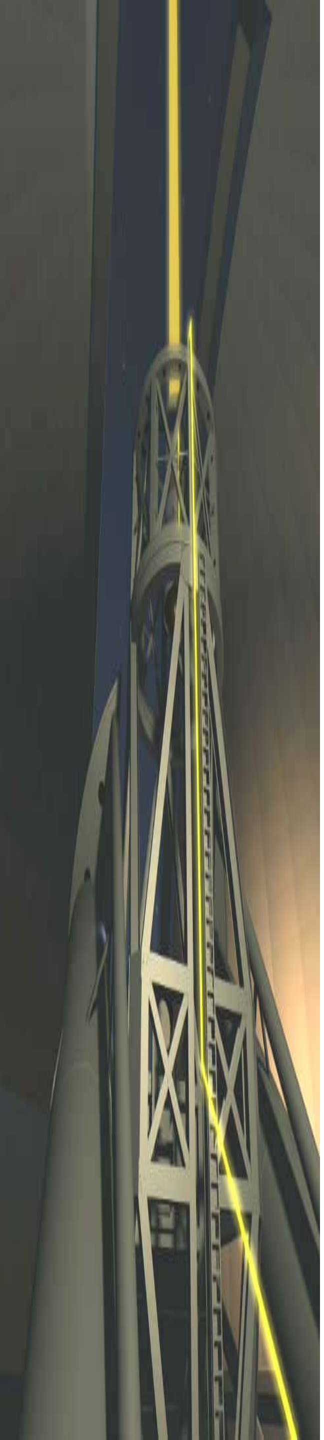
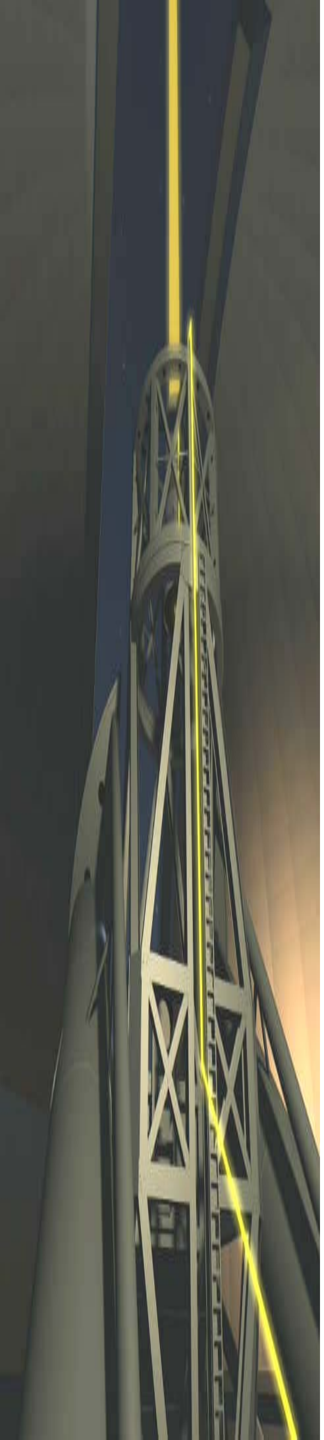


TMT Adaptive Optics Overview

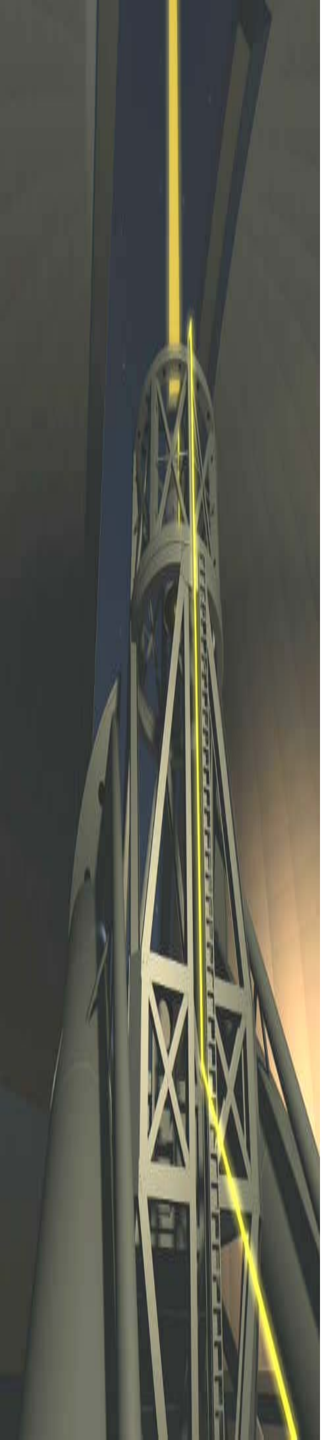
Keck AO Strategy Workshop
September 19, 2004
University of California, Los Angeles

R. Dekany
Caltech Optical Observatories



Outline

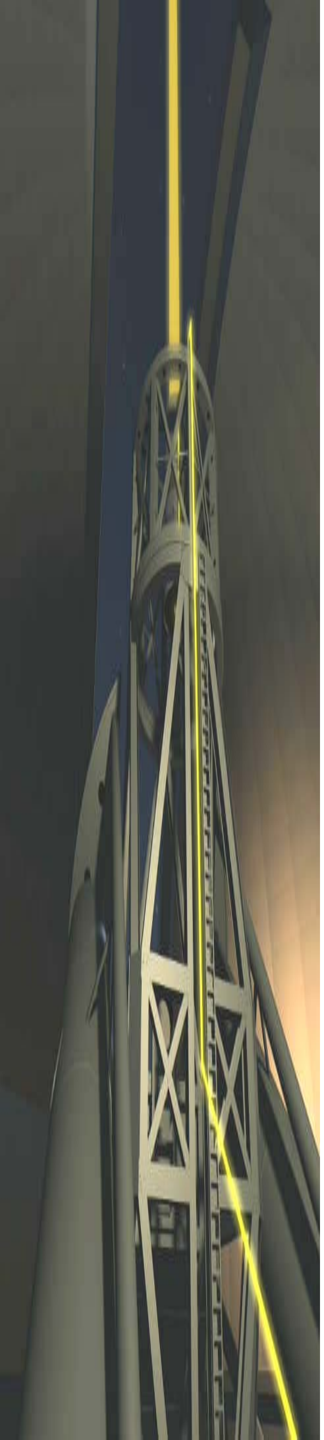
- TMT instrument suite
- Long-term Keck AO sweet spots
  - Narrow field, high Strehl visible/NIR IFU
  - Wide field, visible/NIR GLAO multiobject spectrograph



TMT Instrument Suite

Priority	Acronym	Description
1	NFIRAOS	Narrow Field Infrared AO-fed IFU with 10" FoV
2	WFOS	Wide Field Optical Spectrograph
3	MIRAOIS	Mid-Infrared AO-fed Imaging Echelle Spectrograph
4	MOAO	Near-diffraction limited Multi-object AO IFU
5	PFI	Planet Formation Imager (1st generation ExAO)
6	NIRES	Near-Infrared AO-fed Echelle Spectrometer
7	MTHR	High-resolution optical Echelle
8	NIRC	Diffraction-limited AO-fed imaging camera
9	GNIMIS	Ground-layer AO NIR Multiobject Spectrometer
10	MIRIS	Mid-Infrared Imaging Spectrometer

R. Dekany
Caltech Optical Observatories



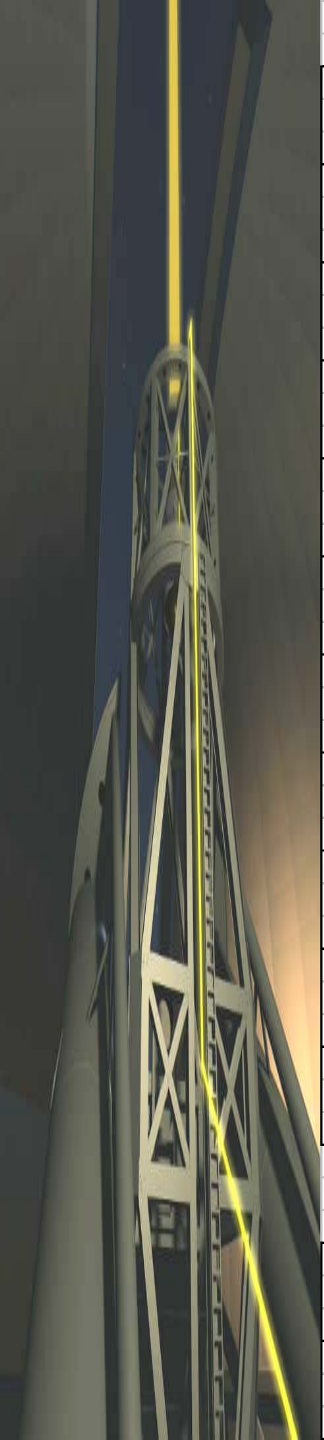
First Generation TMT Instrument Suite

Priority	Acronym	Description (w/example implementation)
1	NFIRAOS	133 nm WFE into 10” imager or 2” IFU; R = 4000 Closed-loop, 7 LGS, 3 NGS, 2 DM
2	WFOS	GLAO option provides 0.1-0.25” θ_{50} thru U-band Open-loop, 6 LGS, 1 NGS, 1 DM
3	MIRAOIS	750 nm WFE into 10” imager or Echelle, R <= 100,000 Closed-loop, 1 NGS, 1 DM
4	MOAO	50% ensquared energy @ 1um into 50 mas pixel Open-loop, 9 LGS, 1 DM per IFU head
5	PFI	10^6 contrast at 30 mas working angle Closed-loop + add’l servos, 1 NGS, 1 DM (~30k actuators)

In all cases, an adaptive secondary mirror may be available:

- Only DM needed for MIRAOIS
- Closed-loop woofer mirror for other instruments

R. Dekany
Caltech Optical Observatories

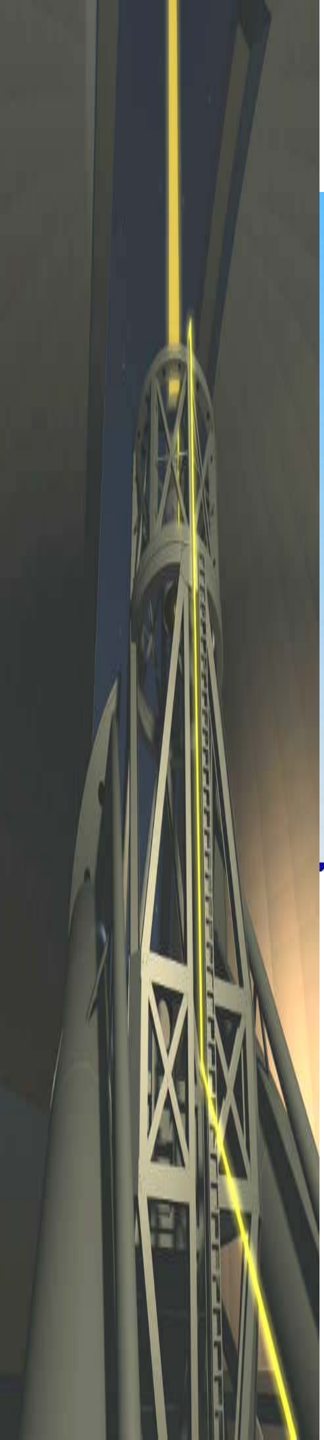


SRD science capability

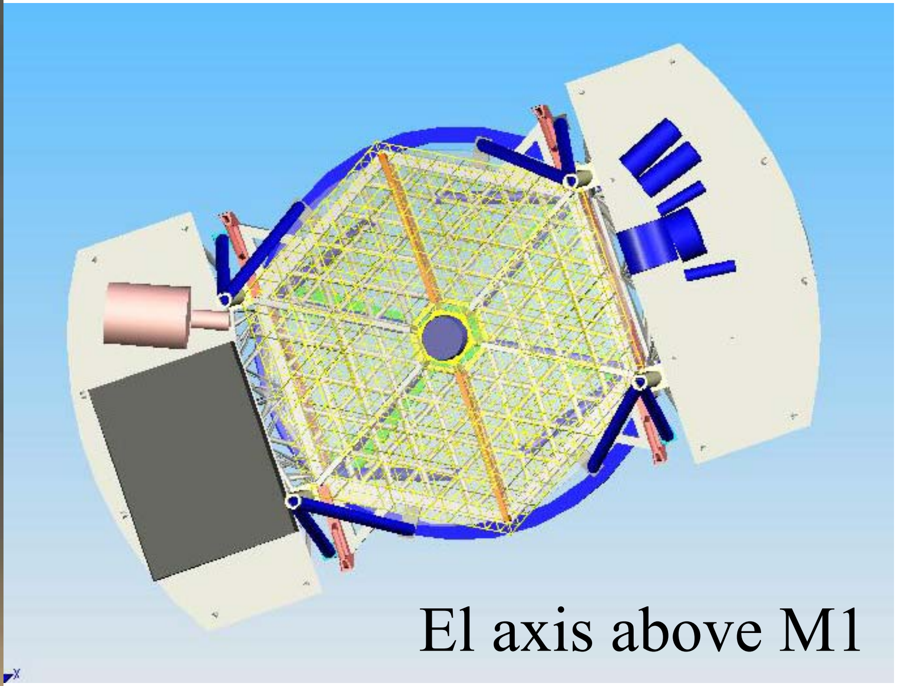
SRD Priority	Band	Image size	Function	FoV	FoR	R	Lambda (um)	Through-put priority
1	NIR	DL	IFU spectrometer "NFAOIRS"	2" IFU / 10" Imag	TBD	4,000/2-50	0.8-2.5 0.6-5 (goal)	
2	Optical	SL	Multi-slit imag. spect. "WFOS"	75 sa 300 sa Total slit length > 500"	N/A	500-5,000 w/ 0.75" slit 150-6,000 w/ 0.75" slit (goal)	0.31-1.0 0.3-1.3 (goal)	High
3	NIR	NDL	Multi-IFU spectrometer "MOAO"	2" IFU	5' packing < 20"	2,000-10,000 complete band @ 4000	0.8-2.5	High
4	MIR	DL	Echelle spectrometer "MIRAOIS"	3" slit / 10" Imag	N/A	5,000-100,000	8.0-18.0 5.0-28.0 (goal)	High
5	NIR	DL	IFU spectrometer "PFI"	2" OWA / 0.03" IWA	N/A	50-300	1.0 - 2.5	
6	NIR	DL	Echelle spectrometer "NIRES"	2" slit / 10" Imag	N/A	20,000 - 100,000	1.0-5.0 Simult 1 - 2.5 *or* Simult 3.5 - 5.0	
7	Optical	SL	Echelle spectrometer "MTHR"	5" slit / 10" Imag	N/A	50,000	0.31-1.3 0.31-1.1 (goal) (sic)	High
8	NIR	DL	Imager "NIRC"	30" contiguous	N/A	5-100	0.8-5.0 0.5-5.0 (goal)	
9	NIR	NDL	Imaging spectrometer "GNIMIS"	5'	10' technical?	3,000-6,000	0.7-2.5	
10	MIR	DL	Imaging spectrometer "MIRIS"	2'	N/A	5-100 / 1000 (grism)	5.0-28.0	High

Common AO modules

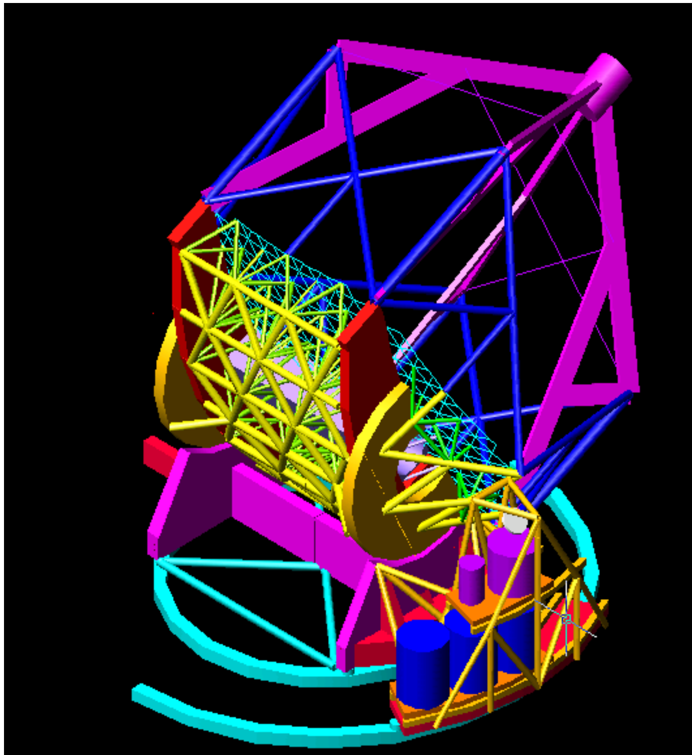
A	NIR	DL and NDL	Near-IR AO "NIRAO"	30" unvignetted	1' for wavefront sensing	N/A	0.4 - 2.5 0.31 - 5.0 (goal)	High
B	MIR	DL	Mid-IR AO "MIRAO"	30" unvignetted	1' for wavefront sensing	N/A	5.0-28.0	High



TMT elevation axis options

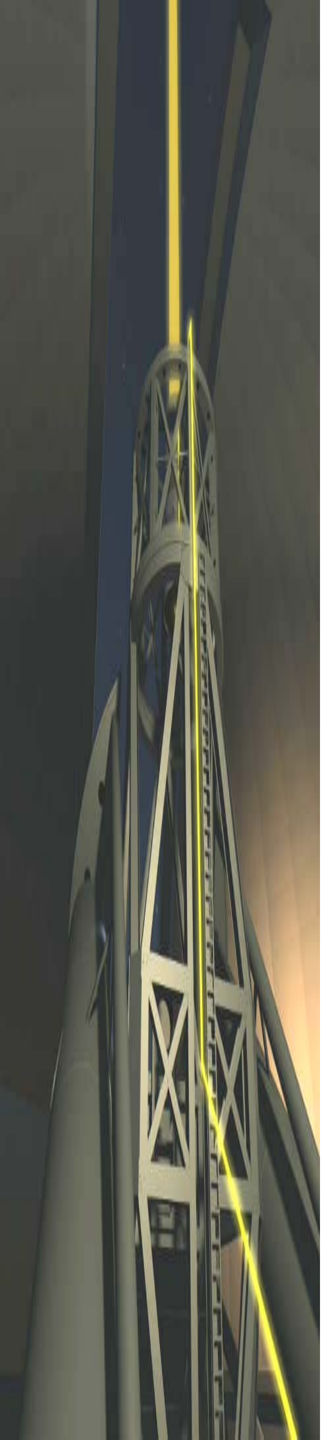


El axis above M1

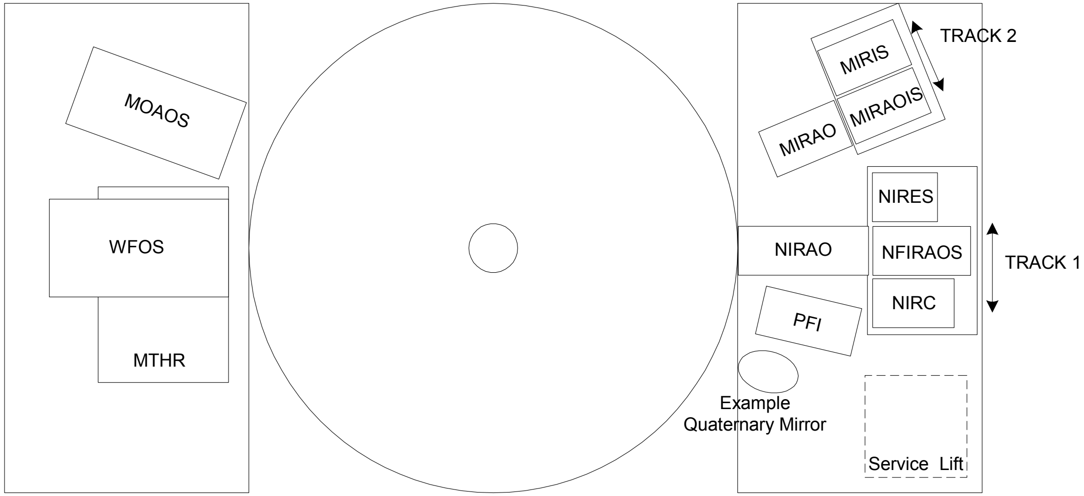


El axis below M1

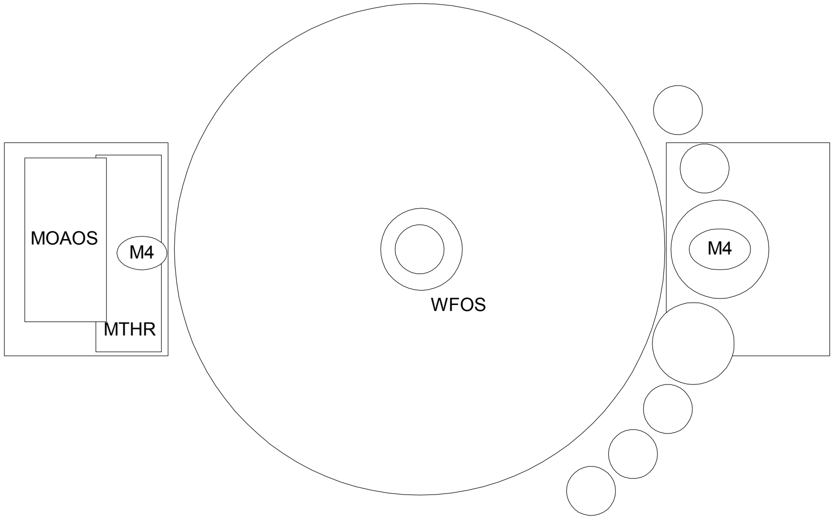
R. Dekany
Caltech Optical Observatories



Example platform layouts

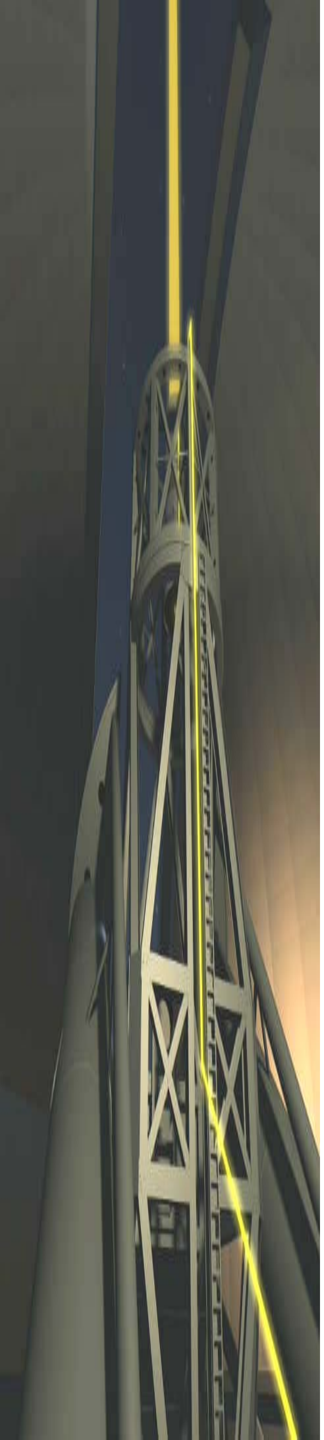


El axis
above M1



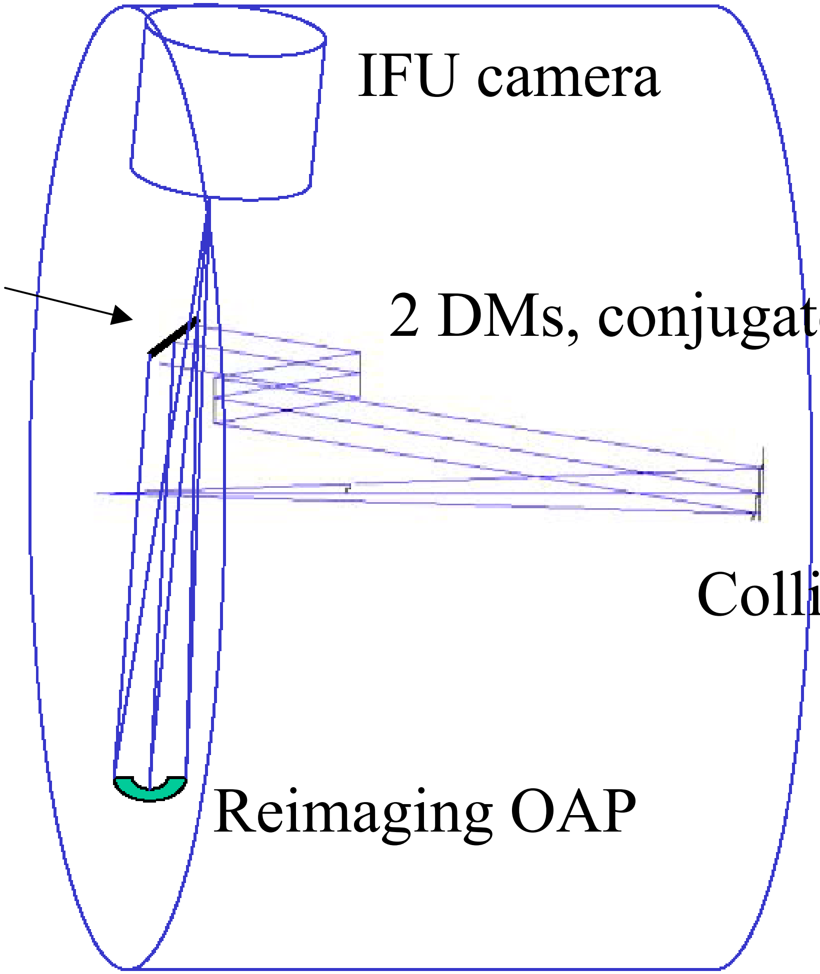
El axis
below M1

R. Dekany
Caltech Optical Observatories



One possible NFAORIS package

(Herriot, following Ellerbroek)



IFU camera

Fold/WFS Splitter (only science path is shown)

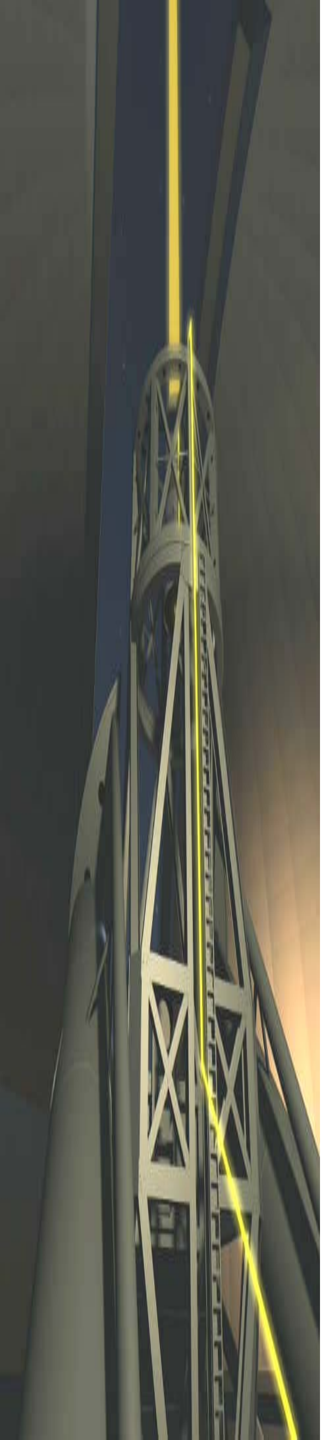
2 DMs, conjugate to 0, 10 km

Collimating OAP

Reimaging OAP

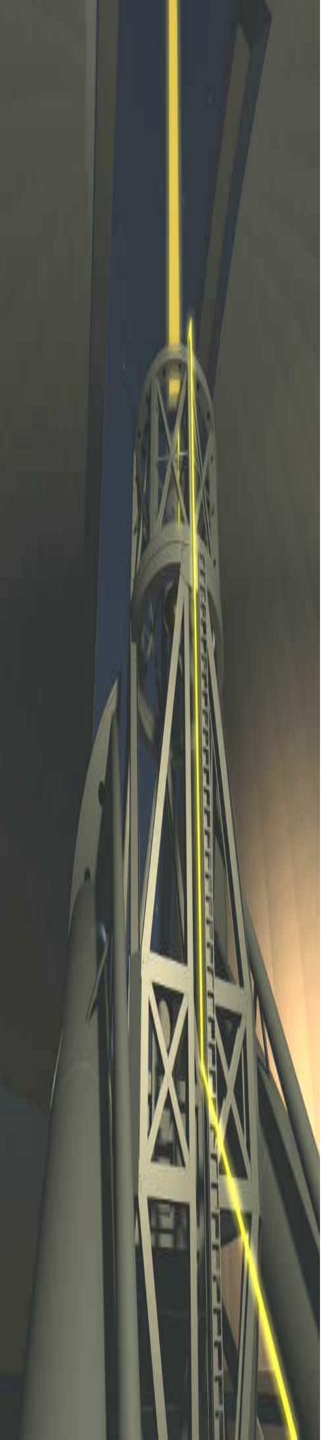
Entire 6m drum rotates to stabilize field rotation

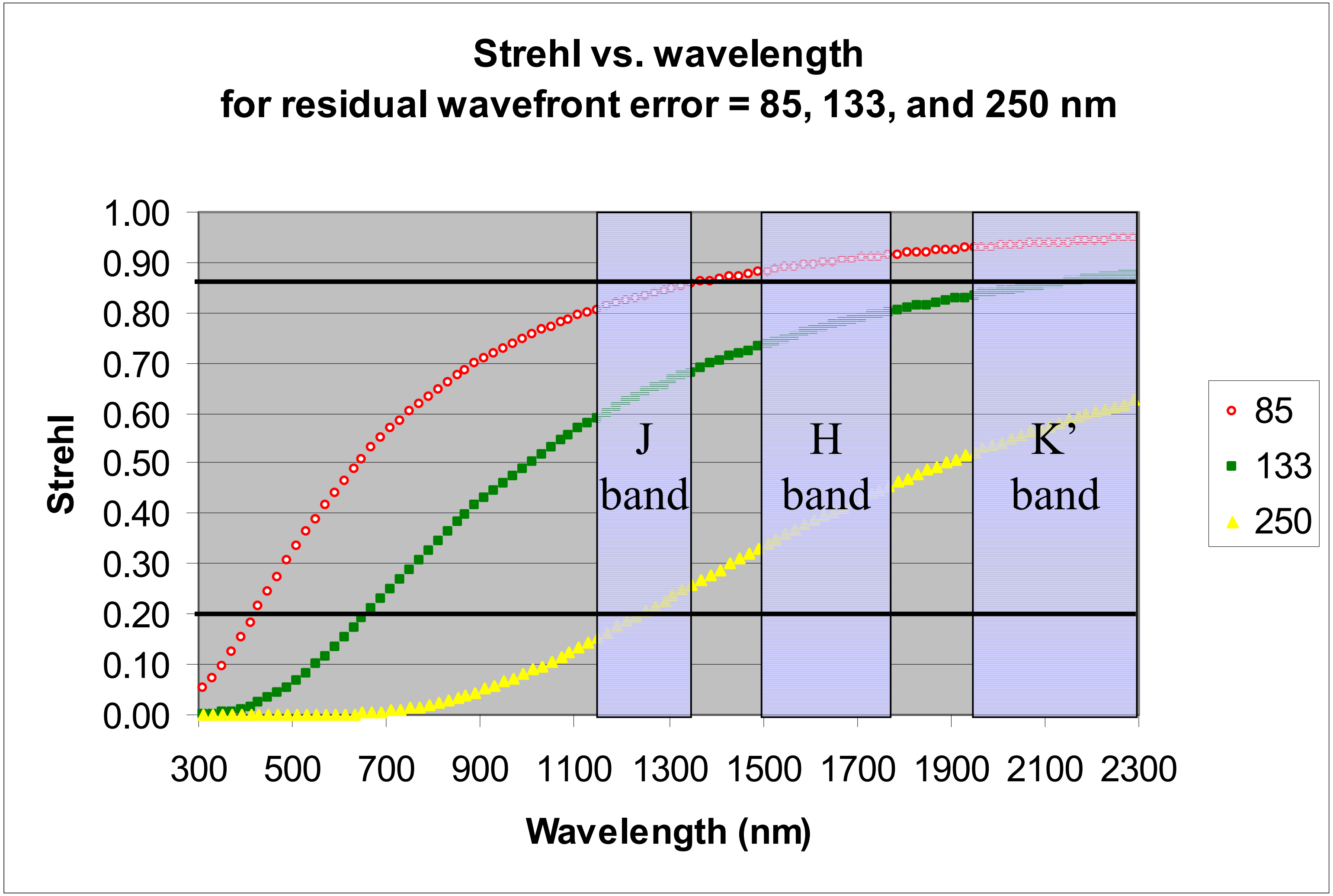
R. Dekany
Caltech Optical Observatories



TMT Timeline / Considerations

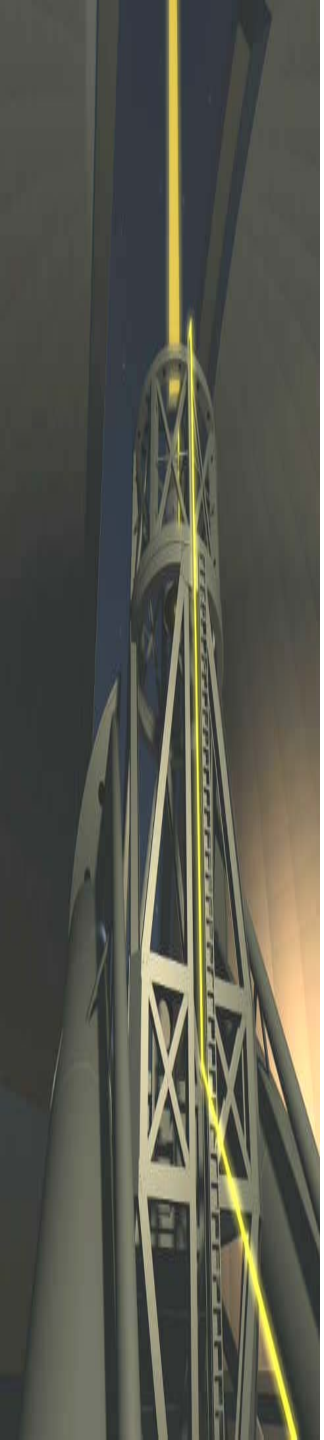
- Instrument studies likely to be launched by Spring 2005
- Observatory PDR in Spring 2006
- Telescope first light in early 2014
- Science observations start early 2015
  - NFAORIS likely at start
  - WFOS likely at start
  - MIRAOIS likely, but Echelle could be pixel starved
  - MOAOS may lag NFAORIS by a few years
  - PFI – straightforward to build, but performance is uncertain due to ambitious technology development and uncertain telescope performance





Strehl vs. wavelength
for residual wavefront error = 85, 133, and 250 nm

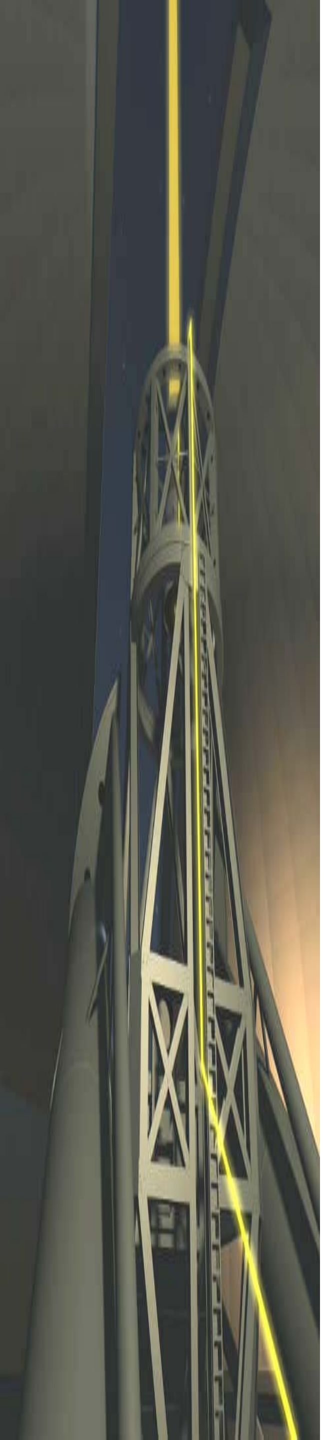
R. Dekany
Caltech Optical Observatories



Narrow field AO sweet spot

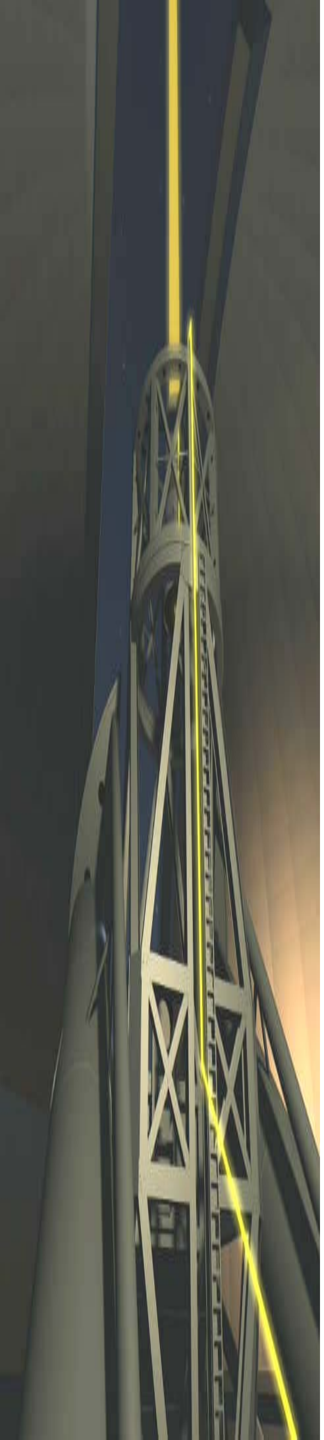
- 85 nm wavefront error feeding R = 4,000 IFU
  - AO correction across visible/NIR
    - V-band: 30% Strehl
      - SNR gain = T * S * (D/r_0) = 0.6 * 0.3 * (50) = 9
      - Sky coverage limited due to available tip/tilt NGS (but fraction is much improved by compensation of the NGS stars)
    - K-band: 94% Strehl
      - High throughput, high-contrast
  - Photometric stability across all NIR bands
    - Short-term (AO driven) and long-term (seeing-driven)
    - Uniformity across the FoV
    - Insensitivity to seeing changes
  - Improved crowded field photometry
    - 20x better H-band SNR than for 250 nm wavefront error
  - MCAO FoV greater than Nθ_0 where N = # of DM's
    - 3 DM's – 2 arcmin at K-band
    - 6 DM's – 30 arcsec at V-band

R. Dekany
Caltech Optical Observatories



Wide field AO sweet spot

- Multi-GLAO channel, multiobject spectrograph
  - Concept
    - A single Na LGS naturally de-weights high altitude turbulence
      - One Rayleigh beacon is basis of Tokovinin’s SOAR GLAO system (under construction)
  - GLAO correction over ~10 arcmin^2 per laser beacon
    - Optimal slit width is function of d_0
      - Typ. slit for U-band ~0.35”, V-band ~ 0.25”, Z-band ~ 0.1”
    - Each region uses it’s own DM
    - At 310nm, improved image offsets add’l losses, but ½ slit width yield 2x spectral coverage
    - Best performance in ‘red channel’ 550-950nm, where gains over DEIMOS can be 10-20x (in integration time)
  - Best results when scheduled for large d_0 (ground-layer turbulence)



Crowded Field Photometry

- Many residual bright star haloes produce a photon noise ‘veil’ that makes faint star photometry in crowded field difficult
  - For TMT AO, individual seeing disks can span 100’s of Nyquist sampled pixels
- 85 nm WFE provides much cleaner separation in crowded fields
  - AO reduces stellar haloes:
    - Halo flux per asec^2 ~ D^2 / (1-S)
    - Halo flux per diffraction-limited resolution element ~ 1 / (1-S)
    - Contrast within a res. element = Q ~ D^2 S / (1-S)
  - For halo photon noise limited case:
    - Halo photoflux noise ~ 1 / sqrt (1-S)
    - SNR ~ D^2 S / sqrt (1-S) for halo photon limited detection