Mirror Technology Assessment

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MIRROR TECHNOLOGY ASSESSMENT ABSTRACT

A mirror technology assessment was provided to ground the TPF science community regarding the current state-of-art in space mirror capabilities within ITAR constraints. A generic assessment regarding the various mirror configurations (active vs passive, on-axis vs off-axis, round vs elliptical, coronagraphic quality vs visible quality) was discussed. The maturity level of each of the various concepts was provided in order to help guide future mission planners regarding programmatic risk and the need for early technology development.

The fundamental conclusion was that any of the concepts are certainly possible from an engineering standpoint. The major variable was the cost to reduce the risk to an acceptable level such that a robust schedule could be proposed and managed on the program. This assessment and long term program plan in turn would drive the technology development process that would be required prior to baselining the program architecture.

TOP LEVEL PRIMARY MIRROR PARAMETERS

The top-level primary mirror parameters are shown on the chart shown on the previous page. The color scale reflects the proven capability with respect to demonstrated TRL and other technology development completed by ITT.

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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PRELIMINARY MIRROR DESIGN CONFIGURATIONS

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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ITT has completed a very preliminary assessment of the mirror design parameters for the various sized mirrors required for the TPF-C program. As can be seen, reasonable areal densities can be achieved for all of the potential telescope designs.

FACILITY ASSESSMENT

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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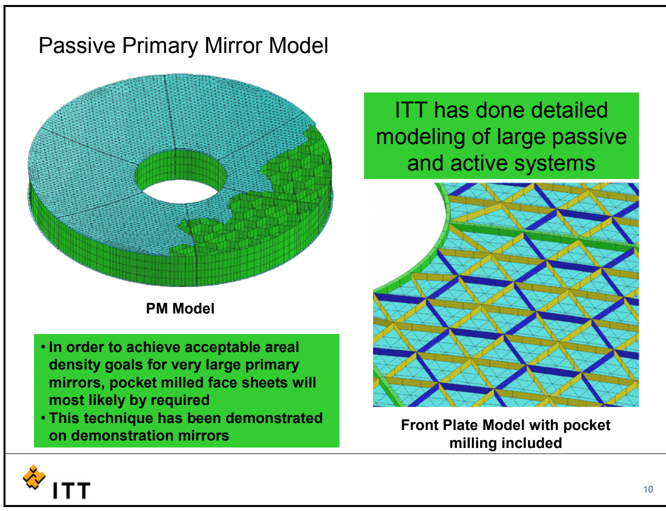
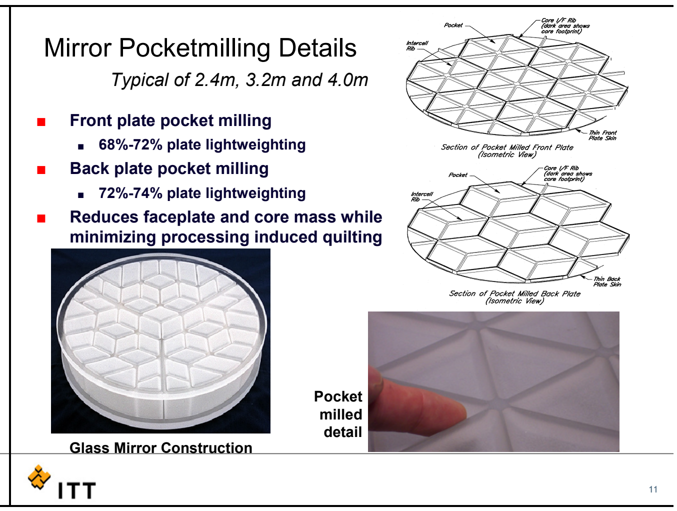
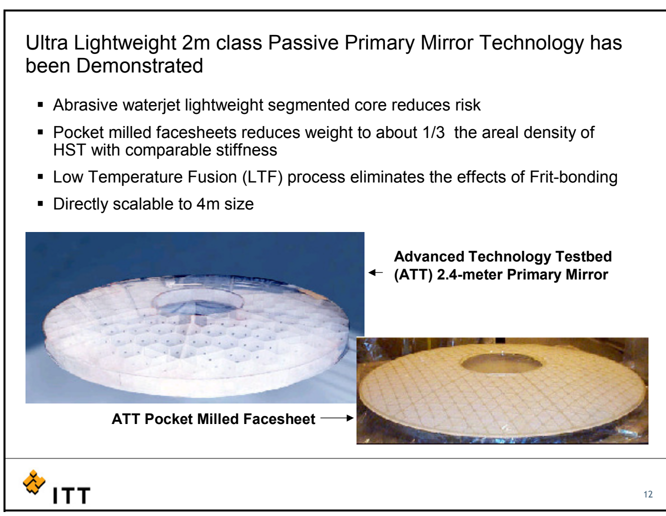
Facility limitations have also been evaluated and recommendations provided regarding engineering models. From our assessment, all of the primary mirror systems in our study are possible to build. Some configurations will require more engineering development than others.

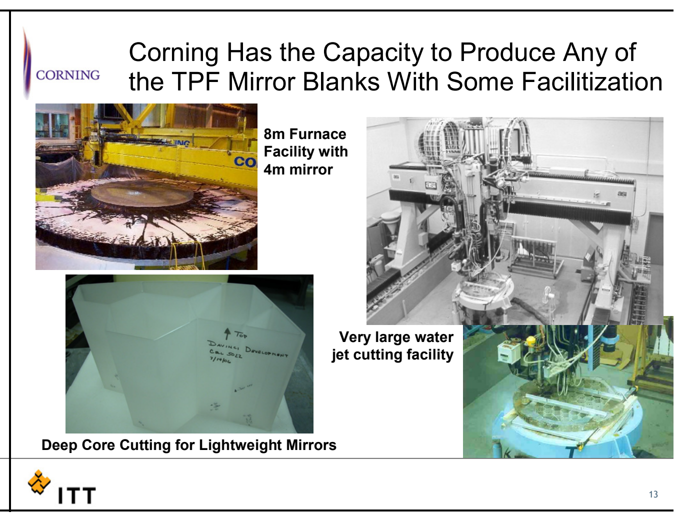
For example, a Hubble-like 2.4m primary mirror is considered to be very low risk. In that configuration, no pathfinders would be needed. As the primary mirror systems become larger and more complicated, pathfinders or qualification units are recommended. In the case of the baseline TPF-C 3.5m × 8m concept, a subscale pathfinder would be needed to work out the critical engineering details prior to making a full scale pathfinder model. This would all have to occur prior to building the flight model off-axis primary mirror. Each of the mirrors fabricated would demonstrate key technology and demonstrate a progressively higher TRL as the development program progressed. The demonstration units and pathfinder program would provide high confidence that the flight primary mirror would be successful and the program cost and schedule could be maintained.

MIRROR FABRICATION TECHNOLOGY





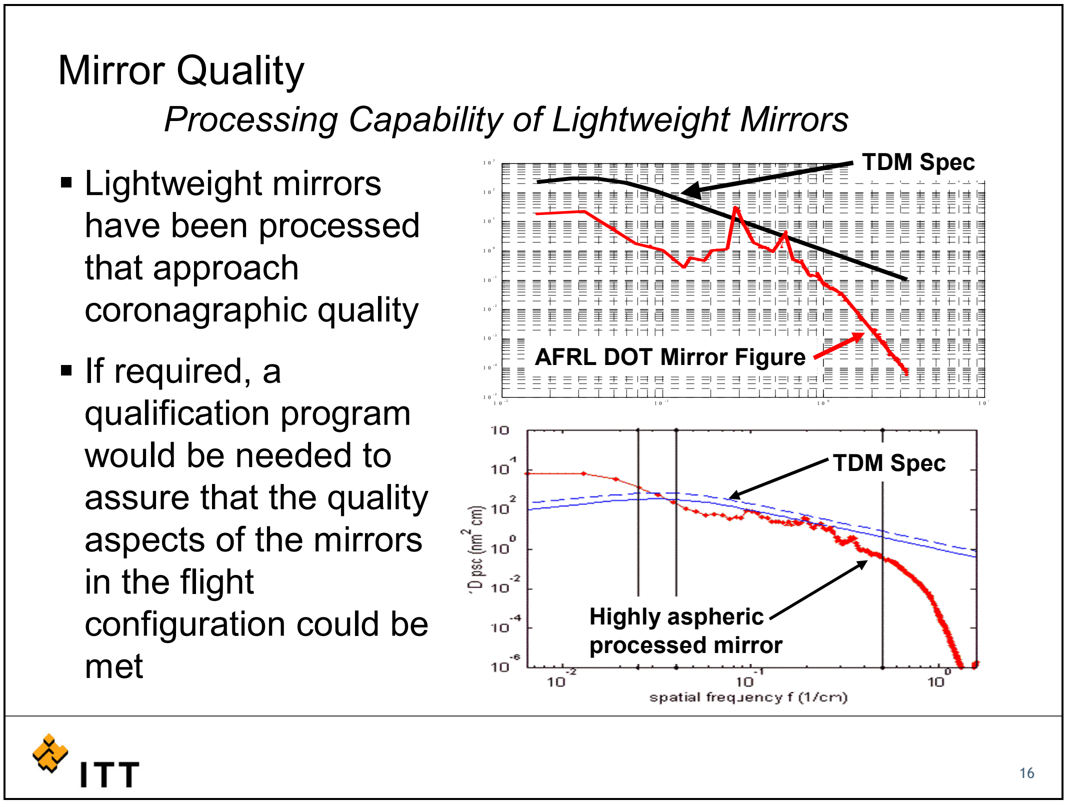




Mirror technology has been developed by Corning and ITT over the last 40 years. These technologies have been demonstrated on various programs and are available and ready for use on the TPF program. These technologies include faceplate pocket milling which provides faceplate support to minimize polishing quilting effects during processing. This added faceplate support allows mirrors with lower areal densities to be fabricated. Using this type of construction, large mirrors can be fabricated with areal densities as shown on page 48.

Facilities at Corning typically fabricate large ground based mirrors up to 8m as shown above. In addition, Corning has large waterjet cutting machinery that allows very deep cores to be fabricated. These facilities and those at ITT allow large mirrors to be successfully produced.

MIRROR QUALITY PARAMETERS



ITT has produced lightweight mirrors that demonstrate that coronagraphic-type quality can be achieved. Two example power spectral density (PSD) results are shown above. In each case, the quality achieved far exceeded the required specification for the mirror and was only compared to the coronagraphic specification for the Technology Demonstration Mirror (TDM) being developed by ITT for JPL. This provides evidence that the very difficult specifications required for the baseline TPF-C mirror are achievable in lightweight mirror systems.

SUMMARY

All TPF Primary Mirror concepts reviewed to date appear feasible to manufacture, process, and test. Some design configurations will require technology development in order to achieve a finished primary mirror with a predictable cost and schedule. Pathfinder/Back-up mirrors are recommended for almost all the configurations in order to reduce schedule risk on the program. For modest sized systems (<3.0m), the primary mirror will not be the critical path of the observatory based on ITT's experience. For larger systems, a rigorous and well-planned development program will provide sufficient risk reduction to allow the primary mirror to be successfully delivered within the cost and schedule constraints of a flight program.