Preparing SCHOTT Extreme Lightweight ZERODUR® Mirror (ELZM) for Testing at MSFC

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SCHOTT
glass made of ideas

UNM

1. **Summary of AMTD-2**
2. SCHOTT Circumstances, Objective and AMTD Scope
3. What is ELZM?
4. Steps to be accommodated in AMTD-2
5. Overall Summary

MSFC: Advanced Mirror Technology Development Phase 2

"Our objective is to mature to TRL-6 the critical technologies needed to produce 4-m or larger flight-qualified UVOIR mirrors by 2018 so that a viable mission can be considered by the 2020 Decadal Review. As identified by Astro2010, a new, larger UVOIR telescope is needed to help answer fundamental scientific questions, such as whether there is life on Earth-like exoplanets; how galaxies assemble their stellar populations; how baryonic matter interacts with the intergalactic medium; and how solar systems form and evolve"…

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Material

- We have heard a number of discussions of elegant approaches to making mirrors for spaceborne application
- Selection of mirrors for a system
  - Depends strongly on operating environment, wavelength and operating temperature
  - Can strongly influence the cost, mass and complexity of a system
- Lightweight ZERODUR®, now available from SCHOTT, exhibits mass, thermal, surface qualities and as well as being cost attractive to small and large spaceborne missions

ELZM Circumstance

- ZERODUR®, a very low expansion heritage mirror substrate material by SCHOTT, has flown on over 30 missions over the last 30+ years.
  - HST M2, Chandra, etc.
- It is currently in production in blanks as large as 4m
- In a series of papers, we have considered methods to rapidly and inexpensively make aggressively **lightweighted** mirrors of ZERODUR®

- The major purpose of this study is not to merely provide another form of lightweight mirror, but one which offers attractive cost, schedule and risk options.
- SCHOTT has built a fully representative 1.2m isogrid ZERODUR® mirror 88% lightweighted.

- SCHOTT's 1.2m mirror was first exhibited at the AAS Annual Meeting in January 2013.
- It is f/1.29, with efficient isogrid 2mm deep ribs
- It is designed to safely accommodate typical launch loads
- It is machined from a single monolithic homogeneous piece of ZERODUR®

Extreme Lightweight ZERODUR® Mirror (ELZM) Objective

- Support efforts to ensure that ELZM is fully qualified to meet the requirements of Spaceborne Missions, especially those of ASTRO2020
- Support the space astrophysics and surveillance communities with a path toward affordable, short lead time lightweight mirrors

ELZM Scope

- SCHOTT will provide MSFC with its 1.2m mirror blank, and under NASA contract will construct supports and polish the mirror to interferometric capture range (~150nm rms)
- Under this contract, SCHOTT will support test and test interpretation.

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Approach to making affordable, lightweight mirrors

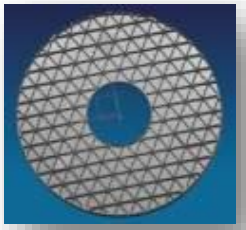
Starts with ZERODUR®

Several hundred metric tons are produced each year for precision applications. Reproducibility of quality is excellent.

ZERODUR®
+
New SCHOTT Machining
+
Advanced OpFab
(Substructure Quilting no longer an issue)

=

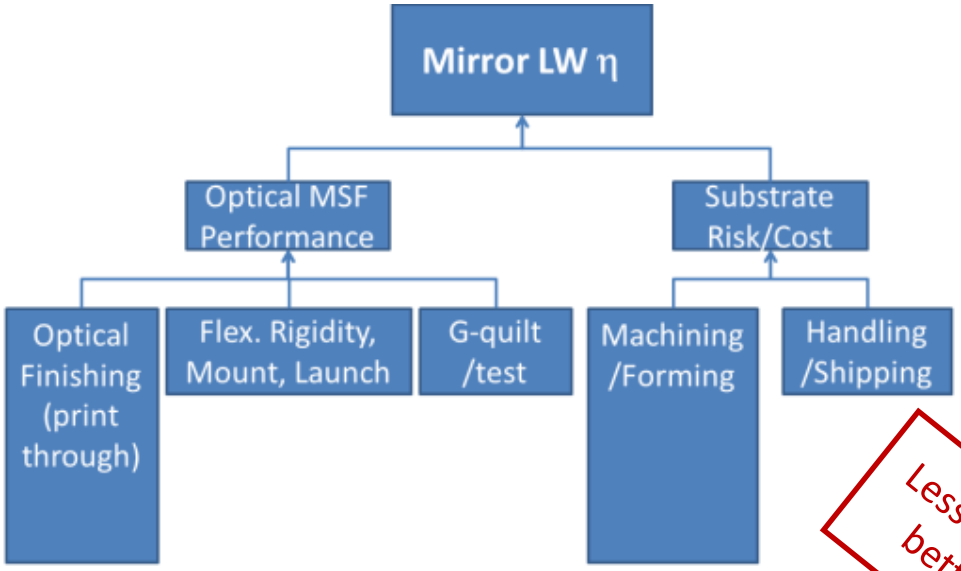
Affordable +
Suitably
Lightweighted
Mirrors



HEX

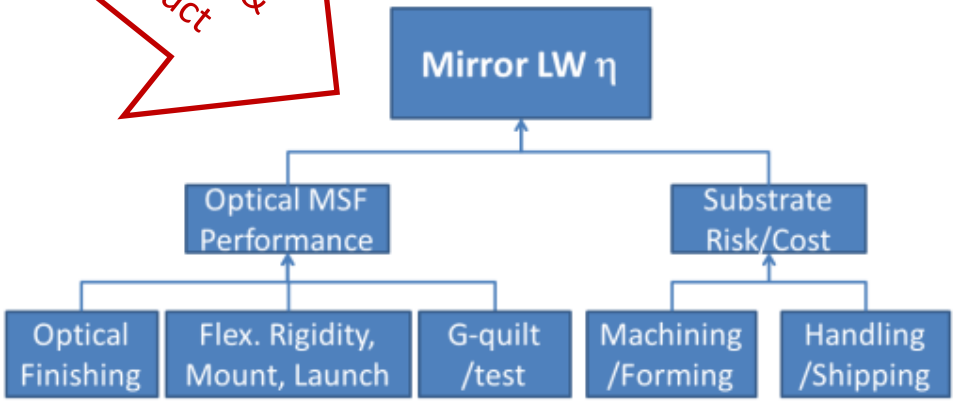
OAP

Much lighter, affordable ZERODUR® Mirrors are available from 0.3m to >4m dia.



This is also suited to segmented mirror hexagonal segments, to elliptical or rectangular mirrors

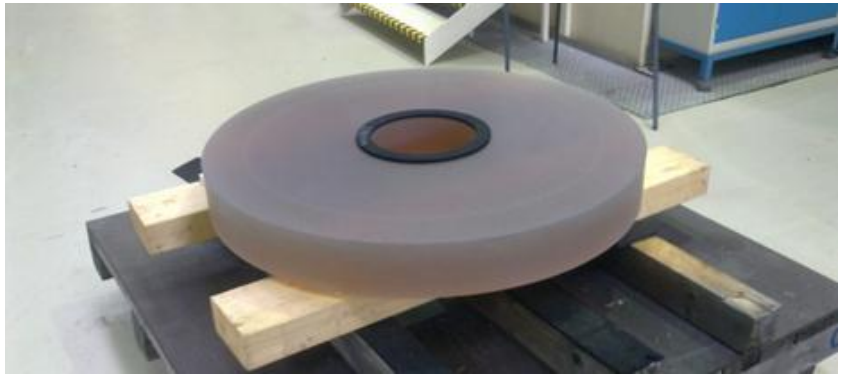
Less constrained & better product



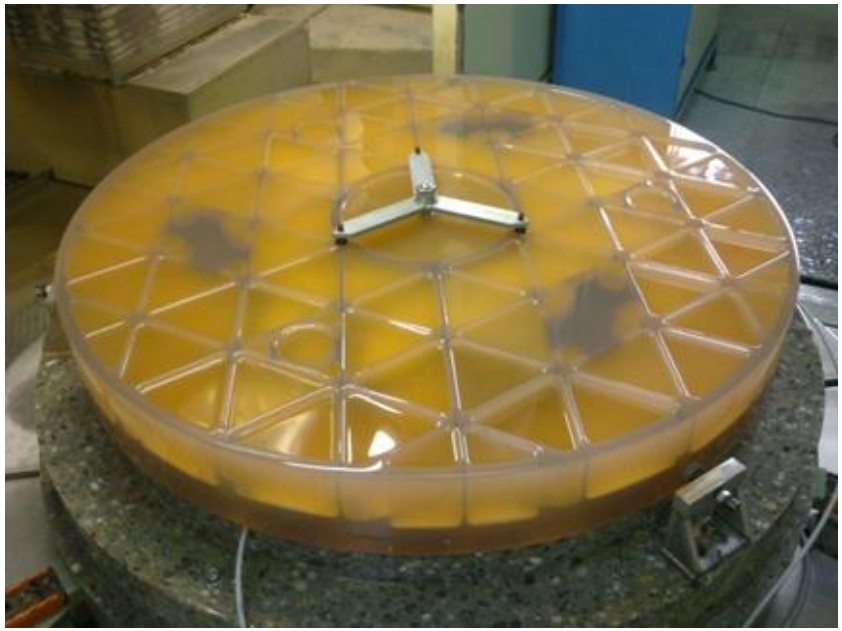
Height represents the extent a design driver

ZERODUR®: Melting to Processing

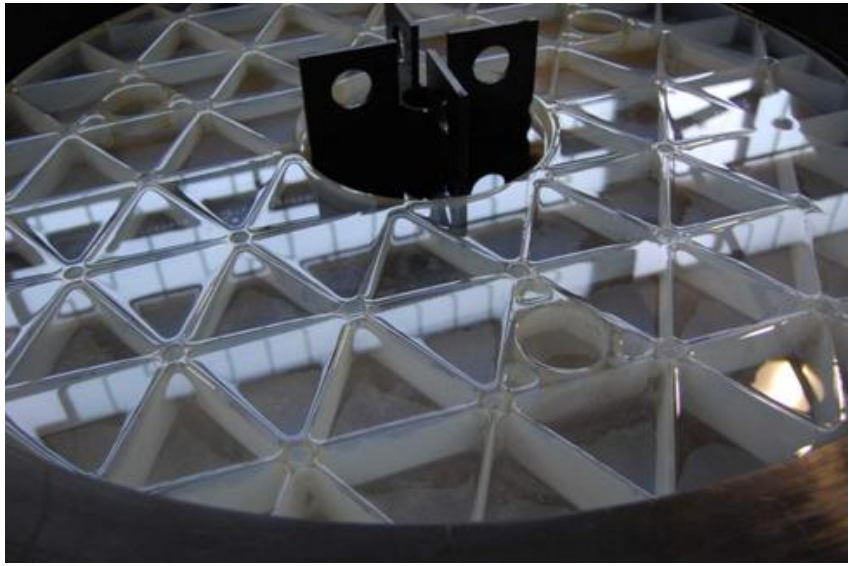
Lightweighting Technology at SCHOTT



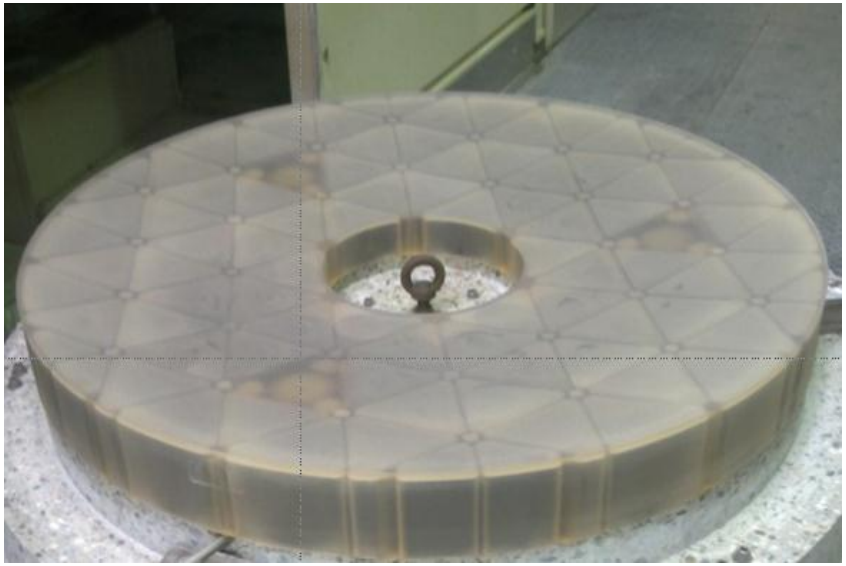
Prepare blank: plano-plano, facesheet generating and center hole



Pocket grinding

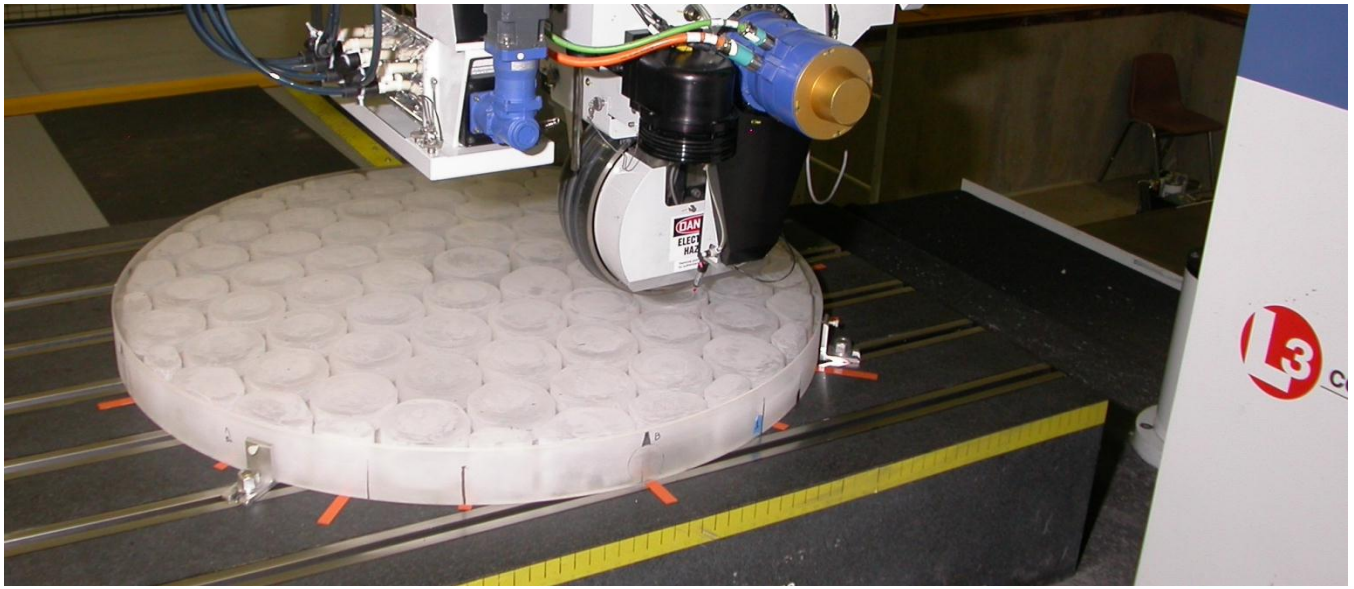


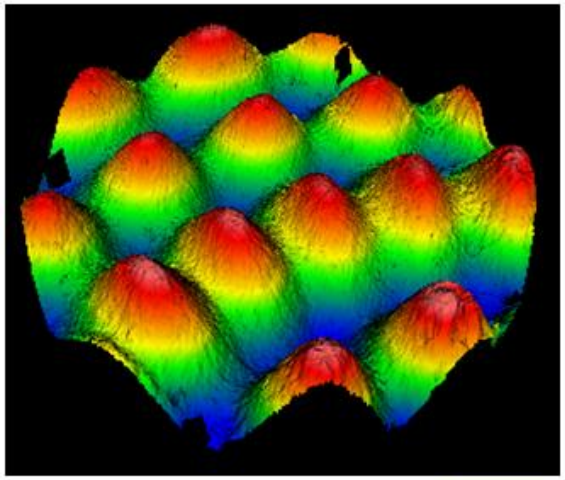
Acid etching to remove subsurface damage

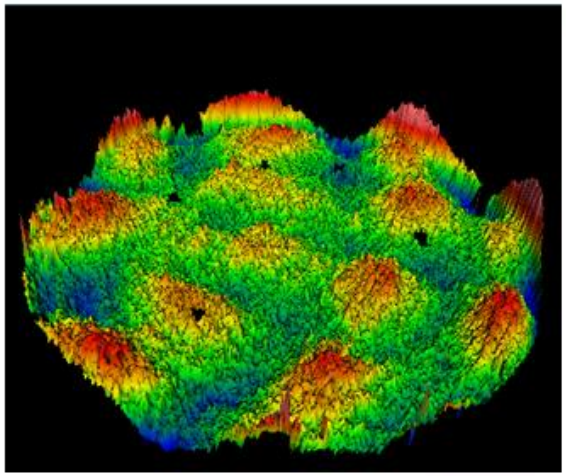


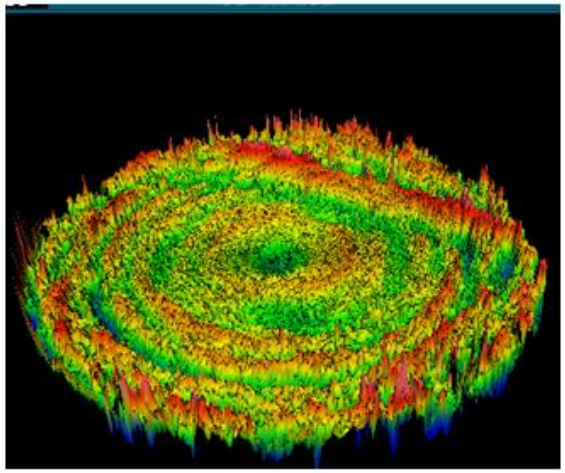
R1 grinding

Deterministic (MRF, IBF, CCOS etc.) optical finishing is one “thin facesheet” approach to mitigating quilting







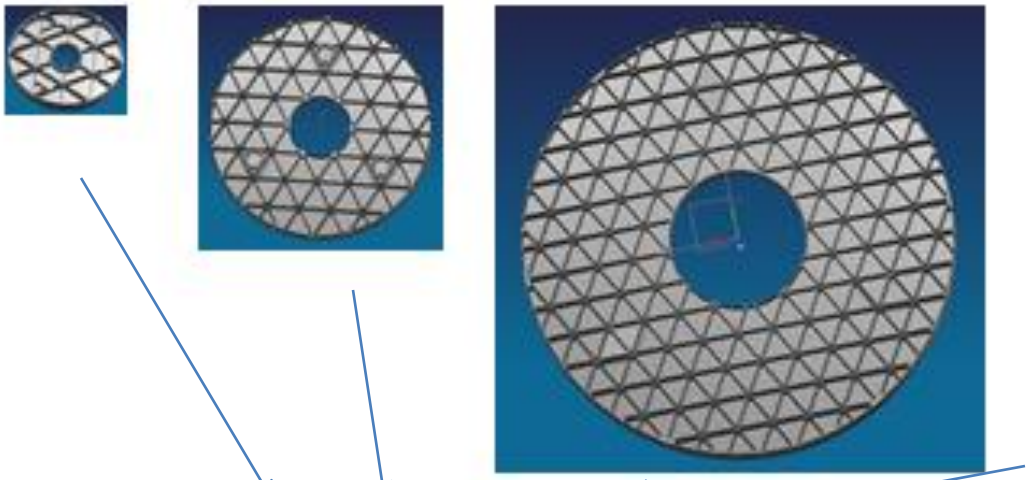


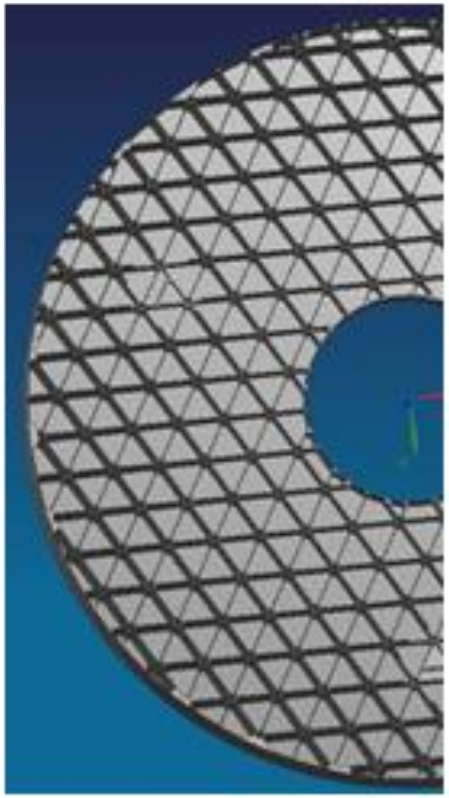
Start: 45nm RMS
For this sector of mirror

1st Run: 6.0nm RMS
10.3 hours on machine 1m ϕ

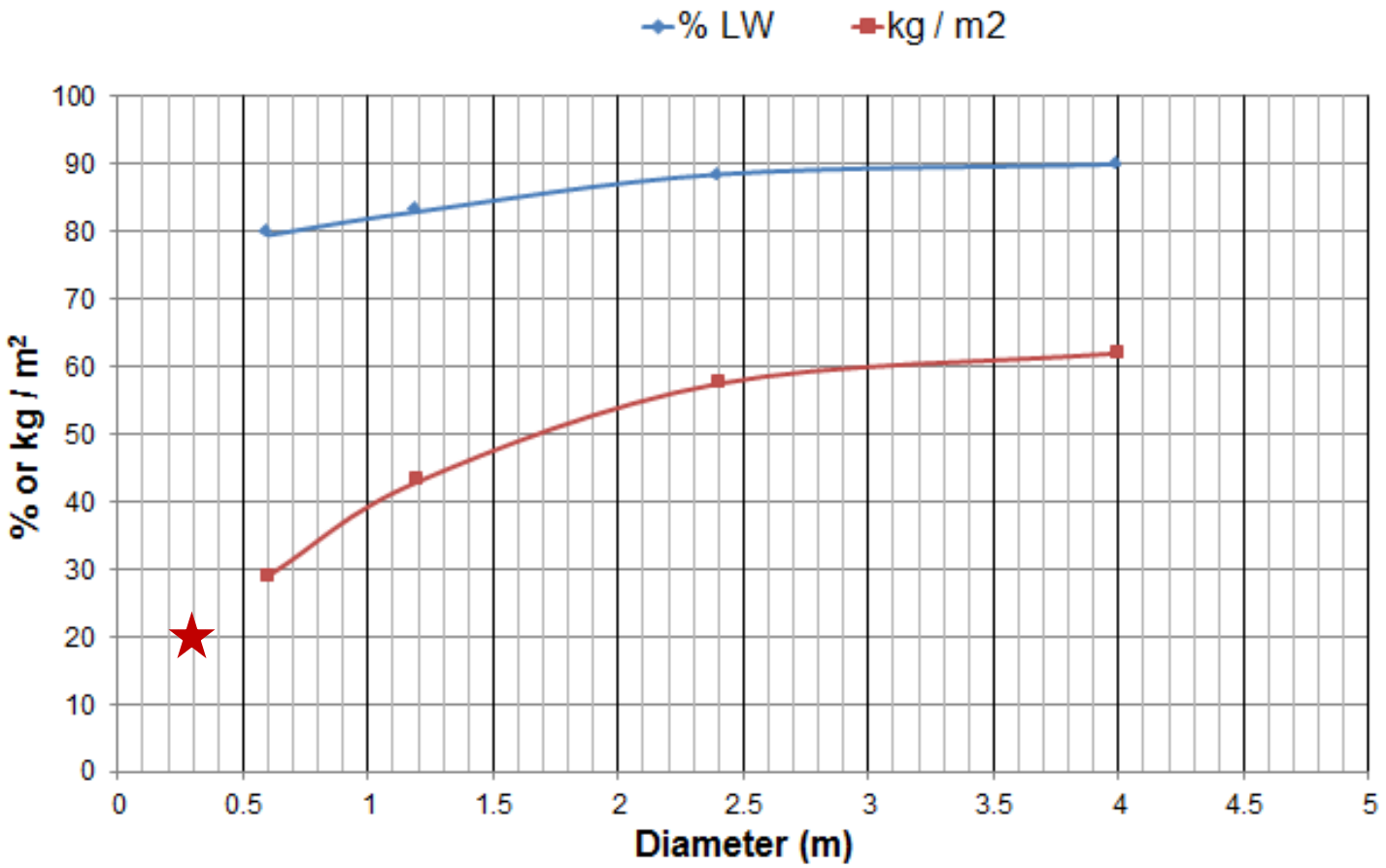
2nd Run: 2.5nm RMS
2.4 hours on machine 1m ϕ

Results from 0.3m to 4m Mirrors



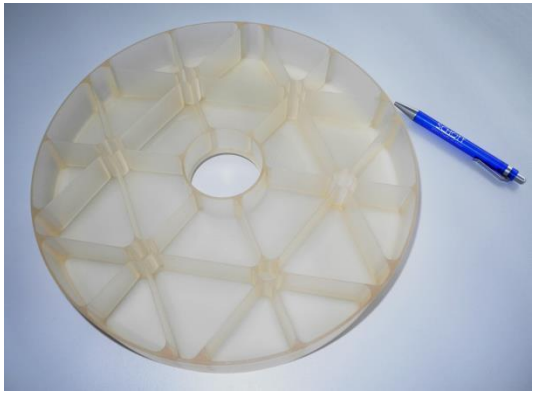


0.3	Outside Dia	0.6	1.2	2.4	4	m
0.774	ROC	1.548	3.1	6.192	10.33	m
1.290	f/#	1.29	1.29	1.29	1.29	
0.060	Center Hole	0.160	0.320	0.750	1.080	m
0.050	Thickness	0.07	0.125	0.25	0.335	m
1.3	Mass	7.6	45	228	718	kg
1200	fo	419	213	115	~80	Hz



Using these methods, 4 practical cases are analyzed. Each is practical and could be built now. Other than 2 mm ribs, the mirrors were optimized for cost-effective fabrication.

As built 0.3m and 1.2m Lightweight ZERODUR® Mirror Blanks



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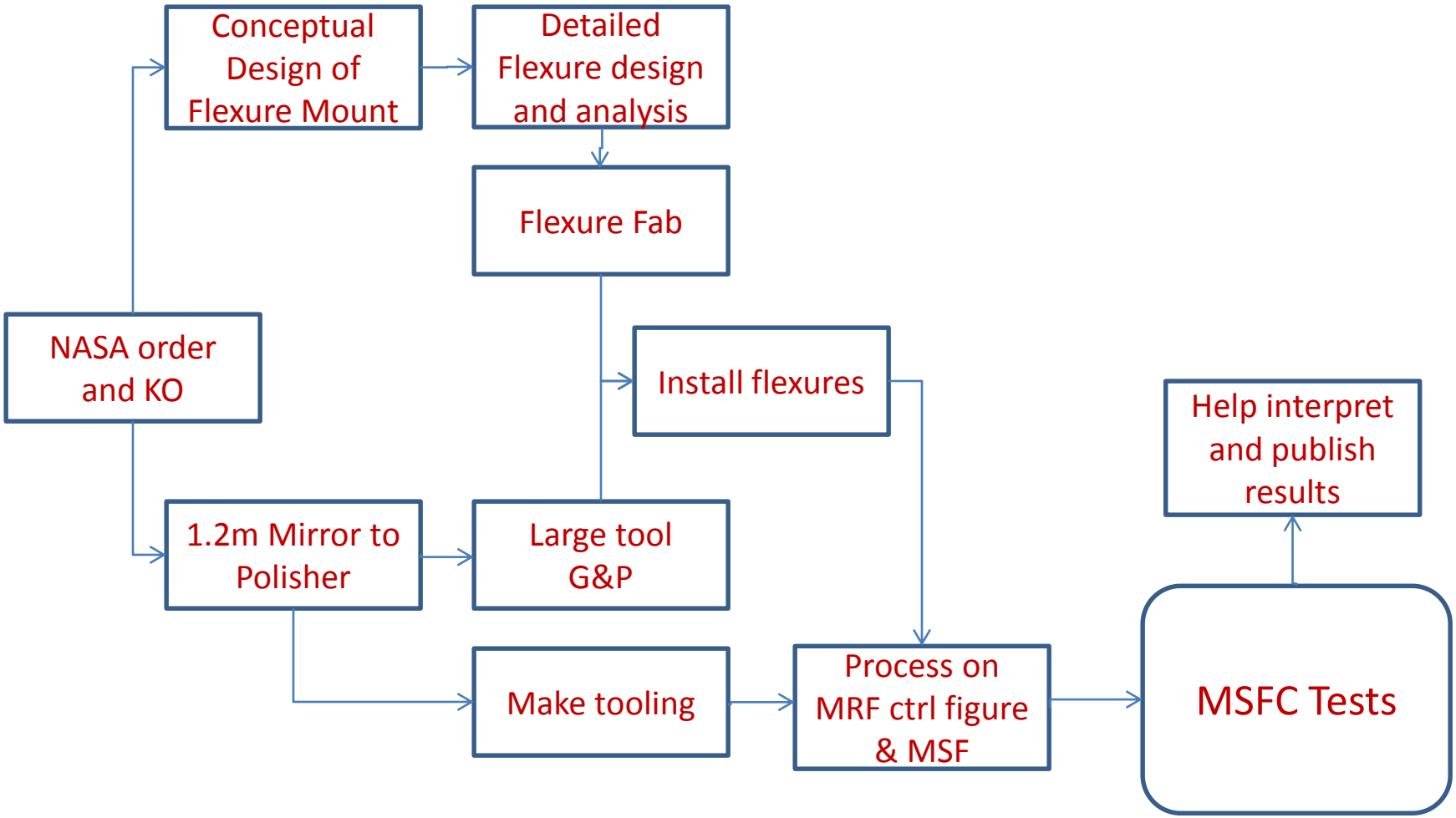
SCHOTT proposed support to AMTD-2



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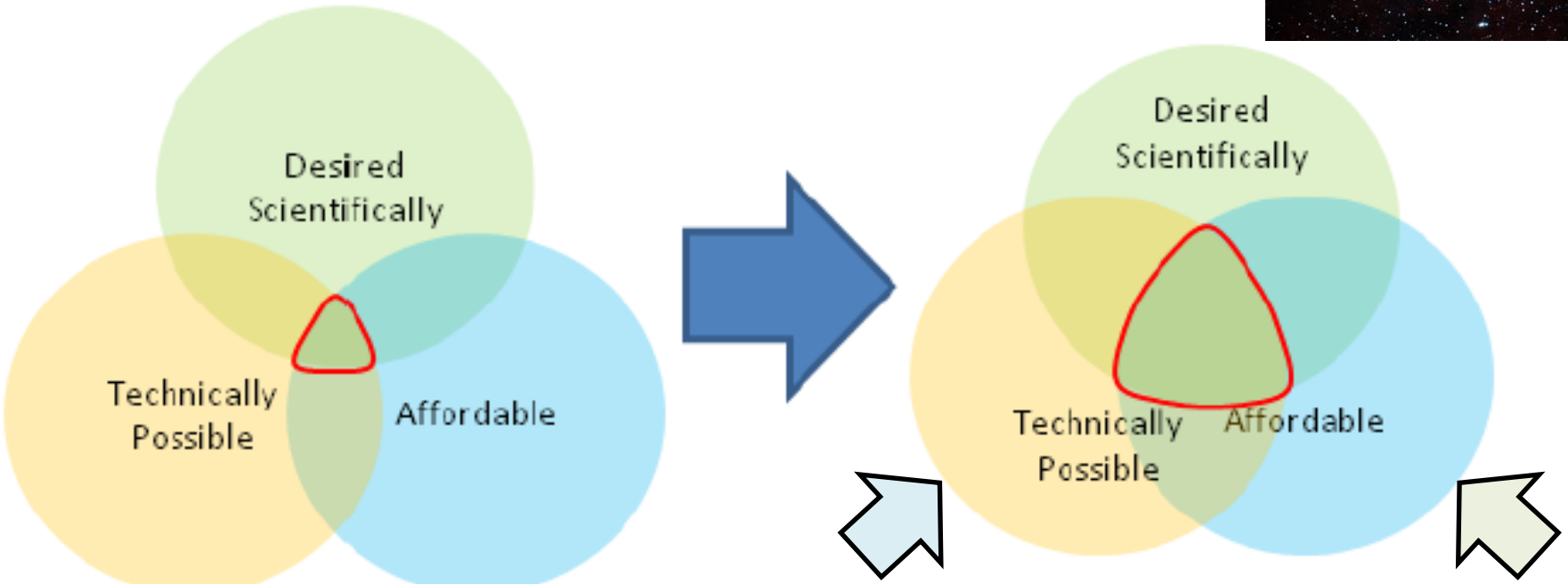
ELZM is a non-developmental, cost-effective approach to mirrors

→ widens solution space

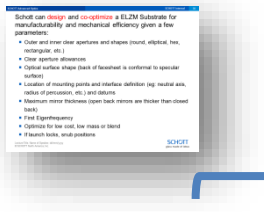
→ enables more desirable science solutions



- The approach can yield a very smooth mirror or mirror segment with exceedingly low response to thermal environments
- SCHOTT can make flight-like isogrid lightweight mirror blanks now using this technology
- Blanks up to 4m diameter are being produced

Example Manufacture Schedule for a 1.2m ELZM Mirror

Customer defines requirement


Schott can design and co-optimize a ELZM Substrate for manufacturability and mechanical efficiency given a few parameters:

- Outer and inner clear apertures and shapes (round, elliptical, hex, rectangular, etc.)
- Clear aperture allowances
- Optical surface shape (back of facesheet is conformal to specular surface)
- Location of mounting points and interface definition (eg. neutral axis, radius of percussion, etc.) and datums
- Maximum mirror thickness (open back mirrors are thicker than closed back)
- First Eigenfrequency
- Optimize for low cost, low mass or blend
- If launch locks, srrub positions

SCHOTT

Potential 5-6 month 1st unit delivery!

Schott design & $ (funded)

1 month

Customer review & place PO

1 month

Schott programs & tooling & queue

1 month

Machine, QA & Ship

2 months

Order of 2nd unit or replacement

2 months

Appreciation to Phil Stahl, and Michael Effinger at MSFC for including Lightweight ZERODUR® in AMTD-2, and Thomas Westerhoff, John Pepi, and Mike Valois for their assistance in this paper.

www.us.schott.com/advanced_optics

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Relevant Papers

1. Hull, T., T. Westerhoff, A. Leys, J. Pepi; "Practical Aspects of Specfication of Extreme Lightweight ZERODUR® Mirrors for Spaceborne Missions"d Proc. SPIE Vol 8836-6, 2013)
2. Hull, T., Westerhoff, T., Pepi, J., Jedamzik, R., Gardopee, G., Piche, F., Clarkson, A., Leys, A., Schaefer, M., Seibert, V. "Game-changing approaches to affordable advanced lightweight mirrors II: new cases analyzed for extreme ZERODUR® lightweighting and relief from the classical polishing parameter constraint", Proc. SPIE Vol 8450 8450-186 (2012)
3. Hull, T., Beasley, M., Kendrick, S., Ebbets, D., Lipscy, S., Lee, A., Barentine, JB, Pepi, J., "Practical Steps toward Spaceborne UV Telescopes beyond HST", Kauai Conference on UV Astronomy: HST and Beyond Website (2012)
4. Hartmann, P., Jedamzik, R., Westerhoff, T., "Zero-expansion glass ceramic ZERODUR® - Recent developments reveal high potential", Proc. SPIE Vol. 8450, 8450-83 (2012)
5. Hull, T. , Clarkson, A., Gardopee, G., Jedamzik, R., Leys, A., Pepi, J., Piché, F., Schäfer, M., Seibert, V., Thomas, A., Werner, T., Westerhoff, T., "Game-Changing Approaches to Affordable Advanced Lightweight Mirrors: Extreme ZERODUR® Light weighting and Relief from the Classical Polishing Parameter Constraint" Proc. SPIE Vol. 8125, 8125-30 (2011)
6. Hull, T., Hartmann, P., Clarkson, A., et al. "Lightweight high-performance 1-4 meter class spaceborne mirrors: emerging technology for demanding spaceborne requirements", SPIE Proceedings Vol. 7739, 7739-118 (2010)
7. Döhring, T., Jedamzik, R., Thomas, A., Hartmann, P., "Forty Years of ZERODUR® mirror substrates for astronomy; review and outlook" Proc. SPIE Vol. 7018, 70180P (2008)