water cycle and tectonic events in these regions.[29]

[29] The European Space Agency (2024). ESA selects four new Earth Explorer mission ideas. Available at: https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Preparing_for_tomorrow/ESA_selects_four_new_Earth_Explorer_mission_ideas

Creation of a spin-out & securing potential commercial contracts

The contractors' successes in advancing the LDRS capability has positioned them as sole suppliers in Europe, attracting commercial interest and facilitating the creation of a unique spin-off technology which can help capture a significant European (and potentially, global) market share.

As 'first movers' in the European LDRS domain, the successful completion of this ESA-funded activity has solidified the contractors' position as credible and reliable leaders of this technology. By also securing a unique status, still, as current sole suppliers of European LDRS capabilities, they are now able to capitalise on the achievements of LEOB as a strategic advantage. This not only enhances their competitive edge but also positions them to seize a larger market share as future demand emerges. With the global satellite antenna market projected to grow at an annual growth rate of 11.8%[30], the contractors are well-positioned to capitalise on this growth and expand their presence in the industry within all scientific, commercial or military markets.

The successful demonstration of engineering model of the CIMR-aligned LDR has enabled HPS to develop a spin-off technology of the mesh they supplied for the reflector. This prompted the creation of the joint venture HPTex (a spin-out company of the space-oriented HPS and technical textile-oriented company Iprotex), where the mesh technology[31] is sold as a standalone product. By leveraging their expertise and existing technology developed on the LEOB project, HPS have been able to transform an internal innovation into a commercially viable spin-out business. This has, in turn, created a valuable new revenue stream for HPS Group and strengthened their position in the industry. The wire supplier for the mesh, LUMA (SE), has just recently been acquired by an important European financial investor in order to further grow as European supplier of mesh wire to the global market, for which the CIMR-involvement had been an important decision factor.

The contractors highlighted that there is a growing demand for foldable/deployable large reflector subsystem technologies within the European and global space industries, due to the need for large reflectors to be foldable and fit within smaller launchers. HPS reported about requests from European startups, including one to develop a 20m LDRS, and several institutional interest from Asian players for the provision of large deployable reflectors. The initial workforce capacity increase supported by ESA-funding has already helped alleviate some of the constraints of limited manpower, with further investment from the companies

[30] Fortune Business Insights (2025). Satellite Antenna Market Size, Share & Industry Analysis, 2024-2032. Available at: https://www.fortunebusinessinsights.com/satellite-antenna-market-110333

[31] This mesh technology is used in multilayer insulation (MLI) for both space (e.g. used on spacecraft and cryogenic systems to minimise heat loss) and terrestrial applications (e.g. used in vacuum-sealed containers utilised by industry and around sensitive lab equipment to minimise thermal conduction), which provides protection against harsh temperatures.

being key to sustaining growth. LSS also reported receiving requests for proposals to supply LDRs from commercial and institutional organisations, and are in the early phases of a commercial telecommunications mission, for which they are the suppliers of small antennas for a modestly-sized constellation.

The contractors emphasised that successful achievements of LEOB objectives and the advancement of the LDRS capability on the CIMR mission will boost commercial competitiveness for the capability in Europe. They noted that this is particularly critical as the European market is competing against a fully developed market in the US, where companies with far greater resources are driving advancements. Developing European capability in this technology and increasing market competitiveness will allow Europe to capitalise on the opportunity cost of acquiring LDRS from American suppliers, valued at €10-50m per reflector, depending on reflector and arm size. Furthermore, it may, in time, help European production to transform from built-for-purpose LDRS specific to each mission, into the creation of a supply chain for commercial, off-the-shelf reflectors, as is available in the American market.

Would these benefits have been realised without ESA

ESA's objective to build a sovereign European LDRS capability has been facilitated by a series of targeted investments over the past decade. The LEOB project represents the culmination of all the previous contracts, achieving successful demonstration of the engineering model of the CIMR-aligned LDR. The funding and technical expertise provided by ESA under the LEOB contract has been crucial in the consortium's success. Furthermore, the contractors reported that increased trust and support from ESA was imperative to them securing follow-on funding to further mature the LDRS capability and provide the ESA CIMR reflector.

> *"ESA's role was of paramount importance. Without ESA, development of the LDRS would not have been possible at the industrial policy level and as an activity through the creation of LEOB, LADEA and CIMR. ESA's role and support were crucial in enabling us and the consortium to continue developing this on the CIMR mission as well" – Martin Lösch, HPS GmbH, Germany*

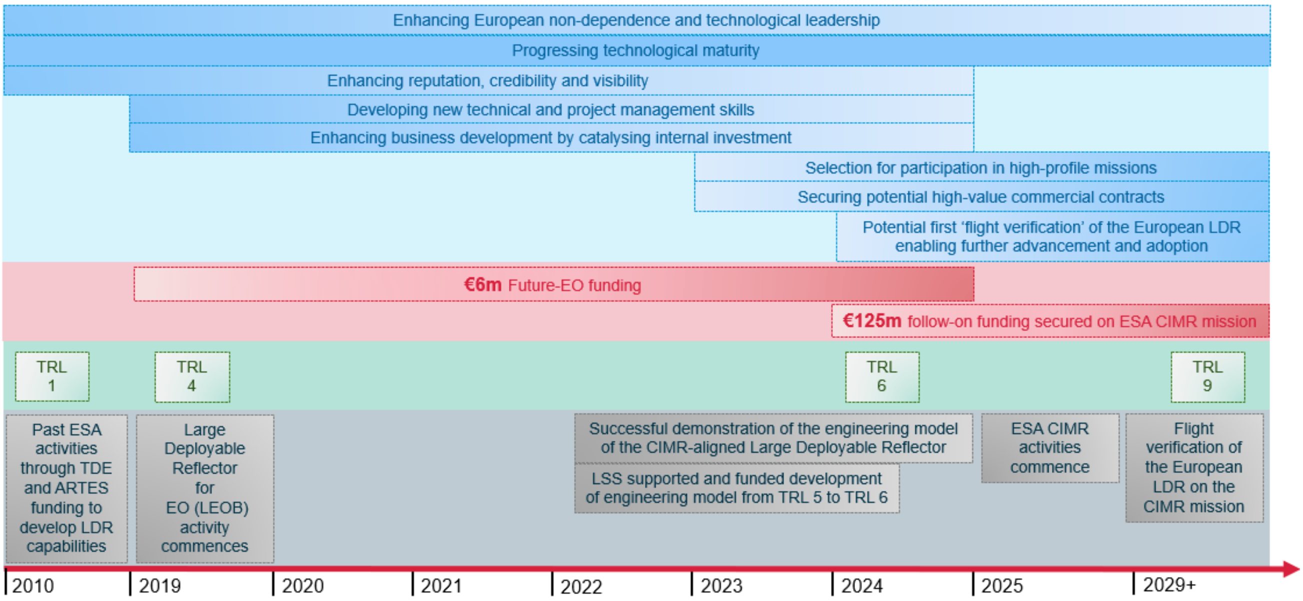
Contractors highlighted that without ESA's intervention, the development of the 7.4m diameter reflector with multifrequency band capabilities would have been much more complex. ESA ensured that a European LDRS capability was realised at the industrial level through the selection and upskilling of the 'WeLEA' consortium, and at the policy level by making continuous funding available for the development of this capability. This has enabled the contractors to secure a competitive edge in the European market as sole suppliers of the scalable, large deployable reflector subsystem with all its related building blocks. In turn, ESA funding has also equipped the workforce with unique skills and capabilities, strengthening expertise and the resilience of the European space economy.

Next steps: Further development, further benefits

The immediate next step for contractors is to further mature the LDRS capability and demonstrate its performance and reliability through successful flight verification as part of the CIMR mission. Additionally, the contractors could capture early European market share upon it is flight demonstrated.

A preliminary timeline overview of the FutureEO-funded ‘Large Deployable Reflector for EO’ project and associated potential benefits is provided below. However, these next steps and their impact are dependent on the availability and timeliness of funding and further support.

Figure 4: Overview of the timeline of the LEOB project and the potential associated benefits



Source: know.space based on LEOB consortium data

Key priority indicators

Programme	FutureEO
Country	Germany, Portugal, Denmark, Sweden, France and Spain
Activity cost	€6 million; €5 million in funding and an additional €1 million in CCN.
Duration	5 years (Q1 2019 – Q1 2024)
Lead contractor	HPS (DE)
Sub-contractors	LSS (DE) – Lead on the large deployable reflector assembly FHP (PT), INVENT (DE) – producing the arm CFRP tubes and Reflector CFRP tubes respectively TICRA (DK), RUAG (DE), vH&S (DE), LUMA (SWE), HPS-RO (RO), INTA (ES), Airbus DS (DE), IRPOTEX (DE), Fraunhofer (DE), ETAMAX (DE), WSS (DE), DLR (DE), ONERA (FR)
TRL progression	TRL 4 to TRL 6; To note: LSS supported and funded development of the engineering model from TRL 5 to TRL 6.
Spin-in into the space sector	-
Jobs created/supported	**LEOB:** LSS: 36 jobs supported including 20 FTE (10 of which came from newly hired employees) HPS: 6 jobs supported Other subcontractors: 14 jobs supported *For awareness:* **CIMR LDRS contract:** LSS: expanded 5x their size on LEOB; 44 FTE working on the CIMR contract HPS: 10 jobs supported, and 10 jobs created Other subcontractors: 6 jobs created; 15 jobs supported
New collaboration with ESA	-
Partnerships created	-
Follow-on funding applied/secured	**Secured:** €125m contract through the ESA Copernicus Imaging Microwave Radiometer (CIMR) mission; LSS' commercial telecommunications contract; 4 early Phase0&A EE12 projects received. **Applied:** Phase0/A studies on Earth Explorer 12 candidate missions – CryoRad & Hydroterra+

Annex A: Scoping and roles

At the time of the LEOB project, unlike CIMR, ROSE-L had not yet been selected as one of the Copernicus Sentinel Expansion Missions. Therefore, internal discussions with ESA led to the prioritisation of the development of an engineering model for the CIMR-aligned LDRS as part of LEOB. This decision was also driven by the fact that the reflector required on the CIMR mission needed to demonstrate multi-frequency scalability up to the Ka band and high performance from its 7.5m diameter reflector surface, to ensure accurate pointing of beams. This contrasted with ROSE-L's reflector only needing to perform in the L-band, making the design and development of the reflector easier compared to CIMR. The scalability and enabling nature of the LDRS developed for CIMR also ensured future adaptability to the ROSE-L mission[32]. The early technology developments (LEOB and LADEA) prior to mission decisions (CIMR) were fully in line with the current wishes of ESA Member States.

The responsibilities of members of the LEOB consortium are as follows:

- **HPS (DE)** are, as prime contractor, responsible for the full Large Deployable Reflector Subsystem (with all its subcontractors) as well as for the deployable arm assembly (DAA) (known as the deployable boom), reflective mesh delivery (via HPtex DE), surface accuracy measurements, subsystem testing and product assurance.
- **LSS (DE)** are responsible for overall deployable reflector assembly (DRA) and its design, development, manufacturing, assembly, integration and testing.
- **INVENT (DE) and FHP (PT):** Produced the arm CFRP tubes and the reflector CFRP tubes.
- **Beyond Gravity (DE)** (previously RUAG GmbH) are responsible for reflector and arm hold-down release mechanisms (HDRMs) and arm hinges.
- **Von Hoerner & Sulger (DE)** (vH&S GmbH) are responsible for the deployment control electronics.
- **TICRA (DK)** are responsible detailed large deployable reflector (LDRS) and reflector RF performance predictions and correlations.
- **Further hardware and testing** are provided by FHP (PT), Luma (SWE), Inegi (PT), HPS (RO), INTA (ES) and Airbus DS (DE).
- **External services and suppliers** include Iprotex (DE), Fraunhofer (DE), FHP (PT), Invent (DE), Etamax (DE), WSS (DE), DLR (DE) and ONERA (FR).

[32] As it stands, the ROSE-L mission has moved away from the requirement of the large deployable reflector capability designed as part of the LEOB project.

Annex B: Publications and conferences

Publications

- S. Endler, et.al. (2023). 41st ESA Antenna Workshop on Large Deployable Antennas: Design, Development and Verification Challenges for the Deployable Arm as Subassembly ff CIMR's Large Deployable Reflector Subsystem. Available at: https://t.hps-gmbh.com/public/d0a285cd87ce
- M. Loesch, et.al. (2023). Proceedings 17th ECSSMET: LDRS – The Scalable European Solution of Large Deployable Reflector Subsystems for Earth Observation and Telecommunication. Available at: https://t.hps-gmbh.com/public/d0a285cd87ce
- M. Loesch, L. Datashvili, et.al. (2022). 7th Workshop on RF and Microwave Systems, Instruments & Sub-systems + 5th Ka-band Workshop: European Large Deployable Reflector and Arm Developments as Pathfinder for Future Earth Observation Missions. Available at: https://t.hps-gmbh.com/public/d0a285cd87ce
- L. Datashvili, et. al. (2021). IEEE: Large European Deployable Reflector: RF Modeling and Measurement Correlation. Available at: https://ieeexplore.ieee.org/document/9704353/authors#authors
- L. Datashvili, et. al. (2022). IEEE: Predicted and Measured Antenna Patterns of the European Large Deployable Reflector. Available at: https://ieeexplore.ieee.org/document/9769024

Conferences

- ESA Industry Seminar on Future of ESA EO Programmes (2022) – "The Deployable Large European Antenna (LEA) – Enabler for Future Earth Observation Missions".
- ESA Living Planet Symposium, Bonn (2022) – "Ultra-Stable Arm in the European Large Deployable Reflector Subsystem LEA".
- ARSI + KEO Workshop (7th Workshop on Advanced RF Sensors and Remote Sensing Instruments 5th Ka band Earth Observation Radar Mission Workshop) (2022) – "European Large Deployable Reflector and Arm Developments as Pathfinder for Future Earth Observation Missions".
- 3rd Georgian International Conference (2018) on "Advanced Lightweight Structures and Reflector Antennas".
- ESA Industry Seminar on Future of ESA EO Programmes (2022) on "The Deployable Large European Antenna (LEA) – Enabler for Future Earth Observation Missions".
- 17th European Conference on Spacecraft Structures, Materials and Environmental Testing (ECSSMET) – Toulouse (2023) on "LDRS – The Scalable European Solution of Large Deployable Reflector Subsystems for Earth Observation and Telecommunication
- 2021 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (APS/URSI) (2021) on "Large European Deployable Reflector: RF Modeling and Measurement Correlation".
- Nationale Konferenz Satellitenkommunikation (2021) on "Large Deployable Reflector Subsystem LEA: Connectivity Schlüsseltechnologie aus Deutschland".