The Cal Poly 18

An 0.47m Direct-Drive Robotic Telescope

Meter-Class Astronomy

January 20, 2012

Richard Berry

Cal Poly 18: Capsule Description

- Economical research-grade telescope
  - 0.47-meter aperture, *f*/4.1 Newtonian
- Alt-azimuth configuration
  - Compact, symmetrical, inexpensive
  - Ever-changing drive rate in three axes
- Computer-controlled motors
  - Alt-az direct-drive: no gears, rapid response
  - Feedback from high-resolution encoders

Cal Poly 18: Timeline

- 2007: Portland I Conference.
  - Dave Rowe direct drive motor prototype.
  - Dan Gray demos “Lollipop” alt-az telescope.
- 2008: Cal Poly student assignment.
  - Design/construct fork and tube.
  - Debut at STAR Conf., San Luis Obispo.
- 2009: Cal Poly 18 moves to TMS.
- 2011: Push begins to make operational.

The PDX I Meeting

Genet, Banich, Berry, Bartels, Gray, and “Lollipop”

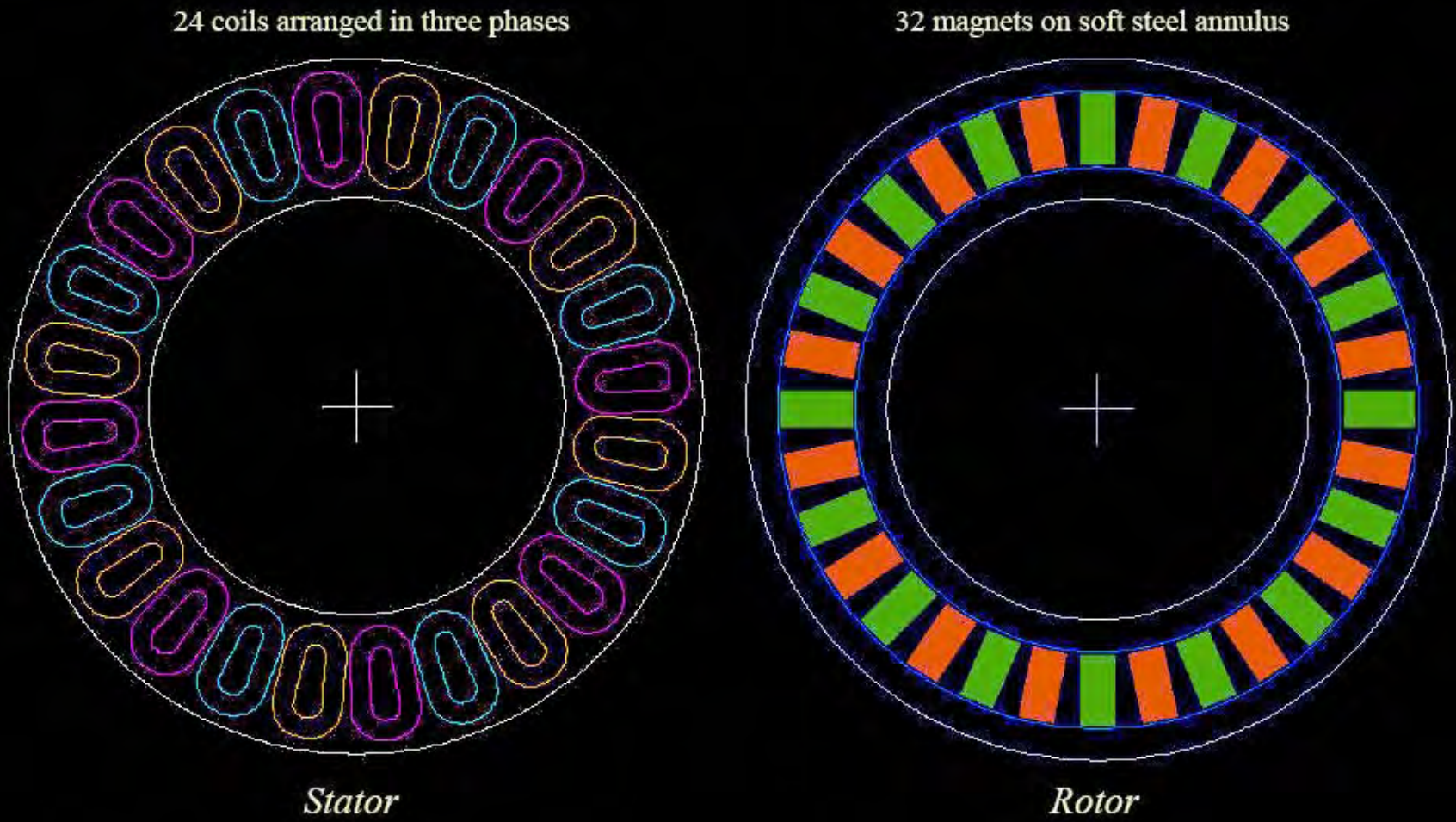
Prototype Direct-Drive Motor

The plywood prototype direct-drive motor

What Convinced Me…

5,000 Images of XX Cygni in four nights!

Direct-Drive Configuration



Credit: Dave Rowe

24 Handmade Coils

Credit: Dave Rowe

32 Rare-Earth Magnets

Magnets

Soft Steel Annulus

Aluminum Housing

Bearing Race and balls

Encoder Mounting Area

Credit: Dave Rowe

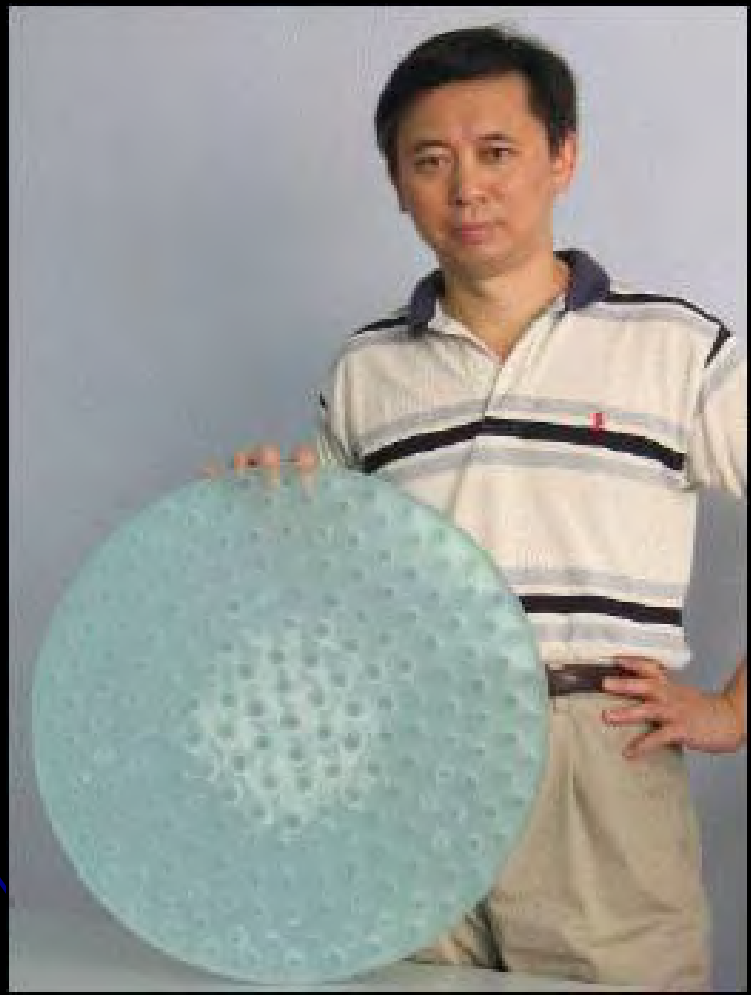
The Cal-Poly Design Team

Matt Swanson, Josh Schmitt, Michelle Kirkup, and absent Wilson Chiu and John Ridgely, advisor, Dept. of Mechanical Engineering

Debut: Cal Poly 18

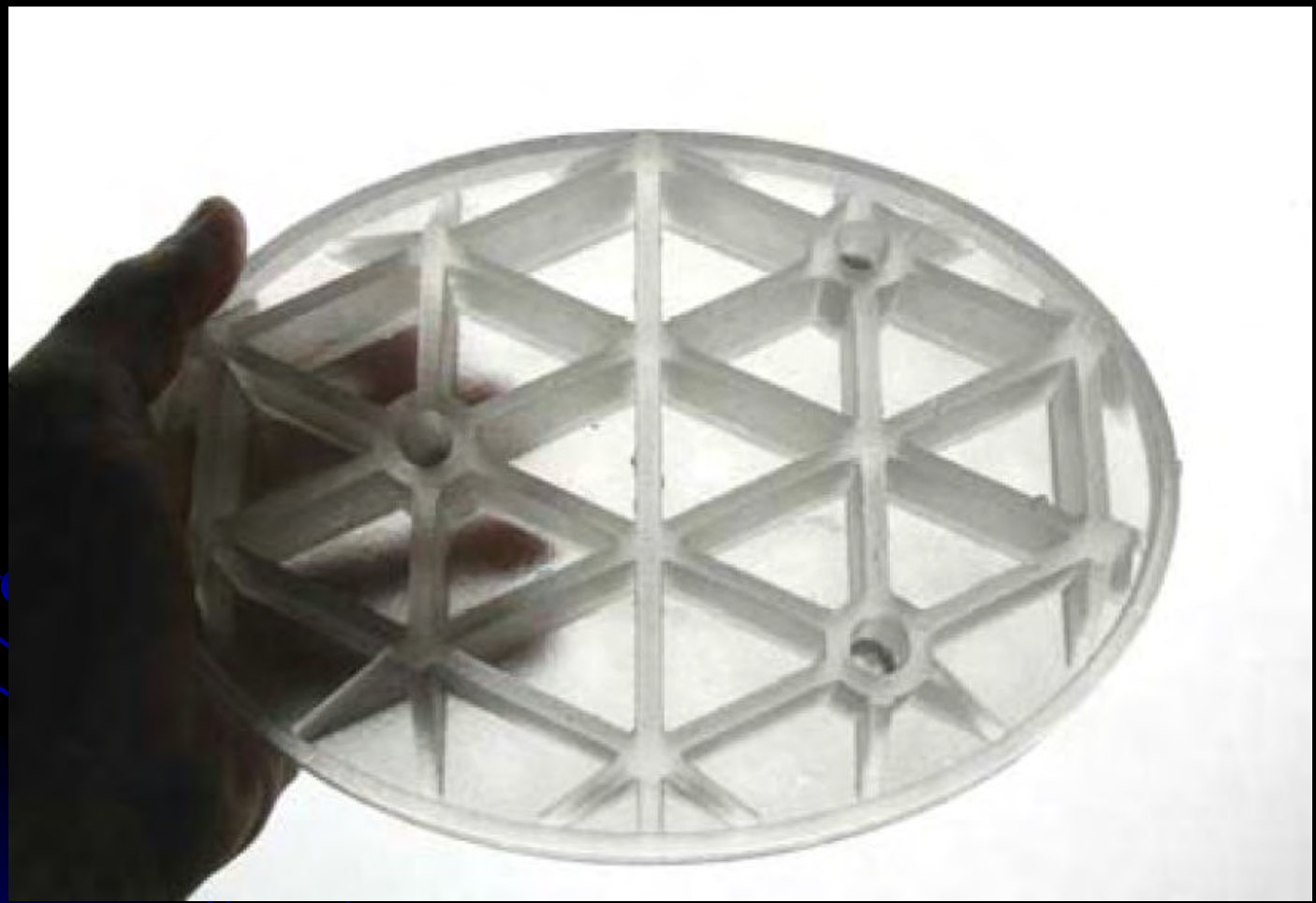
Dan Gray (SciTech) with Cal Poly fork sitting on azimuth axis motor

Fused Sandwich Mirror



Tong Liu, Hubble Optics

Fused Borosilicate Secondary



2009 Status: Functioning Prototype

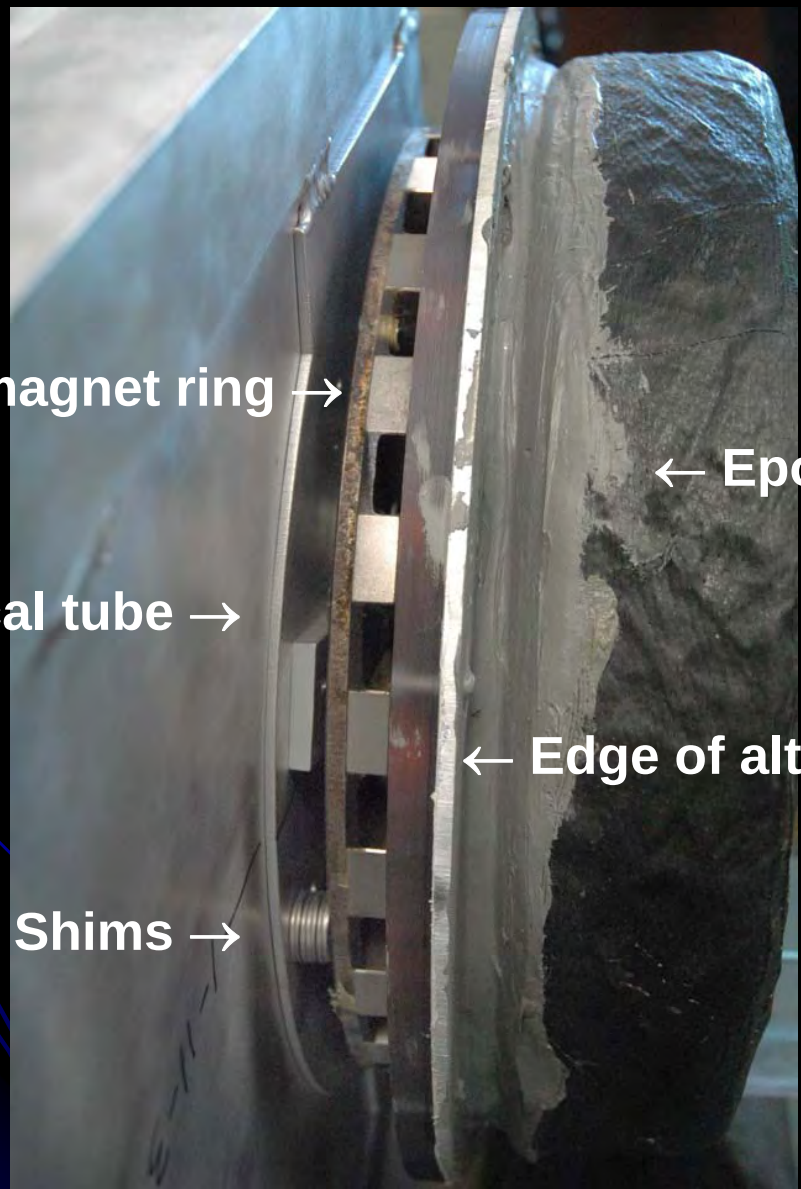
- Moved to TMS in Portland, OR.
- Azimuth base fabricated.
  - Six steel channel legs with adjustable feet.
- Altitude bearing/motor installed.
  - Axes not perpendicular, shimmed and epoxied.
- Mirror cell and secondary assembly completed.
- Slews/tracks under computer control both axes.
  - Slew rates to 30º/second; tracks at sidereal rate.
  - “Functional” as a telescope but untested.

2011 Status: Still a Prototype

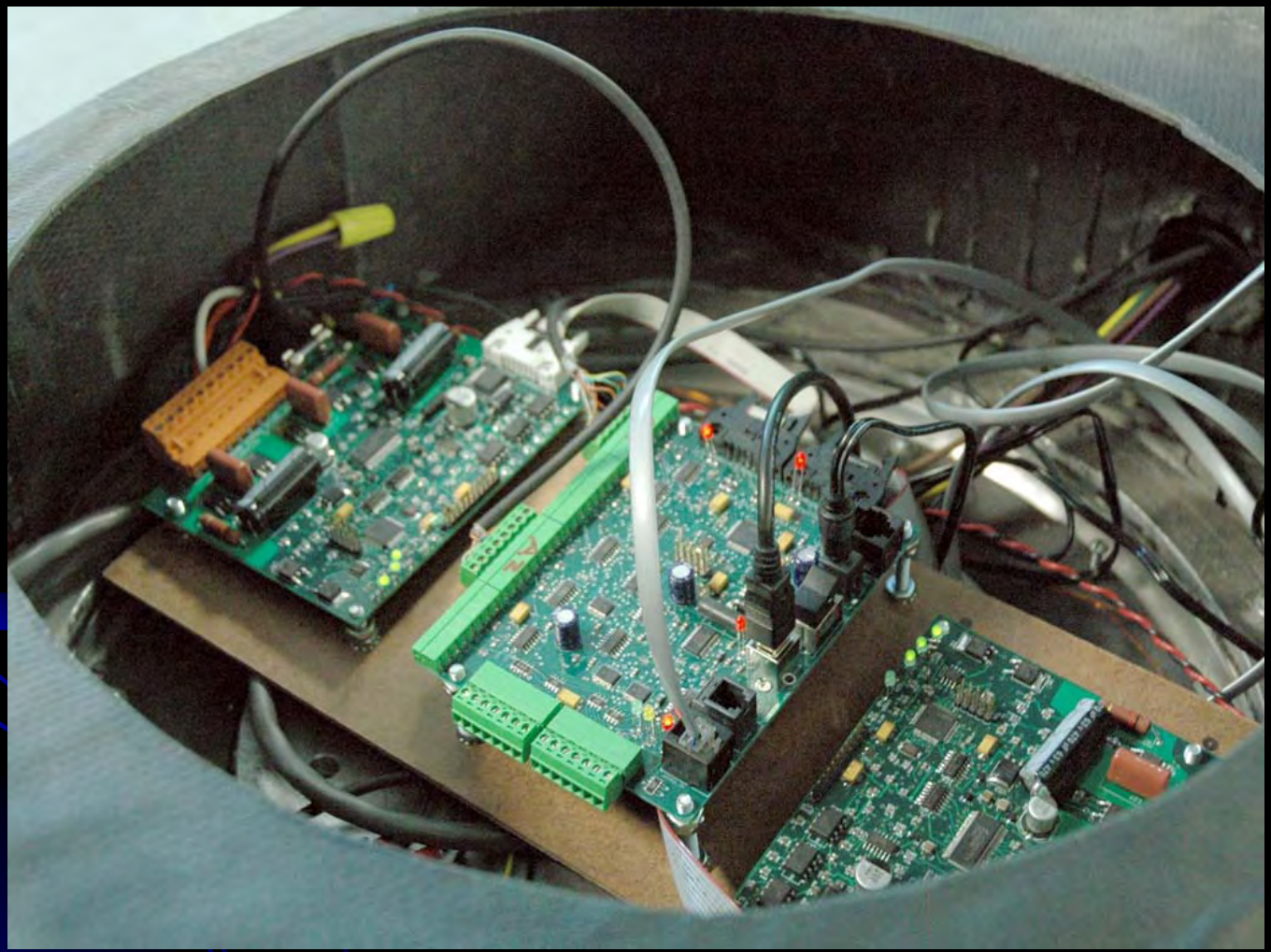
- Minimum needed for science data collection:
  - Add limit/home switches.
  - Complete firmware/software.
  - Boards, wiring, Ethernet extender.
  - Replace unstable spider/upper end.
  - Optics: baffle, blacken, focus.
  - Design/build camera focuser/rotator.
  - Dedicated control computer.
  - CCD camera and filter wheel.
  - Site/shelter for dark-sky testing.
- Iterate until working:
  - Operate, evaluate, correct, repeat.

April 2011

The Altitude Axis Reworked

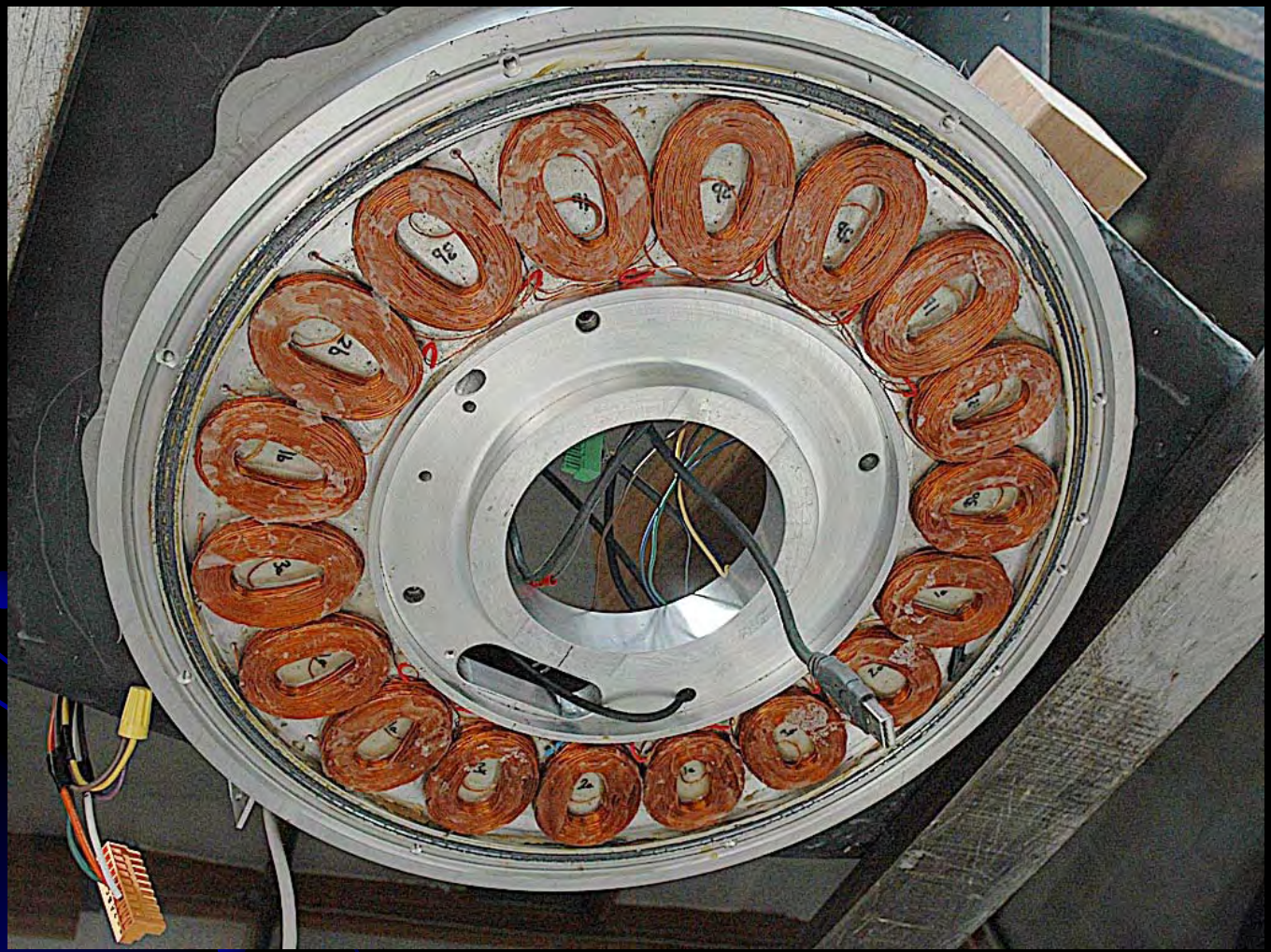


Prototype Control Electronics



SciTech circuit boards in base of Cal Poly 18 fork assembly

Repair to Motor Coils



Seen from below, with telescope fork and tube lifted by fork-lift truck

Magnet Ring and Base

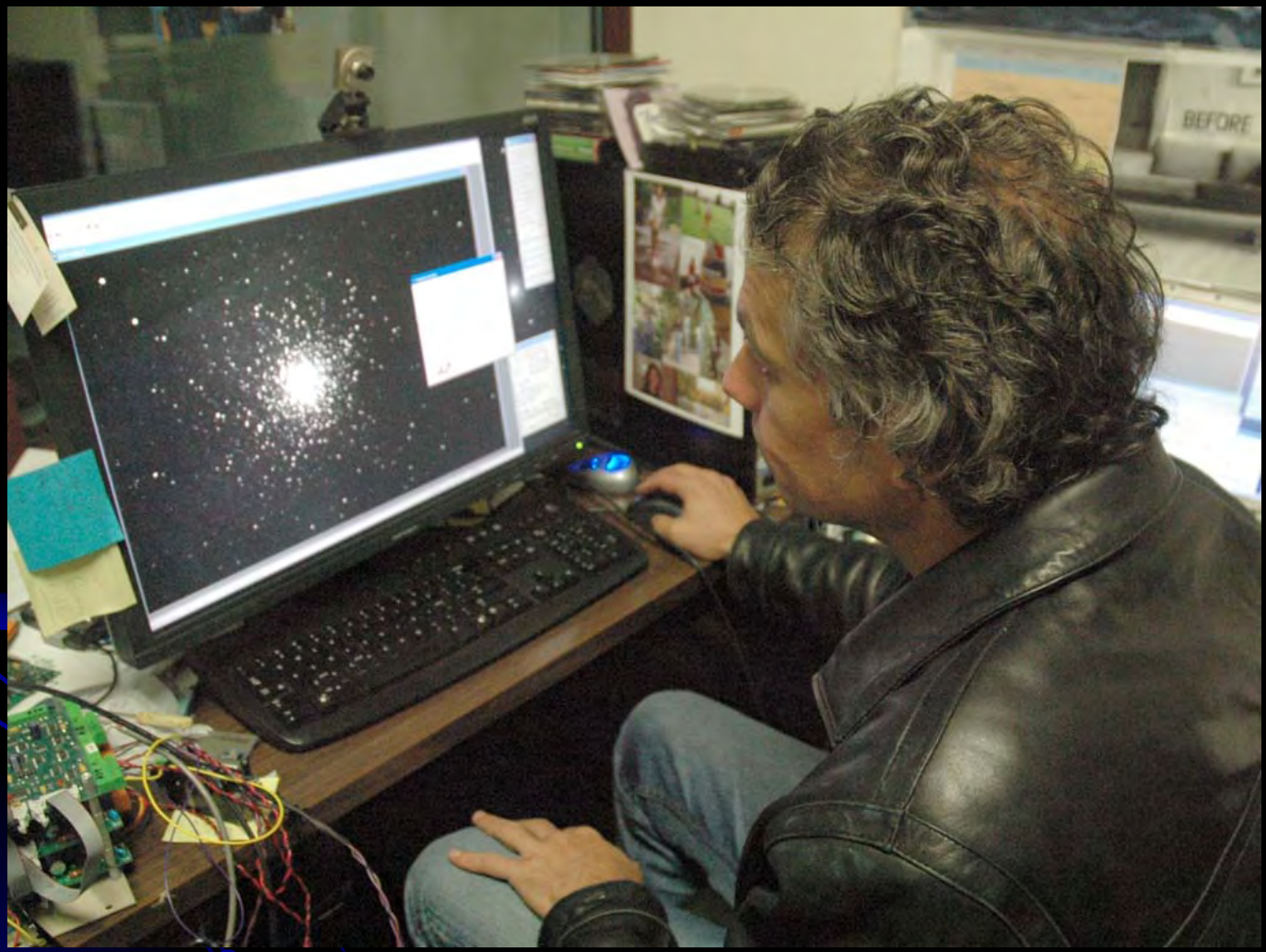
200 glass ball bearings run in V-groove.

Dan Installs Azimuth Encoder

Renishaw encoder tape wraps ~350º in azimuth

Testing in TMS Parking Lot

Dan Sees First Light

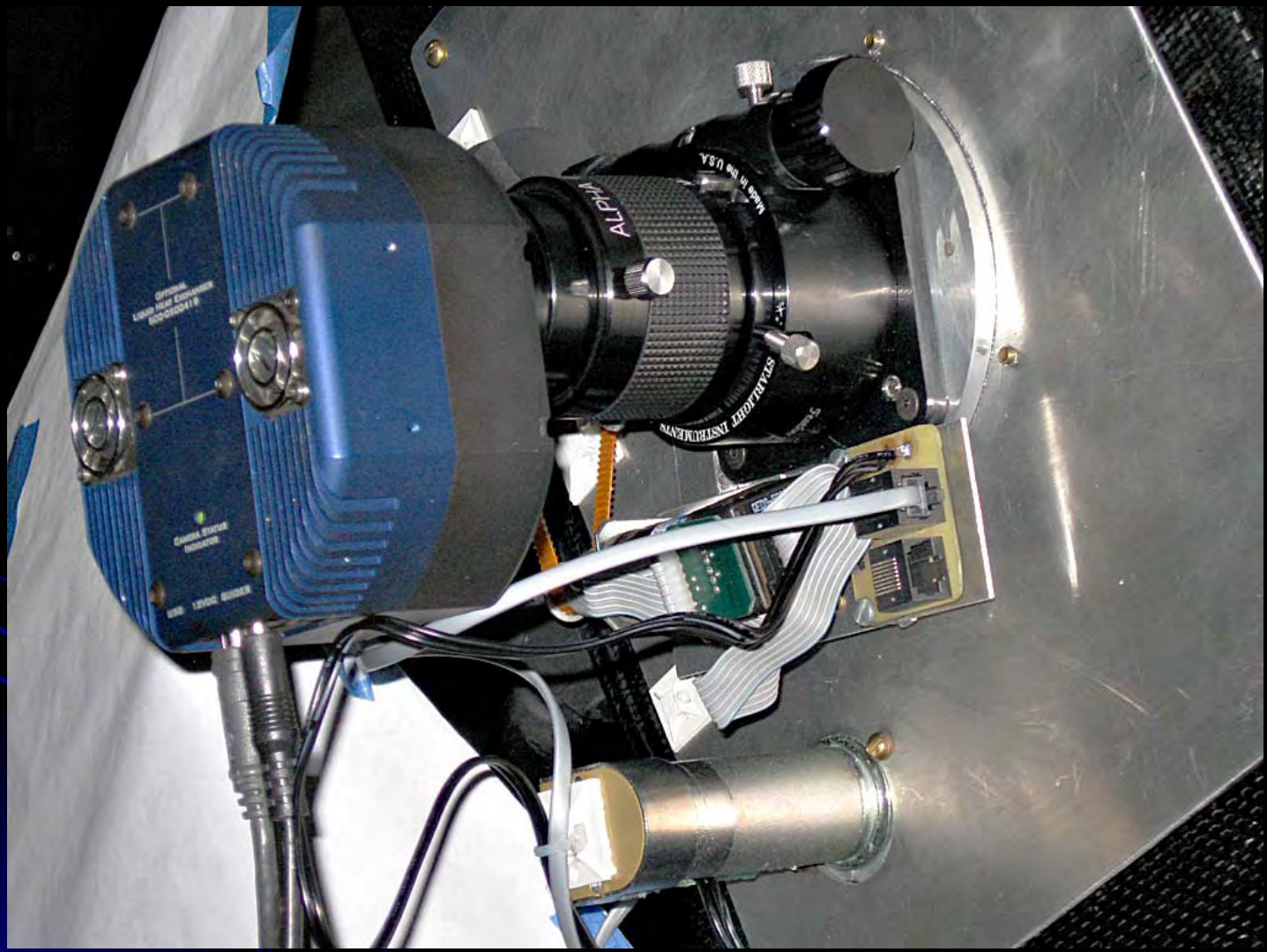


We mirrored the control laptop from Dan’s office computer

First Light

Cal Poly 18 First Light: TMS 2011-06-16

Last Major Component: the Focuser/Rotator

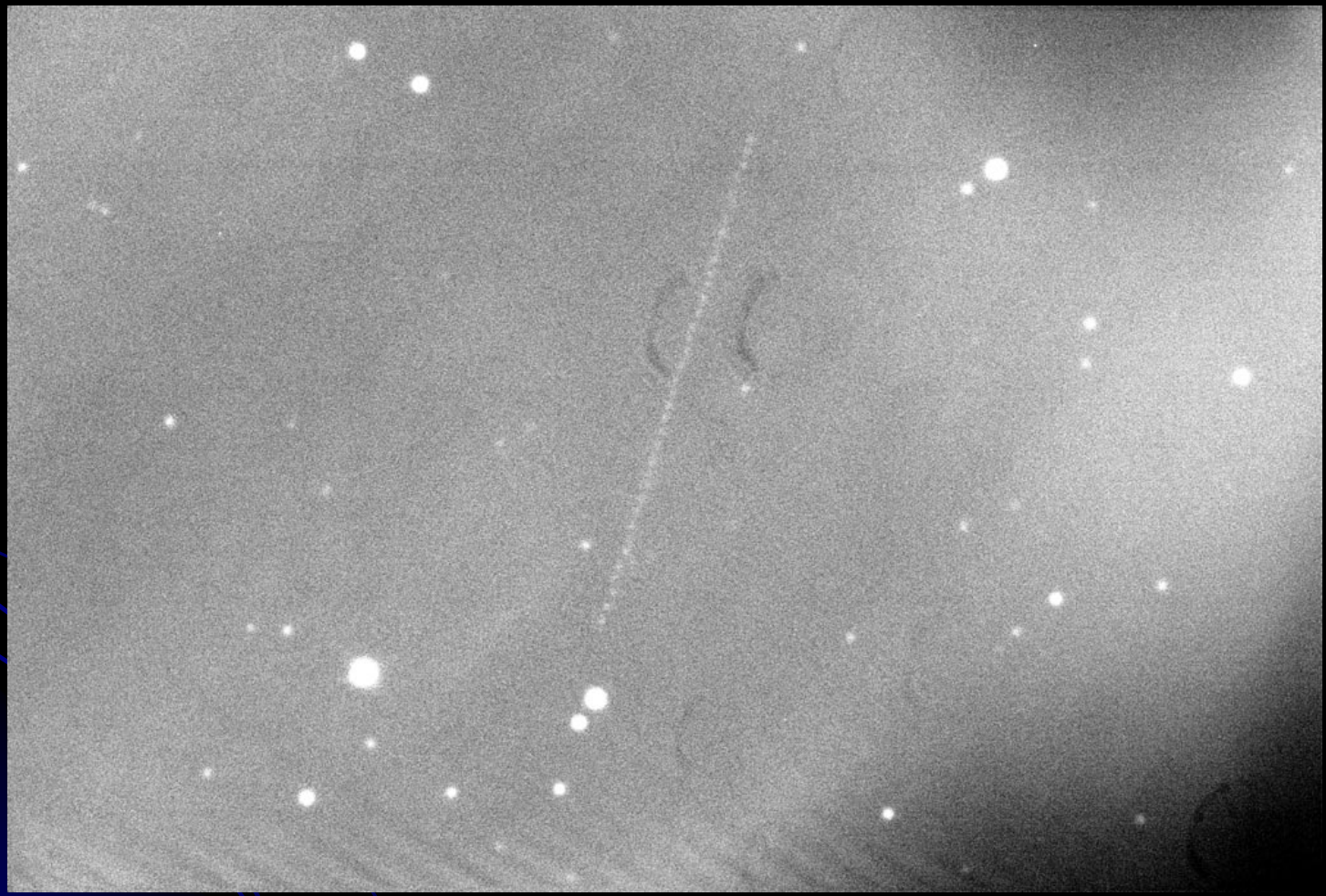


QSI 532 CCD camera, FeatherTouch focuser, TMS rotation stage

January 11, 2012: Everything Works!

Cal Poly 18 with temporary paper light shroud; cold, windy night

Find and Track Satellite

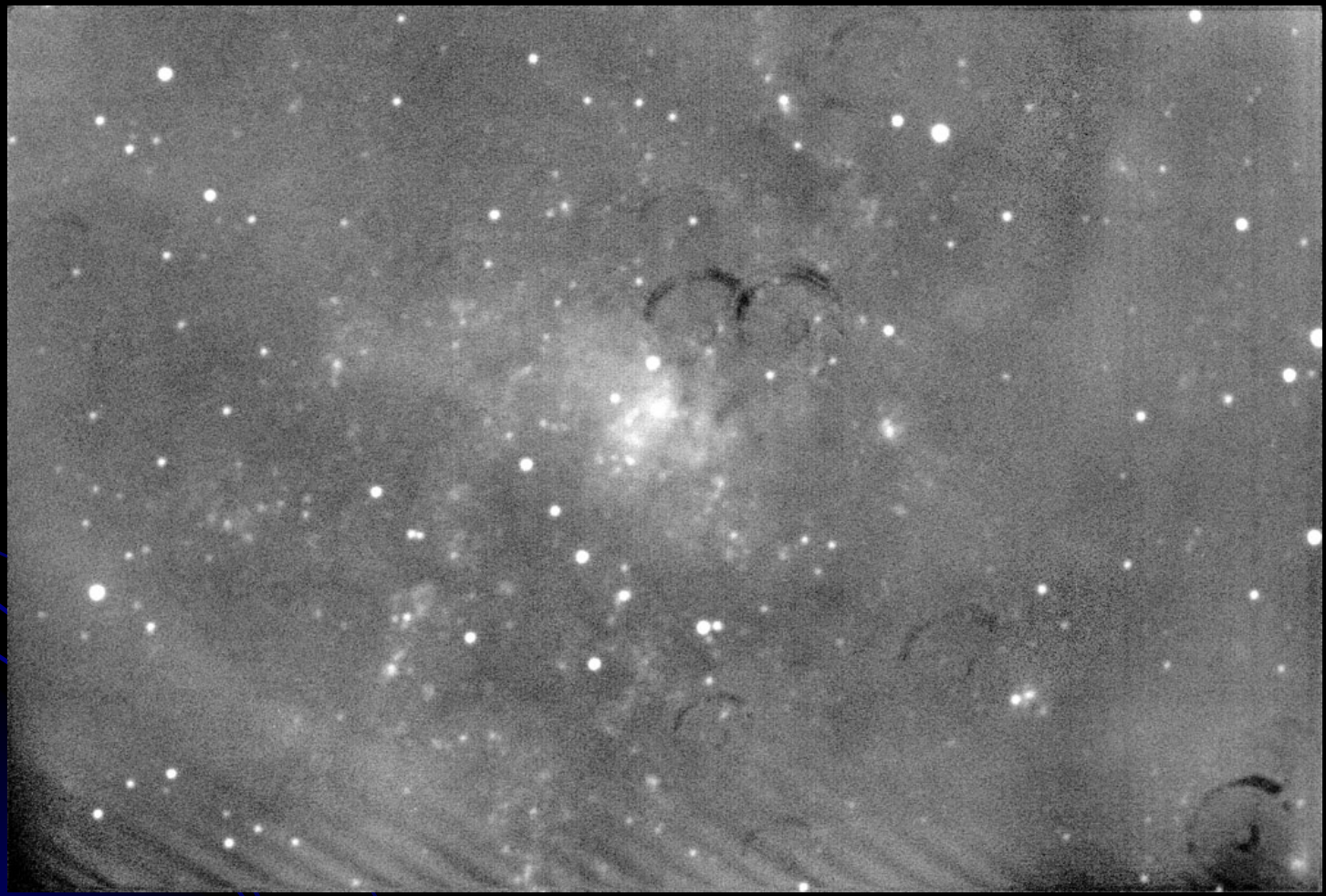


Unguided 60-second exposure while following stars

Find and Track Satellite

Unguided 60-second exposure while following satellite

Accurate Unguided Tracking



Five minute exposure, unguided, round stars!

LRGB 10:10:25:25s “pretty-picture” of the Orion Nebula

Cal Poly 18: New Home

Temporary roll-off housing for convenient shake-down and testing in driveway near Richard Berry's house, Lyons, Oregon

For next time…

- Design telescope as complete system.
- Understand all requirements of system.
- Design subsystems as part of system.
- Avoid “We’ll take care of it later” thinking.
- Test and assess for function in system.
- Make realistic cost projections.

Design as a Complete System

- Make optical function Job #1.
  - Do not clip light path
  - If open tube is necessary, baffle it.
  - Keep heat sources away from optics.
- Tightly integrate motors, fork, and tube.
- Accommodate power and data cables.
  - Pierce bulkheads.
  - Design space for cabling.

Direct-Drive Motors

- Provide dirt covers for sensitive parts.
- Protect all wiring from abrasion.
  - Pot wires leading to coils.
  - Cover exposed wiring.
- Use full 360º encoder ring in azimuth.
- Integrate encoder and sensor in motor.
- Place min, max, home switches in motor.

Base, Fork, Tube

- Plan to accommodate off-spec optics.
- Integrate motor design into design.
- Integrate power and data cables in design.
  - Incorporate pass-through in bulkheads.
  - Design separate paths for power and data.
- Anticipate need for counterweights, etc.
  - Add extra mounting holes, all surfaces.
  - Allow clearance for add-on items.

Cal Poly 18: Conclusions

- Became “operational” December 2011.
- Satisfies basic performance criteria:
  - All-sky model good to ~10 arcsec r.m.s.
  - Acquires desired field/object reliably.
  - Tracks to ~1 arcsec for 5 minutes.
  - Resists reasonably large wind forces.
  - Focuser/rotator corrects field rotation.
- Bulk of performance testing remains.

Thanks to…

- Russ Genet
- Dave Rowe
- Dan Gray
- Howard Banich
- John Ridgely
- John Keller
- Tong Lui
- Cary Chelborad
- Allan Keller
- Mel Bartels
- Greg Rohde
- Ed Harvey
- Billy Alberson
- Wilson Chiu
- Michelle Kirkup
- Drew Murphy
- Josh Schmitt
- Matt Swanson
- Rob Urban
- and many others.

For more information…

Follow work on the Cal Poly 18 at:

www.wvi.com/~rberry/calpoly18/calpoly18.htm

That's All Folks!

Meter-Class Astronomy

January 20, 2012

Richard Berry