DEIMOS

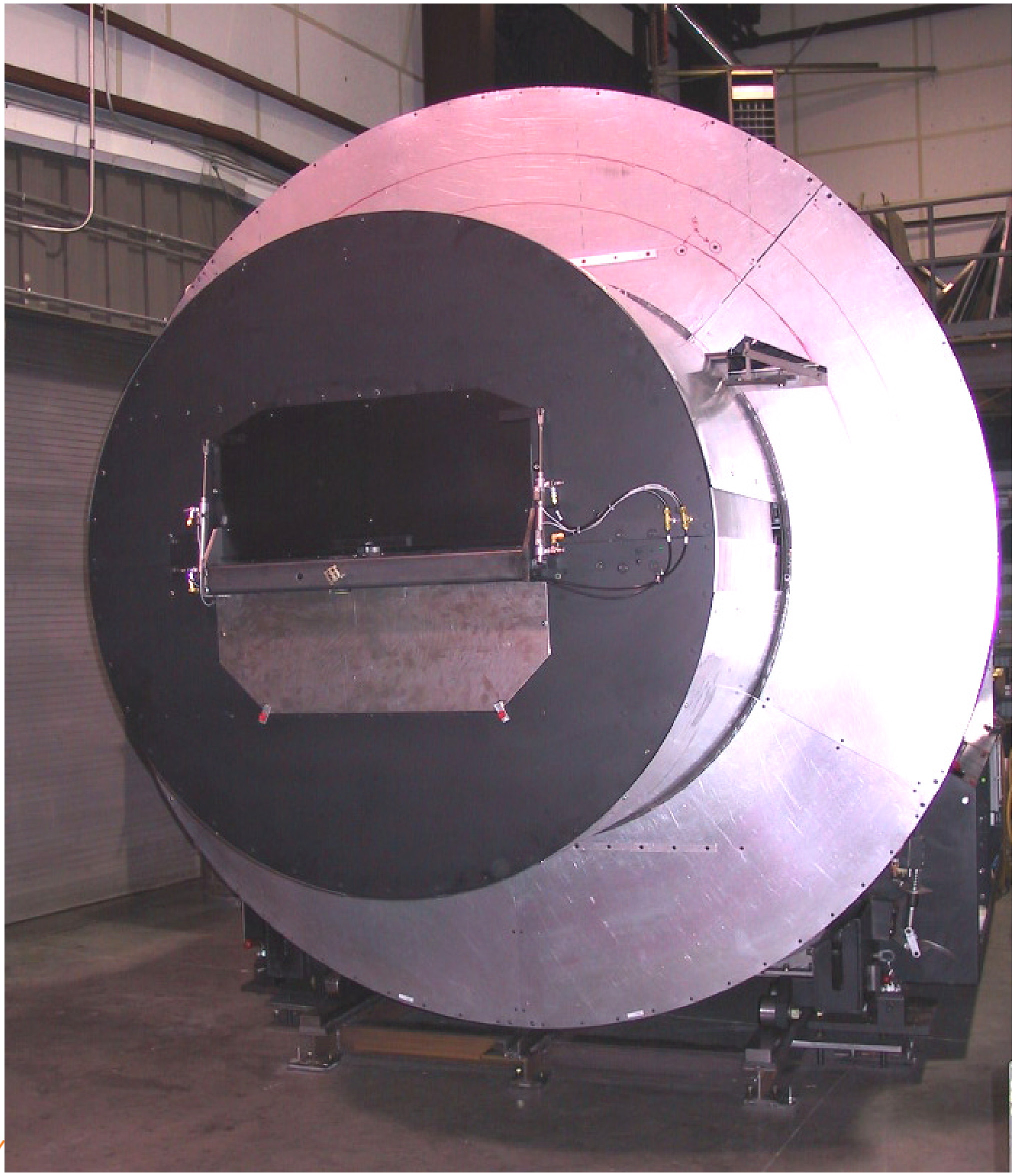
Pre-Ship Review

November 13 &14, 2001

Agenda

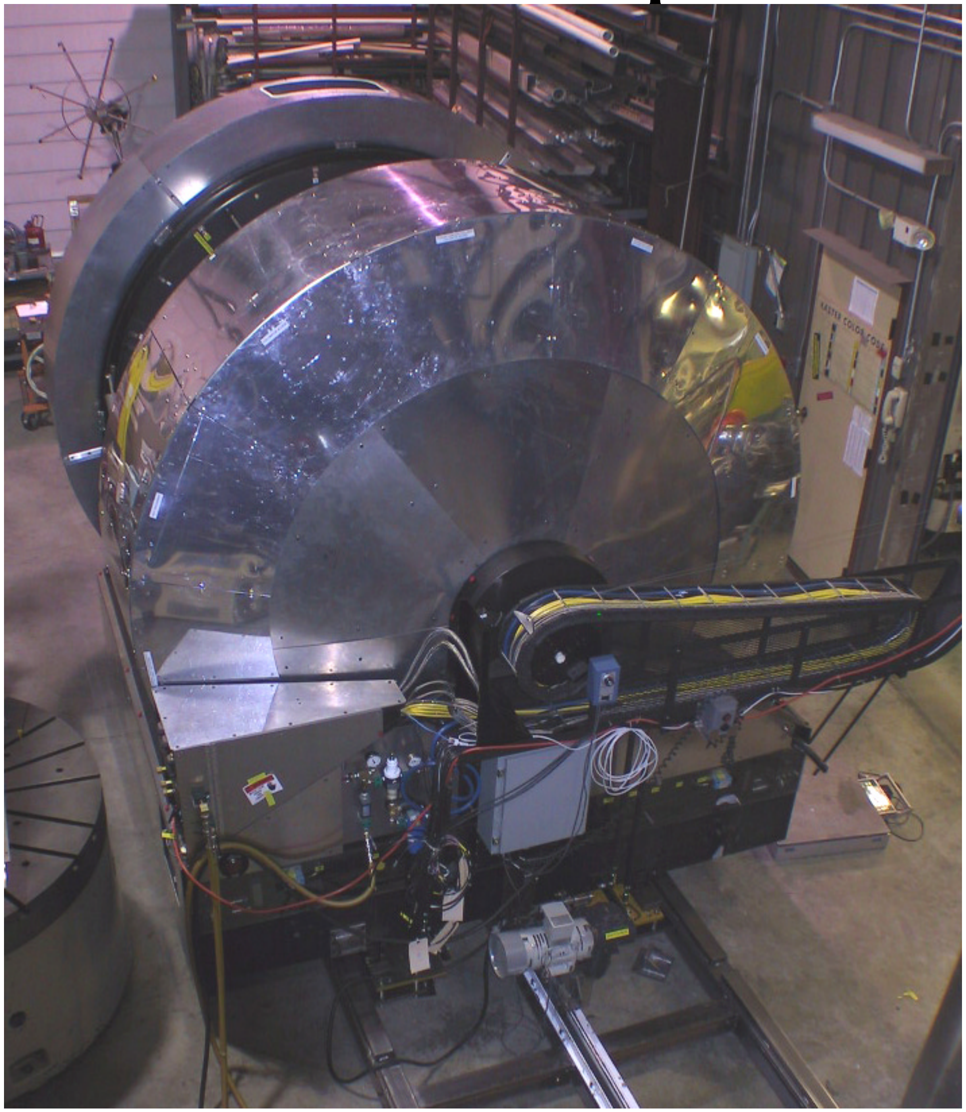
1. Introduction and Science Drivers (Sandy)
2. Instrument Overview and Test Results
   a. Operational modes and overall requirements (Sandy)
   b. Image quality (Sandy)
   c. Flexure control system (Sandy)
   d. Testing overview (Sandy)
   e. Stages and subsystems (David C)
      - Requirements
      - Test results
   g. Other systems
3. Software (Bob K)
4. Instrument demonstration (Drew P)
5. Physical instrument interfaces (David C)
6. Deliverables (David C)
7. Spares (David C)
8. Cost of Operations(David C)
9. Maintenance schedule/cost (David C)
10. Documentation (David C)
11. Shipping and handling (David C)
12. Integration and commissioning plans (David C)
13. Observatory readiness (Greg W (CARA))
14. Outstanding Tasks (Sandy)
15. Outstanding Issues (Sandy)
16. Future Plans (Sandy)

DEIMOS Front View



DEIMOS- Side View

DEIMOS Top View



Introduction

Panel Members

- Dan Fabricant, CFA, Chairman
- Gary Schmidt, U of A
- Craig Foltz, MMT
- Hilton Lewis, CARA
- David Sprayberry, CARA
- Bill Mason, CARA

Charge to the Committee

From Hilton Lewis (3/22/99):

1. Is the instrument ready for commissioning?
2. Have the instrument requirements been met? In particular, have the science requirements and the interface requirements been met?
3. Are the reliability, maintainability and usability of the instrument acceptable?
4. Have the CDR concerns been adequately addressed?
5. Did the instrument meet all applicable CARA standards?
6. Did the acceptance test procedures adequately test the instrument?
7. Was the result of the testing satisfactory?
8. Are the deliverables complete? These include the instrument and its associated hardware, installation and test fixtures, software, documentation and the commissioning plan.
9. Have installation and on-sky commissioning plans been presented and are they acceptable?
10. Are there outstanding issues and concerns? If so, has a satisfactory plan for mitigating them been devised?

Introduction: Science Drivers

•Keck Report No. 90 listed 37 key science projects for a 10 m telescope. 30 out of 37 benefit from a multi-object spectrograph covering ~10' FOV

• Examples:

– Metallicities and dynamics of individual stars:

In Galactic globular clusters

In Galactic open clusters

In the Galactic center and inner halo

In Local Group galaxies

– Metallicities and dynamics of globular cluster populations in nearby galaxies

–H II region metallicities and kinematics in nearby galaxies

–Stellar populations and dynamics of nearby galaxy halos using an extrememly long slit

– Galactic structure and stellar populations in distant galaxy clusters

– Surveys of galactic structure properties and cosmic large-scale structure using distant field galaxies

Introduction
High-level Requirements

- Maximal wavelength coverage: 3900 – 11,000 A
  (set by Keck2 silver)
- Maximal slit length: 16’ on sky per beam
- Maximal spectral resolution consistent with MOS

  Goal: ~1 A FWHM @ 8000 A

  Reasons: FWHM ~ 40 kms for galaxy and cluster dynamics
  90% of spectrum clear of OH lines; reduces mean background by x4; increases speed by x4; cleaner sky subtraction between lines.

CONCLUSION:

- Need big detector
- Need wide-angle camera

Introduction:
High-level Requirements

• Photon noise-limited sky subtraction requires flat-fielding accuracy of 0.2%

   -Fine pixel sampling: 3 px FWHM; 0.119 asec/px

   -Limited by CCD "fringing" between observation and afternoon flat-field

   -Do not want to have to match PAs; too burdensome

   ➔ Images must be stable to 0.25 px rms (1-d)

   ➔ Flexure compensation system is needed

• Minimize imaging relative to spectroscopy to better utilize detector real estate:

   80 sq amin for imaging area

• High throughput: 29% spectroscopic mode, 40% imaging mode

   -Silvered mirrors

   -Excellent AR coatings

   -Clean environment: front window

   -Full performance depends on Keck 2 silvered optics; not there yet

Introduction:
High-level Requirements

- Up to 130 slitlets per mask; 6 asec per slitlet
  - May require a composite "sky"
  - Needs stable PSF and good flatfielding
- High operating efficiency and convenience
  - Rapid object acquisition and mask alignment
  - Rapid reconfiguration (gratings, slitmasks, filters)
  - Rapid CCD readout
  - Accurate, secure guiding
  - Constant telescope focus monitoring
  - Barcode readers provide automatic census of slitmasks, grating, filters
  - Information saved automatically in FITS headers and instrument database

Operational Modes

- Spectrographic
  - 1,200 lines
  - 900 lines
  - 600 lines
- Imaging

Table 1

Gratings

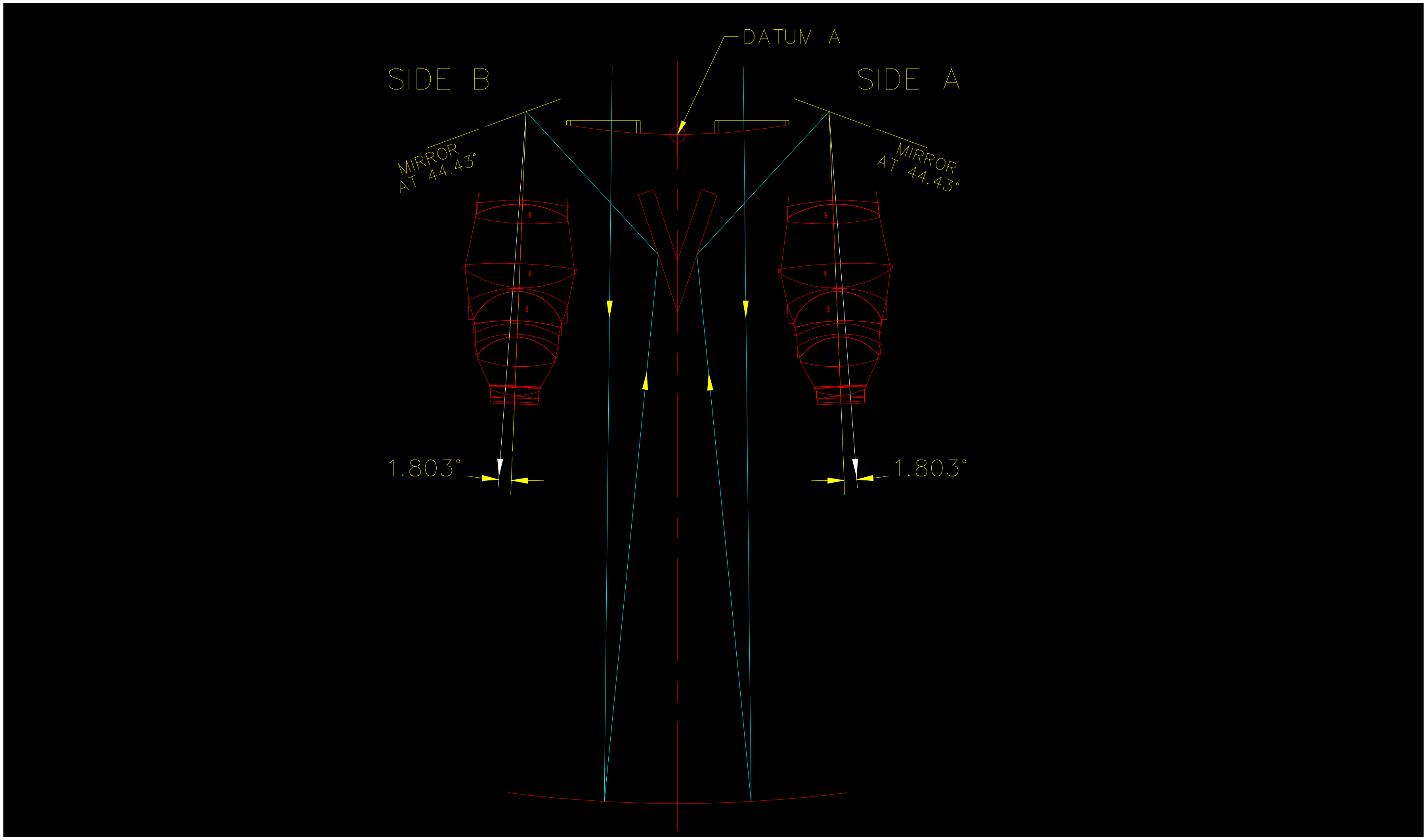
GRATING SUMMARY TABLE: November 2, 1995. Spectrograph angle is 44.451 deg, and imaging position is displaced by 0.472-in. Central beta_0 and lambda_0 are for wavelength at center of detector, which is the nominal spectroscopy zeropoint. Max and Min walues are for wavelengths falling at edges of +/- 4096 px detector with 15 mu px, not allowing for any gaps. Maxangle (for edges of detector) is 9.161 deg, except for 150 1/mm grating, for which it is 2.160 deg to allow for double row of slitlets separated by 4.0' in FOV. The slitwidth is 0.75" on sky. Raw slitwidth (FWHM) is for no aberrations, effective slitwidth (FWHM) includes collimator and camera aberrations. Bratio is the beam elongation on flat or grating. 8x12?: Y if bratio > 1.6, N if bratio < 1.35, otherwise ?. Spectrograph angle of 44.51 degrees corresponds to middle of detector on the optical axis of the camera on the one hand and 4.5 arc min off axis from the center of the telescope FOV on the other. The latter point is the nominal field field center for each DEIMOS beam. November 1997: Correct Eff slitw using updated design and fabrication errors from Camera CDR.

1/mm	alpha	beta_0	betamin	betamax	lambda_0	lambdamin	lambdamax	anamor	bratio	A/px	A/mm	Raw slitw px	Raw slitw A	Eff slitw px	Eff slitw A	8x12?	Order sep. cuton range
Mirror, image centered on detector (not at nominal imaging point).																	
0 1.	22.226	-22.226						1.000	1.080			6.29		6.52			
Mirror, image at nominal imaging point, which puts 4.5' at 0.472-in to right on detector.																	
0 1.	23.127	-23.127						1.000	1.087			6.29		6.52			
1 1200.	62.628	18.177	9.016	27.338	10000.000	8706.238	11227.310	2.066	2.175	0.312	20.781	3.04	0.95	3.50	1.09	Y	6000
1 1200.	57.912	13.461	4.300	22.622	9000.000	7685.008	10265.603	1.831	1.882	0.319	21.271	3.43	1.10	3.85	1.23	Y	6000
1 1200.	53.459	9.008	-0.153	18.169	8000.000	6673.023	9293.781	1.659	1.680	0.324	21.602	3.79	1.23	4.17	1.35	Y	6000
1 1200.	49.207	4.756	-4.405	13.917	7000.000	5668.989	8313.337	1.525	1.531	0.327	21.797	4.12	1.35	4.47	1.46	?	5000
1 1200.	45.111	0.660	-8.501	9.821	6000.000	4672.051	7325.362	1.417	1.417	0.328	21.871	4.44	1.46	4.76	1.56	?	
1 1200.	41.135	-3.316	-12.477	5.845	5000.000	3681.656	6330.700	1.326	1.328	0.328	21.836	4.74	1.55	5.05	1.65	N	
1 1200.	39.183	-5.268	-14.429	3.893	4500.000	3188.605	5830.885	1.285	1.290	0.327	21.780	4.89	1.60	5.19	1.70	N	
1 900.	51.311	6.860	-2.301	16.021	10000.000	8226.668	11739.321	1.588	1.600	0.434	28.954	3.96	1.72	4.32	1.88	?	6000
1 900.	48.171	3.720	-5.441	12.881	9000.000	7225.620	10756.149	1.496	1.499	0.437	29.102	4.20	1.83	4.54	1.98	?	6000
1 900.	45.111	0.660	-8.501	9.821	8000.000	6229.402	9767.149	1.417	1.417	0.437	29.161	4.44	1.94	4.76	2.08	?	5000
1 900.	42.120	-2.331	-11.492	6.830	7000.000	5238.333	8773.387	1.347	1.348	0.437	29.139	4.67	2.04	4.98	2.18	N	5000
1 900.	39.183	-5.268	-14.429	3.893	6000.000	4251.474	7774.514	1.285	1.290	0.436	29.040	4.89	2.13	5.19	2.26		
1 900.	36.293	-8.158	-17.319	1.003	5000.000	3268.991	6771.166	1.228	1.241	0.433	28.868	5.12	2.22	5.40	2.34		
1 900.	34.861	-9.590	-18.751	-0.429	4500.000	2779.311	6267.852	1.202	1.219	0.431	28.755	5.23	2.26	5.51	2.38		
1 830.	47.433	2.982	-6.179	12.143	9500.000	7576.483	11407.654	1.476	1.478	0.474	31.580	4.26	2.02	4.60	2.18	?	6000
1 830.	46.021	1.570	-7.591	10.731	9000.000	7078.359	10913.284	1.440	1.440	0.474	31.611	4.37	2.07	4.70	2.23	?	6000
1 830.	43.243	-1.208	-10.369	7.953	8000.000	6085.447	9920.959	1.372	1.373	0.474	31.615	4.58	2.17	4.90	2.32	?	5500
1 830.	40.515	-3.936	-13.097	5.225	7000.000	5096.784	8924.099	1.312	1.315	0.473	31.548	4.79	2.27	5.09	2.41	N	4700
1 830.	37.829	-6.622	-15.783	2.539	6000.000	4112.300	7923.074	1.258	1.266	0.471	31.412	5.00	2.36	5.29	2.49		
1 830.	35.179	-9.272	-18.433	-0.111	5000.000	3131.611	6917.848	1.207	1.223	0.468	31.209	5.21	2.44	5.49	2.57		
1 830.	33.864	-10.587	-19.748	-1.426	4500.000	2642.679	6413.740	1.184	1.204	0.466	31.084	5.31	2.48	5.59	2.60		
1 600.	39.183	-5.268	-14.429	3.893	9000.000	6377.210	11661.771	1.285	1.290	0.653	43.560	4.89	3.20	5.19	3.39	N	6000
1 600.	37.252	-7.199	-16.360	1.962	8000.000	5394.024	10659.158	1.246	1.256	0.651	43.400	5.04	3.28	5.33	3.47	N	5000-5500
1 600.	35.337	-9.114	-18.275	0.047	7000.000	4413.637	9653.616	1.210	1.226	0.648	43.192	5.19	3.37	5.48	3.55	N	4200-5000
1 600.	33.438	-11.013	-20.174	-1.852	6000.000	3435.962	8645.198	1.176	1.198	0.644	42.939	5.34	3.44	5.62	3.62	N	3800-4500
1 600.	31.551	-12.900	-22.061	-3.739	5000.000	2460.931	7633.956	1.144	1.173	0.640	42.640	5.50	3.52	5.76	3.69		
1 600.	30.611	-13.840	-23.001	-4.679	4500.000	1974.391	7127.291	1.128	1.162	0.637	42.474	5.57	3.55	5.84	3.72		
1 150.	26.407	-18.044	-20.204	-15.884	9000.000	6625.626	11403.833	1.062	1.116	2.496	166.372	5.92	14.78	6.17	15.40	N	6000
1 150.	25.942	-18.509	-20.669	-16.349	8000.000	5632.364	10397.772	1.055	1.112	2.489	165.927	5.96	14.84	6.21	15.45	N	5300
1 150.	25.476	-18.975	-21.135	-16.815	7000.000	4638.780	9391.074	1.048	1.108	2.482	165.470	6.00	14.90	6.25	15.50	N	4400-5000
1 150.	25.012	-19.439	-21.599	-17.279	6000.000	3646.365	8385.253	1.041	1.103	2.475	165.003	6.04	14.95	6.28	15.56	N	3800-4400

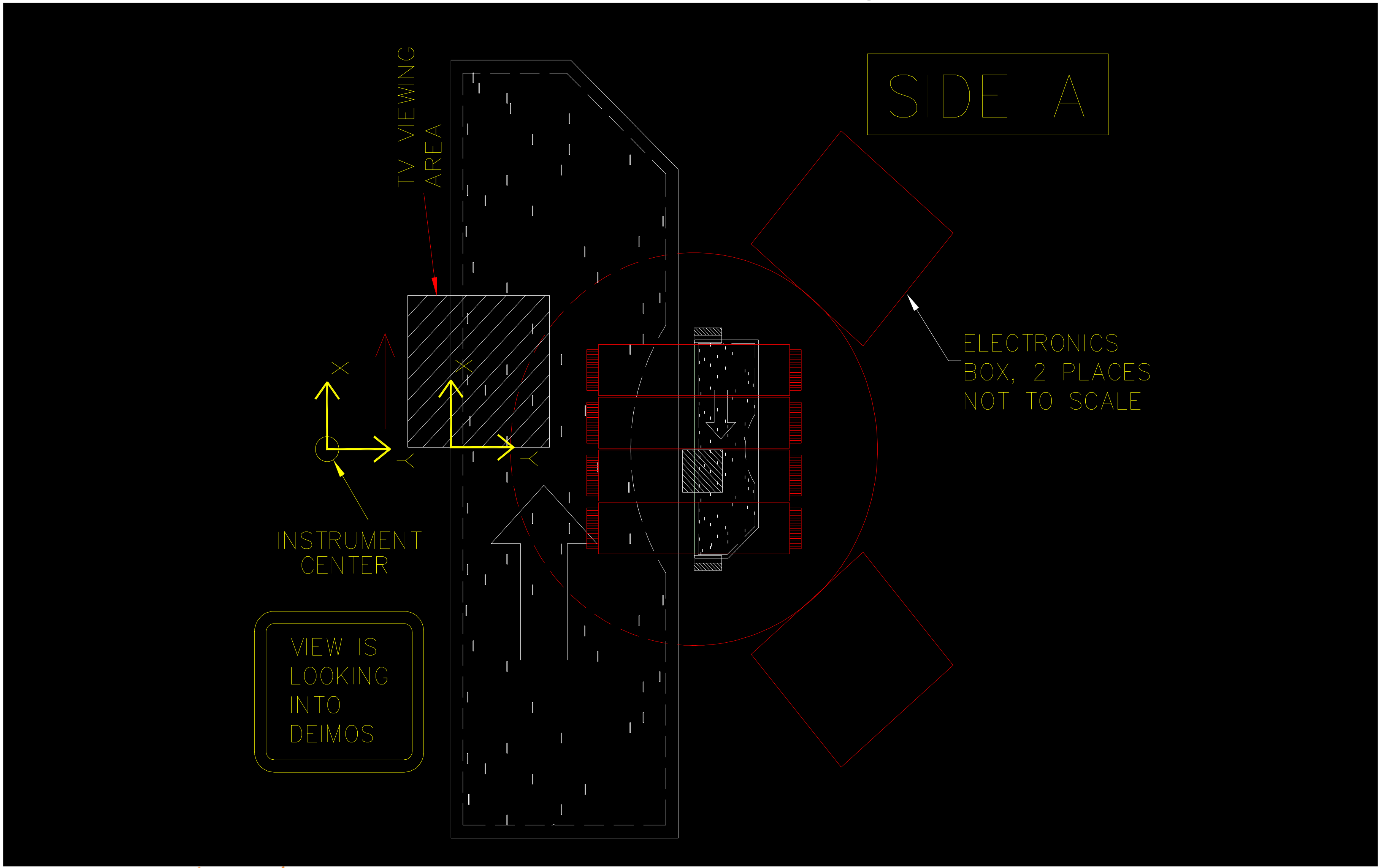
Optical Design Overview

- Double-beam design
  - Doubles slit length; number of objects
  - Slim imaging area makes good use of detector real estate
  - ¾ area reserved for spectra
  - Objects share ¾ spectral length in common
  - Only one beam fabricated at this time
- Mirror collimator yields compact design; fits on Nasmyth deck
- Heart of optical design is camera
  - Tour de force of design
  - Tour de force of fabrication
  - Typical assembly tolerances 0.001 in
- Soul of optical design is large detector
  - 8K x 8K mosaic
  - 16 amplifiers
  - Largest spectroscopic detector in existence

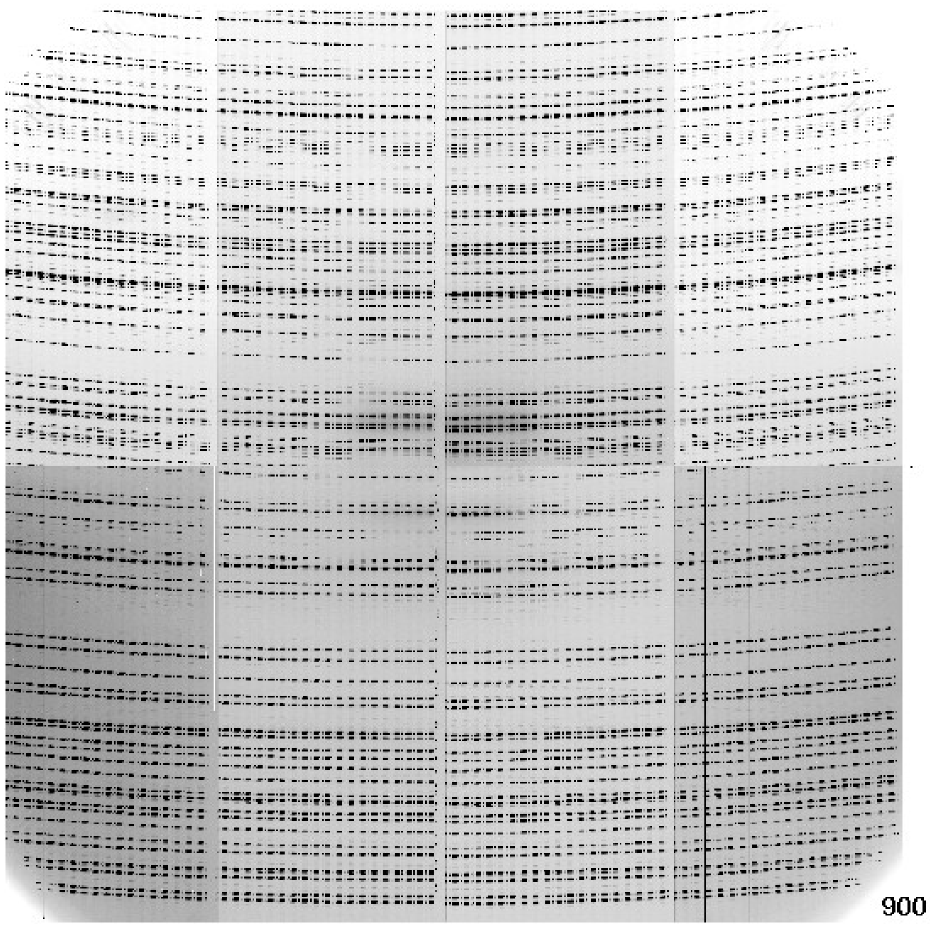
Optical Path



X-Y Coordinate Systems



Picture of spectra from 900 line grating



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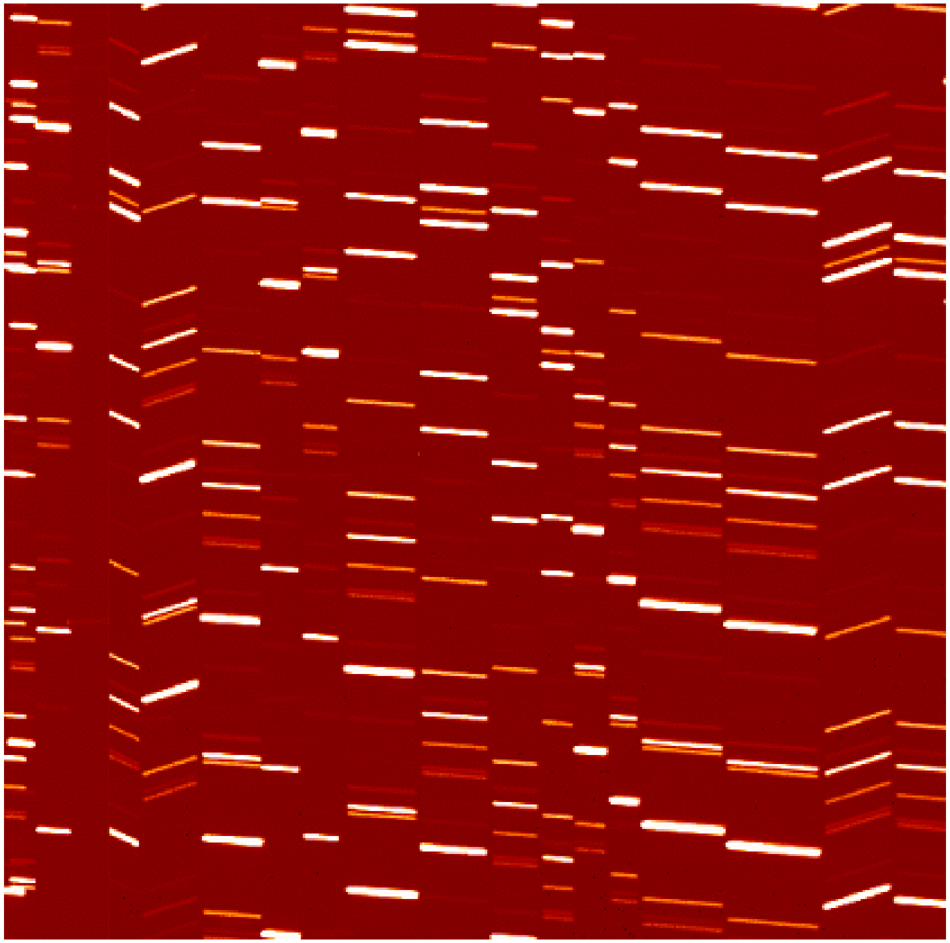
Marc Davis Slitlets

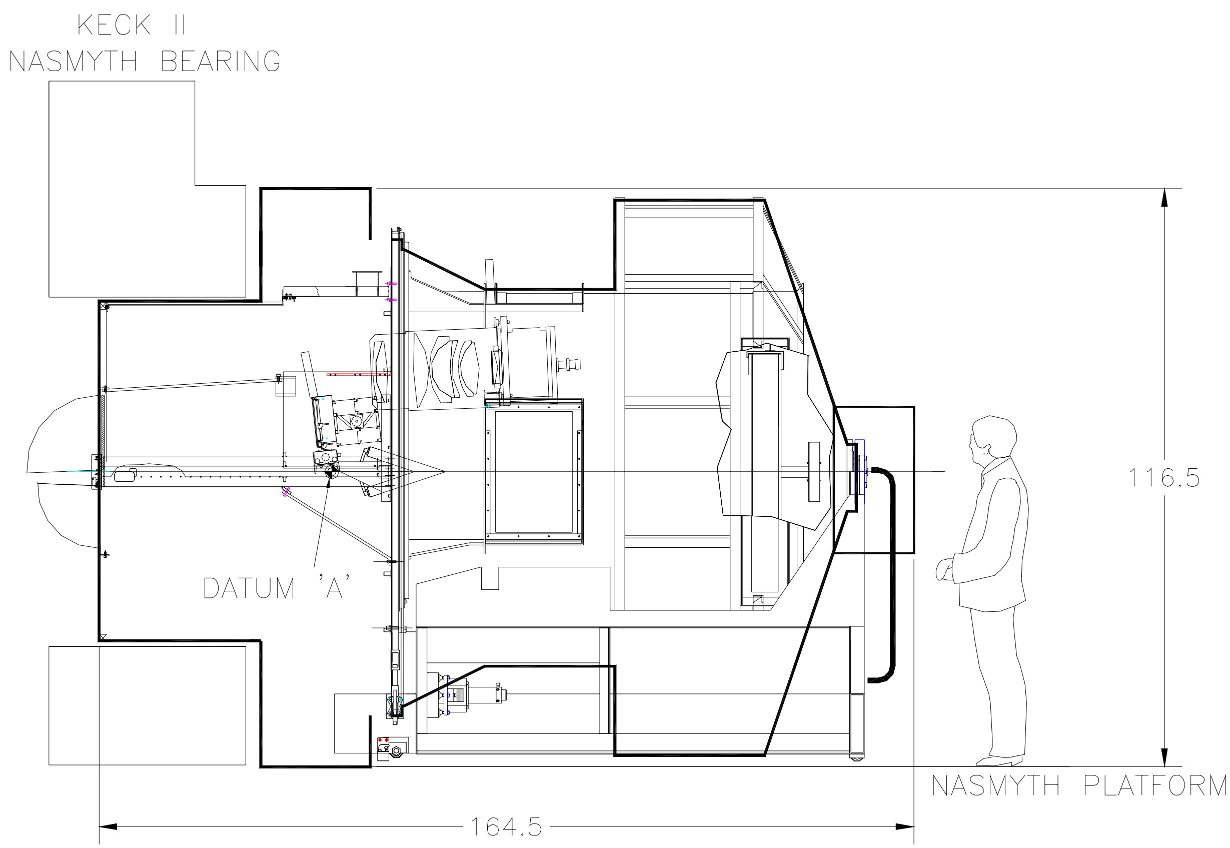


Left: Arc lamp observed through a slitmask designed for DEEP2 (detail). Some slitlets are tilted to allow rotation curve measurements

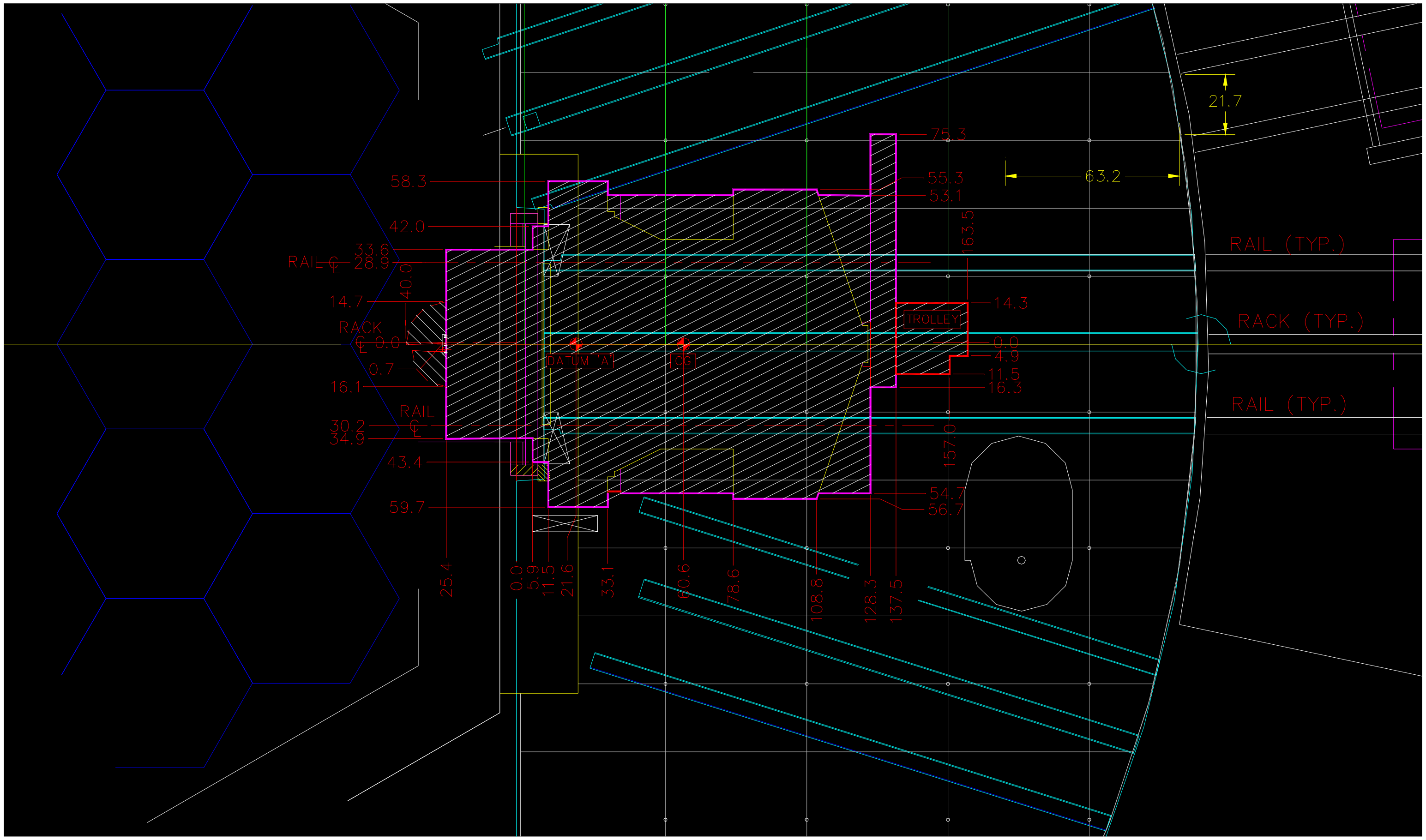
Mechanical Envelope

- Rotating cylinder: 48 in. diameter, 160 in. long
- Front supported on drive disk: 96 in. diameter
  - Doubles as front bearing and optical bench
  - 2-in thick steel plate
- Rear supported on spherical bearing
- Electronics bays ring cylinder with 10 compartments
- Whole held by undercarriage on four wheels
  - Runs on tracks on K2 Nasmyth platform to mount and stow
- Total dimensions: 164 in. long, 120 in. high
- Total weight: 19,489 now; 19,600 at delivery

Size



Size: Mounted



Size: Stowed

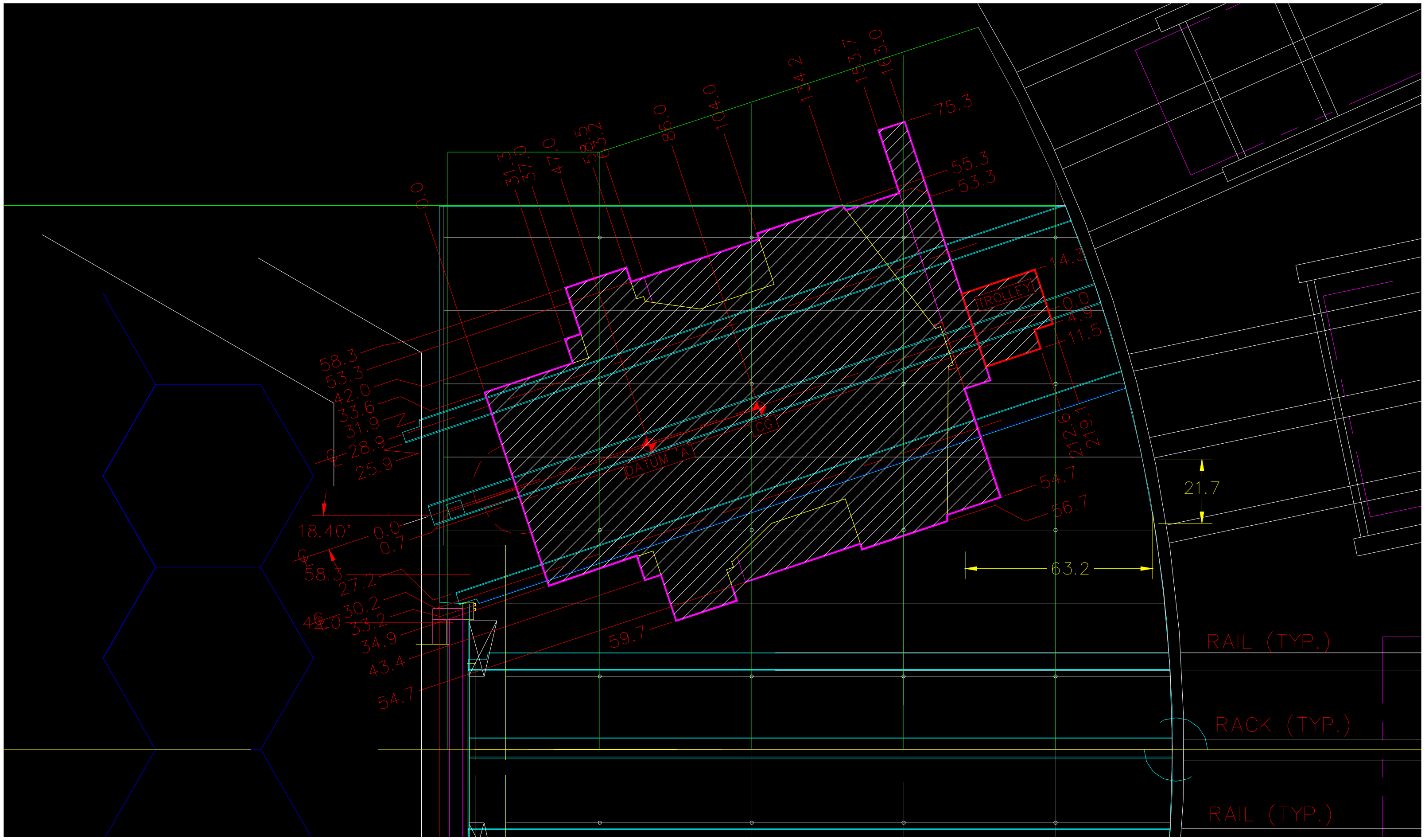


Table 2: Original Physical and Optical Characteristics

• Location	Right Nasmyth platform, Keck II; removable from focus
• Layout	Two cameras fed from common collimator; only one beam fabricated at this time
• Rotator	790 deg rotation
• User access	Slit masks, all gratings and all filters
• Guiding system	Single guider; 13.5 sq amin FOV total, 4.5 sq amin on offset guider, 8.5 sq amin on slitmask
• Spectrograph feedback	Two-coordinate beam-steering with closed-loop feedback flexure control
• Flexure	Goal is 0.25 px rms motion over typical integration (with flexure control system on, 2px rms open loop)
• Slit Masks	11-12 in cassette; cylindrical radius of curvature matched to focal plane curvature

Table 2: Original Physical and Optical Characteristics

Slitlet options	Slitlets of arbitrary shape, size and orientation
Dispersive elements	6-in x 8-in gratings; 3 grating slots
Imaging option	Silvered flat mirror replaces grating
Filters	6.25 x 6.25-in glass filters; 7 slots; BVRI, "clear," and 2 "user" slots
Collim. focal length	86.50-in
Camera focal length	15.00-in
Beam diameter	6.33-in for 10.95 m primary; 5.79-in for 10.02 m primary
Monochromatic f/ratio	f/2.358 for 11.00 m primary; f/2.586 for 10.02 m primary
Polychromatic f/ratio	f/1.29
Scale at detector	0.00759 asec/mu; 0.119 asec per 15mu px
CCD detector array	8192 x 8192 px (15 mu px); 2 x 4 mosaic of 2K x 4K CCDs

Table 2: Original Physical and Optical Characteristics

Angular field radius of camera	11.40 deg
Camera glass xmission	91% for lambda > 5200A; 50% at 3900A; 82% at 4400A
Total camera throughput	83% at lambda > 5200A; 71% at 3900A (including coatings and transmission)

Table 3: Original Imaging Performance Characteristics

• Field shape	Rectangular with 2 lopped-off corners; sliver out of long side
• Outer dimensions of rectangular field	16.7 amin x 5.0 amin
• Area lost to CCD mosaic gaps	0.4 amin x 5.0 amin
• CCD pixel scale	0.119 asec per px (15mu px)
• Wavelength range (imaging)	4000A 11,000A
• Standard filters*	BVRI + 2 user filters
• Throughput at 6000A*	40% (including telescope)
• Image size: B band (0.5 asec seeing)	0.56 asec FWHM (including telescope Aberrations)
• V-->I bands	0.54 asec FWHM (including telescope aberrations)
• Expected count rate*	800 e- per sec in V band at 21.0 mag
• Mode changes	30 sec changeover between imaging and spectroscopy (goal)

Table 3: Original Imaging Performance Characteristics, Continued

Notes:

* Slightly redshifted B band with blue edge at ~3900A.
* End-to-end throughput including telescope and assuming CCD QE=0.6 and all reflecting surfaces are silver coated. No filter or atmosphere included.
* V mag is light entering telescope. Rate is through standard V filter.

Table 4: Original Spectroscopic Performance Characteristics

• Total slit length	16.7 amin
• Usable slit length*	16.3 amin
• Total number of slitlets	85 10-asec slitlets with 1.5 asec gaps
• CCD detector scale	0.119 asec per px (15mu px)
• Wavelength range (spectra)	4100A -11,000A
• Order-blocking filters	TBD
• Slit widths	User selectable by choice of mask; long-slits will provide variety of fixed widths (not provided at delivery)

Table 4: Original Spectroscopic Performance Characteristics, continued

• Design slit widths	0.75 asec nominal, 0.5 asec good seeing
• Current gratings (all 6 x 8 in)	600 l/mm (7500A blaze): 900 l/mm (5500A blaze); 1200 l/mm (7500A blaze);
• Number of grating slots	3 slots available
• Corresponding dispersions	0.65A/px, 0.44A/px, and 0.33A/px
• Spectral lengths (8000 px)	5300A, 3840A, and 2630A
• FWHM resolutions for 0.75 asec slit	TBD
• Throughput at 6000A*	29% (including telescope)
• Count rate at 6000A	1.0 e- per sec at V = 21.0
• S/N on faint stellar objects in one hour*	5:1 for V = 24.0; 12:1 for V = 23.0; 21:1 for V = 22.0

Table 4: Original Spectroscopic Performance Characteristics

Notes:

* Spectroscopic image quality is averaged over all wavelengths and field angles for an object at the middle of the slit.
* Slit length subtended by detector pixels.
* End-to-end throughput including telescope assuming CCD has QE=0.6 and all reflecting surfaces are silver coated.
* S/N per pixel for 3600 s integration, 0.75 slit, on point source with 0.7 asec seeing at 5500A and 0.65A/px (600 l/mm grating). V is magnitude of light going through slit. Assumed V sky brightness is 21.25 mag/asec.

Table 5
Master Specification Table

Significant Unmet Requirements

- Rapid change of gratings was not achieved
  - Goal was 30 sec; typical change will be 3 min
  - Proposed novel acquisition procedure may eliminate need to swap grating and imaging mirror for some programs
- Failed to meet flexure specs on most systems
  - Passive image motion spec was 6 px p-p in each coordinate
  - Actual image flexure is up to 14 px; clamp-up variations add up to 8 px
  - Flexure-corrected image motion spec was 0.25 px rms in each coord; actual corrected motion expected to be ~>0.5 px
  - Effect on flatfielding is TBD
- Abandoned 8 x 12 grating; carry only 6 x 8 gratings
- May deliver with only 2 grating sliders, not 3
- Will not deliver with "long slit" mirrors; postponed or deleted

Major Outstanding Issues

- **Optical quality is not yet satisfactory**
  - Optical performance at 22 C is affected by coma; should resolve at 0 C
  - Two moving camera elements; at least one needs to be fixed
  - Plan is to accomplish the repair without re-mounting in spectrograph; no plan to cold-test camera
  - Unforeseen charge diffusion means best optical quality slightly worse than spec
- **Flexure questions**:
  - Image rotations and shears and clamp-up variations not yet fully explored
  - Definitive break-down of all sources of flexure not yet final
  - Need to track down origin of slow image droop
- **Red science detector is being assembled; will not be tested in spectrograph**
- **Serious ice condensation on dewar window**
  - Element 9 needs to be relieved to make air path
- **FC system needs baffling and tuning to reduce scattered light**
- **Install and test Slider 5**

Image Quality
Error Budget History
RMS Diameters: spectroscopy mode; imaging is similar

	microns	px	arcsec	
PDR	7-32	0.5-2.1	0.06-0.25	Preliminary optical design; camera only
CDR	28-38	1.9-2.5	0.22-0.30	Final camera design
				Add collimator design and errors
				Add proj. fabrication & assembly errors
Camera CDR*	25-34	1.7-2.3	0.20-0.27	Add real fab. errors * & proj. assembly errors

CONCLUDE: Fabrication errors met error budget*

Best poss. at present time	41-47	2.7-3.1	0.33-3.8	Add estim. CCD charge diffusion of 33 mu & Proj. assembly errors

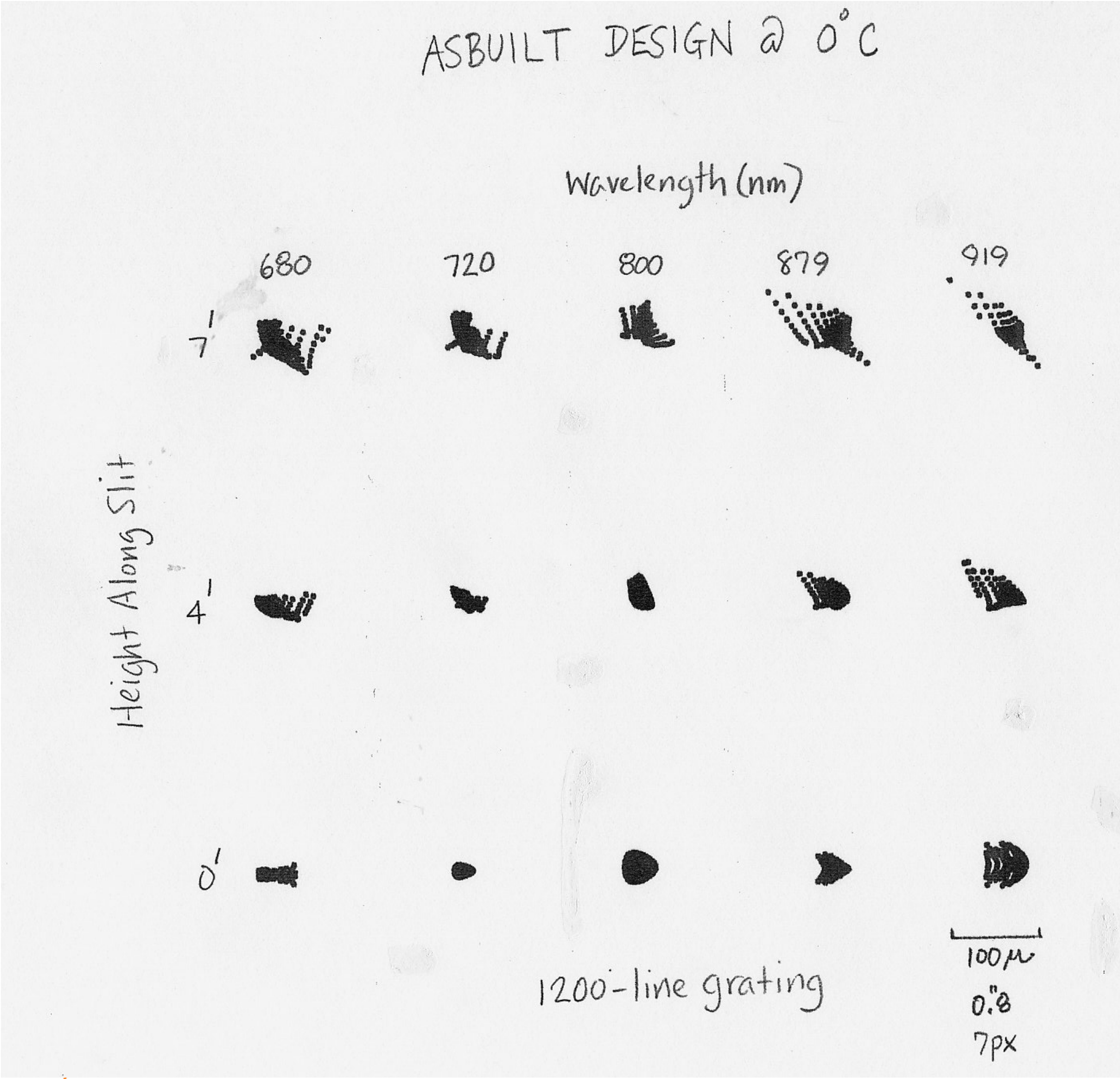
➔ Add FWHM Gaussian seeing: 0.50 asec FWHM ➔ 0.60 asec rms diam
Expected avg rms diam: with charge diffusion: 0.69 asec
w/o charge diffusion: 0.65 asec

*For details, see Camera CDR tables 2.4, 2.5, 2.6 on web.

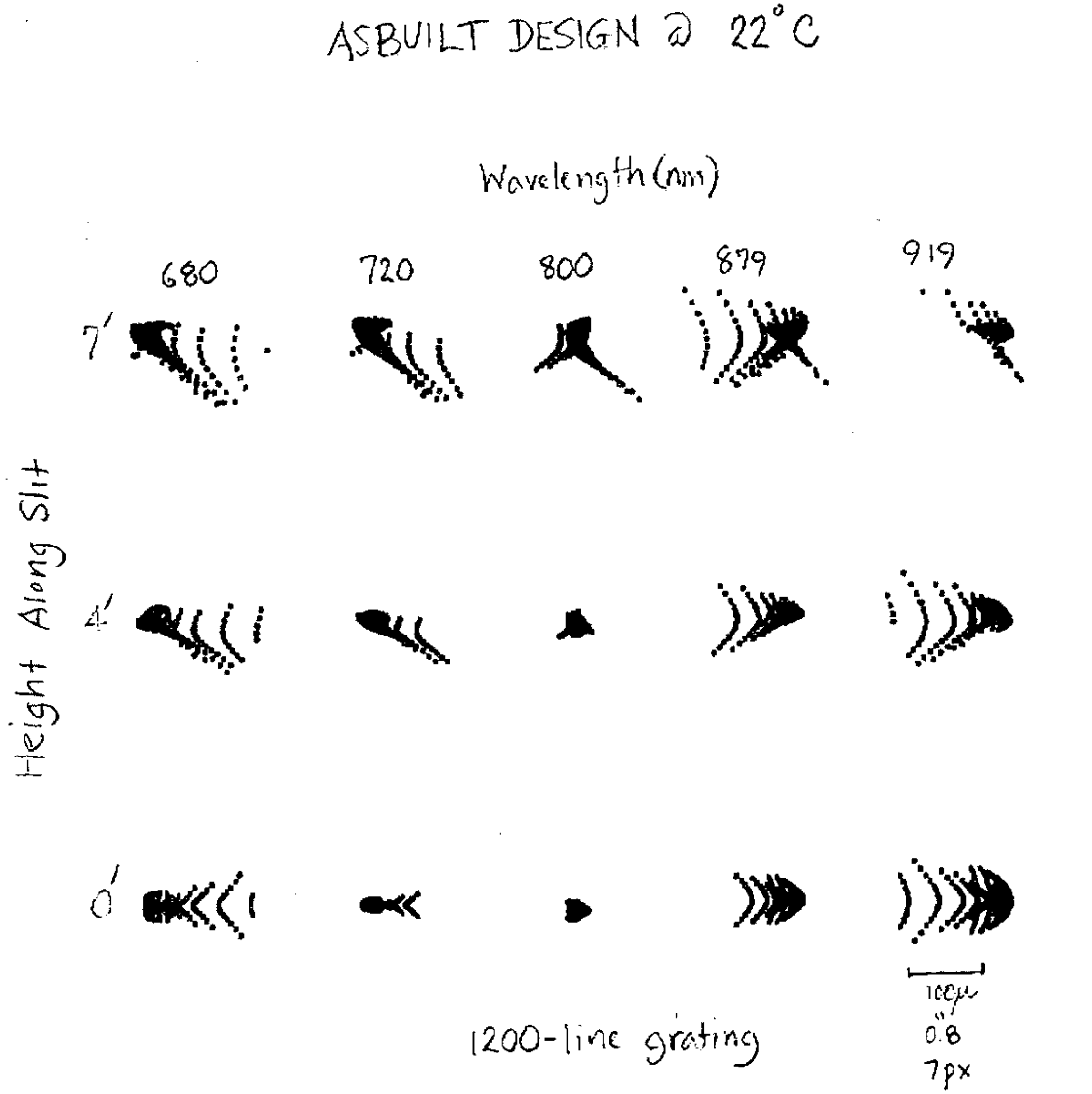
Image Quality
Actual Performance

- Image quality at 22 C is affected by radial “thermal” coma:
  - Tail length = 9 px at ends of spectra, outward
  - Effect should vanish at 0 C (ORA thermal soak analysis)
- Assembly errors are not zero:
  - El 3 and Body 4 in camera are decentering under gravity
  - Amounts have been measured by moving shadow analysis
  - Adds variable linear coma superimposed on constant thermal coma
  - Will be fixed as camera is shipped
  - Testing plan exists that does not need spectrograph or science dewar; described later

ORA spot diagrams at 0 C- Shows thermal coma.



ORA spot diagrams at 22 C- Shows thermal coma.



Camera Moving Element #3

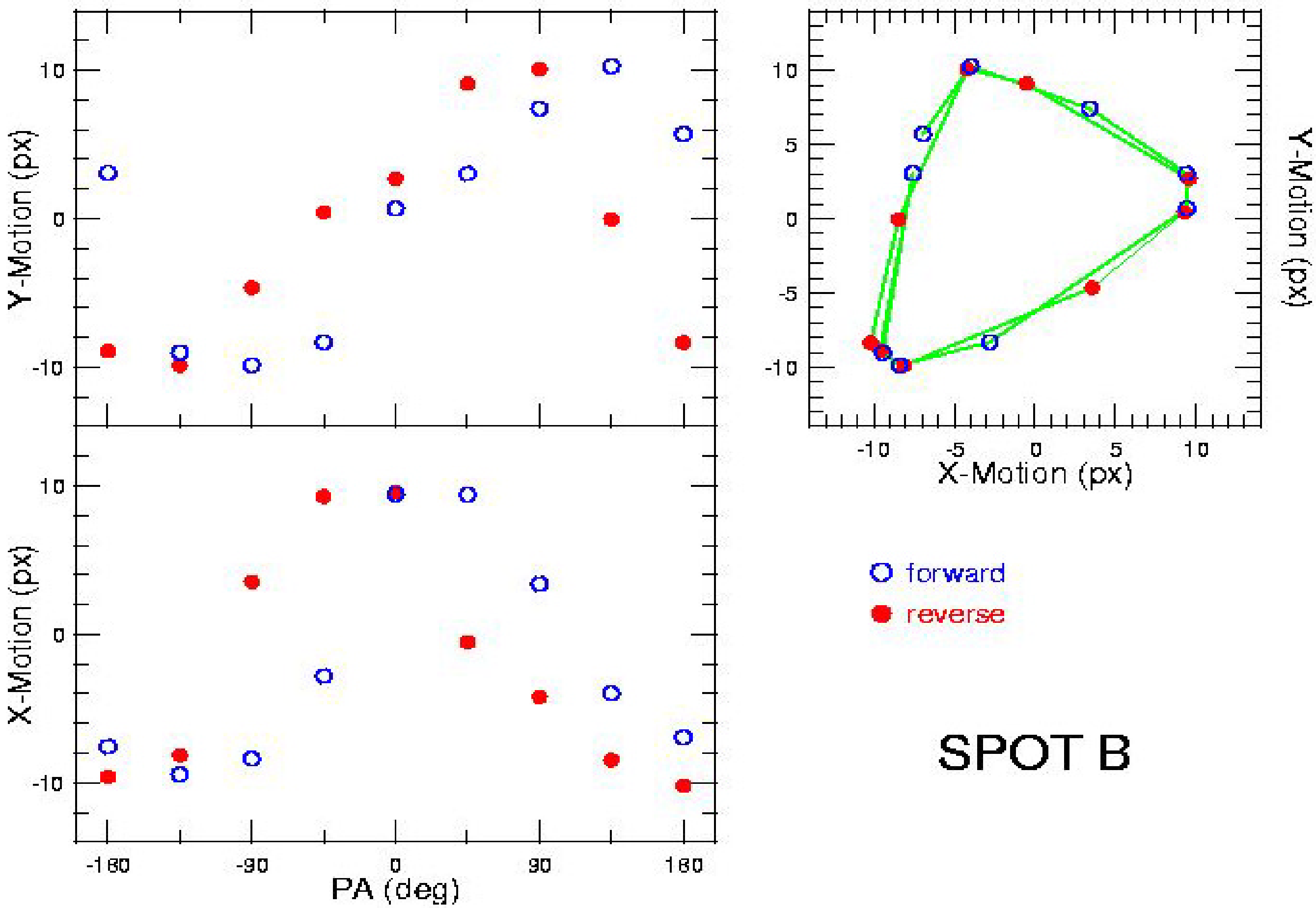


Image Quality
Actual Performance: Best Images

- Predict best images that we can now see:
  - ➢ Use middle of FOV to avoid coma
  - ➢ Through 0.5 asec holes (smallest that can be made)
  - ➢ Take best design, add real fab. errors and charge diffusion, but ignore assembly errors
- Through 0.5 asec hole:

  Predicted best rms diam: 55 mu = 3.6 px = 0.43 asec

  Measured best rms diam: 55 mu = 3.6 px = 0.43 asec

➔Conclude: Best images are as expected for design, fab, and diffusion errors

*Note: We cannot actually go through focus, as detector is mounted too far back. However, we seem to be very close to focus based on measured image sizes.

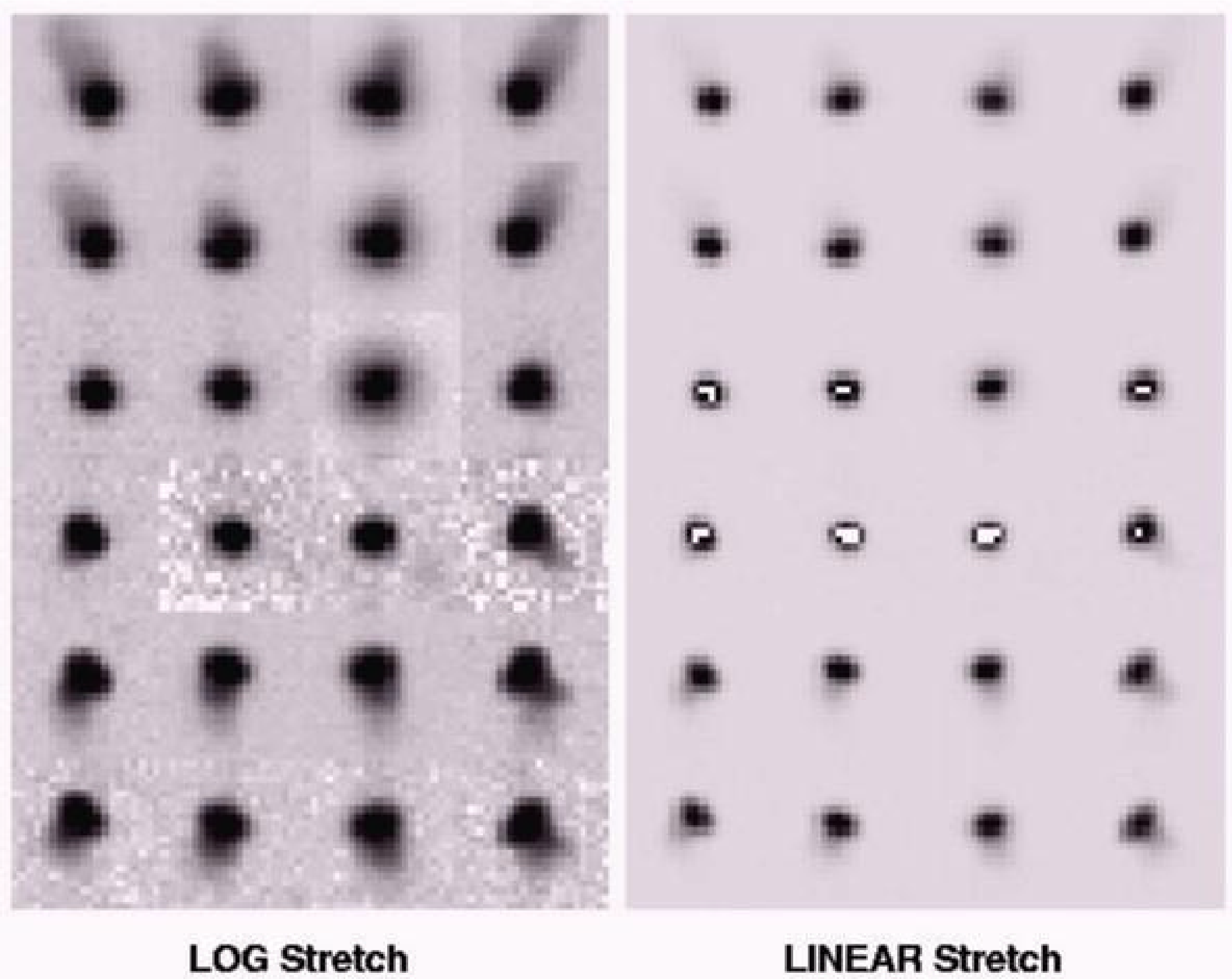
Image Quality
Actual Performance: Edge of Field

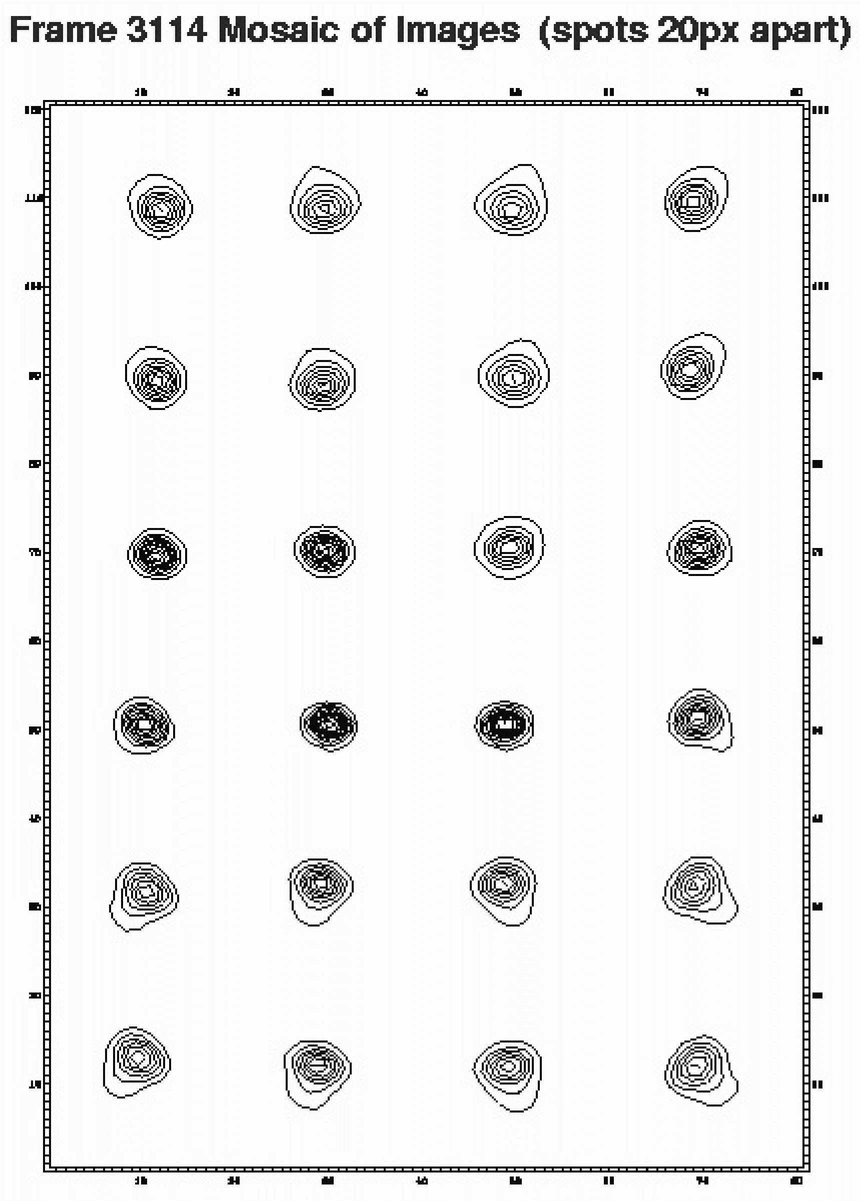
- Measured diameters:
  - RMS major axis diam: 51-120 mu = 3.4-8.0 px = 0.40-0.95 asec
  - RMS minor axis diam: 42-72 mu = 2.8-4.8 px = 0.33-0.57 asec
  - RMS diameter: 64-140 mu = 4.3-9.3 px = 0.50-1.11 asec

  Total image length: 9 – 15 px

  Amount of light in comatic tail: 25%
- Overall increase is due to thermal coma
- Variability is due to moving camera elements; range is best and worst.
- Zemax model with simulated thermal coma and variable decentered El 3 and Body 4 reproduces mean coma and variability. Decenters were taken from moving shadow analysis.

Best Images





Contour Plot of Best Images

Image Quality
Predicted Performance at Keck

- Assume that both moving camera elements will be fixed
- May be able to reduce charge diffusion – not sure; do not assume
- Assume best predicted rms diams including charge diffusion:

	microns	px	asec	
Best poss. at present time	41-47	2.7-3.1	0.33-0.38	Includes estim. CCD charge diffusion of 33 mu plus predicted. assembly errors

- Use above image sizes to estimate best spectroscopic resolution:
  - Convolve along dispersion with slits of different widths; 1200-line grating; include anamorphic factor of 1.65 @ 8000 A:
  - FWHM with 0.75 asec slit: 4.1-4.3 px = 1.36-1.41 A
  - FWHM with 0.50 asec slit: 3.2-3.5 px = 1.06-1.15 A
  - Goal with 0.50 slit @ 8000 A was 0.9 A (see PDR).

Difference is due to charge diffusion; unanticipated effect

Flexure Control System

Overall Stability Requirements

Image Quality

- Needed during a single exposure; no clamp-up
- Through zenith, mainly
- Rms diam < 2 px
  - This implies a 1-d rms = 0.7 px
- PDR said 0.5 px; demanded slightly tighter optical quality

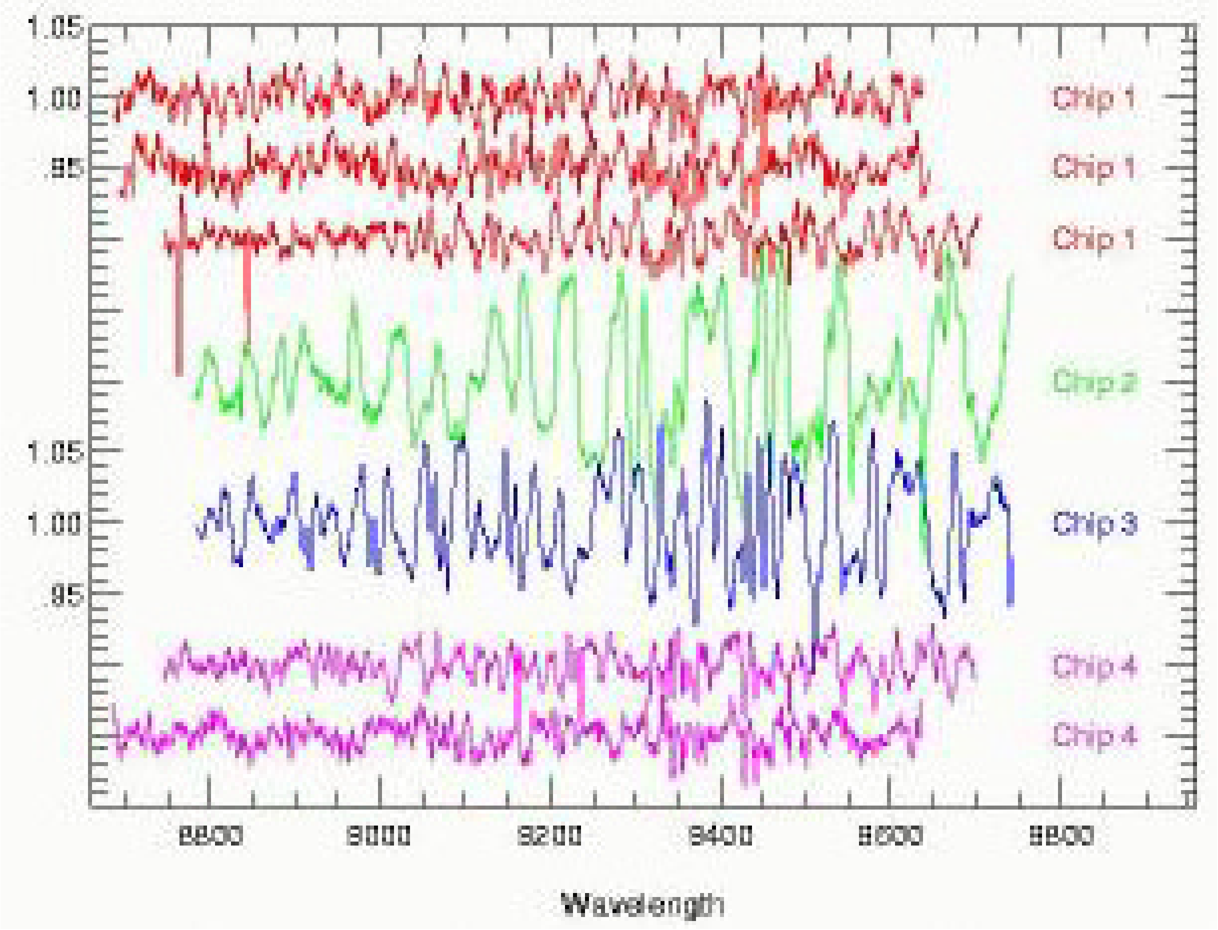
Flexure Control System

Overall Stability Requirements

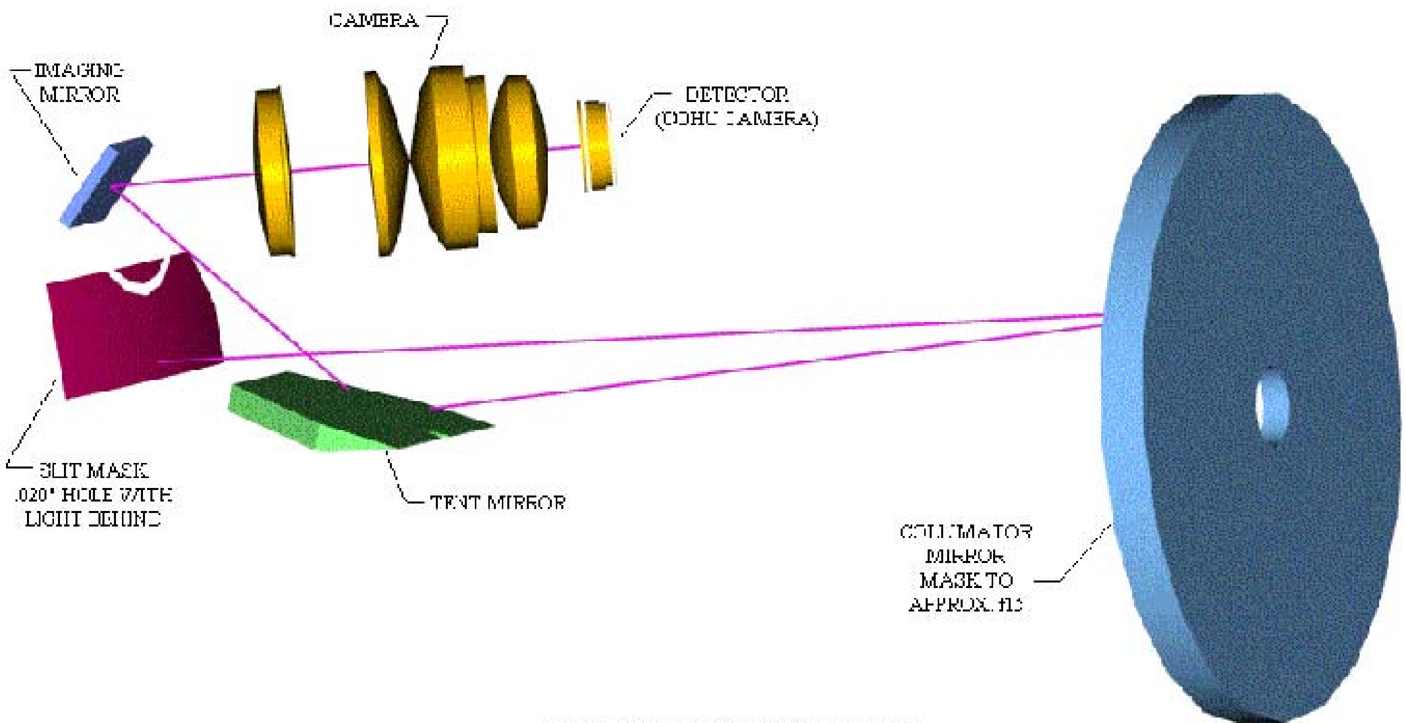
Flat-fielding Accuracy

- Needed between afternoon flat-field and night observation
- Use different clamp-ups, but same slider
- Flat-field is taken at a standard PA
- Observation taken at any PA
- Assume fringing is sinusoidal with amplitude +/- 2% and period 30Å (for Lot 14 CCDs)
- Assume lowest dispersion: 0.65 A/px (600-line grating, worst case)
  - This requires a 1-d rms = 0.5A
    = 0.7 px
- PDR said 0.25 px. Difference is bigger assumed fringing there and a flat-field spec of 0.1% instead of 0.2%.

High-Rho Fringing on CCD's 1 & 4



FC System Elements



DEIMOS FLEXURE TEST
OPTICAL COMPONENTS

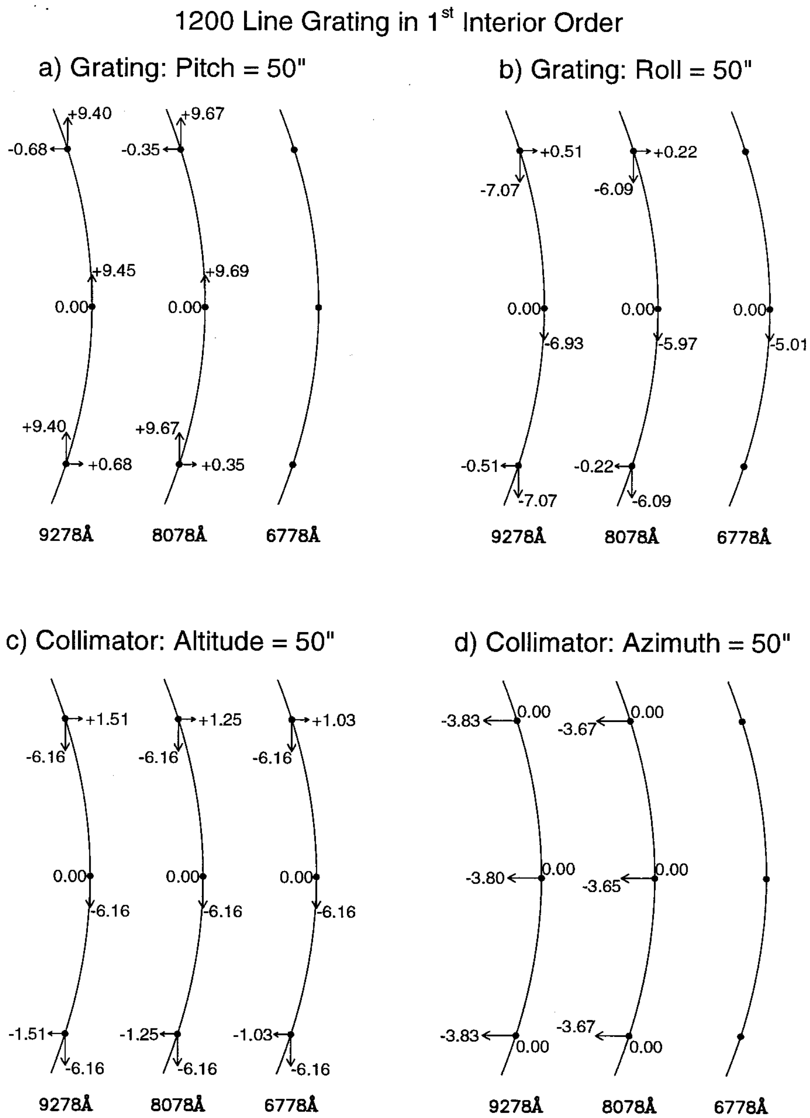
FC System
Dynamic Range Factors

- The FC system does not compensate perfectly for certain flexure modes. These modes must be kept small.
- Define dynamic range parameter D:

$$D_{i,j} = \frac{\text{Amplitude of peak motion in mode i (px)}}{\text{Rms uncorrected distortion in coord. j (px)}}$$

  - For image displacements, amplitude is half peak-to-peak
  - For image rolls, shears, and distortions, amplitude is half peak-to-peak at detector edge (4000 px)
- Assume spectroscopy mode, 1200-line grating, 8000Å center (worst case)
- Assume Y-stage on tent mirror, X-stage on detector

Grating Distortions



← Red
Figure 7.1

FC System

Dynamic Range Factors

Moving Element	Image moves in:	Distortion caused in:	D	Comments
Slitmask	X	X	-	"-" indicates negligible effect
	X	Y	5.8	
	Y	Y	-	
	Y	X	-	
	shear	Y	1.7	Caused by slitmask rotation
	shear	X	-	Caused by slitmask rotation

FC System
Dynamic Range Factors

Moving Element	Image moves in:	Distortion caused in:	D	Comments
Collimator	X	X	-	
	X	Y	5.8	
	Y	Y	-	
	Y	X	-	
Tent Mirror	X	X	-	
	X	Y	5.8	Can be caused by sag around opt. axis
	Y	Y	-	
	Y	X	-	
	shear	Y	1.7	Can be caused by sag around opt. Axis
	shear	X	-	

FC System
Dynamic Range Factors

Moving Element	Image moves in:	Distortion caused in:	D	Comments
Grating	X	X	60:	Pitch
	X	Y	23	Pitch
	Y	Y	-	Tilt
	Y	X	-	Tilt
	shear	X	1.7	Roll
	shear	Y	3.3	Roll
Detector	X	X	-	
	X	Y	-	
	Y	Y	29	
	Y	X	-	
	roll	X	1.7	Caused by detector rotation
	roll	Y	3.3	Caused by detector rotation

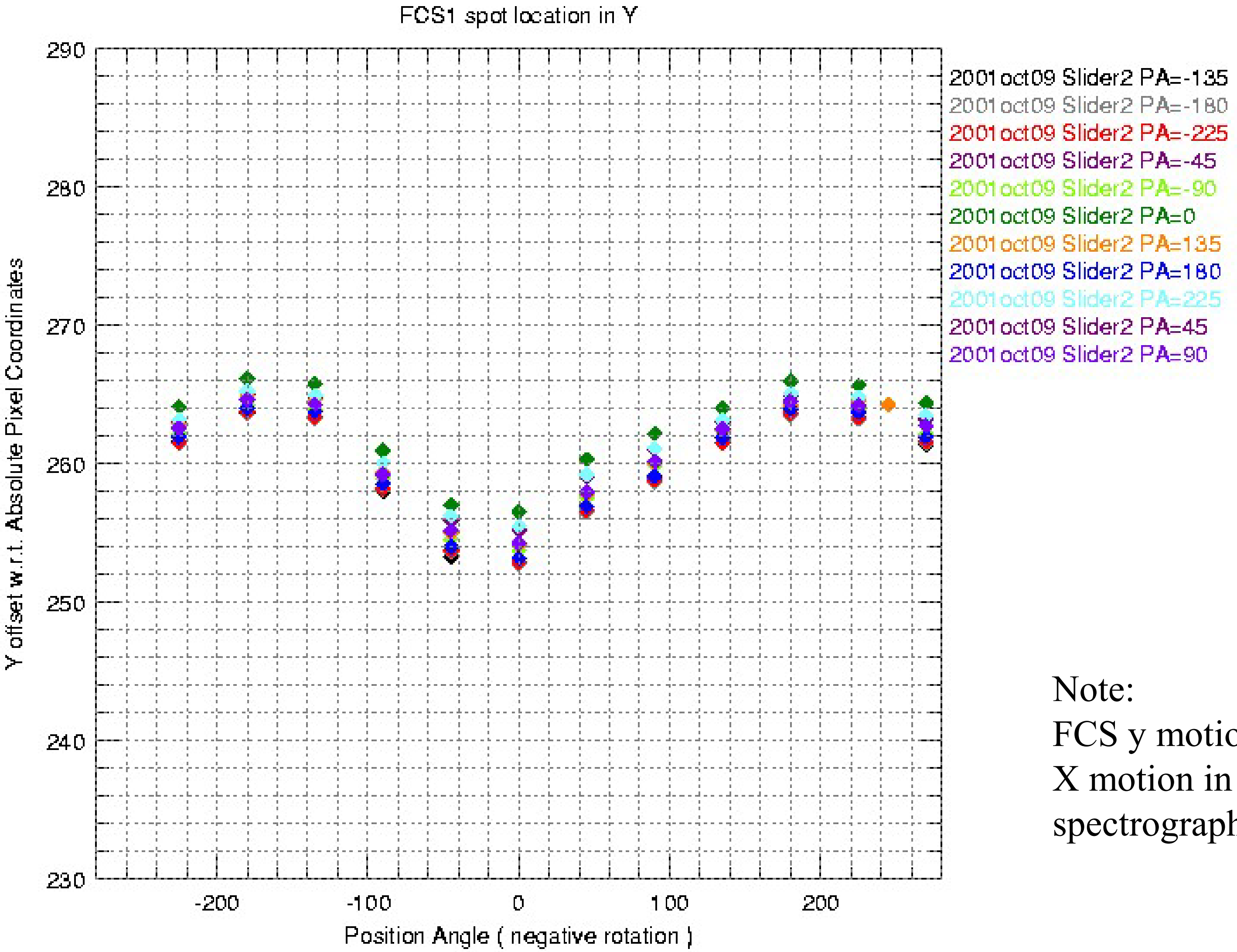
FC System
Dynamic Range Factors

Moving Element	Image moves in:	Distortion caused in:	D	Comments
Camera elements	X	X	1.25	Caused by motion of elements in X direction
	X	Y	-	
	Y	Y	1.25	Caused by motion of elements in Y direction
	Y	X	-	

FC System
Working Principles

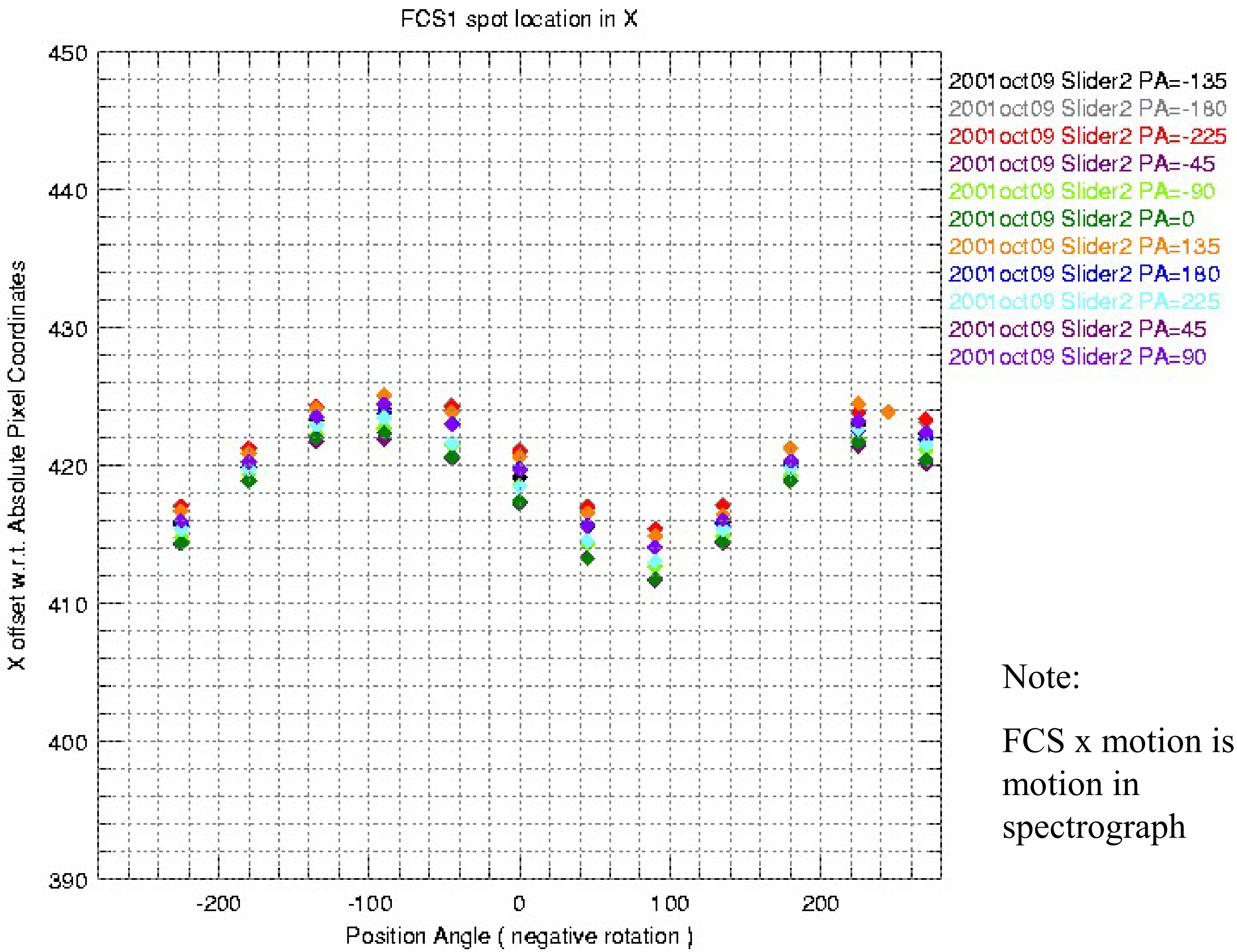
1. Avoid all rotations
2. Avoid camera element displacements
3. Avoid pre-grating motions that move image in X
   - Slitmask
   - Collimator
   - Tent mirror
4. Avoid post-grating motions that move image in Y
   - Detector/Camera
5. Avoid large grating pitch

Flexure –Slider 2-X



Note:
FCS y motion is
X motion in
spectrograph

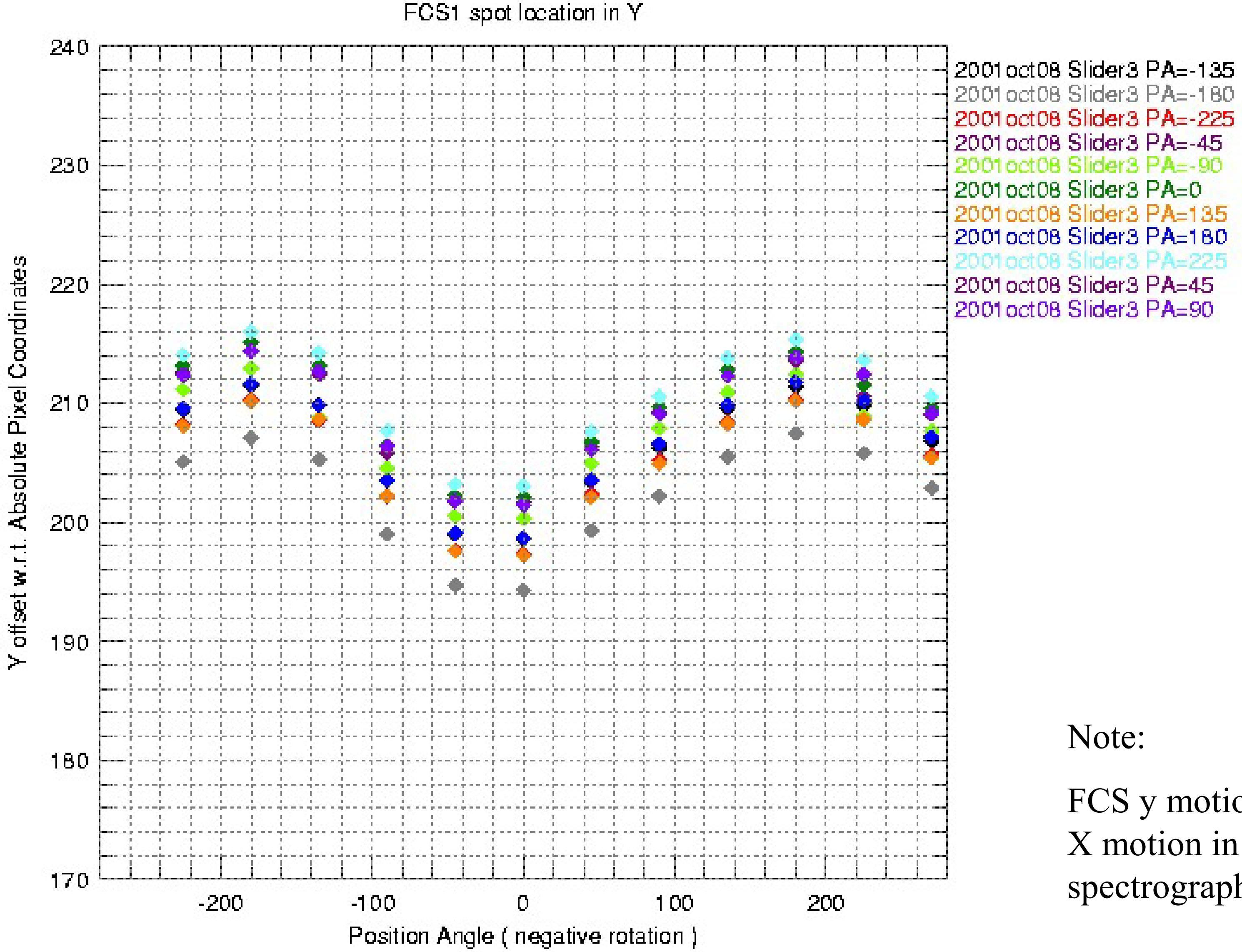
Flexure –Slider 2-Y



Note:

FCS x motion is Y motion in spectrograph

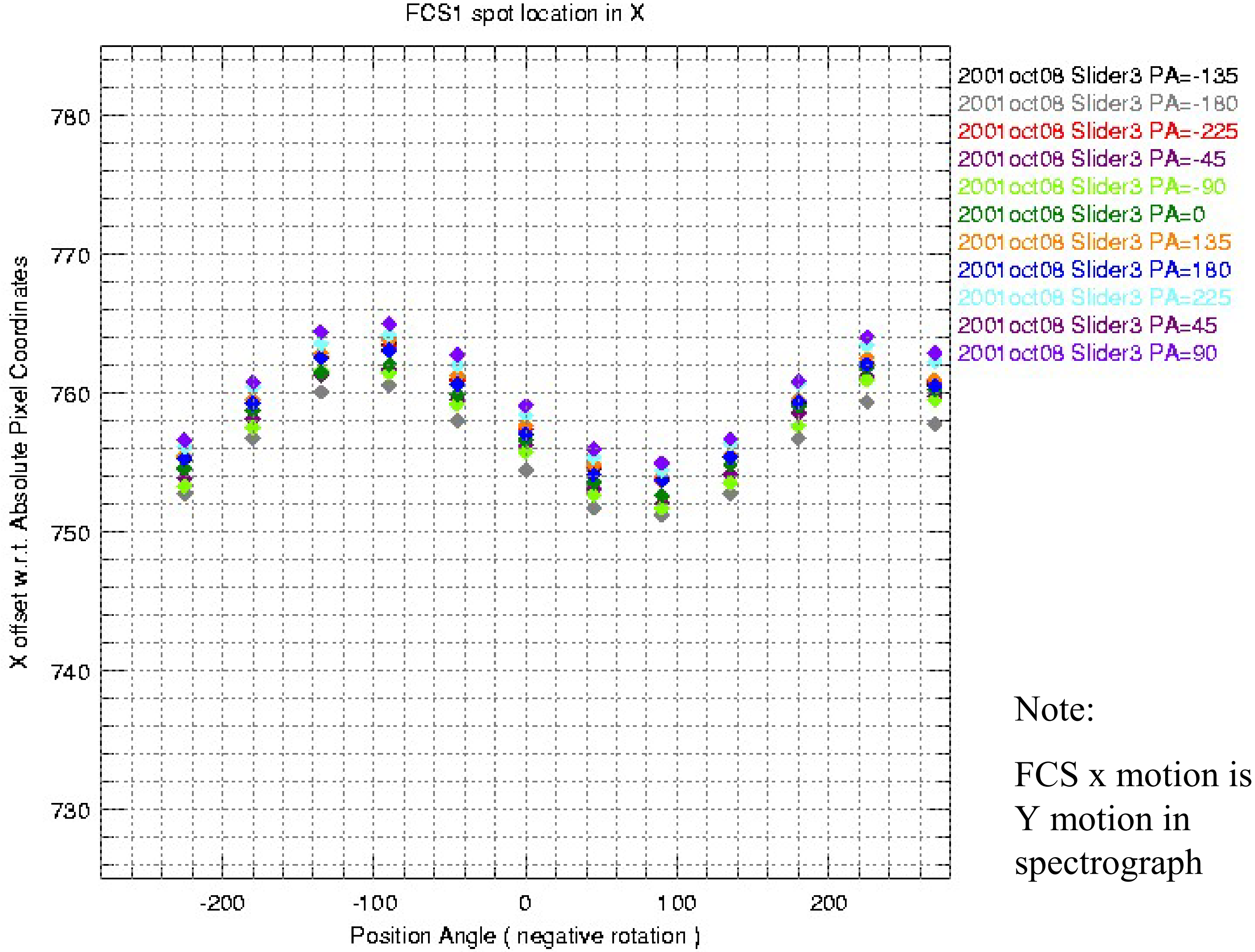
Flexure –Slider 3-X



Note:

FCS y motion is X motion in spectrograph

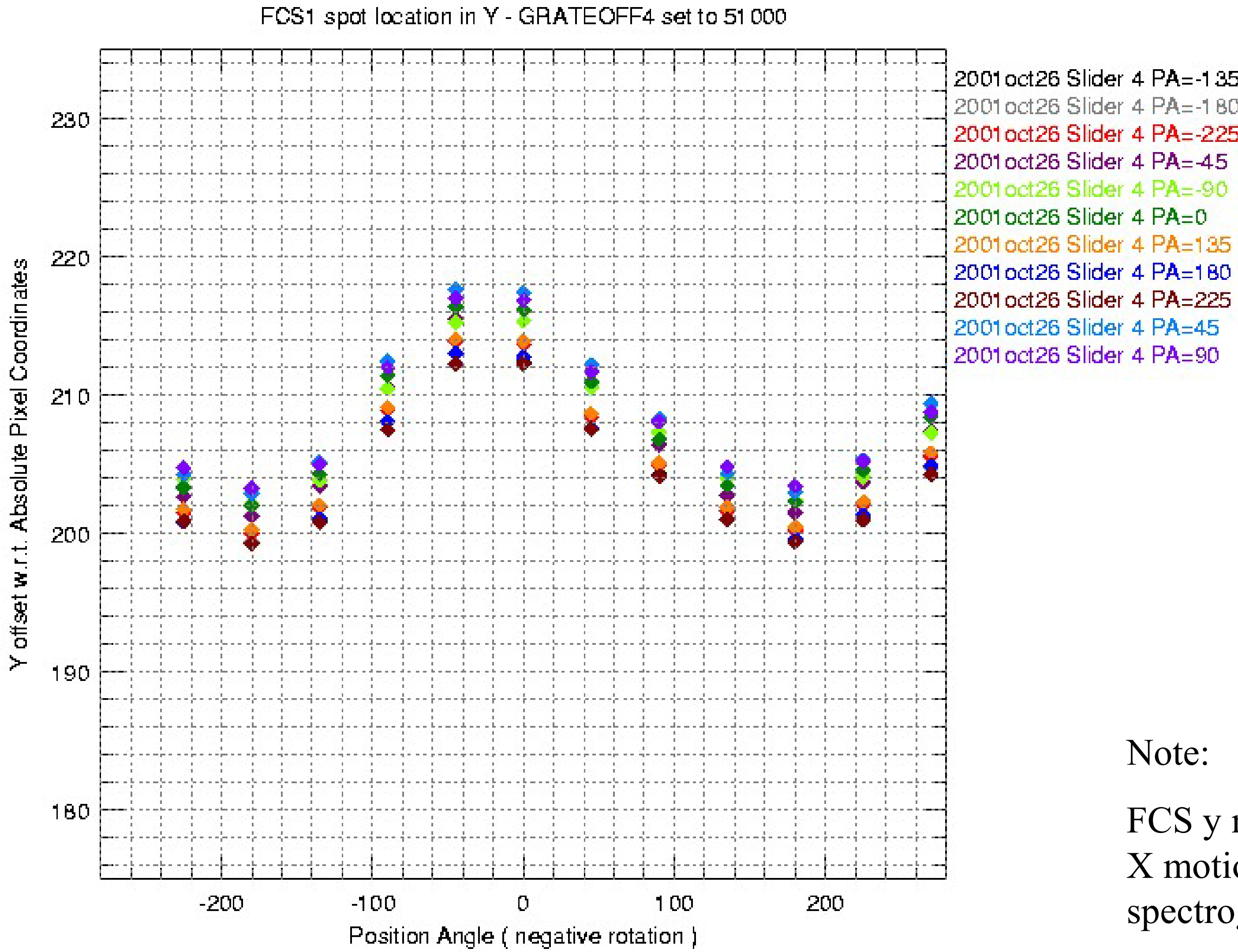
Flexure –Slider 3-Y



Note:

FCS x motion is Y motion in spectrograph

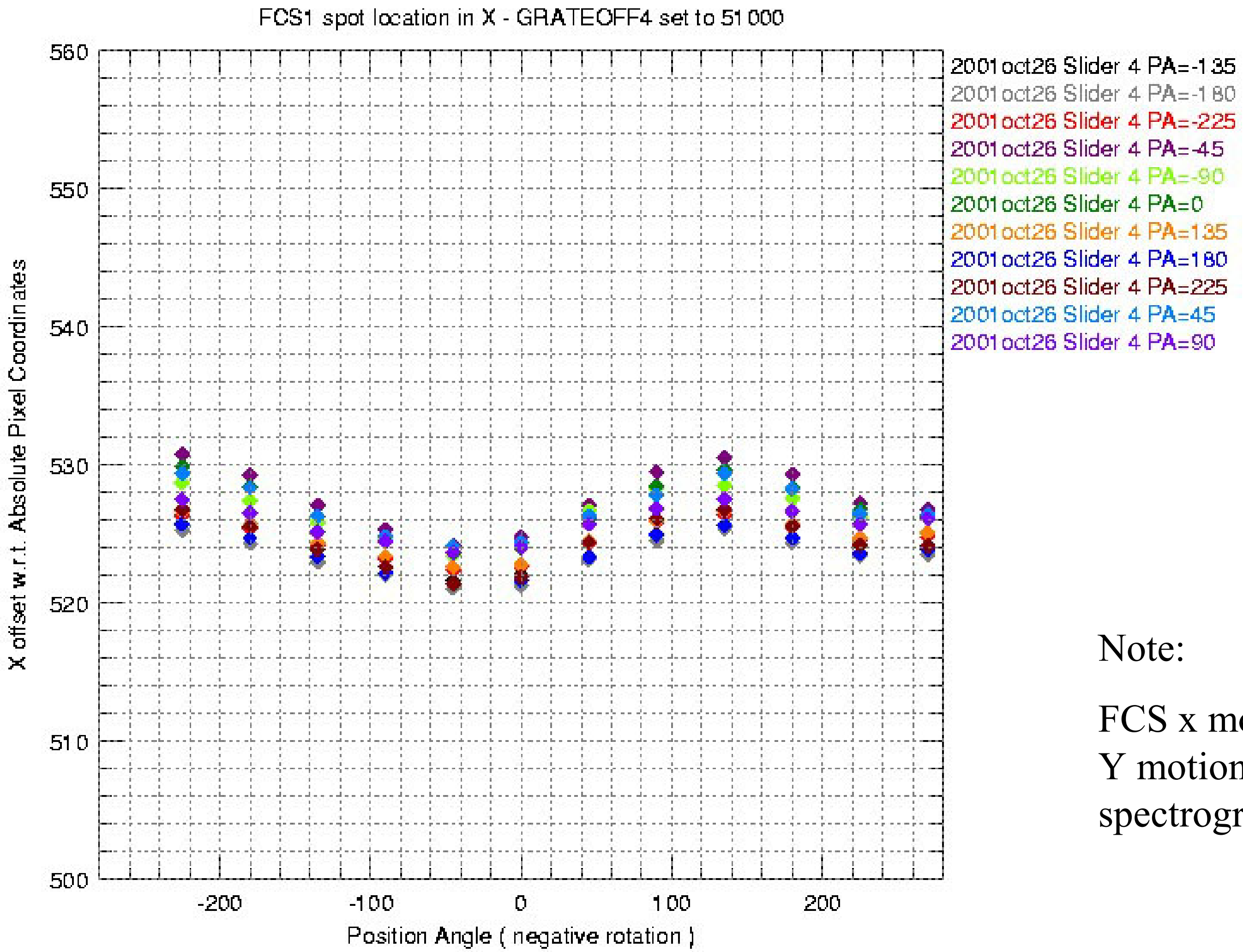
Flexure –Slider 4-X



Note:

FCS y motion is X motion in spectrograph

Flexure –Slider 4-Y



Note:

FCS x motion is Y motion in spectrograph

FC System
Bulk Motion Summary

Measured on FCS 1:

Effects of clamping variations removed:

Pk-Pk amplitude	**Slider 2**	**Slider 3**	**Slider 4**
Clamping removed			
X	10	13	14
Y	10	10	6
Clamping scatter			
X	3	9	6
Y	4	5	5
Total Scatter, with clamping			
X	13	22	20
Y	14	15	11

FC System

Bulk Motion Summary

Remove motions due to El 3, Body 4. Reduces X and Y by 5 px each.

Pk-Pk amplitude		**Slider 2**	**Slider 3**	**Slider 4**	**Actual Actuator Range**
Clamping removed (true flexure)					
	X	5	8	9	
	Y	5	5	1	
Total scatter, with clamping This is the range we will need					
	X	8	17	15	26
	Y	9	10	6	21

FC System

Analysis of Flexure Modes: Slider 4

- Flexure only, clamping not included
- X amplitude (pk-pk)
  - Model

Pre-grating ΔX	6px
Grating pitch	6px
Camera elements	6px
Detector sag	-4px
Total	14px

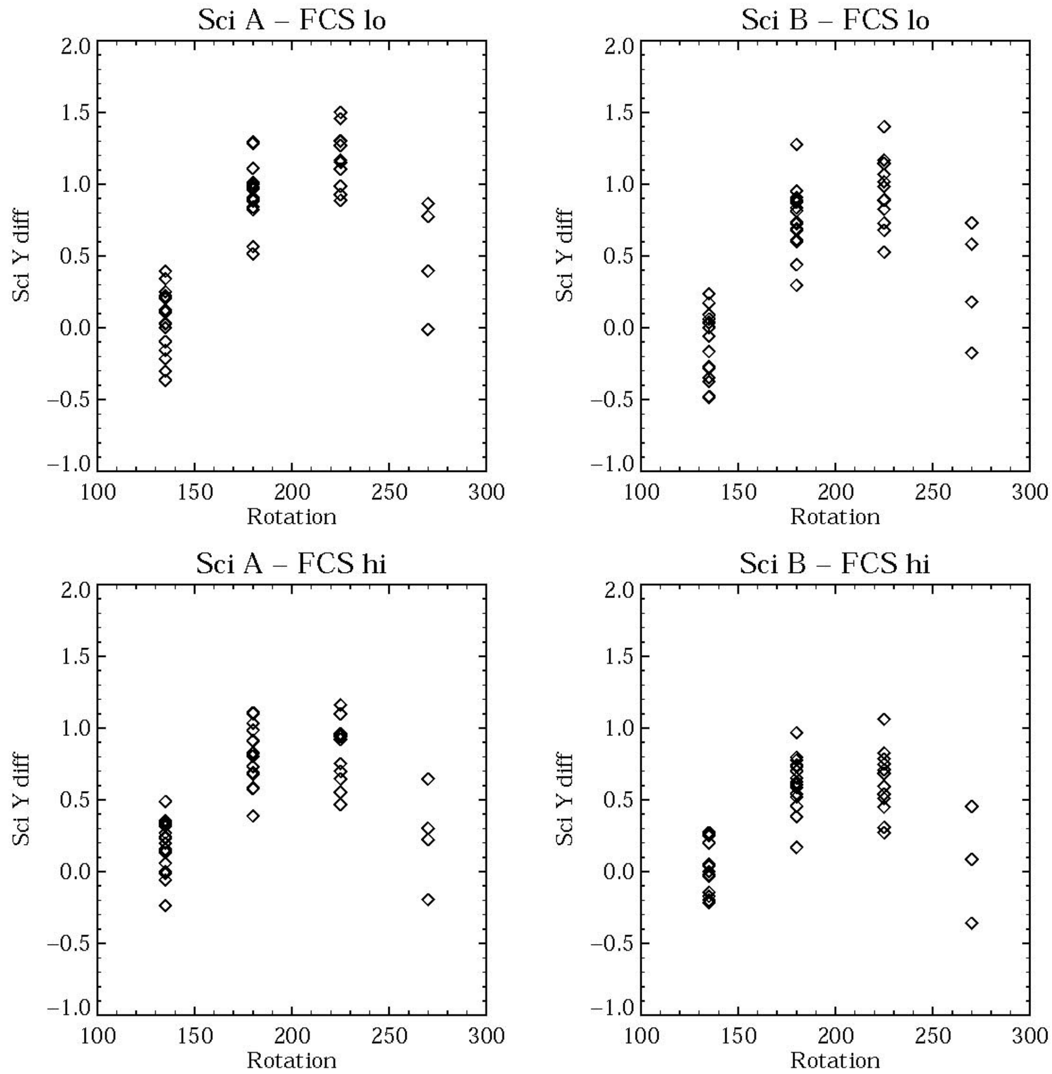
  - Observed 14px
- Y amplitude: not serious, ignore
- Grating roll: +/-0.4px at detector edge

FC System
Image Motion Error Budget

Source of error	rms(X)	rms(Y)	Comment
FC centroid spot error	<0.1 px	<0.1 px	Measured
Fiber feed flexure	0.1	0.1	Assumed
Residual distortion from Body 4	0.1	0.1	Computed
Pre-grating ΔX	--	0.51	Measured
Post-grating ΔY	--	<0.08	Estimate
Grating-roll	0.23	--	Measured
Grating-pitch	0.05	0.13	Measured
Image-rotation	<0.30:	<0.30:	Upper limit, uncertain
Total before clamp up	0.42	0.61	
Variable grating pitch	0.05	0.13	Assume +/- 3 px range
Total	0.42	0.62	
Current spec	0.70	0.70	

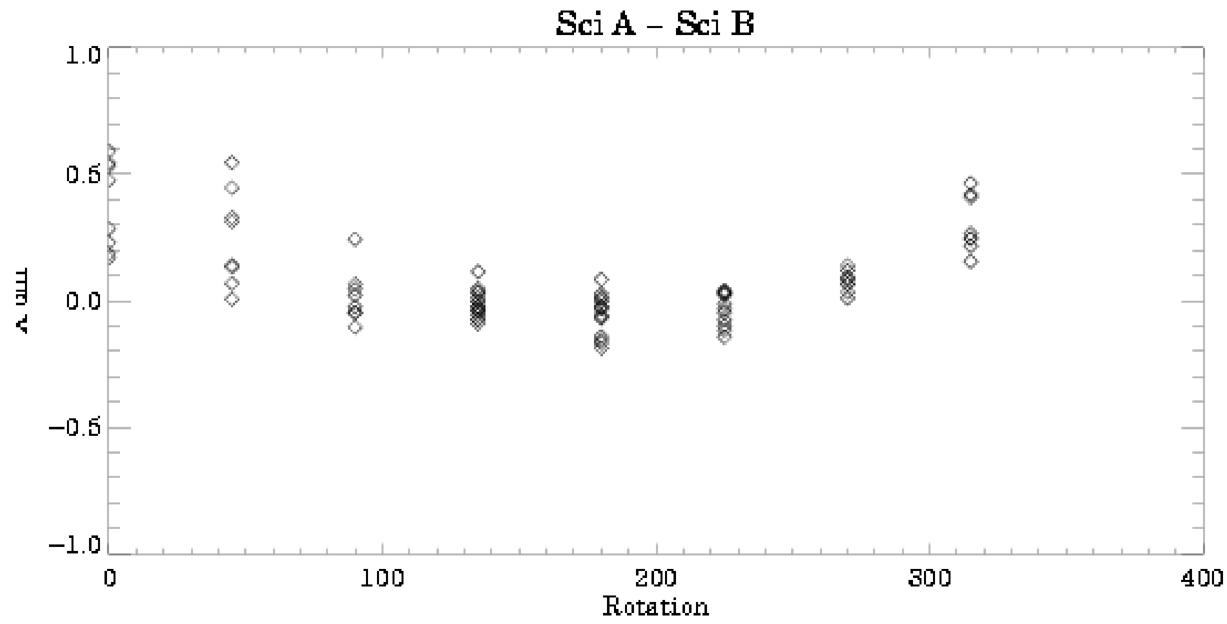
Note: Flat-fields must be taken at standard position angle in middle of X-flexure range, eg PA 270

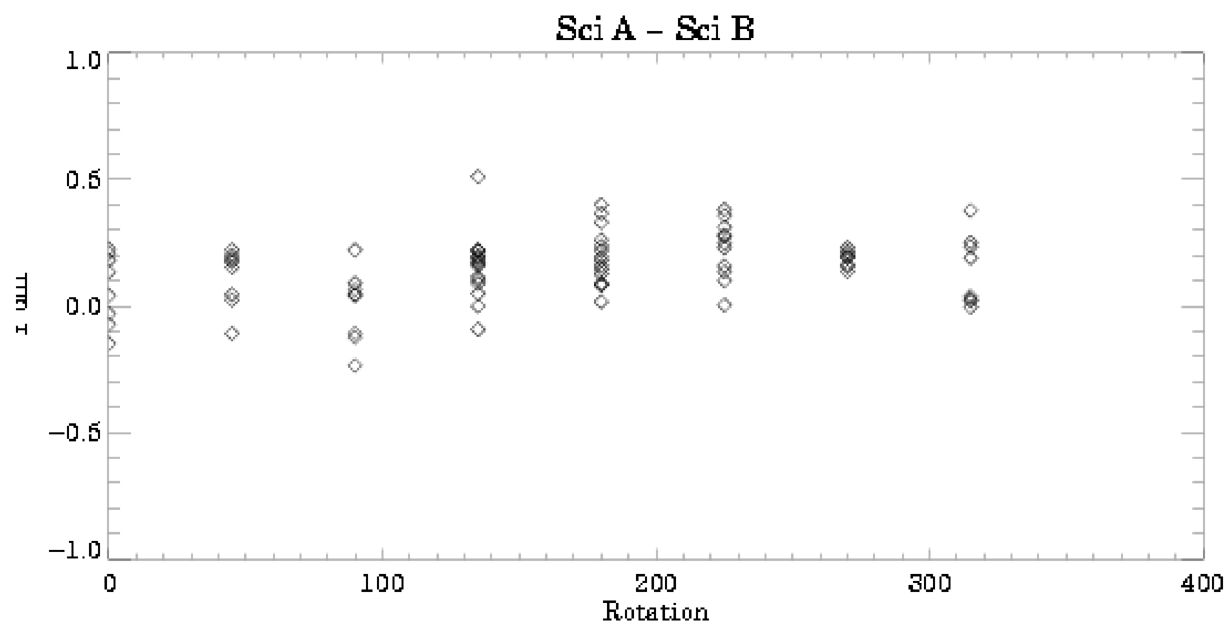
Sag of FCS Spots Relative to Science Detector



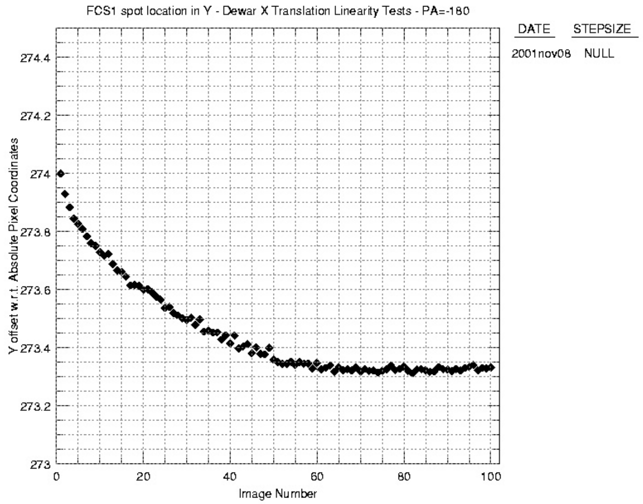
DEIMOS

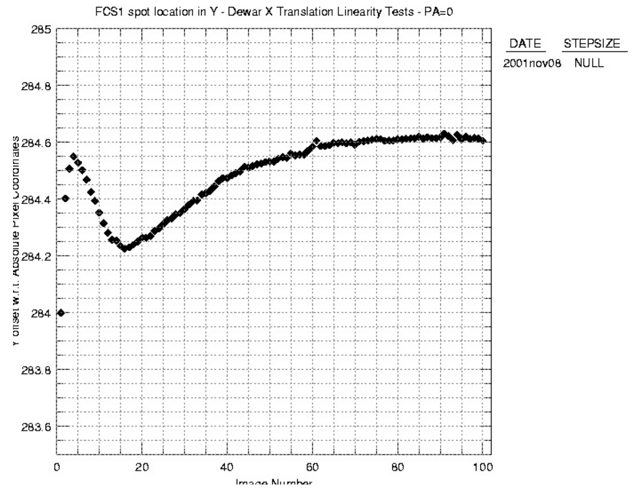
Rotation of Science Detector

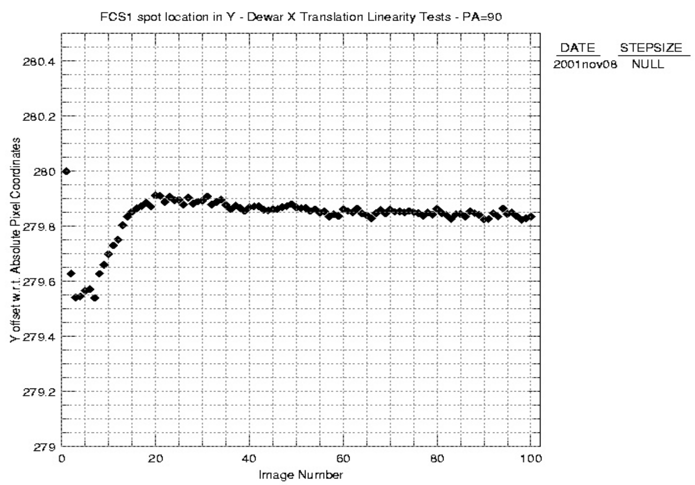


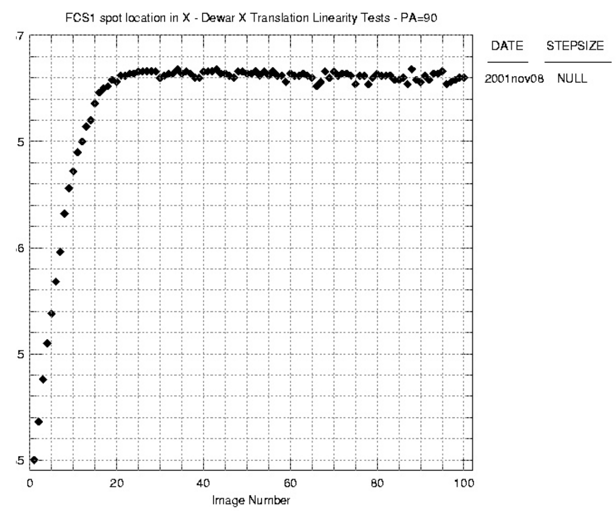


Slow Droop of Optical Elements









FC System
Fiber Feeds and Cu/Ar Light Source

- Fiber feeds are flexing w/r science array by up to 3 px pk-pk
- RMS spot measurement error <0.1 px
  - 0.05 px is goal
  - Will require > 1000 photons per spot
- CuAr spectrum is mostly well filled versus wavelength
  - Low region: 5000-5500 Å
  - May preclude small range of grating tilt approximately < 100 A wide with 1200-line gratings
- CuAr puts out too much light by x 1000-10,000
  - Get 10^7 phot/sec on FCS CCD in red
  - Want 10^3 phot/sec (10^4 in 10 sec exposure)
  - Need to cut by x10^4

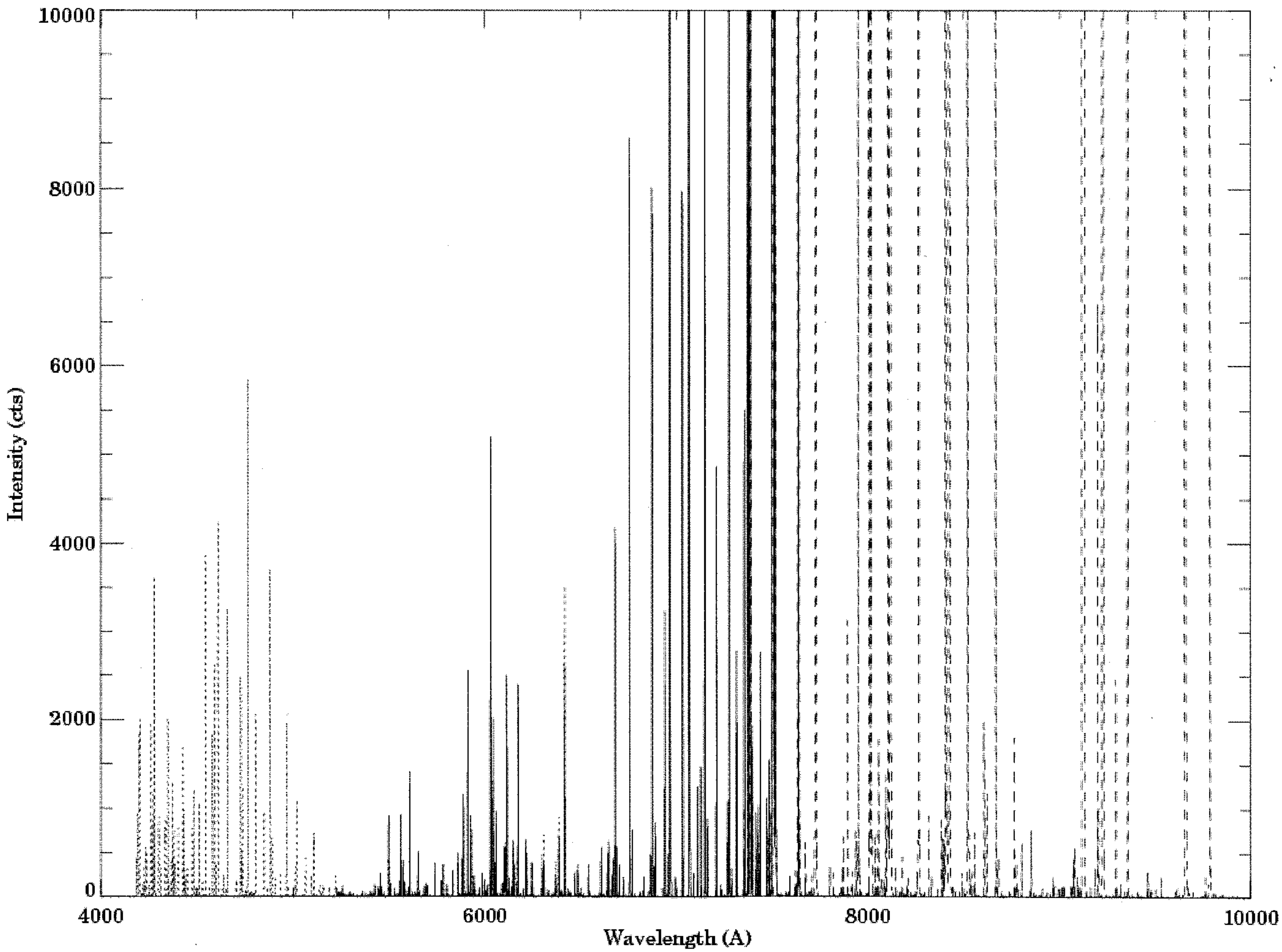
FC System
Fiber Feeds and Cu/Ar Light Source

- Scattered light on science array is 5% of light on FC CCD
  - CCD detector window is not baffled
  - Baffling may cut by x2
- Goal: in 30 min exposure
  - CuAr on FCS CCD: 2×10^6 photons (20,000 per 15 sec frame)
  - CuAr on science array: 10^5 photons (no baffling)
    5×10^4 photons (with baffling)
  - Average scattered light on science array near FCS CCD: 0.5 photon/px

FC System
Fiber Feed and Light Source Action Items

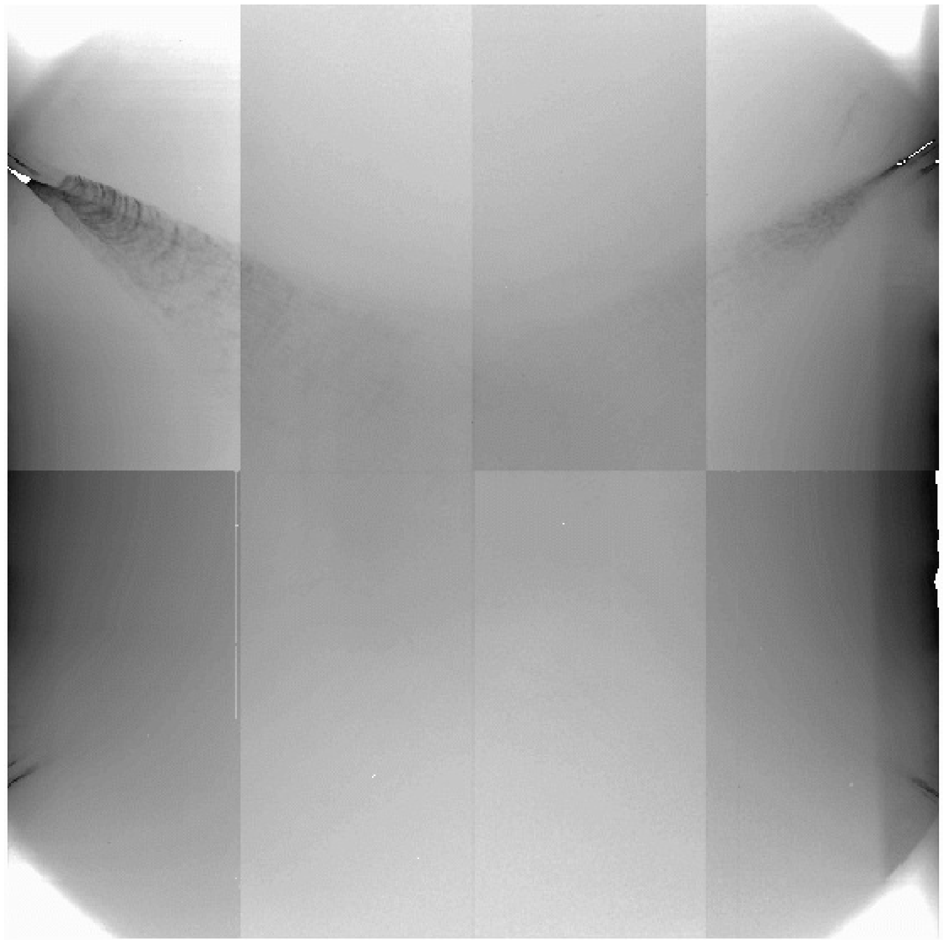
- Strengthen fiber feeds to remove flexure
  - Model remaining flexure in software?
- Baffle detector window around FCS detectors
- Reduce brightness of CuAr lamp by x10^4 (red end)
  - Stop down fibers to f/50: x10
  - BG 38 filter x20
  - ND filter x50
- Check brightness through all color filters
- Possibly program lamp to turn on/off to gain extra x10 flexibility

FCS Spectral Lines: CuAr



DEIMOS

FC Scattered Light Image



DEIMOS Automated Tests

- Low-level tests run on all DC servo stages:
  - Range of travel
  - Range of speeds
  - Operation of limits
  - Homing repeatability
  - Operability of all modes and associated keywords
  - Encoder linearity & registration for dual encoded stages
- Low-level tests run on pulsed solenoid stages
  - Range of travel
  - Operation of limits

DEIMOS Automated Tests

- Examples of high-level tests:
  - Slider flexure .vs. PA at which it was clamped
  - Slitmask insertion and repeatability .vs. PA
  - Dewar X translation non-linearity .vs. PA
  - Tracking performance .vs. telescope trajectory
  - Slider clamping .vs. DEIMOS rotation speed
  - CCD shutter blade timing tests .vs. PA
  - Grating tilt repeatability .vs. PA
  - Image stability over time .vs. PA

Timing Test Results

– Hatch
  - 5 sec to open/close
– Slit Mask
  - Time to insert/withdraw one mask = 10 sec
  - Mask 2 to Mask 3 time = 25 seconds
  - Mask 13 to Mask 2 time = 40 seconds
– Grating translation
  - From Position #2 to Position #4 = 3 min. 20 sec.
  - From Position #3 to Position #4 = 2 min. 0 sec.
  - From Position #5 to Position #4 = 4 min 20 sec (estimate)

Timing Test Results

- Grating Tilt
  - Limit to limit 42 Seconds
- Science Filter Wheel
  - Filter #2 to Filter #5 = 12 Seconds
- Dewar Focus
  - Forward limit to Reverse limit = 13 Seconds
- FCS X-Stage
  - Forward limit to Reverse limit = 34 Seconds
- FCS Y-Stage
  - Limit to limit = 1 second

Timing Test Results

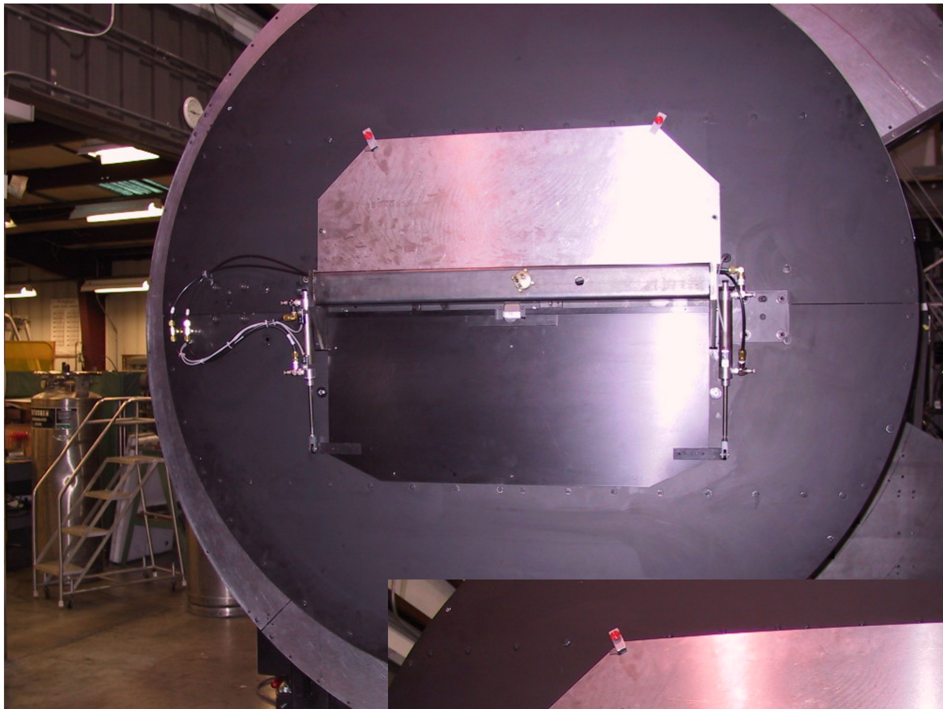
– Instrument Rotation
  - Limit-to-limit time = 5 min 21 seconds.
  - Time to rotate 360 deg = 2 min 38 seconds.

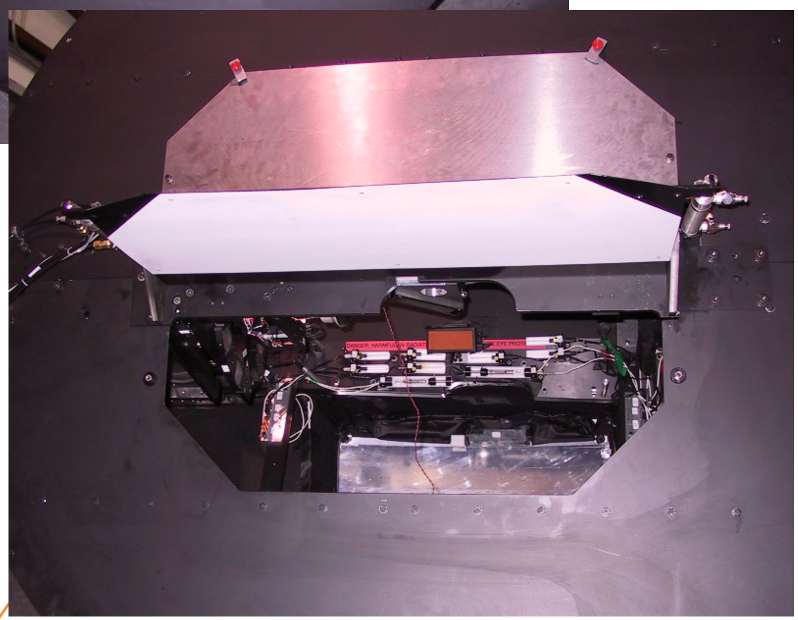
– TV filter wheel
  - Filter “0” to filter “1” = 11 seconds
  - Filter “4” to filter “0” = 14 seconds

– TV Focus
  - Forward limit to Reverse limit = 13 Seconds

Stages and Subsystems

- Hatch & Front Window
- Slitmask system
- Collimator
- Tent mirror
- FC Y-stage
- Grating system
- Camera
- Filter wheel
- Shutter
- Dewar
- Focus
- FC X-stage
- LN2 system
- Detector system
- CCD controllers
- Calibration lamps
- FC light source
- TV system
- Rotation
- Electronics enclosures
- Cladding
- Hatches and access ports
- Cable wrap
- HP temperature system
- Carriage mover
- Kinematic mounts
- Service connections
- Power supply system





Hatch

Test Results

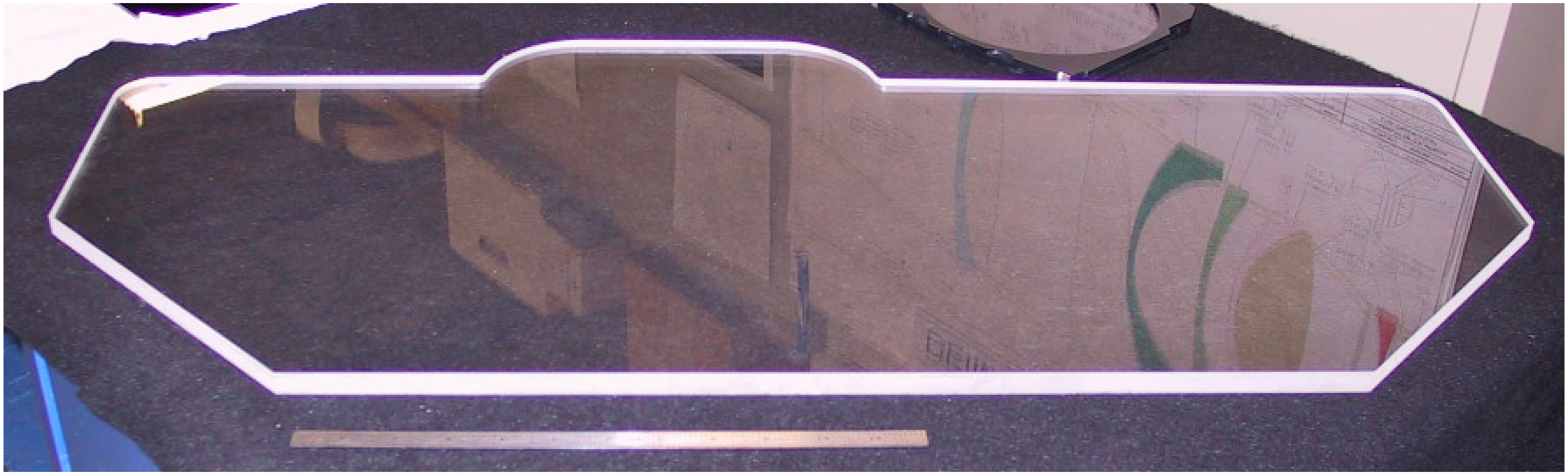
-opens ….

-Interlocked
to calibration lamps

-Time to open/close
5 seconds

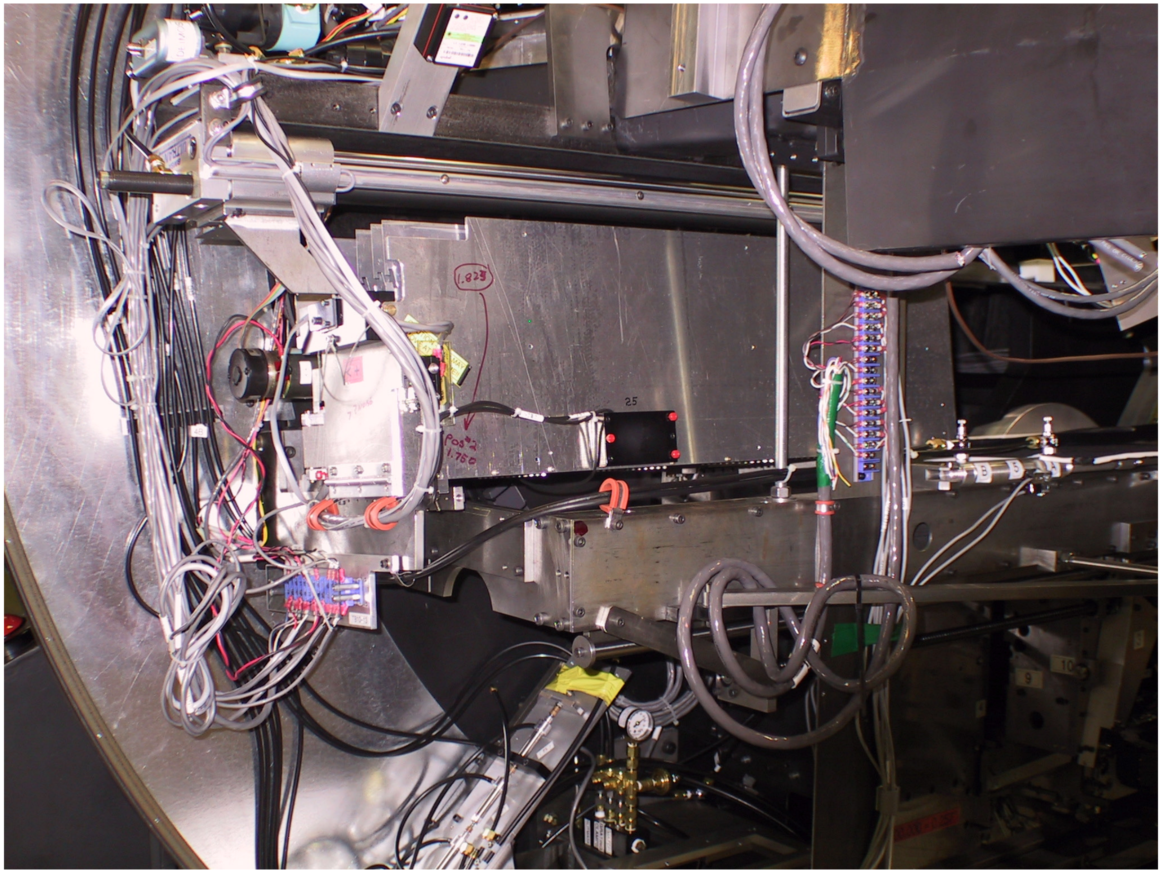
-Will have a foam
“gasket” to form
light-tight seal

Front Window



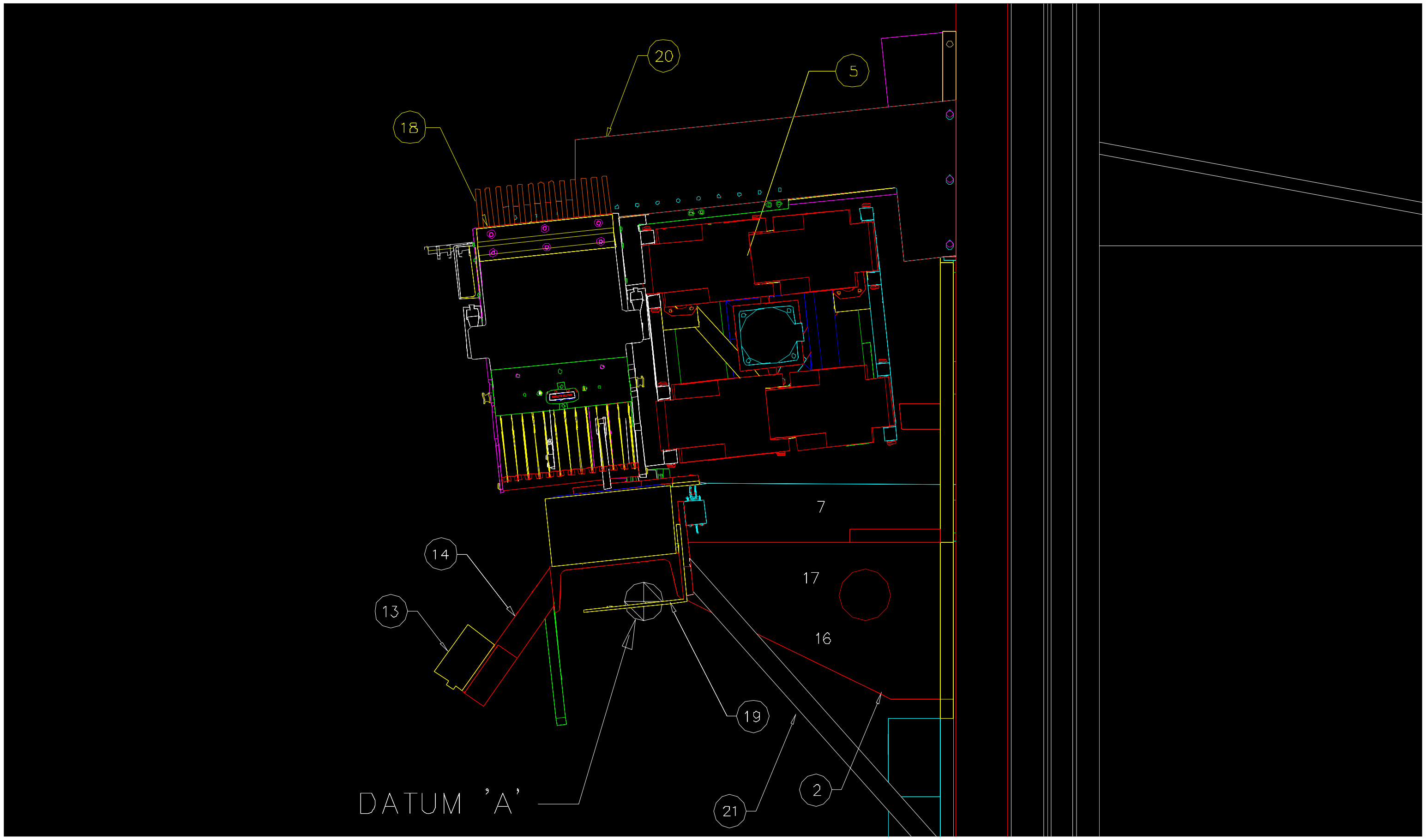
- BK7
- Will be coated with Solgel that will be hardened
- Mean transmission (2 surfaces)- 0.983, 380 to 1005nm

Slitmask Cassette/Insertion

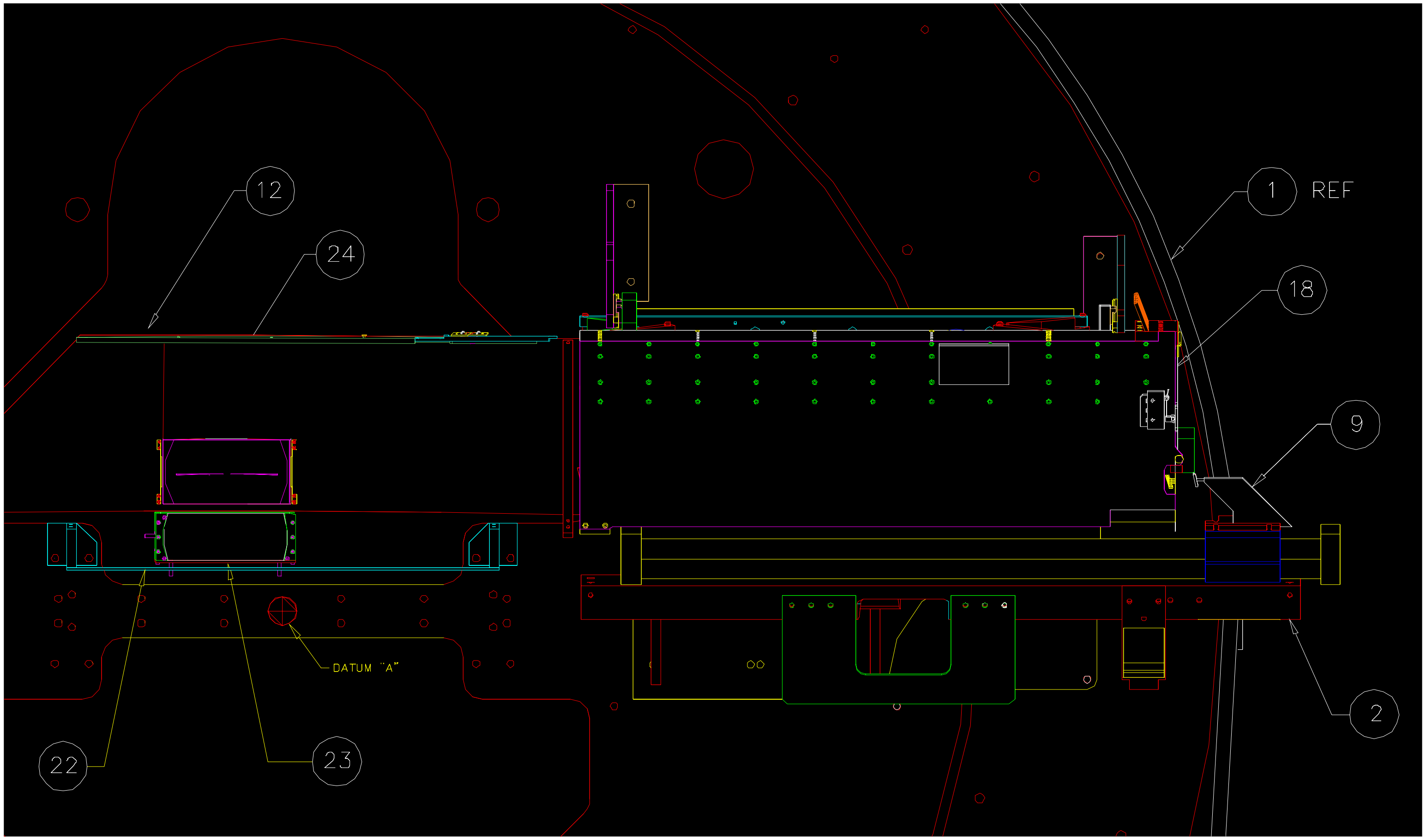


- Holds 11 masks, perhaps 12
- “Keyhole” drive; insertion mechanism air activated
- Slitmasks are “bare skins”, forced into curved cylindrical slitmask form and held by actuator pressure
- Simple: no mounting on separate holders required
- High position stability needed; x-motion not well corrected by FC system
- Interlocks detect insertion failures or masks that hang up on insertion arm

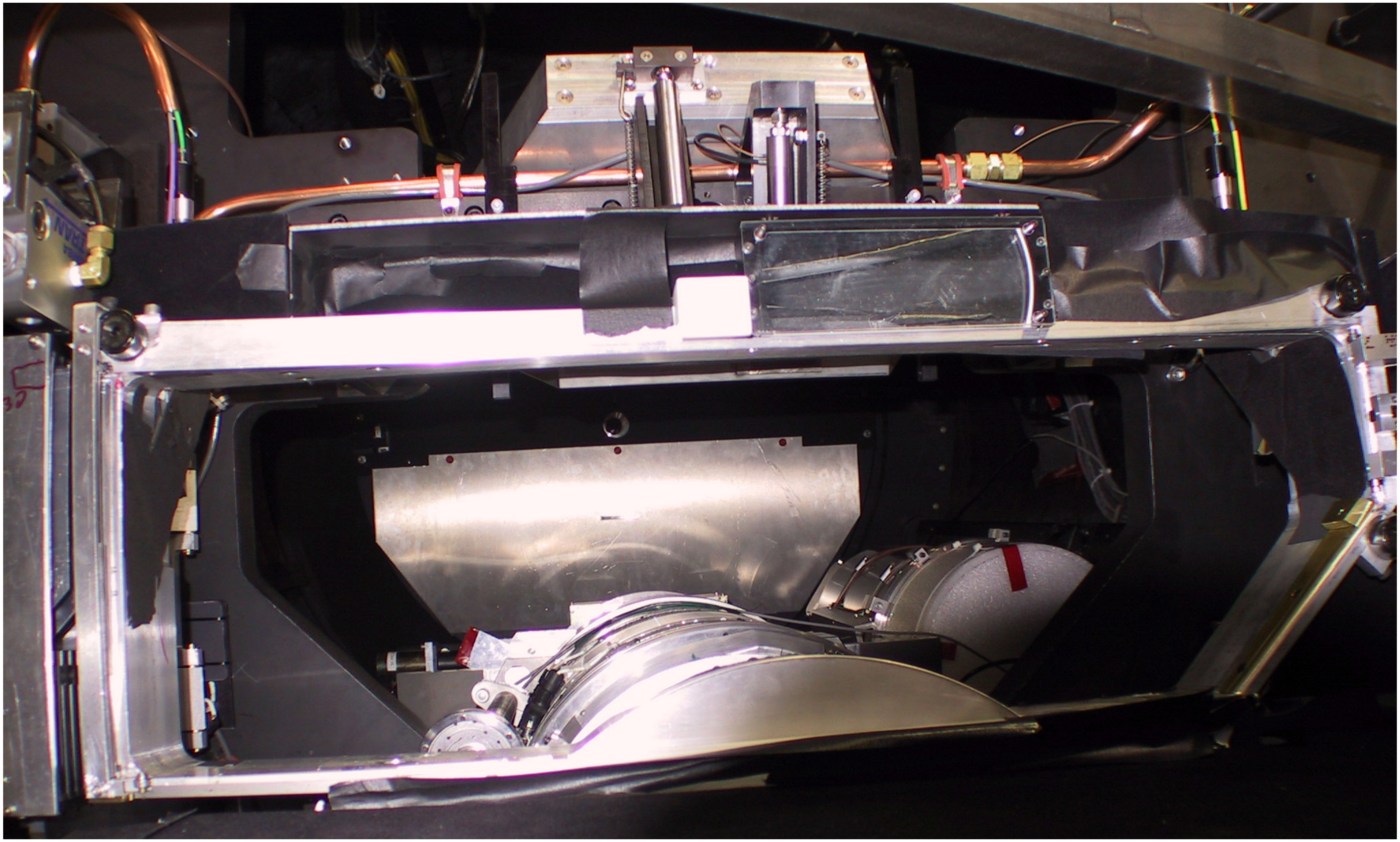
Slitmask System



Slitmask System



Slitmask Form



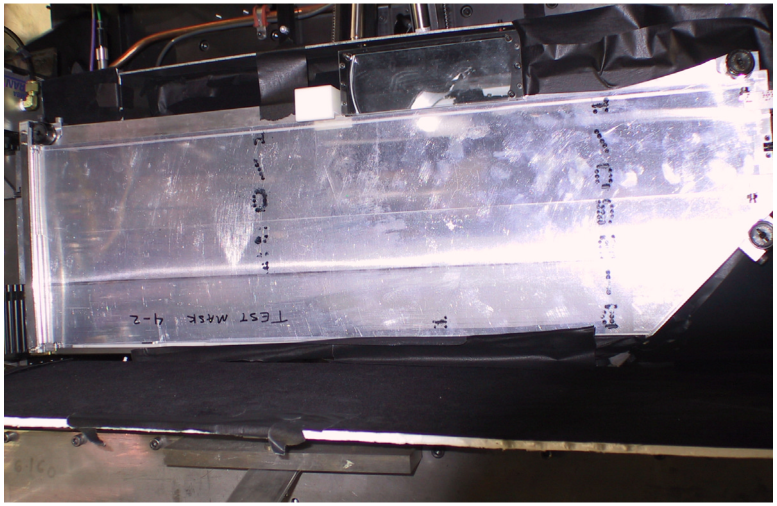
DEIMOS

Pre Ship Review- November 2001

Nov 11

Slitmask Cassette Requirements

	Specification	Achieved
SLITMASK CASSETTE/INSERTION:		
Number of masks	10	11 (perhaps 12)
Time to withdraw/insert	10 sec	10 sec
Time to change any two masks	70 sec	40 sec
Insertion requirements		
At all PAs while stationary	yes	yes
While slewing	yes	Not yet tested
Position tolerance of slitmask form in DEIMOS		
Absolute x, y, z	Loose	yes
Tip-tilt	+/-0.01 in at form edges	+/-0.01 in
Position stability of slitmask form in DEIMOS	See FC table	
Cassette design	"Caterpillar"	"Jukebox"

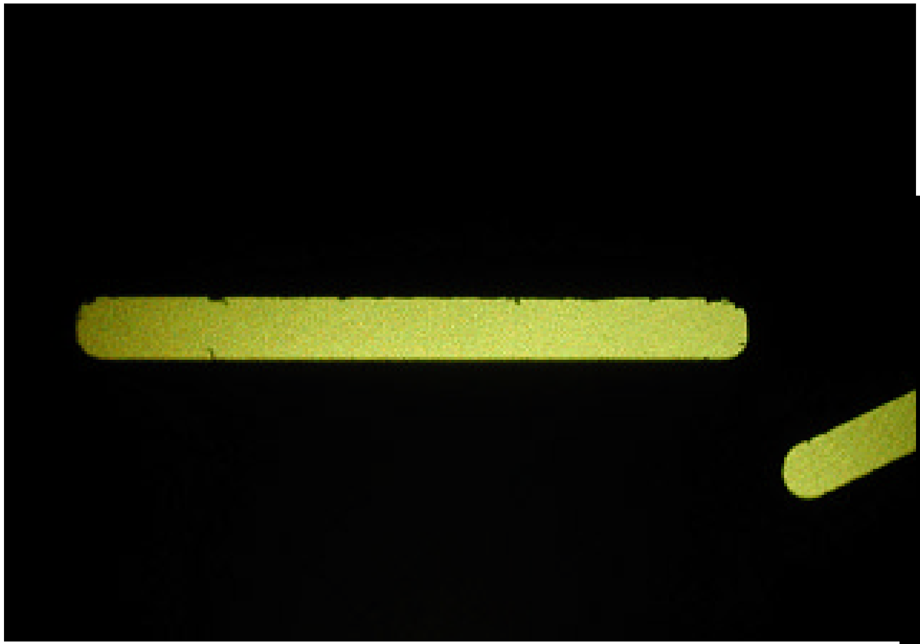


Slitmasks

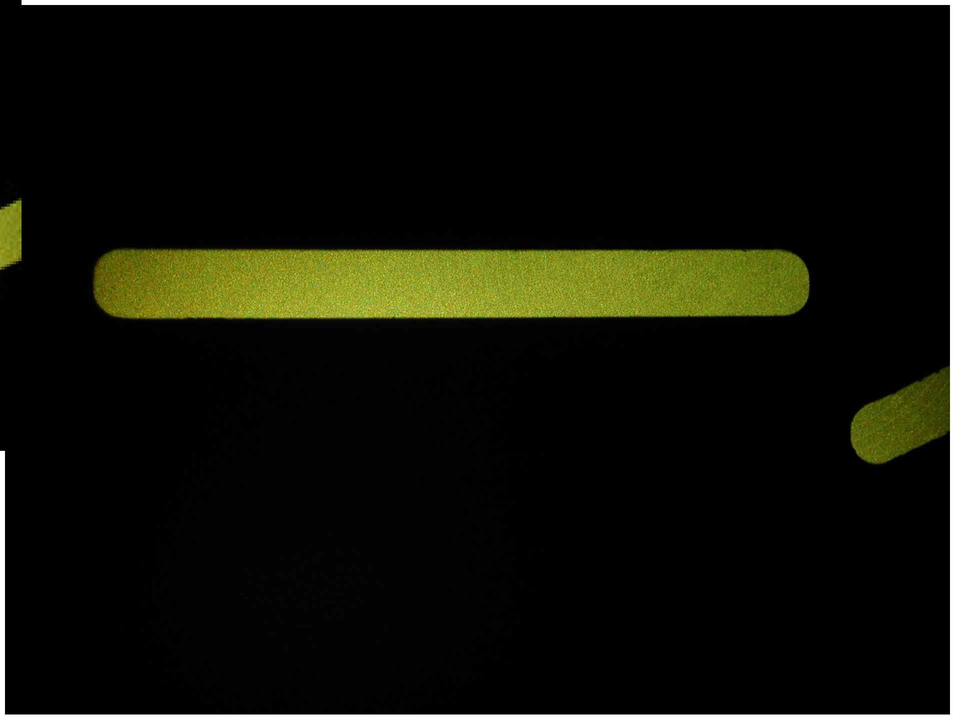
	Specification	Achieved
Slitmask design		
Shape in focal plane	Cylindrical	Cylindrical
Structure	Skin on frame	Bare skin
Material	Aluminum	Aluminum
Position repeatability of slitlets on reinsertion	0.02 asec = 14 mu = 0.17 px	Data being analyzed
Slitlets		
Edge smoothness	0.005 asec	Mostly smooth, few burrs ~0.03 asec
Position accuracy in mask	0.017 asec	5mu = 0.007 asec (manuf.; not tested)
Thermal pos'n error (5 C) along mask at end	0.05 asec in X	0.05 asec in X
Single-object guiding	Special longslit mirrors	Not at delivery; perhaps later

Slits: Width = 0.75 arcsec

Never cleaned, extensively used



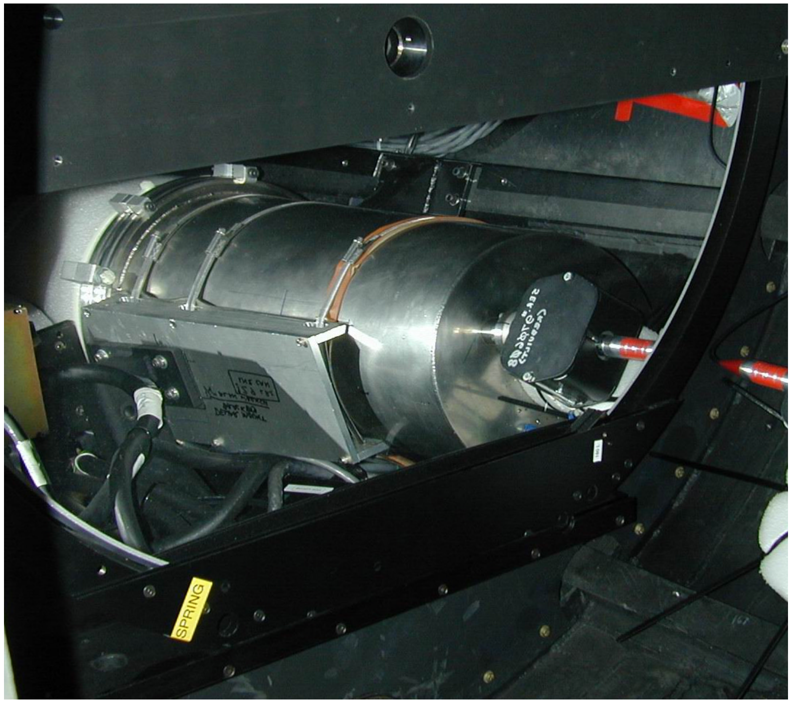
After careful cleaning



Slitmask System

- Test results

Collimator

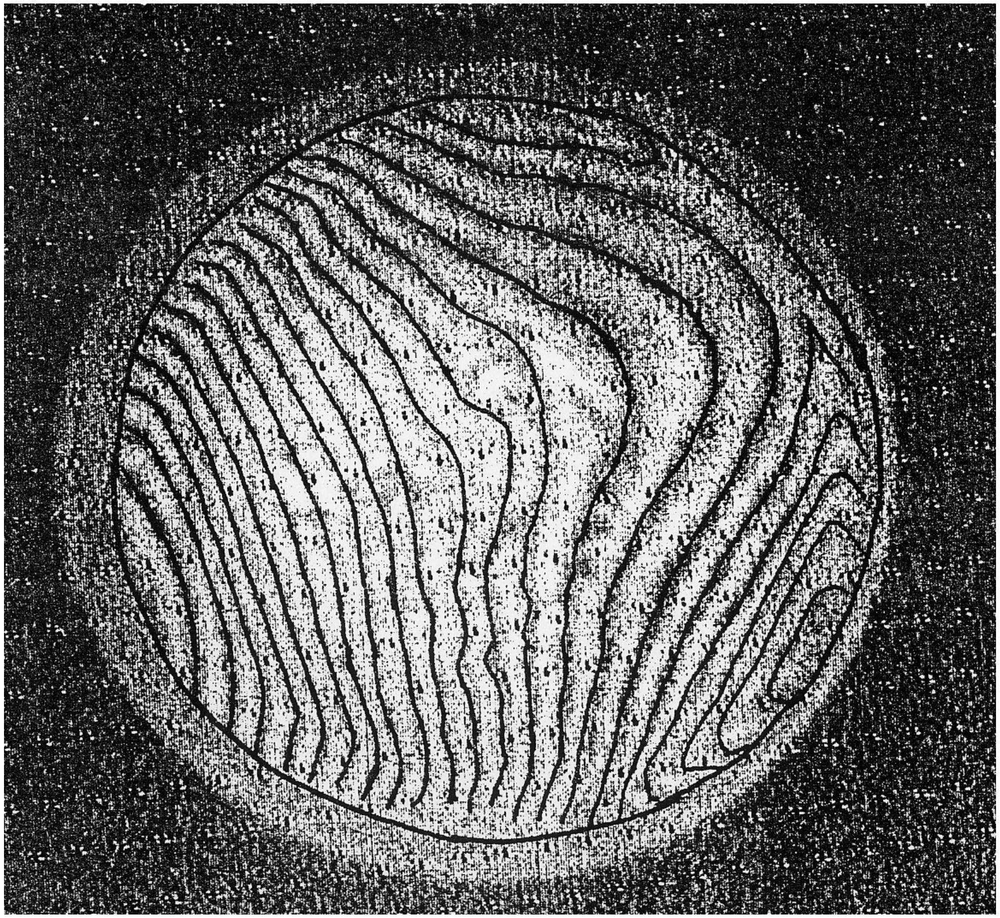


46.3 in dia; 3.45 in thick; 1.46 in sagitta; 4 in dia center hole; Zerodur; Weight 413 lbs

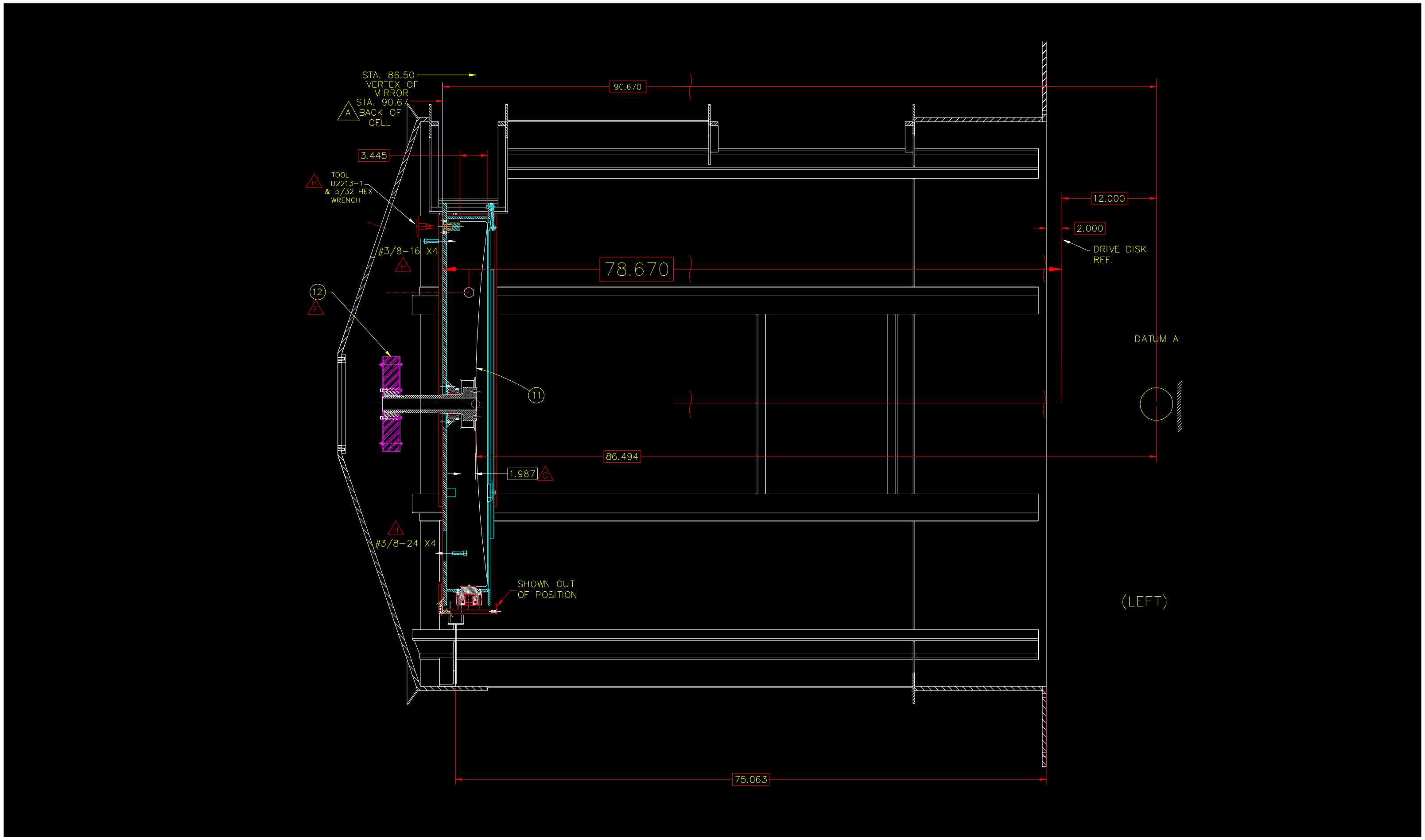
Collimator Requirements

	Specification	Achieved
Radius of curvature	173.000 in	172.968 in
Surface accuracy		
Max deviation	1/4 wave p-p	1/4 wave p-p
Large scale slope err	0.28 asec	0.22 asec
Small scale slope err	0.47 asec	0.40 asec
Position tolerance		
Axial location	0.02 in	0.02 in
Decenter	0.02 in	0.005 in
Position stability	See FC table	---
Coating	Silver	Silver planned

Collimator

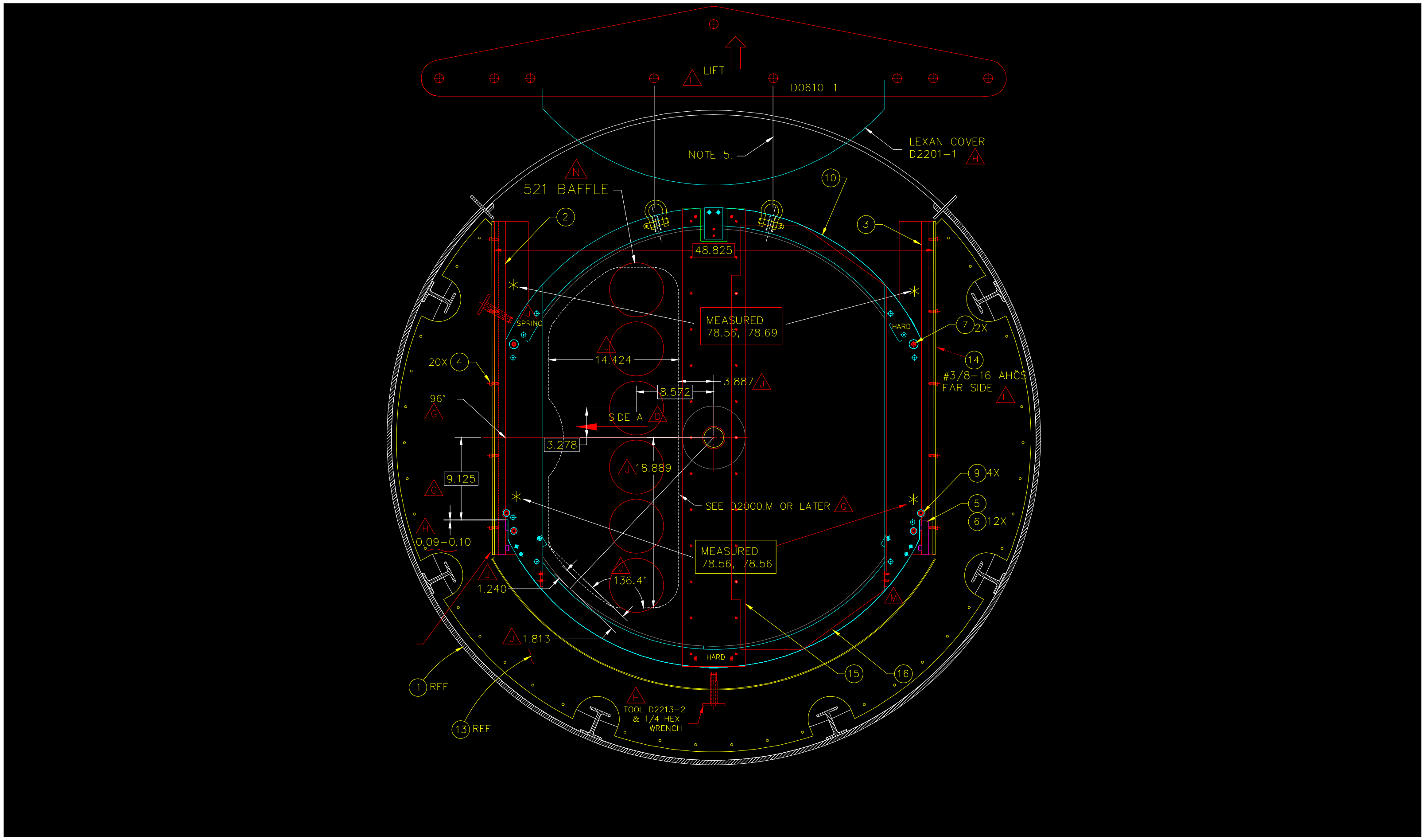


Collimator



STA. 86.50
VERTEX OF
MIRROR
STA. 90.67
BACK OF
CELL
90.670
3.445
TOOL
D2213-1
& 5/32 HEX
WRENCH
#3/8-16 X4
78.670
12.000
2.000
DRIVE DISK
REF.
DATUM A
86.494
1.987
#3/8-24 X4
SHOWN OUT
OF POSITION
(LEFT)
75.063

Collimator



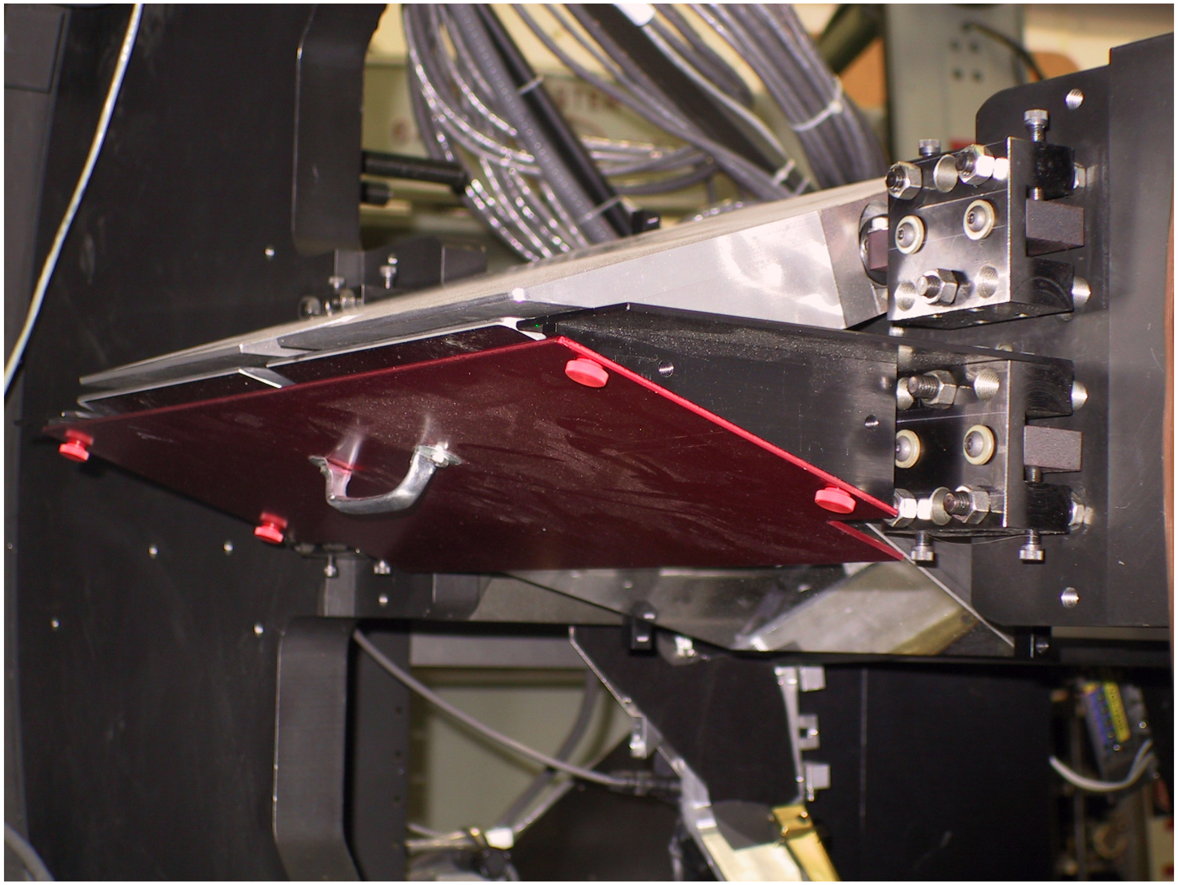
LIFT
D0610-1
LEXAN COVER
D2201-1
NOTE 5.
521 BAFFLE
48.825
MEASURED
78.56, 78.69
SPRING
HARD
20X
14.424
#3/8-16 AHCS
FAR SIDE
3.887
8.572
96°
SIDE A
3.278
9.125
18.889
4X
SEE D2000.M OR LATER
12X
0.09-0.10
MEASURED
78.56, 78.56
1.240
136.4°
1.813
REF
TOOL D2213-2
& 1/4 HEX
WRENCH

Collimator

Coating Plan

- We hope to have overcoated silver by Newport Thin Films
  - Preliminary coating designs are in hand
  - Negotiations are in progress

Tent Mirror

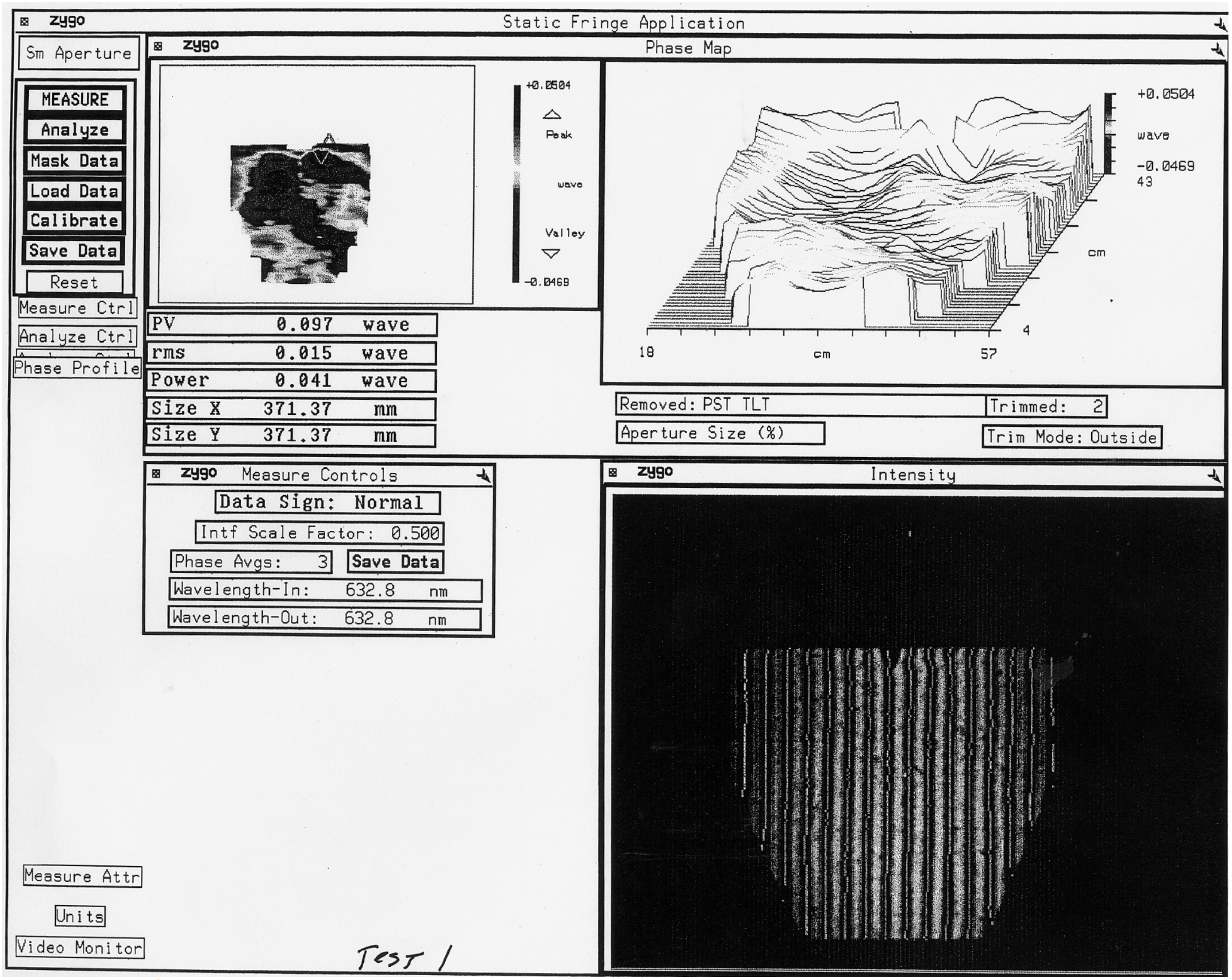


- Zerodur flat
- Approx 15.2 x 17.8 x 2 inch
- Weight approx 38 lbs

Tent Mirror Requirements

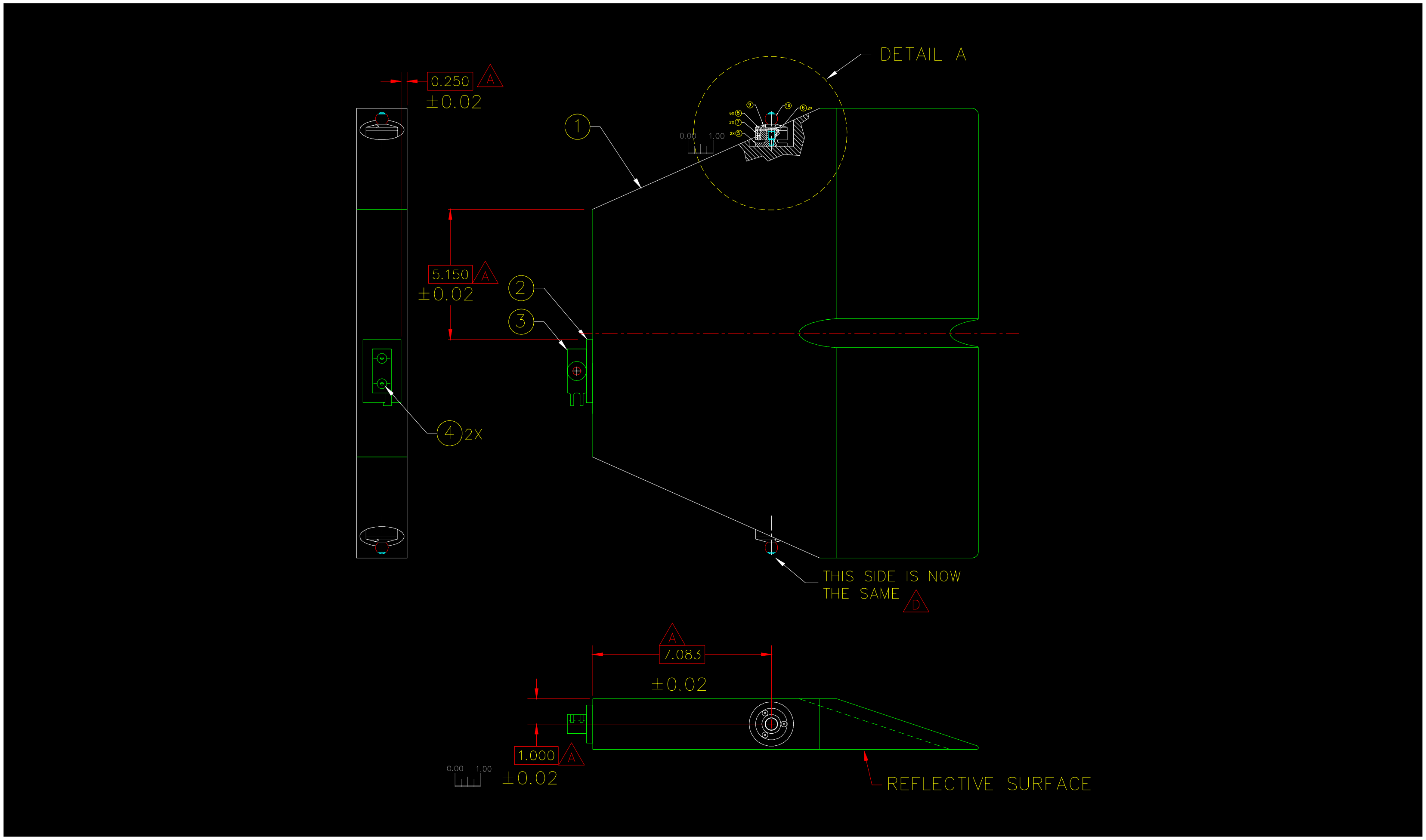
	Specification	Achieved
Surface accuracy		
Max deviation	1/16 wave p-p	1/10 wave p-p
Large scale slope err	0.07 asec	Not measurable
Small scale slope err	0.18 asec	Not measurable
Position tolerance		
Axial location	0.01 in	0.02 in
Tilt	1 amin	2 amin
Azimuthal angle	1 amin	2 amin
Position stability	See FC table	
Coating	Silver	Silver planned

Tent Mirror

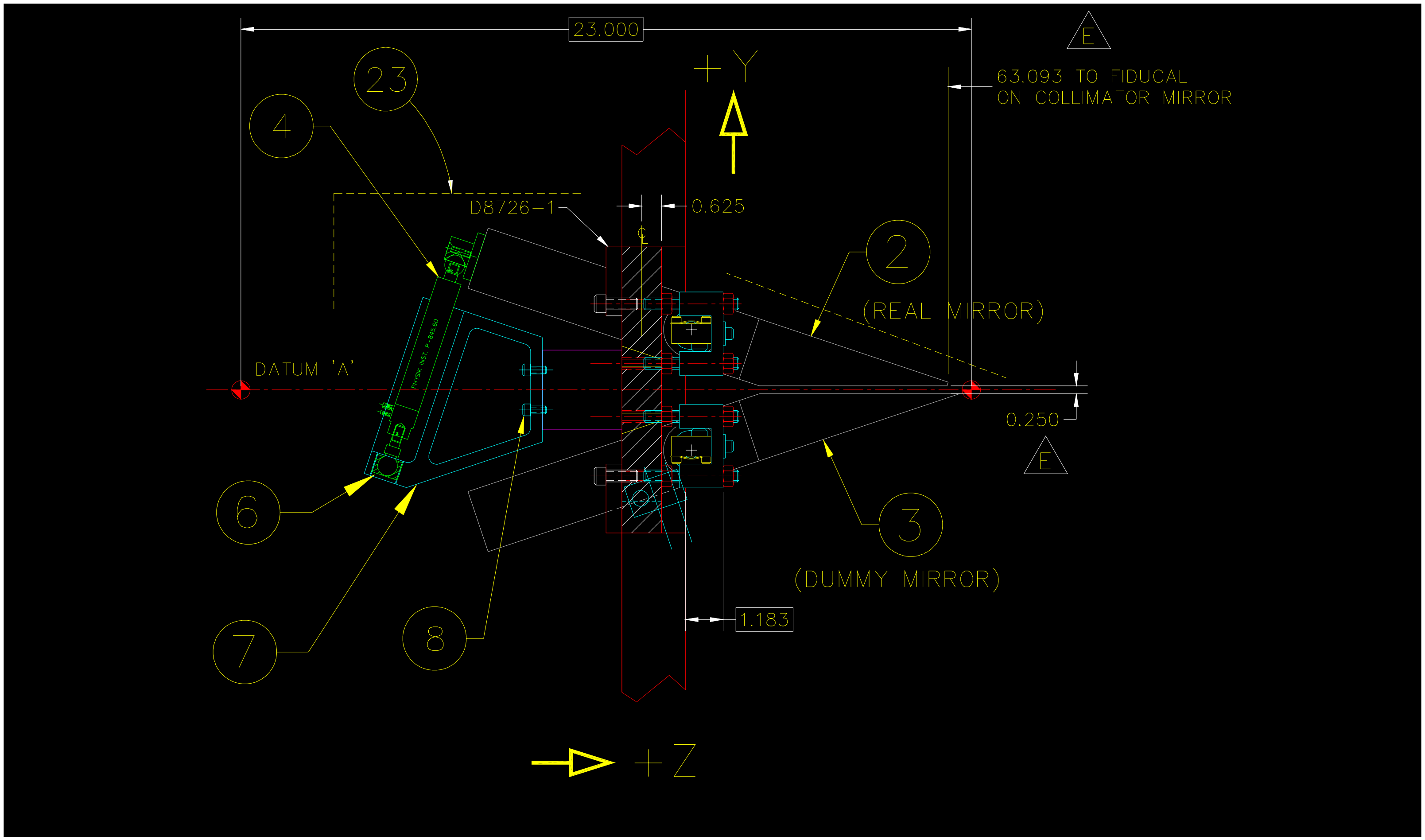


zygo
Static Fringe Application
Sm Aperture
MEASURE
Analyze
Mask Data
Load Data
Calibrate
Save Data
Reset
Measure Ctrl
Analyze Ctrl
Phase Profile
zygo
Phase Map
+0.0504
Peak
wave
Valley
-0.0469
PV 0.097 wave
rms 0.015 wave
Power 0.041 wave
Size X 371.37 mm
Size Y 371.37 mm
+0.0504
wave
-0.0469
43
cm
4
18
cm
57
Removed: PST TLT
Trimmed: 2
Aperture Size (%)
Trim Mode: Outside
zygo
Measure Controls
Data Sign: Normal
Intf Scale Factor: 0.500
Phase Avgs: 3
Save Data
Wavelength-In: 632.8 nm
Wavelength-Out: 632.8 nm
zygo
Intensity
Measure Attr
Units
Video Monitor
Test 1

Tent Mirror


DETAIL A
0.250
±0.02
1
5.150
±0.02
2
3
4
2X
THIS SIDE IS NOW
THE SAME
D
7.083
±0.02
1.000
±0.02
REFLECTIVE SURFACE

Tent Mirror

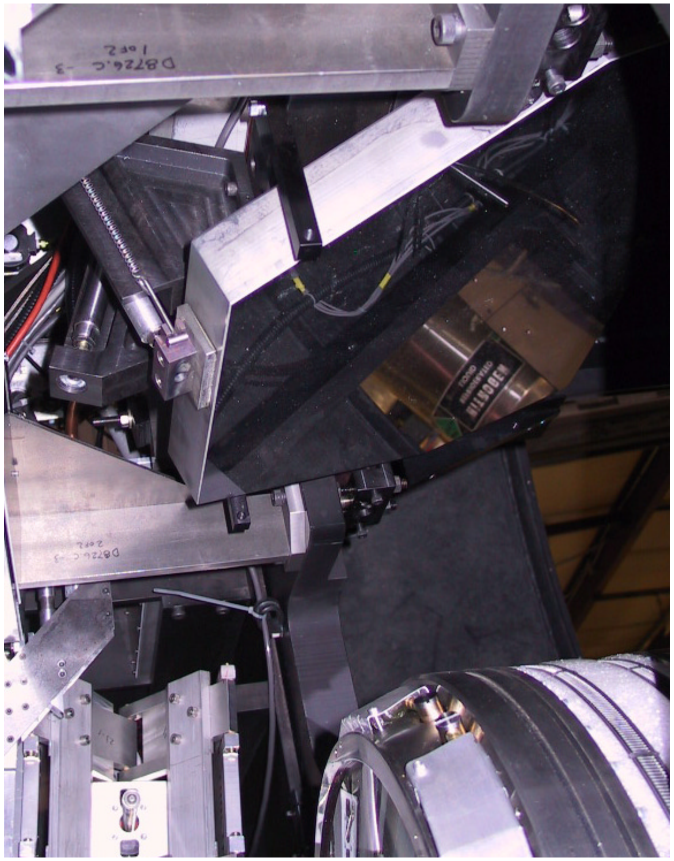

23.000
+Y
63.093 TO FIDUCAL
ON COLLIMATOR MIRROR
E
23
4
D8726-1
0.625
2
(REAL MIRROR)
DATUM 'A'
0.250
E
6
3
(DUMMY MIRROR)
1.183
7
8
+Z

Tent Mirror

Coating Plan

- We hope have over coated silver by Newport Thin Films
  - Preliminary coating designs are in hand
  - Negotiations are in progress

Flexure Control Y- Stage

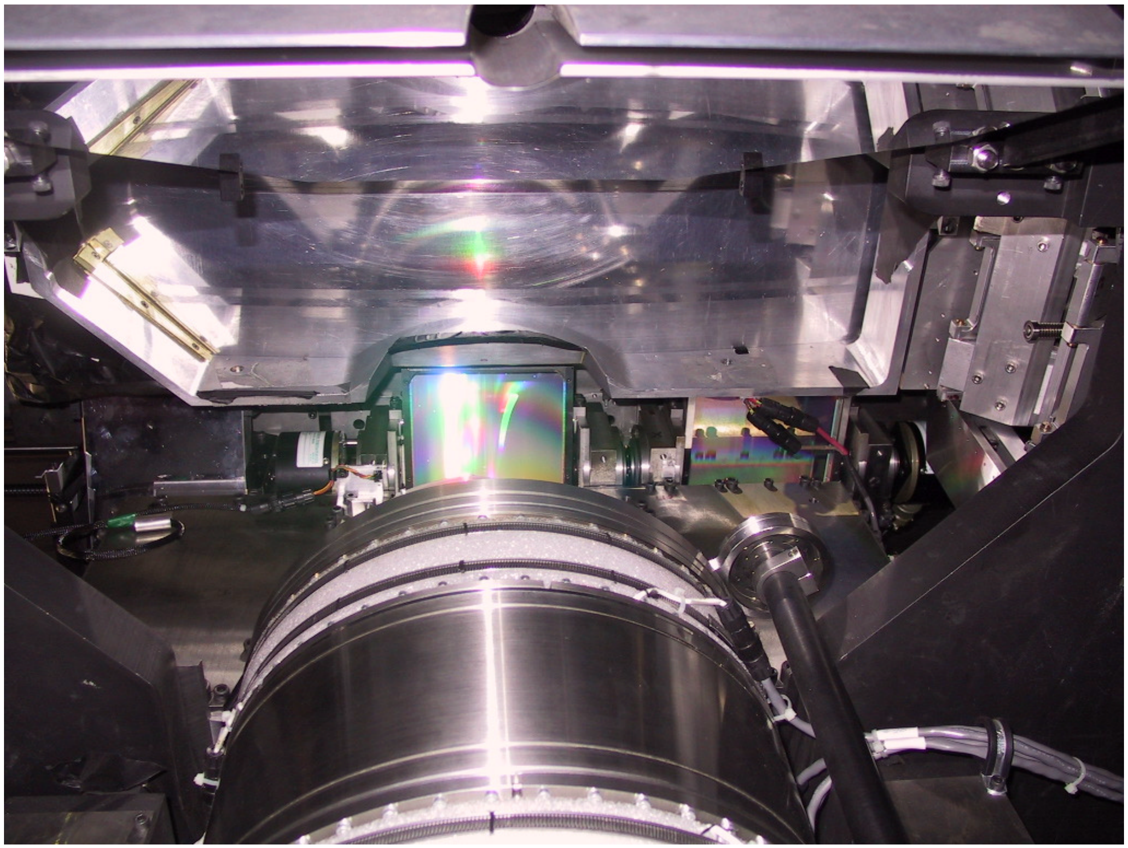


- Piezo actuator located at one end of tent mirror
- Moves image in Y direction +/- 10 pixels (theta X)
  - Total range of travel 90 microns
  - +/- 45 microns pivot to actuator

Flexure Control Y –Stage Requirements

	Specification	Achieved
Range of motion	20 px	21 px
Resolution	0.01 px	Data being analyzed
Repeatability	0.05 px	Data being analyzed
Backlash	0.05 px	Data being analyzed
Time to limits	No spec	1 sec

Grating System



- 3 grating and 1 mirror sliders
- Gratings individually tiltable and do not need to be re-tilted to move out of beam
- All sliders kinematically located in beam
- All 3 gratings are replaceable during daytime servicing

- Tilt servo drive (3 sliders)
- Transport servo drive
- 5 clamps (pneumatic)

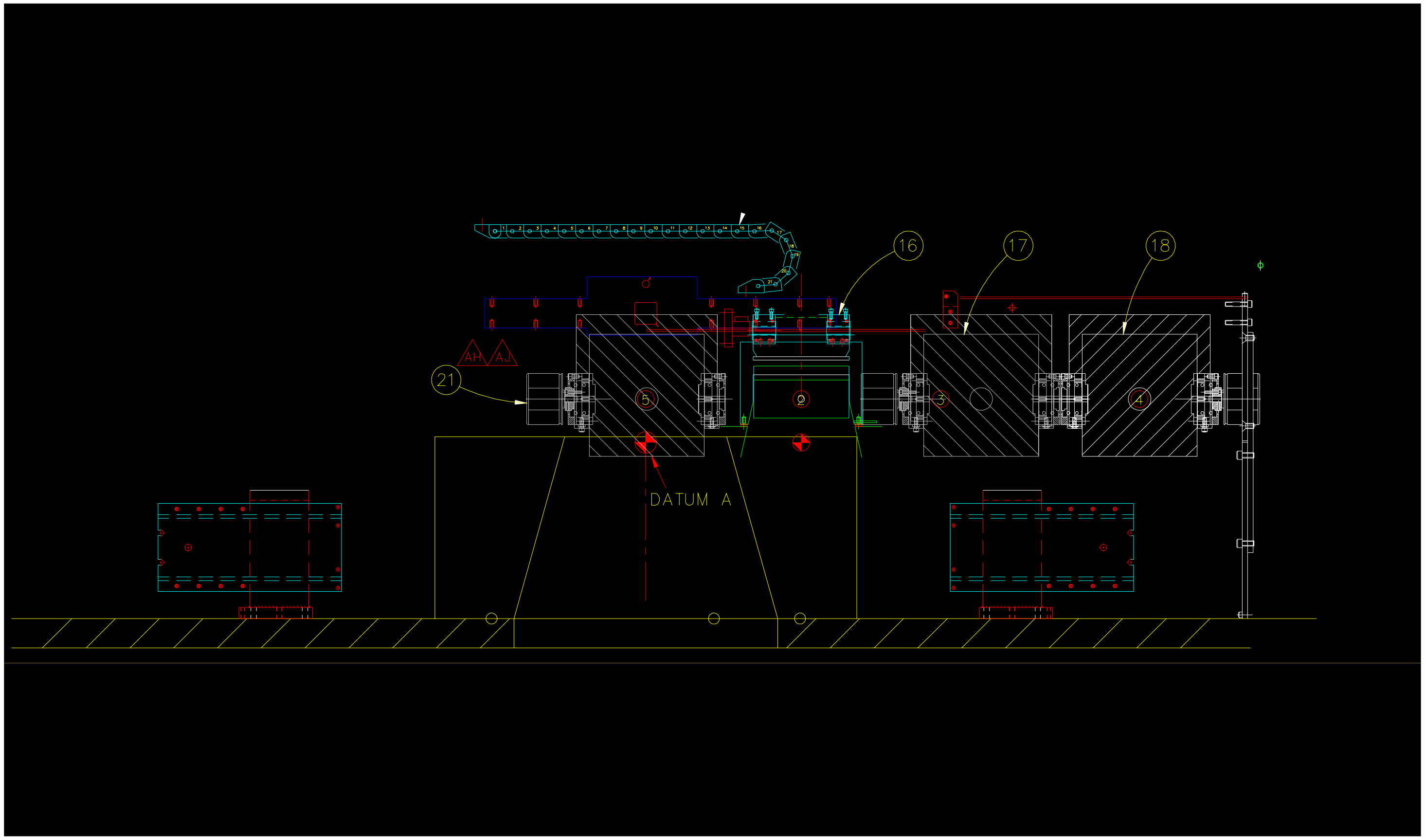
Grating System Requirements

	Specification	Achieved
Grating System, General:		
Imaging Mirror	1	1
Number of grating stations	3	2 presently; 3rd to be installed post-PSR (goal)
Number of delivered gratings	3 (600, 830, 1200)	3 (600, 900, 1200)
Stow needed between grating changes?	No	No
Grating exchange times		
Maximum time to change two gratings (now)	30 sec	Slider 2 to;3: 120 sec Slider 3 to;4: 120 sec Slider 2 to;4: 190 sec
Maximum time to change (with slider 5)	30 sec	Slider 5 to;4: 260 sec (extrapolated) Clamp/unclamp time = 66 sec Unclamp = 8 sec PRM search = 10-20 sec Set to PRM = 1 sec Clamp up = 15-20 sec

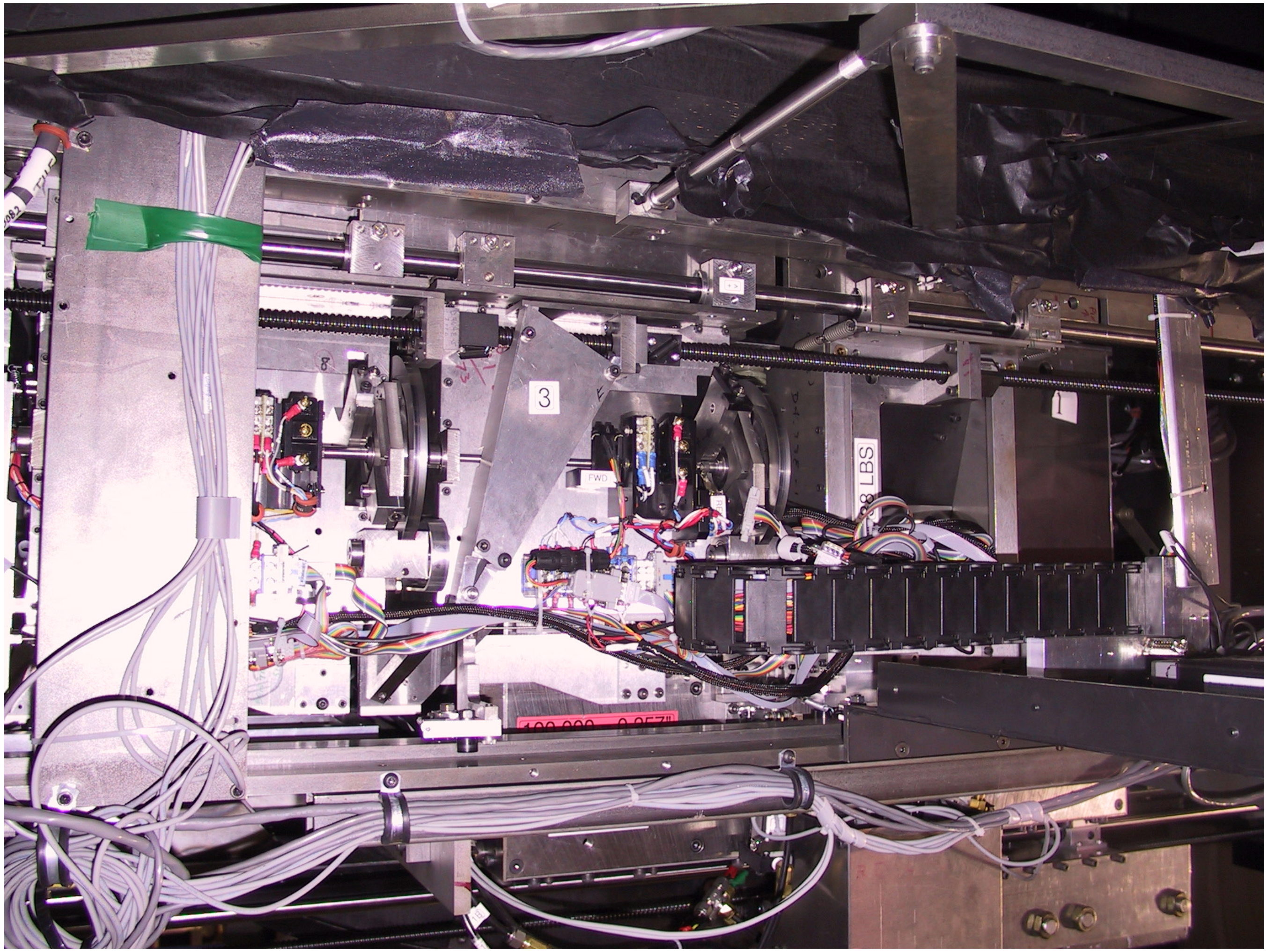
Grating System Requirements Continued

	Specification	Achieved
Largest grating	8 x 12 in	6 x 8 in
Clamp requirements		
At all PAs while slewing	yes	mostly
At all PAs while tracking	yes	yes
Grating protection		
Protective covers	yes	yes

Grating System



Grating Transport Mechanism



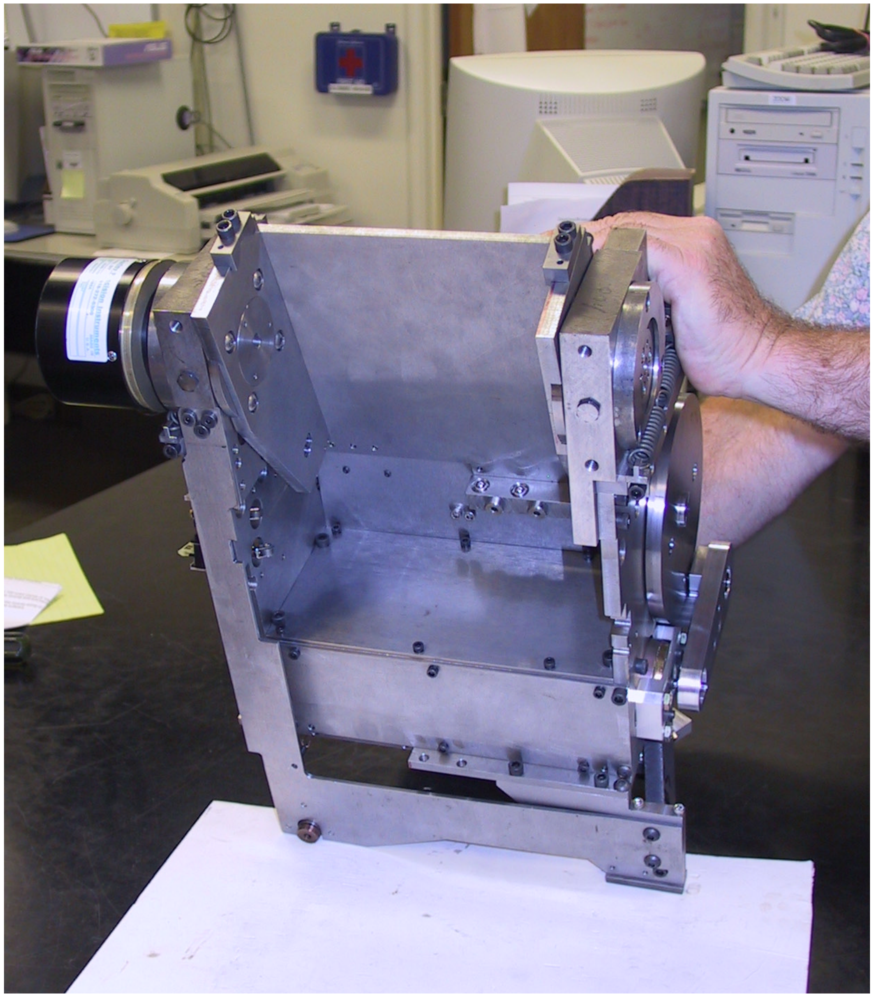
Grating Transport Mechanism

- Drives 3 grating sliders and one imaging mirror slider on lead screw with counterweight
- Position found using precision reference mark (PRM); then pinned and clamped with 5 pneumatic clamps
- Drive accuracy needed to place pin in hole: 0.015 inches
- Clamps reliably in all PAs while tracking
- Drive mechanism is much slower than specification. Could be speeded up with bigger motor (but packaging would be difficult)
- For flexure data, see FC system

Transport Mechanism Requirements

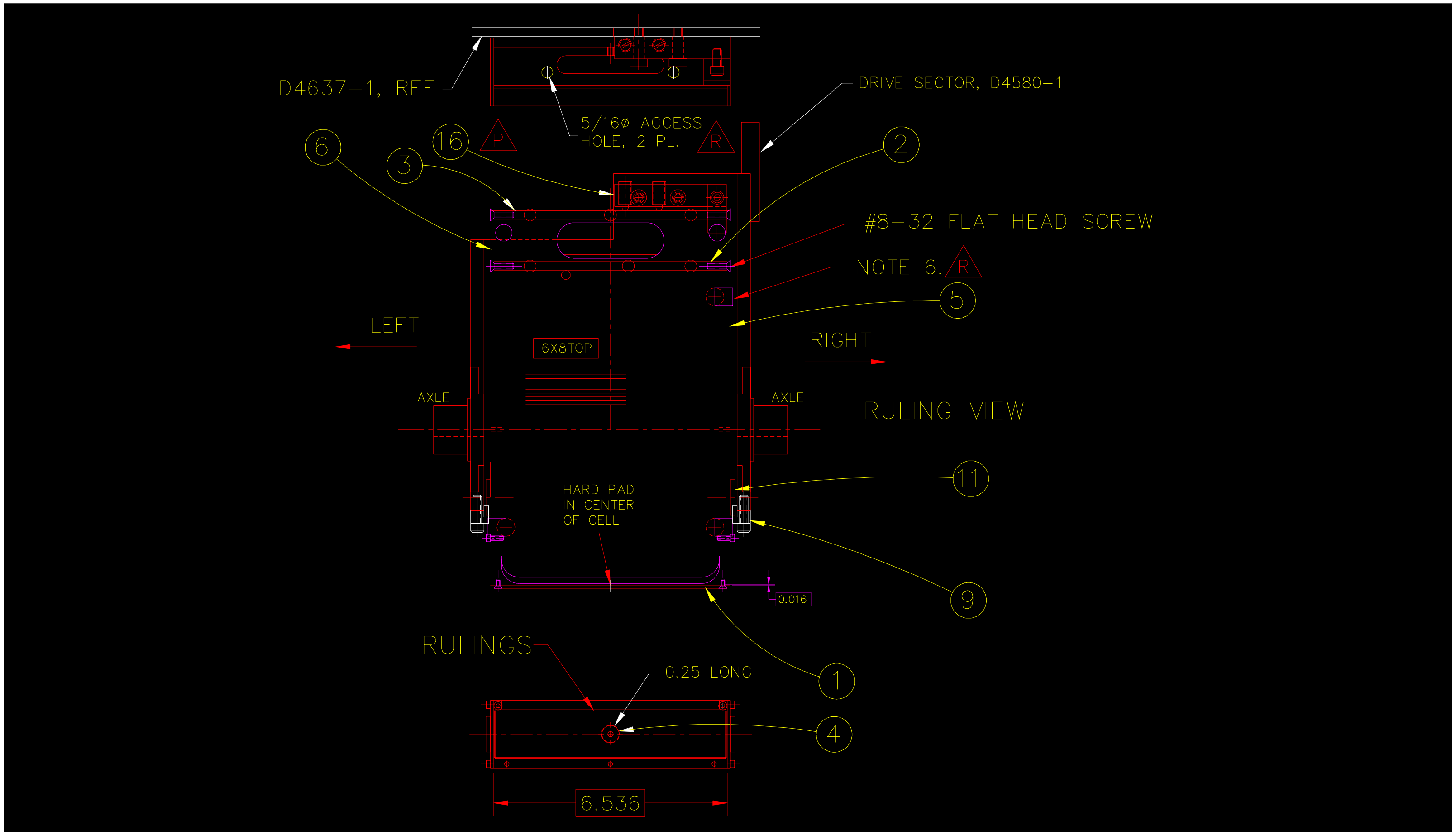
	Specifications	Achieved
Accuracy needed to seat pin	No spec	+/-0.015 in
Time to limits	25 sec	175 sec

Grating System

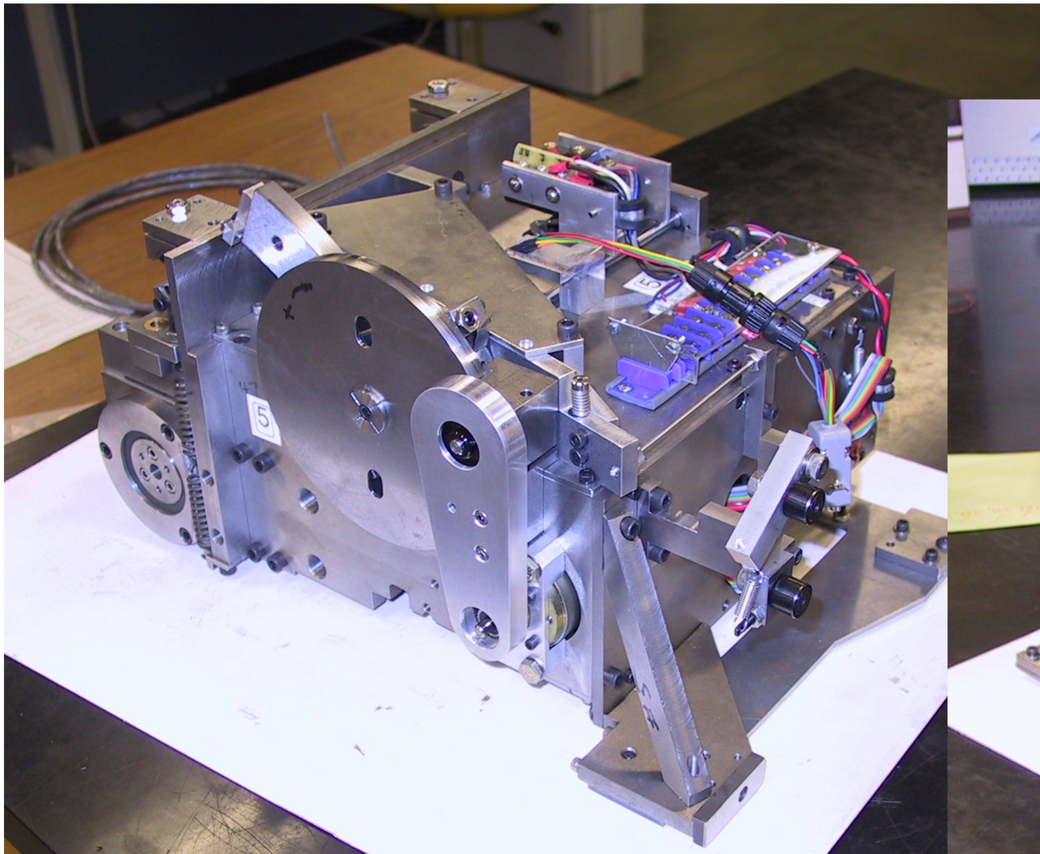


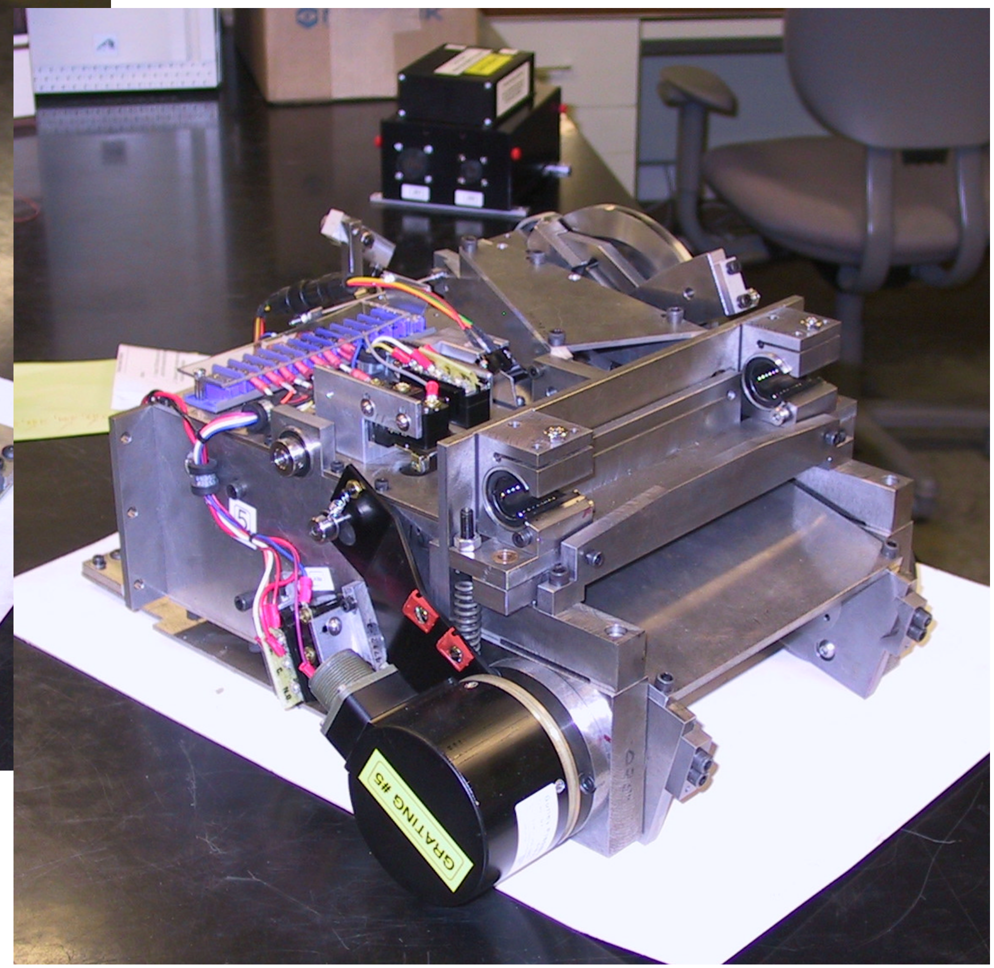
- Sliders have tilting holders to accept grating in cells
- Tilt angle measured with Gurley encoders; resolution is 1.4 arcsec
- Tilt maintained by centering on step between counts; tilt stability is ¼ encoder counts
- Gratings loaded at special load position via loading “chute”; with protective covers
- Cells and sliders will be aligned so that spectrum position and angle is constant on interchange of gratings (see specs)
- Slider weight: 64 lbs; imaging slider weighs 38 lbs

Grating System



Grating System





Grating Tilt/Slider Requirements

	Specifications	Achieved
Tilt resolution, one encoder count	1.4 asec = 0.3 px	1.4 asec = 0.3 px
Tilt "dither"	+/-0.1 ct = 0.03 px	+/-0.125 ct = 0.04 px
Repeatability	0.1 ct	0.125 cts
Time to limits	85 sec	42 sec
Position stability	See FC system	

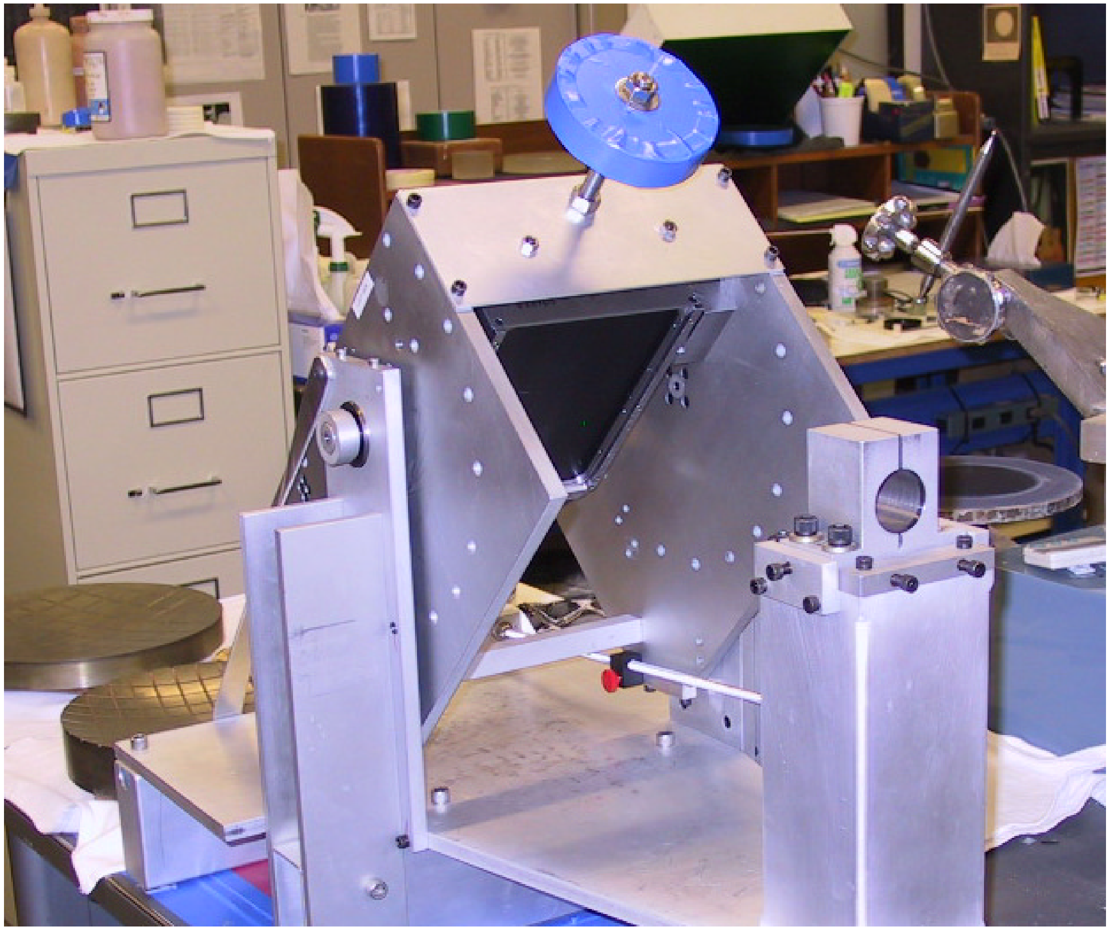
Spectral Alignment

	Specifications	Achieved
Alignment of gratings in cells		
Pitch	+/-20 asec +/- 5px	Not yet adjusted; predict will be +/- 40 asec
Roll	+/-50 asec = +/- 1 px @ detector edge	Data being analyzed; predict will be +/- 40 asec
Spectra to CCD cols	+/-5 px @ ends	Data being analyzed; spec is now +/-10 px @ ends for red mosaic
Spectral X coord		
Absolute	+/-20 px	Not yet adjusted
Uniformity	+/-10 px	Not yet adjusted

Grating System Test Results

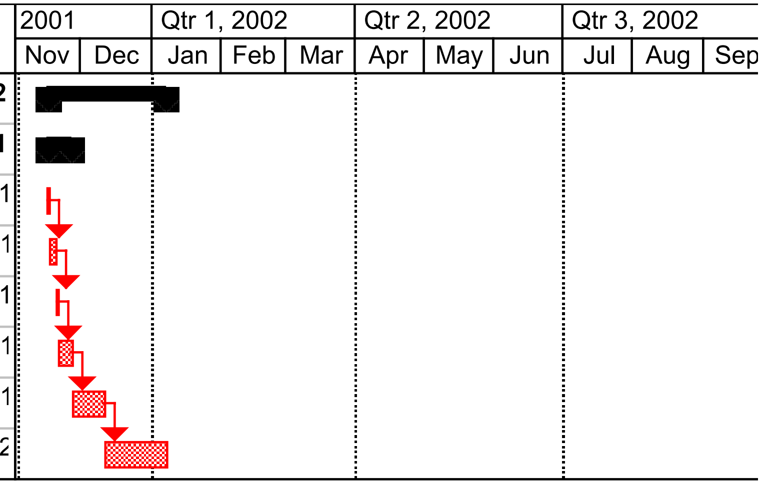
- Tilt
- Transport

Grating Installation into Cell Jig

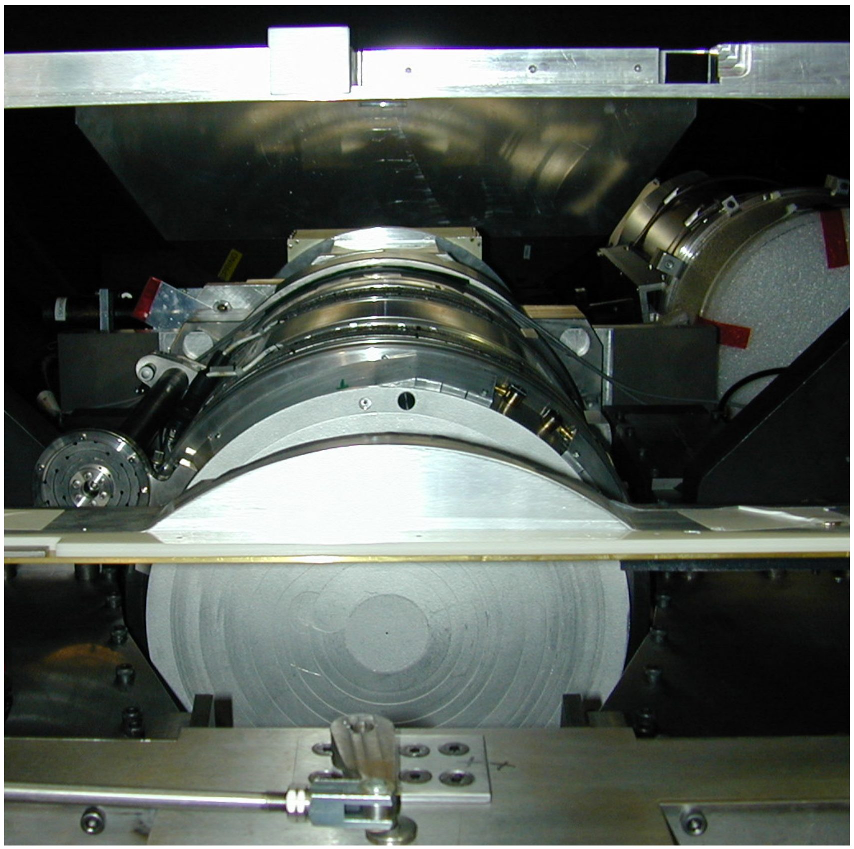


Slider 5 Installation

ID		Task Name	Duration	Start	Finish
1		**Post Pre-ship review**	**27.5 days**	**Thu 11/15/01**	**Mon 1/7/02**
2		**Slider 5 installation**	**5.5 days**	**Thu 11/15/01**	**Mon 11/26/01**
3		install slider 5	12 hrs	Thu 11/15/01	Fri 11/16/01
4		install grating baffling	8 hrs	Fri 11/16/01	Mon 11/19/01
5		install new counter weight sprockets	8 hrs	Mon 11/19/01	Tue 11/20/01
6		test	2 days	Tue 11/20/01	Mon 11/26/01
7		Post Pre-ship Review	10 days	Mon 11/26/01	Mon 12/10/01
8		Disassemble DEIMOS	12 days	Mon 12/10/01	Mon 1/7/02



Camera



- 9 optical elements plus filter and dewar window
- High optical throughput: >85% beyond 5200A
- 3 large CaF2 elements
- Multiplets coupled with Cargille laser liquid
- Radial supports
  - Element 3 –shims
  - All others : cast in place athermalized RTV seals
- Typical assembly tolerances: 0.001in
- AR coatings by Coherent; avg reflectivity per surface is 1.1%
- Body 4 has x,y decenter adjustments for final coma minimization
- Thermal compensator stablizes plate scale to 0.1 px rms from –5C to 5C

Camera Requirements

		Specifications	Achieved
Wavelength range		0.39-1.1 mu	0.39-1.1 mu
Throughput (PDR)			
Glass:	>5200A	91%	97%
	4400A	82%	93%
	4000A	No spec	90%
	3900A	50%	87%
Total:	> 5200A	83%	85%
w/AR	4400A	No spec	81%
coat'gs	4000A	No spec	77%
	3900A	No spec	71%
Coatings		Solgel	Conventional
Avg. refl/surf		No spec	1.1%

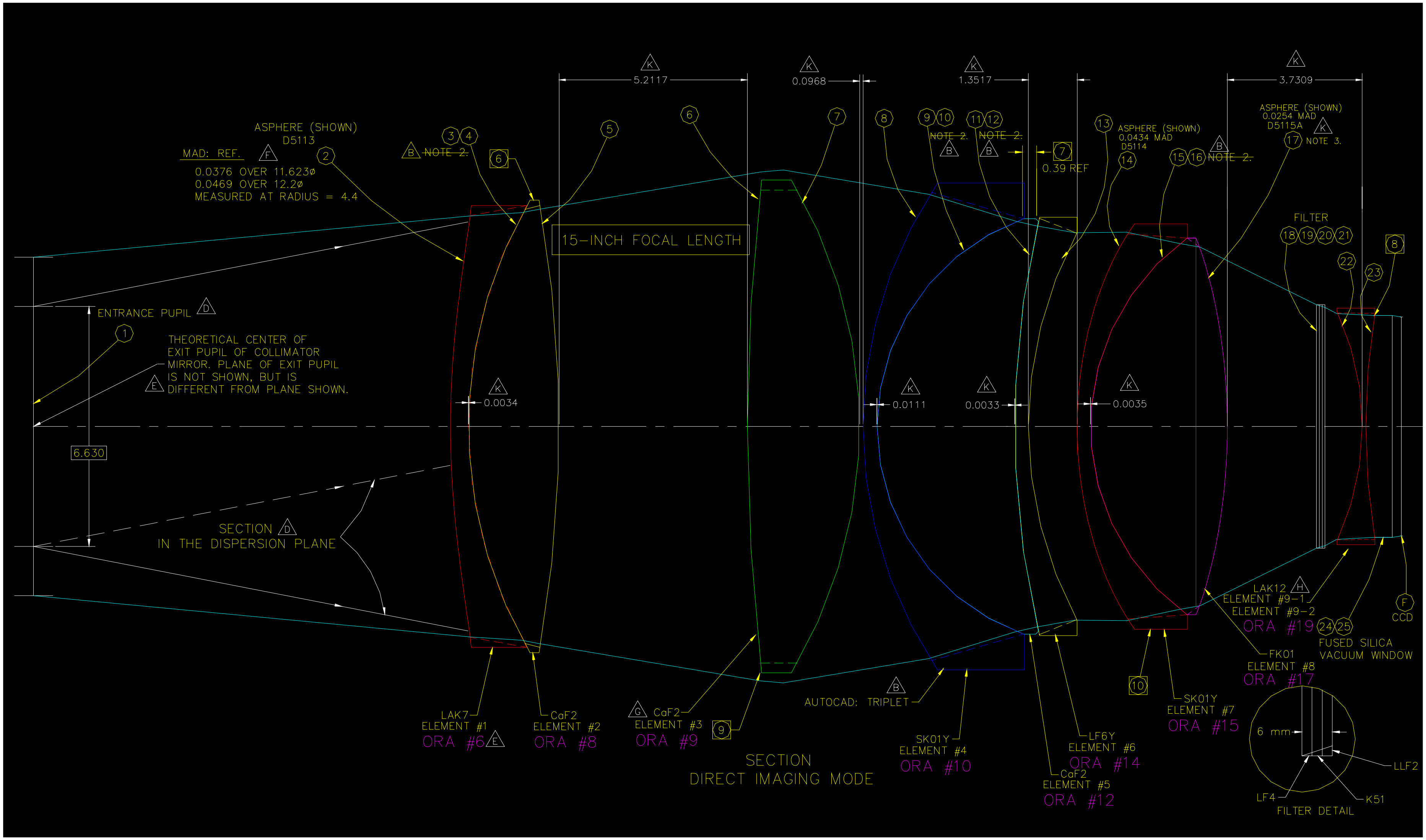
Camera Requirements, Continued

	Specifications	Achieved
Lens fabrication errors		
Surface accuracies	See Camera CDR	All OK
Wedges, thicknesses	See Camera CDR	Two wedges slightly over spec
Aspheric decenters	0.001 in	El 1: 0.0016 in
		El 7: 0.0146 in
		El 8: 0.0144 in
		(minor optical effect)
Refractive indices	See Camera CDR	All OK
Typical assembly tolerances		
Decenters, tilts	0.001 in	Two elements decenter under gravity: El 3: .0027-.0034 in
		Body 4: .0008-.0016 in
Axial	0.002-0.005 in	No separate test

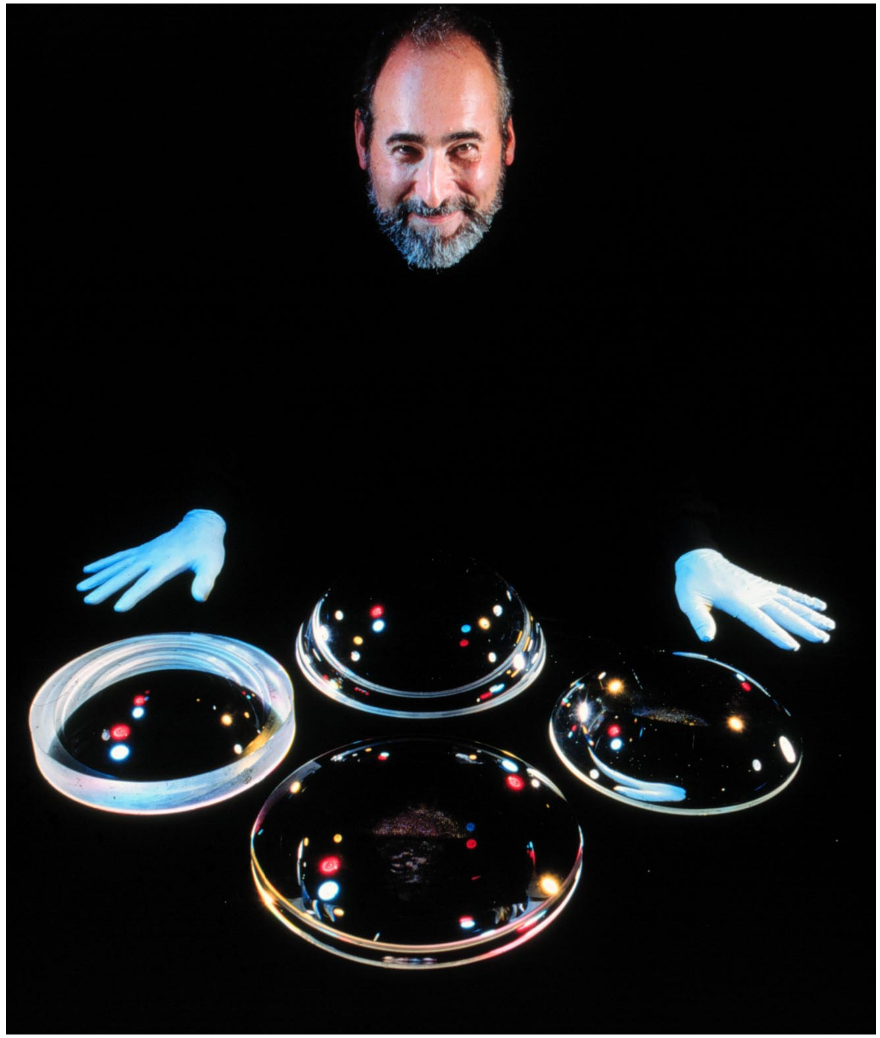
Camera Requirements, Continued

	Specifications	Achieved
Thermal compensator		
Geom focus blur	0.04 asec	Not yet tested
Plate scale change	0.1 px rms over 5 C @ detector edge	Not yet tested

Camera Optics

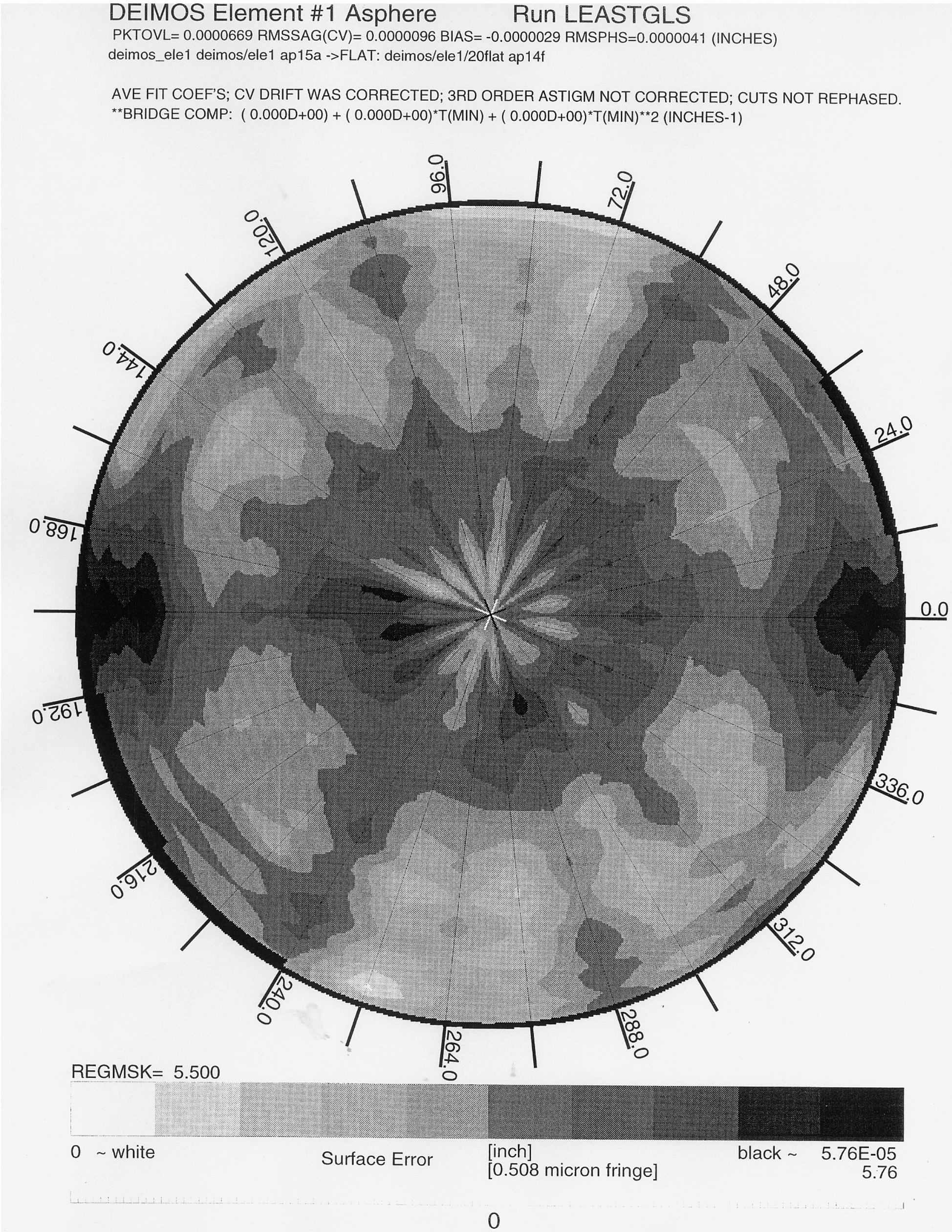


Camera Optics



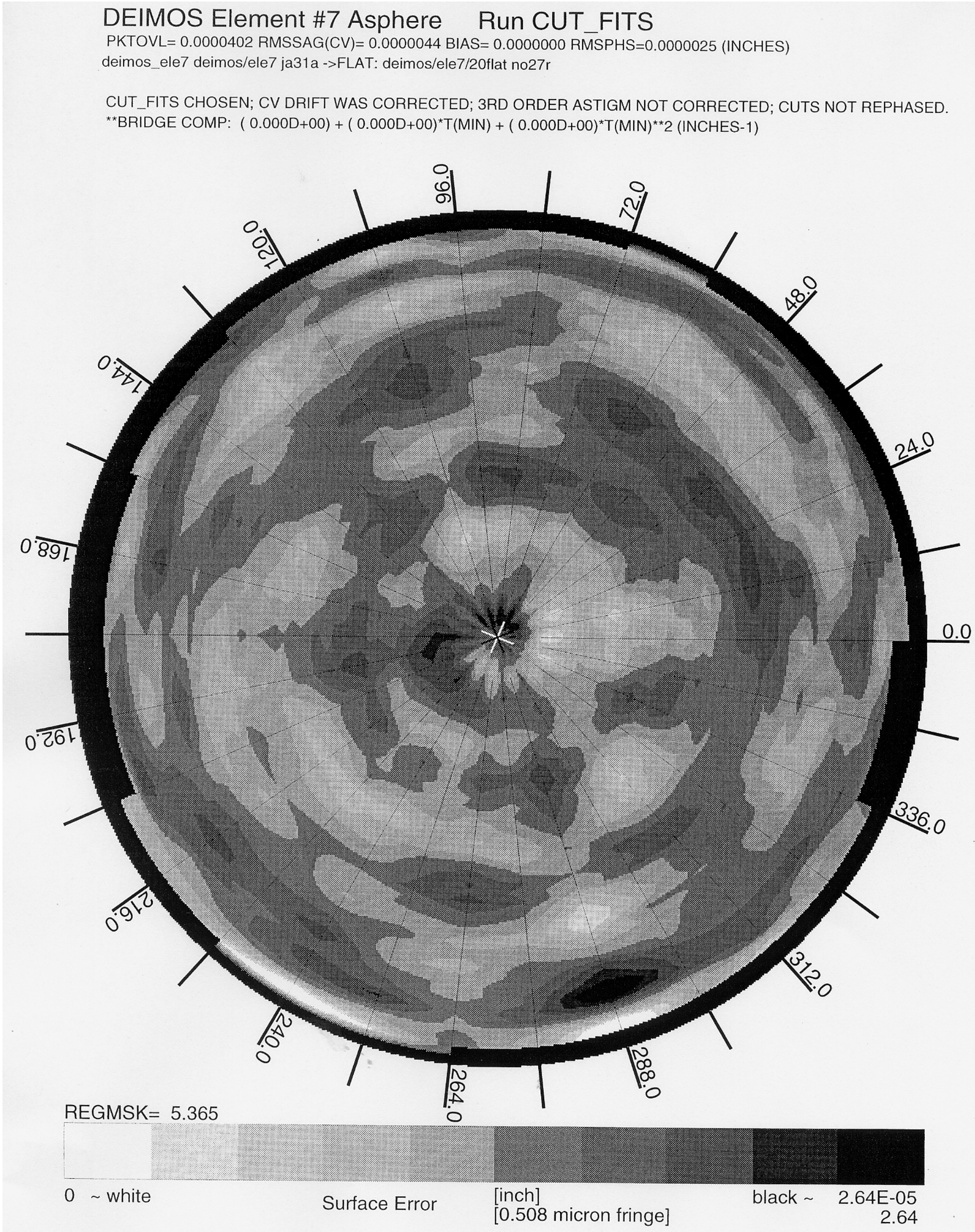
DEIMOS Camera Elements

					DEIMOS					
			Design Vs. Achieved Data. All Elements. 04.05.99 GKL					GKL		
		Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7	Element 8/#2	Element 9/#2
R1	Design	636.73	313.97	1508.2	304.57	154.713	629.622	300.43	162.74	191.945
	Achieved	637.074	313.883	1509.08	304.532	154.722	629.679	300.471	162.665	191.906
	Error*	.344	–.087	.88	–.038	.009	.057	.041	–.075	–.039
	% Error*	0.0539	0.027	0.058	0.0124	0.0058	0.009	0.013	0.046	0.0203
	Profile	CX/Asph.	CX/Sph.	CX/Sph.	CX/Sph.	CX/Sph.	CX/Sph.	CX/Asph.	CX/Sph.	CC/Sph.
R2	Design	314.04	908.69	336.02	154.79	629.698	287.879	162.82	441.427	500.46
	Achieved	313.927	908.028	336.038	154.767	629.64	287.773	162.736	441.387	499.941
	Error*	0.113	0.662	–0.018	0.023	0.058	0.106	0.084	0.04	0.519
	% Error*	0.0359	0.072	0.005	0.015	.009	0.0368	0.0515	0.009	0.104
	Profile	CC/Sph.	CX/Sph.	CX/Sph.	CC/Sph.	CC/Sph.	CC/Sph.	CC/Sph.	CX/Asph.	CC/Sph.
A.T.	Design	12.7	63.5	78.74	9.525	96.52	9.525	9.525	96.5	2.54
	Achieved	12.57	63.6	78.76	9.597	96.62	9.57	9.25	96.07	2.603
	Error *	0.13	–0.1	–0.02	–0.072	–0.1	–0.045	0.275	0.43	–0.063
	% Error*	1.023	0.157	0.0253	0.007	0.1035	0.047	2.887	0.447	2.42
WEDGE	Design	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.0254	0.254	0.0254
	T.I.R.	0.004	0.0178	0.008	0.005	0.035	0.01016	0.038	0.06	0.015
	Seconds	2.6	11.5	4.7	3.02	24.7	7.14	27.5	46.8	18.6
OFFCTR THO/DEG		114.08						78.89	117.25	
OFFCTR/INCHES		0.0016						0.0147	0.0144	
AZIMUTH HIGH @	Degrees	323						331	194	
DIAMETER	Design	309.9	317.5	345.85	340.41	292.1	292.1	284.5	264.2	165.66
	Achieved	309.9	317.66	345.85	341.53	292.02	293.547	284.44	264.36	165.93
	Error*	0	.16	0	1.12	–.08	1.447	–.06	.16	.27
Comments:										
Made By:		DH	DH	DH	GKL	DH	DH/GKL	DH	DH/GKL	GKL
		* All achieved specs are within design tolorances. Error here indicates diviation from the nominal specs specified.								
		All trailing zeros are discarded by the software								



Element 1-Asphere Surface Error

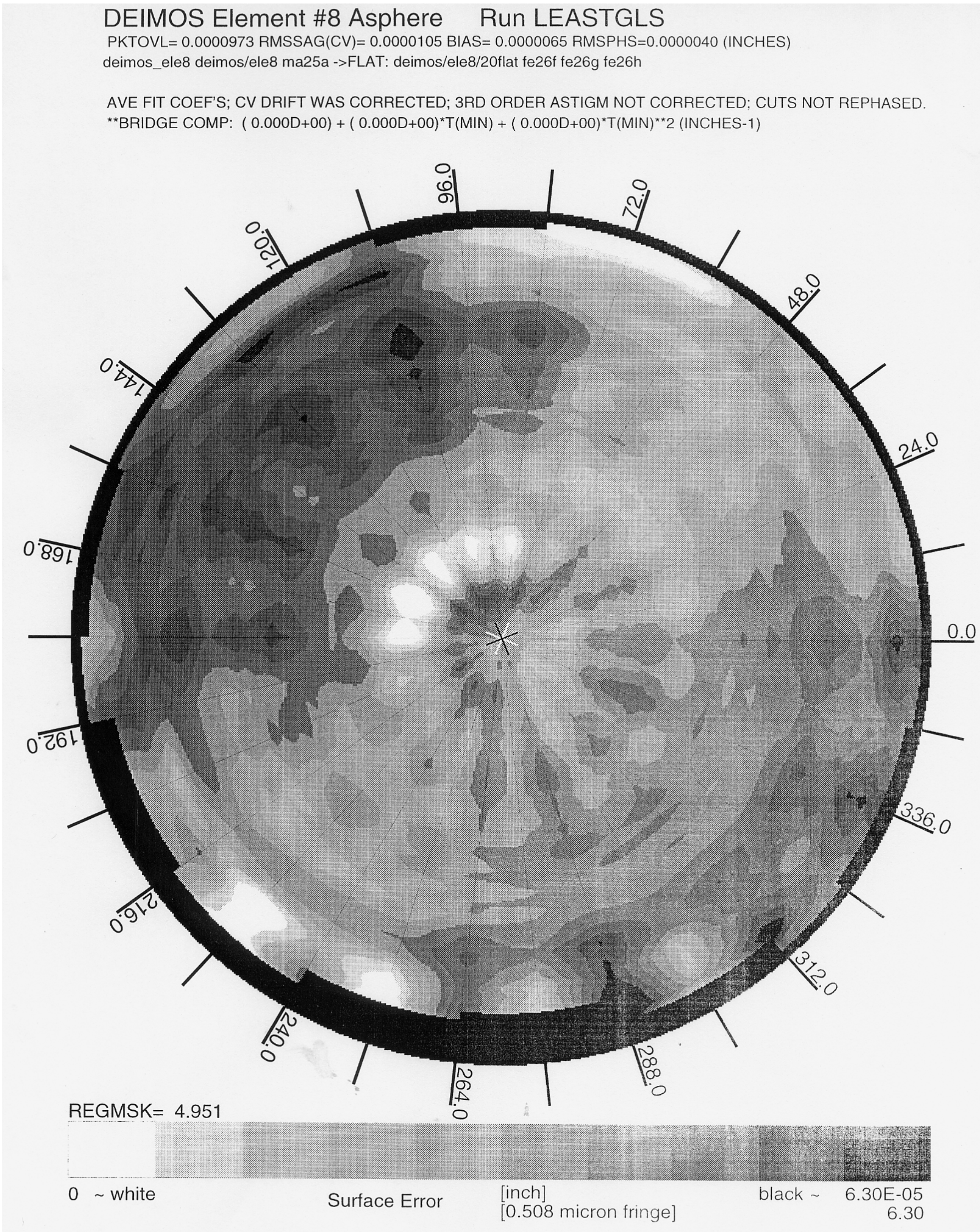
Black- 1.5 microns



Element 7-Asphere

Surface Error

Black- 0.67 microns

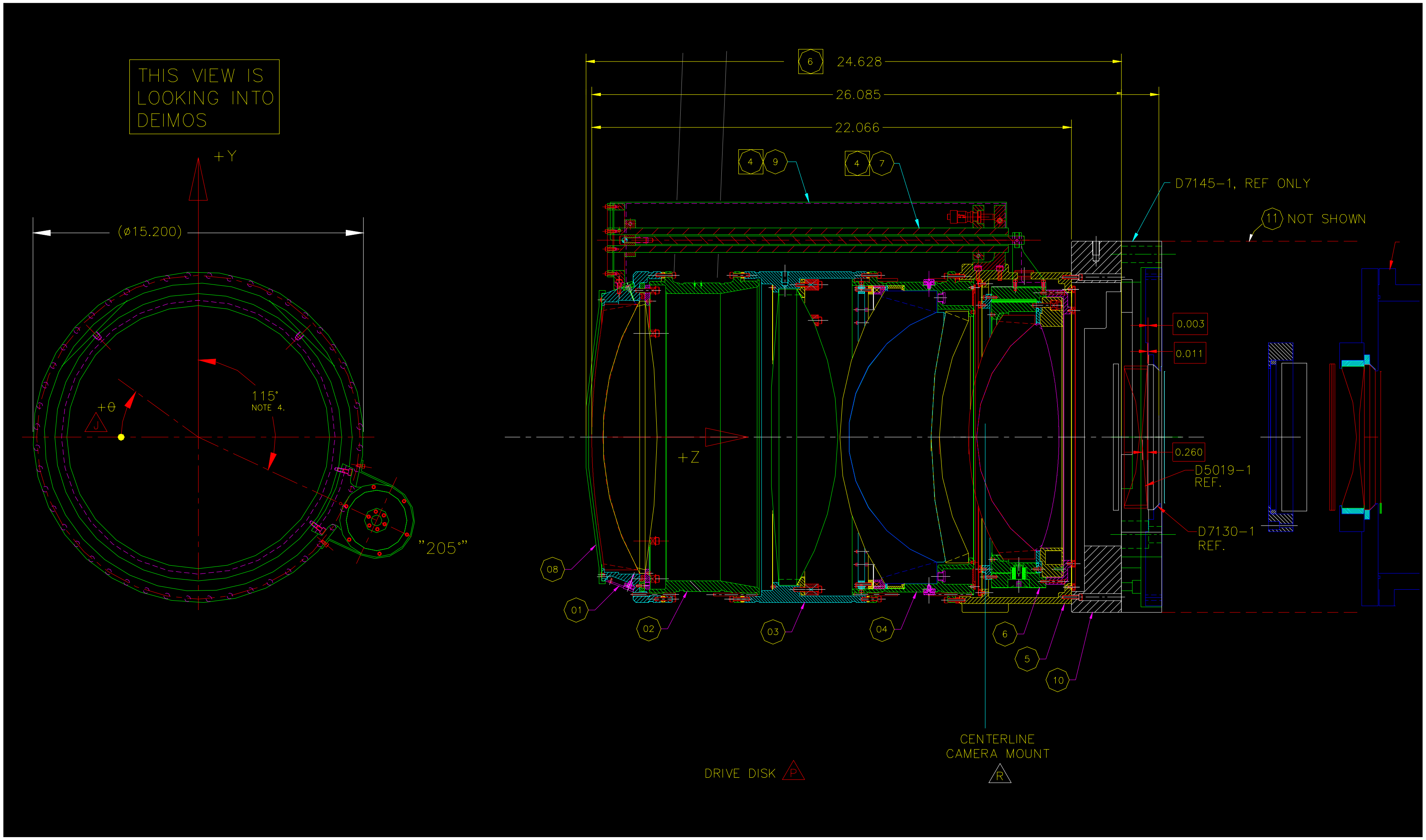


Element 8-Asphere

Surface Error

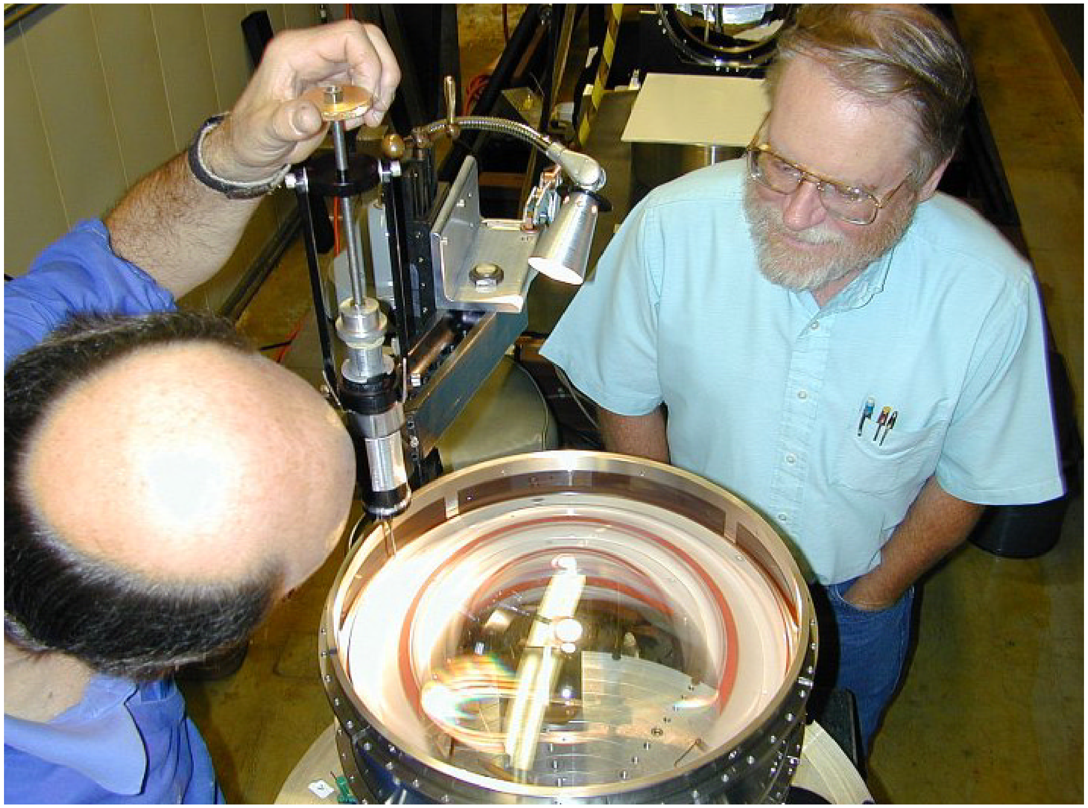
Black- 1.6 microns

Camera Cell



DEIMOS

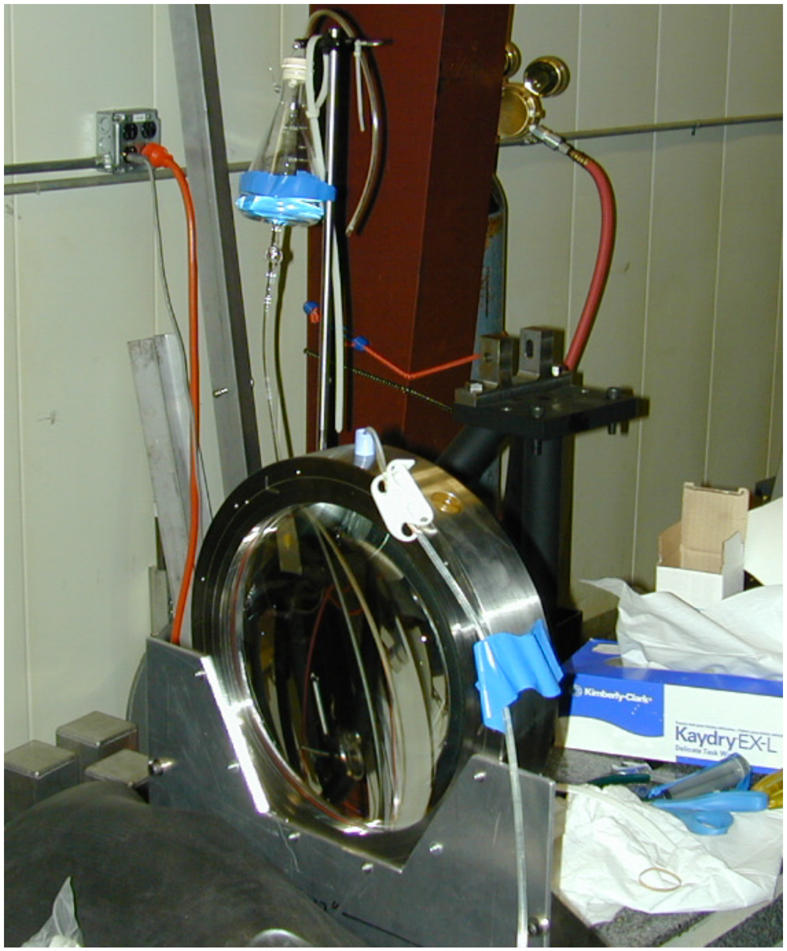
Camera Assembly



- Bodies 1,2,3,&4 assembled one at a time.
- Elements RTV-ed into cell

Body 3

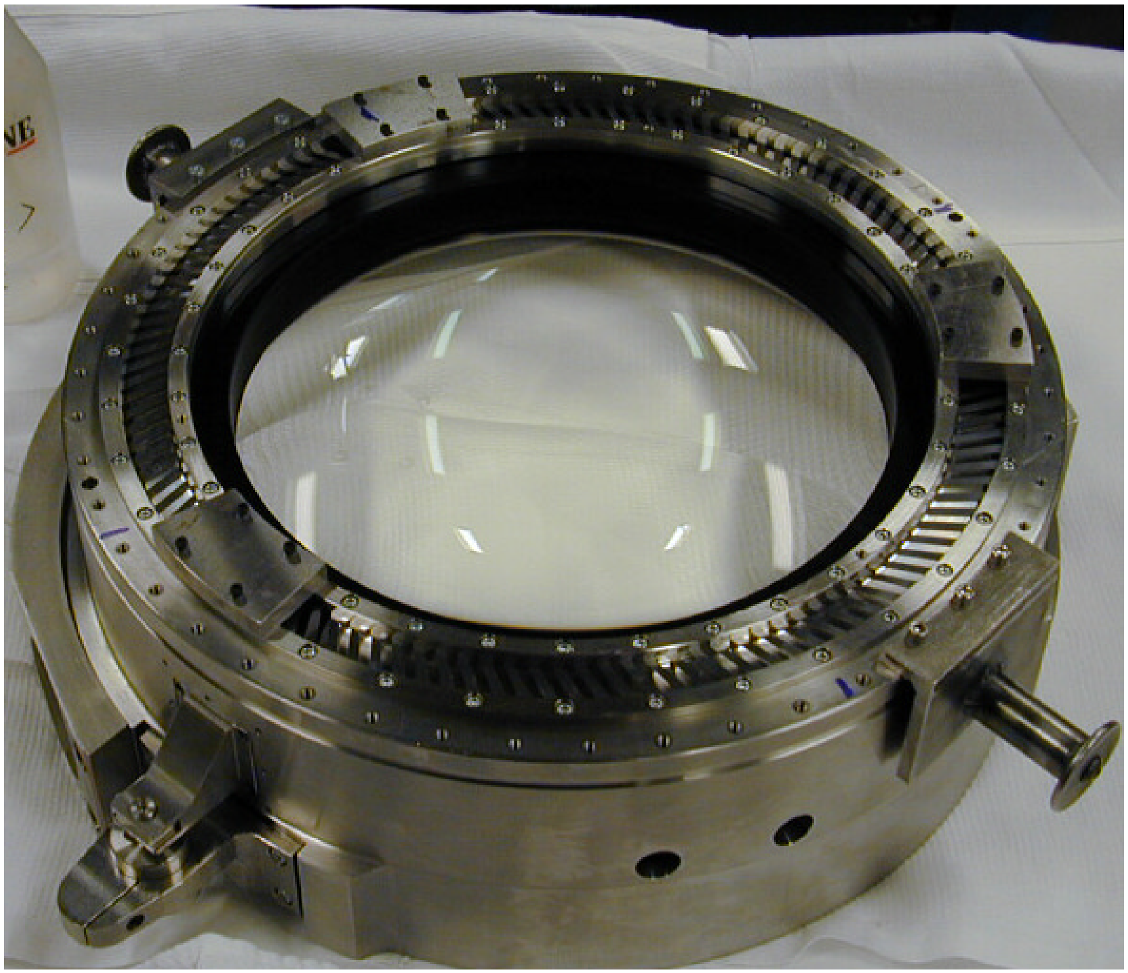
Camera Assembly



Cell 4

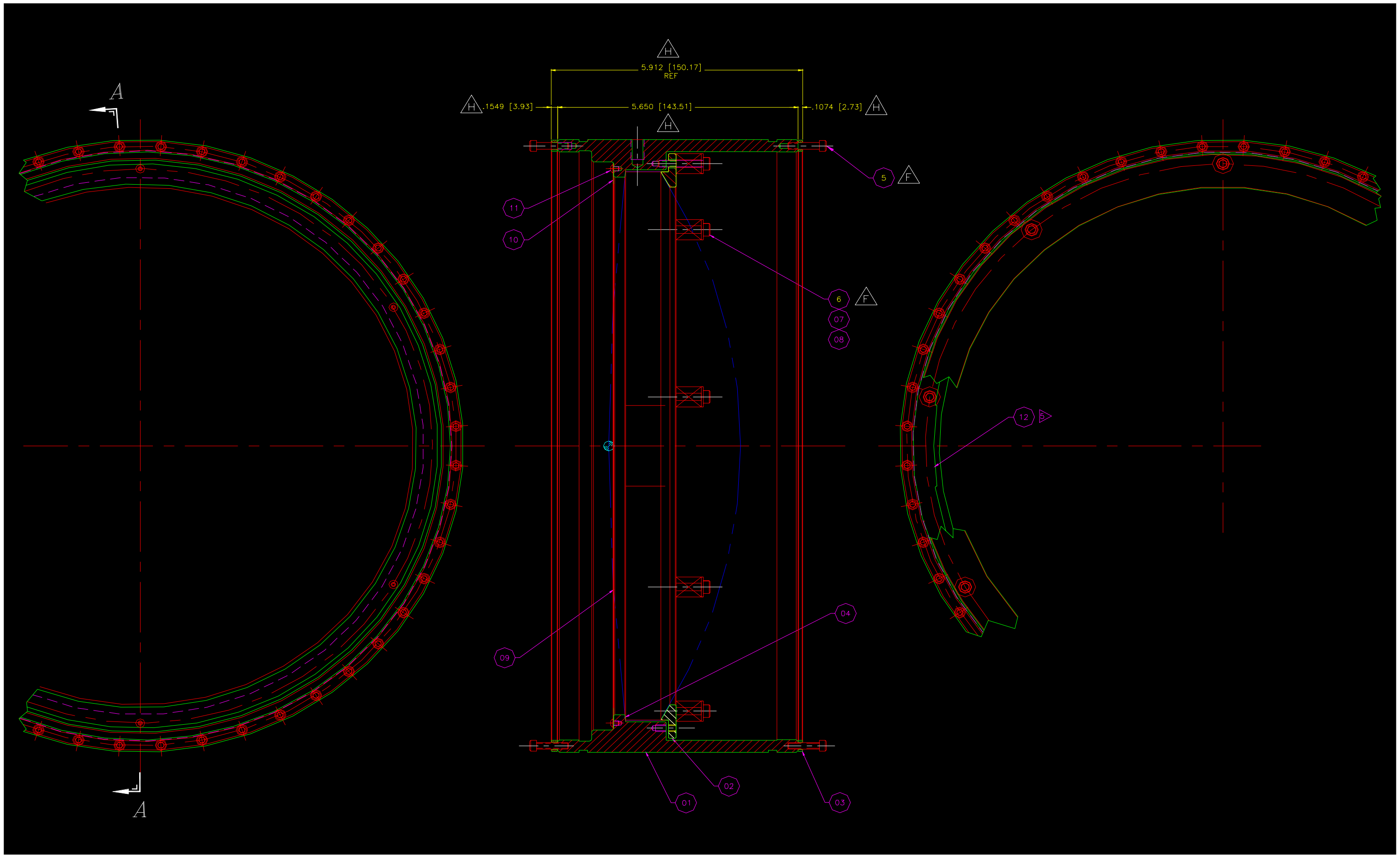
- Cargille Laser Liquid 1074 used as couplant

Camera Assembly



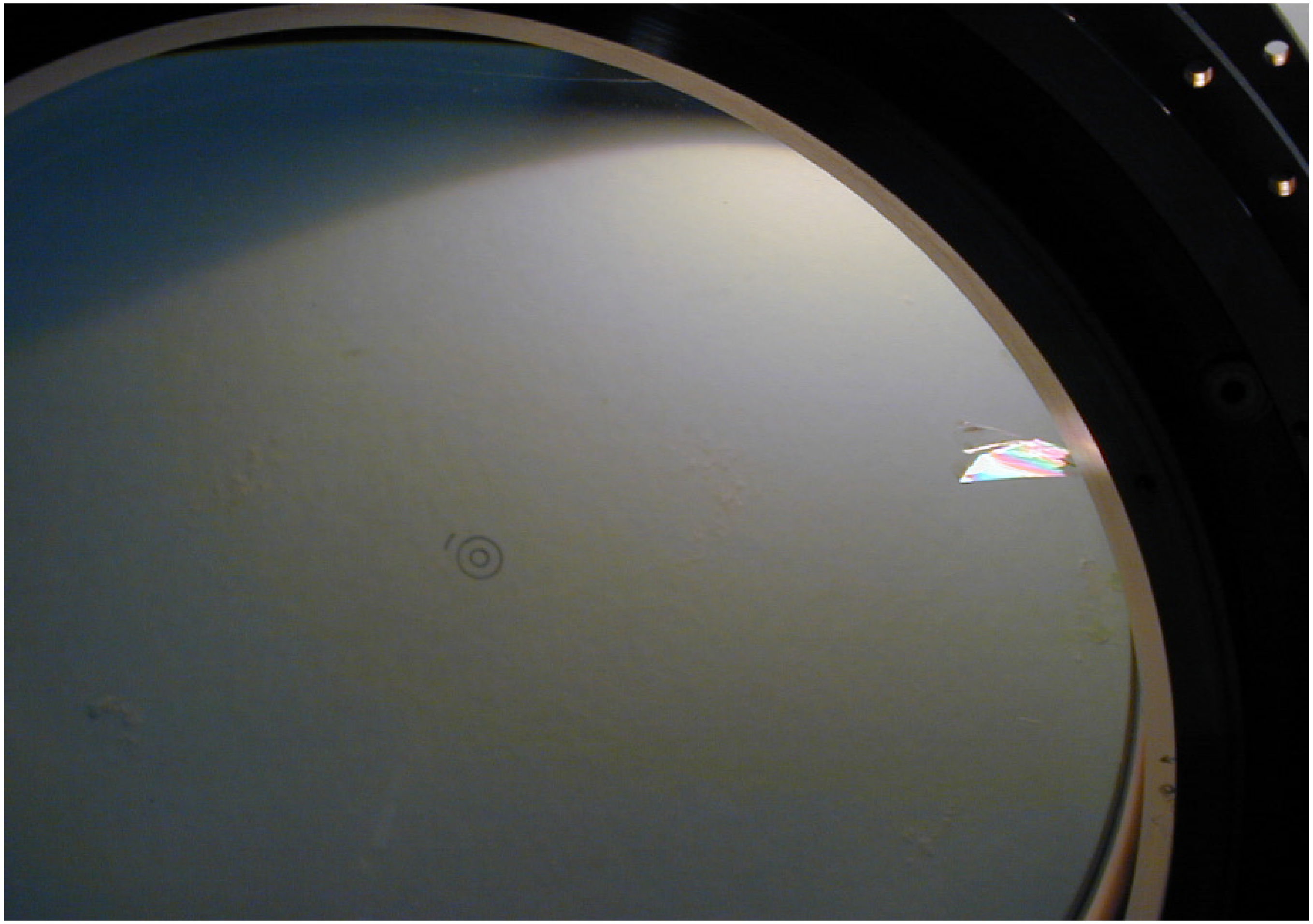
Body 4 with axial flexure for thermal compensator

Camera



Body 2, Element 3

Camera

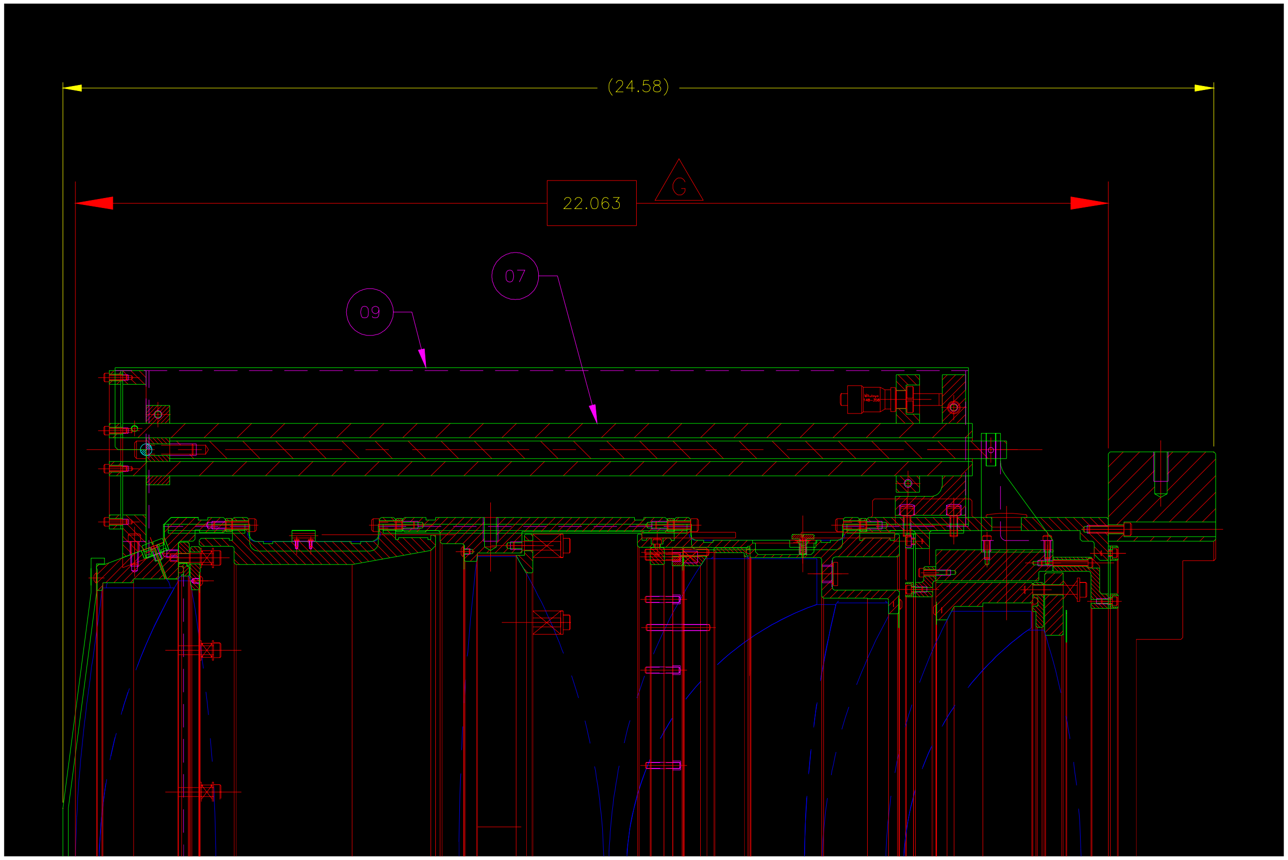


Fracture in Element 5

Camera

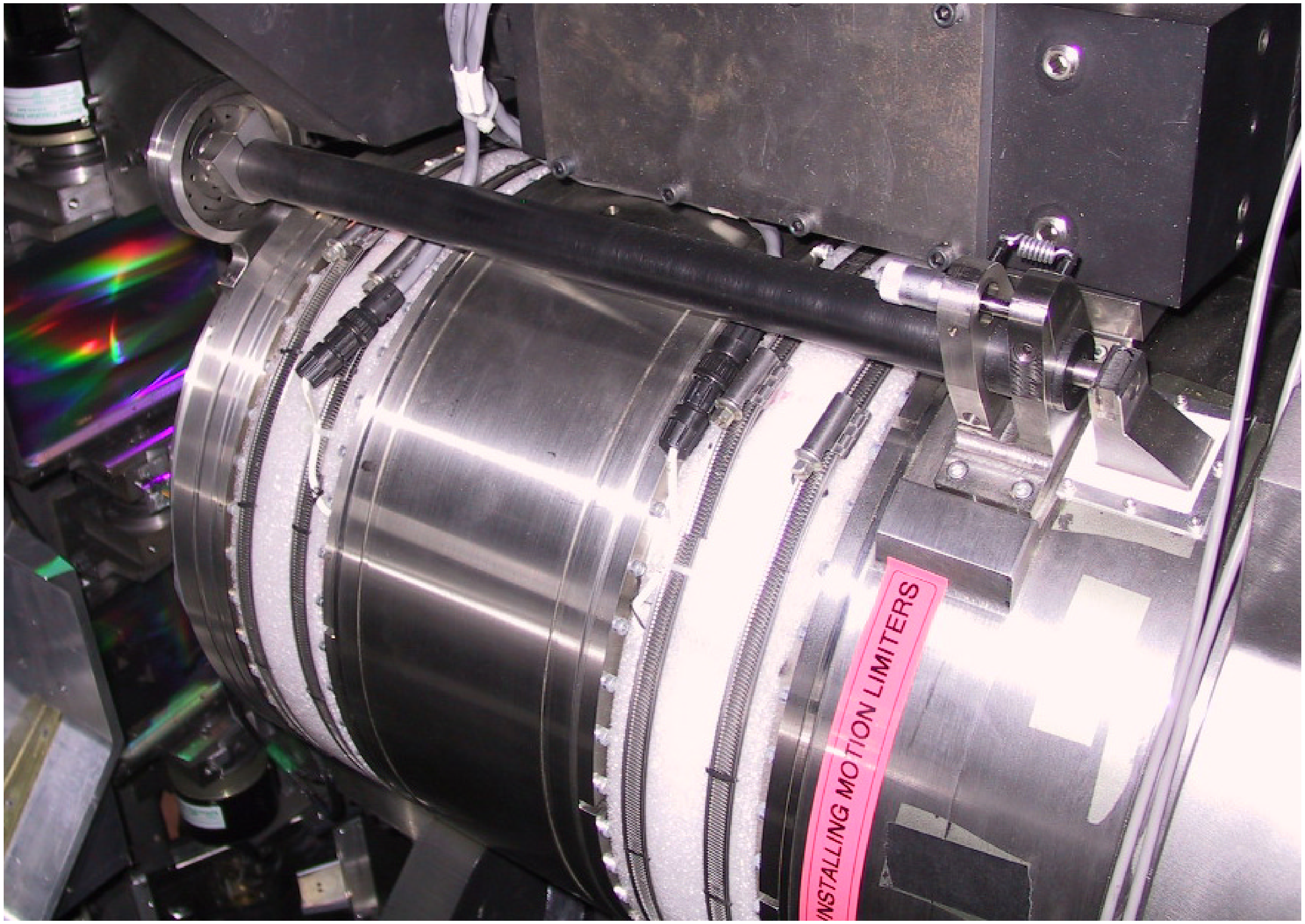
- Fully assembled with two adaptor rings for accommodation of shutter and filter wheel. Dewar bolts directly to top ring with tip tilt adjustment

Thermal Compensator



- Compensates for changes in plate scale with temperature
- 18 inch invar rod inside a delrin tube
- Controls axial position of body 4
- Working temperature range –4C to 6C

Thermal Compensator



DEIMOS Camera Repair
The Problem

- We believe that the main problem is Element 3 moving in its cell. It is held radially by shims that could have moved.
- It is possible that some of the motion is in Body 4, which has three degrees of adjustment designed into it, and on disassembly we will look at this also.
- All other elements are cemented into place with the exception of Element 5, which is held in place by Elements 4 and 6. Shadow tests indicate they are not moving.

DEIMOS Camera

- Motion in the camera is confirmed by two independent methods:
  – Double-pass test using a point source at the focal plane, a mirror at the front of the camera, and the Cohu detector at the rear. Does not need the spectrograph or science detector.
  – Shadow test looks at the shadows of particles on element surface cast by pinhole light source. Moving pinhole determines which surface particle is on. Motion of shadows in science detector vs. PA determines element motion.

DEIMOS Camera

- Original tests in the optics lab did not look for image motion. We were testing for image quality using a microscope and the Cohu detector on and off axis. The off-axis tests were done at 4 different position angles in the camera FOV.

DEIMOS Camera

Planned Tests before Removal from Spectrograph

- Repeat the double-pass test with the Cohu detector and fiber after dewar is removed from DEIMOS; this will be the key diagnostic test used in the optical lab during the repair process. Measures both image motion and image quality.

DEIMOS Camera
Repair Plan: Element 3

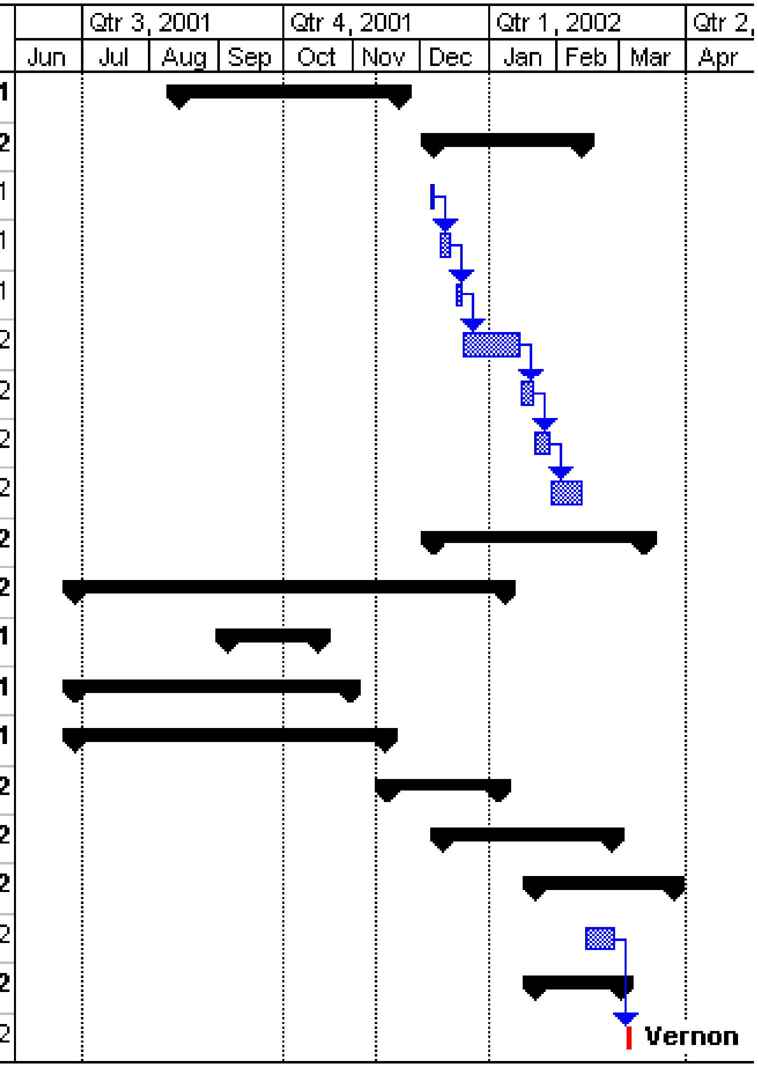
- Place camera on rotator and verify tests in spectrograph
- Remove camera from rotator and disassemble Body 2 from camera.
- Measure motion of Element 3 in Body 2 using a feeler gauge.
- We expect that all 3 shims are in place but are too thin. Replace with shims of proper thickness
- Reassemble camera and test in rotator using the double-pass test and the Cohu detector

DEIMOS Camera
Repair Plan: Element 4

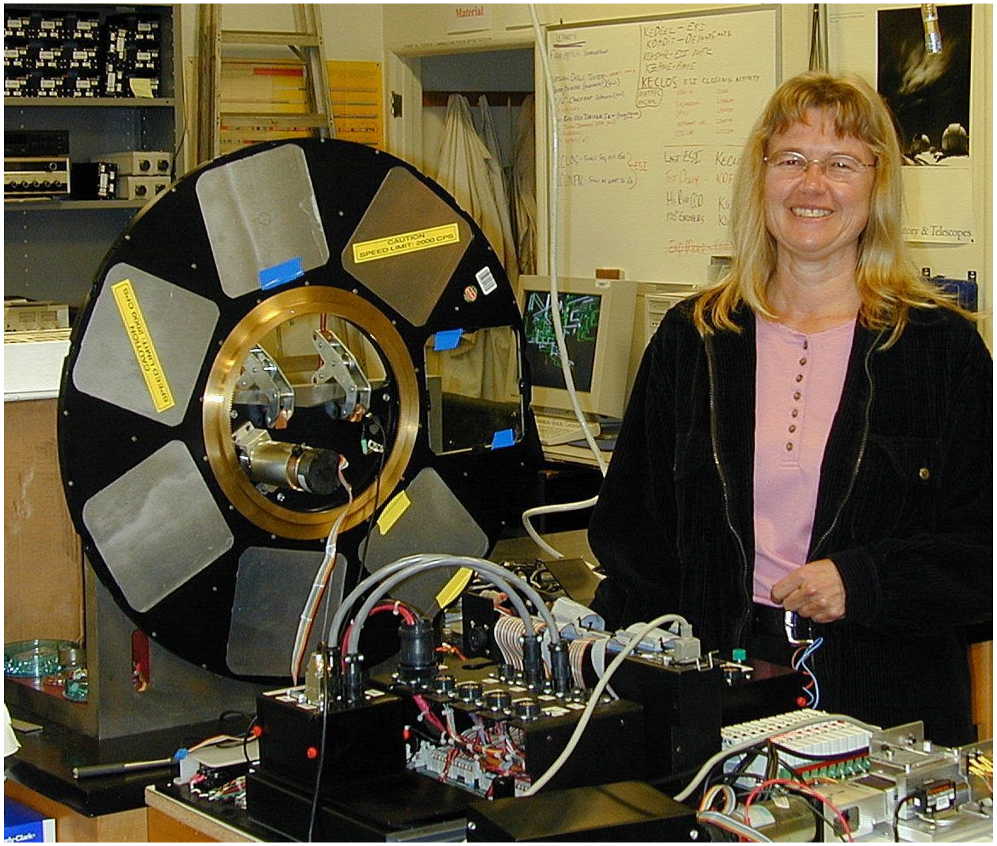
- Disassemble Body 4 from camera
- Pattern of motion is axially symmetric; suggests sagging element is axial diaphragms
- Check this by applying lateral force to horizontal element
- If axial diaphragms too compliant, replace with thicker steel
- Reassemble camera and test in rotator double-pass test

Camera Repair Schedule

ID		Task Name	Duration	Start	Finish
1		**Engineering**	**72 days**	**Mon 8/13/01**	**Wed 11/21/01**
5		**Camera Repair**	**40 days**	**Thu 12/6/01**	**Mon 2/11/02**
6		remove camera	2 days	Thu 12/6/01	Fri 12/7/01
7		test on test stand	1 wk	Mon 12/10/01	Fri 12/14/01
8		diassemble	3 days	Mon 12/17/01	Wed 12/19/01
9		repair	2 wks	Thu 12/20/01	Mon 1/14/02
10		assemble	1 wk	Tue 1/15/02	Mon 1/21/02
11		test on test stand	1 wk	Tue 1/22/02	Mon 1/28/02
12		diassemble and pack	2 wks	Tue 1/29/02	Mon 2/11/02
13		**Red Mosaic installation/test**	**60 days**	**Thu 12/6/01**	**Mon 3/11/02**
20		**Fabrictation**	**127 days**	**Wed 6/27/01**	**Mon 1/7/02**
27		**Electrical**	**30 days**	**Tue 9/4/01**	**Mon 10/15/01**
30		**Software**	**87 days**	**Wed 6/27/01**	**Mon 10/29/01**
35		**System Testing**	**99 days**	**Wed 6/27/01**	**Wed 11/14/01**
44		**Post Pre-ship review**	**27 days**	**Thu 11/15/01**	**Fri 1/4/02**
47		**Pack and Ship**	**47 days**	**Tue 12/11/01**	**Mon 2/25/02**
57		**Assemble in HI**	**44.25 days**	**Tue 1/22/02**	**Mon 3/25/02**
58		assemble camera	10 days	Wed 2/13/02	Tue 2/26/02
59		**Assemble spectrograph**	**29 days**	**Tue 1/22/02**	**Fri 3/1/02**
81		Install camera	2 days	Mon 3/4/02	Tue 3/5/02

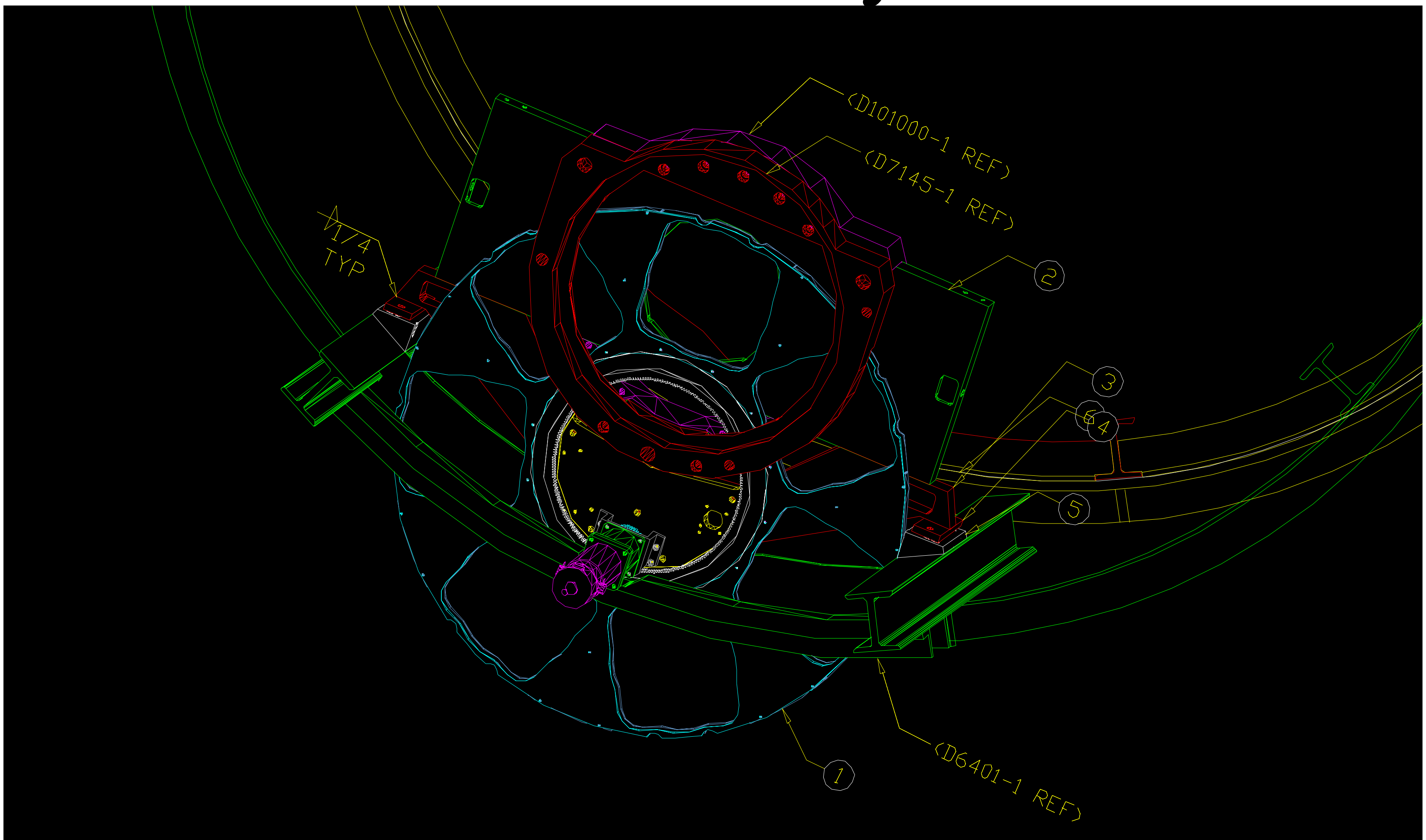


Filter Wheel



- 7 filter positions
- Servo-driven through 50/1 gear box
- Filters 6.25 in x 6.25 in
- BVRIZ plus 4 order blocking

Filter Wheel and Shutter Assembly

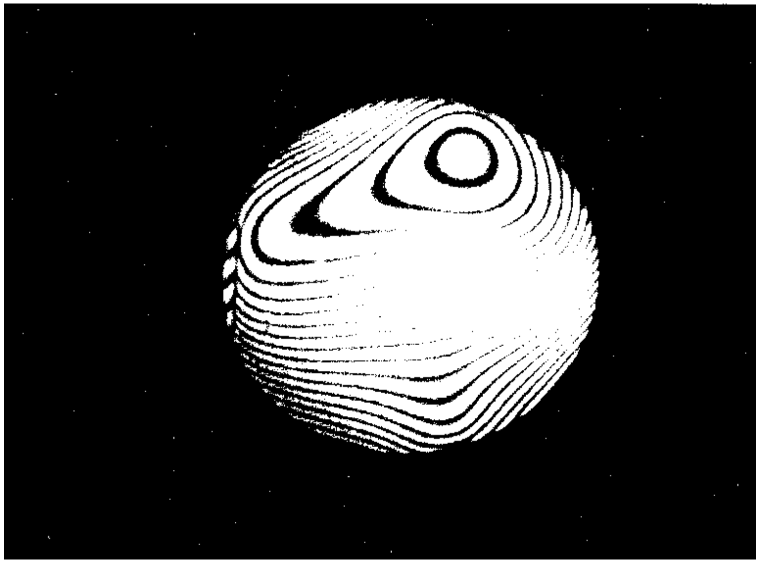


Filter Wheel Test Results

Filters & Holders

Filters
Typical Wave Front Error Map

Laminate filter in double-pass transmission.
(6 inch aperture)



Max. P-V = 9 fringes double pass = 4.5 Fringes single pass. P-V over 6” diameter = 2.25 waves. Spec. = 1 wave/inch. Achieved = .40 wave/inch.

GG 400 & WG 305 cemented, after 44 hour cure.
No change from 19 hour cure.
(ZC&R coated filters)

Filter System Requirements

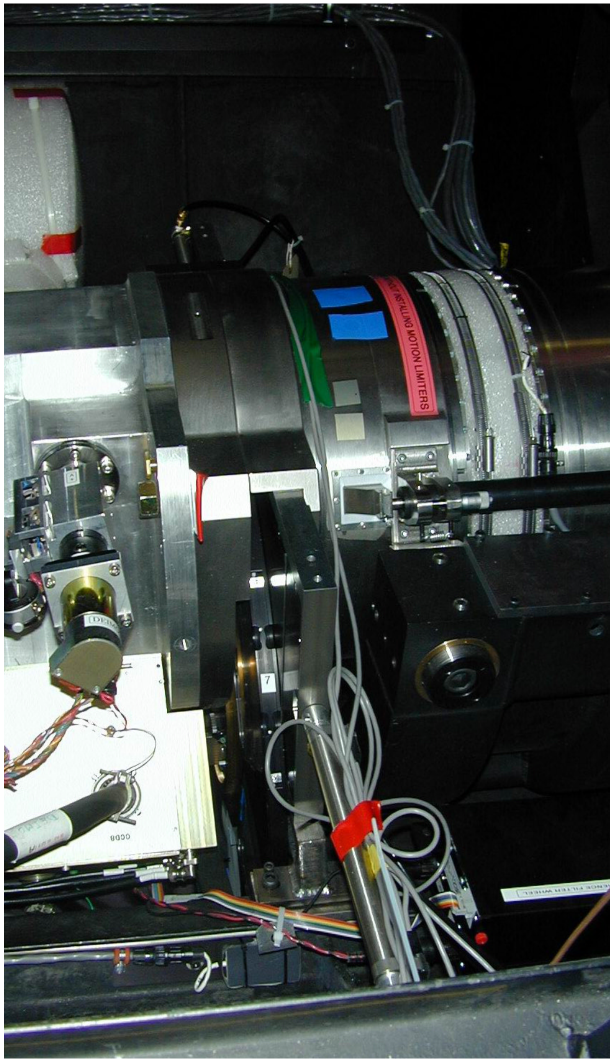
Filter Wheel

	Specifications	Achieved
Number of filters	7	7
Maximum time to change filters	55 sec	28 sec

Filters

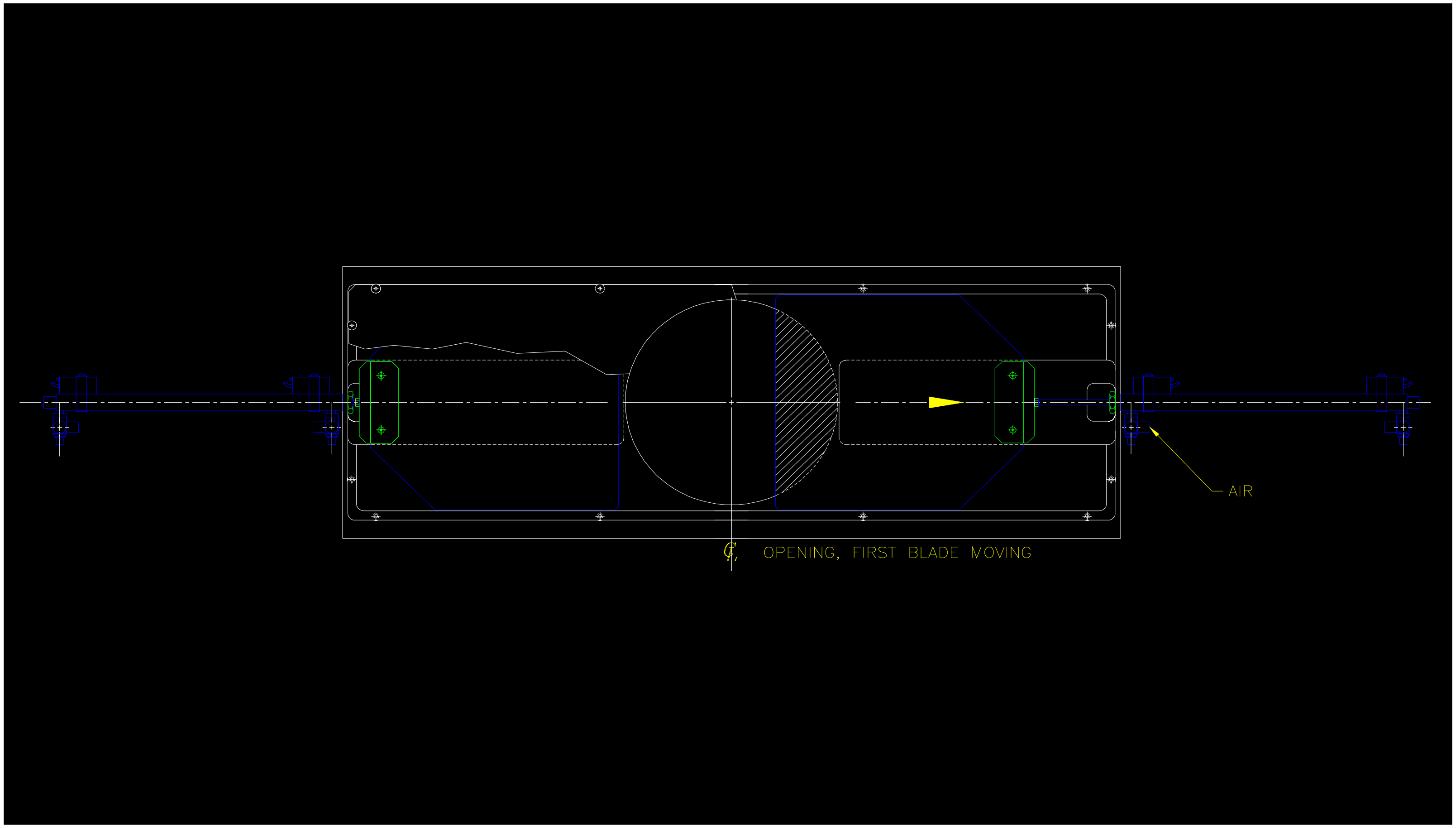
Filters provided	BVRI + clear	BVRIZ + clear
	+ 2 order-block	+ 4 order-block
Thickness uniformity		
Among filters	6.0 +/-0.10 mm	6.0 +0.10 –0.05 mm
Within a filter (wedge)	+/-0.02 mm	+/-0.02 mm
Max wavefront slope	1 wave/inch = 0.01	<;0.6 wave/inch

Shutter



- 27 inches long
- 10 inches wide
- 1 inch thick
- 2 blades (Ti)
- 2 pneumatic cylinders
- Blade transit time <210 msec
- Timers time beginning and end of blade motions
- Transit times slightly affected by gravity at +/- 25 msec level

Shutter



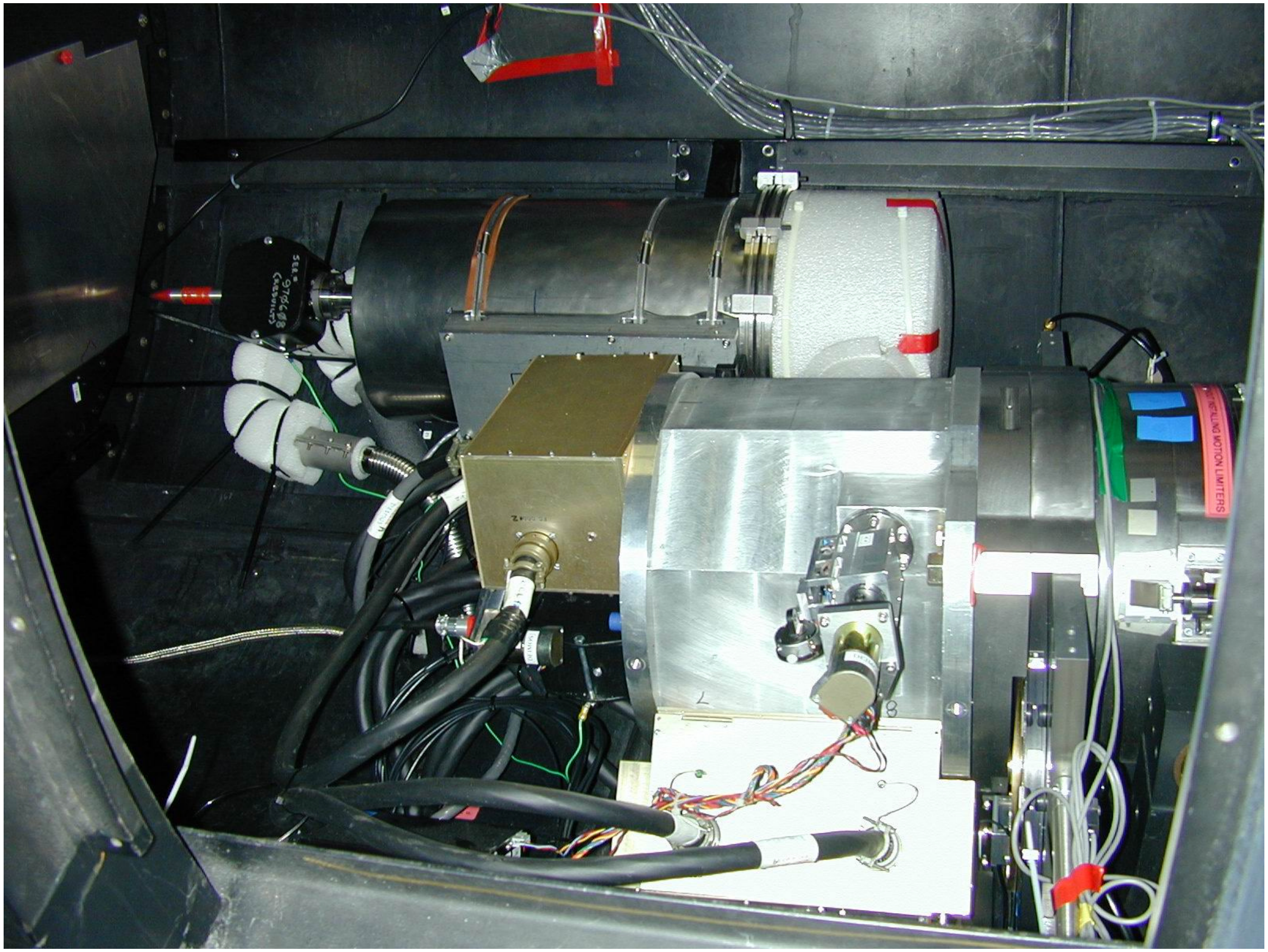
Shutter

- Shutter error specification:
  - Absolute accuracy: +/- 1% in mean exposure time at 1 sec
  - Relative accuracy: +/- 1% variation with position in 1 sec exposure
- Test results
  - Both blades close more slowly than they open (important)
  - Both blades move more slowly against gravity (not important; effect cancels when blade times are differenced, so no PA dependence)
  - Exposure difference across focal plane
    - Left opens first: 50 msec (worse than spec of 20 msec)
    - Right opens first: 5 msec (better than spec)
  - Observers who need accurate time will use right-open mode
  - Software will record actual times of blade opening and closing

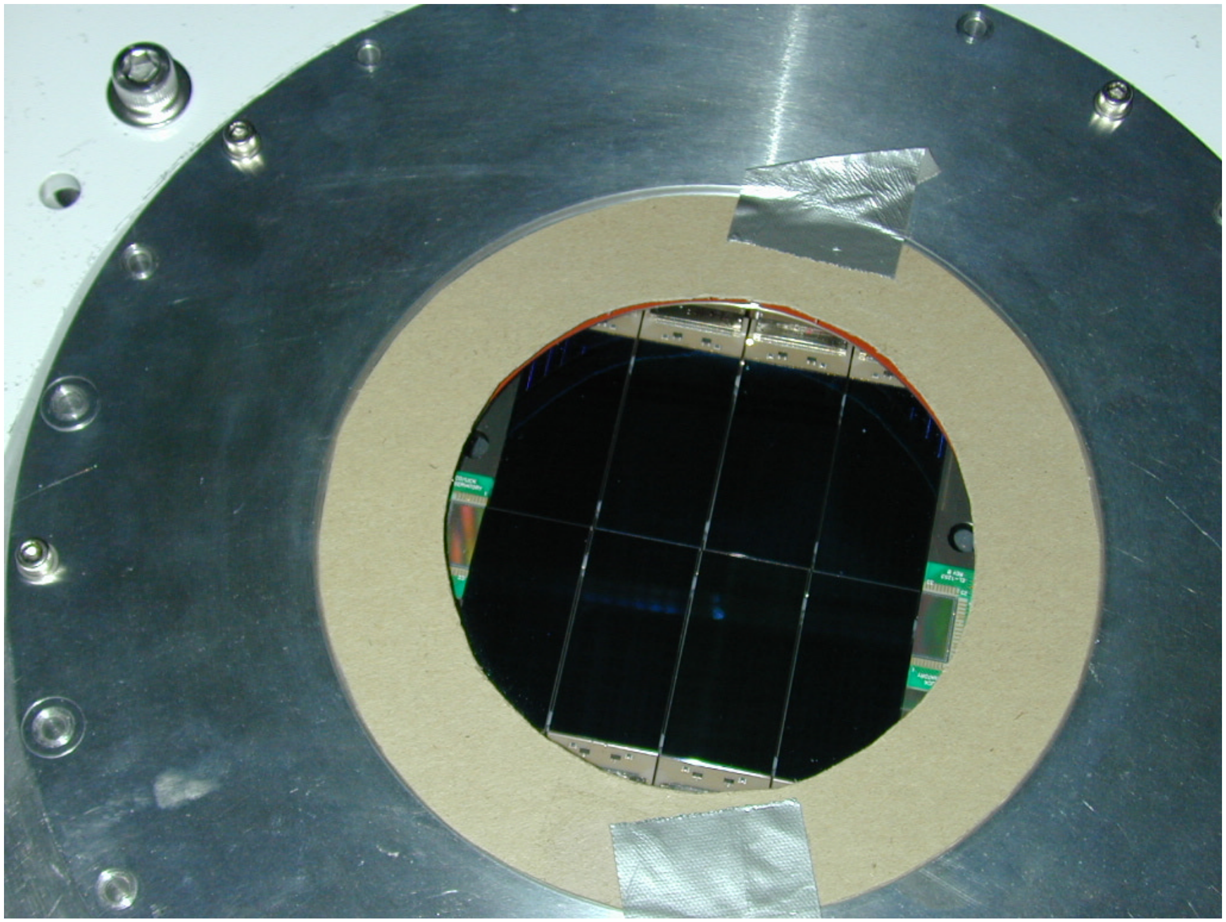
Shutter Requirements

	Specifications	Achieved
Minimum commandable time	0.1 sec	1 sec
Accuracy at 1 sec		
Mean commanded time, absolute accuracy	1%	0.25%, right blade open 2.5%, left blade open
Mean reported time	Not required	1%? (software reports times to 2 ms but blade acceleration is unknown)
Internal uniformity	+/-1%	+/-0.25%, right blade open +/-2.5%, left blade open

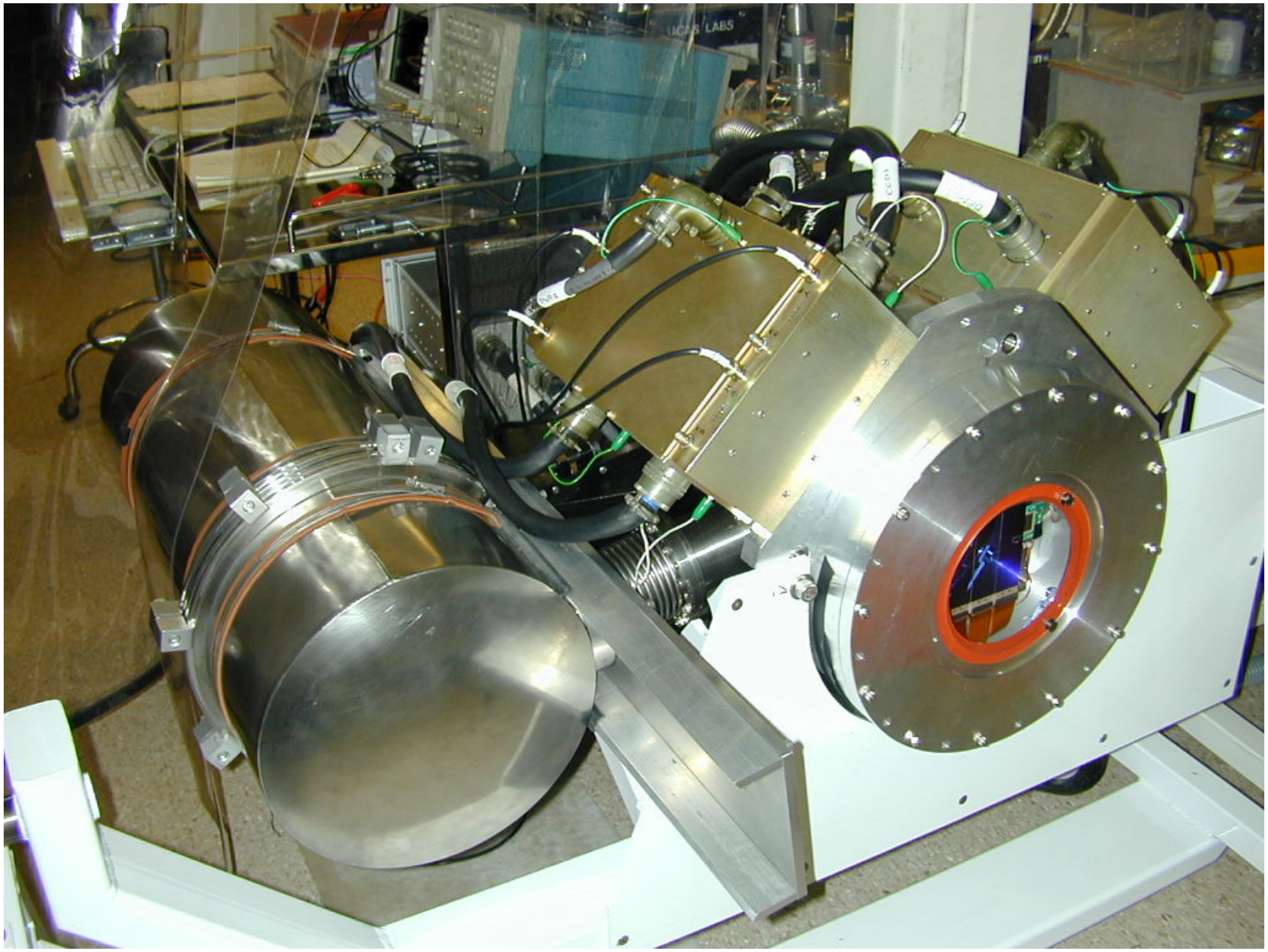
Dewar



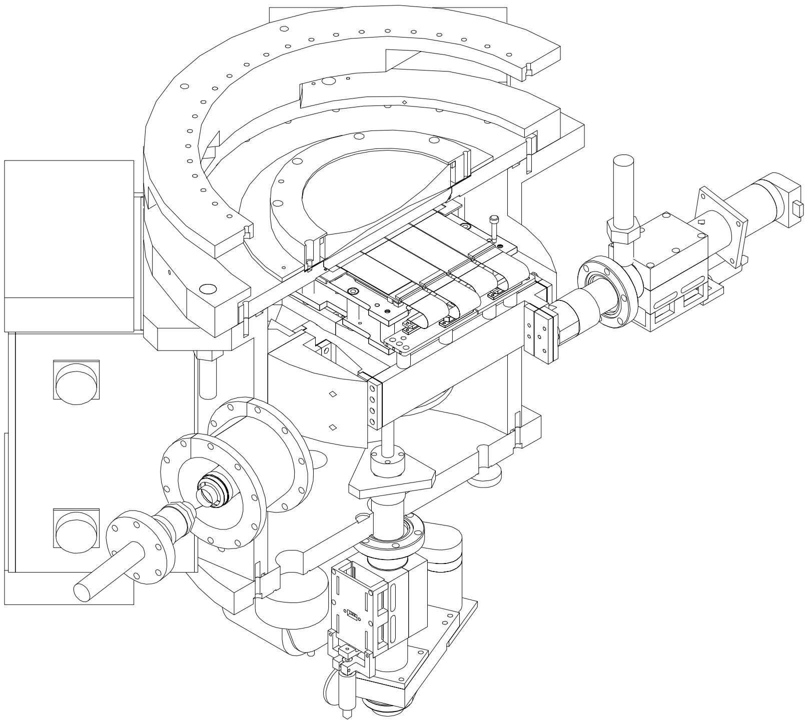
Dewar



Dewar



Dewar



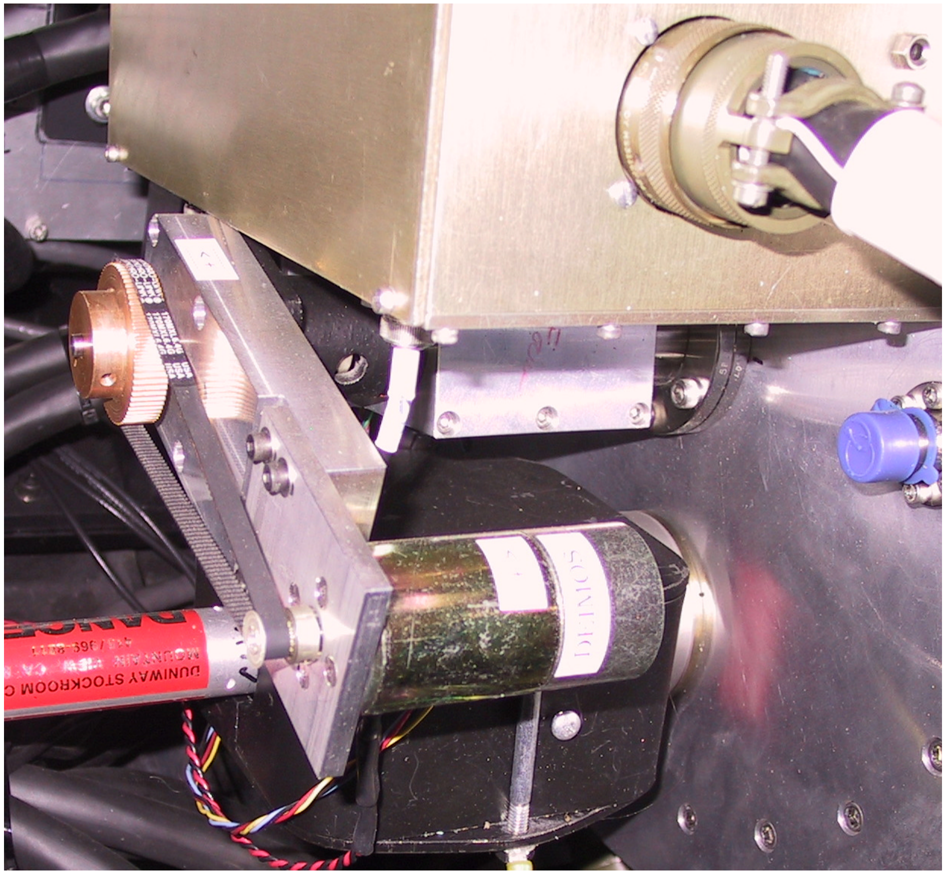
- Mosaic of 8 2x4 K CCDs
  2 1200x600 CCDs
- 3 electronics boxes for CCD
- Focus stage
- FC X-stage
- Cold finger
- Dewar window
- Field flattener
- Ion pump

Dewar System Requirements

Dewar

	Specifications	Achieved
Internal light	None	Very small
Vacuum	Adequate	Adequate
Contamination	None	Not measurable
Window condensation	None	Severe
Tip-tilt adjust in spectrograph	+/-0.017 in across detector	+/-0.017 in

Dewar Focus Stage

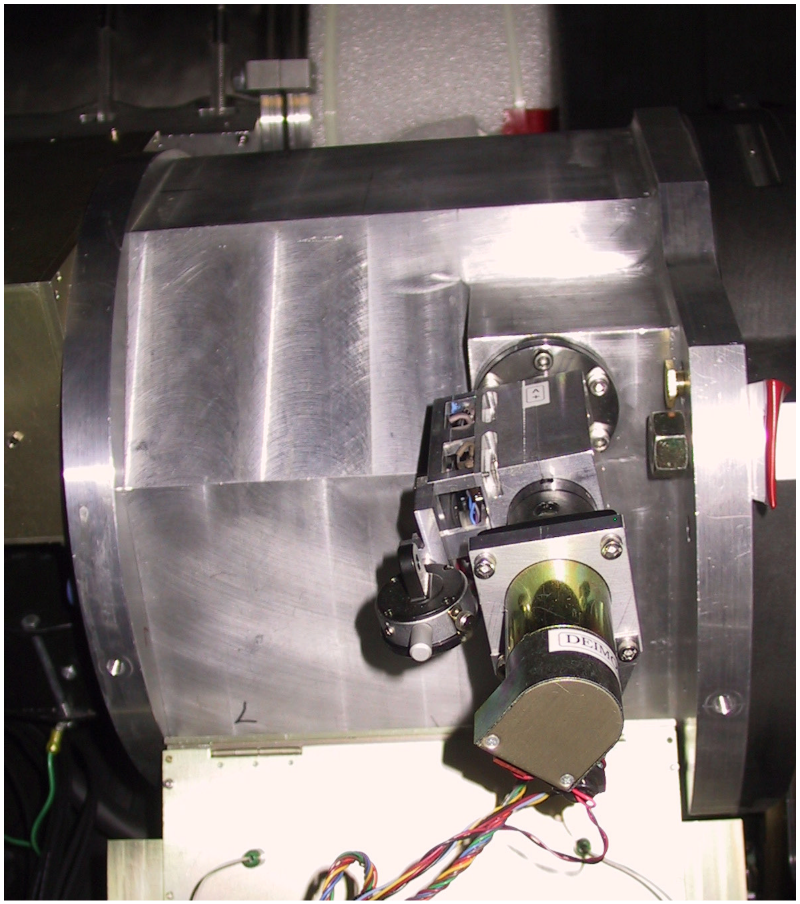


- Pistons detector mosaic inside dewar
- Stiff under gravitational deflections
- Terminates in aluminum plate; detector mounts using 4 Delrin standoffs

Focus Stage Requirements

	Specifications	Achieved
Mechanical design	Move dewar/field	Move detector in dewar flattener
Range of travel	+/-1 mm	+/-0.9 mm
Resolution	5 mu	Not yet tested
Backlash	2 mu	Not yet tested
Time to limits	75 sec	47 sec
Sag under gravity	+/-0.5 px	+/-0.9 px (X)
		+/-0.6 px (Y)

FC X-stage

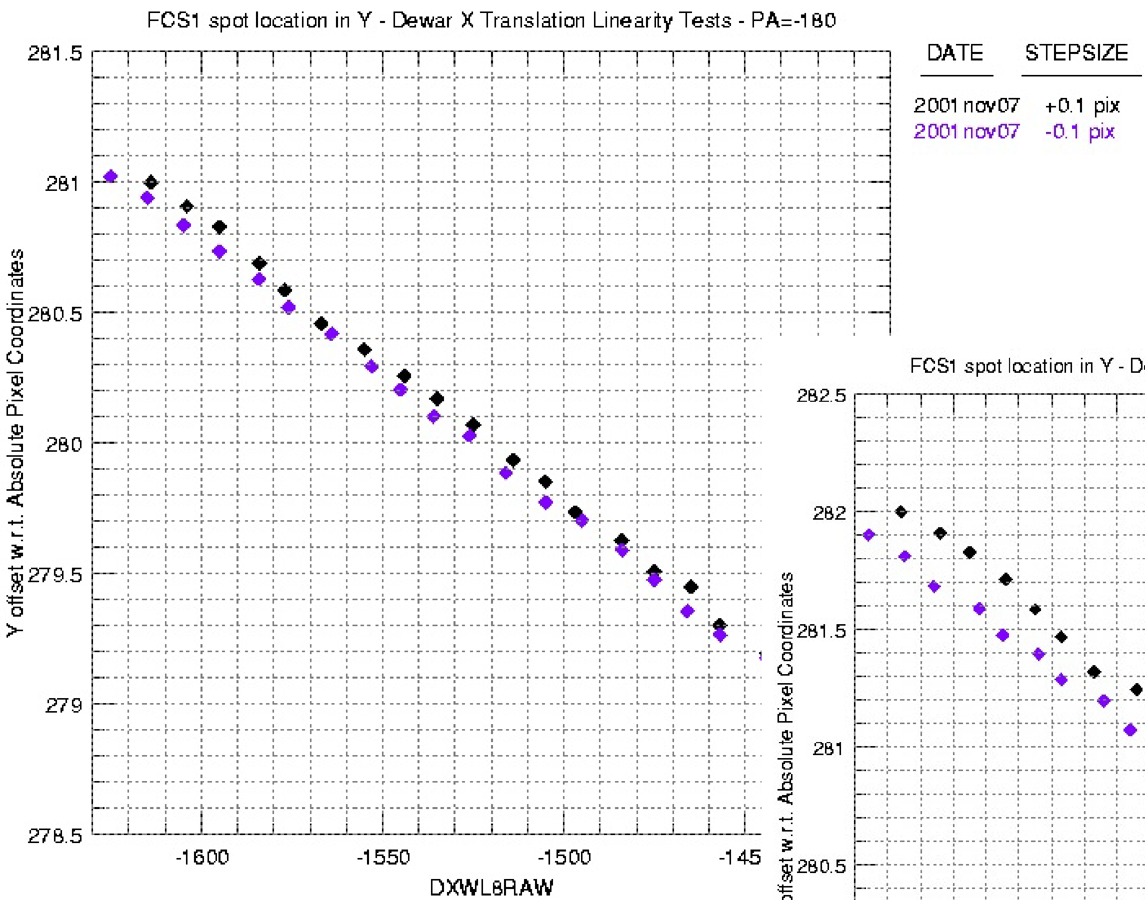


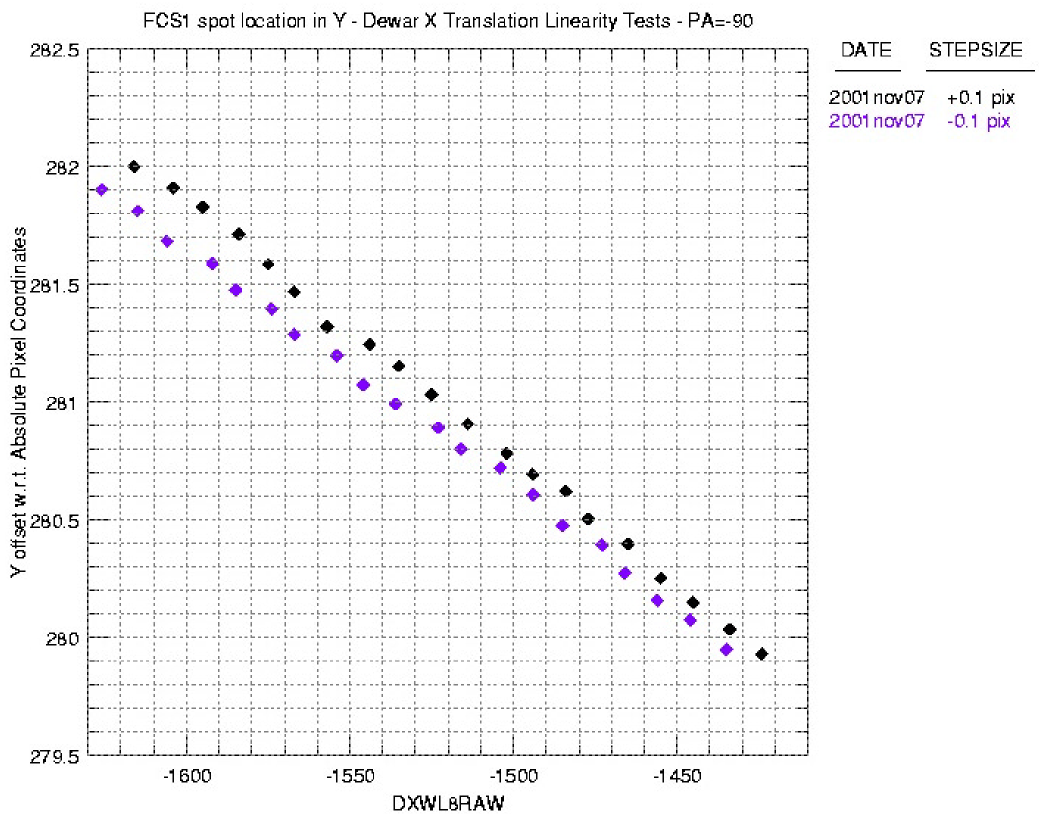
- Translates detector in X direction parallel to slit
- 4 bar mechanism with low backlash

FC X-Stage Requirements

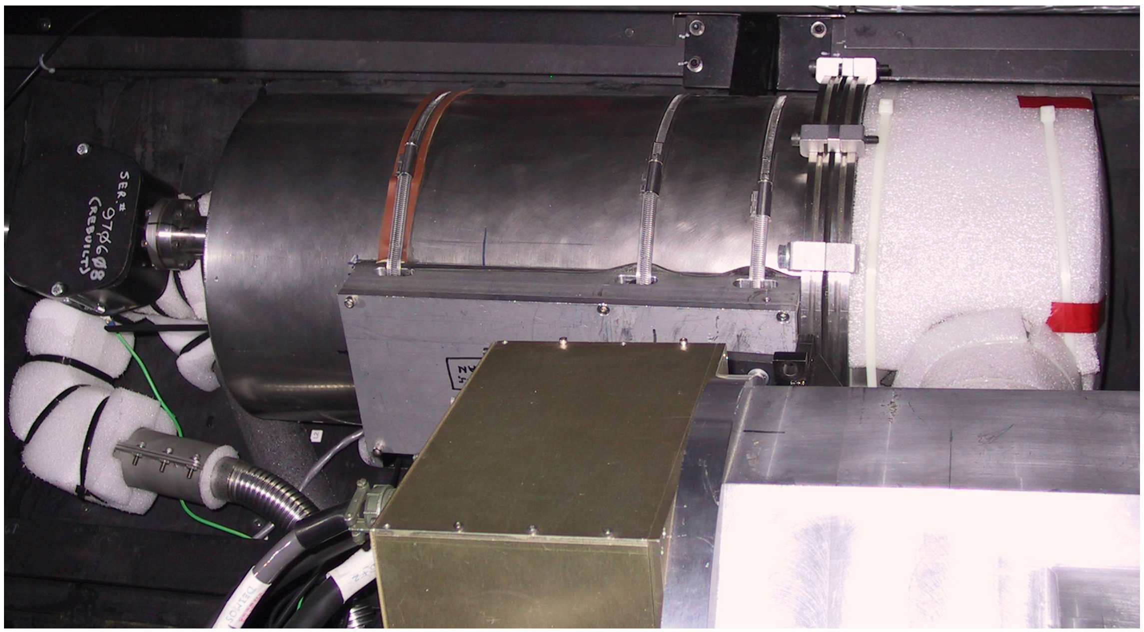
	Specifications	Achieved
Mechanical design	Tilt camera/dewar	Move detector in dewar
Range of motion	21 px	26 px
Resolution	0.01 px	0.02 px (preliminary)
Accuracy	0.05 px	0.05 px (preliminary)
Backlash	0.05 px	0-0.1 px, PA dependent (preliminary)
Time to limits	No spec	34 sec

Plot of 0.1 px steps





Detector Cooling System



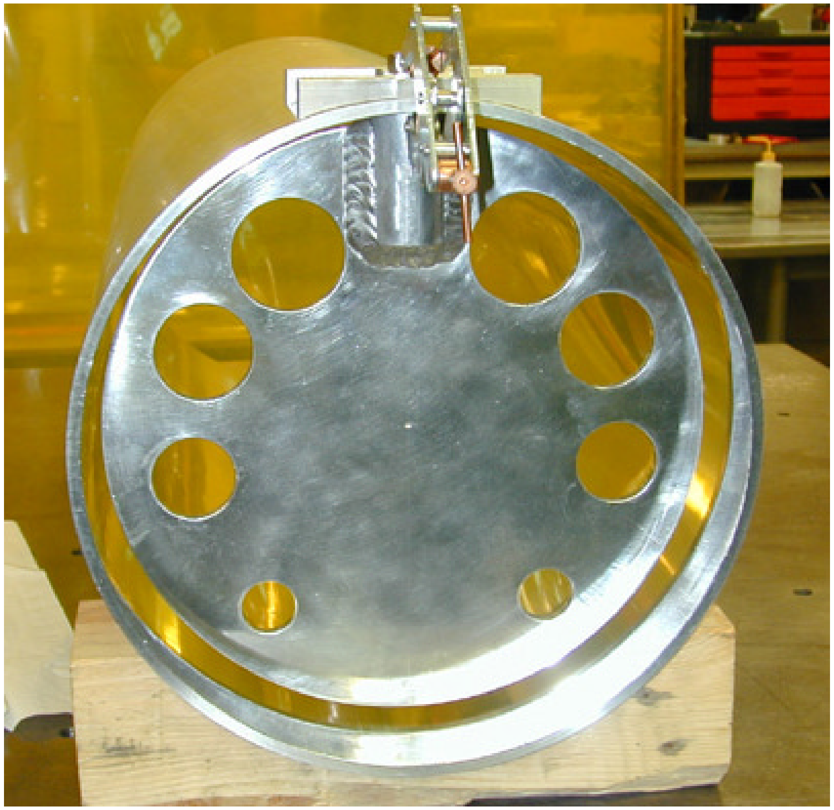
- Separate LN2 reservoir, capacity 22 l
- Cold circuit is Cu; 8 branches of equal thermal lengths to 8 CCDs
- Each CCD connected to cold circuit with flexible silver leaf springs; high compliance
- Manual fills
- Operating temperature – 90C (for Blue detector)
- Expected operating temperature at Keck –110C
- Hold time presently 22 hrs
- New larger LN2 can holds 24 l; estimated hold time at Keck > 30 hrs

Detector System Cooling Requirements

Detector Cooling System

	Specifications	Achieved
Target operating temperature	<110 C	Now: -90 C
		At MK: <110 C
Temperature stability	+/-1 C	Now: +/-1 C
		At MK: +/-0.1C
Temperature uniformity among CCDs	+/-1 C	Now: +/-1 C
		At MK: +/-1 C
Hold time	30 hr	Now: 24 hr
		At MK: >30 hr with new LN2 can (est)
Filling method	Autofill	Manual

New LN2 Container



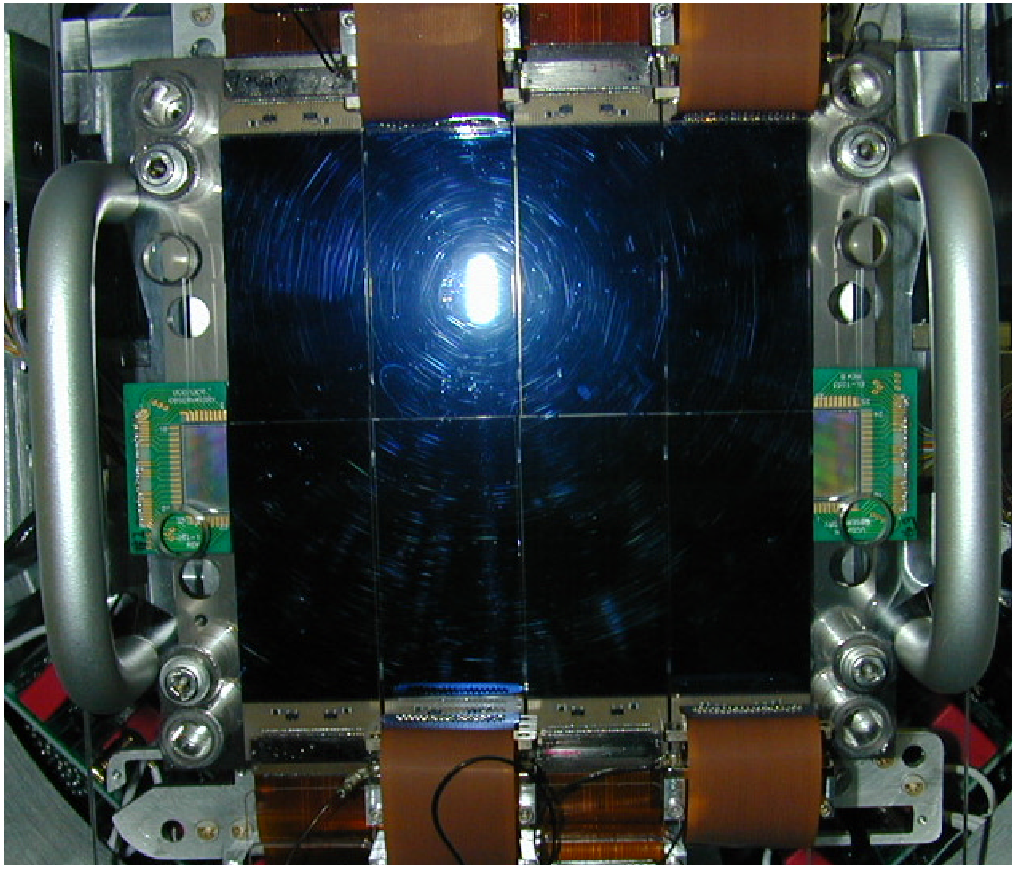
New container:

•24 liters LN2 vs 22 for original
•Better cold "finger"
•Can is polished inside

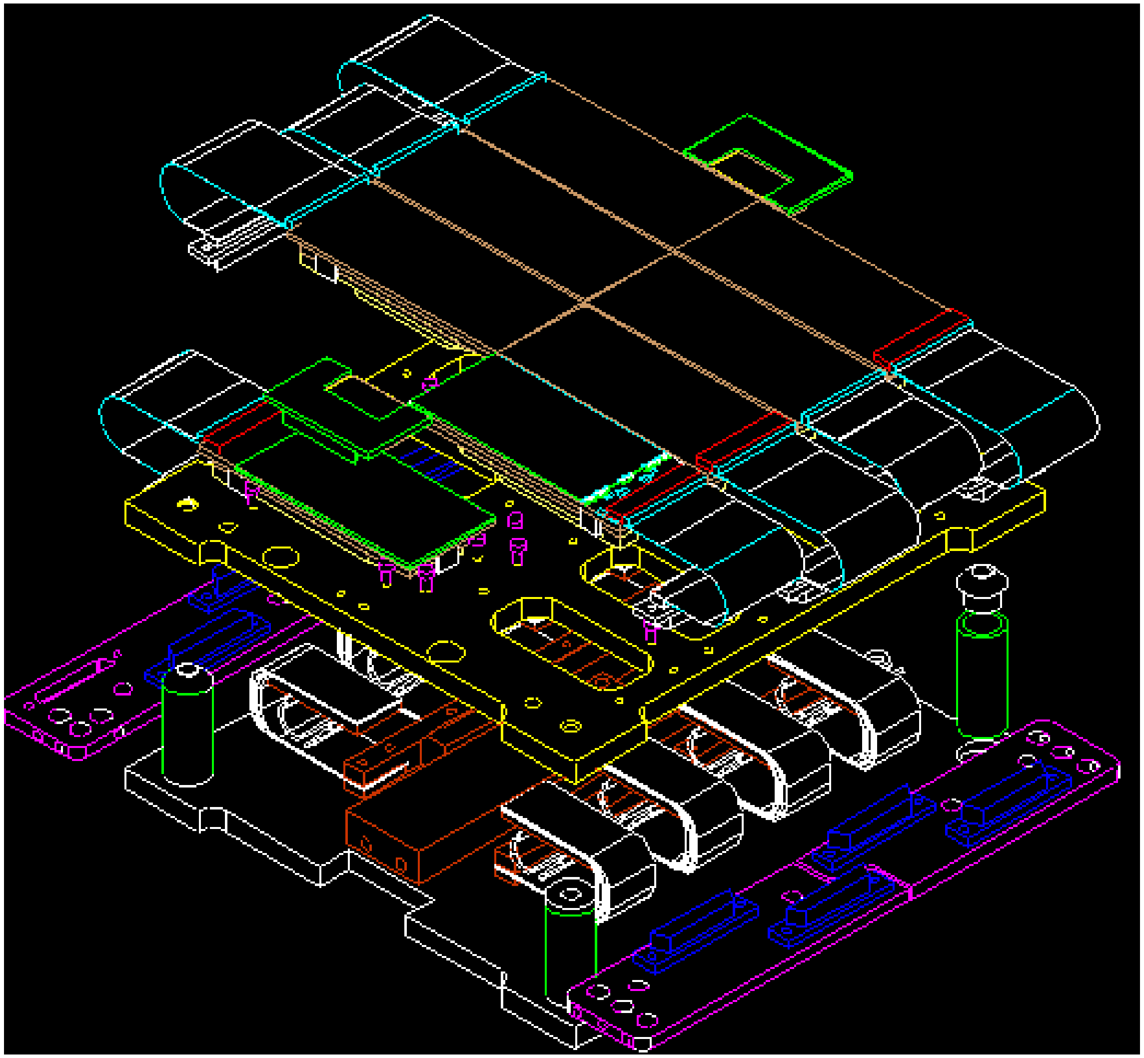
Test results:

•10% longer hold time than original container
•7.4 C difference with PA as compared to 27 C difference seen with current container

Detector System



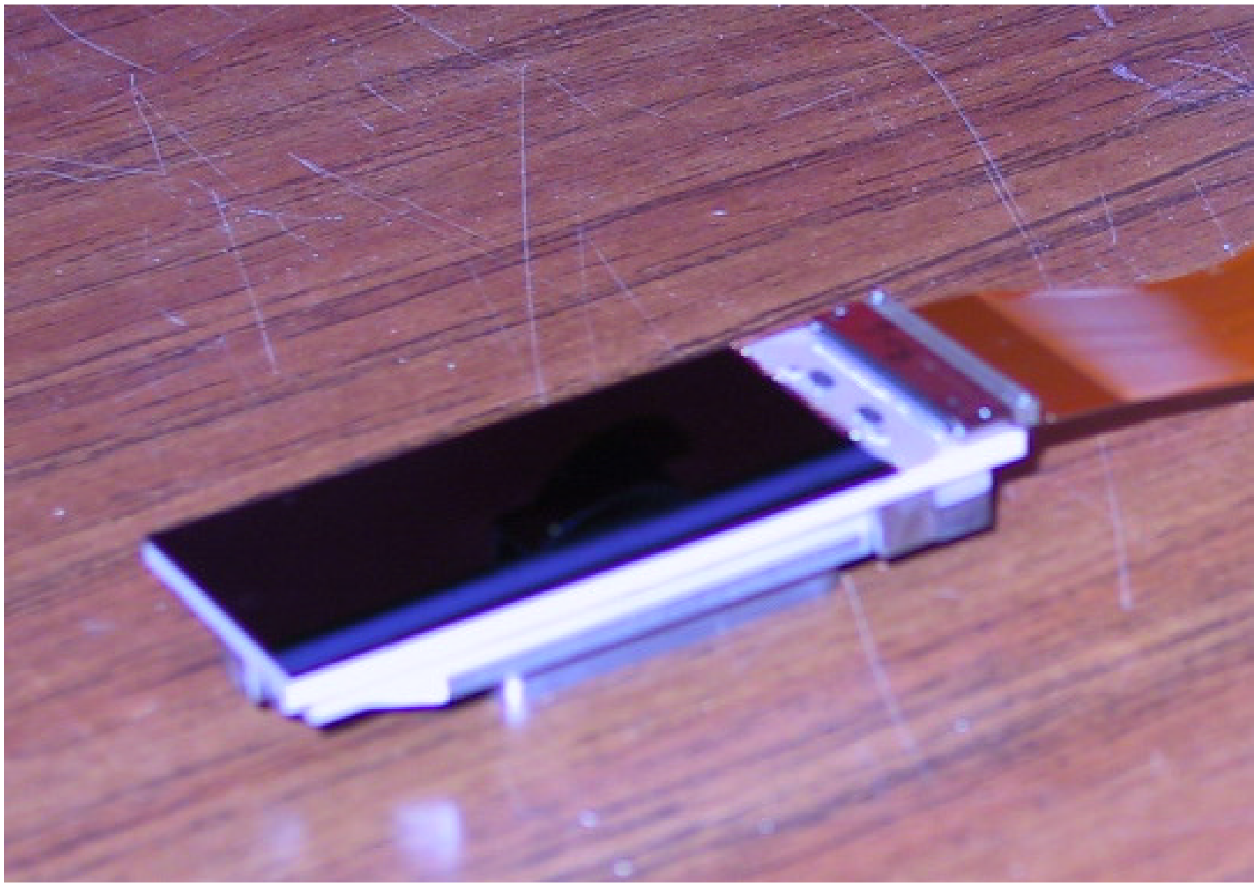
- Science Detectors
  - 8 2k x 4K MIT-LL CCDs, "High-rho", 45 micron thick for enhanced red response, 15 micron pixels
- FC detectors
  - 2 600 x 1200 Orbit CCDs front illuminated, 15 micron pixels
- Presently using "Blue" array, will replace with better, more sensitive "Red" array



Mosaic

- •AlN packages mounted on molybdenum blocks
- •Held with three screws to optical polished Invar backplane
- •Gaps (px to px)
  - –300 micron along spectra
  - –1.4 mm along slit

CCD mounted on Moly Package



Detector System
Mosaic Geometry

	Specifications	Achieved
Red Mosaic Geometry		
Flatness	7 mu rms	10 mu rms (predicted)
Gaps imaging area		
Long sides	1 mm	1.4 mm
Short sides	100 mu (7 px)	300 mu (20 px)
Alignment	+/-10 px parallel to spectrum	Tests show this is reasonable

Detector System CCDs Requirements

Red Detector CCDs: Note: red mosaic not yet assembled and tested; some data refer to blue mosaic.

Number CCDs	8 + 2 spares	8 + 4 spares
Size of full array		
Pixels	8192 x 8192	8192 x 8192
Physical	4.96 in x 4.96 in	4.96 in x 4.96 in
Surface Treatment	AR coat, red-opt	AR coat, red-opt

Detector System CCDs Requirements, continued

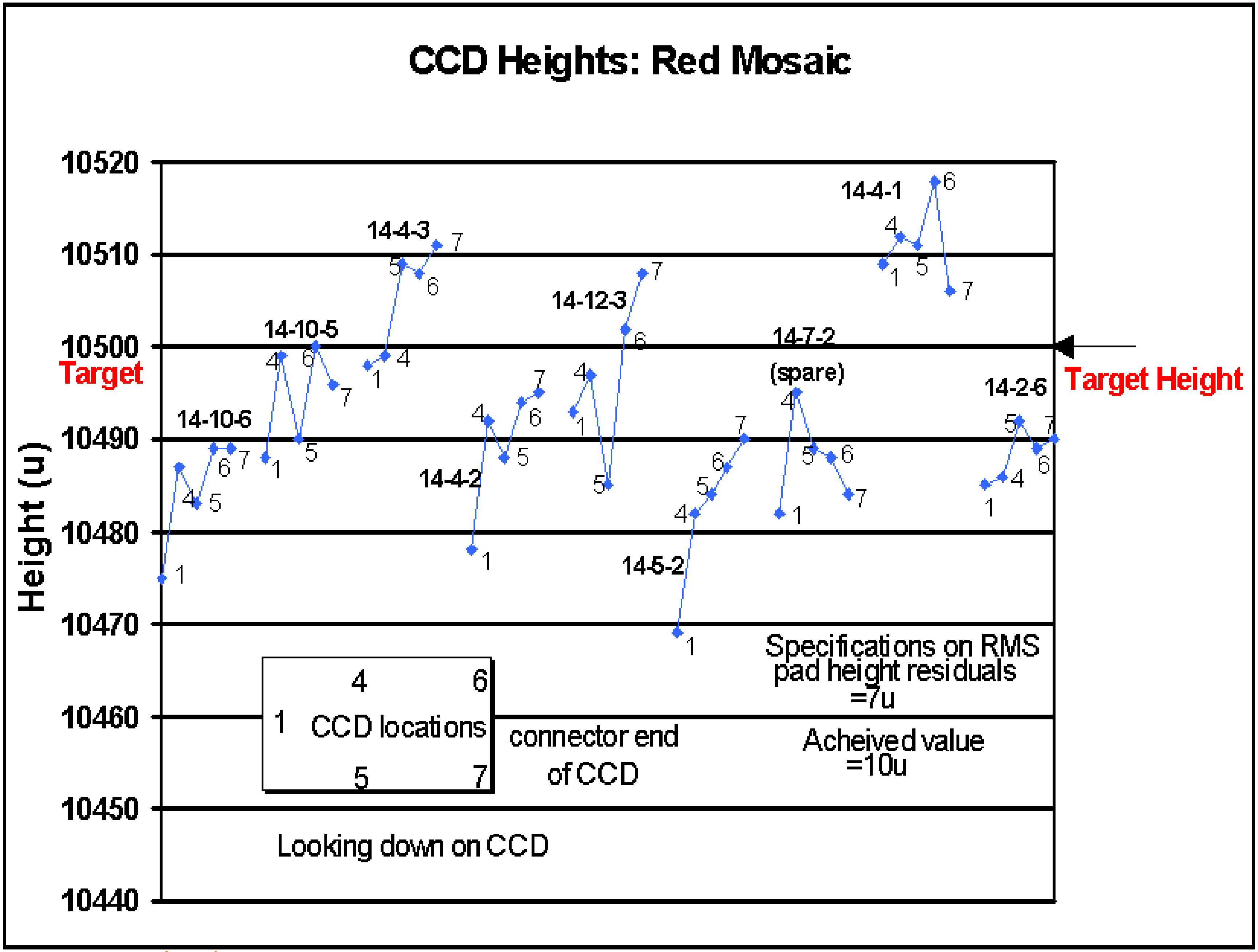
	Specifications	Achieved
Backside passivations	Coating or implant	Boron Implant
Manufacturer	No spec	MIT-LL
Geometry		
Pixels	2048 x 4096	2048 x 4096
Pixel size	15 mu	15 mu
Buttability	3-edge	3-edge
No. amplifiers	2	2
Illumination	Back-side thinned	Back-side thinned
Flatness	10 mu p-p	10 mu p-p
QE		
Peak QE	>70%	86% avg at 8000 A
QE at 9000 A	>40%	68% avg
QE at 10000 A	No spec	23% avg

Detector System CCD Requirements, continued

	Specifications	Achieved
Amplifiers	2 per CCD	2 per CCD
Total amplifiers, full mosaic	16	16
RO speed	10 musec/px	7 musec/px
RO time whole array	40 sec goal, 120 sec req.	40 sec (expected; 16 amp) 70 sec (maximum; 8 amp)
RO noise @ 100Kpx/sec	<5 e-	2.3-3.3 e-
Gain (low)	No spec	1.4 e-/DN, blue mosaic; red will differ
Full well	100K e-	90K e- (low gain), set by A/D converter; CCD full well = 460K e-
Linearity	+/-1% over lower half well	+/-0.5%
CTE	>0.999995	>0.99999
Dark count	<3.6 e-/hr	2-5 e-/hr @ -110 C

Detector System CCDs Requirements, continued

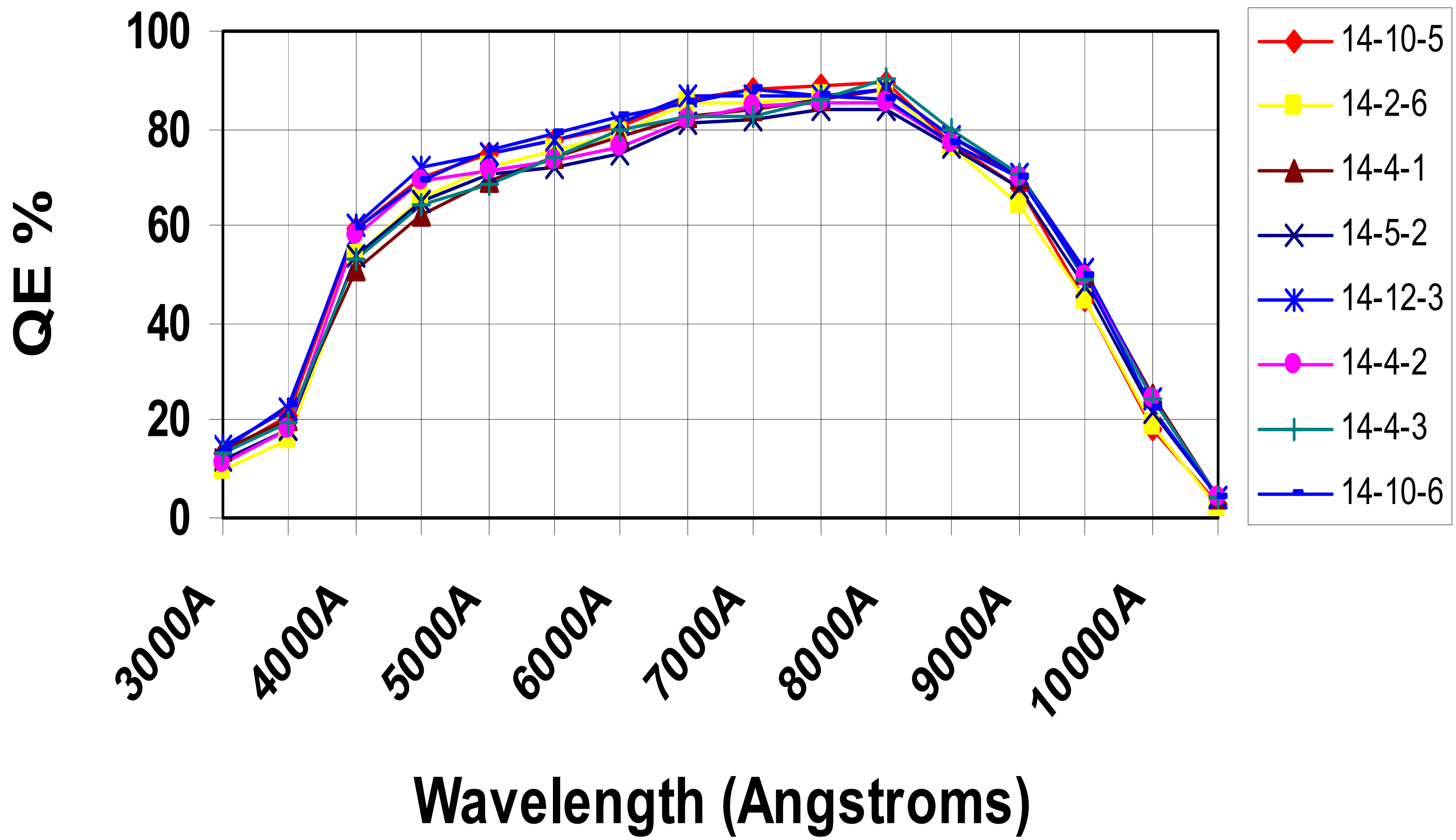
	Specifications	Achieved
Flatness	<10 mu p-p	<10 mu p-p (mostly)
Charge diffusion	No spec	33 mu rms diam.
Cosmetics		
Hot columns	<10	0-5 (est. @ -110 C)
Traps	<100	5-11
Amplifier glow	None	None
Glowing pixels	None	On one CCD; mild
QE uniformity	10% p-p	Not yet measured
Fringe amplitude	<10% p-p max	7-11% p-p @ 9000 A


CCD Heights: Red Mosaic
Height (u)
10520
10510
10500
Target
10490
10480
10470
10460
10450
10440
Target Height
14-10-6
14-10-5
14-4-3
14-4-2
14-12-3
14-5-2
14-7-2
(spare)
14-4-1
14-2-6
4
6
1
CCD locations
5
7
connector end
of CCD
Looking down on CCD
Specifications on RMS
pad height residuals
=7u
Acheived value
=10u

Red Detector CCDs

Device	Cosmetics	QE				QE Var. (%)		RO Noise		# Vert Traps	Dark e-/hr@T	flatness p-p(u)	fringe (%) at 9000A (p-p)	Comments
		3500	4500	7000	9500	3500	4500	L amp	R amp					Serial CTE good at all
	Main Devices													Temps
14-10-6	5 warm cols.	23	69	88	50	44	7	2.5	2.2	7	2.1 -90	NA	11	
14-10-6	1 warm col. -130C													
14-12-3	1 hot col + ~10 warm cols.	23	72	87	51	33	3	2.7	2.9	3	4.5 -90	NA	7	
14-12-3	1 hot col (2 col. Wide) + 1 short hot col. -130C													
14-5-2	Two hot and two warm cols at -90 or -95	18	65	81	47	27	5	3.1	2.9	11	2.6 -95	NA	8	
14-5-2	Two hot cols (1 is 3 col wide) at -130C													
14-4-1	Glowing serials contaminated by hot px. 4 hot columns at least one very hot near serials. No dark	20	63	84	50	36	8	2.8	3.2	5	NA -90	NA	7	3600x2048 images
14-4-1	1 ½ hot cols, one very hot same as above. -130C													Dark OK
14-2-6	Columns 1049,1050 share charge below row 843	16	66	85	45	38	2	2.2	2.3	6	2.7 -132	NA	11	
14-10-5	two warm columns	21	70	88	68	36	5	2.2	2.4	10	2.0 -130	NA	10	
14-4-2	One warm column	18	69	85	51	18	1.2	3.1	2.9	7	6 -90	NA	9.5	
14-4-3	two warm columns	19	65	82	49	21	5	3.4	3.2	11	4.3 -90	NA	7.5	
	Spare Devices in order of Preference													
14-7-2	At least 28 hot pixels producing partial or full hot columns - distributed over entire CCD; mostly singles	16	58	79	47	16	8	2.7	2.5	8		8		3600x2048 images
14-7-2	3 warm cols at -123C													
97C2	Poor serial CTE; Poor PSF- Images fuzzy.	12	51	73	NA	38	3	3.1	2.9	5	2 -127	NA	9	
14-1-6	1 warm col. 1 dark col. High freq QE variations	8	53	66	27	48	5	2.1	1.3	15	2.7 -137	5		Poor AR Coating
14-1-1	3 hot columns; high frequency variations	8	53	66	28	49	8	2	2.3	27	2.5 -137	3		Poor AR Coating

QE Curves for Red Science Mosaic



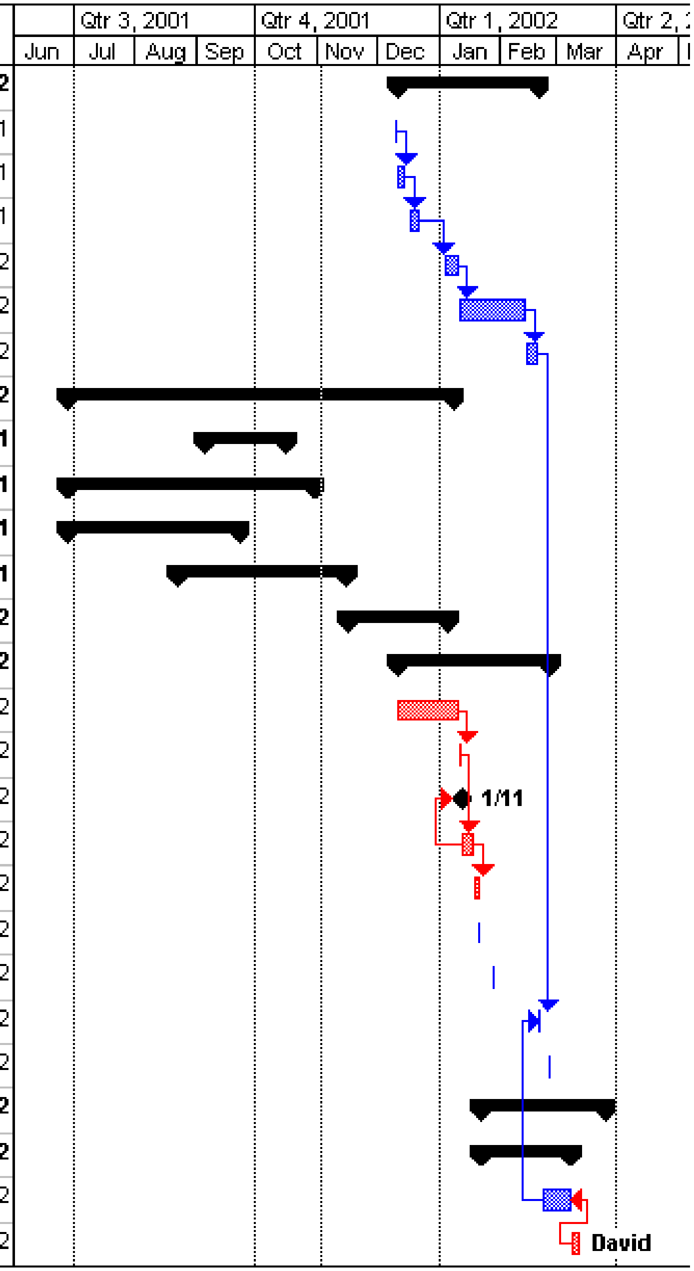
FC CCDs

- Presently show low-level 60 Hz ground-loop noise from science CCD power supply. We plan to fix this.

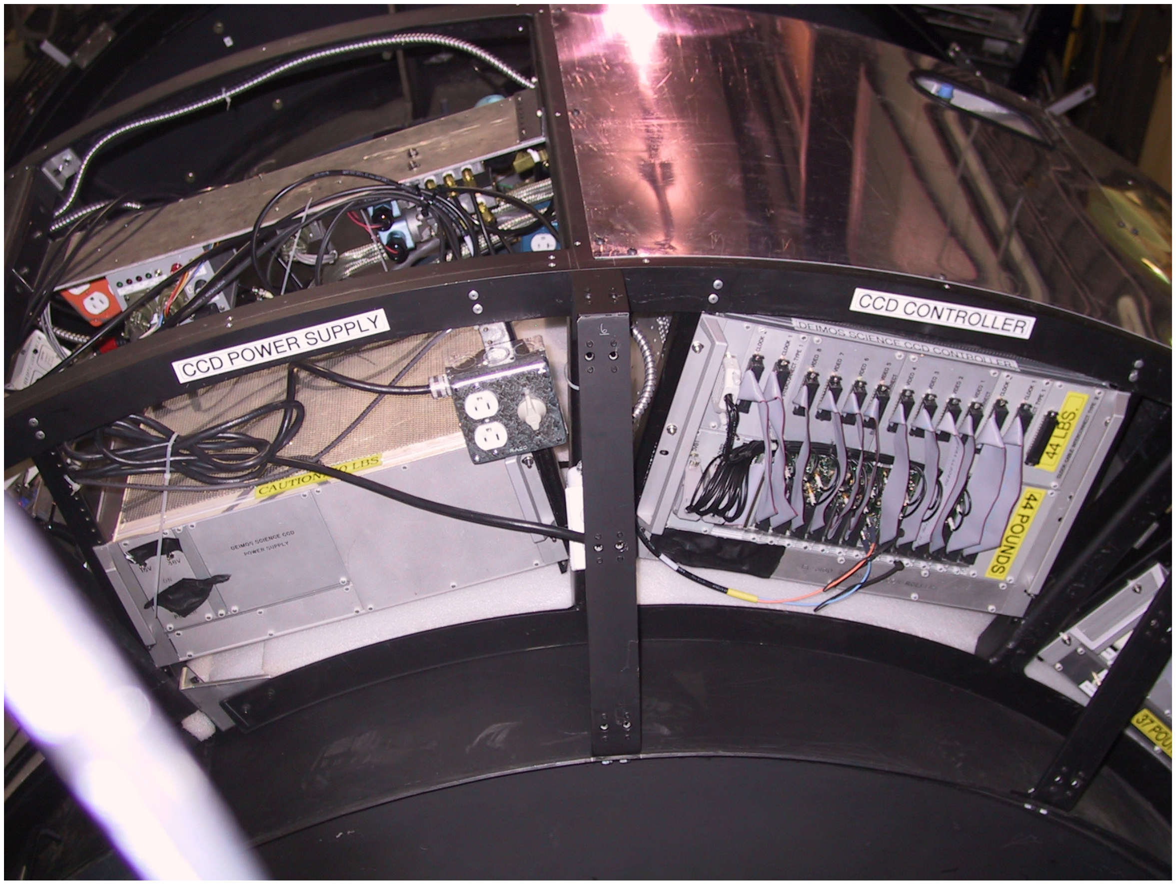
FC CCD Requirements

	Specifications	Achieved
Manufacturer	Orbit	Orbit
Geometry		
Size	600 x 1200 px (frame transfer; 300 x 1200 usable)	600 x 1200 px (frame transfer; 300 x 1200 usable)
Pixel size	15 mu	15 mu
Buttability	1-edge	1-edge
No. amplifiers	1	1
Illuminations	Front-side thick	Front-side thick
Peak QE	>50%	40%
RO speed	<30 musec/px	?? musec/px
RO noise	5 e-/px	10 e-/px
Gain	No spec	2.8 e-/DN

ID		Task Name	Duration	Start	Finish
12		**Red Mosaic installation/test**	**44 days**	**Mon 12/10/01**	**Tue 2/19/02**
13		move dewar to CCD lab	1 day	Mon 12/10/01	Mon 12/10/01
14		clean and open dewar	4 days	Tue 12/11/01	Fri 12/14/01
15		pump down and test new LN2 Can	1 wk	Mon 12/17/01	Fri 12/21/01
16		Installation of mosaic/leveling	1 wk	Thu 1/3/02	Wed 1/9/02
17		test run red mosaic	24 days	Thu 1/10/02	Tue 2/12/02
18		warmup and pack	1 wk	Wed 2/13/02	Tue 2/19/02
19		**Fabrictation**	**127 days**	**Wed 6/27/01**	**Mon 1/7/02**
26		**Electrical**	**30 days**	**Tue 9/4/01**	**Mon 10/15/01**
29		**Software**	**87 days**	**Wed 6/27/01**	**Mon 10/29/01**
34		**System Testing**	**61 days**	**Wed 6/27/01**	**Fri 9/21/01**
40		**Reviews**	**60 days**	**Wed 8/22/01**	**Wed 11/14/01**
44		**Post Pre-ship review**	**27 days**	**Thu 11/15/01**	**Fri 1/4/02**
47		**Pack and Ship**	**47 days**	**Tue 12/11/01**	**Mon 2/25/02**
48		Pack	14 days	Tue 12/11/01	Wed 1/9/02
49		Truck to Oakland	1 day	Thu 1/10/02	Thu 1/10/02
50		Ship Date	0 days	Fri 1/11/02	Fri 1/11/02
51		Marine Shipment	5 days	Fri 1/11/02	Thu 1/17/02
52		truck to mountian	2 days	Fri 1/18/02	Mon 1/21/02
53		Airshipment 1	1 day	Mon 1/21/02	Mon 1/21/02
54		Airshipment 2	1 day	Mon 1/28/02	Mon 1/28/02
55		Airshipment3	1 day	Wed 2/20/02	Thu 2/21/02
56		Airshipment 4	1 day	Mon 2/25/02	Mon 2/25/02
57		**Assemble in HI**	**44.25 days**	**Tue 1/22/02**	**Mon 3/25/02**
58		**Pre Dewar**	**33.5 days**	**Tue 1/22/02**	**Fri 3/8/02**
87		Test dewar in lab	10 days	Fri 2/22/02	Fri 3/8/02
88		Install dewar assembly	2 days	Fri 3/8/02	Tue 3/12/02



Science CCD Controller



- Leach II video, timing and utility boards
- 8 video boards
- 16 video channels (dual amp readout for all 8 CCDs)
- Separate power chassis
- On-board UPS (in DEIMOS carriage)
- Dual-amp readout speed: 39 sec
- Video crosstalk (A to B amplifiers) 3/60,000

CCD Controller Requirements

	Specifications	Achieved
Exposure modes		
Regular	Yes	Yes
Multiple w/single readout	Yes	Yes
Multiple w/shift of image by N rows	Yes	Yes?; not tested
Dark and bias	Yes	Yes
User-definable overscan	Yes	Yes
Subregions, for mask align	Yes	Not yet; (subregions do not span CCDs)
On-chip bin and window	Yes	Yes (windows are same on all CCDs)
Software selection between 2- and 1-amp mode	Yes	Yes
Hooks for frame transfer	Yes	Hardware is here
Option for drift scan	Yes	Unclear

CCD Controller Requirements

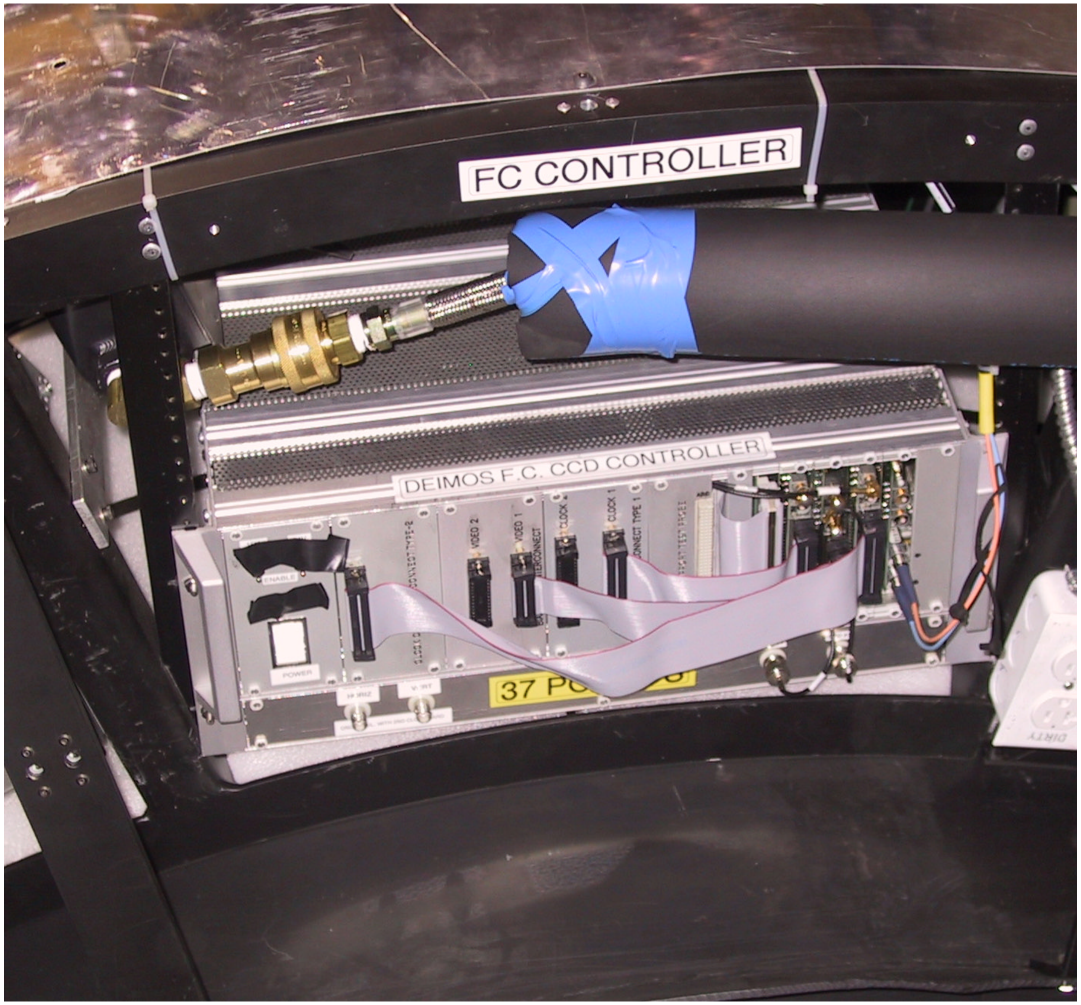
	Specifications	Achieved
Software-selectable gains	4	2
Software-selectable clamp/sample times	2	2: 1 and 5 musec
Linearity of electronics	<0.5% up to 64K DN	Predict OK
A/D converter resolution	16-bit	16-bit
A/D converter accuracy	+/-1 bit	+/-1bit
Bias level flatness across one row	+/-1 DN	+/- 1 DN
Correlated noise	<1e	Odd-even row effect on #5, cause unknown; all others OK
Resid. image on over-expose	None from x100 over- exposure (goal)	Data being taken
CCD amplifier xtalk	<1/100,000	3/60,000
Match bias levels	+/-5 DN	5-6 DN
Match gains	+/-1%	Not possible for MIT-LL CCDs

Science CCD Controller

Outstanding Issues

- Odd-even noise on CCD5
- Power up/down sequence needs to be tested.
  Implement recommended MIT-LL scheme?

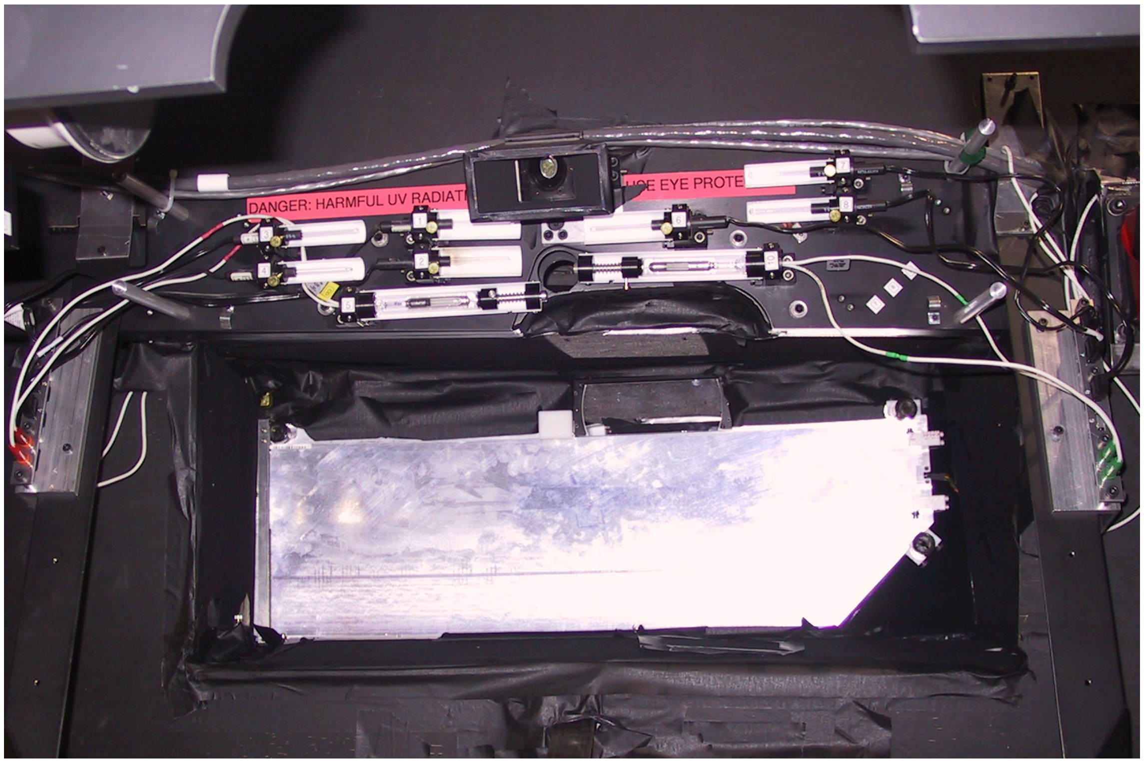
FC CCD Controller



- Leach II electronics
- 1 video boards
- On-board UPS
- Supports 2 amplifiers (single amp readout for each FC's ccd)
- Presently showing low-level ground-loop noise. Plan to fix

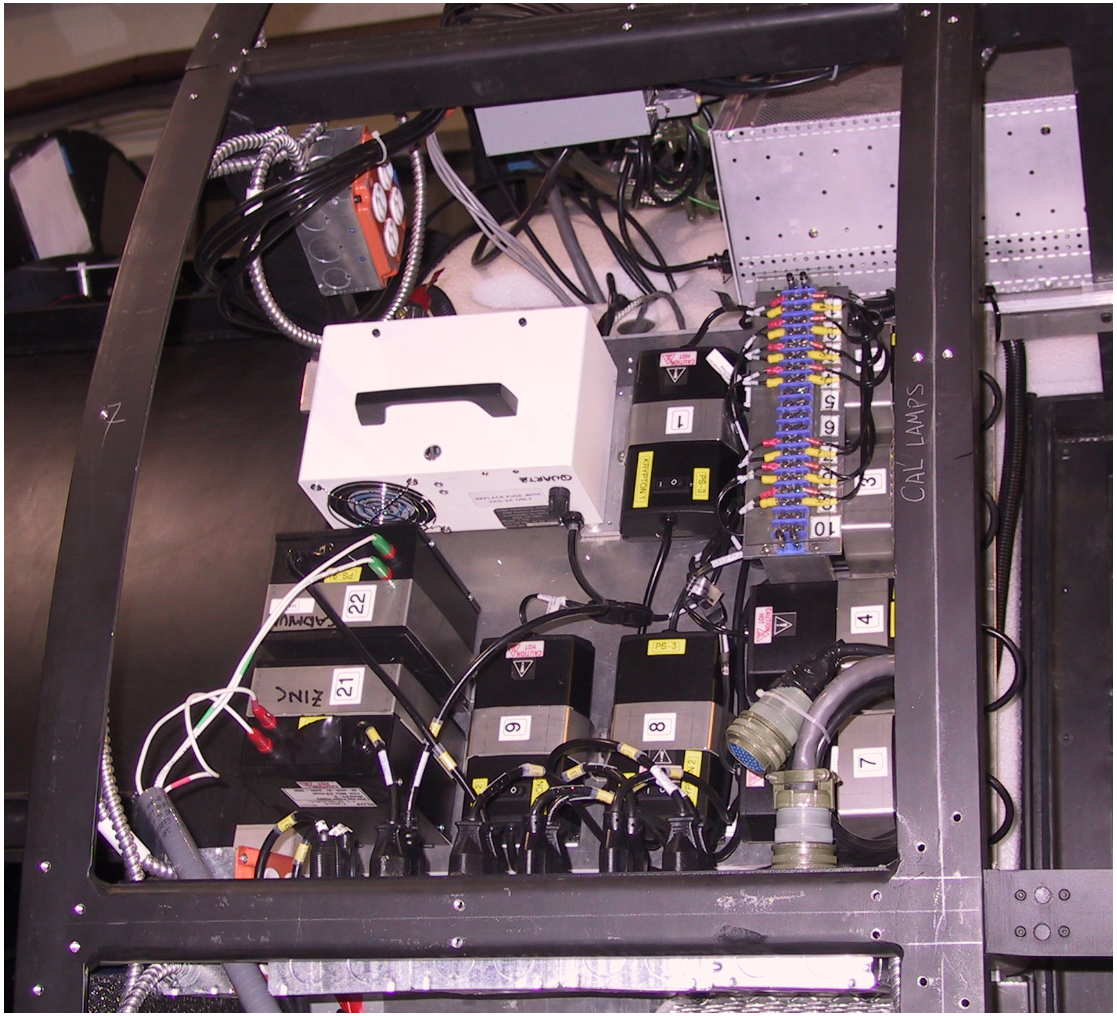
VME Crates

Calibration System



- Ne, Ar, Zn, Cd, Hg, Kr, Xe
- Mounted near focal plane; illuminate hatch
- Quartz continuum lamp: light piped in by fibers from electronic ring
- Interlocked to front hatch
- Good blue coverage

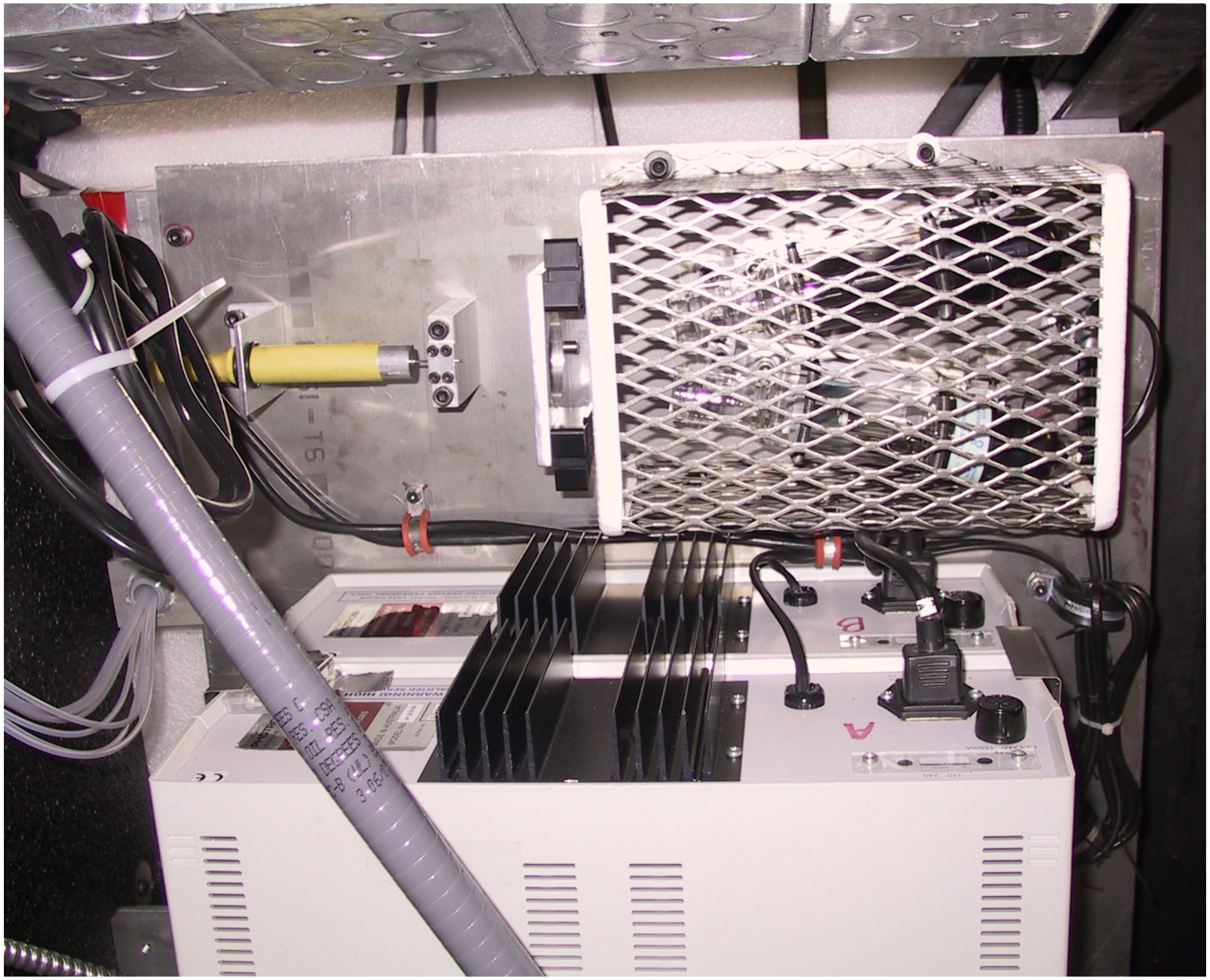
Calibration System



Calibration System Requirements

	Specifications	Achieved
Wavelength lamps:		
Spectral coverage	4000-10500 A	Not yet tested
Maximum exp time	> =1 sec	>=1 sec
Brightness uniformity along slit	x2	x2
Continuum lamp:		
Spectral coverage	4000-10500 A	Not yet tested
Maximum exp time	>=1 sec	> 1 sec
Brightness uniformity along slit	x2	x2

FC Light Source

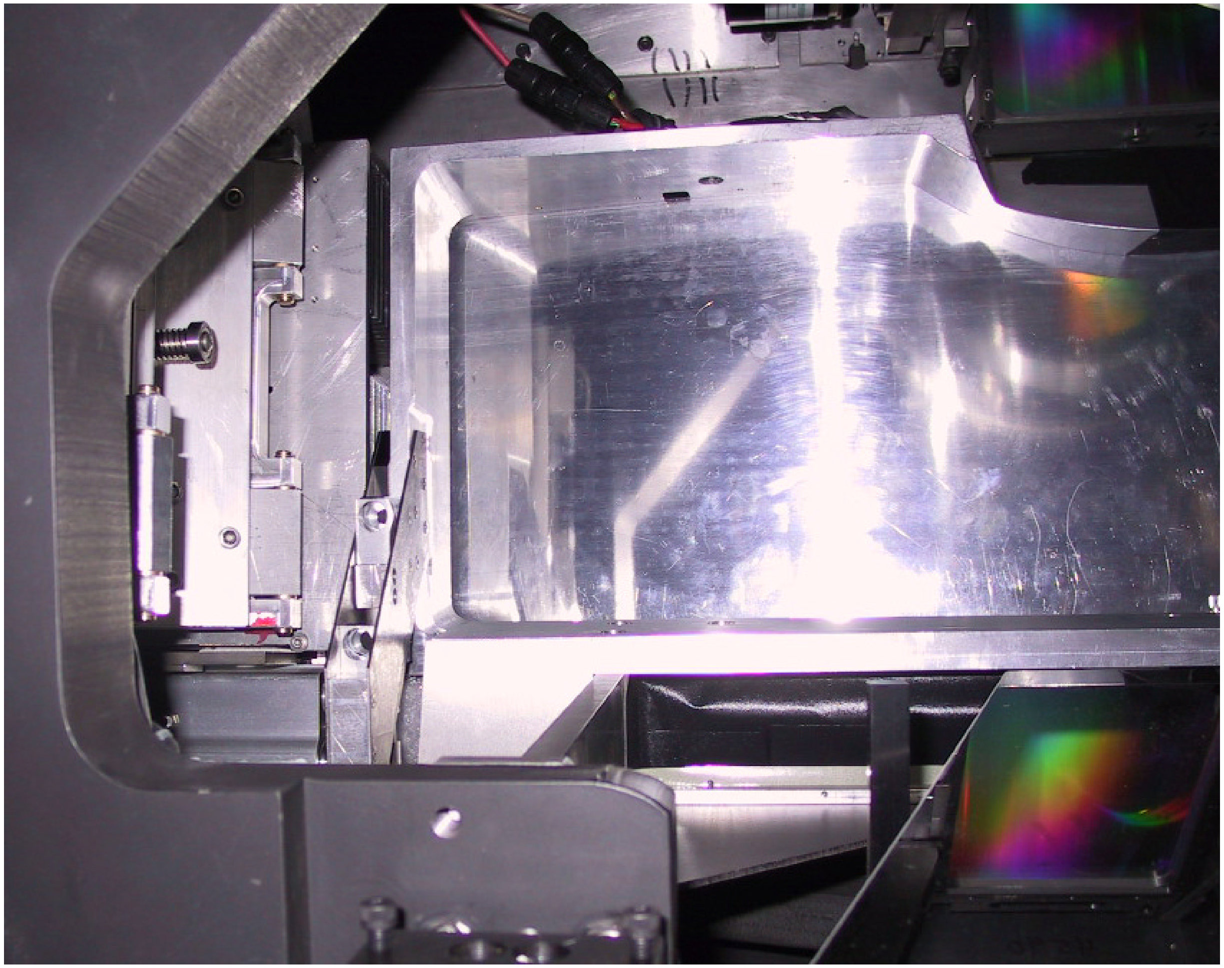


- 2 Cu/Ar lamps for spectra
- One used at a time, second can be turned on if first fails
- "White" LED for imaging
- Piped into spectrograph focal plane via four optical fibers
- Four fiber feeds mounted at opposite ends of slitmask form; light falls on FC CCDs

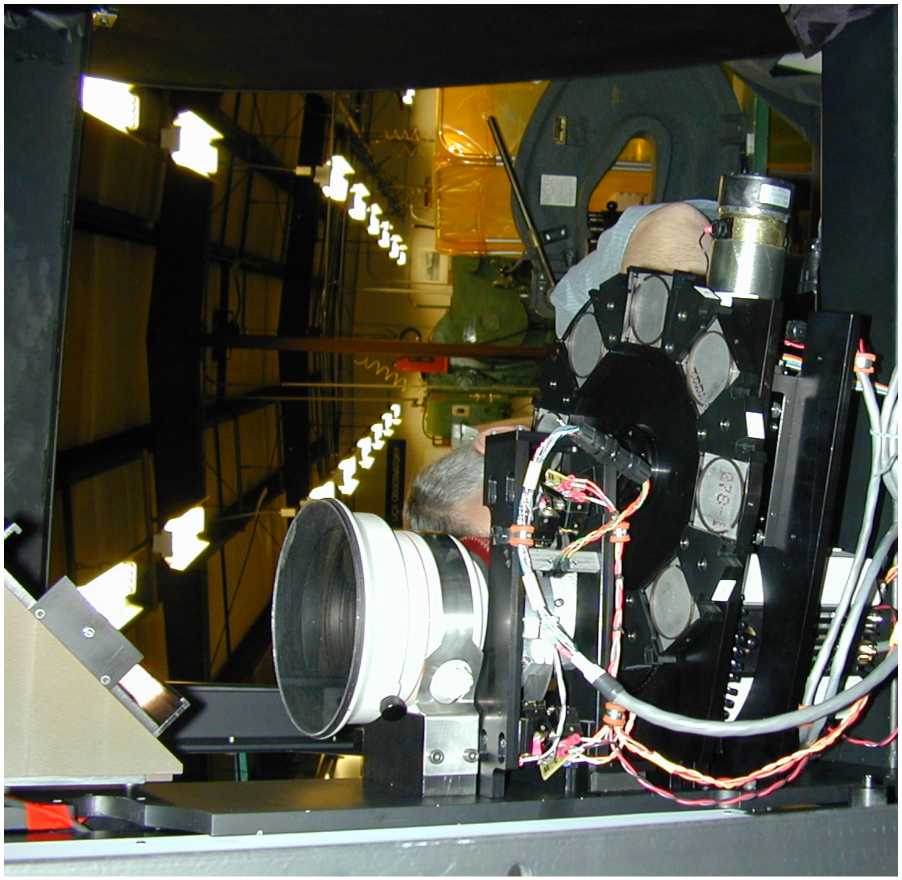
FC Light Sources

	specification	achieved
Exposure time	10 sec	10 sec
Spectroscopic mode		
Lamp type	CuAr	CuAr
Spectral coverage	Service all gratings and tilts	Yes
Onboard spare	Yes	Yes
Direct imaging mode		
Lamp type	CuAr	Diode or CuAr
Spectral coverage	Service all filters	Not yet tested

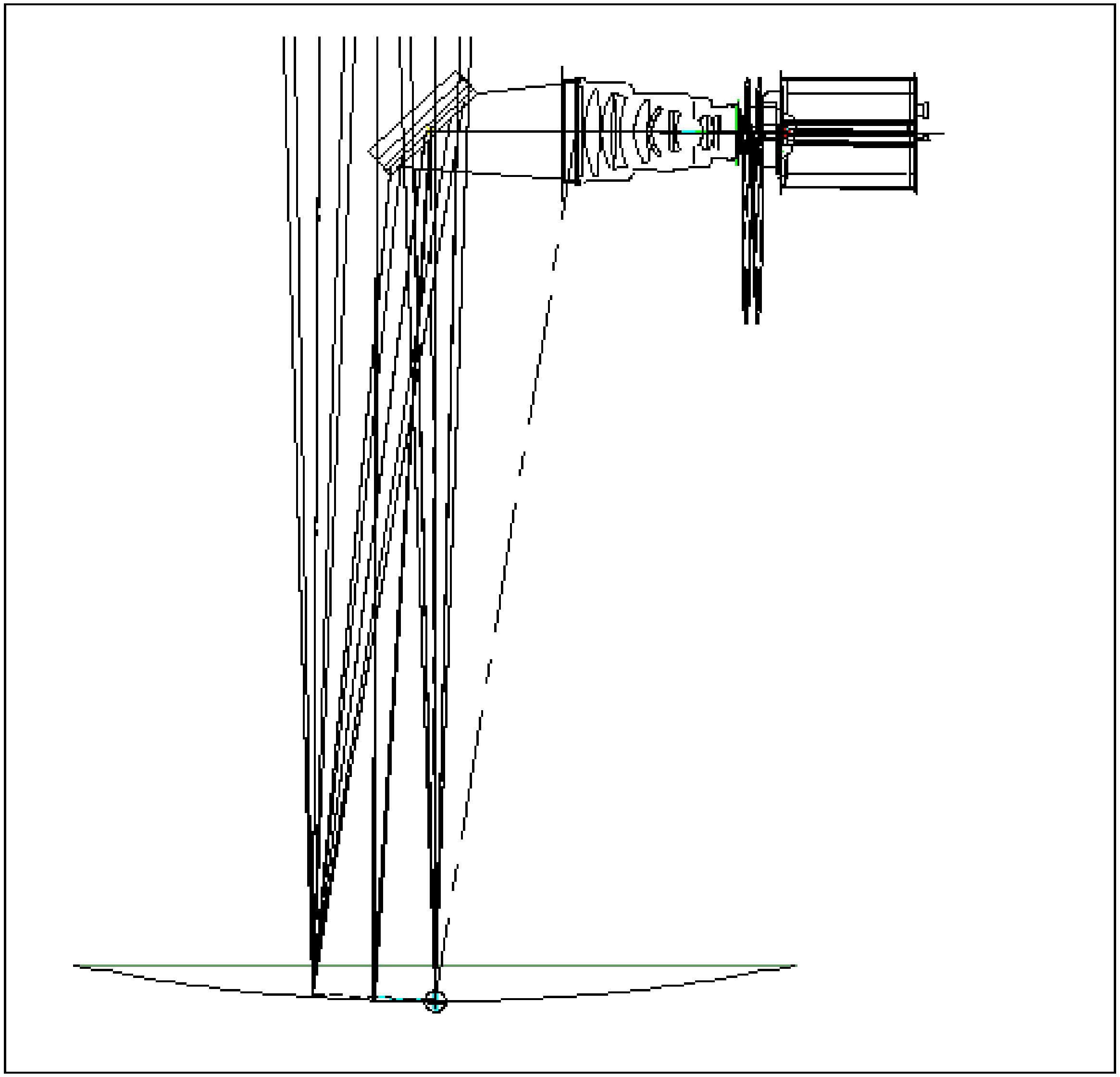
FC Fibers Feeds



TV System Specs

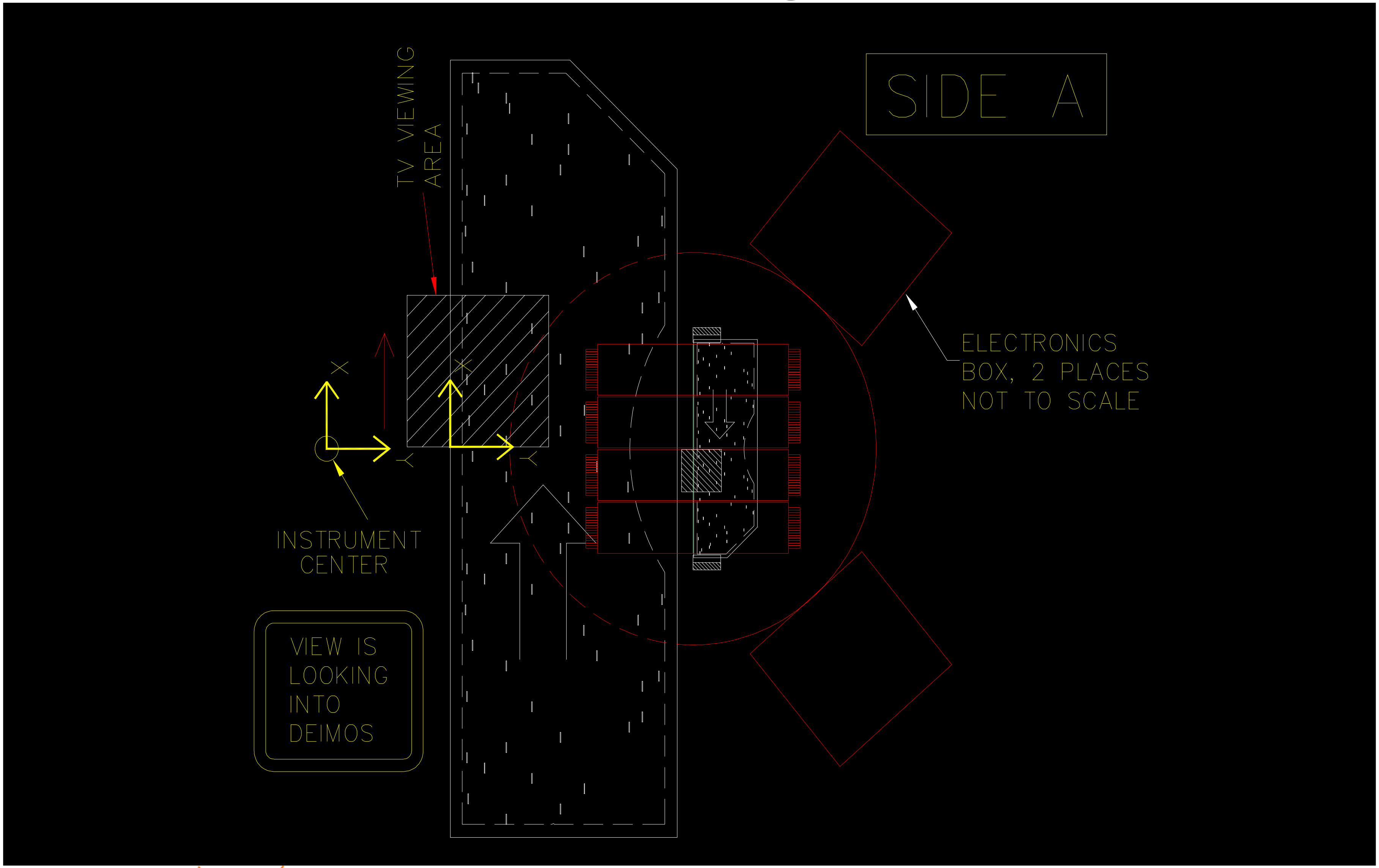


- Canon 200 mm lens stares directly at telescope focal plane
- View encompasses TV pickoff mirror (4.5 sq. arcmin) and slitmask (8.5 sq. arcmin)
- Vignetting on pickoff mirror small; vignetting on slitmask area 0-60%
- 1000 x 1000 px Site CCD from Photometrics
  - 24 micron pixels
  - Thinned, back illuminated
- Flexure less than 1 sec on sky
- Accurate guiding relative to permanent reseau mark in focal plane
- 8 TV filter slots (BVRI supplied)
- Remote focusing mechanism
- Longslits (not supplied at delivery)

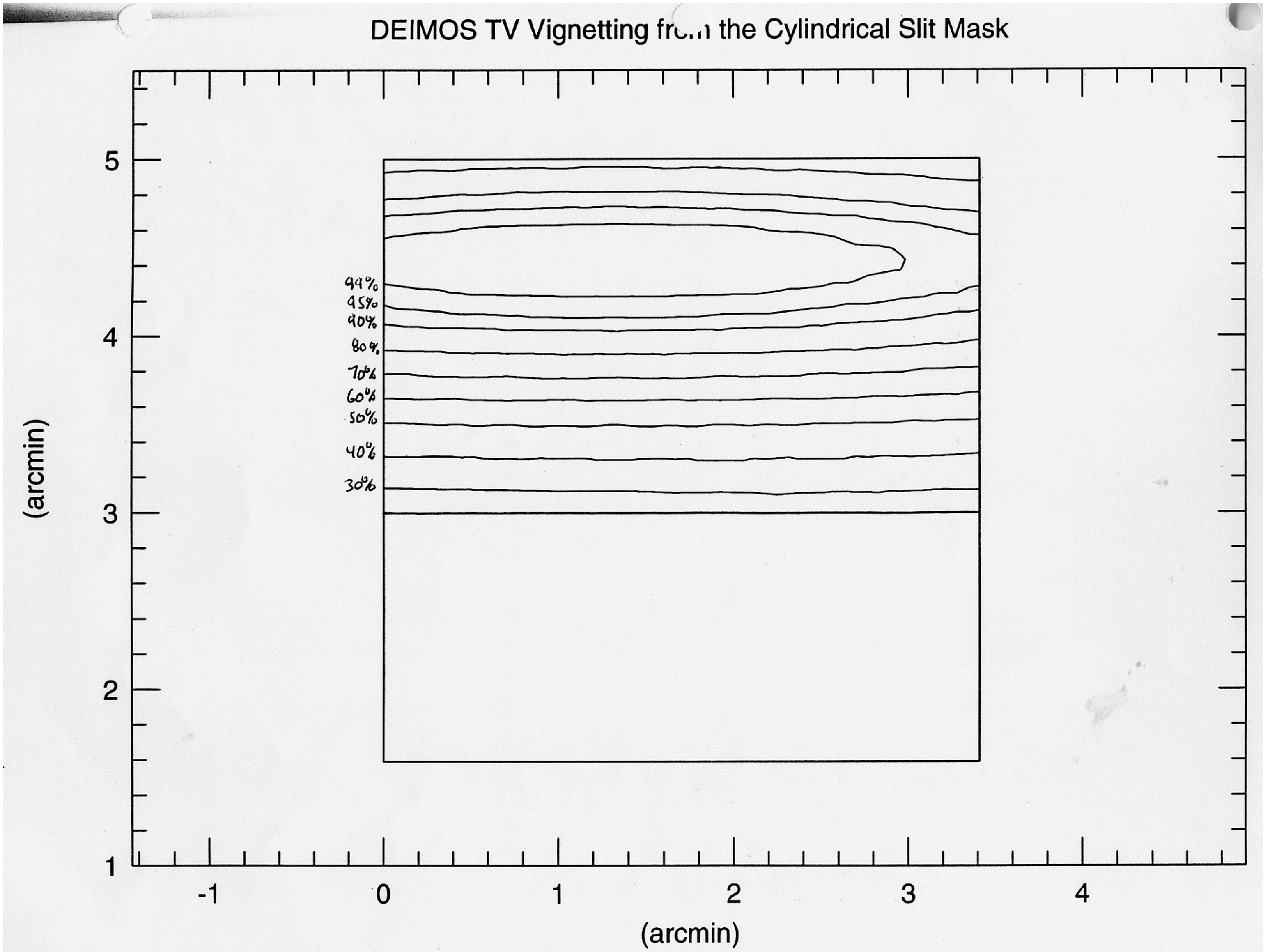


TV System Light Path

TV FOV: see diagonal lines

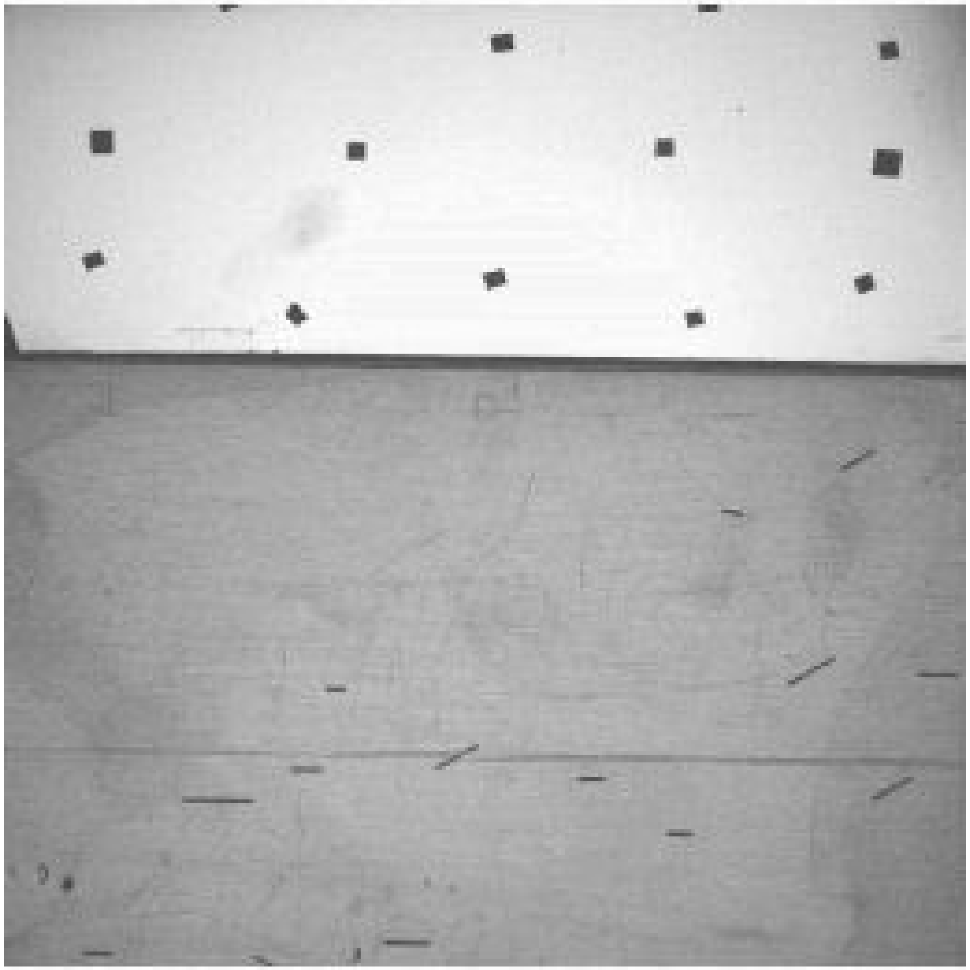


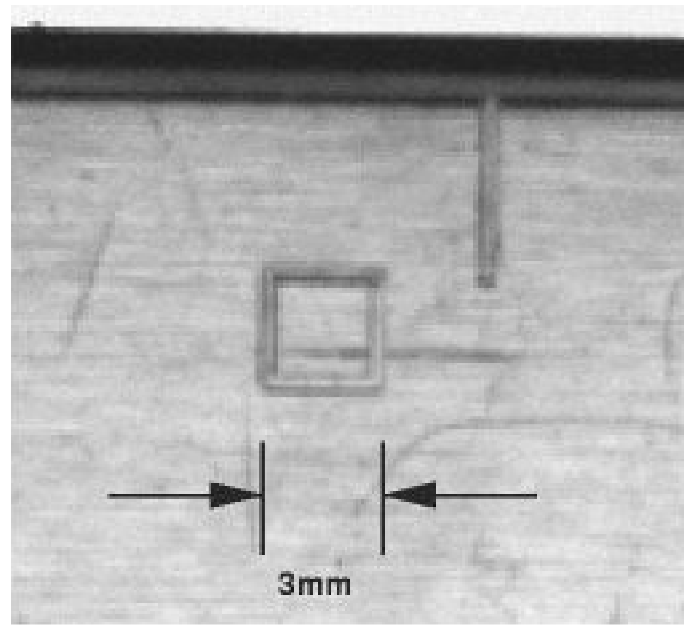
TV Slitmask Vignetting



TV Pickoff Mirror

Picture from TV System





TV System

	specification	achieved
Optical layout	Offset guider; flip mirror to view slitmask	Staring view of offset guider mirror and slitmask
FOV offset guider	5.3 sq amin	4.5 sq amin
FOV on slitmask	5.3 sq amin	8.5 sq amin
Scale	0.135 asec/px	0.205 asec/px
Vignetting on 30 asec	No spec	None
Keck destack (needed to run Malign)		

TV System

	specification	achieved
Fastest frame time	1 sec per full frame	12 sec per full frame (limited by Keck electronics; 7 sec in Santa Cruz) 5 sec for offset guider only
Slit-viewing area	3 longslit mirrors	Not at delivery; TBD
Parfocal with telescope focal plane	±0.04 in	TBD
Focus	Mechanized	Mechanized
Time to limits	No spec	13 sec

TV System

	specification	achieved
Filter wheel		
Number of slots	8 slots	8 slots
Time to limits	No spec	21 sec
Filters provided	BVRI	BVRI, ND1.0 and 2.0
Flexure		
Linear	<1 asec	0.6 asec x 0.25 asec
Rotation	No spec	±0.03 asec @ edge FOV
Guiding mode	Star relative to reseau mark in tel focal plane	Star relative to reseau mark in tel. focal plane
Image quality	No spec	Good; not yet quantified

TV System: CCD

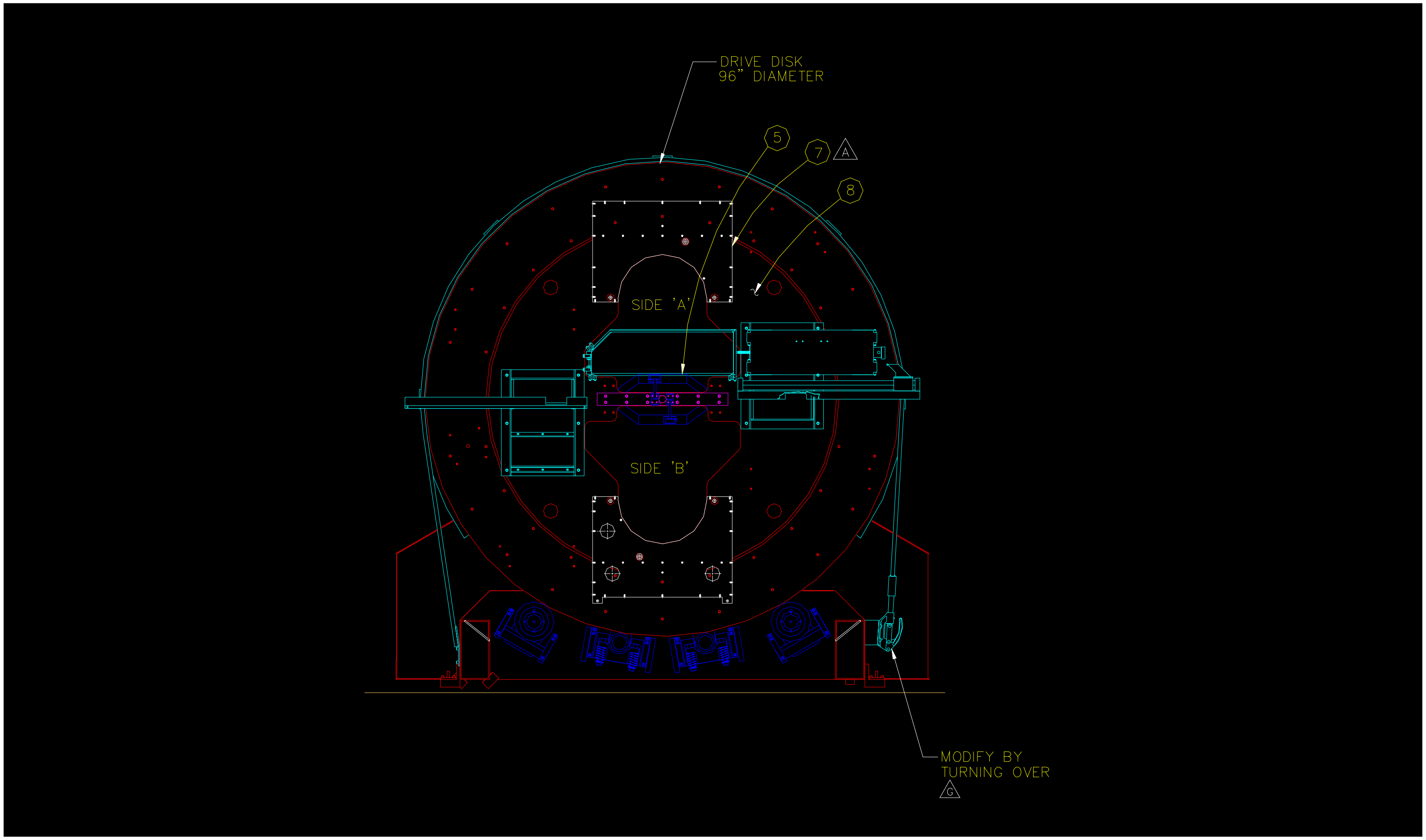
	specification	achieved
Geometry		
• Pixels	1024 x 1024	1024 x 1024
• Pixel size	15-24 mu	24 mu
• Illumination	Back-side thinned	Back-side thinned
• RO speed	1 musec/px	5 musec/px @ 200KHz
• RO time whole array	1 sec (goal)	7 sec (Santa Cruz) 9 sec (Keck)
• RO time offset guider	1 sec (goal)	3 sec (Keck)
• Gain	No spec	3.9 e-/DN=Gain 4 (manuf.)
• RO noise	<10 e-/px	11.4 e-/px, Gain 4 (manuf.) 17 e-/px, Gain 4 (meas.)
• Dark count	<10 e-/px/sec @ -25 C	12.3 e/px/sec (manuf.)
• Binning	At least 2 x 2	Multiple bin sizes
• Number guide boxes	>2	Multiple
• Cosmetics	No blemishes	No blemishes

TV System Test Results

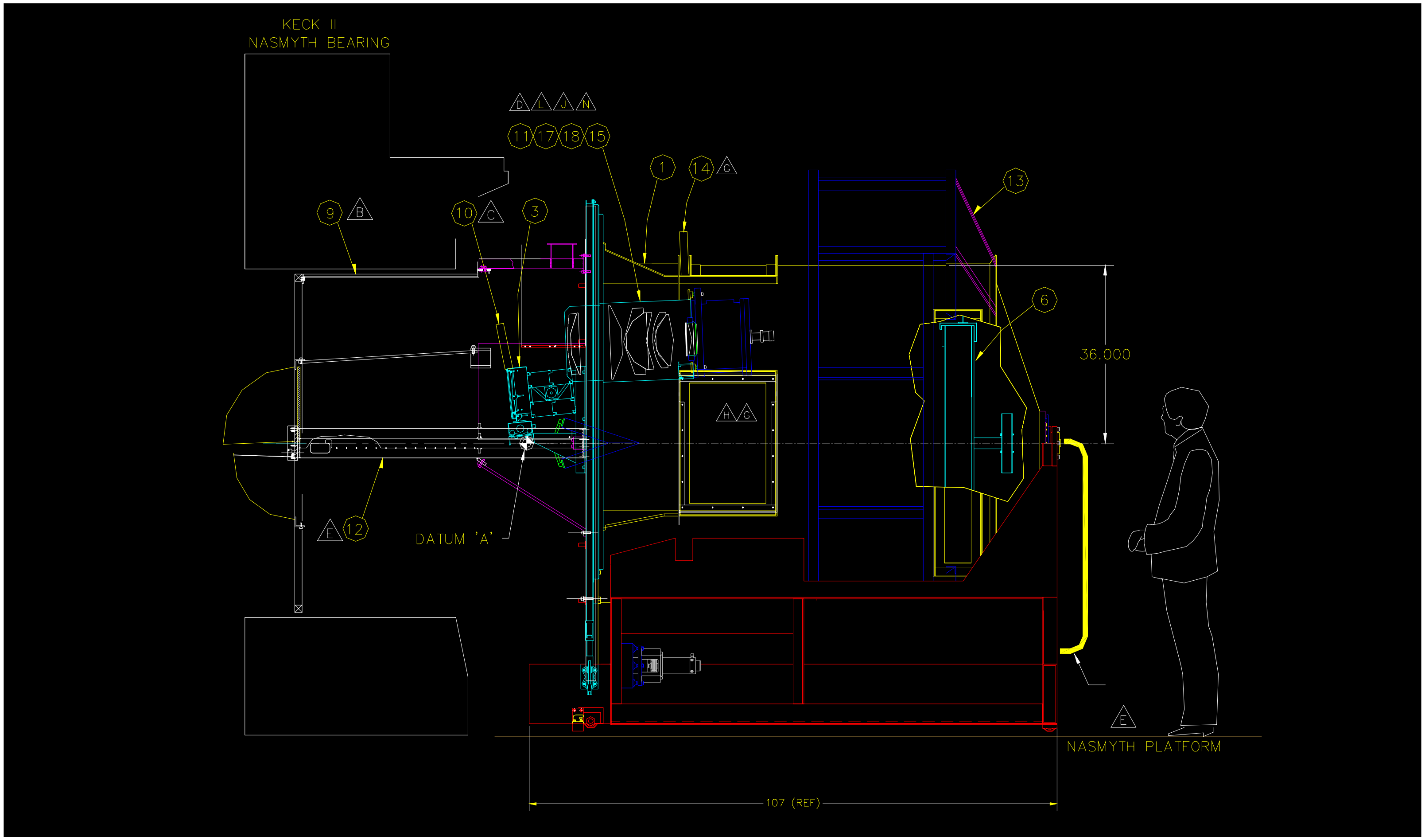
Rotation

- Front bearing; 2 in thick steel disk, 96 in diameter; turned to TIR of > 0.0005 inches on diameter
- Rear bearing: roller bearing in spherical bearing mount
- Driven by Galil 500-1000C servomotor
- 260/1 harmonic drive
- 12/1 disk/drive wheel reduction
- Encoders
  - Galil motor encoder
  - Renishaw optical encoders on rear bearing; two heads
- Velocity servo-loop to motor encoder
- Position servo outer loop to Renishaw encoders

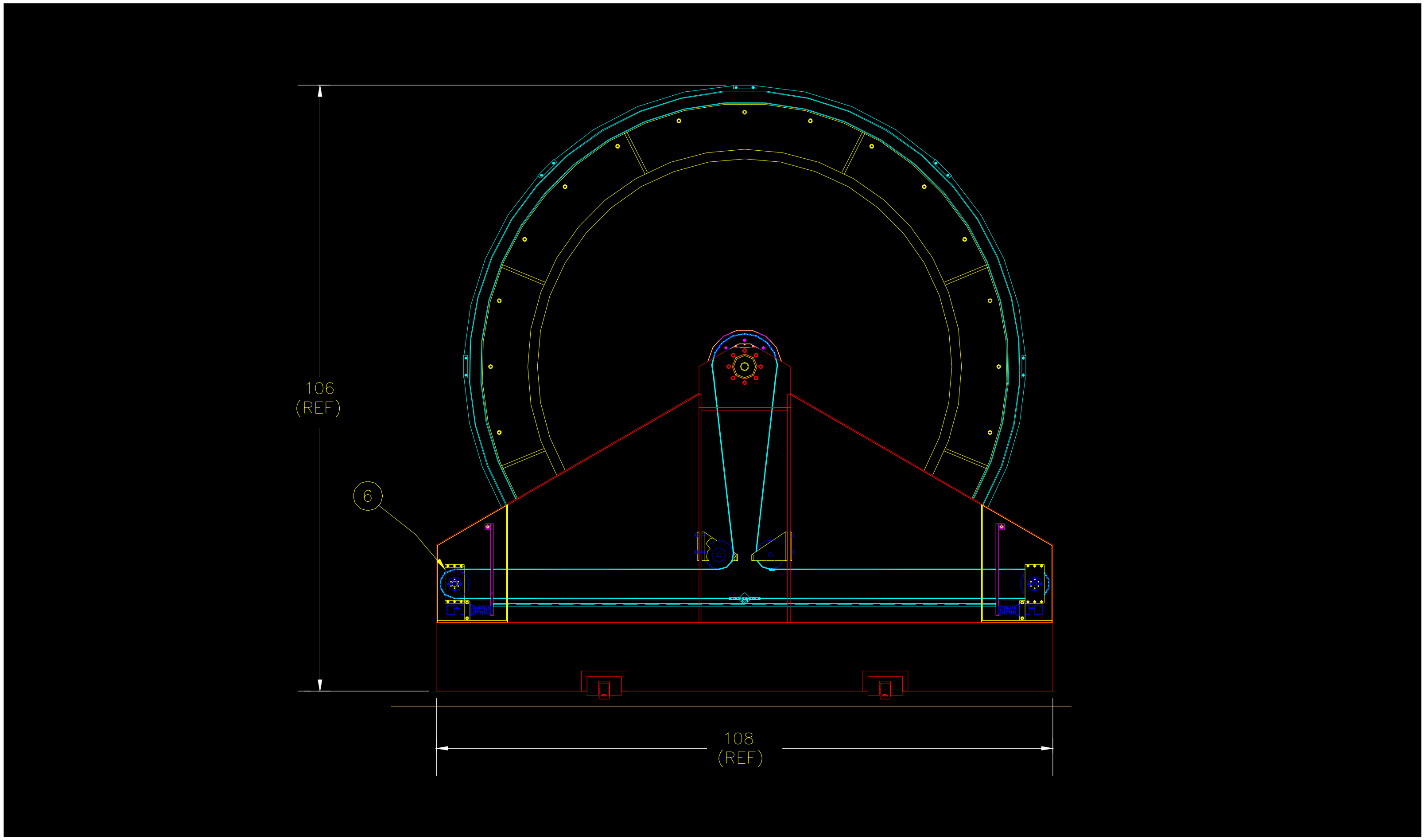
DEIMOS Rotation



DEIMOS Rotation



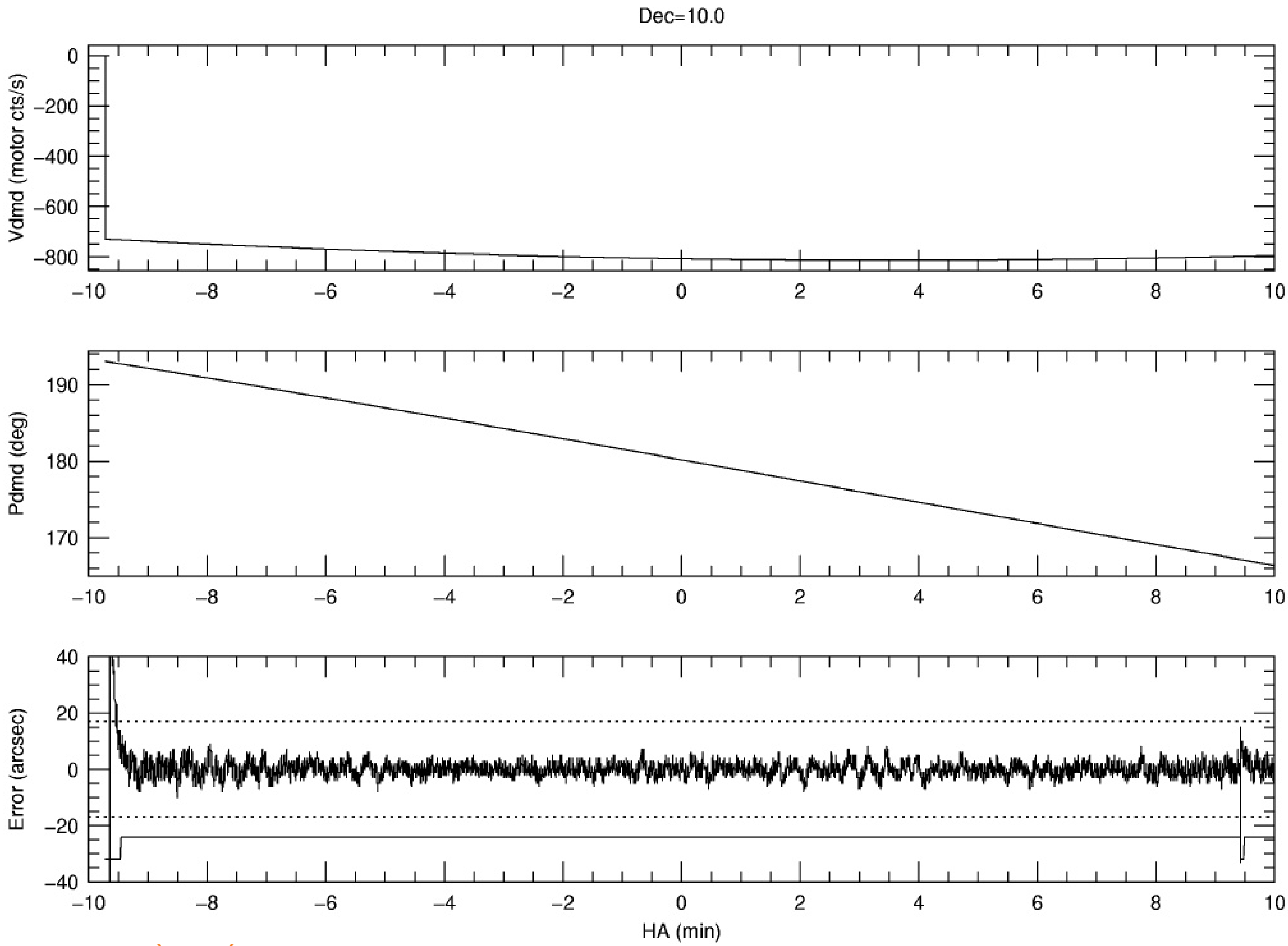
DEIMOS Rotation



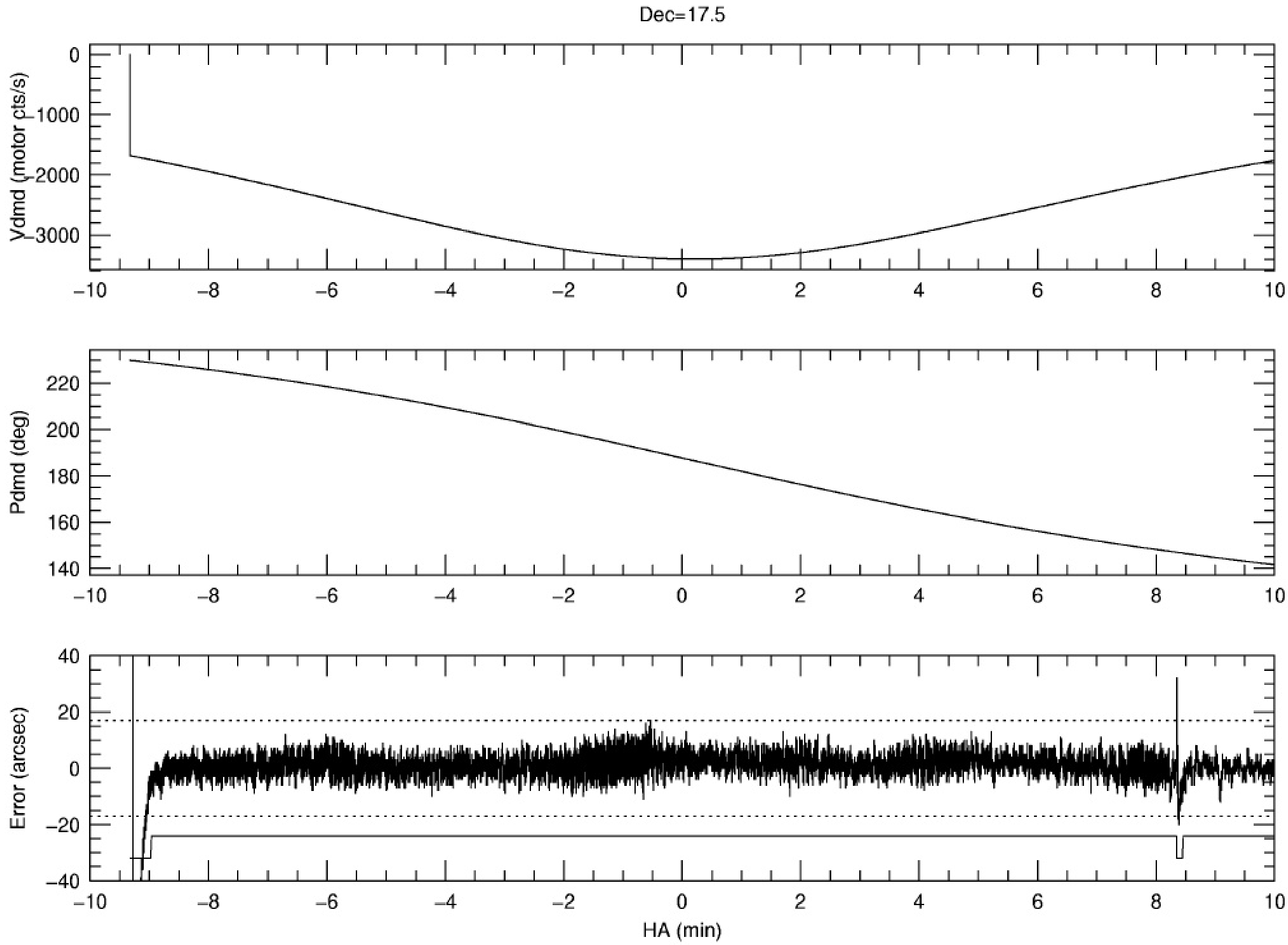
Rotation

	Specification	Achieved
Cablewrap range of travel.	810 deg	790 deg
Slew speed	360 deg / 2 min	360 deg / 2.6 min
Max tracking error	17 arcsec =0.05 arcsec at ends of slitmask	17 arcsec over most of sky; 40 arcsec near zenith (see below)
Radius of zenith hole	0.5 deg	0.5 deg
Out-of -tracking summary:	Zenith distance	Duration of error
	>2.0 deg	Never out of track
	1.8	|HA| < 2 min
	1.3	2min < |HA| < 4min
	0.8	3min < |HA| < 4min
Settling time	No spec	10 sec

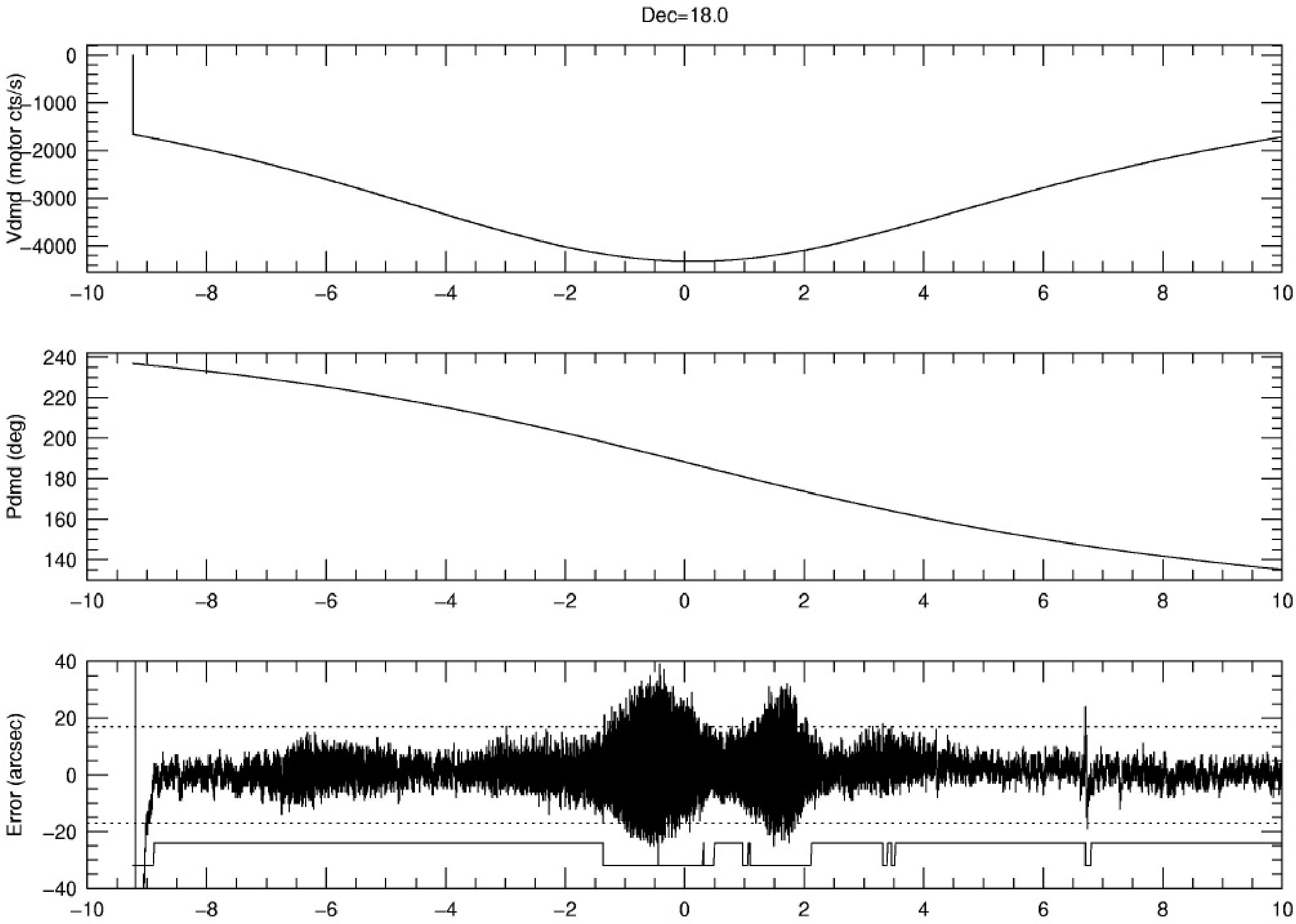
Rotation Test Results



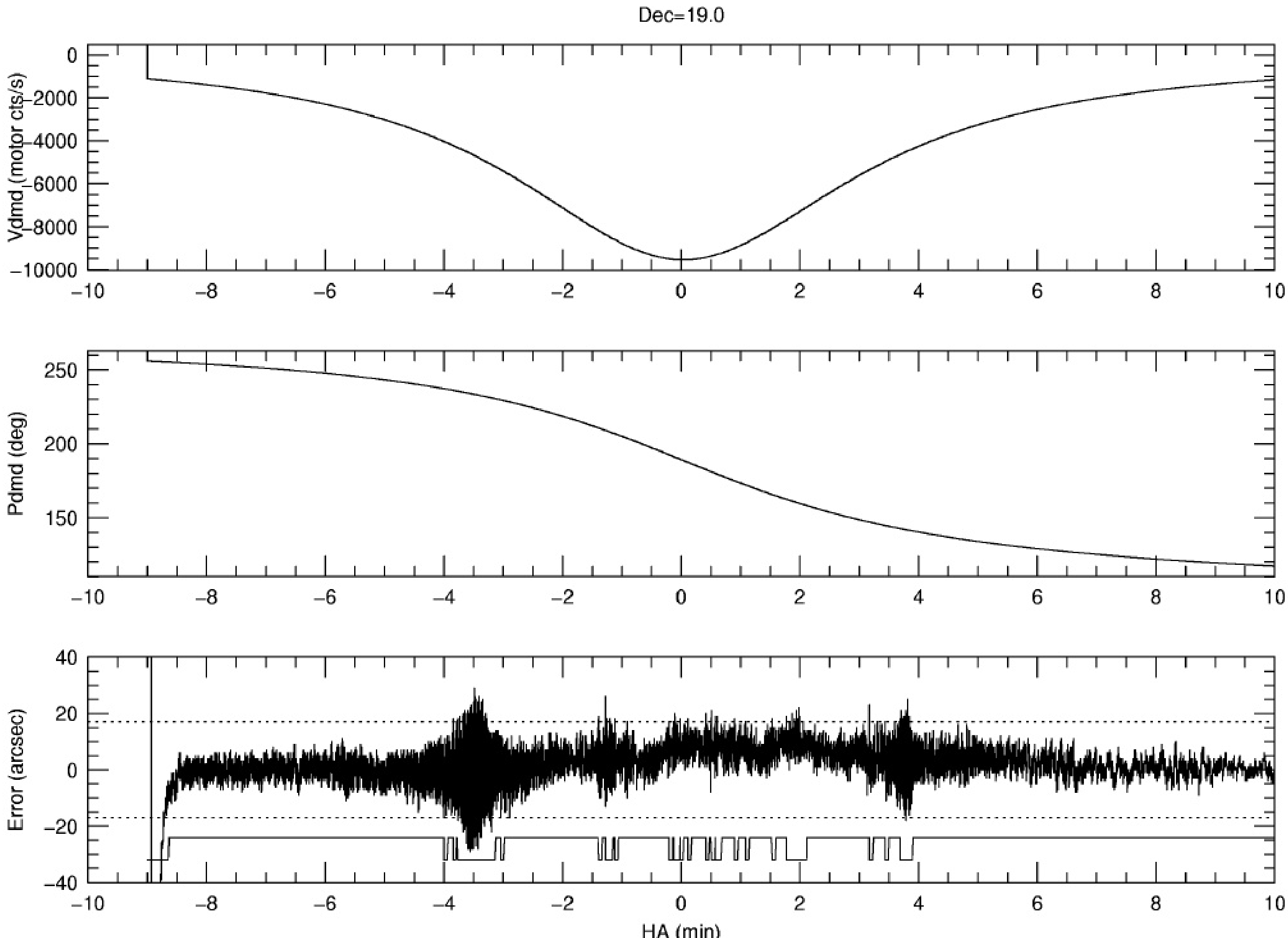
Rotation Test Results



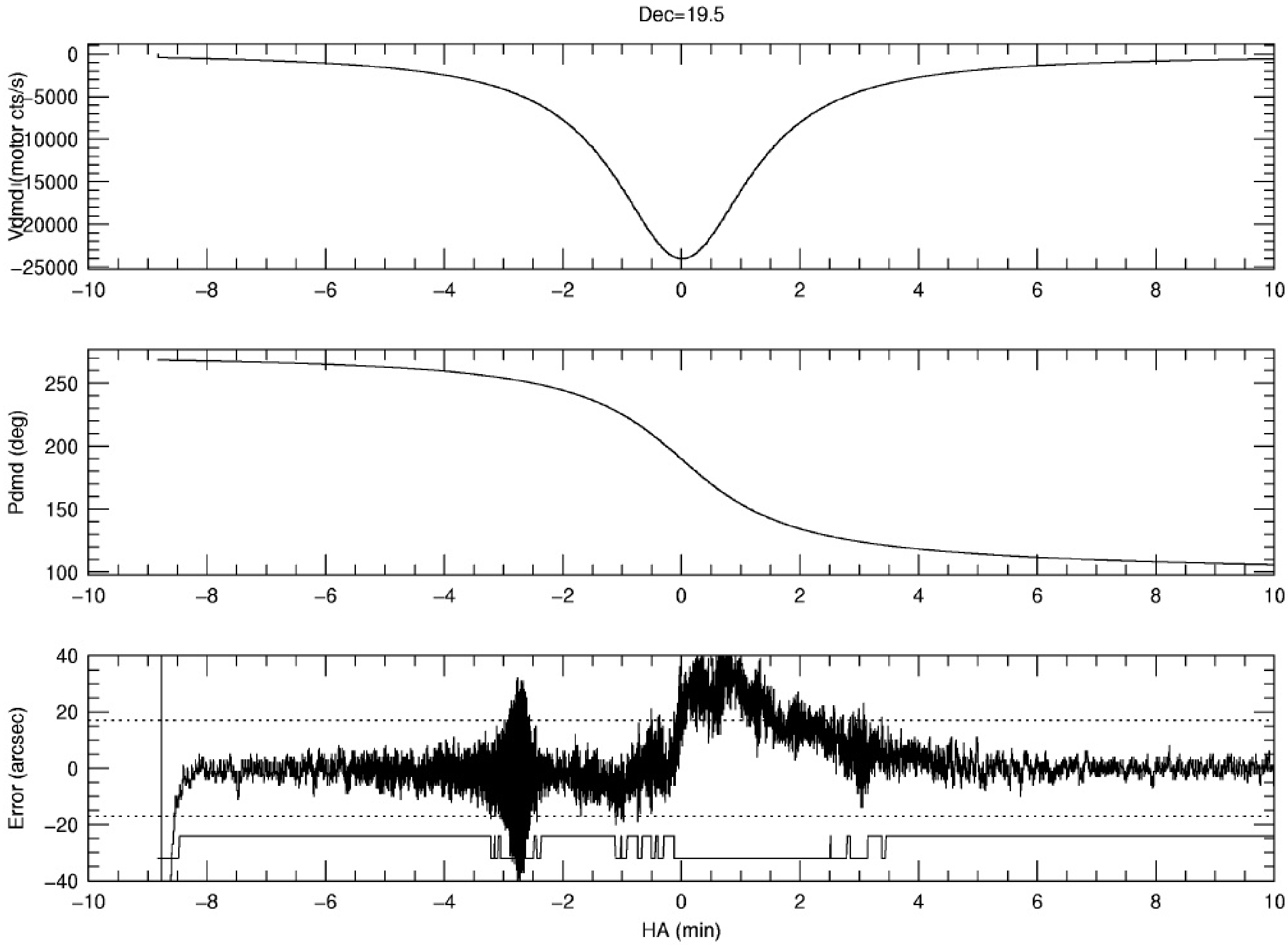
Rotation Test Results



Rotation Test Results



Rotation Test Results



Rotation

- **Safety Issues:**

- Power to the rotator is cut off when:
  - the dome's estop button is pressed;
  - one of DEIMOS's red panic buttons is pressed;
  - the band brake is applied;
  - the instrument enters a secondary limit;
  - a hatch is open.

- Computer control of motor power is bypassed when:
  - the power-bypass switch is toggled. This is necessary to drive the rotator out of a secondary limit, because the Galil power is cut off entirely when the rotator is in the secondary limit.

- Keyword-driven control of motion is disabled when rotation control is switched from keyword to hand paddle. (Rotation control is set by a toggle switch on the hand paddle.)

Rotation

Rotation Modes and DCS:

The rotator has several rotation modes in which it operates; the mode is controlled by the ROTATMOD keyword. These modes are ignored when under manual control.

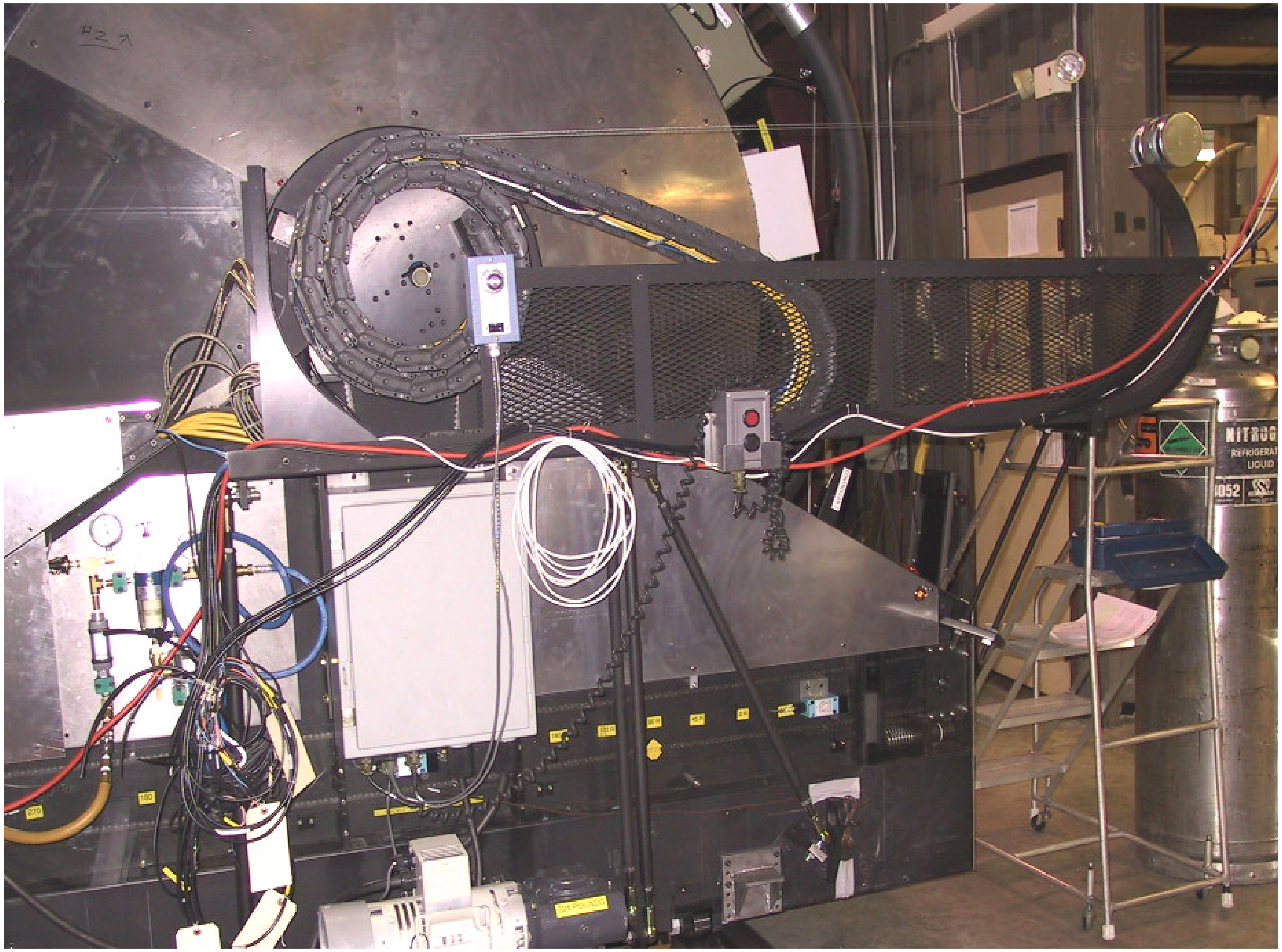
Mode	Meaning
Pos	Keyword-specified positions may be entered (e.g. ROTATPOS=-190). DCS demands (ROTINITC, ROTHALTC, ROTSTBYC, ROTPDSTS, etc) are ignored -- this allows the DEIMOS operator to carry out tests or other operations in Pos or Jog mode, without being affected by the telescope operator pressing INIT/HALT/STBY buttons at a DCS GUI.
Jog	Keyword-specified velocities may be entered (e.g. ROTATVEL=1.5). As in Pos mode, DCS demands are ignored.
Halt	Keyword-requested positions and velocities are ignored. Can be switched into DCS-tracking mode by setting the DCS keyword ROTINIT=true or ROTSTBY=true.

Rotation

DCS: The instrument will start tracking DCS demands (ROTPDSTS and family). The instrument responds to the usual ROTSTBYC, ROTINITC, and ROTHALTC keywords.

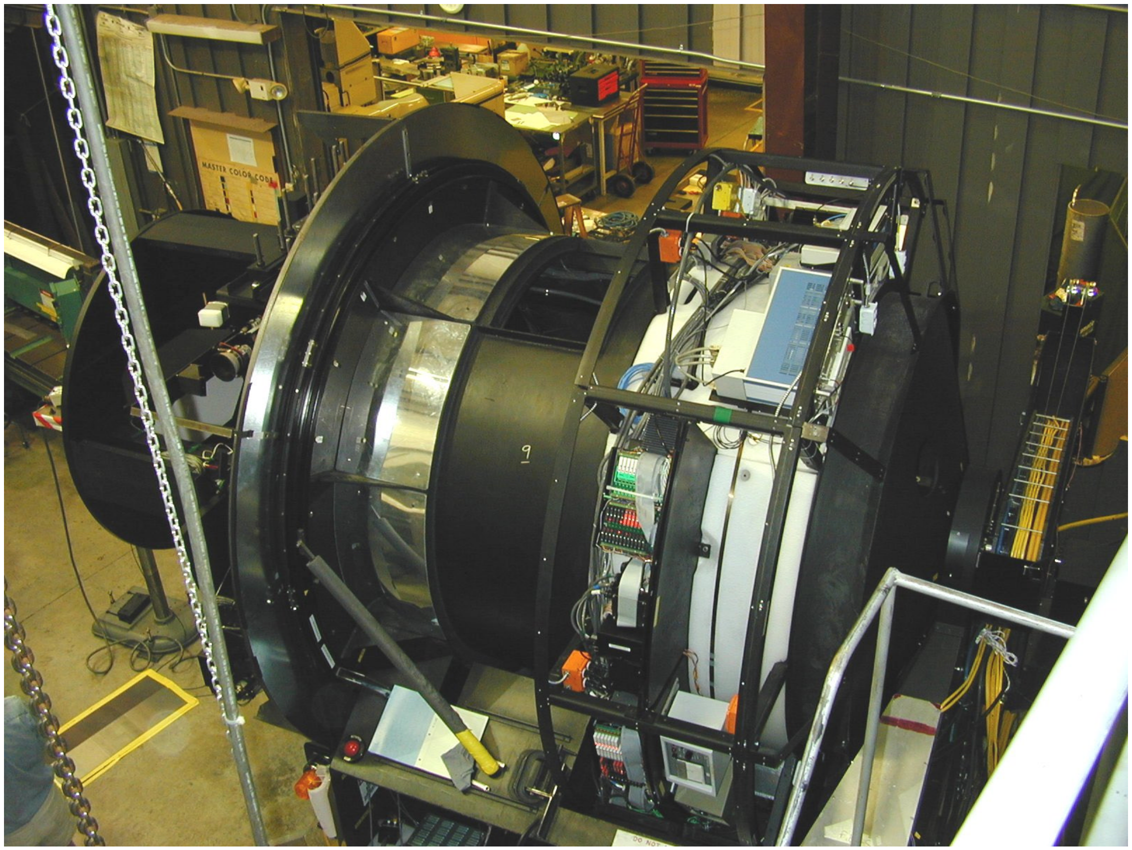
DCS tracking is implemented following the standard DCS state model described in KSD 46, sec 3.5.

Cable Wrap



- •Allows for 790 degrees of rotation
- •Been in constant use for 11 months

Electronics Enclosures

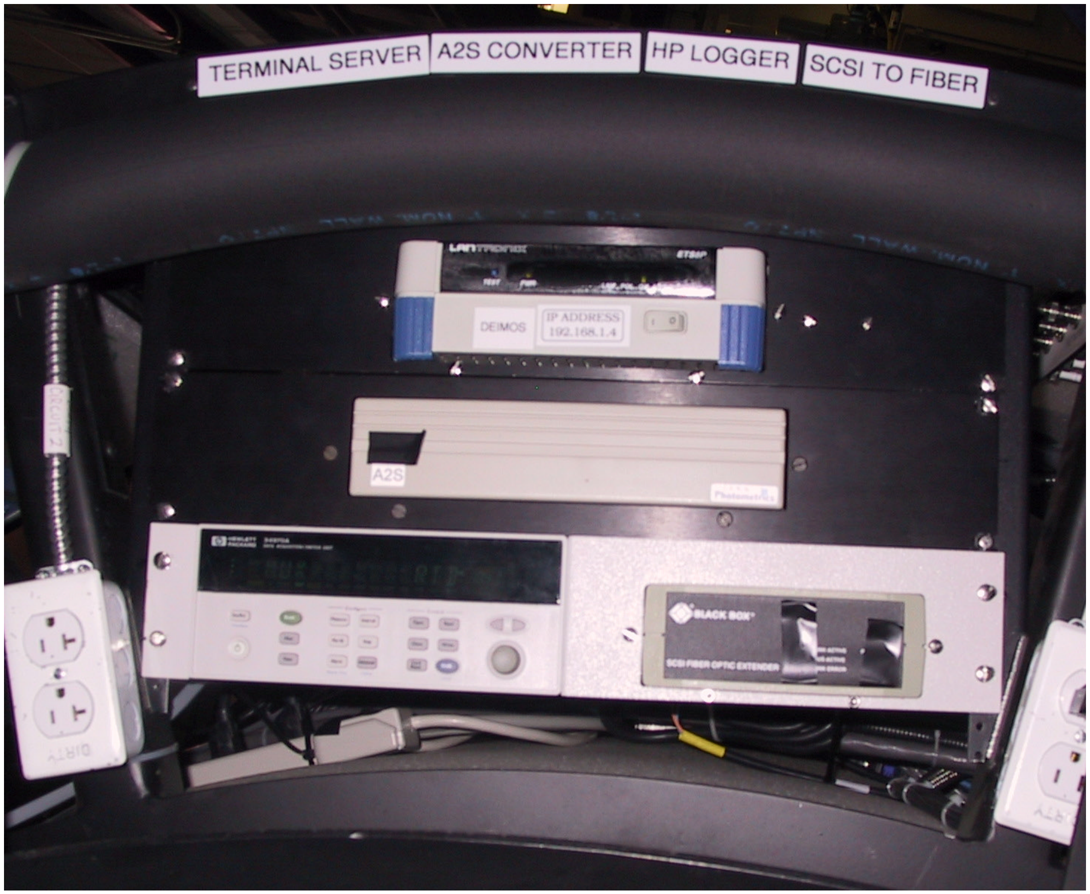


- Insulated from spectrograph interior
- Insulated from dome
- Cooled by glycol heat exchangers
- Temperature monitored by Galil system
- The Galil motor controller turns the heat exchanger fans on and off to control the temperature in the enclosures at about 5C

Thermal Insulation

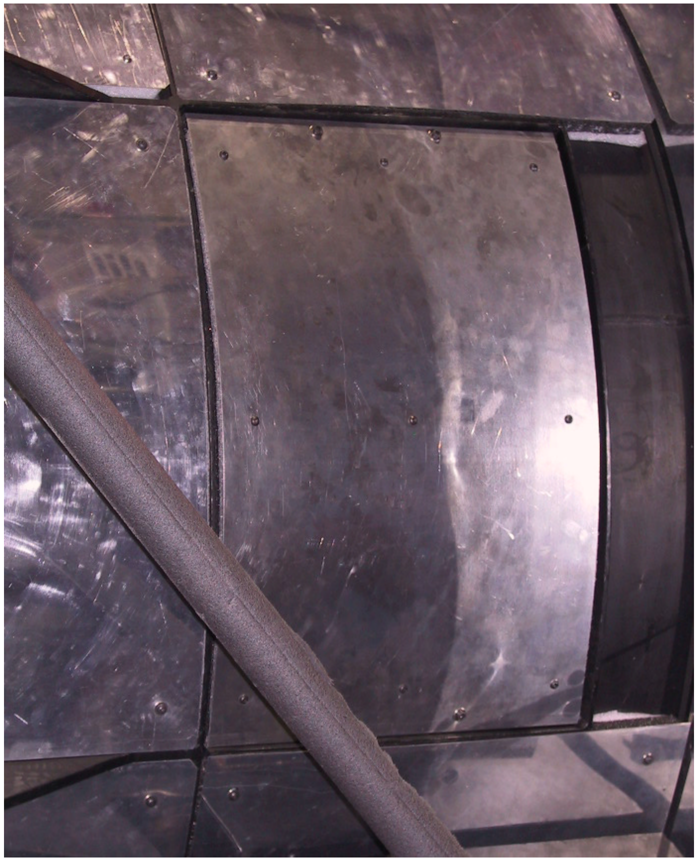
- Al covering, 2 inches of poly insulation
- Calculated time constant 24 hours
- Minimize internal temperature variation
- Goal: internal temp. variations <1C.

HP Temperature System



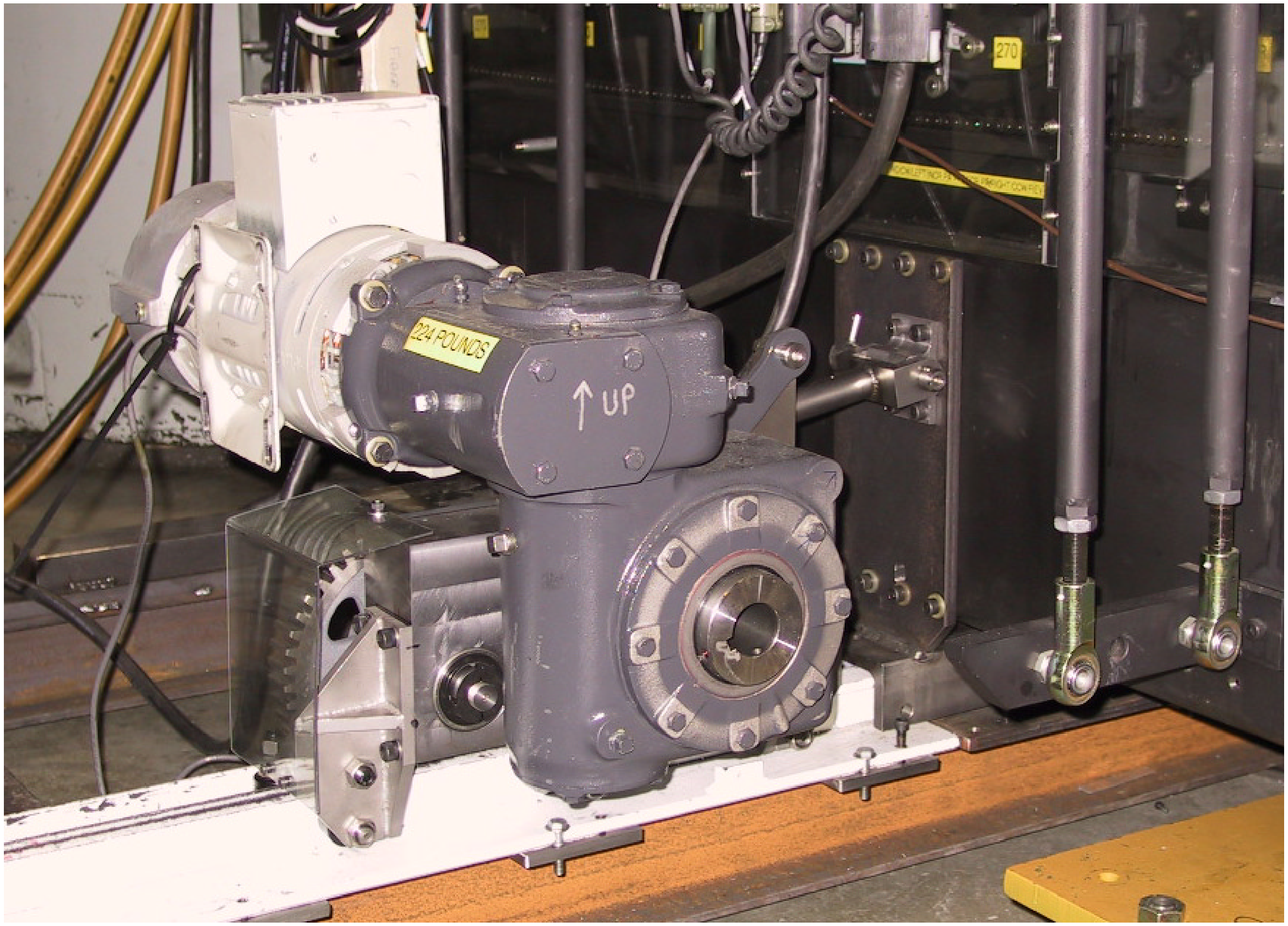
- HP 34970A
- 27 RTD sensors on instrument
  - 8 on drive disk
  - 8 on barrel
  - 8 on camera
  - 3 on grating
- Resolution +/- 0.1C

Hatches and Access Ports



- All man hatches are interlocked to the rotation

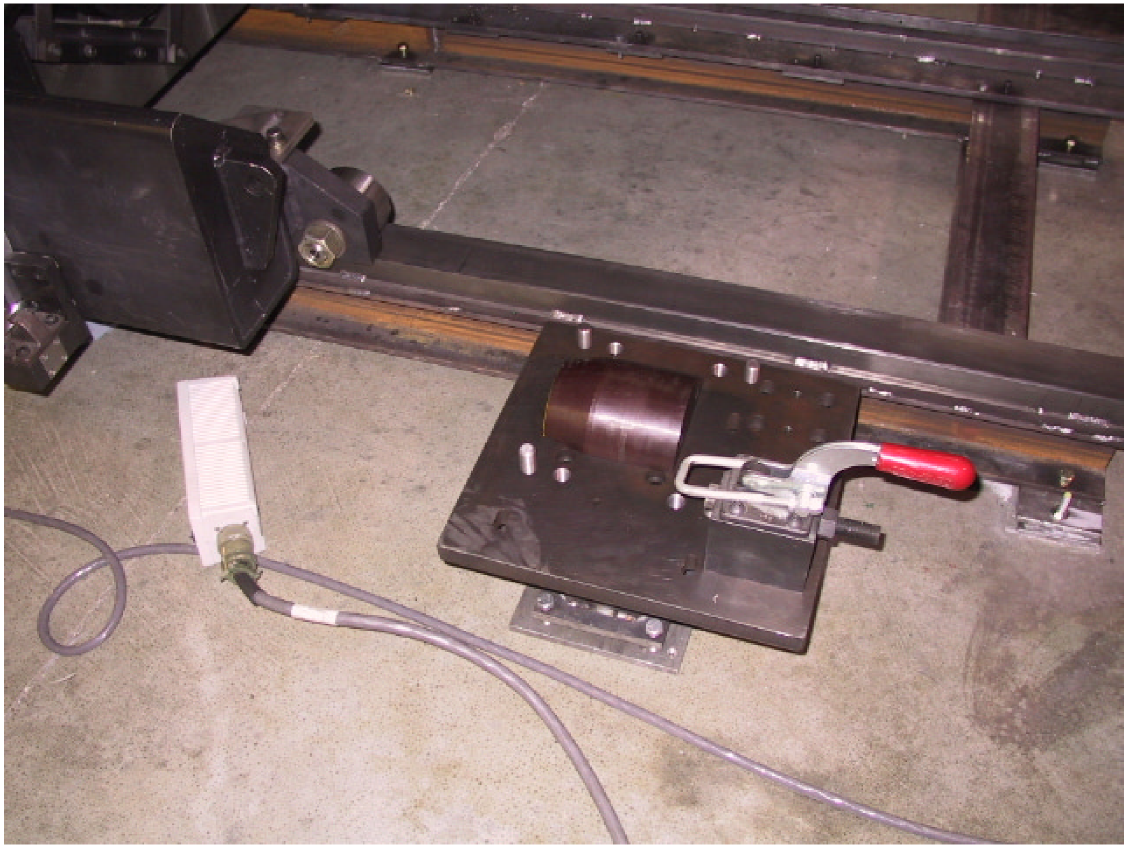
Carriage Mover



•Moves DEIMOS at about 3 ft /min
•Drives DEIMOS onto kinematic mounts

•Tested by driving DEIMOS on 12 feet of rails to the end stop and back onto the kinematics 100 times.

Kinematic Mounts



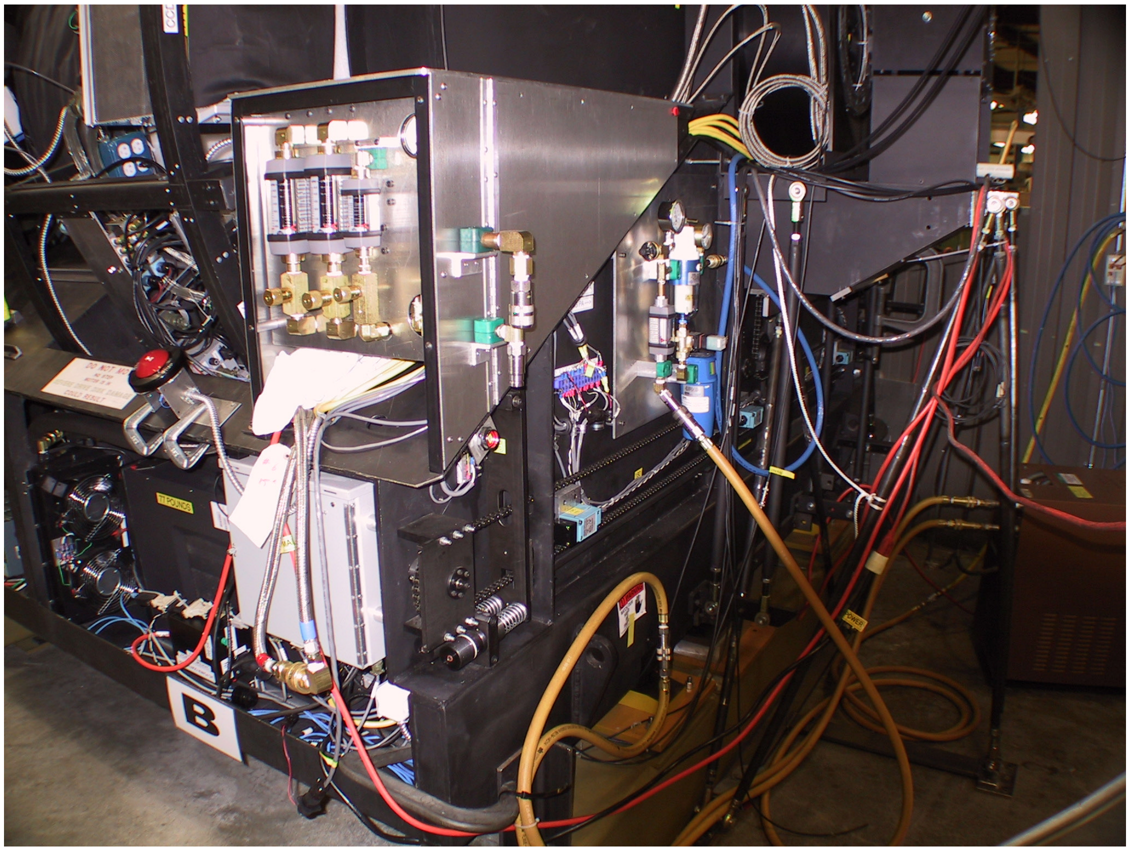
Requirement:

• Reposition DEIMOS to +/- 0.020 in x, y, & z

Tested:

•Reposition to +/- 0.005 inches

Service Connections



- Glycol supply and return
- Compressed air (>90 psi)
- Clean and line 110AC
- 3 pairs of fibers
- 2 co-ax cables

AC Power Service on DEIMOS

- Blue Circuit
  - On-board UPS
  - Powers the CCD controllers
- Orange Circuit
  - Observatory-conditioned instrument power
- White Circuit
  - Service outlets and lighting

Physical Instrument Interfaces

Summary

- Glycol
- Air
- 110 AC
  - Clean power
  - Line power
- Network
  - Private net
  - Public net
- Fiber
  - CCD controllers (2 duplex)
  - TV guide camera (1 duplex)
- Track and carriage system
- Carriage interlocks to telescope and dome
- Kinematics

DEIMOS Software (Pre-ship)

- DEIMOS software overview
- Current status
- Tasks remaining
- Issues and concerns

DEIMOS Software Overview

- DEIMOS Software Layers
  - Client applications
  - Keyword libraries
  - Server and daemon processes
  - Controller firmware

DEIMOS Software Layers

- Client applications
  - Graphical user interfaces (GUIs)
    - Observer's GUI
    - Engineering GUI (for maintenance functions)
    - Image Displays (ds9 and figdisp)
  - Scripts (e.g., csh, Tcl/tk)
    - Observing sequences (e.g., twilight flats)
    - Maintenance (e.g., "Health & Safety script")

Observer's GUI

- Layout and graphical metaphors same as ESI:
  - DEIMOS elements displayed in light-path order
  - Key status values always available on top-level
  - More detailed views provided via pop-up sub-panels
  - Double-click on a top-level element to bring up sub-panel
  - Pop-up alarms for serious errors or conditions
  - Context sensitive help
- Multiple copies can run simultaneously
  - Helps coordination between sites (summit & HQ)

DEIMOS Image Displays

- Figdisp (used for engineering development)
  - Advantages:
    - Derived from version now used by HIRES, LRIS, ESI
    - Familiar to Keck optical observers and support staff
    - Mature and reliable package
    - Provides all basic quick look functions (e.g., cuts, statistics)
    - Provides detachable and re-sizable location window
  - Disadvantages:
    - Used and supported only at Keck
    - Does not support multi-HDU mosaic images or FITS files
    - Pretends that DEIMOS mosaic is an 8K x 8K CCD (no WCS)
    - Does not provide more advanced functions (e.g., blink compare)

DEIMOS Image Displays

- DS9 (will be used for observing)
  - Advantages:
    - Supported by Harvard CfA and in use at many sites world wide
    - Provides support for multi-HDU mosaic images and FITS files
    - Provides support for FITS world coordinate system (WCS)
    - Provides many advanced functions and more scaling options
    - Can provide live image readout simultaneously to multiple sites
  - Disadvantages:
    - Mosaic features are under development and not fully debugged
    - Performance currently slower than figdisp but may improve
    - Support staff not yet as familiar with using it (learning curve)

Image Display Strategy

- Use figdisp for DEIMOS engineering until:
  - DS9 mosaic features are fully supported and debugged
    - Problems with line plots of arbitrary cuts through the mosaic
      - Pixel coordinates are mislabeled
      - Cuts that cross mosaic boundaries are missing data points
      - Cuts across the bottom half of the mosaic cause DS9 to crash
    - Multiple FITS WCS support not yet available (next version)
  - DEIMOS analysis routines updated for multi-HDU FITS
- Continue to test DS9 regularly as updates arrive
  - Can switch between figdisp and DS9 in under 2 minutes
  - Affords opportunities for training users and support staff

DEIMOS Goals for DS9

- Complete migration to DS9 by the end of 2001
  - Allows 5 more weeks to complete:
    - DS9 debugging and performance optimization at CfA
      - Bill Joye at CfA has been extremely responsive to bug reports
      - Patched versions typically received within a week to 10 days
    - Conversion of DEIMOS analysis scripts at UCSC and UCB
    - Training of DEIMOS observers and support staff at UCSC
  - Allows 6 to 8 weeks of heavy use prior to shipment
    - Instrument tear-down is slated for mid-to-late December
    - But: DEIMOS CCD subsystem does not ship until late February
    - DEIMOS red mosaic will be run in clean room until mid-February
  - Fallback: if DS9 not ready, can commission with figdisp

Client applications – scripts

- Several scripting environments supported:
  - Unix shells (sh, csh, tcsh)
  - Tcl/Tk
- Maintenance functions
  - Health and safety script: used for checkout
  - Configuration scripts (e.g., slitmask inventory)
- Diagnostic and mechanism burn-in: ktest
- Observing sequences (e.g., focus sequence)

The DEIMOS Keyword Layer

- All client applications act through keywords
- Keyword layer is a Keck-mandated standard
  - Provides consistent API across instruments
  - Ensures FITS headers contain instrument state
  - Provides simple commands for status and control:
    - Show – reads the current value of a keyword
    - Modify – writes a new value into a keyword
    - Xshow / Cshow / Tshow: displays the current value
  - Enables scripting of observing and test sequences

Keyword examples

- Each device has its own keywords
- Writing a keyword changes the device state:

  'modify –s deimot gratepos = 3'

  moves grating slider 3 into position and clamps it
- Reading a keyword returns the device state:

  'show –s deiccd tempdet1'

  reads the temperature of mosaic CCD #1

DEIMOS Keyword Services

- DEIMOT: control of mechanisms and lamps (719)
- DEIROT: control of instrument rotation (95)
- DEICCD: control of science CCD mosaic (212)
- DEIFCS: control of flexure compensation (104)
- Current number of DEIMOS keywords = 1130
- Comparison to other Keck optical instruments:
  - HIRES (+ exposure meter): 508
  - LRIS (red + blue): 310
  - ESI: 461
  - DCS: 445

The DEIMOT keyword service

- Interfaces to dispatchers (keywords servers):
  - Galil dispatchers:
    - Servo motor stages (e.g., filter wheel, dewar focus,…)
    - Air cylinder devices (e.g., hatch, clamps,…)
    - Digital I/O (e.g., relays for lamps, hatch switches,…)
    - Analog I/O (e.g., flow and pressure sensors, …)
  - Piezo dispatcher (Piezo actuator controller)
  - Bar code dispatchers (Fixed and handheld)
  - HP Temperature Logger

The DEIMOT keyword service

- DEIMOT dispatchers drive the controller firmware
  - Galil dispatcher derived from one developed for ESI
  - Galil dispatcher interfaces to a firmware hybrid:
    - Lick-developed code downloaded to Galil EPROM
    - Runs on top of Galil embedded firmware in ROM
    - Enables standalone operation of devices from:
      - Local pushbutton control stations (e.g., science filter wheel)
      - Hand paddles
    - Downloaded code in EPROM reduces serial I/O
  - Other dispatchers interface only to vendor firmware

Devices within DEIMOT service

- Dewar (focus, X-translation, filter wheel)
- Slitmask mechanism (cassette & insertion)
- Grating mechanism (slider transport & clamp)
- Piezo actuator (for tent mirror)
- TV stages (focus and filter wheel) and hatch
- Lamps (calibration and flexure compensation)
- Bar code readers (fixed and handheld)
- High-resolution temperature sensors (HP logger)
- Miscellaneous (fans, AC power, flow sensors, etc.)

The DEIROT keyword service

- Interfaces to DEIMOS rotation control system
  - Runs on diskless-PC mounted in DEIMOS craddle
  - Boots Linux over network from supervisory computer
  - Embedded PCI-bus Galil controller board in PC
    - Receives encoder feedback from motor and Renishaw encoders
    - Generates control voltage applied to rotation drive motor
- ROTATMOD keyword sets control mode
  - “Position” and “Velocity” modes provides local control
  - “DCS” mode slaves DEIMOS rotation to telescope track

The DEICCD keyword service

- Interfaces to DEIMOS science mosaic CCD system:
  - CCD keyword server follows HIRES, LRIS, ESI model:
    - Runs under VxWorks system on a VME CPU card in VME crate
    - Interfaces to SDSU CCD controller DSP software via fiber
    - Isolates custom fiber interface in VME crate
    - Provides standard Ethernet interface to data taking computer
  - CCD pixel data sent via image transmission protocol
    - Same protocol as is used for HIRES, LRIS, and ESI
    - Bypasses keyword layer due to large volume and high rates
    - Added protocol extensions to support mosaic formats
    - Upgraded VME Ethernet to 100 Mbps for mosaic data rates

The DEIFCS keyword service

- Interfaces to flexure compensation CCD controller
- Simplified version of DEICCD service:
  - Supports only 2 CCDs rather than 8
  - No support for temperature sensing or control
  - No support for shutter
- DEIFCS and DEICCD namespaces overlap
  - DEIFCS keywords only appear in FCS FITS headers
  - DEICCD keywords only appear in mosaic FITS headers

DEIMOS Daemons and servers

- Traffic: communications multiplexer
  - Common to all Keck optical instruments
  - Enables transparent multiuser & multisite operation
- Infoman: single-service keyword server
  - Used by HIRES, LRIS, ESI and DEIMOS
  - Serves miscellaneous keywords for a single service
  - DEIMOS needed two instances: DEICCD and DEIFCS
- Infopatcher: multiple-service keyword server
  - Replaces infoman
  - Can simultaneously service DEICCD and DEIFCS

DEIMOS Daemons and servers

- Watch_ccd: collects keywords for FITS headers
  - Common to all Keck optical instruments
  - ASCII configuration file specifies keywords to capture
  - Packages keywords for insertion into FITS header
- Lickserv: captures pixel data streams
  - Assembles images into shared memory
  - Signals image display as pixels become available
  - Obtains packaged FITS header from watch_ccd
  - Combines header with pixels and writes FITS file to disk

DEIMOS Lickserv upgrades

- Lickserv upgrades occurred in two phases:
  - Phase 1: provided support for ‘fake’ mosaic: (lickserv)
    - Mosaic treated as if a large, monolithic detector
    - DEIMOS mosaic treated as a single 8K by 8K CCD
    - Assembled into shared memory as a single image
    - Realtime display to upgraded version of figdisp
    - Image written to disk as a single FITS HDU
  - Phase 2: provided support for real mosaic: (lickserv2)
    - Each amplifier of each CCD has its own WCS and HDU
    - Assembled into shared memory as a multi-HDU FITS file
    - Realtime display to mosaic-capable version of DS9
    - Image written to disk as a multi-HDU FITS file with WCS

Lickserv2 operational details

- ‘write_image’ now runs as a separate process
  - Runs under observer’s account
  - Stopped and re-started when observer changes
- ‘lickserv2’ runs as a daemon process
  - Runs under kics (or deimoseng) account
  - Is always running and always available to catch images
- Can switch between lickserv and lickserv2 quickly
  - Use lickserv with figdisp during engineering phase
  - Switch to lickserv2 with ds9 prior to commissioning

DEIMOS Controller Firmware

- Galil downloadable firmware:
  - Software cloned from ESI:
    - Singly-encoded DC servo motors
    - Pulsed-solenoid devices (e.g., hatch)
    - Digital I/O control and status (e.g., lamps and fans)
    - Analog I/O (pressure and flow sensors)
    - Hand paddle controls
  - New software specific to DEIMOS:
    - Grating tilt servo dithering routine for Gurley encoder
    - Slitmask hybrid device: cassette stage & insertion arm
    - Grating select hybrid device: slider transport stage & clamps
    - Pushbutton control stations

DEIMOS Controller Firmware

- CCD controller and VME crate DSP firmware:
  - Timing board DSP software upgrades:
    - Mosaic waveform generation and pixel processing
    - Abort during readout and erasure now covers end-to-end pipeline
    - Multiple readout windows for alignment boxes (IN PROGRESS)
  - Utility board DSP software upgrades:
    - Mosaic temperature readout and temperature servo control
    - Analog loopback and test of ALL clock and bias voltages
    - High resolution CCD shutter blade timing (IN PROGRESS)
  - Fiber optic interface (VMEINF) DSP software upgrades:
    - Software selectable pixel stream filtering (odd, even, or both)
    - Upgrades for larger VME memory and Motorola CPU support

DEIMOS Software Sharing Summary

- Mechanism control derived from ESI
  - Uses same control hardware: Galil DMC-1500
  - Use similar ‘dispatcher’ software
- CCD control derived from ESI, HIRES, LRIS
  - Uses SDSU-2 controller hardware (like ESI)
  - Uses similar VME crate software
    - ESI/LRIS Force 5CE software ported to Motorola MVME2304
  - DEIMOS CCD Mosaic software will be shared with LRIS new blue camera and HIRES detector upgrade

DEIMOS Software Status

- All DEIMOS devices operable from keywords
- Engineering GUI complete
- Observer's GUI in preliminary release
- Low-level tests run on all devices (ktest suite)
  - Most devices pass all phases of tests. Exceptions:
    - Dewar focus limit switches misadjusted; fails limit test
    - Grating tilt dither servo can't be rehomed; fails recalibrate test
- Higher-level tests run on complex (hybrid) devices:
  - Most high-level tests are successful. Exceptions:
    - Sliders 3 and 4 fail to clamp 1 out of 10 times if DEIMOS slewing
    - Slitmasks fail to insert about 1 to 2% of the time

Software Tasks Remaining

- Primary task: flexure compensation control
  - Building blocks have all been tested:
    - FCS image readout, display, and recording
    - Cross-correlation algorithms
    - FCS Y axis control:
      - Piezo actuator dispatcher and keywords
      - Grating tilt dithering servo and keywords (fallback for piezo)
    - FCS X axis control: dewar X translation keywords
    - Both control axes tested for non-linearities
  - DEIMOS likely will be disassembled before FCS done
  - Initial debug and test will occur at summit (just like ESI)

Software Tasks Remaining

- Other post pre-ship major software tasks:
  - Port FCS VME software to Motorola MVME2304 board
  - Upgrades for multiple readout windows for mosaic
  - Complete DS9 upgrades, debug, and test
  - Pushbutton control for slitmasks and gratings
  - Removable element configuration software
  - Write and run additional ktests:
    - Test slitmask insertion while slewing and tracking
    - Test flexure of gratings that were clamped while slewing
  - Refine observer's GUI
  - Reconfiguration of DEIMOS computers to CARA profile

Software Tasks Remaining

- Commissioning software:
  - Scripts for instrument calibration
  - Scripts for instrument initialization
  - Calibration of DEIMOS rotation encoders on sky
  - Daemons for copying DEIMOS images to HQ
  - Environmental monitoring, logging, and alarms
  - FCS performance monitoring

Software Tasks Remaining

- Post Commissioning Software:
  - Turn-Key system for DEIMOS slitmasks
    - Mask design software (prototype is operational)
    - Mask fabrication software:
      - Mill control software (some pieces tested)
      - Mill control sequencing
    - Slitmask database:
      - Design ingestion (protoype is operational)
      - Mask identification and tracking
    - Slitmask graphic overlays onto DS9 display

Instrument Demonstration (Drew P)

Draft

-Physical setup:
  - 900-line grating in Slider 3; 1200-line in Slider 4
  - LOSH mask
  - GOH mask (for TV pictures)
  - Other masks to fill all slots, all with barcodes
  - Marc Davis mask
  - Filters in filter wheel: whatever Dave has
- Startup and initialization
  - Run wakeup program
- Physical inspection
  - Open nose hatch; view focal plane and calibration lamps
  - Open barrel hatch; view interior
  - Inspect cable wrap
  - Demonstrate removable element barcode reader
  - Demonstrate manual pushbuttons
  - Remove and replace a filter
  - Remove and replace a grating (too hard?)
  - Load slitmasks; have computer read barcodes and load into database
- Mechanical control
  - Committee members control instrument using observer GUI

Instrument Demonstration (Drew P), Continued

- Data-taking/data pathway (Bob K and Greg W)
  - Turn on the light sources and take exposures
  - Where the data are going
- Quick-look analysis
  - Interrogate and manipulate images with DS9
  - Retrieval of images back from disk
- Turn on the TV system and take TV pictures
  - Focus the TV
  - Change TV filters
  - Observe reseau marks
- Mask fabrication demonstration (Drew P and Jeff L)
  - Sample mask: features
  - Design program
  - Milling process

Deliverables

- Spectrograph including:
  - Main frame
  - Cladding
  - Cable wrap
  - Hand paddles (3 – one for each controller)
  - Emergency interrupt system
  - Entrance window and hatch
  - Slitmask mechanism
  - Slitmask focal plane form with position sensors
  - Collimator, cell, and cover
  - Collimator counterweight
  - Tent mirror, cover, and cell
  - Piezo mover for tent mirror
  - Aluminum tent mirror (dummy)
  - Barcode scanner for removable elements
  - Internal barcode scanner for slit masks
  - Hatches and removable service ports (list)

Deliverables (page 2)

- Grating system including:
- 2 grating sliders with tilt mechanisms (possibly one more grating slider)
  - 1200 line/mm grating + cell and cover
  - 900 line/mm grating + cell and cover
  - 831 line/mm grating + cell and cover (supplied by the DEEP Project)
  - 600 line grating + cell and cover
  - Flat mirror + slider
- Grating alignment jig
- 9-element, 15-inch camera with passive thermal plate scale compensator; front and rear covers
- 7-position science filter wheel including:
- 14 cells (10 filled; 4 spares)
- 5 science filters: (6.25” x 6.25”)
  - B
  - V
  - R
  - I
  - Z
- 4 order-blocking filters (6.25” x 6.25”)
- 1 glass clear “filter”

Deliverables (page 3)

- Science shutter
- Two adaptor plates between camera and dewar
- Cryogenic detector housing including:
- Dewar window
- Dewar
  - Focus stage
  - X translation stage
  - CCD mosaic with 8 science 2048x 4096 MIT/LL high/rho CCDs and 2, 600x1200 FC CCDs
  - Ion pump and electronics
  - Cold finger

Deliverables (page 4)

- Detector cryogenic system including:
  - LN2 reservoir and vacuum ion pump and electronics
  - Cold finger connection to dewar
  - LN2 fill tube to reservoir
  - Detector electronics
- CCD controller with 8 video boards for 16 amp readout
- CCD controller with 1 video boards for FC CCD readout
- CCD cabling
- UPS for CCD controller and detector system

Deliverables (page 5)

- TV guider including:
  - 8-position filter wheel
  - 8 filter holders for TV filter wheel
  - Filters (2” x 2”):

    B
    V
    R
    I
    ND1.0
    ND2.0
  - 200mm f /1.8 Canon lens
  - TV shutter
  - PXL detector and electronics
  - TV focus mechanism
  - TV fold flat mirror
  - TV offset guider mirror (in focal plane)

Deliverables (page 6)

- Calibration lamps, lamp holders, and power supplies including:
  - Pen-Ray mini lamps
    - Kr (2)
    - Xe (2)
    - Ar
    - Ne
    - Hg
  - Zn Pen-Ray
  - Cd Pen-Ray
  - Quartz flat-field lamp and separate power supplies
- FC light source with:
  - 2 Cu/Ar Photron lamps with separate power supplies
  - 1 white-light LED and power supply
  - 4 fibers to focal plane plus 4 spares
  - Four FC light feeds in focal plane

Deliverables (page 7)

- Carriage mover and control electronics
- 2, 8-channel Galil motion control modules and amplifiers
- Rotation motor and gear train
- Renishaw encoder with two read heads
- 1 Dell diskless computer + Galil motion control card and amplifier for rotation control
- HP data logger
- 27 RTD temperature sensors
- 3 cooled electronics vaults, 2 on rotating cylinder, one on carriage
- Air filter and control system
- Counterweights for Side B, to keep DEIMOS balanced
- Baffles:
  - Focal plane baffle
  - Grating/mirror baffles
  - Possible front external baffle

Deliverables (page 8)

- 2 VME crates with Motorola power PC boards
- Video signal cables
- 2 Lantronix terminal servers (one on rotating cylinder, one on carriage)
- Instrument control computer
- Data acquisition computer
- RAID array for data acquisition computer
- Slitmask milling infrastructure (including necessary mods to existing Keck hardware)

Deliverables (page 9)

- Software including:
  - Mask design
  - Mask fabrication
  - Mask management (TBD)
  - Spectrograph control
  - Rotation control
  - Detector control
  - Header collection
  - Science data capture
  - Flexure compensation
  - User interfaces/tools removable element installation
  - Monitoring/logging
  - Database
  - On-line documentation
  - Scripts for instrument calibration
  - Scripts for instrument diagnosis
  - Scripts for instrument initialization

Deliverables (page 10)

- Lifting spreader bar for main frame
- Spare counterweights in case a chassis needs to be removed
- Miscellaneous fixtures for the many complicated setups, too numerous to mention, but we have several cabinets full (will list later)
- Tent mirror aluminizing fixturing
- Assorted slitmasks with patterns of slitlets and holes for optical tests
- Retainers and clamps for securing various items during shipping (list needed)
- Grating file for storage
- Filter file for storage
- Cart for holding spare gratings during grating installation/removal (TBD)
- Fixtures/slings for removal/installation of:
  - Camera
  - Tent Mirror
  - Collimator mirror
  - Dewar
  - Cart for holding Dewar and LN2 Can

Deliverables (page 11)

- Spare barcode labels for new filters, gratings
- Spare barcode labels for slitmasks
- Spare parts listed separately

Spares Provided

- Canon 200 mm f1.8 lens shared with ESI
- Galil 500-1000c servo motor
- Galil 50-1000 servo motor
- Galil DCM-1580 controller shared with ESI
- Galil AMP-1140 amp shared with ESI
- Lambda power supply
- Rotation computer/controller
- Rotation drive gear box
- Bearings for rotation drive/followers
- Cam followers for kinematics
- Bearing for filter wheel
- 6 science filer holders
- Set spare Pen-Ray Cal lamps
- Spare quartz continuum lamp
- Spare Cu/Ar lamp
- Couplings for all drives
- Couplant fluid for camera
- Stage interconnect box(s)
- SDSU-2 boards shared with ESI
- Lantronics terminal server
- Electronic part spares listed on web page (approx 45 items)

Spares not provided

- Physik Instrumente piezo translator- P-845.60 -$6500.00

Cost of Operations

- LN2 use approx 52 liters/day including burn-off during fills
- Slit masks up to 10 per night, ½ hour per mask to produce== 5 hours work/observing day
- Cooling – approx 900W
- Electrical service –approx 900W

Maintenance Schedule/Cost

- Clean drive disk bearing surface every month
- Adjust drive roller patch and skew every 6 months
- Clean slit mask cassette every 3 months

- Calibration lamp replacement as required
- Cu/Ar lamp replacement as required

Maintenance manual will be provided as part of the documentation

Documentation

1. Electronics schematics (B size, web-based versions, plus CD copy) (Barry)
2. Stage data (web page)
3. Web-based description of all mechanical parts and assemblies (Dave C.)
4. Assembly manual, including use of assembly, lifting, and transport equipment (Dave C.)
5. Maintenance manual for mechanical systems, including general troubleshooting instructions (Vernon, Jack, CARA)
6. Description of all custom electronic/electrical systems, including general troubleshooting instructions (Barry, Chris, CARA)
7. Manuals received with purchased parts (Barry)

Documentation (page 2)

8. Operations manuals received with computers bought by DEIMOS (Bob)
9. Software documentation compliant with KSD-3 (Bob)
10. Zemax files of optical system on CD plus all available data on optical elements, including reflectivity curves for gratings, transmission curves for filters, AR coating performance files from Coherent, and measurements of surface errors when available (Sandy)
11. Optical alignment procedures (Sandy, David H , Jack, Vernon)
12. Summary report on optical performance (image quality, distortion, astrometry, throughput) (Drew/Sandy)
13. Documentation of CCDs (Kirk, Sandy)
14. CCD electronics manual and drawings (Barry, Chris)
15. FCS electronics manual and drawing (Barry, Chris)

Documentation (page 3)

16. A document on the FC system as a whole (Sandy)
17. Interface document (Sandy, CARA)
18. PDR document (exists)
19. Mechanical CDR document (exists)
20. Software CDR document (exists)
21. Camera CDR document
22. Detector CDR doucment
23. Pre-ship Review document

Shipping

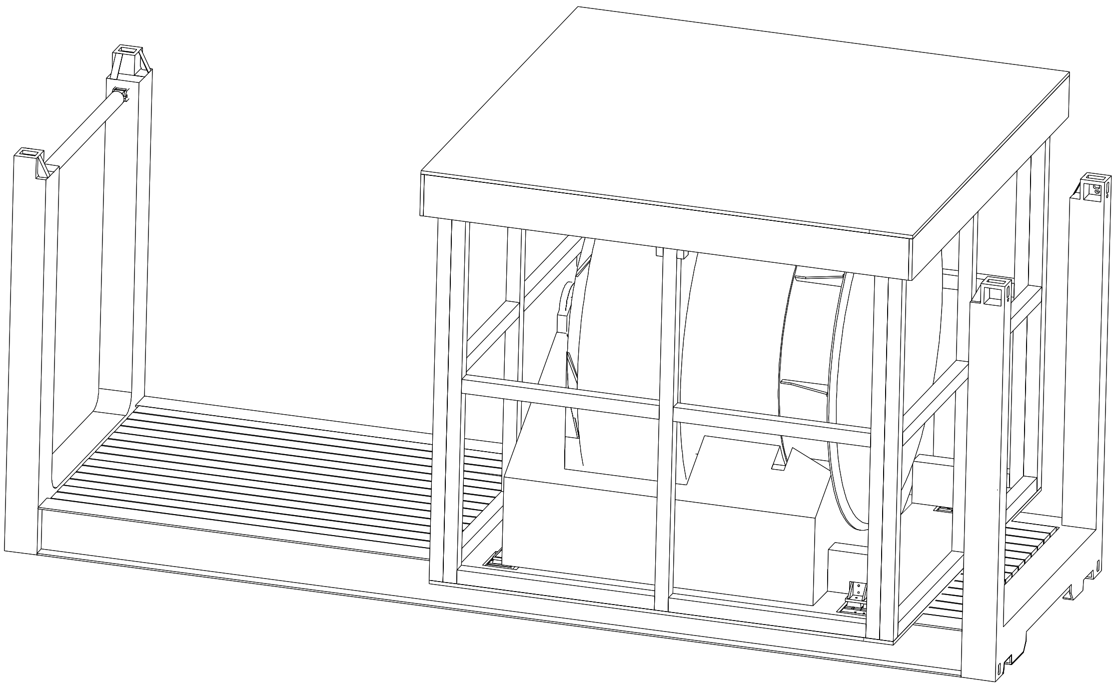
- Sea –Matson
- Air –United Airlines
- Key dates
  - Jan 10- container and rack leave Lick
  - Jan 17- container and rack arrive in Kawaihae
  - Jan 21- container and rack arrive on Keck summit
  - Jan 21- first air shipment – nose area assemblies
  - Feb 12 - second air shipment – camera
  - Feb 21- third air shipment - dewar
  - Feb 26- fourth air shipment – major optics

Shipping

Shipping Rack

Shipping Container

DEIMOS Main Frame Shipment



- Hard mounted to heavy duty vibration mounts
- Packed with desiccant
- Fully sealed in membrane enclosures;
  - Polyethylene shrink wrap, LDPE, 6 mil
- Crate water-proofed top and bottom
  - Hypalon CSPE, 45 mil
- Protective crate of 4x4, 2x4 and plywood
  - Bolted in panels for quick disassembly
  - Bottom flooring, sides and top

DEIMOS Shipping - Trucks

- Matson will truck the container and rack to Oakland, and they will arrange for pilot cars and necessary permits
- Kona Transport will truck the container and rack to the summit of Mauna Kea, and they will arrange for pilot cars and necessary permits
- Kona Transport will truck both the empty container and rack back to Kawaihae

Shipping -Air

- Air shipment 1 - Nose area assemblies including
  - Gailil controllers
  - Cal/FC lamps and assemblies
  - HP Datalogger
  - TV assembly and Photometrics camera
  - Instrument computer
- Air shipment 2 -Science camera
- Air shipment 3 -Dewar
  - Dewar and CCD controllers
  - Data-taking computer
- Air shipment 4 –Major optics including
  - Collimator
  - Tent mirror
  - Gratings
  - Filters

Shipping

- **Camera**
  - Air shipped in pieces (4)
  - Boxes designed to take 20 g shock load; thermally tested
- **Other optics**
  - All have appropriate boxes
- **Dewar and CCD controllers**
  - Dewar and LN2 can have custom boxes
  - Controllers shipped in Hardigg Cases
- **Computers**
  - Air shipped in original boxes where possible

Air Shipments -Trucks

- Lick will truck all shipments to the airport
- Lick will truck camera boxes (air shipment 1) to the summit
- CARA will be asked to transport air shipments 1 and 4 to the summit.
- Lick will truck air shipment 3 to the summit

Commissioning Plans

Sequence of major events

• Lift to rails	Jan 25 –Puna Crane, telescope down for morning
• Test carriage system	Jan 30,31
• Complete camera ass	Feb 7
• Install slitmask sys	Feb 11,12
• Install grating sys	Feb 13-19
• Install inst computer	Feb 27
• Install TV	Feb 21
• Install camera	Mar 5 –need Jib Crane
• Install collimator	Mar 8 –need Jib Crane
• Install tent mirror	Mar 11
• Install dewar	Mar 11 –need Jib Crane

Commissioning Plans

Sequence of major events

• Install rotation drive	Mar 13,14
• Alignment	Mar 19-Mar 25
• Start full up inst test	Mar 26
• First star light	Apr 28

Commissioning Plans

DEIMOS Travel schedule					Total # project of people in HI
16-Jan	1	arrives			1
21-Jan	3	arrive			4
24-Jan	3	arrive			7
2-Feb	3	arrive			10
8-Feb			4	depart	6
11-Feb	2	arrive			8
18-Feb	1	arrives			9
20-Feb	4	arrive			13
20-Feb			2	depart	11
22-Feb			4	depart	7
24-Feb			1	departs	6
1-Mar			2	depart	4
3-Mar	4	arrive			8
11-Mar	2	arrive			10
15-Mar			4	depart	6
23-Mar			3	depart	3
25-Mar	5	arrive			8
12-Apr			7	depart	1
22-Apr	6	arrive			7
1-May			7	depart	0

Commissioning Plans

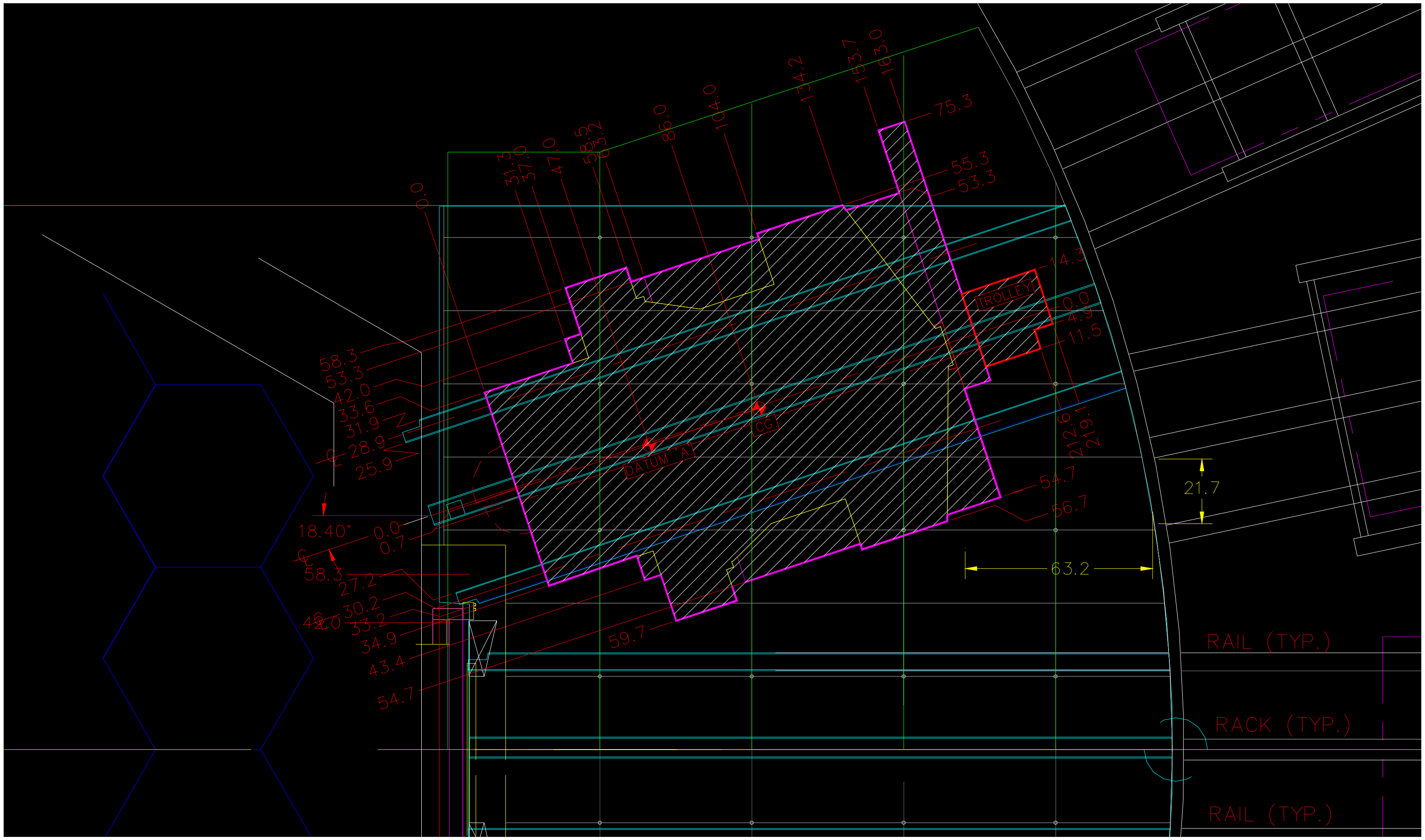
- Maximum # of people in HI for assembly – 13
- The plan is not to have any one person in HI for more than 30 days at a time
- We will have up to 4 vehicles, including 3 4x4s
- Will bring hoist for smaller lifts

Commissioning Plans

Lift into the Dome

- Puna Crane
- Lift from west side of Observatory onto Nasmyth deck

Commissioning Plans



January 02

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	31	1	2	3	4	5
6	7	8	9	10	11	12
				Truck to Oakland, 1 da	Marine Shipment, 5 days **Ship Date**	
13	14	15	16	17	18	19
Marine Shipment, 5 days						
20	21	22	23	24	25	26
		Uncrate DEIMOS, 2 days		Hoist into dome, 8 hrs	Cleanup the DEIMOS structure, 2 days Unpack and organize subsystems, 2 days	
27	28	29	30	31	1	2
Cleanup the DEIMOS structure, 2 days Unpack and organize subsystems, 2 days		Test cradle drive, 2 days		Test kinematics mounting to telescope, 2 days		

February 02

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	31	1	2
Cleanup the DEIMOS structure, 2 days; Unpack and organize subsystems, 2 days		Test cradle drive, 2 days		Test kinematics mounting to telescope, 2 days		
3	4	5	6	7	8	9
	Install UPS	Install cable wrap and; Leak che	Install drive motor and cal/FC electronics on rin		Install slit mask system, 2 days	
10	11	12	13	14	15	16
Install slit mask system, 2 days		Install grating system, 5 days				
17	18	19	20	21	22	23
Install grating system, 5 days		Install FC light source	Install TV system, 1 da	Install calibration lamp	Integrate electronics to nose area subsystems, 3; Install instrument computer, 3 days	
24	25	26	27	28	1	2
Integrate electronics to nose area subsystems, 3 days; Install instrument computer, 3 days			Test nose area subsystems, 2 days; Install data computer, 3 days		Install cladding on outs	

March 02

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
24 Integrate electronics to nose area subsystems, 3 days; Install instrument computer, 3 days	**25**	**26**	**27** Test nose area subsystems, 2 days; Install data computer, 3 days	**28**	**1** Install cladding on out	**2**
3	**4** Install camera, 2 days	**5**	**6** Install filte; Install shu	**7** Install colli; Install col	**8** Install tent; Install dewar assembly, 2 days	**9**
10 Install dewar assembly, 2 days	**11**	**12** Test tent mirror and de; I; Install rotation drive mo	**13** Install Baffling, 1 day; Install rotation drive	**14** Install cladding on DEI; Test rotation drive, 2 days	**15**	**16**
17 Test rotation drive, 2 days	**18** Final Alignment, 4 days	**19**	**20**	**21**	**22** Install cradle cladding, 1 day	**23**
24 Install cradle cladding, 1 day	**25** Full up instrument tests, 10 days	**26**	**27**	**28**	**29**	**30**

April 02

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
31	1	2	3	4	5	6
Full up instrument tests, 10 days						
7	8	9	10	11	12	13
Full up instrument tests, 10 days	Float, 14 days					
14	15	16	17	18	19	20
Float, 14 days						
21	22	23	24	25	26	27
Float, 14 days					First Commissioning run, 3 days	
					FIRST LIGHT	
28	29	30	1	2	3	4
First Commissioning run, 3 days						

It could happen

On-Sky Commissioning Plan

To be provided

CARA Tasks: Mechanical

Modify elevation cable wrap	Complete 06/2001
Modify elevation bearing bolts	Complete 09/2001
Reinforce Rt. Nasmyth platform	Complete 10/2001
Reinforce Right Nasmyth deck	Complete 10/2001
Extend Right Nasmyth platform	TBD by 12/2001
Install rack & rails	TBD by 12/2001
Supply air & glycol	TBD by 01/2002
Fabricate oil splashguard	TBD by 01/2002
Construct DEIMOS cable boom	TBD by 01/2002

CARA Tasks: Electro/Operational

Supply coaxial cable, fiber optic link, AC power	Completed 09/2001
Install rack for DEIMOS control computers	Completed 09/2001
Install trolley AC power and interlocks on Rt Nasmyth deck	TBD by 01/2002
Install DEIMOS control computers, disks, etc.	TBD by 02/2002
Determine cryogen handling procedure	TBD by 02/2002

CARA Tasks: Software

Revise Keck guider software for DEIMOS needs	TBD by 05/2002
Configure DEIMOS observer accounts	TBD by 05/2002
Provide data archive capability	TBD by 05/2002
Adapt telescope focus (MALIGN) s/w for DEIMOS	TBD by 06/2002
Provide observer mass storage capability (e.g., Exabyte tape)	TBD by 08/2002

Outstanding Tasks

Draft

Before Disassembly

- Installation of slider 5
- Completion of instrument cladding
- Complete baffling
- Testing of stray light
- Testing for light leaks
- Tune FCS System
- Measure and pin all optical cells/holders

Before Assembly in Hawaii

- Test power up and down sequence on blue detector
- Installation and testing of the red mosaic; camera baffling
- Repair of the moving element in the camera
- Completion of the Flexure Control software
- Elimination of condensation on dewar window
- Silver coating of mirrors
- Re-install piezo on Y stage

Future Plans

- Complete long slits?
- Complete mask milling software and infrastructure
- Software
  - Quick-look routines
    - Subtract bias and divide by flatfield
    - Subtract video crosstalk
  - Pipeline data reduction procedure
  - Data archive
  - Automatic calibration script
- TV guider upgrades
- Silver Keck mirrors
- Build Side B