

ATST Thermal Design

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Problem: Seeing

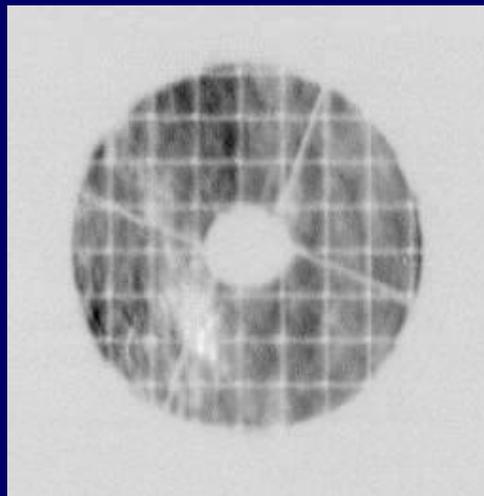


Other solar telescopes:

- Helium backfill
- Evacuated optics

ATST must be open-air.

Surfaces must be individually temperature-controlled.



T. Rimmele & BBSO

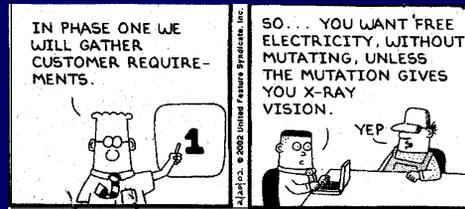


Approach



Two concurrent tasks:

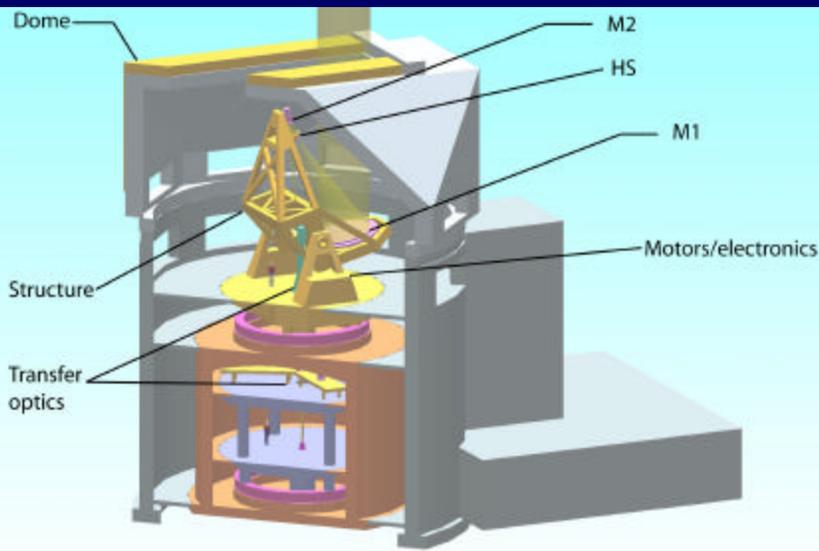
- Define thermal requirements
 - Flow down from SRD, error budgets, interfaces
 - Connect image quality to surface temperature with modeling and empirical correlations
 - Continue refining until early 2003
- Explore concepts
 - Examine prior work
 - Assemble short list of concepts
 - Model/analyze concepts, list pros/cons
 - Can we meet requirements?
 - Examine interfaces/trades
 - Select baseline concept (~CoDR, spring 2003)



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Big Picture



Thermal Problem Areas

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Thermal Concerns

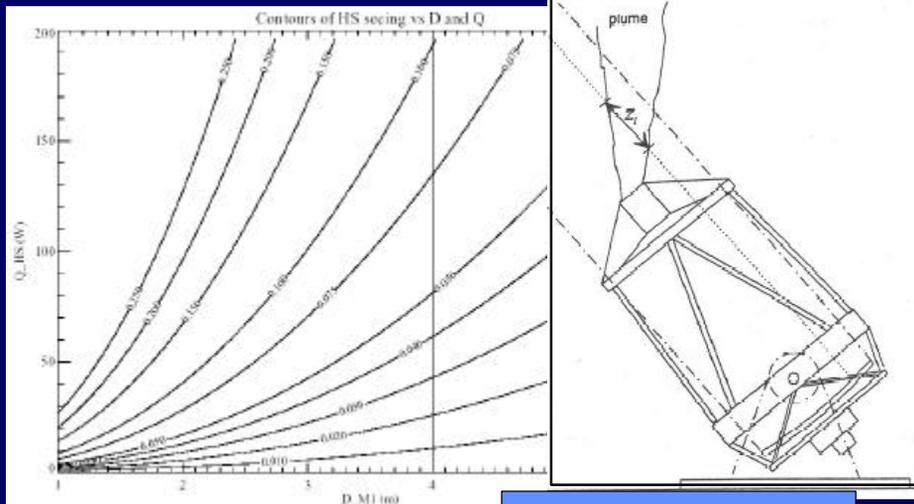


surface	Absorbed flux (W/m^2)	Absorbed heat (W)
M1	110	1382
Heat stop (reflective)	303,000	$1866 + 10,271 = 12,137$
M2	60	30
M3	2034	27
M4	271	25
M5	694	22
M6	280	20
Exterior shell	300	150,000

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Heat Stop Seeing

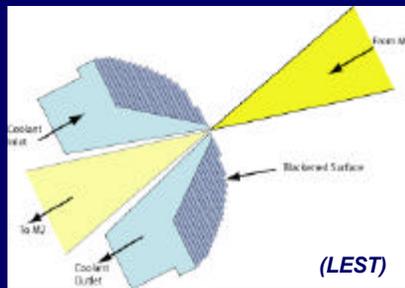


Not very restrictive on D T.
Shoot for D T = 10 – 20 °C.

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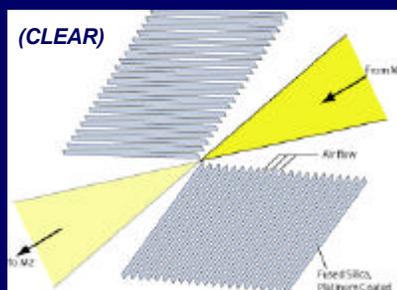
Heat Stop Concepts



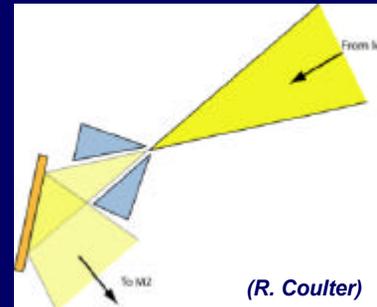
(LEST)



(ATST baseline)



(CLEAR)

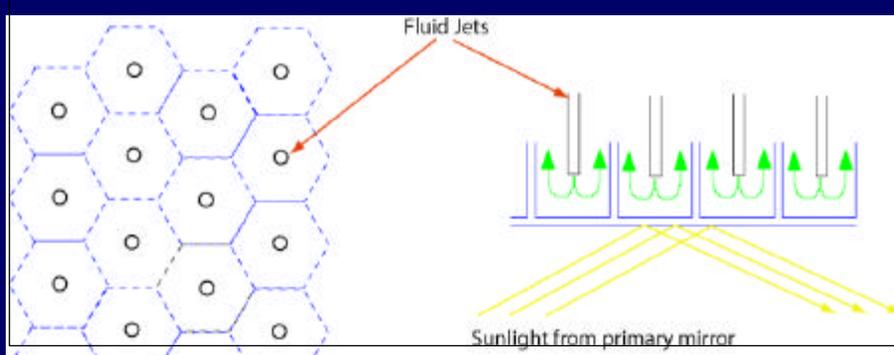


(R. Coulter)

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Jet Cooling Scheme



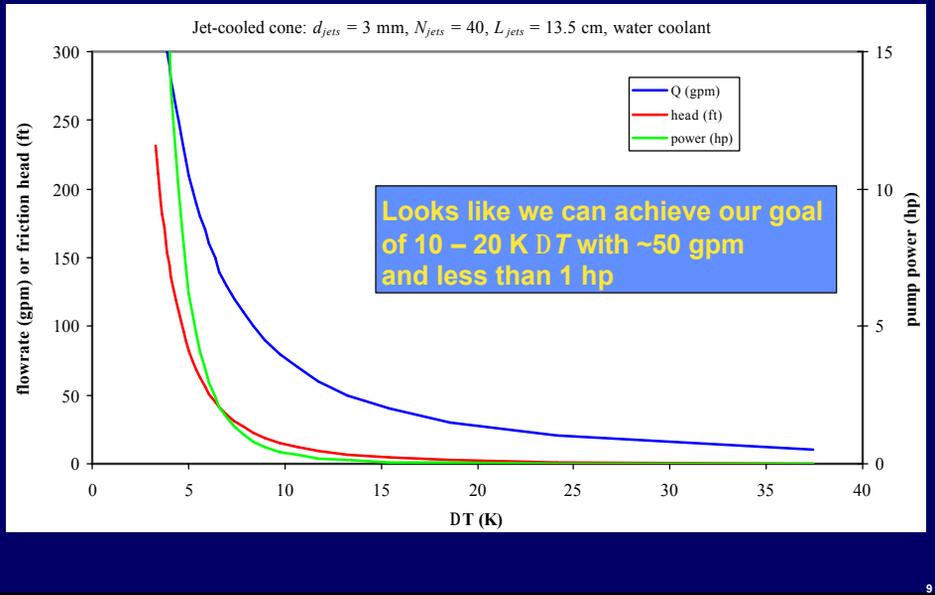
Array of normal jets gives very large heat transfer coefficient:
 $h = 30 \text{ kW/m}^2\text{-K}$ or larger not unreasonable.

Large h allows coolant to be near ambient temperature—
no complex control systems needed.

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Heat Stop Design Curves



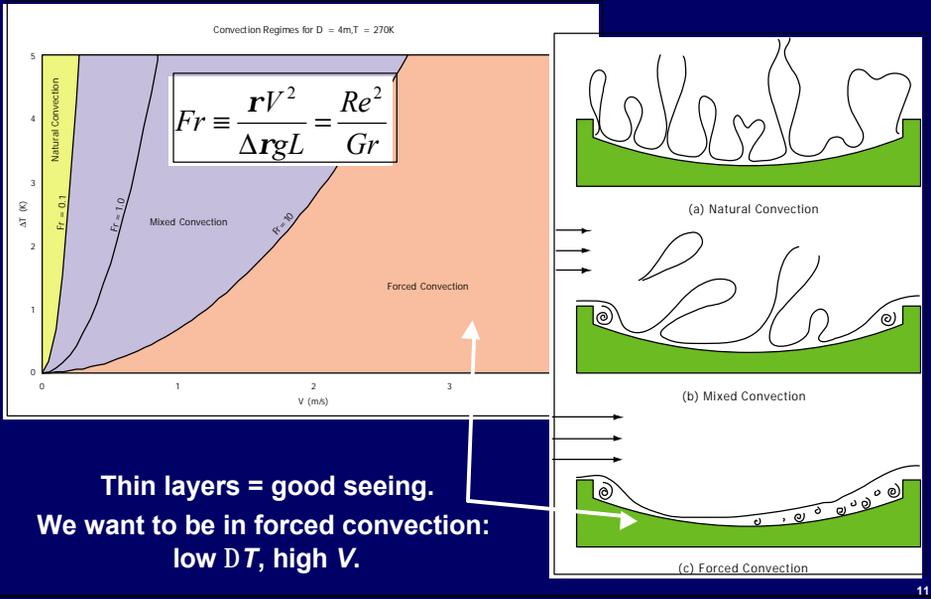
Heat Stop Summary



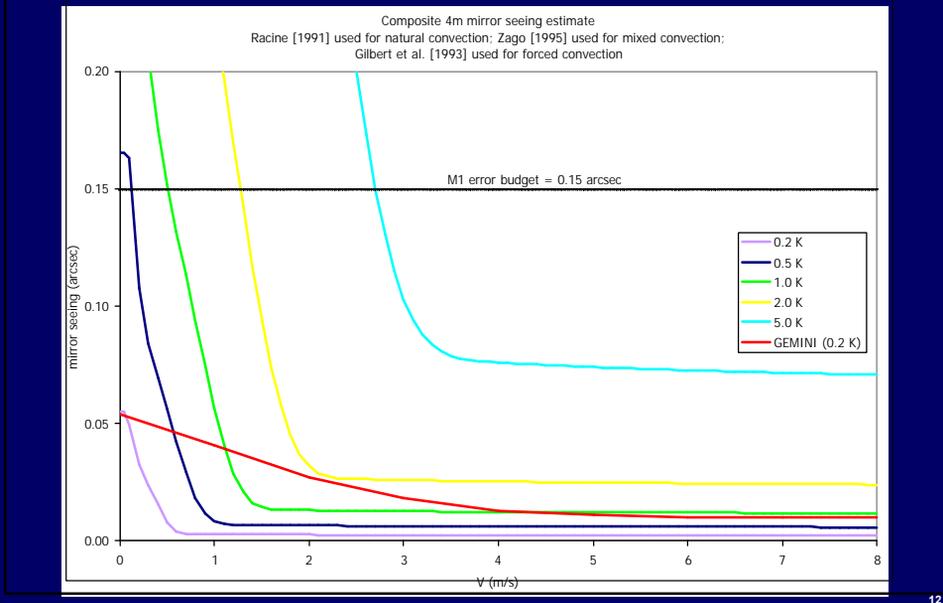
- Seeing contribution expected to be low, although it is unclear how small-scale plume turbulence affects AO system performance
- Baseline concept: jet-cooled reflective cone
- 10 – 20 K DT with 50 gpm water coolant near ambient temperature
- May implement plume suction with larger DT
- Shape influences scattered light



Primary Mirror Seeing



M1 Thermal Requirements



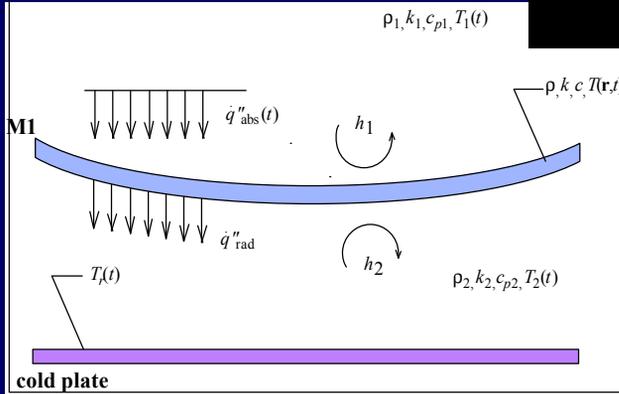
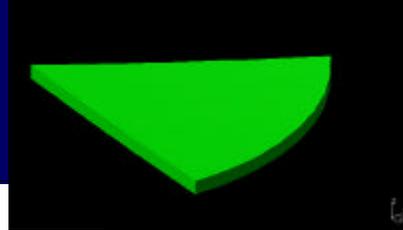


M1 Thermal Models

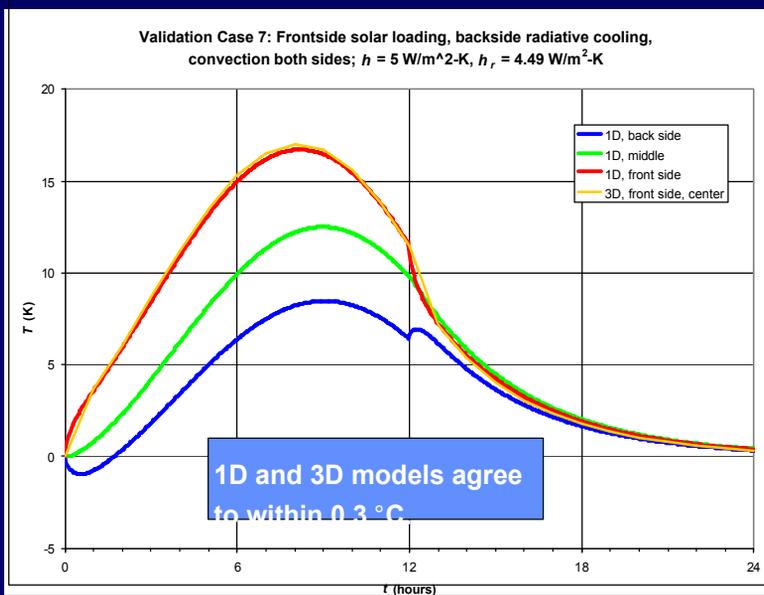


- 1D finite-difference on spreadsheet
- 3D FEM package (TMG)

Would like to use simplest, yet still physically realistic model.



1D Model Validation

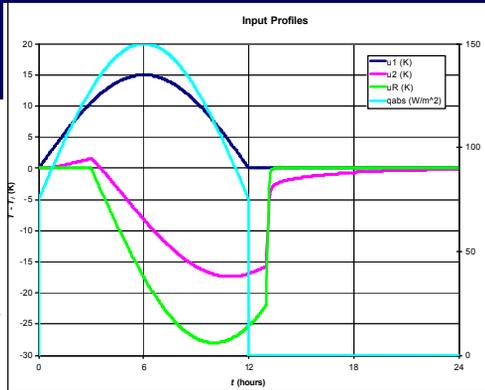
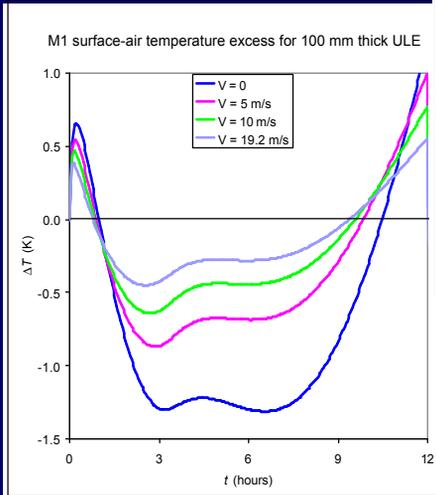




M1 Thermal Model Results



100 mm thick ULE



Results:

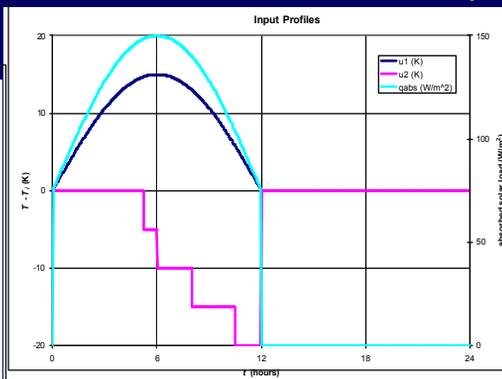
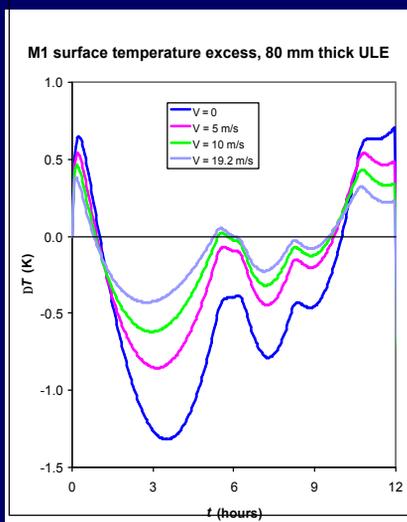
- < 1 K ΔT over most of the day.
- Mirror flushing assists temperature control.



M1 Thermal Model Results II



80 mm thick ULE



- Result: < 1 K ΔT over most of the day
- Easier cooling than 100 mm case

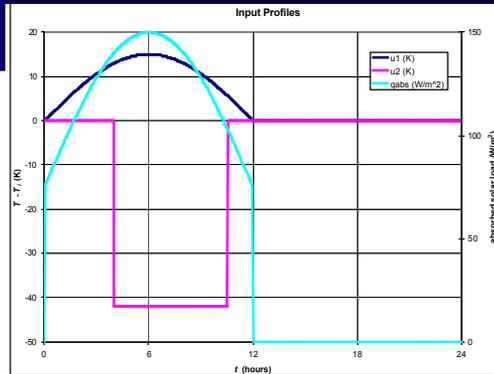
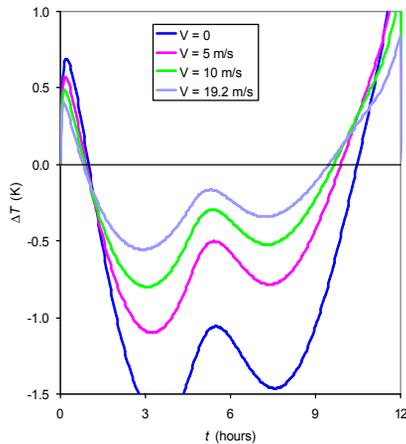


M1 Thermal Model Results III



200 mm thick ULE

M1 surface temperature excess, 200 mm thick ULE



**Result: < 1 K DT over most of the day.
Cooling more difficult.**

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M1 Summary



- Surface temperature requirement is a strong function of wind speed:
 - $DT < 0.5$ K for $V < 0.5$ m/s
 - $DT < 1$ K for $0.5 < V < 2$ m/s
 - $DT < 2$ K for $V > 2$ m/s
- $DT < 1$ K is achievable with 80 – 200 mm thick ULE mirrors
- Cooling difficulty increases with M1 thickness
- Wind flushing assists M1 temperature control

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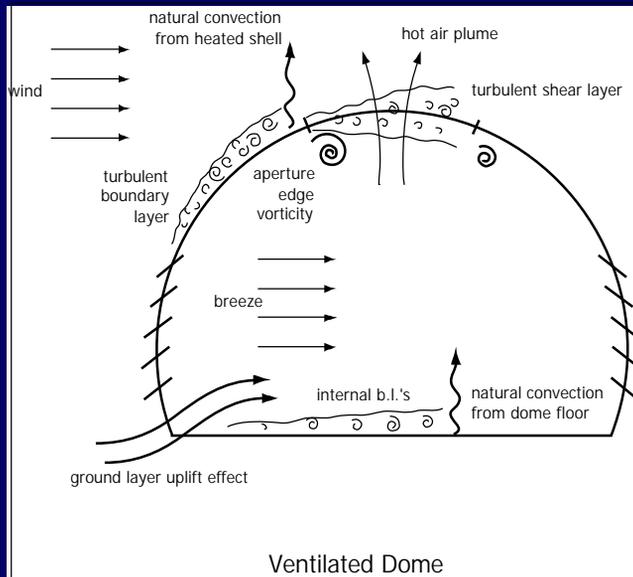
Enclosure Seeing



Variety of sources:

- Shell
- Ground layer
- Internal nat. conv.
- Shutter plume
- Shear layer
- Aperture edges

Passive ventilation reduces internal seeing sources



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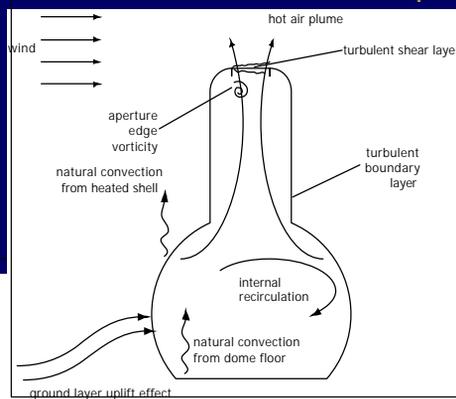
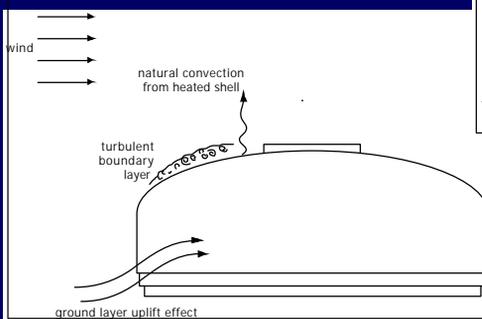


Other Concepts



CLEAR concept:

- Reduction in heated shell area
- Snout may extend past shell layer
- Internal ventilation more difficult



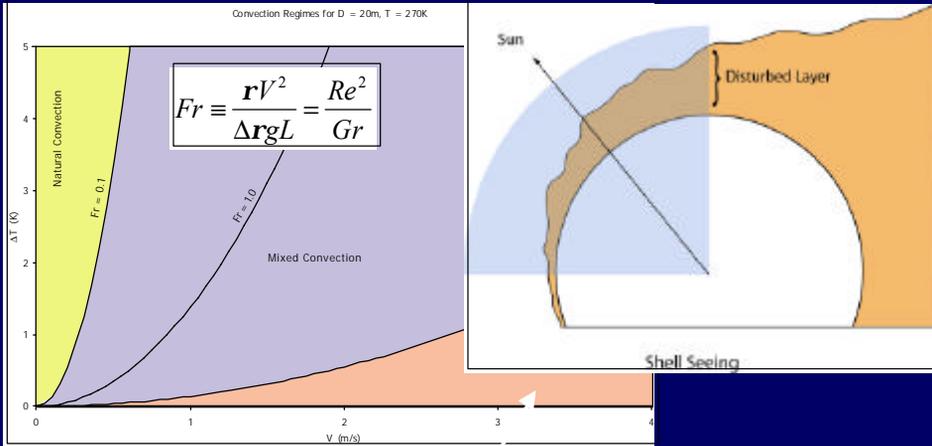
Retractable:

- Eliminates many seeing sources
- Still have shell seeing (reduced)

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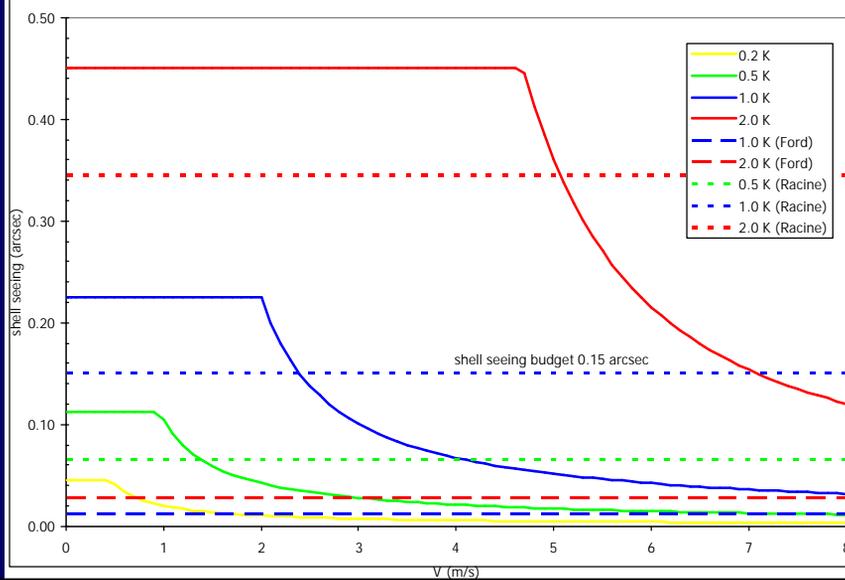
Shell Seeing



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Shell Seeing Requirement



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Enclosure Summary



- Major trade in process
- All concepts suffer from shell seeing
- Wide spread in shell temperature requirement:
 - 1 – 8 K DT for 0.15 arcsec, depending on source
- Guess: ~2 K sun-facing DT will be adequate (must refine)
- Must provide for internal flushing
- Performance: future work, must model/measure

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Future Work (to CoDR)



- For every surface:
 - Refine requirements
 - Define thermal concepts
 - Model/measure to predict performance
 - Define interfaces/trades
- Complete major trades, e.g.
 - Enclosure style
 - M1, M2, etc thickness/material/thermal control

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Discussion

