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TPF Mirror Technology Assessment

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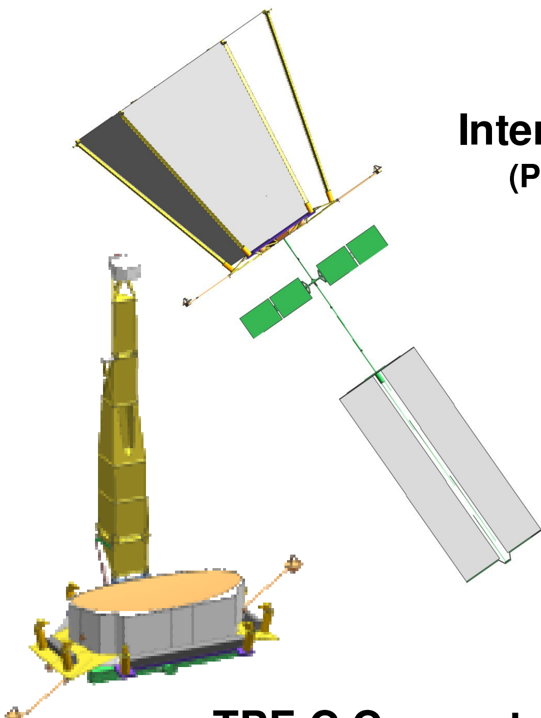
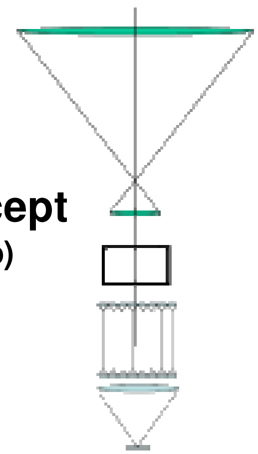
Planet Finding Concepts Continue to Emerge and to Redefine What TPF May Be

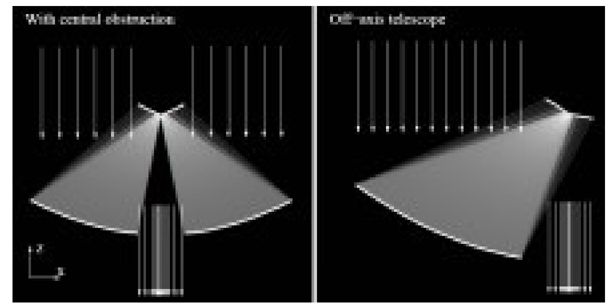
- Several new baseline concepts have been developed recently that provide alternatives to the traditional TPF-C mission architecture



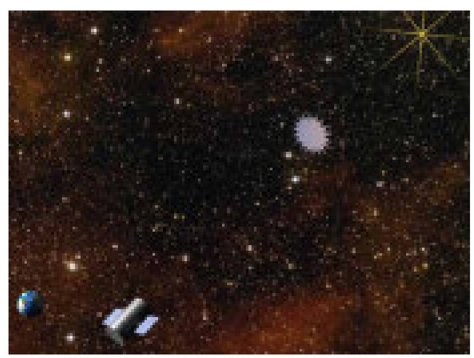
TPF-C Concept



Visible Nulling Interferometer Concept
(Paper by Michael Shao)



Phase-Induced Amplitude Apodization (PIAA) Telescope Concept
(Paper by Olivier Guyon)



New Worlds Observer Concept
(Paper by Webster Cash)

Mission Concepts Will Drive the Mirror Requirements and the Need for Technology Development

- Current concepts span a wide range of configurations and technologies

Coronagraphic to visible imaging quality

Active and passive designs

On-axis and off-axis designs

Round and elliptical configurations

A Top Level Requirements Comparison Provides Some Keys to Required Technology Development

	TPF-C (Baseline)	New World Observer (NWO)	Phase-Induced Amplitude Apodization (PIAA)	Visible Nulling Interferometer (VNI)
PM Size Range	3m x 6m 3.5m x 8m	2m --- 4m	4m	4m
PM Configuration	Off-axis	On-axis	Off-axis	On-axis
PM Actuation	Low Authority	Passive	High Authority	Passive
Quality	Corona-graphic	Visible	Visible	Visible

— No Technology Development (TRL 6 Minimum)
— Engineering Process Development (TRL 5)
— Technology Development Needed (TRL 4 or Less)

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Mirror Configurations for the Various Sizes of Primary Mirrors Under Consideration

Configurations Characteristics	2.4m Passive f/1.25	3.2m Passive f/1.25	4.0m Passive f/1.25	4.0m Set & Forget f/1.25	3.5m x 8.0m F/3.8
Mirror					
Outside Diameter (m)	2.43	3.23	4.03	4.03	3.5 x 8.0
Inside Diameter (m)	0.44	0.62	0.77	0.77	N/A
Pocketmilled Facesheets	Yes	Yes	Yes	Yes	Yes
Core Cell Shape	Hexagonal	Hexagonal	Hexagonal	Triangular	Hexagonal/Segmented
Force Actuators	N/A	N/A	N/A	21	20-50
Material	ULE	ULE	ULE	ULE/Composite	ULE/Composite
Total Weight (kg)	176.4	304.1	601.5	450.9	1100.0
PM Mounts					
Material	MP35N/Invar	MP35N/Invar	MP35N/Invar	MP35N/Invar	MP35N/Invar
Total Weight (kg)	4.5	13.6	26.3	26.3	TBD
AMS					
Material	Composite	Composite	Composite	Composite	Composite
Total Weight (kg)	38.1	67.7	106.1	276.1	750.0
Mirror Area (m^2)	4.5	7.9	12.3	12.3	44.0
Total PMA Mass (kg)	219.0	385.4	733.9	753.3	1850*
PMA Areal Density (kg/m^2)	48.8	48.8	59.7	61.3	42.1*

* Does not include PM Mount Mass

Note: Design details are available
No contingency is included in these estimates

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Mirror Technology Maturity

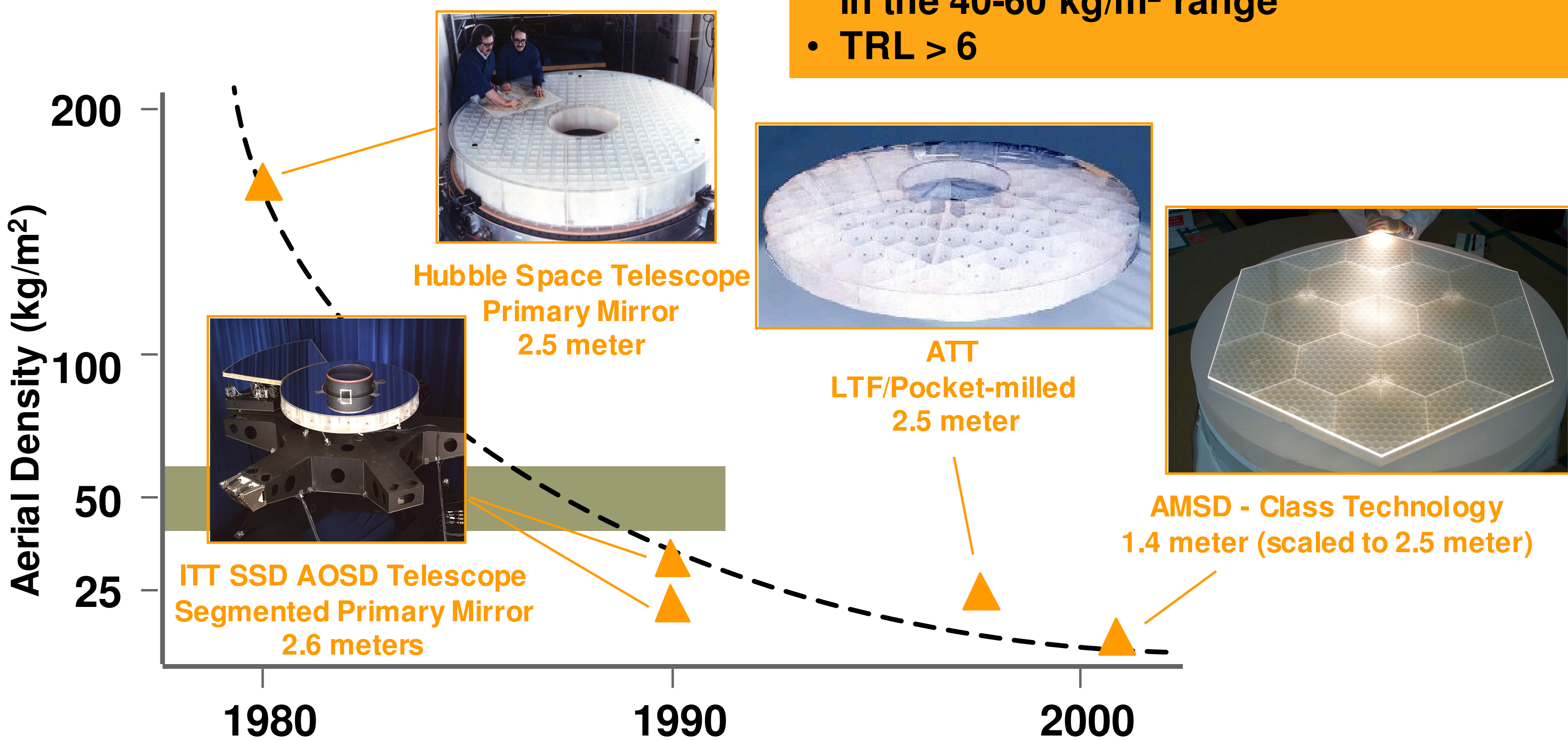
Primary Mirror Size and Areal Density

Space Flight Designs

- Based on previous efforts by ITT and Corning, any of the mirrors under consideration by TPF can be manufactured
- There are several breakpoints in facilities that would require some investment
  - Demonstrations and risk reduction recommended for mirrors larger than 3m
- Significant technology development required for the very large, active 3.5mx8m primary mirror configuration
  - Based on previously reported LMM (Large Monolithic Mirror) study conducted by ITT

Evolution of Lightweight Mirror Technology

- 2m-class primary mirrors can be manufactured and processed routinely in the 40-60 kg/m^2 range
- TRL > 6



Facility Break Points have been identified

	2m - 2.5m	2.5m – 3.0m	3.0m – 4.0m	3.5mx8m
ULE® Glass Manufacturing	No issues. Raw glass manufacturing has been demonstrated to 8m diameter at Corning			
Mirror Blank Manufacturing	Facilities in place at Corning	Facilities in place between Corning and ITT	New furnace required	Segmented manufacturing process requires development
Mirror Processing and Coating	Facilities in place	Minor upgrades required for final finishing and test. Coating chamber required.	Some modifications required for finishing and test. Coating chamber required	Major facility upgrades required.
Recommendation	No issues. Pathfinder will reduce schedule risk.	Pathfinder suggested to harden processes	Qualification model recommended to verify processes	Subscale pathfinder and full scale pathfinder recommended

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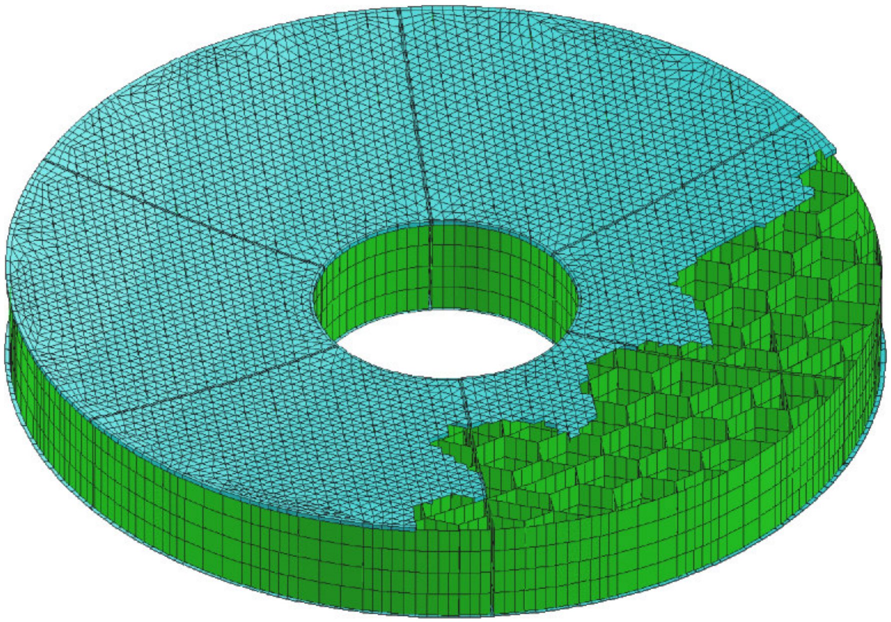
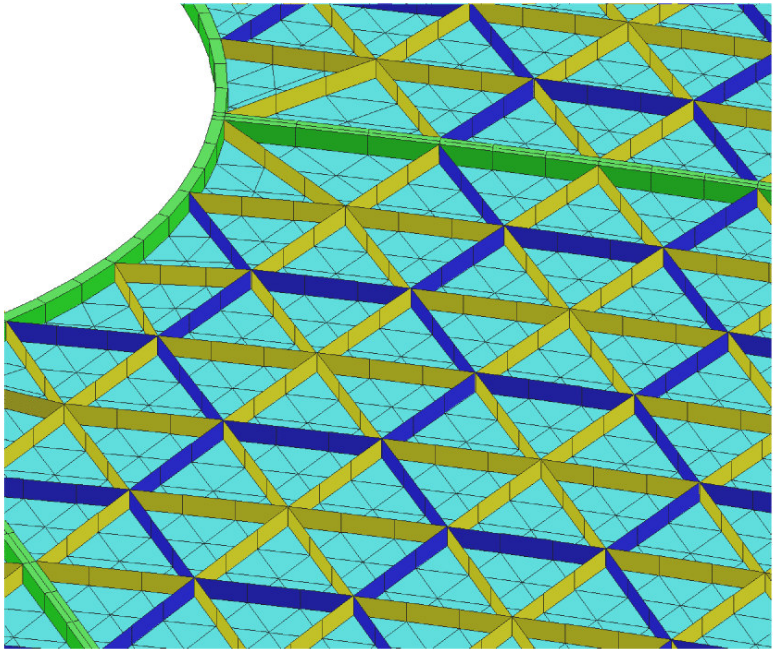
Passive Primary Mirror Model



PM Model

ITT has done detailed modeling of large passive and active systems



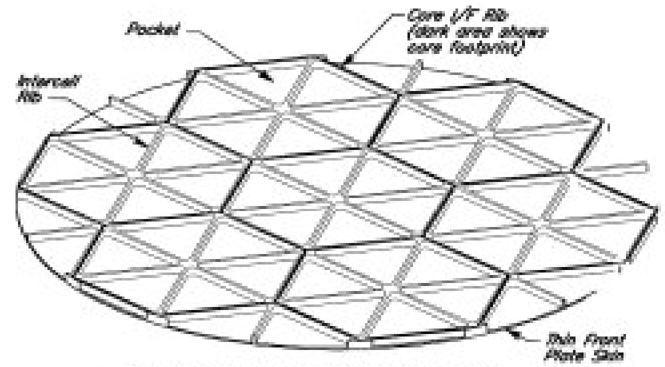
Front Plate Model with pocket milling included

- **In order to achieve acceptable areal density goals for very large primary mirrors, pocket milled face sheets will most likely by required**
- **This technique has been demonstrated on demonstration mirrors**

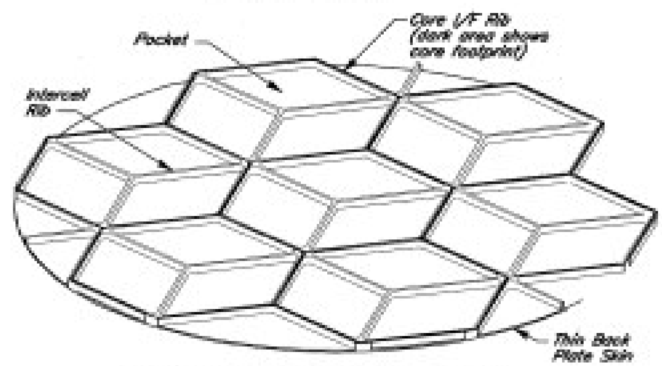
Mirror Pocketmilling Details

Typical of 2.4m, 3.2m and 4.0m

- **Front plate pocket milling**
  - **68%-72% plate lightweighting**
- **Back plate pocket milling**
  - **72%-74% plate lightweighting**
- **Reduces faceplate and core mass while minimizing processing induced quilting**



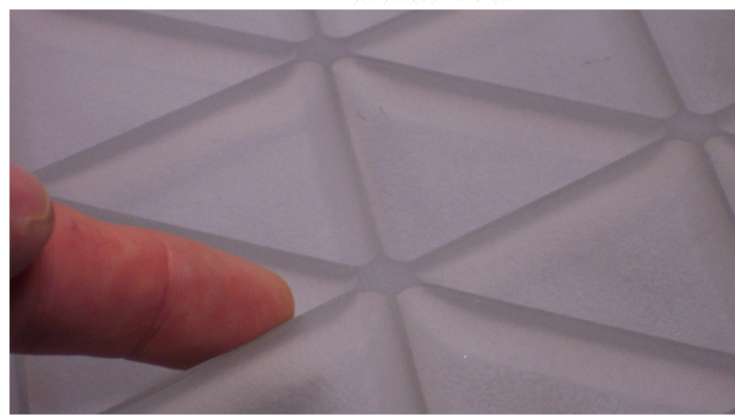
Section of Pocket Milled Front Plate (Isometric View)



Section of Pocket Milled Back Plate (Isometric View)

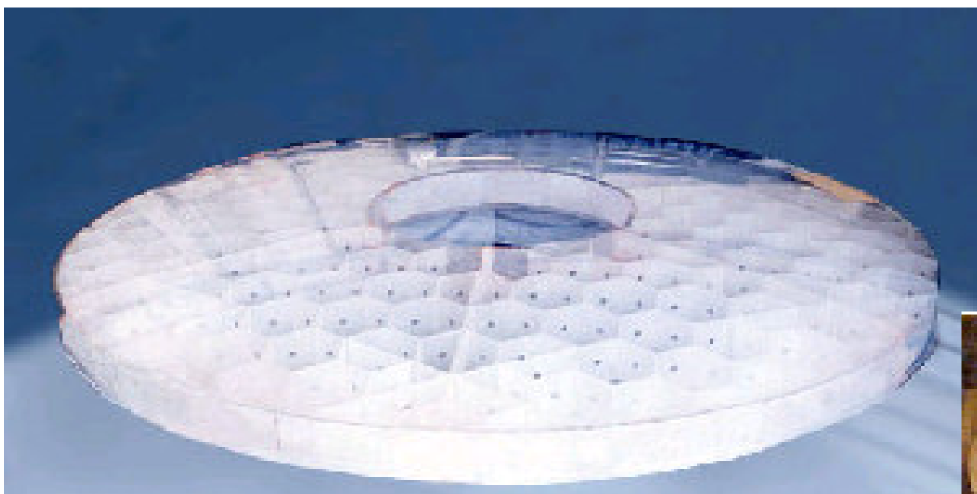
Glass Mirror Construction

Pocket milled detail



Ultra Lightweight 2m class Passive Primary Mirror Technology has been Demonstrated

- Abrasive waterjet lightweight segmented core reduces risk
- Pocket milled facesheets reduces weight to about 1/3 the areal density of HST with comparable stiffness
- Low Temperature Fusion (LTF) process eliminates the effects of Frit-bonding
- Directly scalable to 4m size

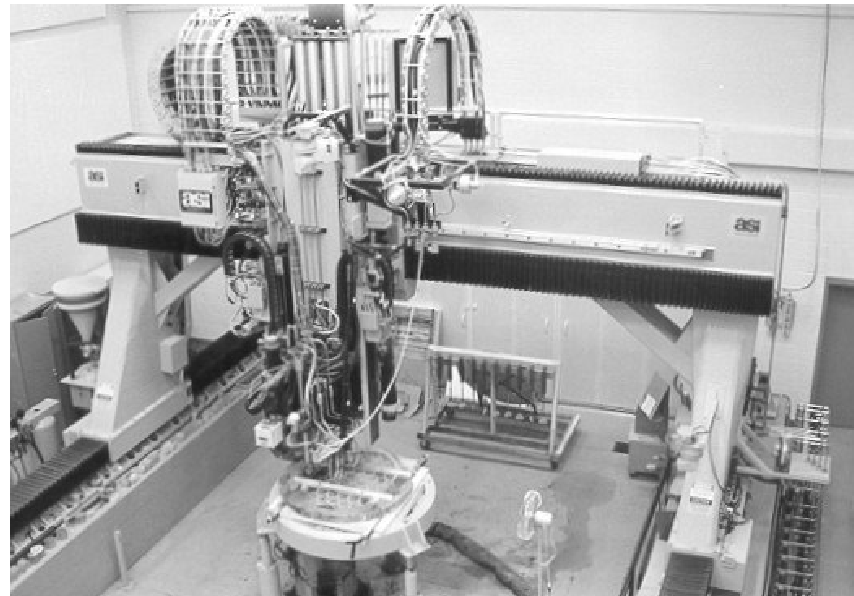


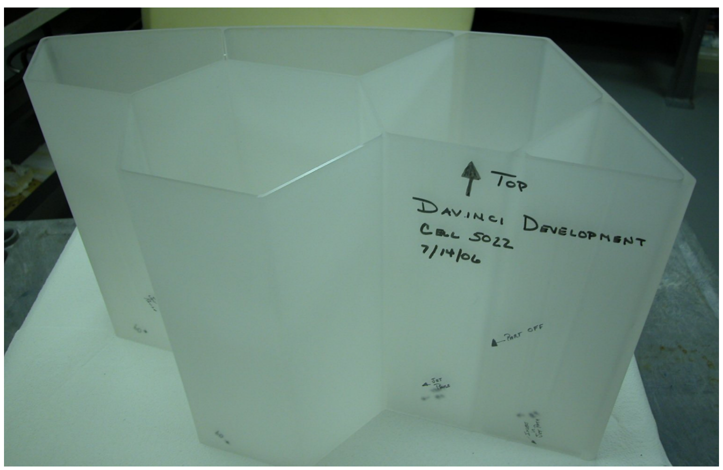
Advanced Technology Testbed (ATT) 2.4-meter Primary Mirror

ATT Pocket Milled Facesheet

Corning Has the Capacity to Produce Any of the TPF Mirror Blanks With Some Facilitization

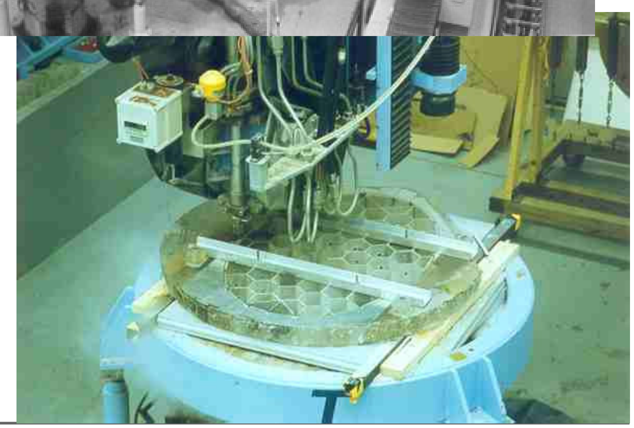
8m Furnace Facility with 4m mirror





Deep Core Cutting for Lightweight Mirrors

Very large water jet cutting facility



Primary Mirror Configuration

On and Off-Axis Designs

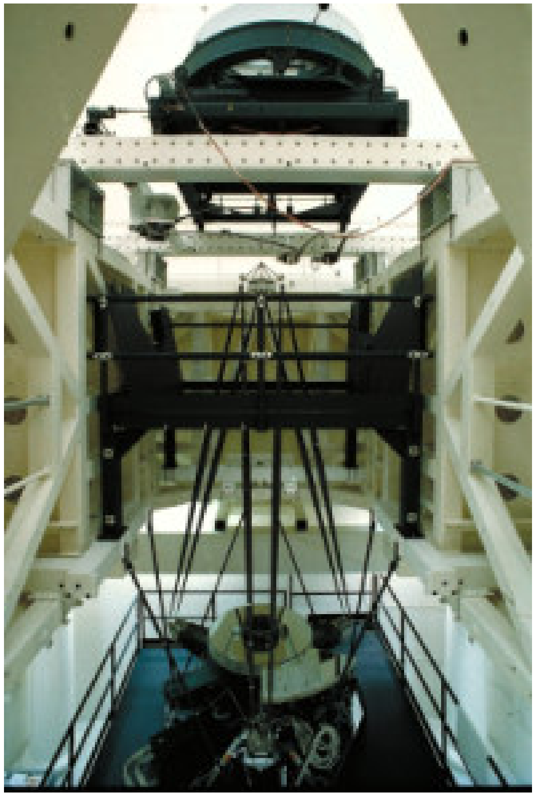
- No major difference in making the various designs given today's processing technology
- The development of large, off-axis, lightweight mirrors has been demonstrated
  - Quality and clear aperture need to be considered
- TDM was a key step in demonstrating coronagraphic quality mirrors in a lightweight, off-axis configuration

Passive and Active Mirror Designs

Flight Qualification and TRL

- No flight qualified active primary mirrors have been developed to TRL 6
- Several demonstrations have been completed
- Technology development will be required to achieve required maturity level prior to flight

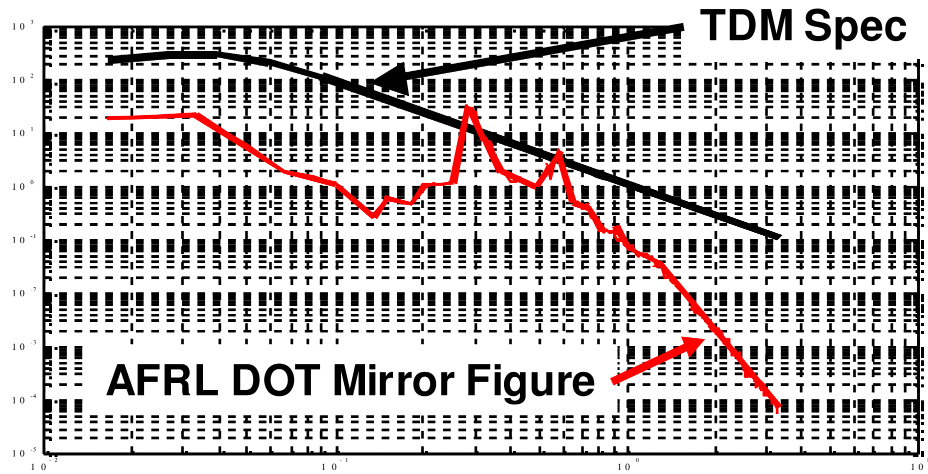
ITT's Advanced Optical System Demonstrator showed the viability of phase and figure control of an active primary mirror

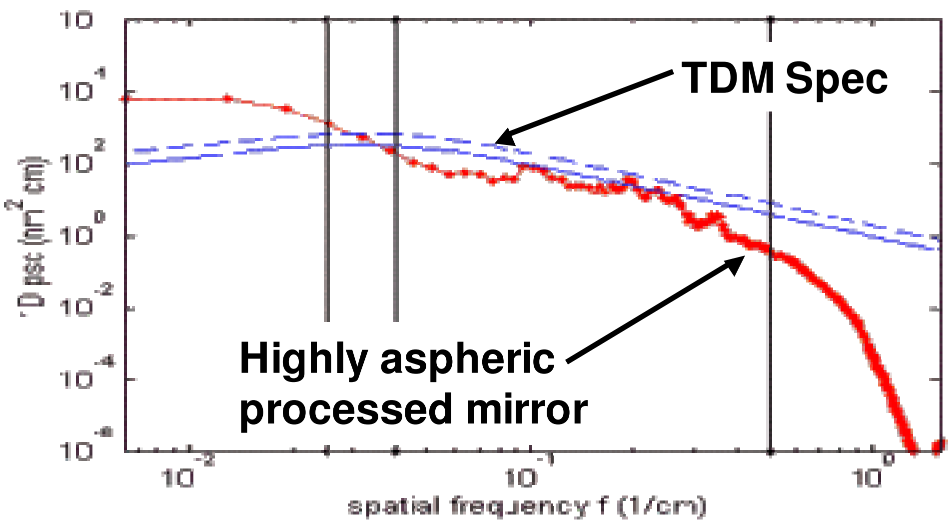


Mirror Quality

Processing Capability of Lightweight Mirrors

- Lightweight mirrors have been processed that approach coronagraphic quality
- If required, a qualification program would be needed to assure that the quality aspects of the mirrors in the flight configuration could be met





Summary

- All TPF Primary Mirror concepts appear feasible to manufacture, process, and test
  - Some designs will require technology development to achieve
  - Pathfinder/Back-up mirror recommended for all configurations to reduce schedule risk
- For modest sized systems (<3.0m), the primary mirror will not be the critical path of the observatory