DECam – Dark Energy Camera

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Fermilab Institutional Review
June 6-9, 2011

U.S. DEPARTMENT OF ENERGY

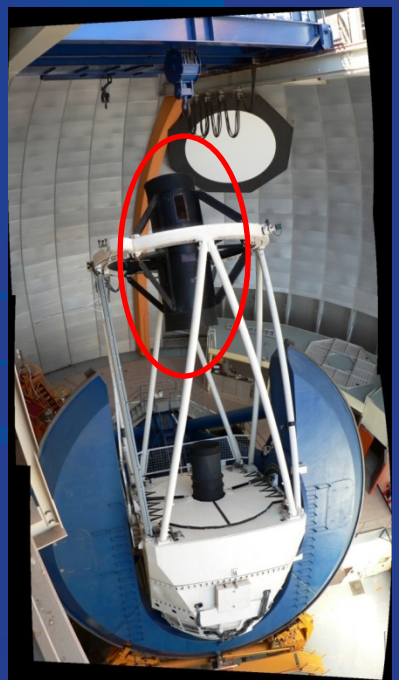
Fermilab

Outline

- Introduction
- DECam Systems
- DECam Integration
- DECam Schedule
- Conclusion

Dark Energy Survey (Cf. J. Frieman talk Tue. Plenary)

- Cerro Tololo Inter-American Observatory in Chile
- Blanco 4 m telescope
- DECam: 3 deg^2 FOV, 570 MegaPixels
- 5000 deg^2 southern sky survey in g,r,i,z,Y bands (Map out 300 million galaxies)
- 30 deg^2 repeat survey for Type Ia Supernovae
- Starting from late 2012 for 5 years
- Synergy with SZ cluster detection from South Pole Telescope & with VHS NIR survey



DECam – New Prime Focus Instrument (DOE funded)
Data Management System (NCSA – NSF funded)
CTIO Facility Improvements (NOAO – NSF funded)

Schedule:

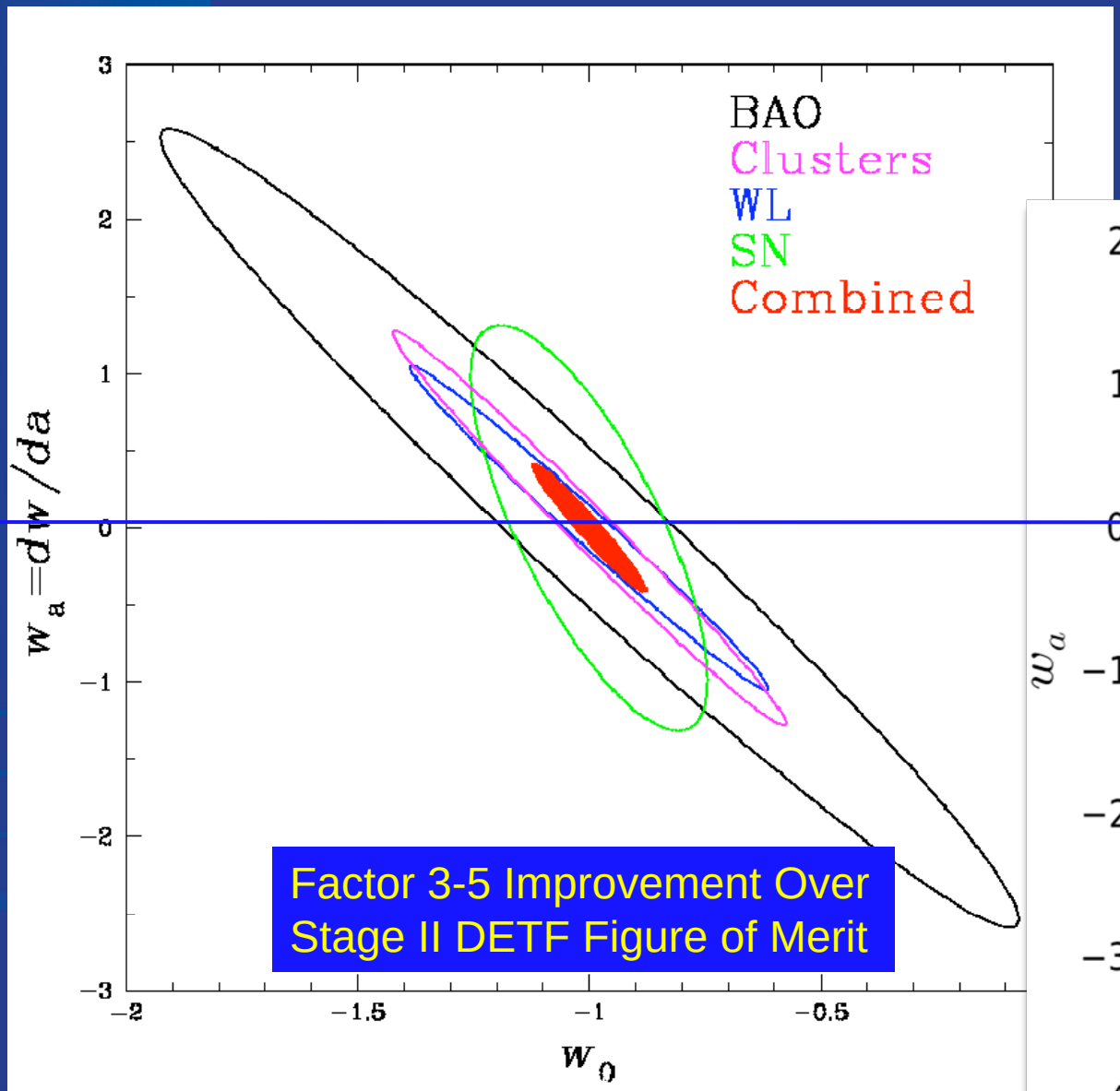
DECam Shipment to CTIO (Chile) Will complete 9/2011
Mounting on telescope: 11/2011
First light: 1/2012

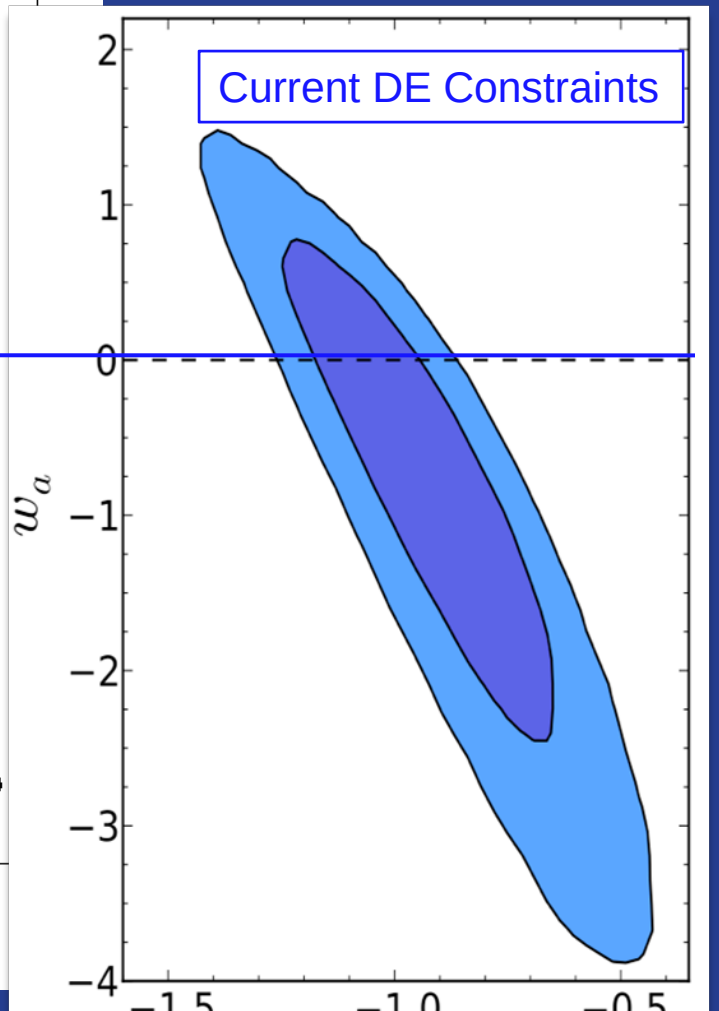
Four Probes of Dark Energy with DES

- Galaxy clusters
  - ~100,000 clusters to z>1
  - Synergy with SPT
  - Sensitive to growth of structure & geometry
- Weak Lensing
  - Shape measurements of 300 million galaxies
  - Sensitive to growth of structure & geometry
- Baryon Acoustic Oscillations
  - Angular correlation of 300 million galaxies
  - Sensitive to geometry
- Supernovae
  - 30 deg^2 time domain survey
  - Yields ~ 4000 well-sampled SNe Ia to z ~ 1
  - Sensitive to geometry

- Use clusters as proxies for dark matter halos – predicted by N-body sims
- Measure cosmic shear ang. power spectrum in redshift slices
- Measure galaxy ang. power spectrum in redshift slices
- Measure supernova distance vs redshift (Hubble diagram)

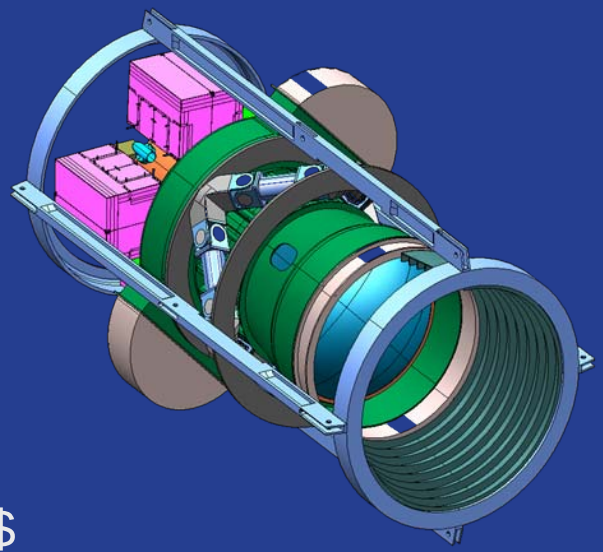
DES Dark Energy Forecast Combined Result





DECam Project

- Fermilab-based DOE project that builds a 570-MPixel CCD camera to be installed on the 4-M Blanco Telescope at Cerro Tololo, Chile, for the Dark Energy Survey



- Scope: $35.15M TPC, 3+ yr construction period CD 3b Oct 2008, forecast completion Jan 2012
- Current Status: MIE 93% complete, remaining $ contingency $1.03M, schedule contingency 9 mos

Notable Project Features

New Capability for SiDet:

CCD Packaging and Testing

Built on Silicon Detector expertise from collider exp'ts

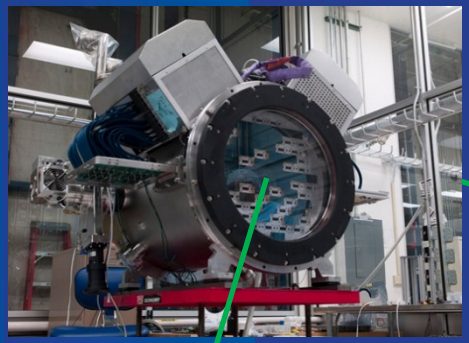
Low noise Electronics

Cryogenic Cooling System

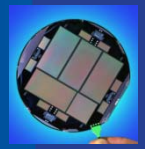
Precision Large Mechanical Systems

Fermilab

DECam Systems

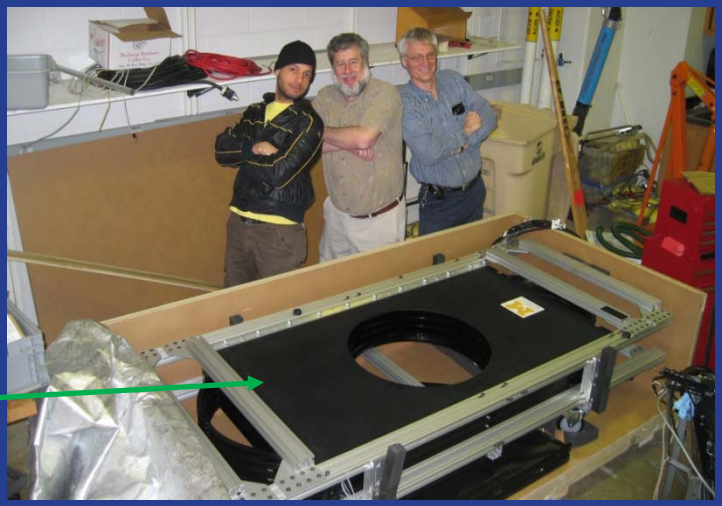


Imager, FNAL

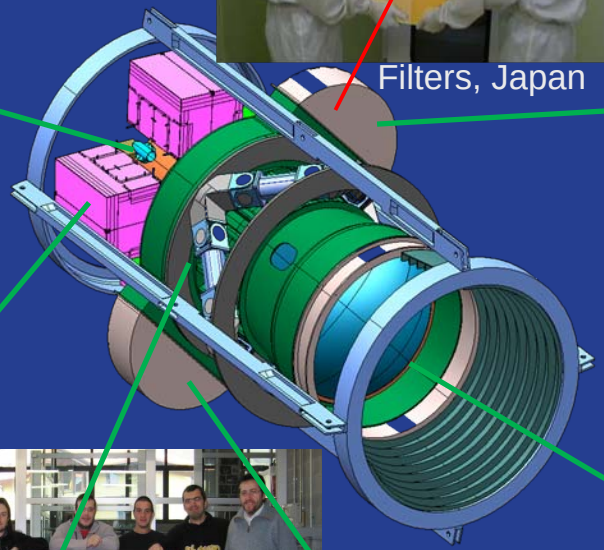


CCDs, wafer from LBNL, packaged at FNAL

Filters, Japan

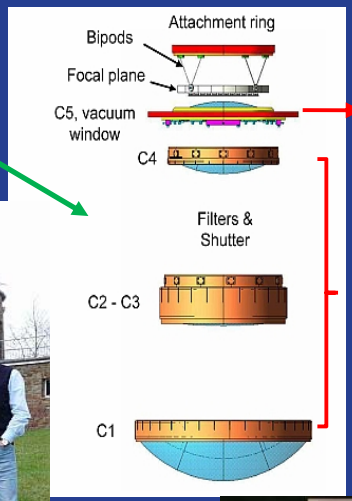


Filter changer, Univ. of Michigan



Hexapod, Italy

Electronics, Spain and FNAL



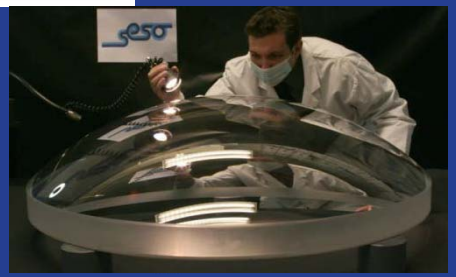
Optics

ANL/FNAL

UCL@ UK

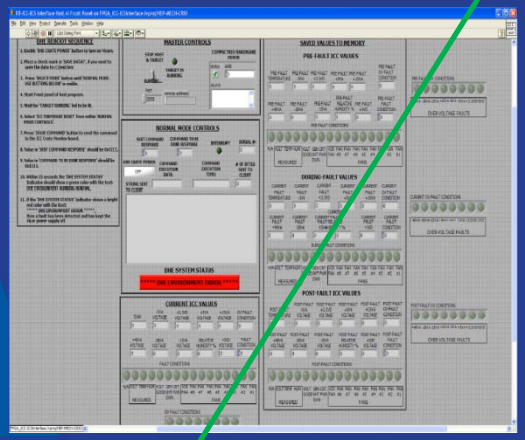
Optics design: UCL, UMich, UC

Shutter, Germany

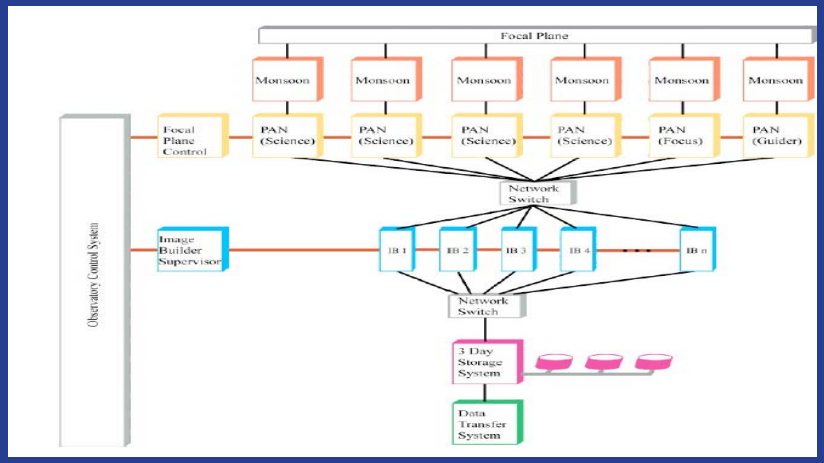


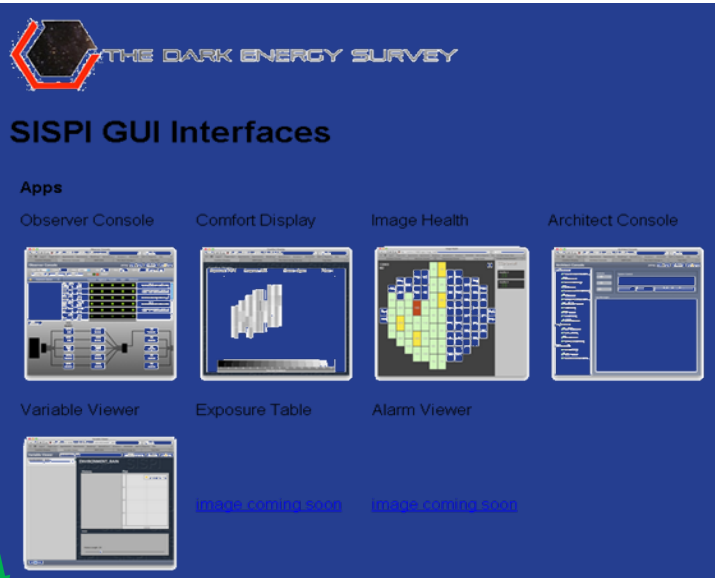
DECam Supporting Systems

Cooling and Vacuum System, FNAL,
Keep CCDs at 173K, 10^{-6} Torr



Instrument Control System, ANL, FNAL

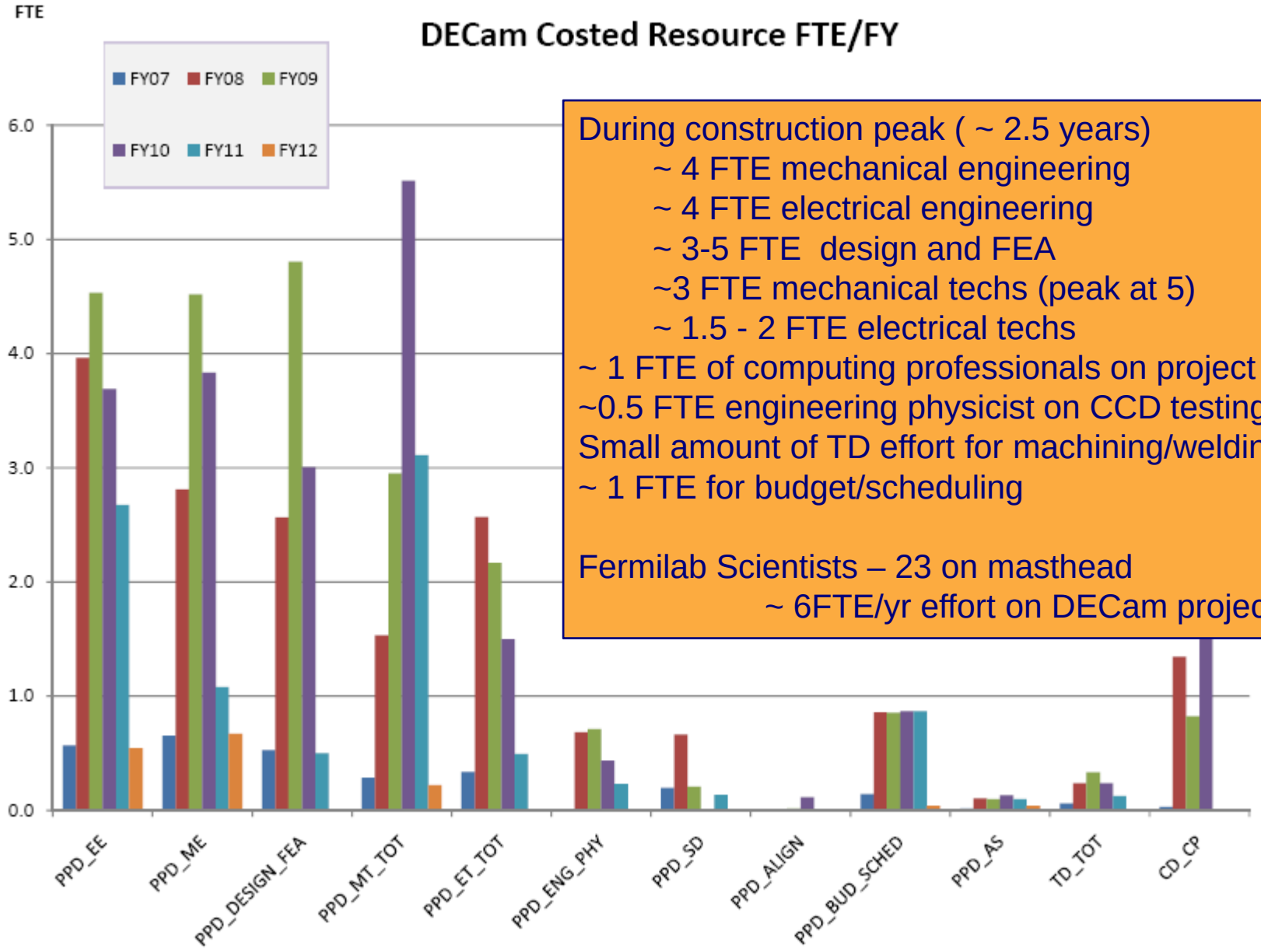




DAQ / Controls / Monitoring System
OSU, UIUC, FNAL

Fermilab Effort on DECam Project

- Project Management (PM, Deputy PM)
- WBS 1.2 (CCDs) – L2 Managers, packaging & testing @ Fermilab
- WBS 1.3 (FEE) – L2 Manager, design of 12-chan boards, heater boards, vacuum interface boards, testing & integration
- WBS 1.5 (Opto-Mech) – L2 Manager, Project Engineer, design of barrel, cooling, telescope simulator and other systems, many procurements, integration
- WBS 1.6 (SISPI DAQ & Ctrls) – Database design & implementation, ObsTac design & implementation
- WBS 1.7 (Simulation & Survey Strategy) – L2 Manager, simulations programming & production on OSG, survey strategy planning, calibration strategy and PreCAM work
- Overall testing and integration on multiple platforms (MCCDTV, 1-m telescope, Telescope Simulator)



During construction peak (~ 2.5 years)

- ~ 4 FTE mechanical engineering
- ~ 4 FTE electrical engineering
- ~ 3-5 FTE design and FEA
- ~3 FTE mechanical techs (peak at 5)
- ~ 1.5 - 2 FTE electrical techs

~ 1 FTE of computing professionals on project

~0.5 FTE engineering physicist on CCD testing

Small amount of TD effort for machining/welding

~ 1 FTE for budget/scheduling

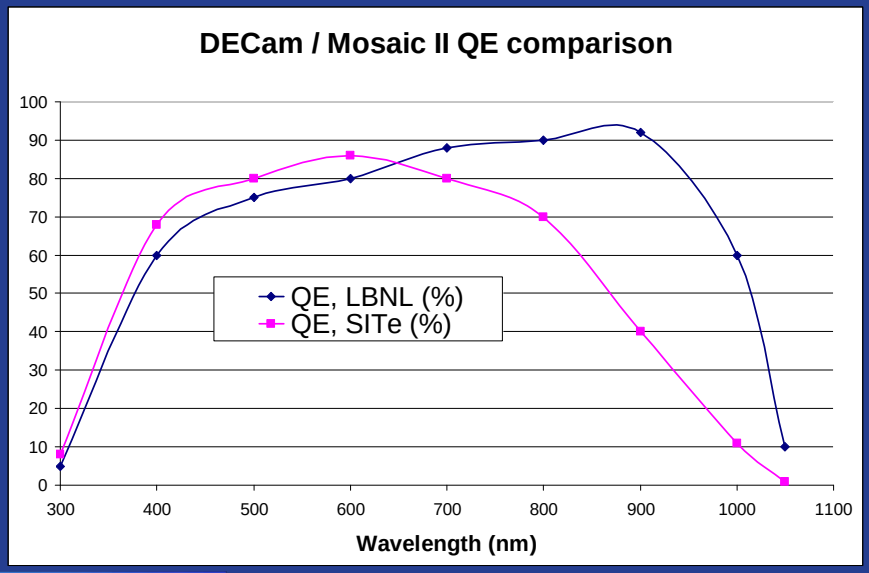
Fermilab Scientists – 23 on masthead

~ 6FTE/yr effort on DECam project

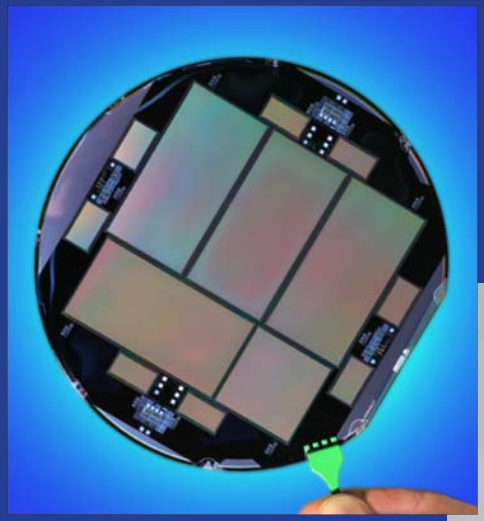
Technical Risk in DECam

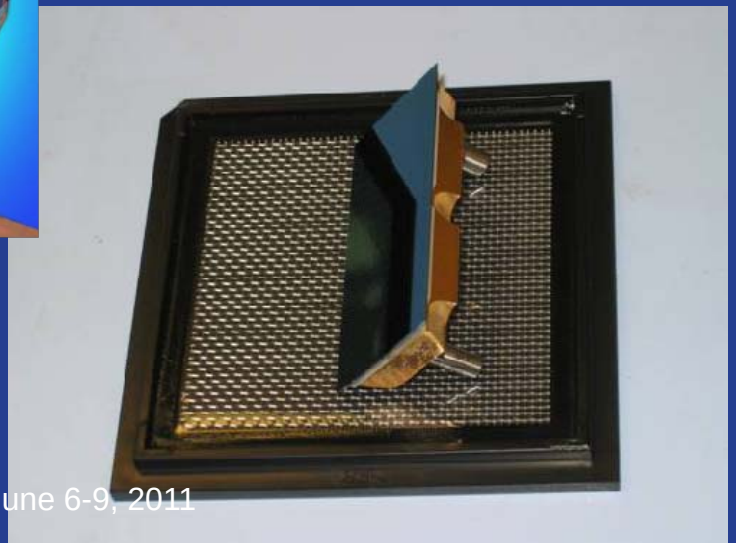
- CCDs – intrinsically low yield devices (15-20%). New design. Have met specs w/ factor 2 spares – retired.
- Optical Corrector – lens are delicate, difficult to manufacture. Have met specs – retire risk except for handling during assembly & shipping.
- Front end electronics – need low noise. Have met specs – retired.
- Hexapod – unique device (for combined precision & load requirements). Have met specs – retired.
- Cooling system – unique system (large cooling requirement at top of telescope). Have met specs – retired.
- Filters – largest ever attempted. Needed R&D for manufacture. Schedule delayed, but now have 2 of 5 completed. Risk still outstanding.

DECam CCDs



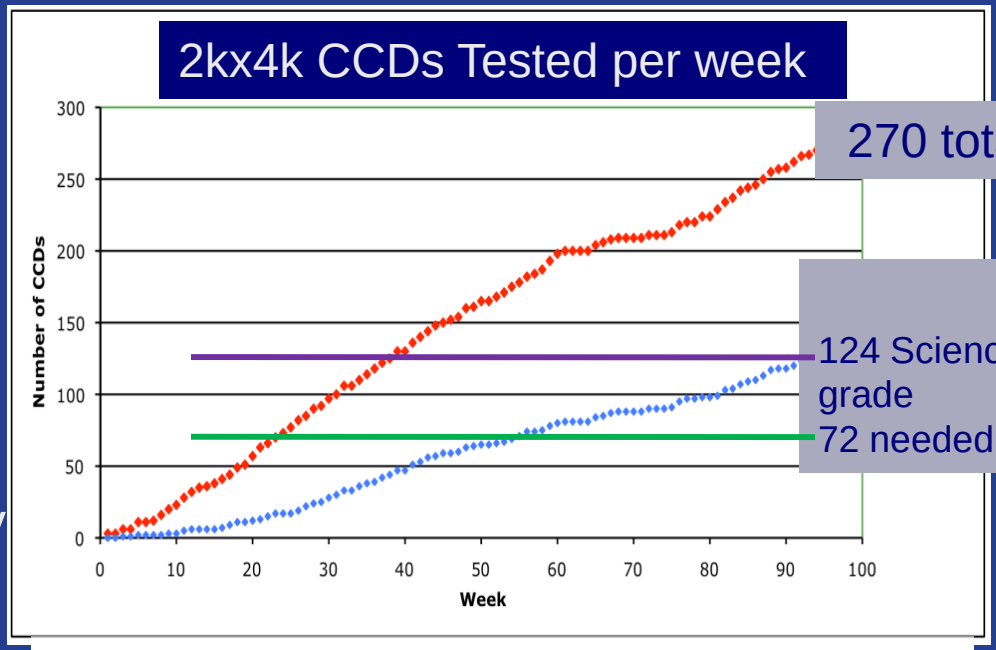
- Red Sensitive CCD wafers, designed by LBNL, processed at DALSA and LBNL:
  - QE> 50% at 1000 nm
  - 250 microns thick
  - readout 250 kpix/sec
  - 2 RO channels/device
  - readout time ~17sec
- Bare diced wafers are delivered to Fermilab
- At Fermilab we package and test the CCDs

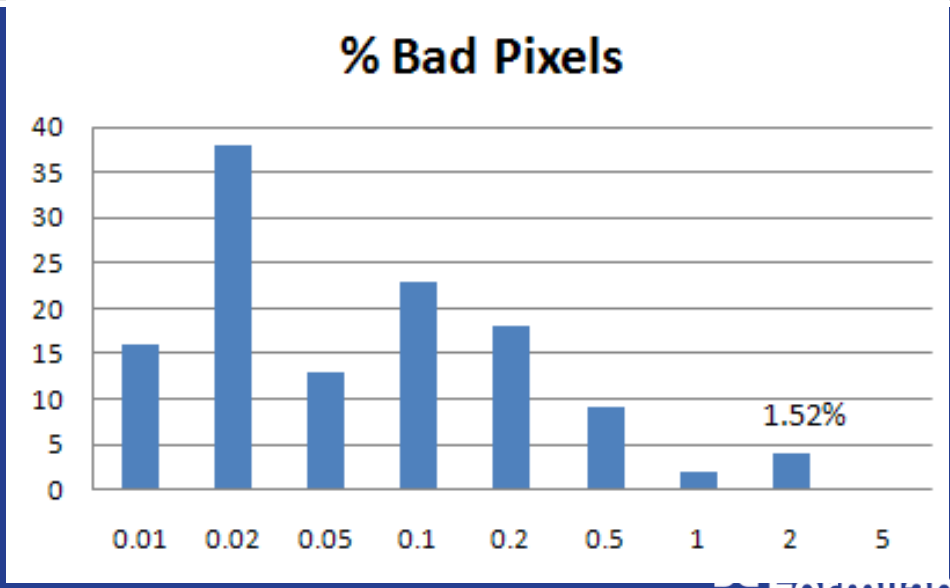




CCD Production is complete

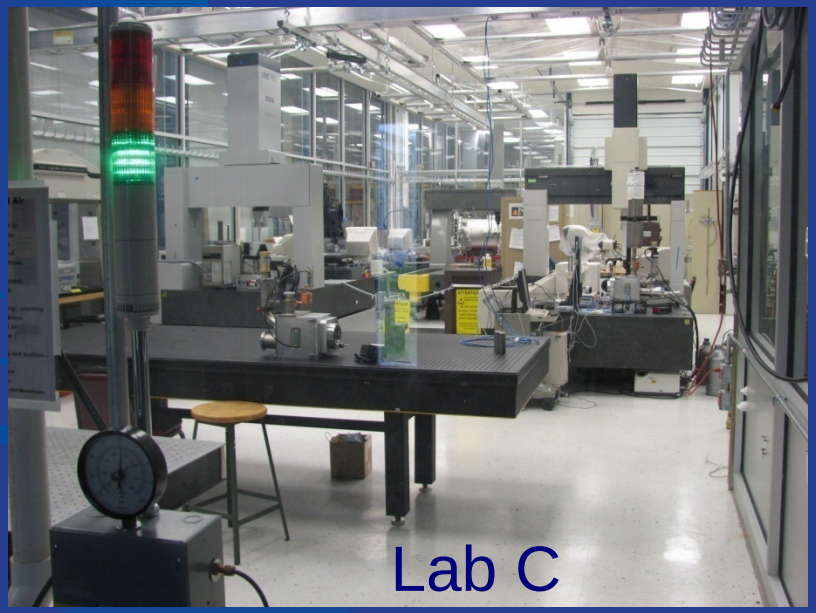
- Packaging and testing started Nov. 2008, finished Oct. 2010
  - 270 2kx4k CCDs packaged and tested
  - 124 are Science Grade ready for the focal plane
  - 62 + 10 spares are required
  - 26 science grade 2kx2k (need 12 plus spares, for guide and focus)
  - Mean # bad pixels = 0.12%

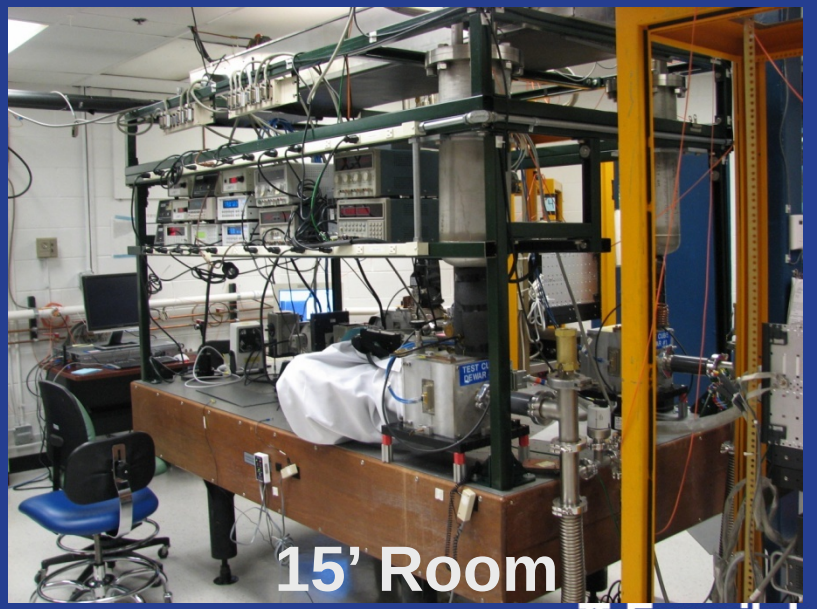




CCD Packaging and Testing Infrastructure

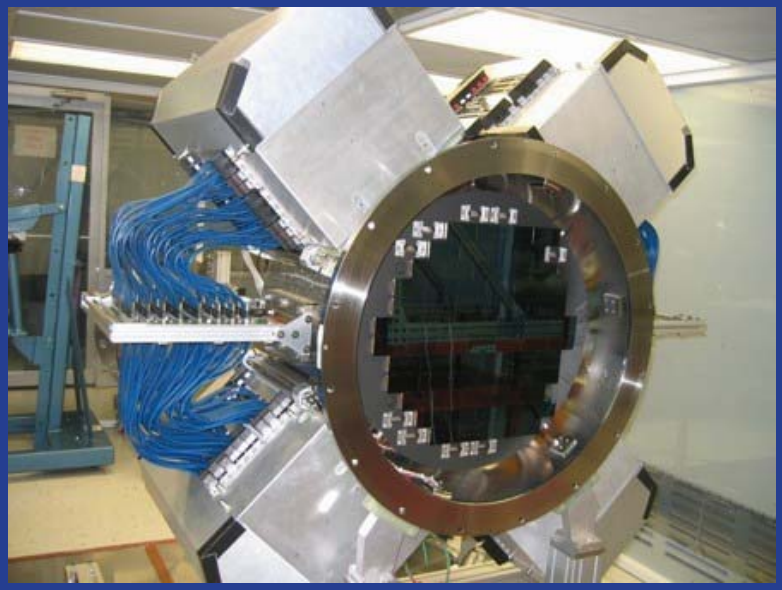
- Operations in two clean rooms at SiDet
  - Clean Assembly Area for Packages, MCCDTV, and flatness measurements in Lab C.
  - CCD & electronics testing in “15’Bubble Chamber Control Room”in Lab A: 5 parallel testing stations
  - ~ 1 week to test a CCD

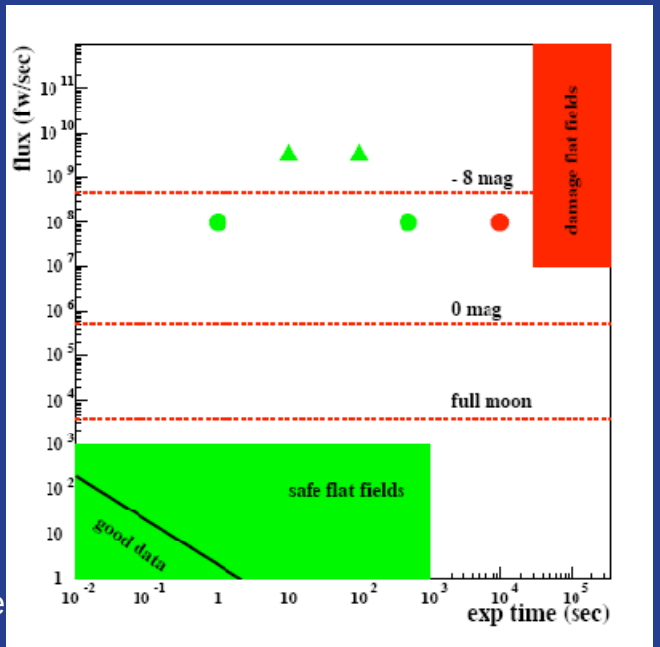




Imager with 56 engineering grade CCDs

- By-product of our CCD production strategy: large number of engineering grade CCDs
- ~ 2 years experience with CCDs in prototype imager
- 10 months operating experience with imager completed in April, most of time with 28 CCDs, last 2 months with 56 eng. grade 2kx4k CCDs and 3 2kx2k CCDs
- Defined safe operating phase space for these devices (Estrada, Hao)
- No Science grade devices used during testing – being installed now (26 of 62 in place and being tested)





Telescope Simulator: testing all components except optics together @ FNAL

- Test all the electrical and mechanical components of DECam in a realistic setting
- Test the software – mock observing

DECam on the Fermilab Telescope Simulator

The camera installed on the telescope simulator which we built at Fermilab in SiDet for extensive systems tests including orientations as expected on the telescope. We installed the camera in Oct 2010 and removed it in February 2011.

Telescope Simulator Testing of DECam

- Imager operation: 2 weeks at zenith position
- Imager operation: At 12 deg wrt horizontal:
  - At 0,90 and 131 degrees, full measurements:
    - filter reposition test
    - photon transfer curve for shutter linearity test and noise
    - hexapod x,y,z movement
    - hexapod tilt movement
    - about 2 days at each angle
  - at 45 and 117 degrees we did quick checks:
    - quick check of projection system through the filter
    - about 30 minutes in these intermediate positions
- F/8, Imager and cage installation procedure tests

Results of TS Testing

- Readout of CCDs with < 10 e- noise
- Imager vessel integrated with shutter and filter – both work at all orientations
- Hexapod moves reliably in all orientations
- Cooling system works well in all orientations
- Demonstration of the software we need to operate DECam in the telescope
- Installation procedures checked out
- Mock observing run

Successful Mock Observing

- **Invited experienced astronomers to “observe” using the SISPI system for 4 ‘nights’ (4 hrs/night)**
- **All the components, shutter, filter, hexapod, etc were operated as in the real observation**

5 Night checklist

This section describes the sequence of procedures to be followed by the observers during the “night” of mock observing – as this will be done during the day at Fermilab, all times are given in US Central times. It covers all the steps necessary to accomplish the observing plan. We scale down the number of exposures to make the “night” last 3.5 hrs. We anticipate to have 4 realizations of the mock night: 2 per day, in 2 days.

Before sunset – 9am/1pm

1. Check that all the hardware is ready. The star projector must be off.
2. A session at the workstation should already be running. If that’s not the case, log in as user sispi.
3. If SISPI is not yet running, open a terminal, get a new kerberos ticket and start SISPI from decamsrvr01:
   > ssh decamsrvr01
   > cd decam/architectures/simulator
   > setup Architect
   > architect -i mock_obs_n1 -c mock_obs.ini

-14 degrees elevation, just after beginning of Astronomical twilight – 11am/3pm

18. Observations in survey mode. ObsTac should jump automatically into this.
19. This is a good time to exercise procedures such as: pause, restart, etc. It is also a good time to explore and test the GUIs, look at telemetry information, check the headers.

-14 degrees elevation – 11:30pm/3:30pm

20. Stop Obstac. Start a sequence of standard stars at this time.

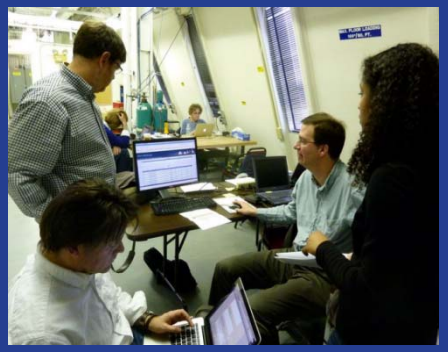
-7 degrees elevation – 12pm/4pm

21. Take a sequence of dome flats (∼ 15 min):
    > execute mock_obs/flat_script

Sunrise – 12:15pm/4:15pm

22. Set system to safe:
    > FCS set Vsub Off
23. Make final edits to your log.
24. Complete the end of the night report.

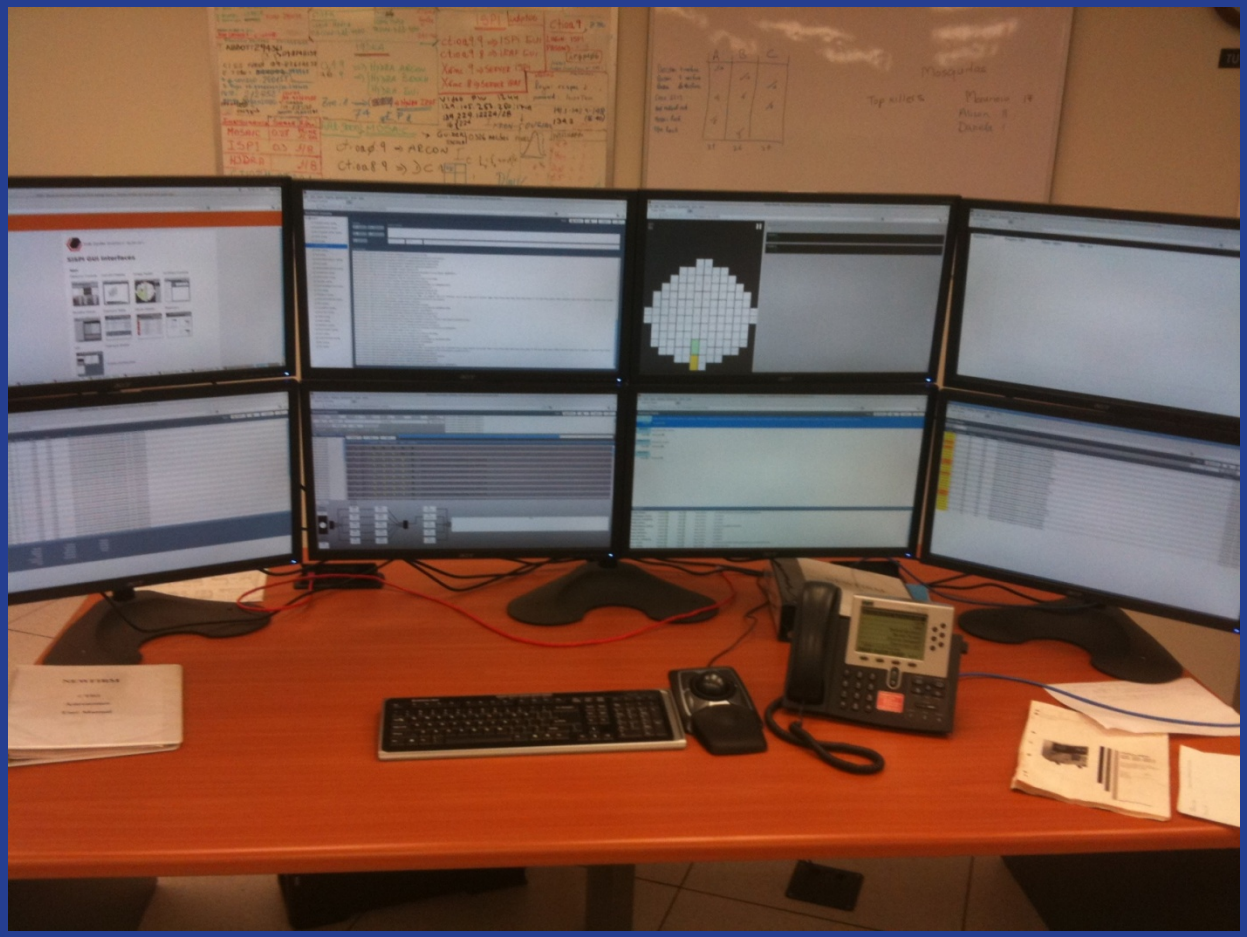
End of the mock night – 12:30pm/4:30pm



Photos courtesy of M. Soares-Santos

Both software and hardware work great!!

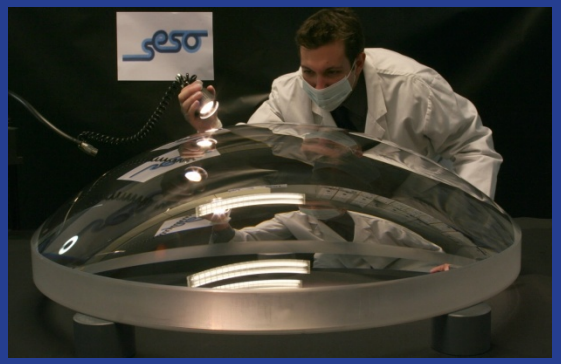
SISPI running in new CTIO control room

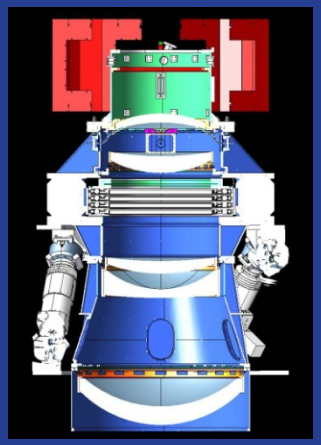


CTIO built the computers and installed them in the new computer room. The DECam personnel visited CTIO and worked with CTIO in April for installation of SISPI software.

Optical Corrector for DECam

- 5 large lenses (UCL) and a precision mechanical barrel (FNAL)
- Lens blanks ordered 9/2007 (Corning)
- Sent for polishing ~ 1 yr later (SESO)
- Polishing completed ~ 2.5 yrs after that
- Coating of final lens completed May 2011
- Barrel and cell 5 constructed at FNAL
- Cells 1-4 constructed in England and shipped to FNAL
- Precision alignment of cells to barrel – Lab 3
- Barrel and cells shipped to UCL
- Lens installation and alignment at UCL
- Shipment of Corrector to CTIO – 9/2011





Shipping Status for DECam

Purple – at CTIO
Green – en route
Blue – being packed
White – still in testing or procurement

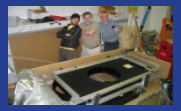
DECam Shipment Acceptance Status

6/1/2011

Category	Shipment	Status	Acceptance for Export	
Filters	1st 2 filters	Complete		
	Remaining filters	In production		
RASICam	RASICam	En route to CTIO	DocDB 4705	Y
Corrector Barrel	Corrector	At UCL		
SISPI	SISPI hardware	At CTIO		
	Remaining S-Links	Will ship with Imager		
Imager	Imager & full focal plane	In testing		
	FEE Boards & Cables	In testing		
Camera Support Equipment	Non-LN2 Cooling Systems	Packed	DocDB 5331	Y
	Hexapod	En route to CTIO		Y
	Cage/Fins/Platform/Wts/Etc	Packed		Y
	Shutter/FC	En route to CTIO		Y
	ICS Hardware	Packed		Y
F/8	F/8 Platform	At CTIO	DocDB 4852	Y
CCDs	Full focal plane	Will ship with Imager		
	Spare CCDs			
LN2 Cooling	LN2 Cooling System Air	En route to CTIO	DocDB 5331	Y
	LN2 Cooling System Boat		DocDB 5331	Y
	Telescope Utils for LN2	In procurement	DocDB 5331	N
Calibration	Shipment 1	Ready for packing		
	Shipment 2	In production		
PreCam	PreCAM & assoc equip	At CTIO	done	done

Current Schedule for Remaining Work

5/2011 – 8/2011:  Mounting Science Grade CCDs on the Imager @ FNAL

6/2011     From FNAL 

7/2011: Cage, NW platform parts, installation fixtures From FNAL 

9/2011  From FNAL 

 From UCL

11/2011  Installation on Telescope @ 

1/2012: First Light 

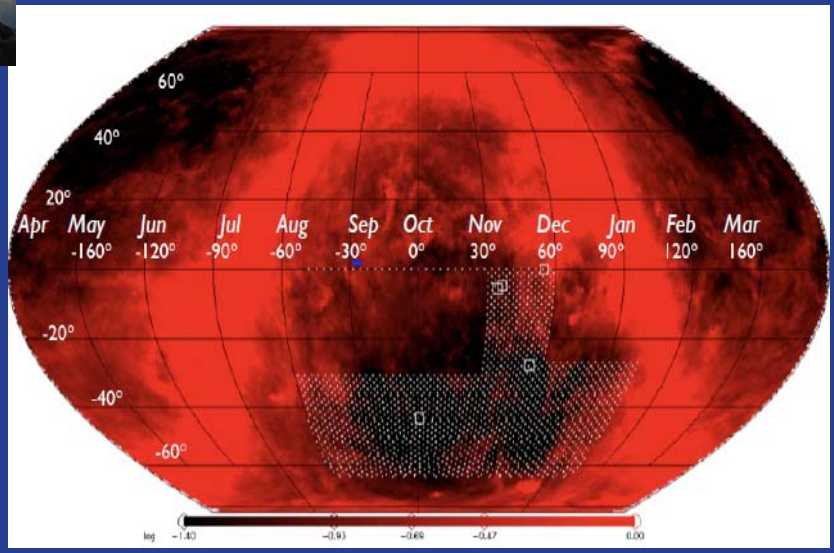
1/2012 – 4/2012: DECam commissioning, F/8 observing, engineering @ 

Current Schedule for DES Science

3/2012: two weeks for community science verification @

4/2012: DES science verification: mini survey

- ~ 7-10 nights, 100 deg^2
- Overlapping with other fields of interest
- Data go public immediately
- Early Science Results summer 2012



9/2012: Dark Energy Survey Starts

2/2017: Dark Energy Survey ends. Completed DE Science Results will be published

Conclusion

- DECam construction is nearly complete
- Remaining steps
  - CCD installation
  - Corrector assembly
  - Filter procurement
  - Reassembly at CTIO
- CD-4 definition for project: all deliverables at CTIO and ready for telescope installation. 9 mos. schedule contingency remaining.
- First light for the camera in Jan 2012
- Dark Energy Survey to begin in Sept 2012
- 1st Dark Energy Science results after second season
- 5-yr Survey to be completed in 2017