

PULSAR

Enabling the Next Generation of Large Space Telescopes Through Precision Mechanisms and In-Orbit Assembly

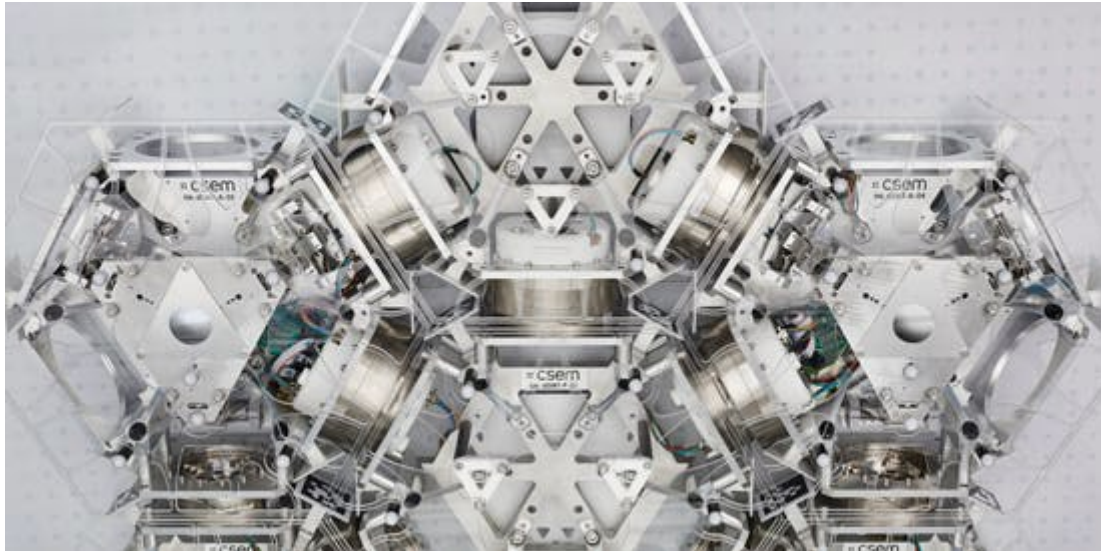
Future space observatories will require telescope apertures far larger than those that can be launched within the constraints of existing launch vehicles. To achieve the scientific ambitions of next-generation astrophysics missions, large segmented structures must be assembled and aligned directly in orbit. The European Horizon 2020 project PULSAR (Prototype for an Ultra Large Structure Assembly Robot) was established to address this challenge by developing and demonstrating key technologies for autonomous in-space assembly of large telescope structures.

Within this framework, CSEM contributed its expertise in precision mechanisms, compliant systems, advanced manufacturing, and space instrumentation by developing a high-precision mirror tile demonstrator capable of compensating for assembly inaccuracies after robotic installation. The project represents a compelling example of how CSEM combines precision engineering and innovative manufacturing technologies to enable future space systems.

Addressing a Fundamental Space Engineering Challenge

Large space telescopes rely on segmented primary mirrors composed of numerous individual mirror elements that must be positioned with exceptional accuracy. During robotic assembly in orbit, unavoidable mechanical tolerances and positioning errors can degrade optical performance unless active alignment mechanisms are available. PULSAR therefore focused on technologies capable of both assembling and subsequently aligning large telescope structures in space.

The project investigated the assembly of a future segmented telescope with a primary mirror diameter of up to 35 meters, demonstrating concepts and technologies required to make such missions technically feasible.



CSEM's Innovation: Precision Mirror Positioning Through Flexure-Based Engineering

CSEM developed a Single Mirror Tile (SMT) demonstrator equipped with a precision adjustment mechanism designed to correct mirror alignment errors after assembly. The system enables accurate positioning of each mirror segment along three critical degrees of freedom: piston, tip, and tilt.

At the heart of the design lies a tripod architecture combining:

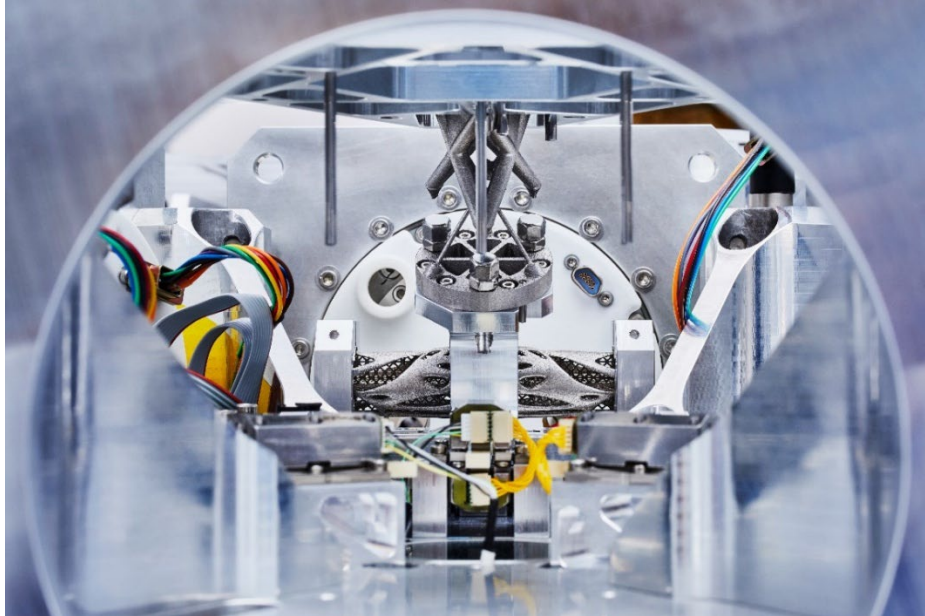
- Precision actuation stages
- Compliant transmission mechanisms
- Flexure pivots and gimbals
- High-precision metrology
- Additively manufactured kinematic components

The use of compliant mechanisms was particularly important. By replacing conventional bearings with elastic deformation of carefully engineered structures, the design eliminates friction, backlash, lubrication requirements, and wear. This approach provides exceptional repeatability and long-term stability while reducing complexity and improving reliability, key requirements for space applications.

Leveraging Additive Manufacturing for High-Performance Mechanisms

PULSAR also demonstrated the benefits of additive manufacturing for precision space mechanisms. Flexible pivots and gimbal structures were designed and produced using metal additive manufacturing, enabling geometries that would be difficult or impossible to realise with conventional manufacturing processes.

The integration of compliant structures and additive manufacturing allowed CSEM to develop lightweight, highly integrated components with excellent mechanical performance while reducing part count and assembly complexity. This approach illustrates how modern manufacturing technologies can be leveraged to enhance both functionality and system robustness in demanding environments.



Demonstrated Performance

The mirror positioning mechanism achieved performances compatible with the stringent requirements of future segmented telescope missions. The demonstrator provided:

- Three-axis positioning capability (piston, tip and tilt)
- ± 3 mm piston stroke
- $1\text{ }\mu\text{m}$ piston resolution
- Better than $5\text{ }\mu\text{m}$ piston repeatability
- $\pm 1^\circ$ angular stroke
- $4\text{ }\mu\text{rad}$ angular resolution
- Better than $20\text{ }\mu\text{rad}$ angular repeatability

Furthermore, the implemented flexure-based architecture delivered sub-micrometer positioning repeatability, demonstrating the capability of compliant mechanisms to achieve the precision required for future space observatories.