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Advanced Mirror Technology Demonstration – 1.5m Pathfinder Mirror

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Advanced UVOIR Mirror Technology Development (AMTD) Program

- Develop mirror blank technology applicable to building a cost effective, large (4m-8m class), passive, monolithic mirror capable of imaging in the UV spectrum
  - 0.43m demonstration mirror fabricated
  - 5.5nm RMS overall surface figure demonstrated
- Current limitations regarding a 4m class mirror
  - Significant mirror depth required to achieve stiffness
  - Core depth drives up cutting costs, schedule, risk, and areal density
  - Stack sealing of boules to achieve overall depth is very expensive and time consuming
- AMTD program addresses these issues to reduce the cost and lead time for building a 4m class mirror blank and demonstrates the ability to polish and test the blank to UV quality

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Phase I Review

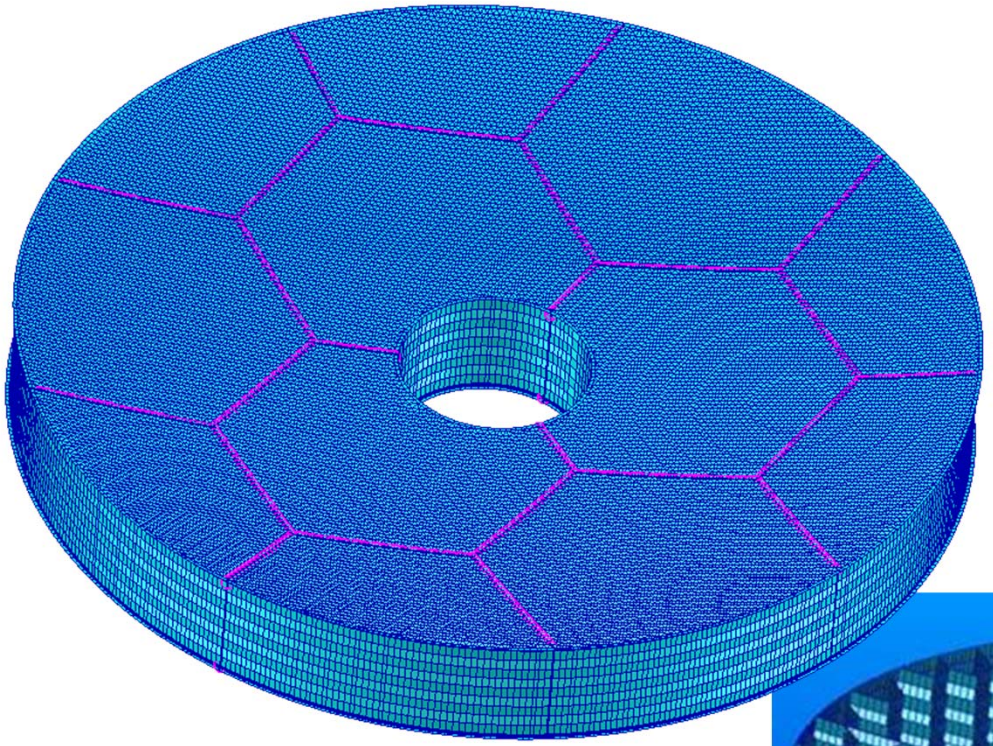
Developed a 4m design baseline

- ULE® glass
- 0.4m deep core
  - Requires 3 boule deep core structure
  - Developed stacked core, co-fired design to eliminate very deep core cutting
- Pocketmilled Facesheets
- Low Temperature Fused and Low Temperature Slumped design

Built and Tested a 0.43 diameter demonstration mirror

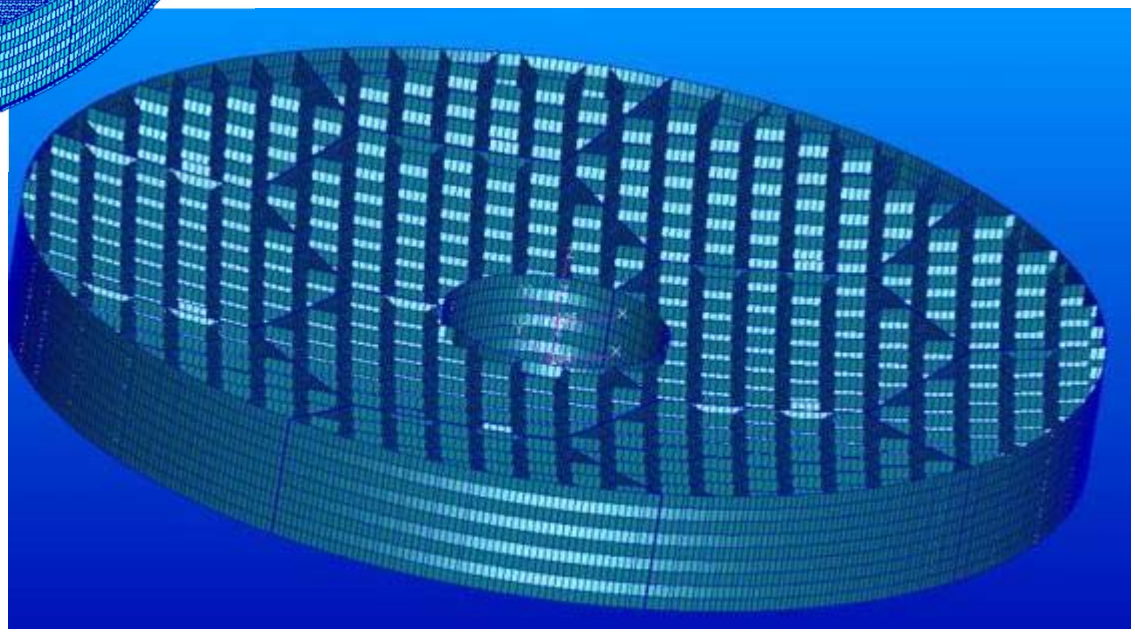
- Polished to 5.5nm RMS which was limited by the repeatability of the V-block mount
- Tested at MSFC to 250K with no adverse change in surface figure

4m Mirror Concept



4m Mirror Physical Attributes

- **Pocket Milled Facesheet allows larger core cells while controlling quilting**
- **12 Core Segments**
- **3 Stacked Core Deep**
- **10m RoC (F#1.25)**



- **Fabrication risk reduced by eliminating stack sealing and deep core cutting**
- **Reduced glass needs for tooling glass**

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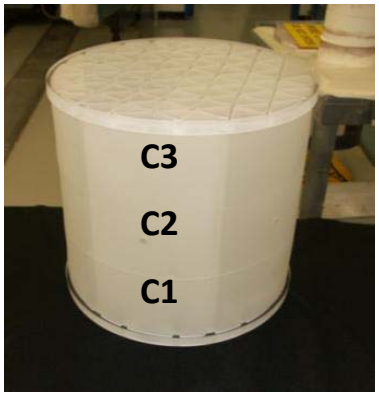
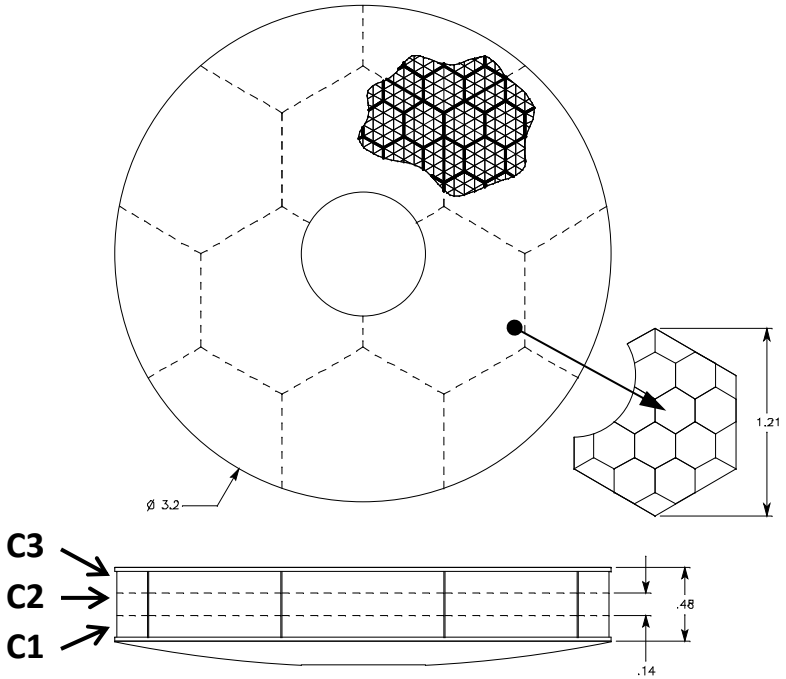
AMTD is Developing Technologies for Near Term Large Lightweight Primary Mirrors

Stacked core

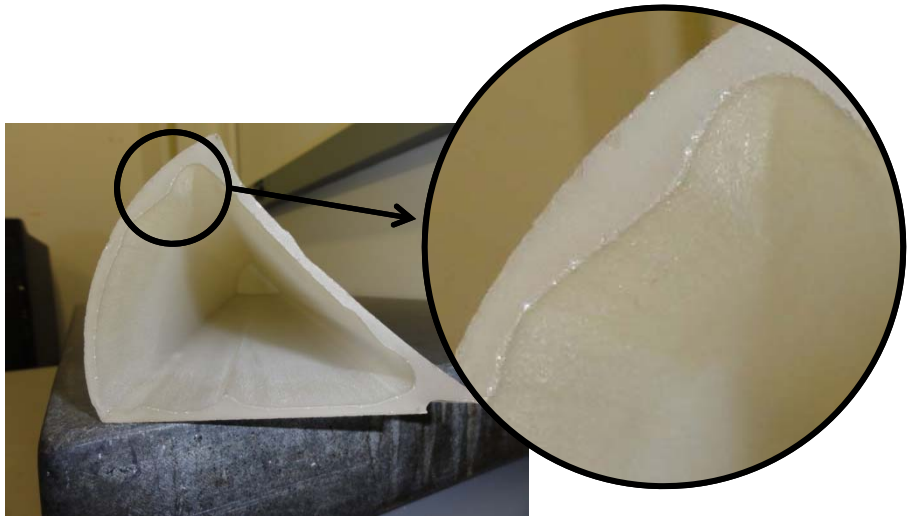
- Core segments are fabricated from standard thickness boules, then stacked & fused during blank assembly to achieve a deep core
- Eliminates need for stack sealing of boules and deep AWJ cutting of cores
- Enables lighter weight cores and reduces cost & schedule for blank fab





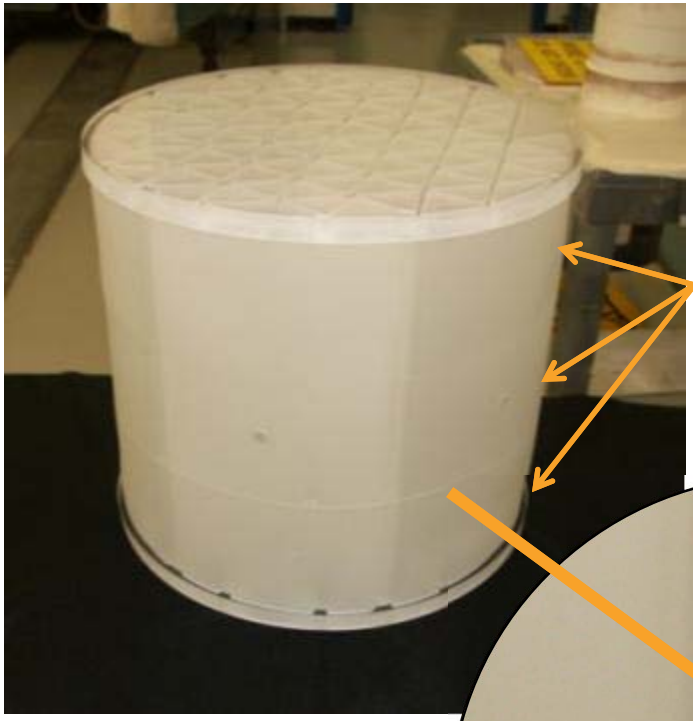
Deep AWJ Cutting

- Current state-of-the-art AWJ cutting depth for LW cores is ~300mm (12 in)
- More difficult to control exit surface parameters

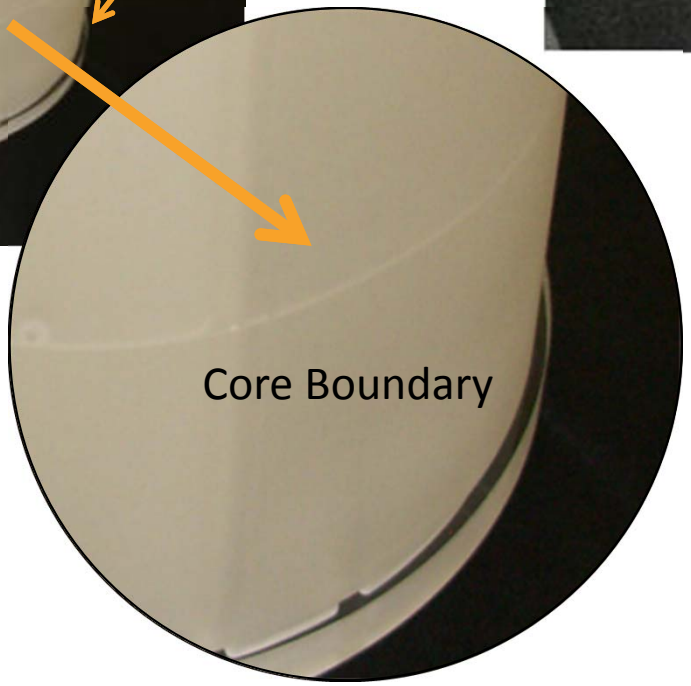


Stacked Core Mirror Demonstration

0.4m Demonstration part fabricated



Mirror Blank is 3 cores high



Single Mirror Core
(Note large cell size)

- The individual core segment surfaces are polished and AWJ just like traditional LTF mirrors
- During Low Temperature Fusion (LTF), the faceplates **and** the core segments are fused together (Co-Fired)

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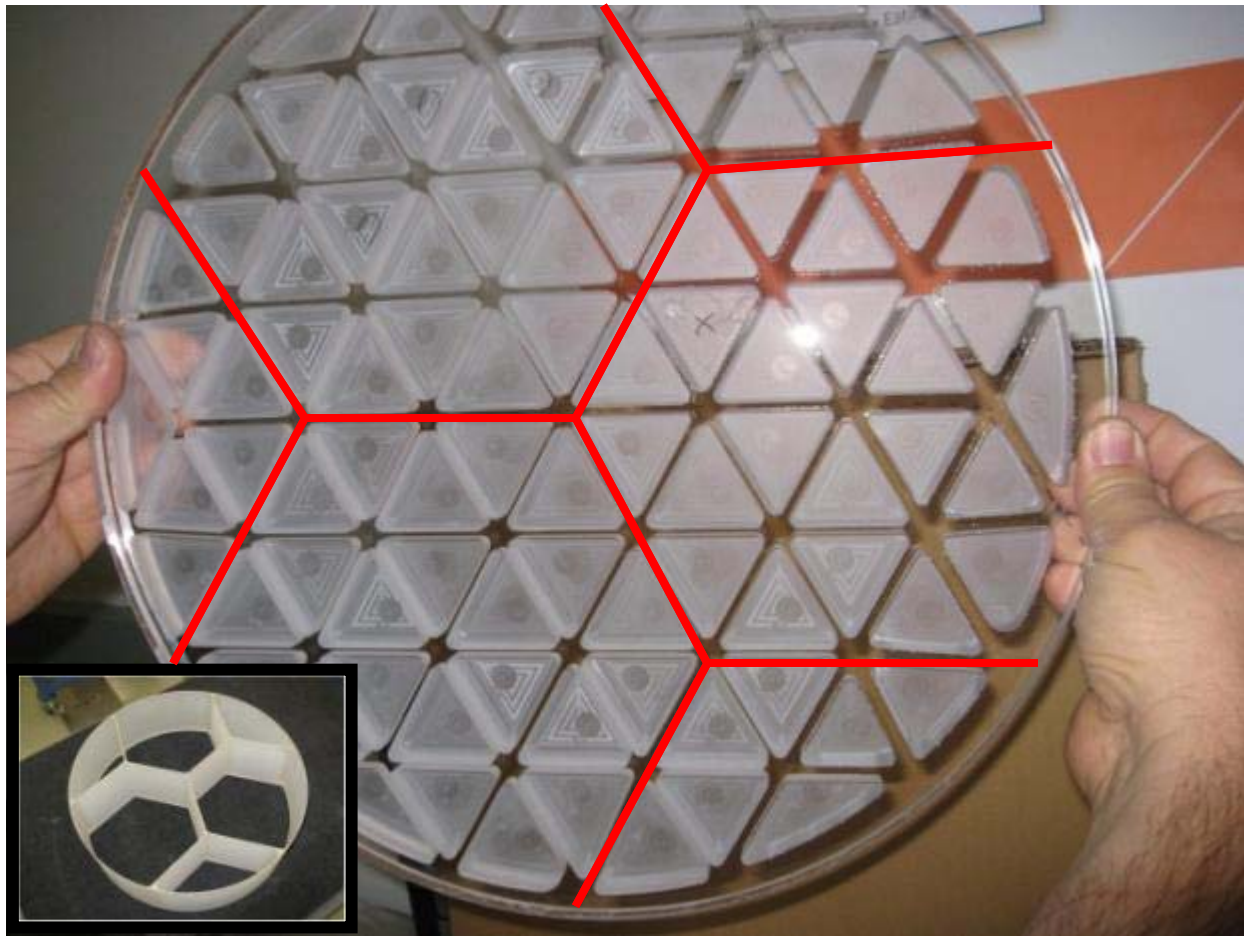
Faceplate Pocket Milling

- Pocket milled facesheets have been used on other mirrors to provide additional stiffness between cell supports
- Allow for much larger core cell size to reduce overall areal density
- Extended to 24 pockets to enhance UV performance

Pocket Milled Facesheet



Pocket Milled Facesheet
Core cells locations shown in red
(Core shown for reference)

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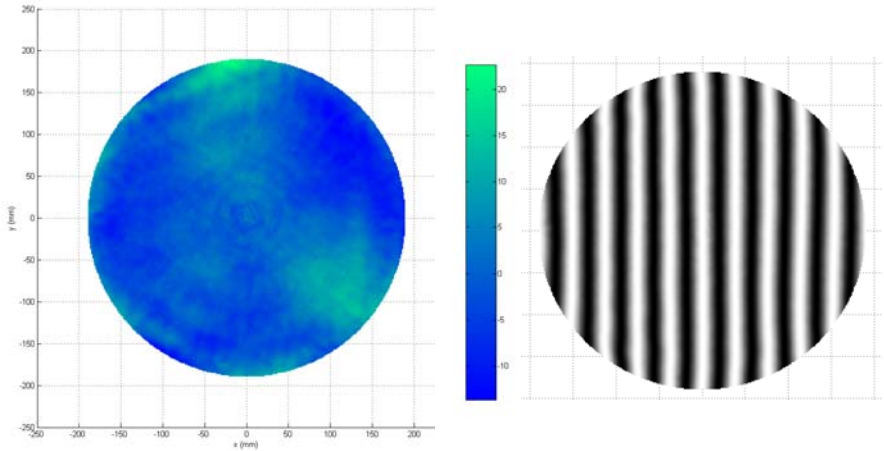
Processing Quality

Processing completed to demonstrate that UV quality (5nm RMS) could be achieved

Multiple orientation test minimized test errors and analytical backouts

- > Some minimal trefoil did not cancel out during testing
- > Mount repeatability ultimately limited final performance

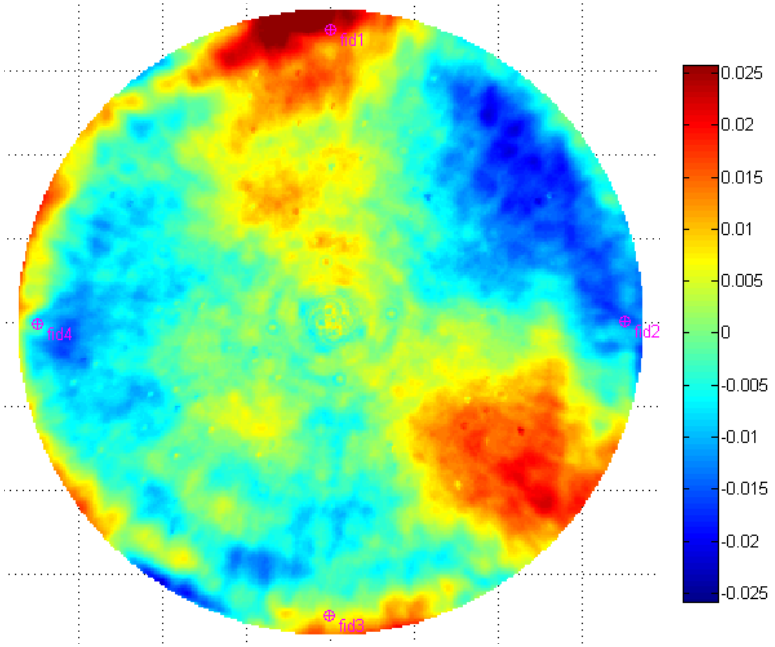


Final Optical Test – 5.5nm RMS

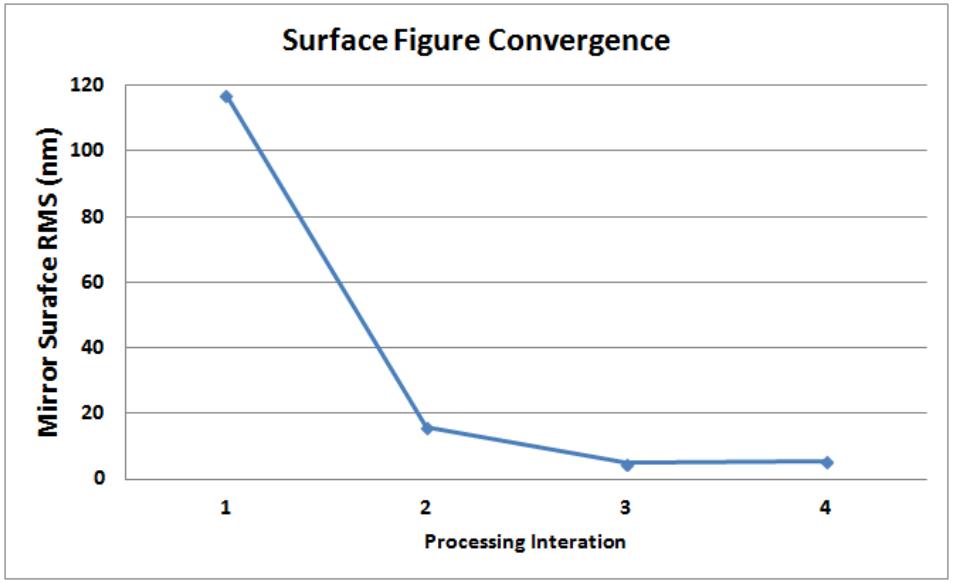
Demo Part in V-Block for Horizontal Testing

Post Ion Figuring #3

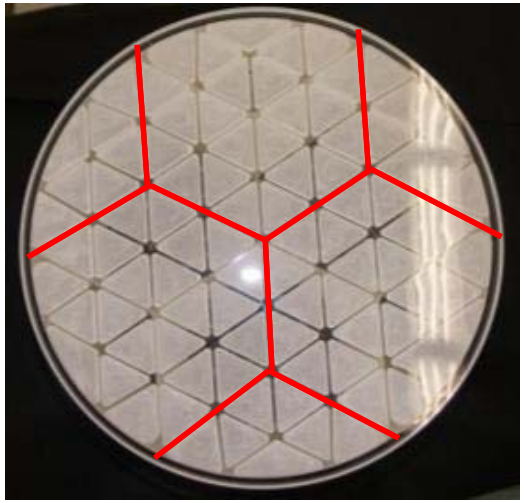
5.4nm RMS – 37nm P-V
Power Removed

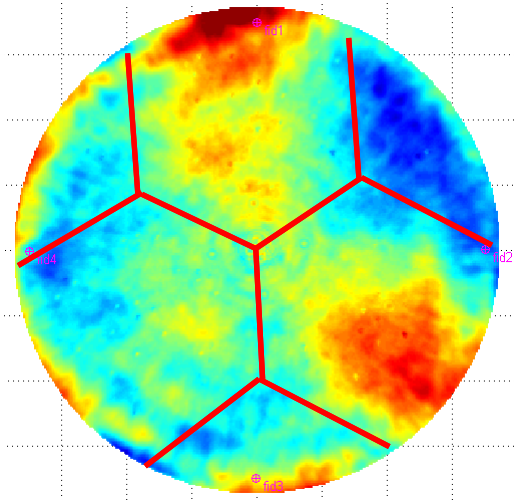


- Final ion figuring run focused on pocket quilting errors
- Mount repeatability limits overall surface quality



- Rapid convergence to final surface quality
- Deterministic processes reduce schedule time





Phase II Program

Build and test a Pathfinder Mirror

- 1.5m on-axis design provides a scalable article that can replicate the performance of the larger 4m design concept
- 1.5m design is based on Phase I experience and further analysis of 4m design and manufacturing parameters

Pathfinder mirror design nearing completion

- Replicates the expected 4m design performance
- Demonstrates scale up of enabling technologies
- Not optimized for a 1.5m mirror

Advances technology to TRL6

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1.5m Design

Design is optimized to best replicate the performance parameters of the much larger 4m mirror while maintaining representative aspect ratios

- Design is not optimized for a 1.5m mirror

Production of the baseline design will demonstrate scalability of enabling technologies

- Cores stacked three high and co-fired during LTF
- Low Temperature Fusion (LTF) of mirror blank
- Low Temperature Slumping (LTS)

Trade study completed evaluating pocket milling advantages and risk

1.5m LTF/LTS Stacked Core Initial Concept Design

Core Layout Design Constraints

- The core OD and core ID were developed based on a first order LTS analysis of a previous Exelis FRIT 1.5m PM design assuming 200mm deep core
- Segment gap based on heritage segmented core designs

Given above constraints, there are only 2 credible cell sizes for consideration that layout well within a core segment petal

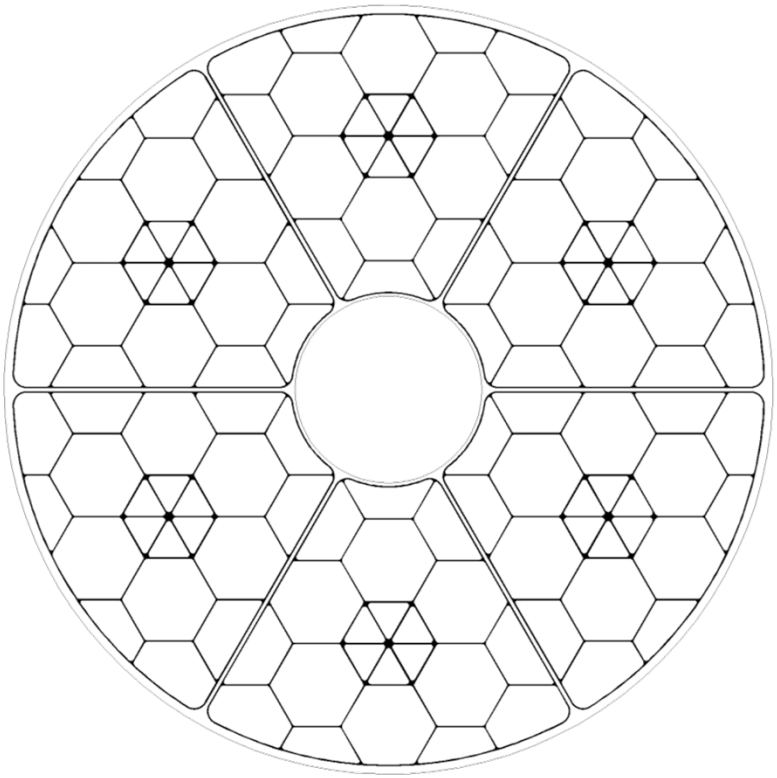
- 169.3mm (6.665”)
- 191.8mm (7.5525”)

Layout using 169.3mm cell is preferred based on performance

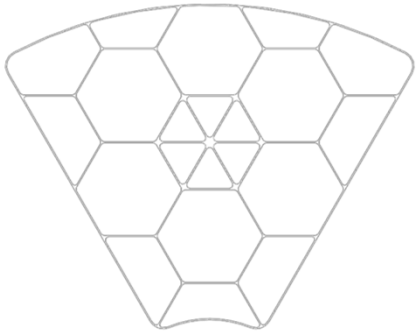
- Lower areal density
- Smaller mount pads
- Mount pad location after slumping closer to 0.7X radius

Cell size may be modified in future

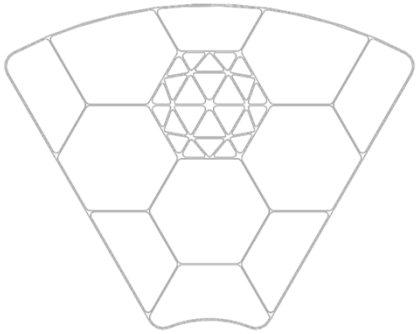
- If an updated LTS analysis indicates that the O.D. of the plano blank needs to change to meet finished O.D. requirements



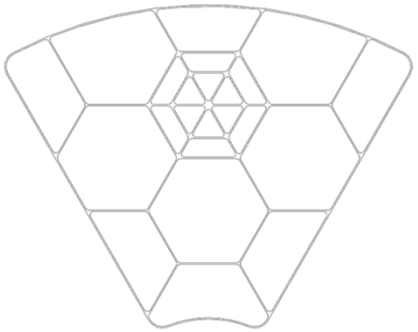
Other 1.5m mirror core layouts were considered



Baseline
(Concept 2)



Concept 3



Concept 4

Baseline concept provides the best compromise between mount stress control and cell size

Pocket Milling Trade Results

Pocket Milled vs non-Pocket Milled Faceplates have been traded for years at Exelis

Pocket Milled Pro's	Pocket Milled Con's
Less Faceplate Mass	Longer Schedule
Slightly Lower Areal Density	Higher Risk
Less Uncorrected Gravity Quilting	Ion Figure Final Quality
	Higher Cost

Cost, Schedule, and Risk play heavily in decision

- Higher risk of damage of single, monolithic face sheet during a very long machining program

Lower overall areal density of the larger mirror with a pocket milled implementation

Final figure error is actually be better without pocket milling due to larger cores cells that are easier to ion figure

- At a slight (10%-15%) mass penalty

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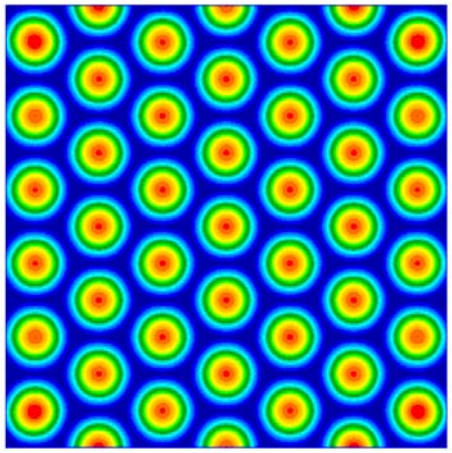
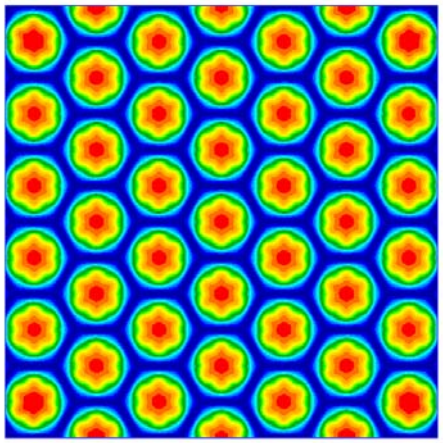
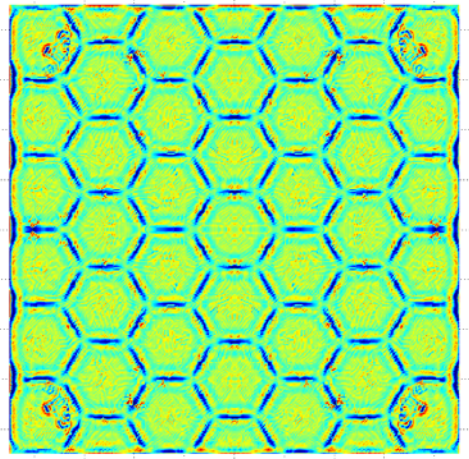
Ion Figuring Analytical Results

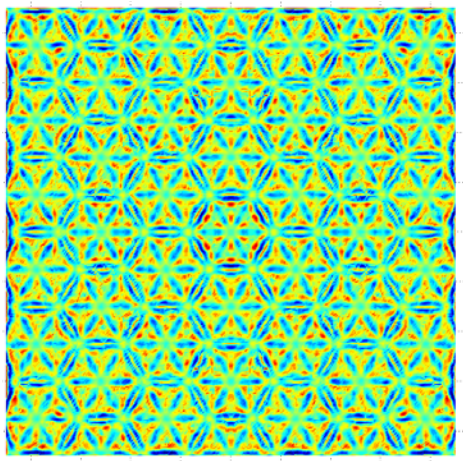


Pre-Ion	Infinity-30cm	20cm-2cm	2cm-1.4cm
Non-Pocket	7.5nm	245nm	0.6nm
Pocket	4.6nm	190nm	0.6nm





Pre-Ion	Infinity-30cm	20cm-2cm	2cm-1.4cm
Non-Pocket	0.0nm	0.7nm	0.3nm
Pocket	0.0nm	1.7nm	0.6nm



Non Pocket Milled Face Sheets

Higher frequency errors due to smaller effective cells create larger residual surface error post ion figuring

Pocket Milled Face Sheets

AMTD Phase II Summary

The Phase II Pathfinder mirror is currently in final design

- Draws on experience from Phase I Demo mirror
- Provides traceability to full scale 4m design

Boule glass selection in progress using existing Corning stockpile

- Glass delivery from Corning expected early next year

Blank completion in 2015

All work performed under NASA contract number NNM12AA02C

- COTR: Michael R. Effinger

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