



FIBSTAR Project Final Review

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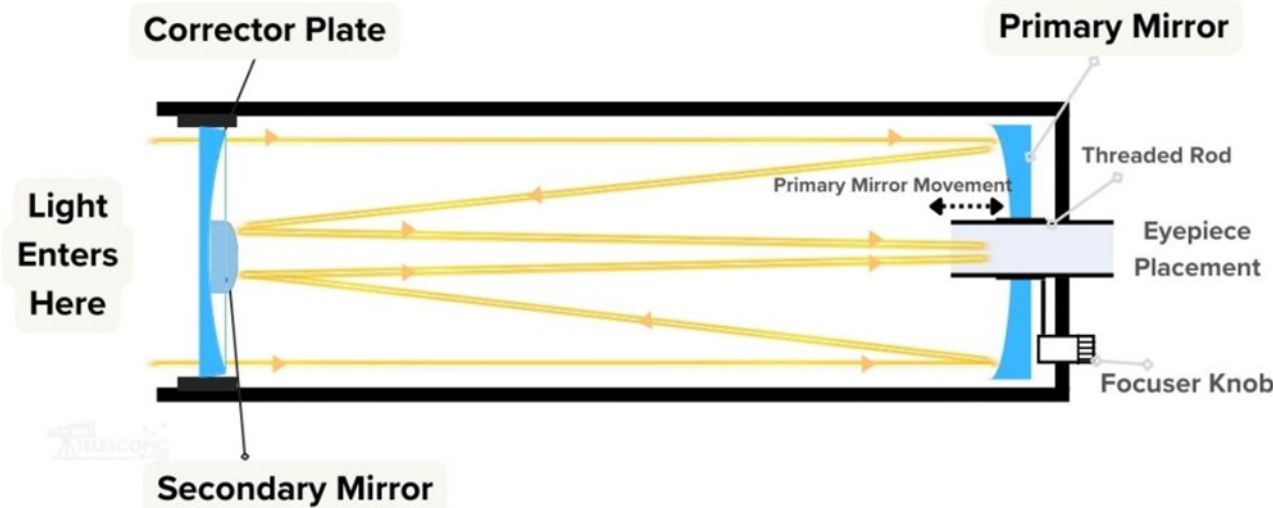
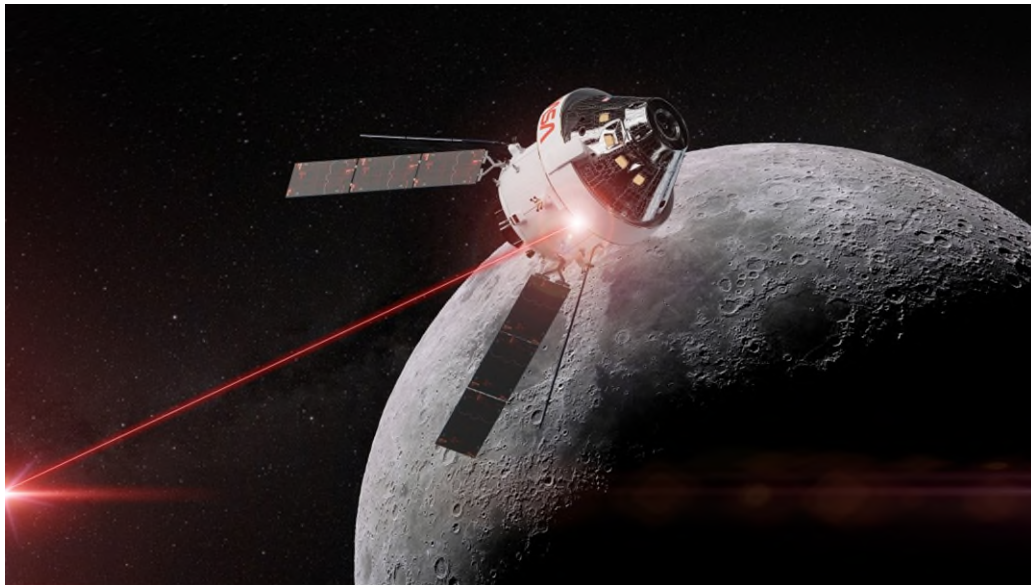
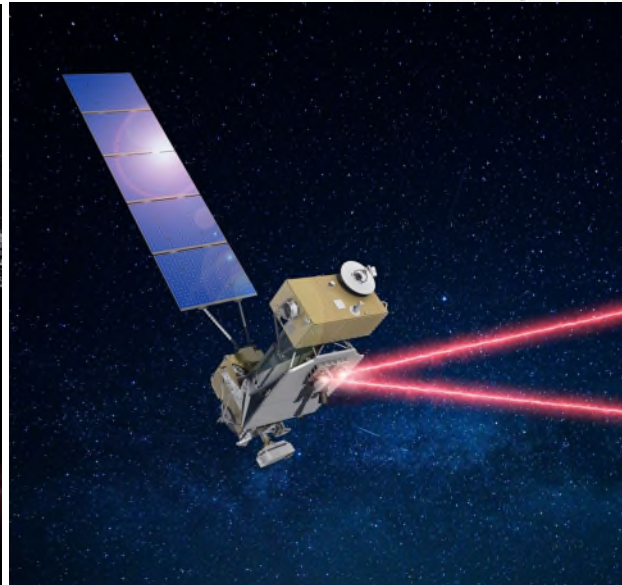
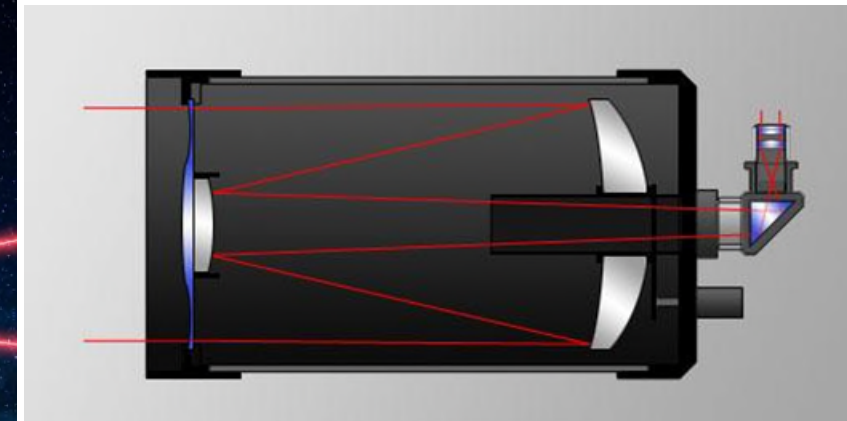
10/04/2026

Cranfield University & iCOMAT Ltd.



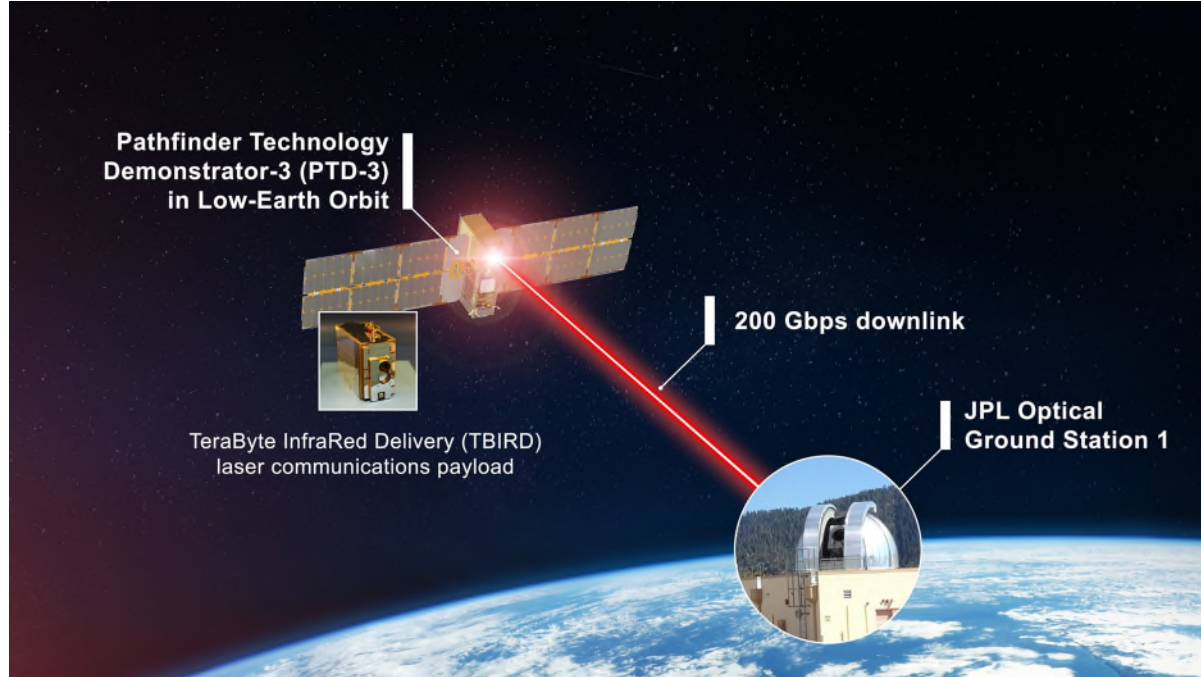
A New Way to Build Space Mirrors

- Build lighter mirrors for space
- New manufacturing approach: fibre steering
- Designed for Schmidt–Cassegrain telescope
- Prove it works with real prototypes
- Show clear benefits over current methods

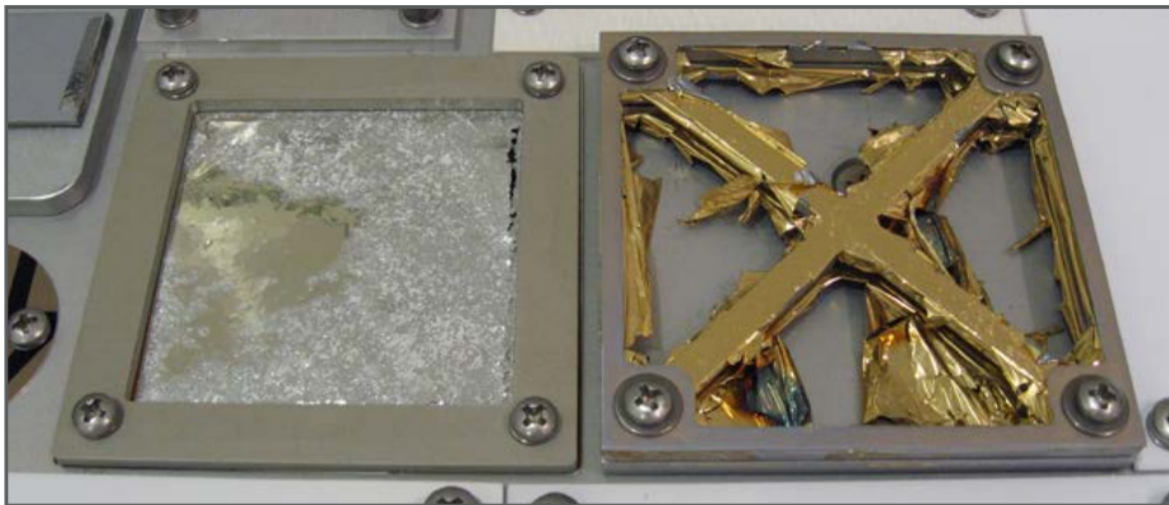
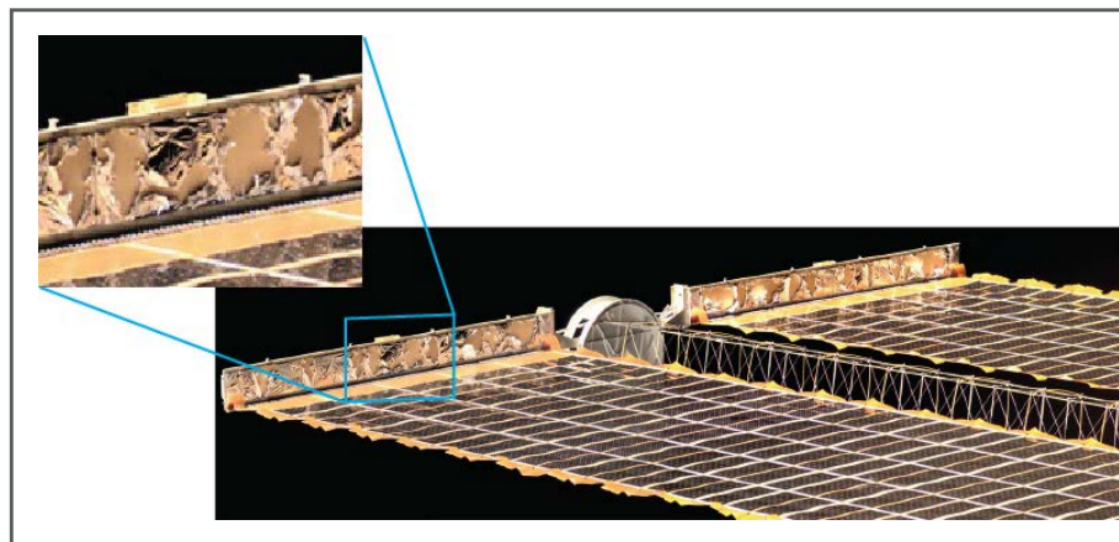


Why Space Mirrors Matter

- Used in satellite laser communication
- Enable faster, more secure data transfer
- Critical for future systems like:
 - Earth observation, navigation, defence and security



The Core Challenge



Preflight



Postflight



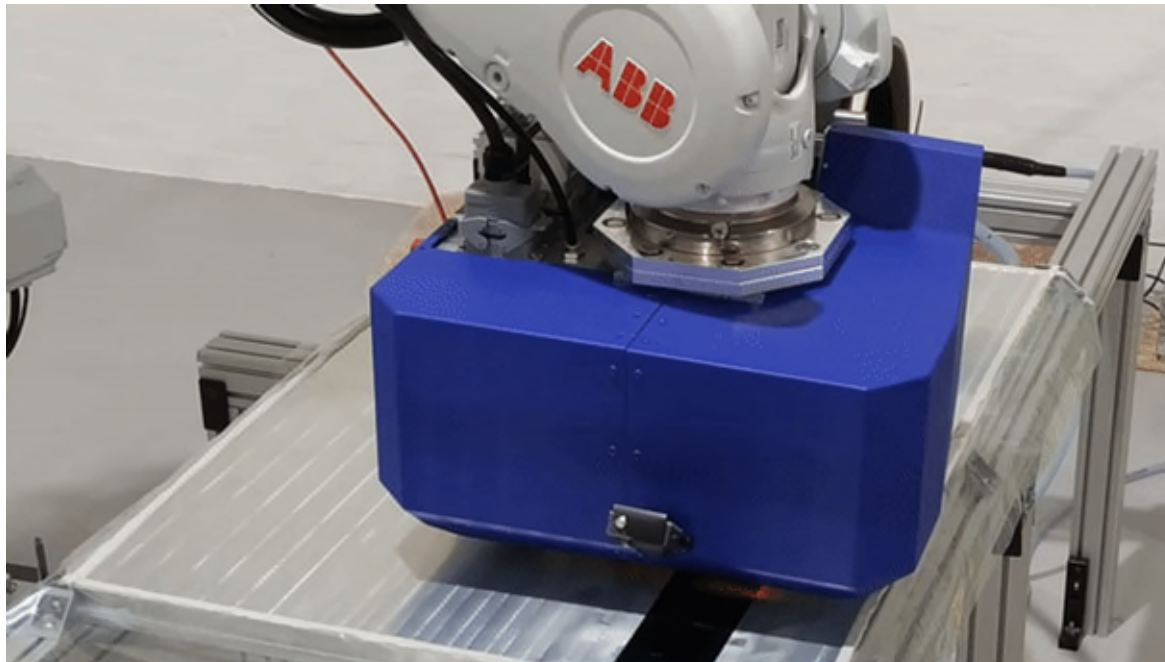
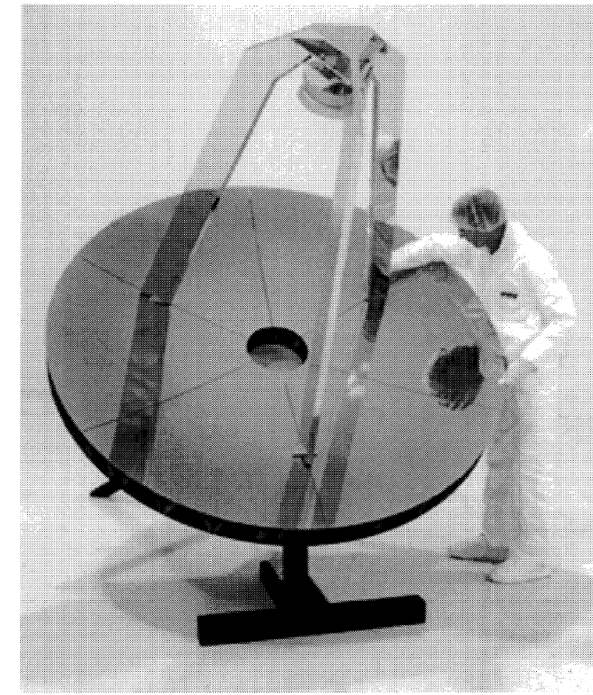
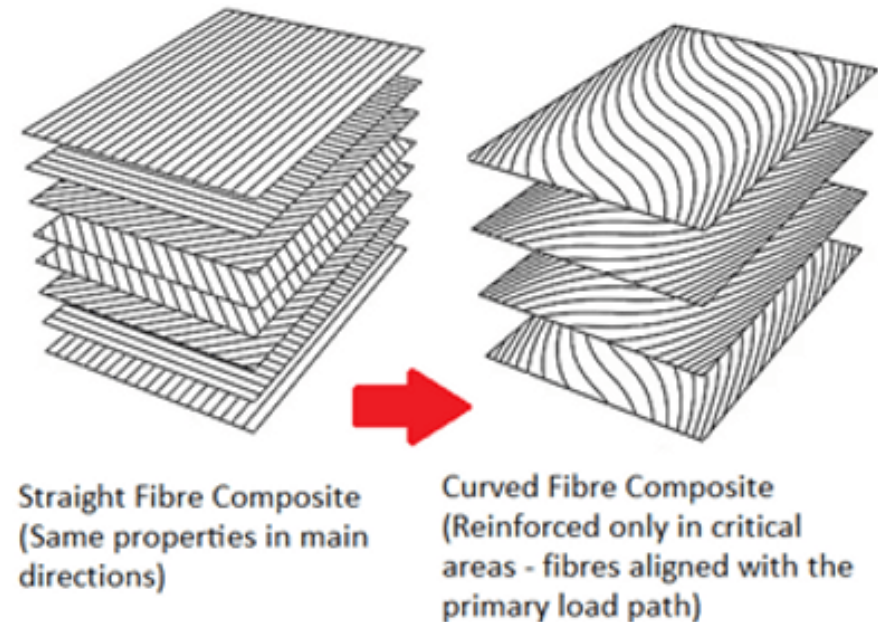
Preflight



Postflight

Our Solution

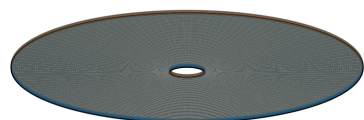
- Use advanced carbon fibre materials (IM7/8552)
- Introduce a new way of placing fibres
 - Rapid tow shearing (RTS)
- Carefully control how the mirror behaves
- Combine design, manufacturing, and testing



Two Designs Tested

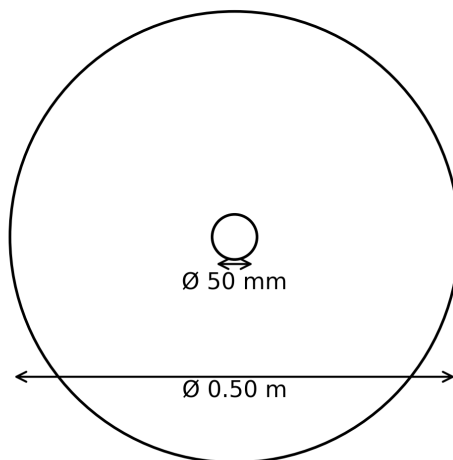
- Standard design (current approach)
- New design (with fibre steering)
- Same size, geometry, and material system
- Allows a direct and fair comparison

(a) Primary mirror geometry



Spherical radius of curvature
RoC = 8 m

(b) Plan view



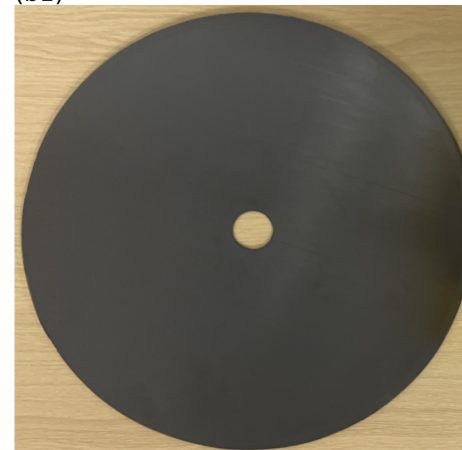
(a1)



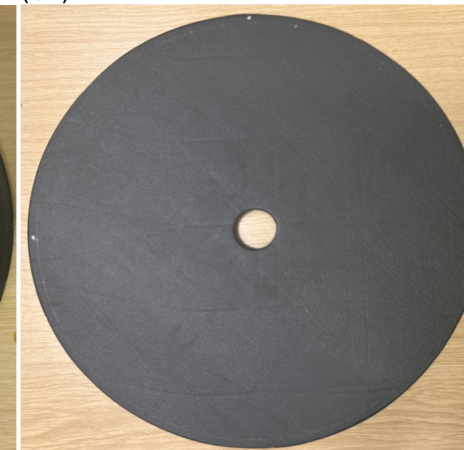
(a2)



(b1)



(b2)

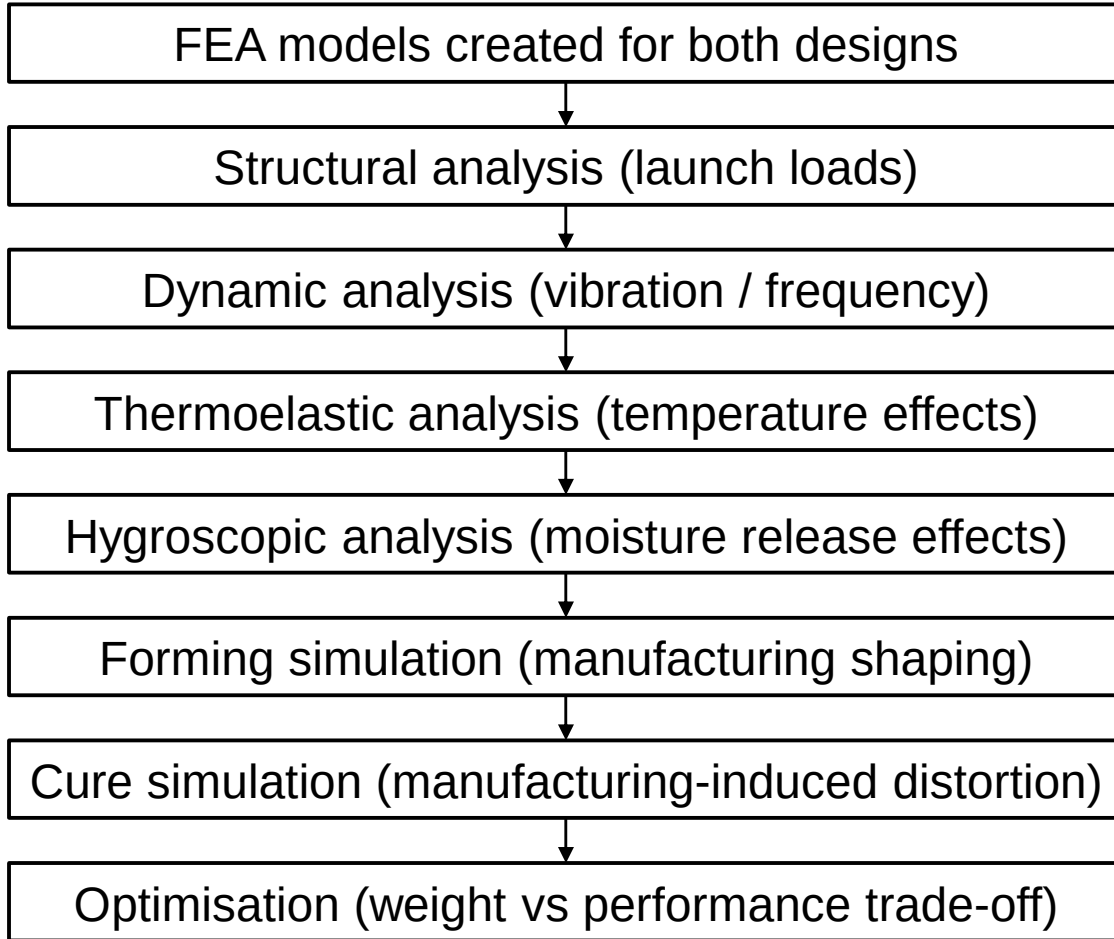
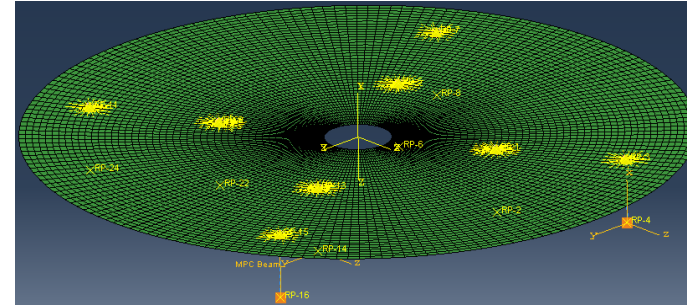
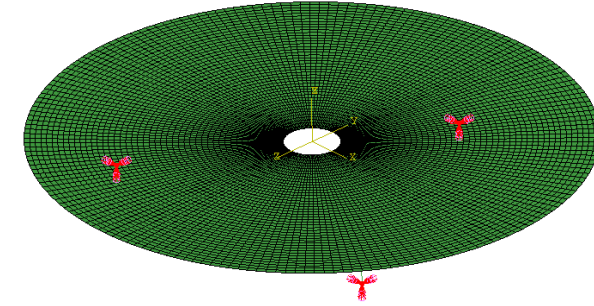
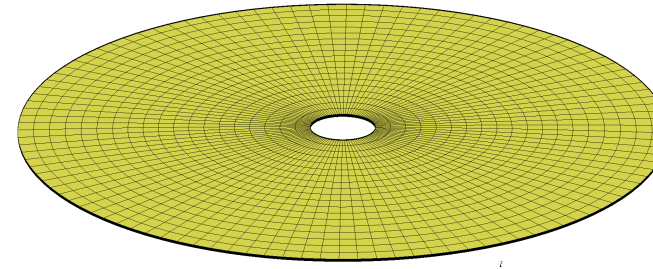
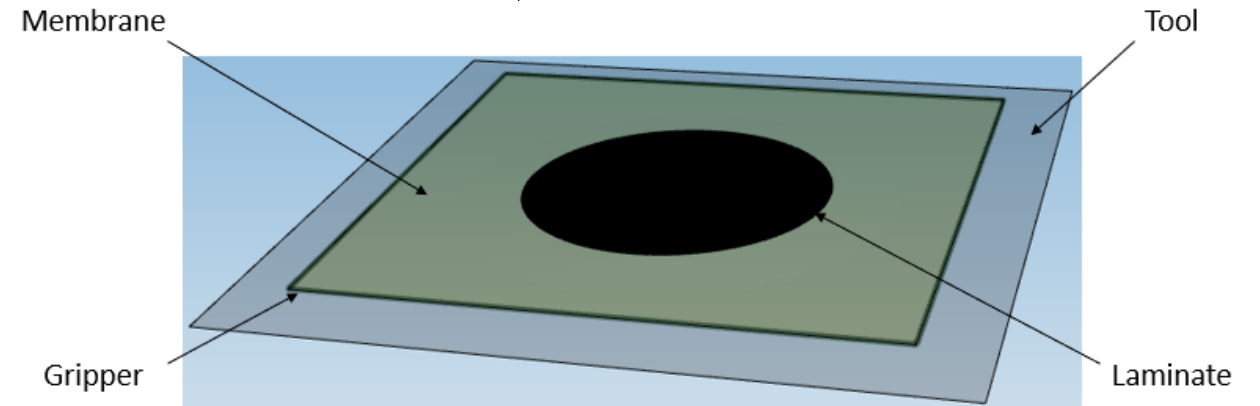


Manufactured composite reflectors:
straight-fibre laminate (a1) optical side, (a2) non-optical side;
RTS laminate (b1) optical side, (b2) non-optical side.

What We Evaluated

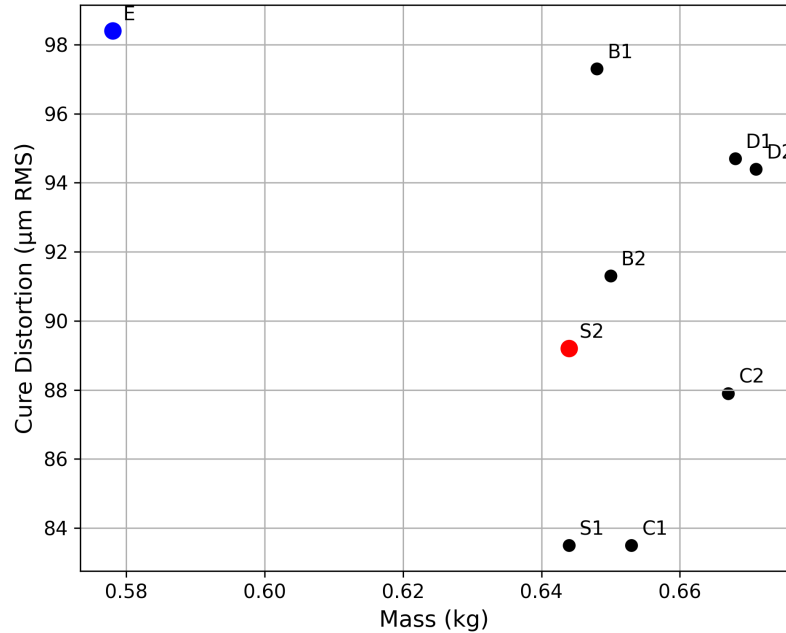
- Shape accuracy — how closely the mirror matches its intended form
- Stability under temperature changes — does it keep its shape in space?
- Structural strength — can it survive launch conditions?
- Manufacturing quality — are there defects or inconsistencies?
- Surface quality — is it smooth enough for optical performance?
- Consistency — do results match predictions and repeat across tests?

Simulation Approach

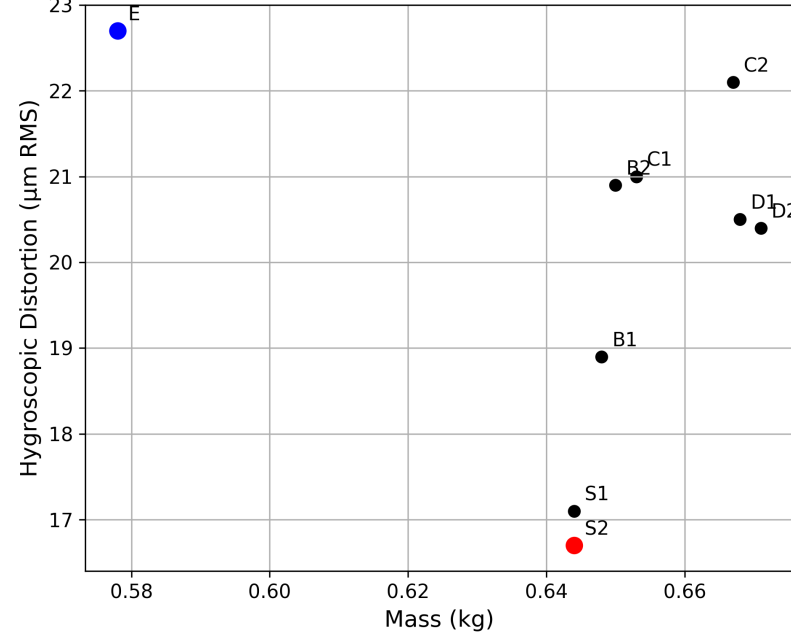


Simulation Results

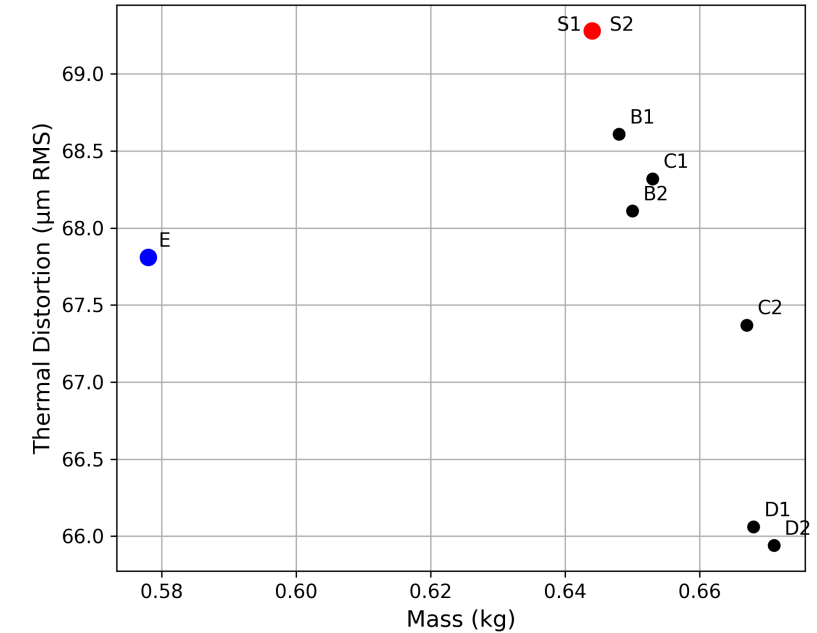
Mass vs Cure Distortion



Mass vs Hygroscopic Distortion



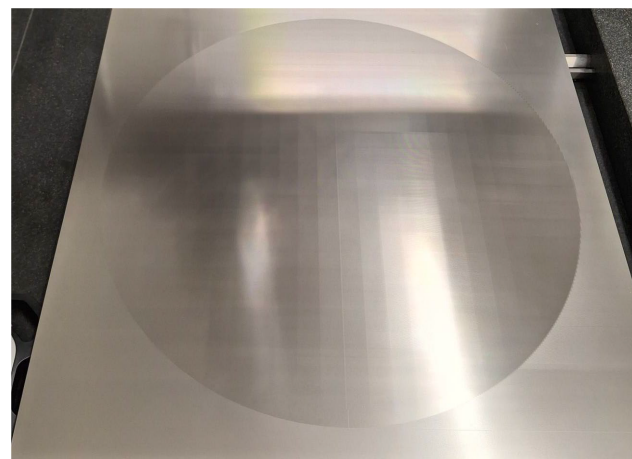
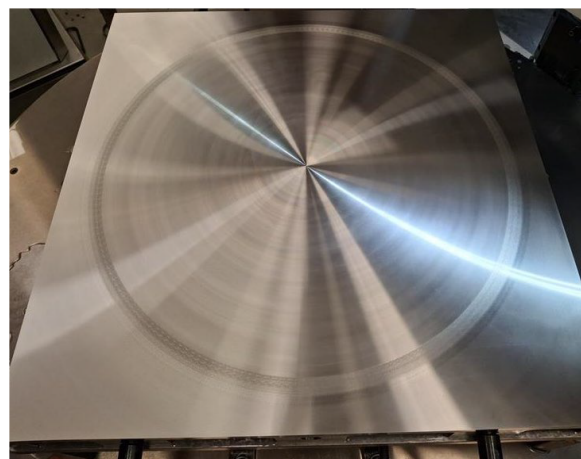
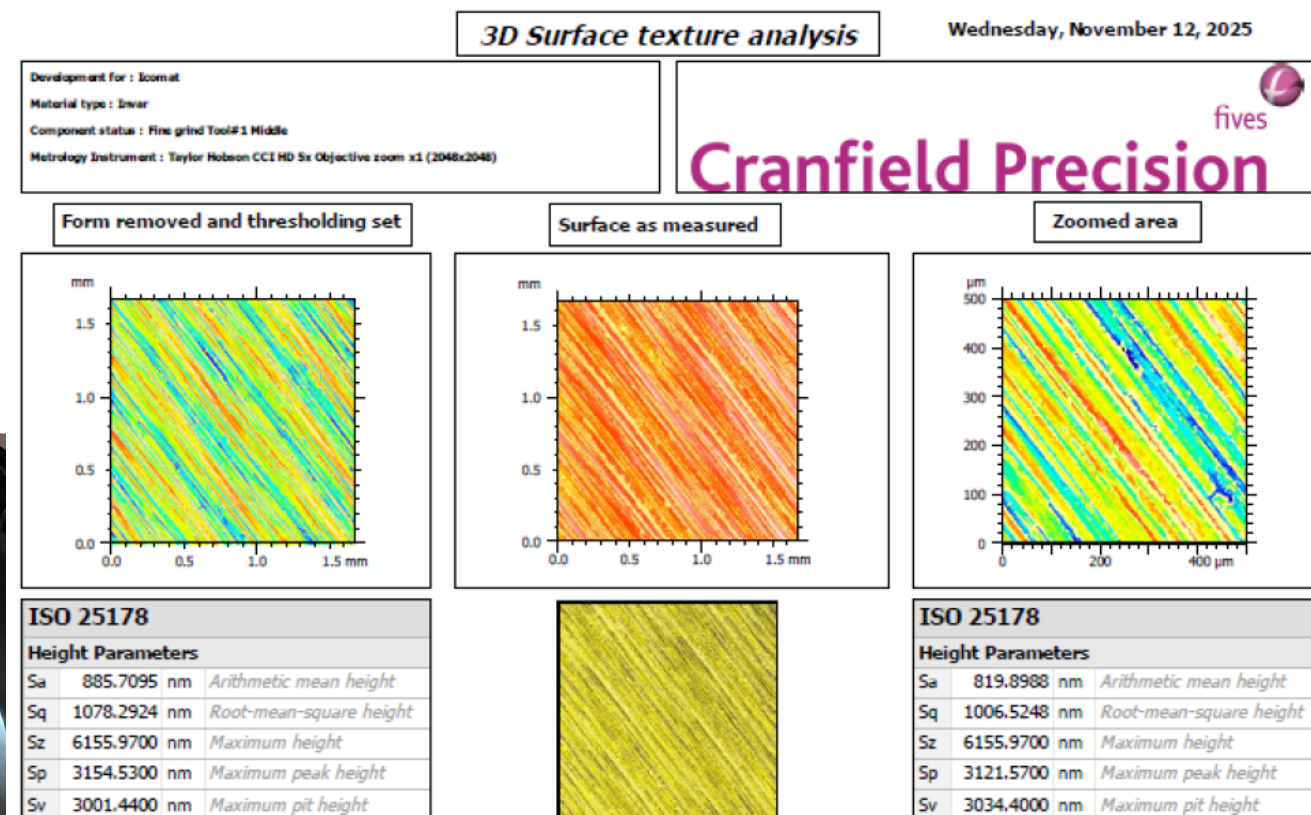
Mass vs Thermal Distortion



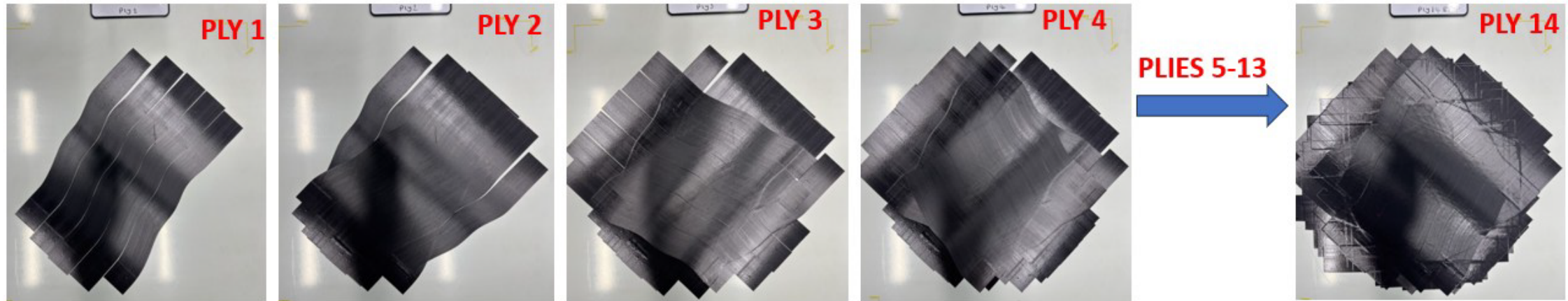
- Optimisation study identified best-performing designs
 - Straight-fibre S2 i.e. $[0/90/45/-45]_{2S}$
 - RTS E i.e. $[45/45^*/-45/-45^*/0/0^*/90/90/0^*/0/-45^*/-45/45^*/45]$
- Both achieve similar stability and meet all design requirements
- The new RTS design is ~11% lighter without losing performance

Precision Tooling

- High-precision Invar tool manufactured
- Polished by Fives for optical-grade surface
- Very smooth surface ($\approx 0.1 \mu\text{m}$ roughness)
- Stable under temperature changes
- Critical for achieving final mirror accuracy



Manufacturing — Fibre Layup

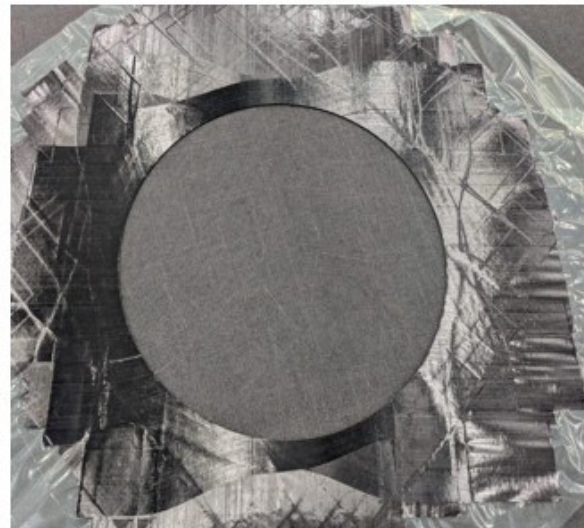


- Fibres placed on flat surface
- Two designs laid up: straight-fibre and fibre-steered
- Precise control of fibre direction



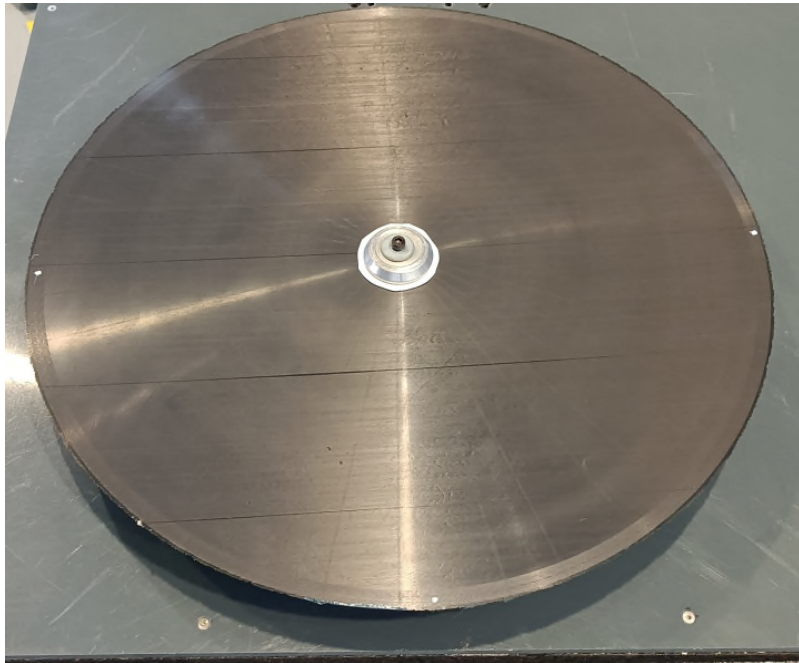
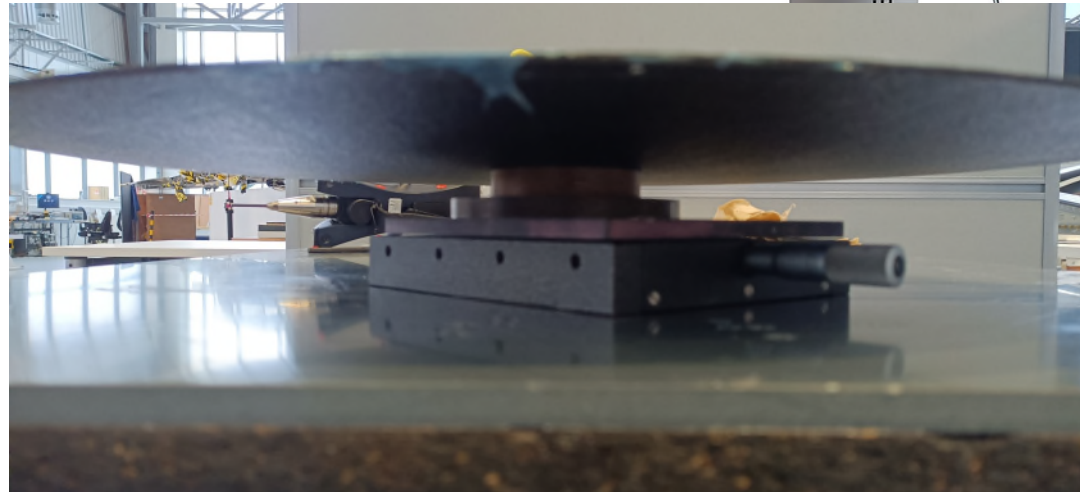
Manufacturing — Shaping & Curing

- Cut into circular shape with central opening
- Placed onto Invar tool
- Formed into final curved shape
- Cured in autoclave under heat and pressure



Non-Destructive Testing — Geometry Accuracy

- Measured using Leica Absolute Tracker AT901 (T-Probe)
- Compared with ideal shape
- Global distortion observed ($\sim 100\text{--}180\text{ }\mu\text{m}$ RMS)
- No local defects, good manufacturing accuracy

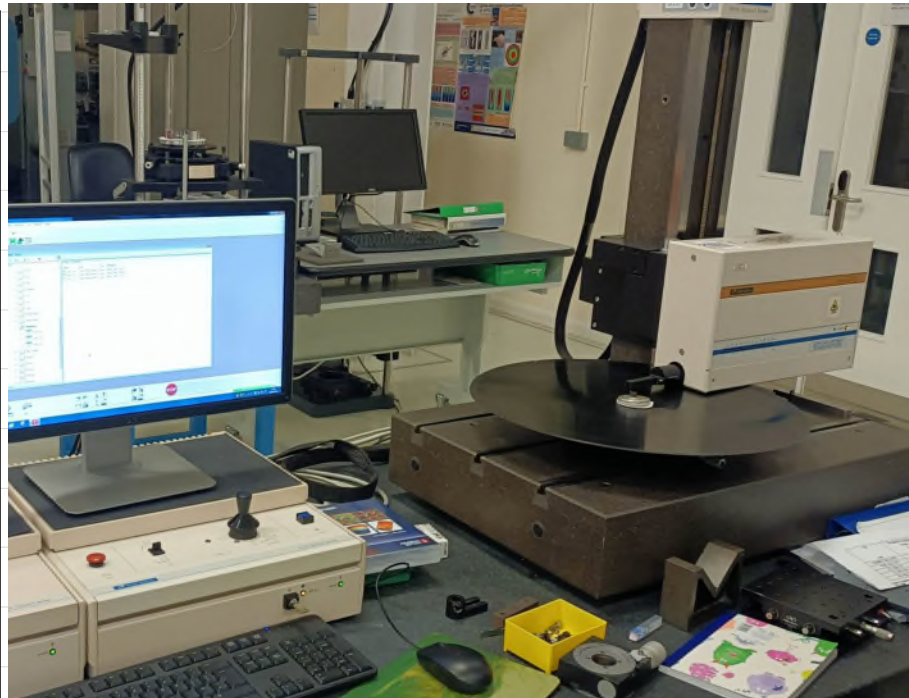
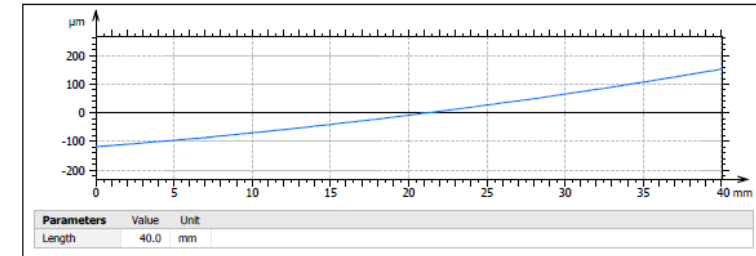
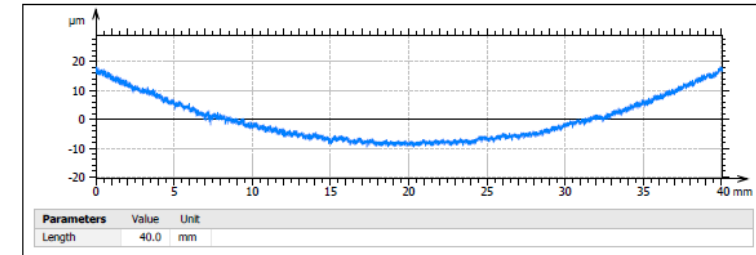
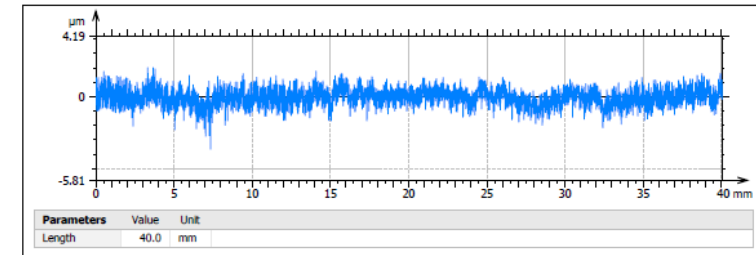
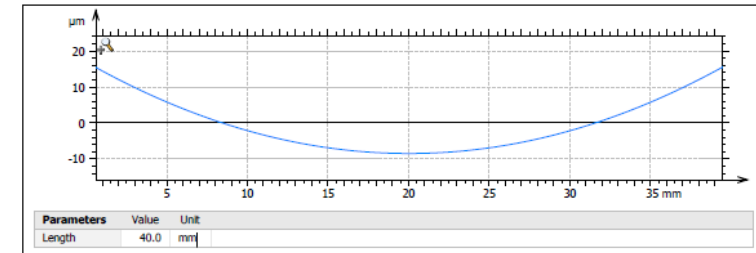


Non-Destructive Testing — Surface Quality



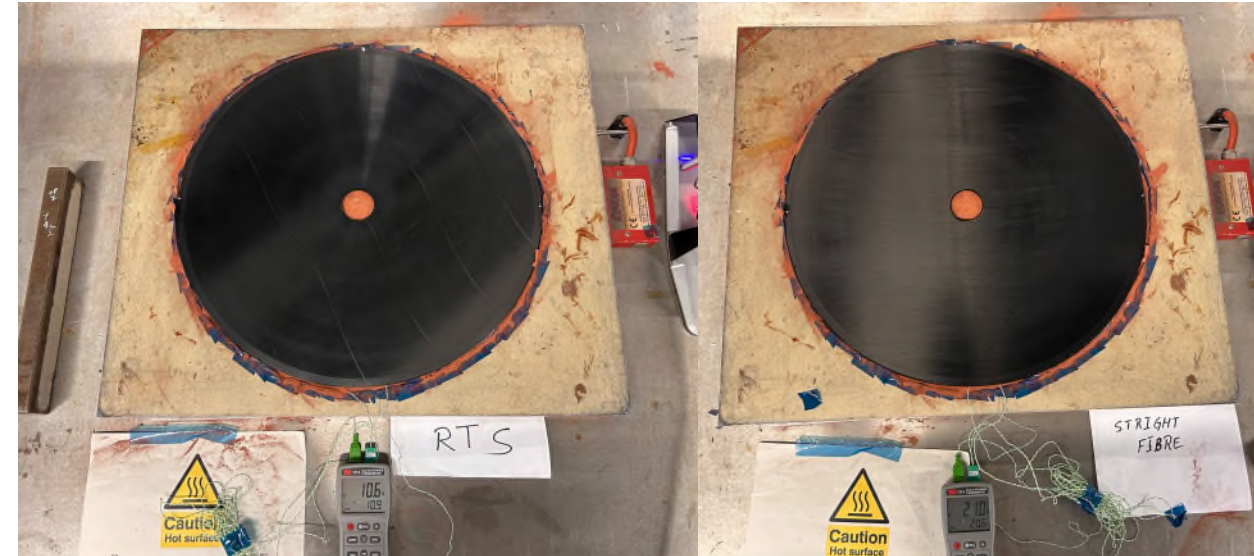
- Measured using Taylor Hobson Form Talysurf 120L
- Very smooth surfaces achieved
- Roughness $\approx 0.2\text{--}0.5\text{ }\mu\text{m}$ ($< 1\text{ }\mu\text{m}$ design limit)

ISO 4287		
Amplitude parameters - Roughness profile		
Rp	1.15	μm
Rv	1.40	μm
Rz	2.55	μm
Rc	1.35	μm
Rt	4.72	μm
Ra	0.381	μm
Rq	0.475	μm
Rsk	-0.219	
Rku	2.94	
Material Ratio parameters - Roughness profile		
Rmr	5.51	%
Rdc	0.798	μm
Amplitude parameters - Primary profile		
Pp	2.01	μm
Pv	3.63	μm
Pz	5.64	μm
Pc	1.43	μm
Pt	5.64	μm
Pa	0.453	μm
Pq	0.571	μm
Psk	-0.224	
Pku	3.30	



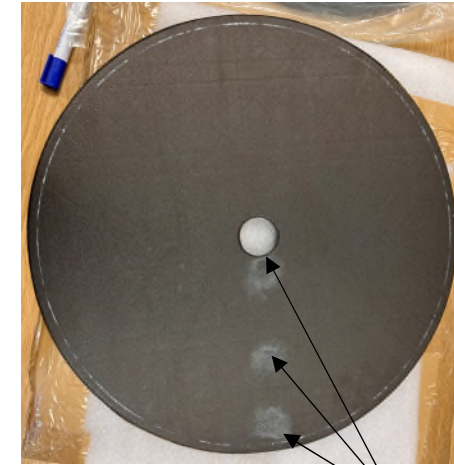
Non-Destructive Testing — Thermal Response

- Tested under temperature changes using 3D laser scanning (Hexagon AS1)
- Measured full-surface shape changes
- RTS shows better thermal stability
- Lower thermal deformation than conventional design

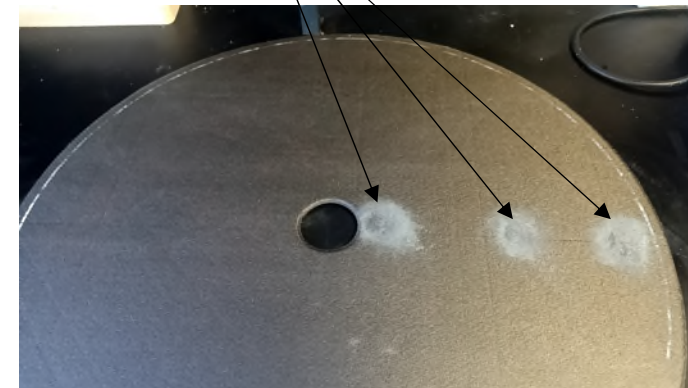


Destructive Testing — Material Quality

- Verified curing quality using Differential Scanning Calorimetry (DSC)
- No defects found
- High manufacturing quality
- High degree of cure achieved (~93–95%), confirming process consistency

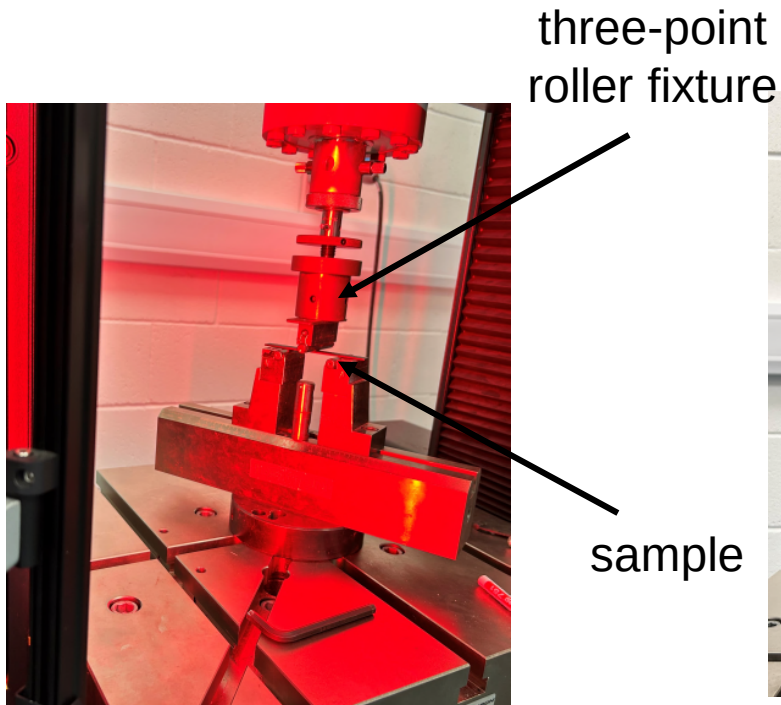


DSC sampling locations (centre → edge)

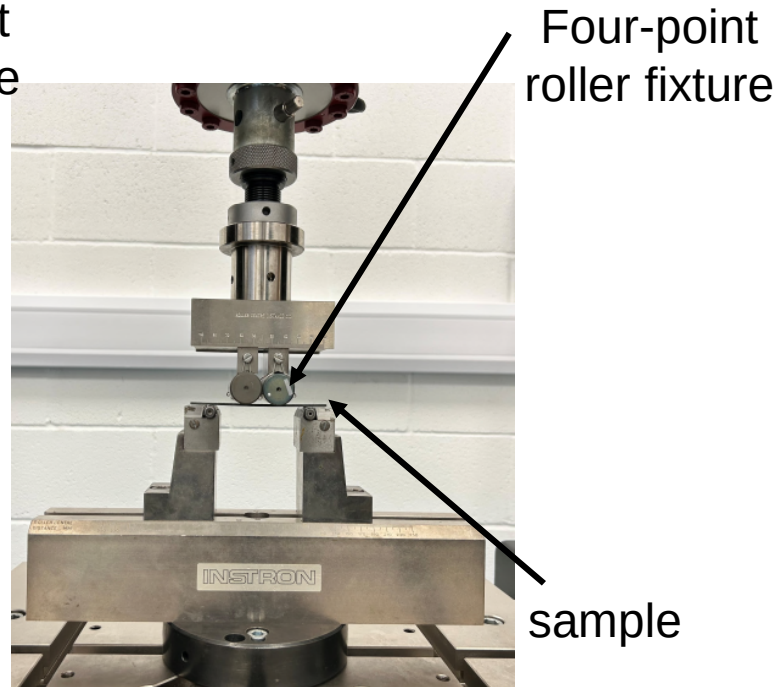


Destructive Testing — Mechanical Performance

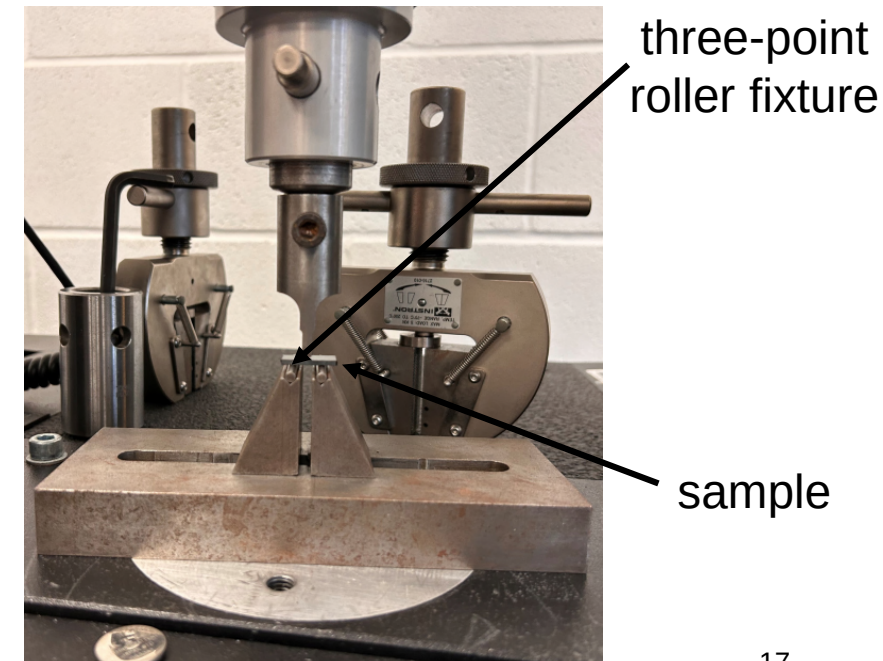
- Mechanical performance tested using three-point bending, four-point bending, and short beam shear (ILSS) test
- RTS design shows slightly lower stiffness compared to straight-fibre
- RTS retains ~85–90% strength and meets all performance requirements



Three-point bending test setup



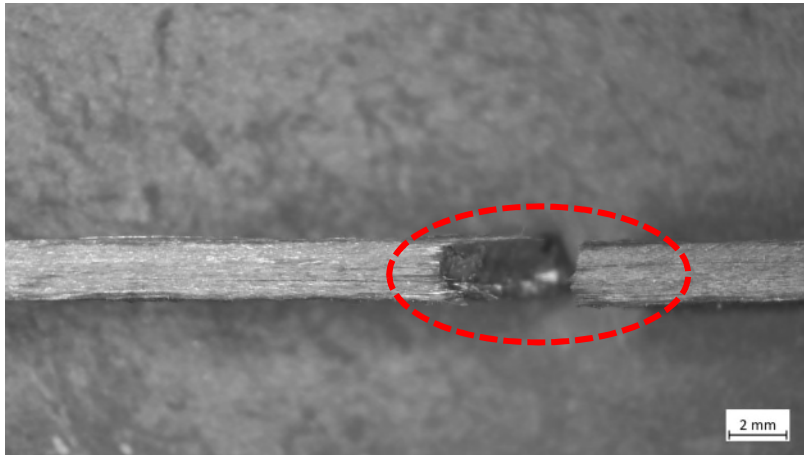
Four-point bending test setup



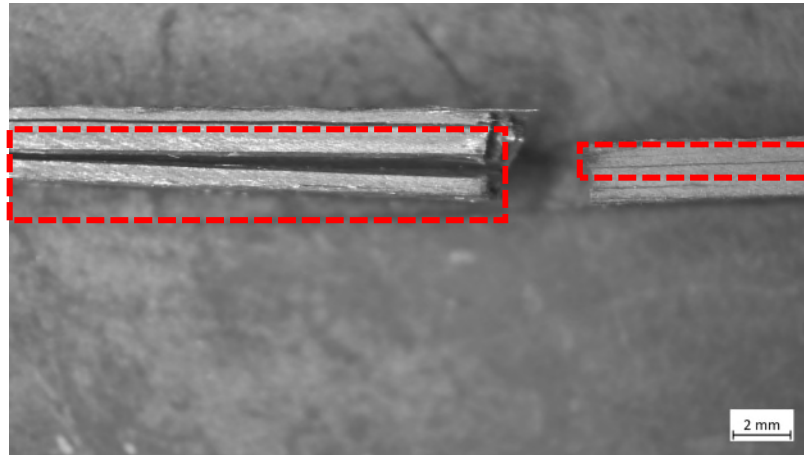
ILSS test setup

Understanding Failure

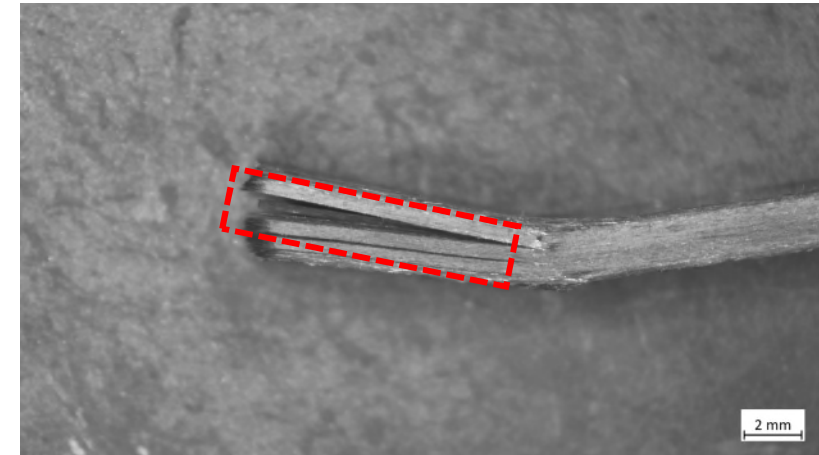
- Tested using bending and shear test equipment (standard mechanical testing rigs)
- Failure occurs in expected ways
- No unexpected defects observed
- Controlled and predictable behaviour
- Result: all tested samples failed as expected under three-point, four-point bending, and shear tests
- Confirms material reliability



Three-point bending coupon



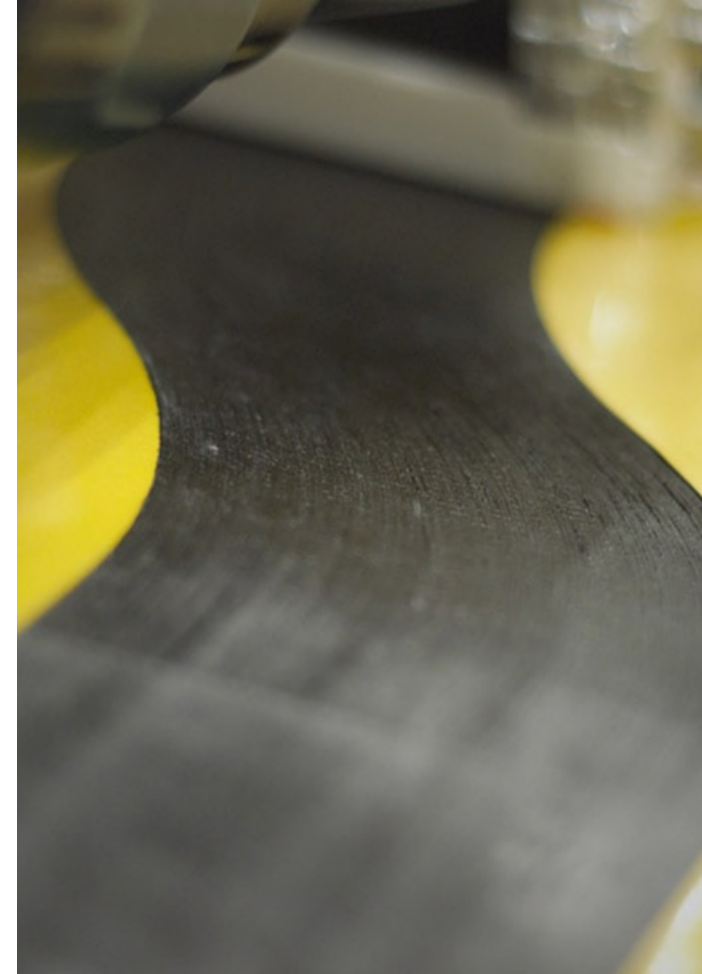
Four-point bending coupon



ILSS coupon

Real-World Impact & Why This Matters

- ~11% weight reduction with no loss of performance
- Lower launch cost and better satellite efficiency
- Proven with real prototypes and testing
- Compatible with existing manufacturing (low risk)
- Scalable to future space systems
- Ready for next development phase
- Strong opportunity for further optimisation and use



References

- European Space Agency (ESA) (2025) *The Ground Laser Receiver at the Helmos Observatory*. Available at: https://www.esa.int/ESA_Multimedia/Images/2025/07/The_Ground_Laser_Receiver_at_the_Helmos_Observatory2 (Accessed: 3 April 2026).
- Massachusetts Institute of Technology Lincoln Laboratory (2024) NASA's record-breaking laser demo completes mission. Available at: <https://www.ll.mit.edu/news/nasas-record-breaking-laser-demo-completes-mission> (Accessed: 3 April 2026).
- National Aeronautics and Space Administration (NASA) (2020) A researcher's guide to: Space environmental effects. September 2020 revision. Available at: https://www.nasa.gov/wp-content/uploads/2020/10/researchers-guide-space-environment-effects_tagged.pdf (Accessed: 3 April 2026).
- National Aeronautics and Space Administration (NASA) (2025a) Laser Communications Relay Demonstration (LCRD). Available at: <https://www.nasa.gov/goddard/esc/lcrd/> (Accessed: 3 April 2026).
- National Aeronautics and Space Administration (NASA) (2025b) Laser communications. Available at: [Laser communications page](#) (Accessed: 3 April 2026).