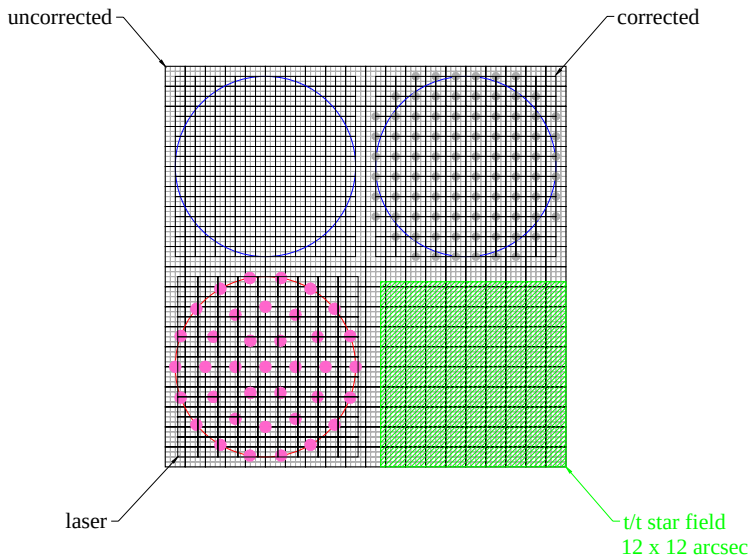
Wavefront Sensor Nonlinearity
in Open-Loop Mode

Nonlinearity of Villages Wavefront Sensor

Laboratory for Adaptive Optics

Villages

Map of WFS CCD



Assumptions:

- 4x4 center of mass
- 1, 1.5, and 2 arcsec pixels
- Simulations done with 16x oversampling of pixel
- r0 = 7, 11, 15 cm
- No spatial filter

Varying pixel size and seeing

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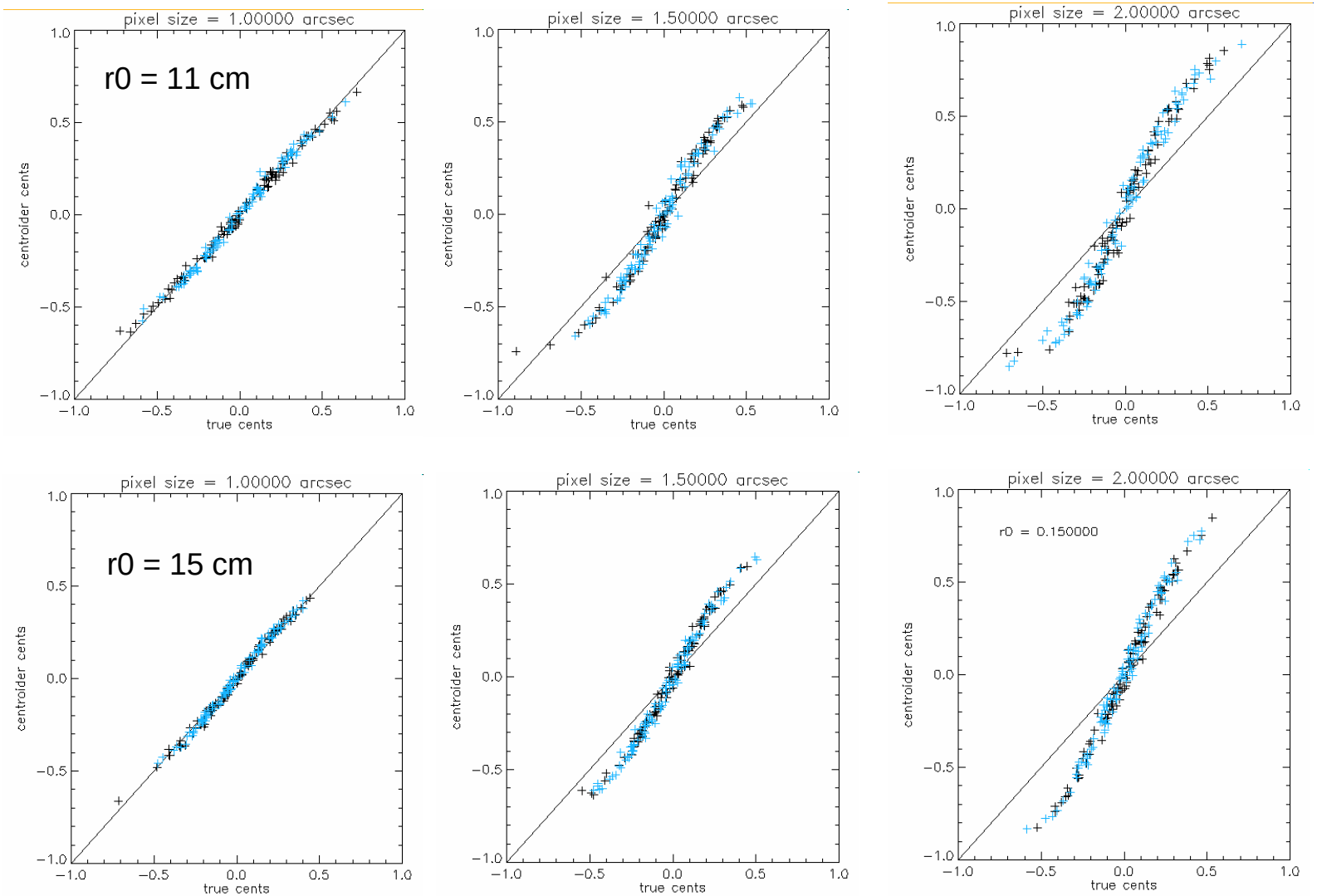
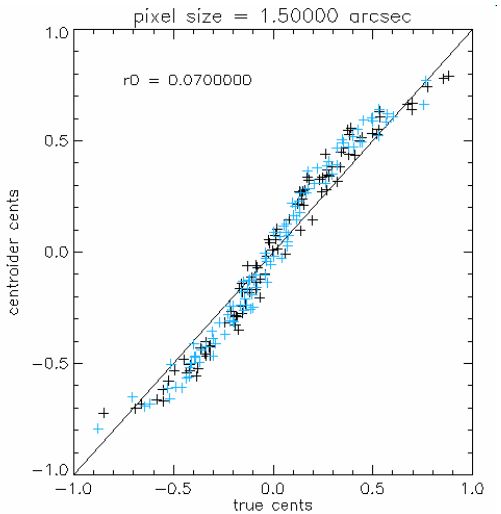
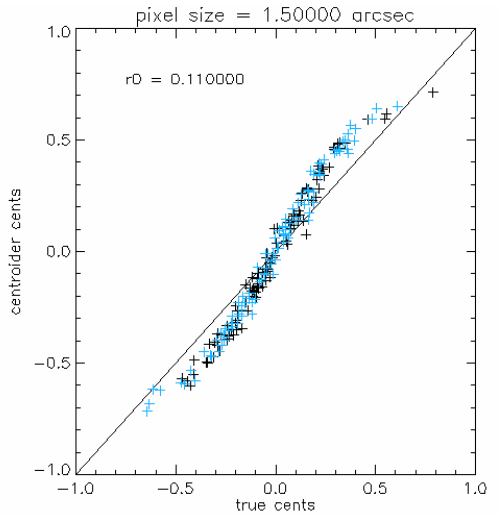
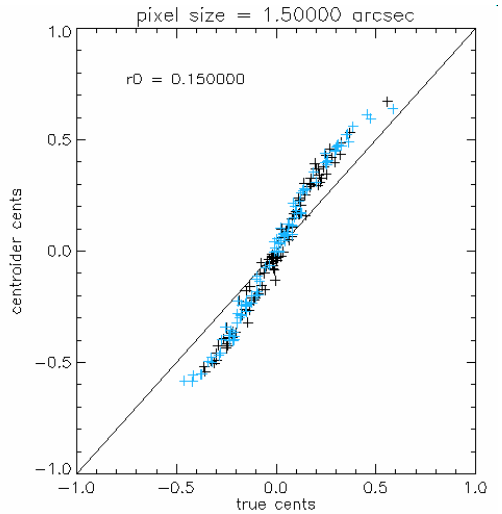


Varying seeing with fixed pixel size







Summary of nonlinearity errors

- Standard deviations due to nonlinearity

CCD scale	Centroid(arcsec)	Wavefront(nm)
(1.0”/pix)	0.030	15
(1.5”/pix)	0.058	25
(2.0”/pix)	0.104	48

- “wavefront” = $d \times \sigma_{\text{cent}}$ (i.e. noise propagator assumed = 1)

Impact on error budget

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No nonlinearity:

Strehl vs wavelength

	radians^2	nm	300	500	589	800	1000
Fitting	0.3	43.58638	0.434598	0.740818	0.805584	0.889418412	0.927743486
Bandwidth	0.264253566	40.90728	0.479967	0.767779	0.826605	0.901924875	0.936071523
Measurement	0.325390923	45.39341	0.405002	0.722245	0.790978	0.88064047	0.921873072
WFS nonlinearity	0	0					
Total	0.889644489	75.05824	0.08448	0.410802	0.526713	0.706439737	0.800586158

Nonlinearity with 1.5 arcsec pixel at r0=11cm:

Strehl vs wavelength

	radians^2	nm	300	500	589	800	1000
Fitting	0.3	43.58638	0.434598	0.740818	0.805584	0.889418412	0.927743486
Bandwidth	0.264253566	40.90728	0.479967	0.767779	0.826605	0.901924875	0.936071523
Measurement	0.325390923	45.39341	0.405002	0.722245	0.790978	0.88064047	0.921873072
WFS nonlinearity	0.314159265	25					
Total	1.203803754	87.3108	0.035299	0.300051	0.420004	0.624854884	0.740114083

Conclusions

- Nonlinearity has a modest impact on error budget
- Mitigation actions
  - Use non-linearity lookup table in centroider
    almost independent of seeing: consequence of $d \cong r_0$
  - Backup option: 1 arcsec CCD pixel scale
    requires smaller field stop $\Rightarrow$ tighter alignment and acquisition tolerances

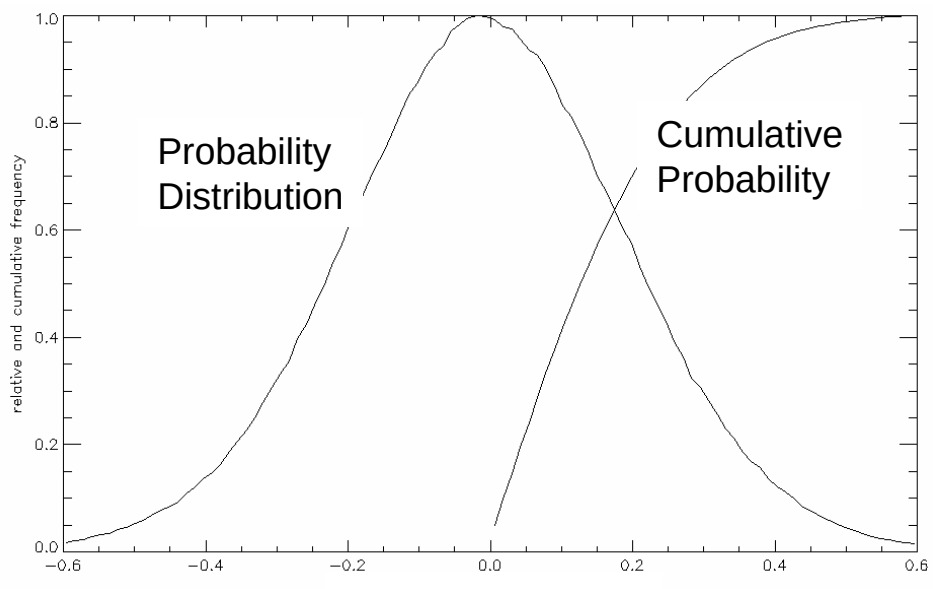
Stroke Budgets

DM Stroke Budget

- Boston Micromachines 140-actuator DM with 3.5 microns stroke (surface)
- Stoke allocation:

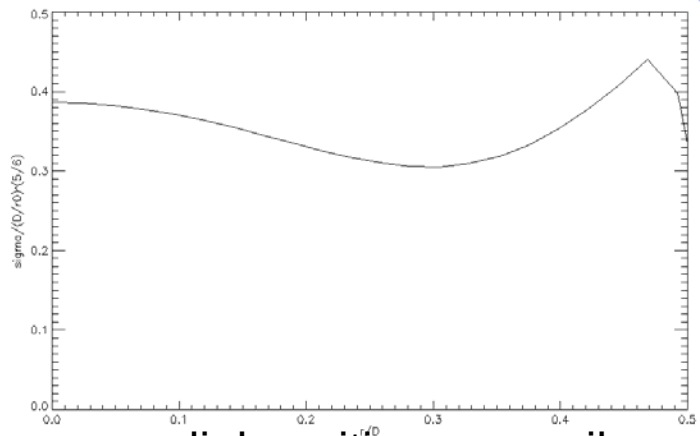
Atmosphere correction	0.6 micron
Primary Mirror static aberration correction	0.6 micron
DM window static aberration correction (~l/5)	0.2 microns
Other static aberrations:	0.2 microns
Total	1.6 microns (surface)

DM Stoke Analysis



OPD, microns

relative OPD
(tip/tilt/pistonremoved)



radial position on pupil

Tip/Tilt Stroke Analysis

- PI tip/tilt stage:
  - ±25 microns motion
  - 30 Hz closed loop bandwidth
- Atmospheric requirements

Dtele	1	m
r0	0.11	m
sigma_tt	0.3915	arcsec
beam diam	3.6	mm
mag factor	277.78	
5 sigma stroke	2.6365	milliradian
TT bandwidth		
windspeed	36.667	m/s
fT	18.712	Hz

Conclusions

- The DM has a factor of 2 margin in available stroke
- The TTM has a factor of 10 margin in available stroke and meets bandwidth requirements

Revised Project Schedule (more time for laboratory I&T)

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WBS	Task Name
1	**VisibleLightLGSAO(ViLLaGES)**
1.1	**OptoMechanical**
1.1.1	Optical Design
1.1.2	Mechanical Layout and Design
1.1.3	Preliminary Design Review
1.1.4	Telescope Mount Design
1.1.5	Critical Design Review
1.1.6	**Active Components Purchasing**
1.1.7	Optics Purchasing
1.1.8	Mechanical Fabrication
1.1.9	Optics Mounting and alignment
1.2	**Software**
1.3	**Telescope Facility**
1.4	Phase 1 Lab Integration and Test
1.5	Phase 1 Telescope Integration and Test
1.6	Phase 1 Experiments
1.7	**Laser**
1.7.1	**LLNL Laser**
1.7.2	**LMCT Laser**
1.8	**Laser Safety System**
1.9	Phase 2 Telescope Integration and Test
1.10	Phase 2 Experiments