CFRP Panel Study

Composite Mirror Applications
Tucson, AZ

CCAT

CMA Personnel Involved:
Robert Martin, Robert Romeo, Jeff Kingsley

CMA Profile

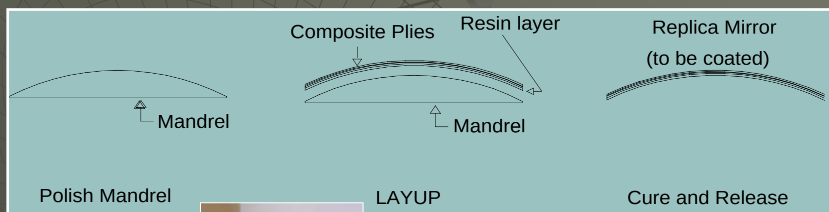
www.compositemirrors.com

- Composite Mirror Applications, Inc. (CMA) founded 1991
  - Design, prototype and manufacture custom lightweight optics
  - CFRP lightweight structures
  - Has developed and optimized processes for producing ultra-smooth, high precision lightweight mirrors
  - Applications in imaging, LIDAR, particle physics, astronomy
  - CMA is ***the*** industry leader in ultra-smooth, extremely lightweight precision composite reflectors.
- Previous CMA projects which are relevant to the CCAT Panel Study include
  - Secondary Mirrors for ALMA and APEX antennas
  - CFRP components for the ALMA and APEX chopping systems
  - CFRP/ Aluminum sandwich tertiary mirror for the SMTO
  - CFRP secondary mirrors for CBI dishes
  - CFRP 16” optical wave mirrors and OTA for ULTRA and NRL projects
  - 1 m CFRP optical wave mirrors and OTA for ULTRA (in construction)
  - 1.4 m CFRP optical wave mirrors and OTA for NRL (in construction)

Mirror Fabrication Surface Transfer

What are Composite Mirrors?

Carbon Fiber Reinforced Plastic Composite material Molded over an Optical Quality Mold



Scope of the CFRP Panel Study

Defined by contract from JPL to CMA:

- Review Technical specifications.
- Develop baseline panel design concept.
- Analyze concept performance under environmental loads.
- Optimize within rough boundary conditions supplied.
- Develop manufacturing plan.
- Critical risk assessment of all areas related to design & manufacture.
- Initial cost estimate and schedule.
- Recommend steps for further development and design of panels.
- Scope of work does not include detailed panel design nor a prototype.

Panel Requirements and Goals

- Optical specs defined by CCAT
  - 25m diameter, 3m central hole, f/0.6 primary.
  - 6 or 7 rings
  - Radial layout preferred
  - 3 point mount for panels
  - 5 µm rms surface under all loading conditions
  - “specular” surface on small scale
  - Panel gaps 5 mm or less
  - Panel areal density < 10 Kg/m^2
  - Panel cost < $10,000/$m^2$

Feasibility of Approach

- Feasibility of meeting specs is proven by previous projects and current CMA development
  - Example 1: SMT panels 1.55m on side & 6 µm rms.
  - Example 2: Current CMA development of rigid 1.4m optical mirrors.
- Approach is of acceptable risk. Similar products have been field tested. Manufacturing technology is successful & cost effective.
- Challenge for CMA concept design is ***Value Engineering***. Our design process aims to
  - maximize performance
  - reduce cost
  - reduce overall weight

Possible Panel Design Approaches

- All CFRP
  - Use for CMA Optical mirrors
  - Complex core structure
  - Stiff and stable
  - Costly in material & labor
  - Higher areal density
- Meniscus mirror bonded to stiff frame
  - Lightweight
  - Fairly labor intensive
  - Some further development worth considering
- CFRP face sheets and Aluminum honeycomb Core
  - Proven approach
  - Known costs

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Baseline Panel Design

- Design:
  - Sandwich Panel construction
  - 1.5mm thick CFRP face sheets of high modulus fiber lay-up
  - Aluminum 5056 honeycomb core
  - 3 point mounting to backside
  - baseline panel is for 7-ring segmentation
    - 1.57 m radial side; < 1.5m in width
    - Good aspect ratio for panels
    - Tooling and handling less than 60” for all widths
  - Replication over glass mandrel

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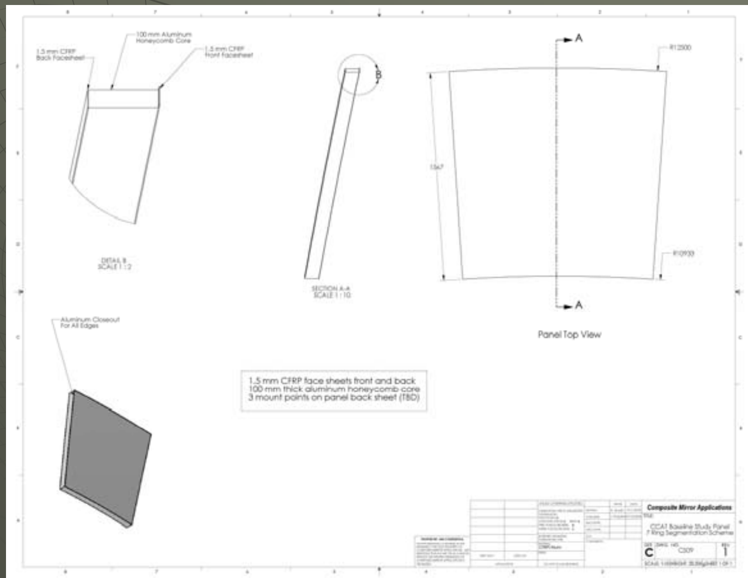
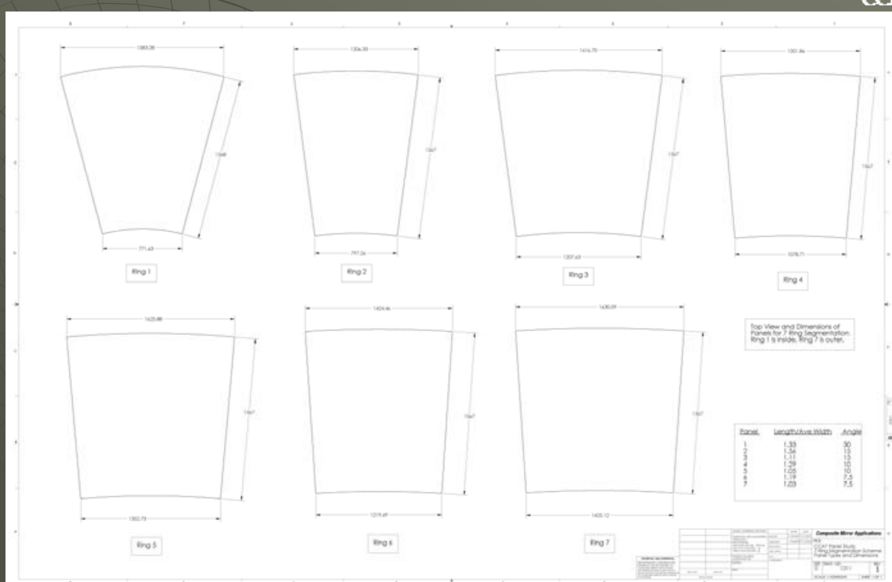
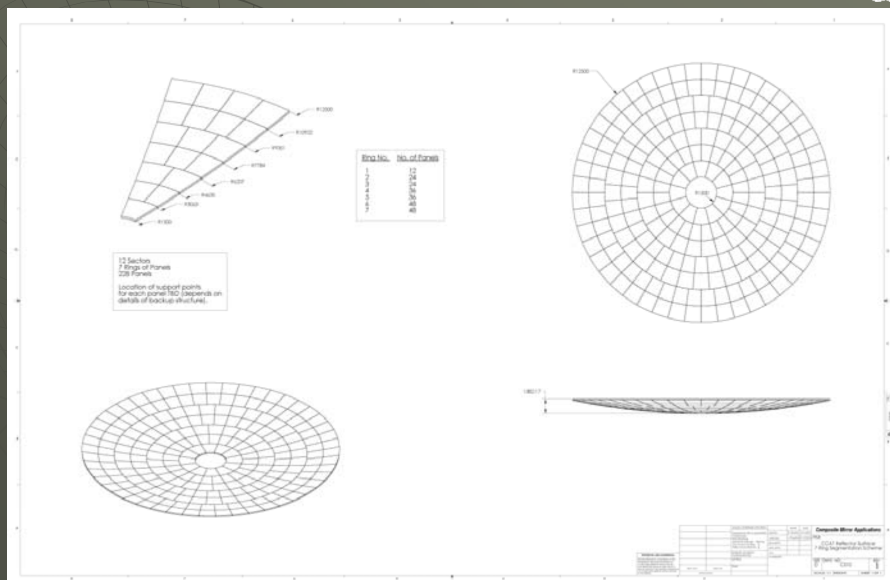
Baseline Study Panel



Panel Set for 7-Ring Segmentation



7-Ring Segmentation Scheme



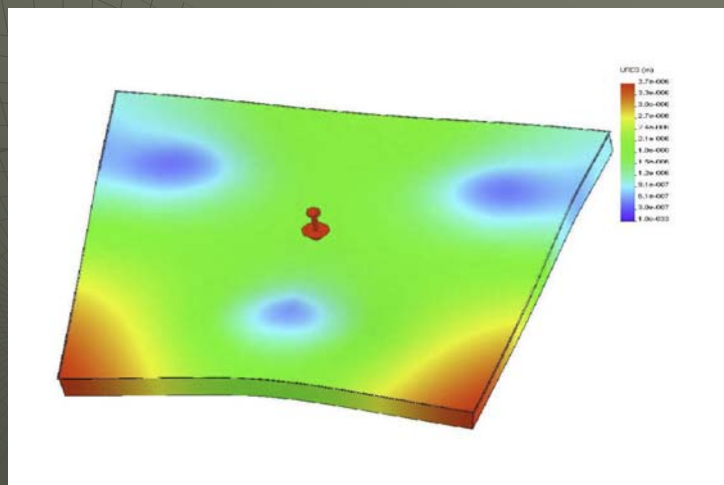
Analysis

- Analysis:
  - FEA study (using *Solidworks and Cosmos*)
    - Use material properties based on previous projects and supplier's specs.
    - optimize mounting locations and panel thickness
    - Evaluate for gravitational and wind loading
    - Thermal loading not in analysis (low CTE for CFRP)
  - Evaluated 6-ring segmentation and Hex panel shapes for comparison
  - Evaluated constraining panel at more than 3 points

Panel Deformations under Gravity

6-ring Segmentation panel:

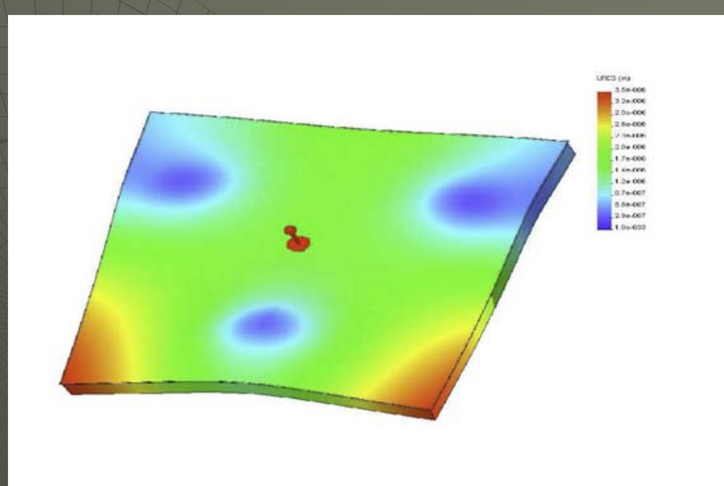
- 140 mm thick
- 1.83 m R side
- 9.8 Kg/m^2



Panel Deformations under Gravity

7-ring Segmentation panel:

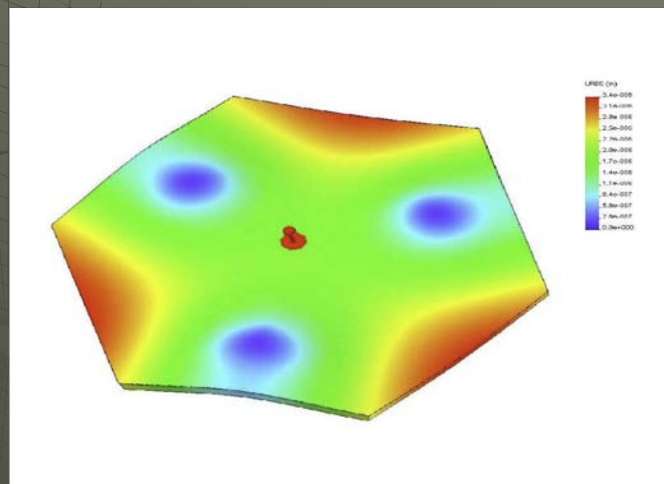
- 100 mm thick
- 1.57 m R side
- 8.3 Kg/m^2



Panel Deformations under Gravity

Hex Segmentation panel:

- 65 mm thick
- 1.67 m side-side
- 7.0 Kg/m^2



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Summary of Design Conclusions

	6 ring trapezoidal	7 ring trapezoidal	Hexagonal
Number of panels	162	228	210
Areal density	9.8 Kg/m^2	8.3 Kg/m^2	7.0 Kg/m^2
Total reflector mass	4740 Kg	4010 Kg	3390 Kg
Shape & aspect ratio	Worse	Acceptable	Good
Attachments *	Unnatural match to 3-point mount	Unnatural match to 3-point mount	Natural match to 3-point mount
Performance	Acceptable	Better	Better
Cost	Baseline + 20%	Baseline cost	Baseline – 10%

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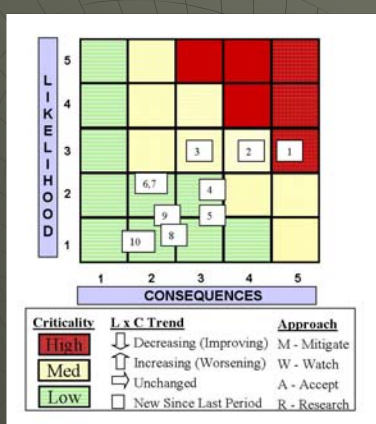
Panel Error Budget

(for all panels, worse case)

Item	general panel rms (micron)	sub-aperture use rms (micron)
Mold	1	0.05
Replication	1.5 (TDC)	0.10
Gravitational	2	n/a
Wind (5 m/s)	1	n/a
Absolute T change	1	n/a
T gradient	0.5	0.2
Aging	0.5	0.3
Total (RSS)	3.1	0.38
CCAT current spec:	5	

Critical Risk Assessment



ID	Risk Description
1	Potential trapezoidal warp
2	Handling of glass mandrel
3	Durability of surface
4	Production schedule
5	Long term stability
6	Material availability
7	Shipping
8	Handling in field
9	Galvanic corrosion
10	CFRP/honeycomb core technology

Composite Mirror Applications

Recommended Next Steps

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- Demonstration (or prototype) panel
  - Verify design and check warping risk
  - Use existing mandrels
- Environmental tests at site on small panel samples
- Investigate designs issues which reduce: primary surface cost = panels + mandrels