The Case for Automated Telescopes:

The Variable Young Stars Optical Survey

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Operating Costs

- Rule of thumb: operations cost is 10% of capital cost
  - i.e. a $100M telescope will cost $10M/yr to operate
  - applies to new large telescopes ($8-10M/yr or more)

- 4 meter class telescopes on Mauna Kea cost $4-7M/yr
  - nominally UKIRT costs $0/yr ... but complicated
  - UH 2.2 meter costs < $1M/yr

- A significant cost is nightly observers
  - CFHT expects to save $400k/yr by going remote

Automated Telescopes

- Most research telescopes require at least one person to operate (and a second person on-site for safety)
- even *remotely operated* telescopes have an operator monitoring the system and the astronomer logs in remotely

- this is expensive
  - automation should reduce operations costs
  - over time operations costs dominate capital costs

- The challenge is that an automated telescope will have no one monitoring the system as it operates

Automated Telescopes

- VYSOS faces problems similar to large observatories
  - maintenance (we have many of the same systems)
    - IT/network, dome, telescope, mount, instrument, monitoring systems
    - we don’t have a multitude of instruments and observers
    - we’re not a general facility, we specialize in one type of observation

- We have other unique challenges
  - we have no on-site presence
    - we need reliable condition sensing to make up for that
    - we do primary diagnostics remotely
  - operational decisions done by computer (no operator)
    - we must foresee and preprogram all necessary responses
    - i.e. wind constraints

Automated Telescopes

- Goal: operate two telescopes with much less than 1 FTE of maintenance, upkeep, & operations work
  - replace day crew and night crew with automation

Observatory Systems

- An observatory is much more than just a telescope and some supporting equipment
  - an automated observatory is a systems engineering challenge

- Design Principle: Simplicity
  - the K.I.S.S. principle works
    - “perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away.”
      -Antoine de Saint Exupéry
  - also quicker to diagnose problems and make repairs
    - especially important if no on-site expertise
  - simplicity competes with capability and redundancy needs

What makes up an Observatory System?

Telescope/Mount
CCD
Filter Wheel
Guider
Instrument Rotator
Focuser
Enclosure
Weather Safety
Environmental Control: fans / AC
Environmental Control: lights
Monitoring: cameras
Monitoring: all sky camera

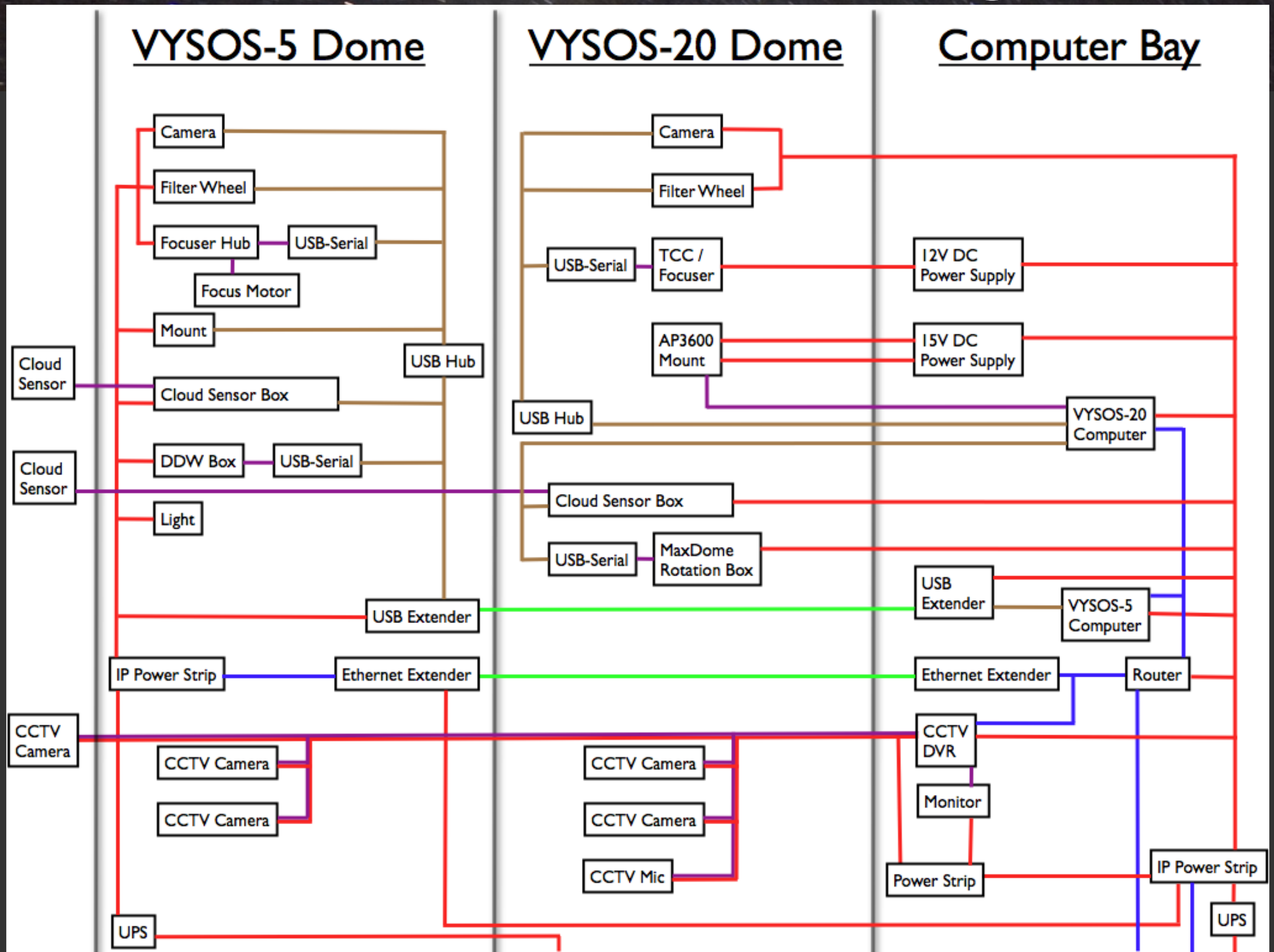
Back Up Power (UPS)
Power Supplies
Remote Power Strips (PDUs)
USB-Serial Converters
Fiber Optic Extenders
Internet Connectivity (router, switches, etc.)
Computers
Data Storage
Remote Operation Software
Automation Software (Scheduler)
Data Reduction Software
Photometry Software

Including cables, easily over 100 components

each of which must work to have functioning observatory

---> 100 components each at 99% reliability = 37% up time

This is the Theory



This is The Reality

- Chaos builds quickly
- Image at Right:
  - one telescope
- Must be designed as a system
  - system relationships & communications should be design considerations
  - as well as capabilities

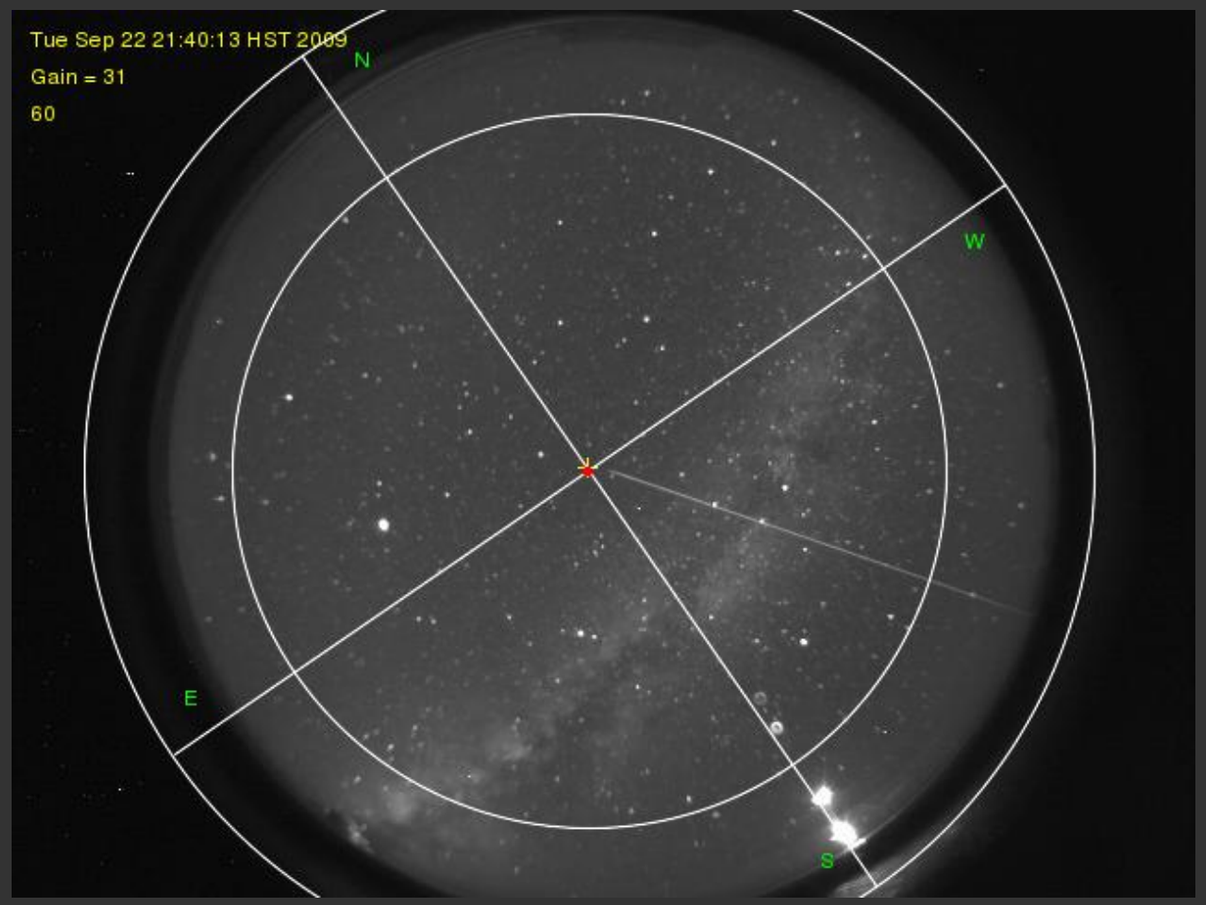
Observatory Infrastructure

- Monitoring
  - Clouds: Boltwood Cloud Sensor (soon to be two)
  - Clouds: All Sky Camera
  - Weather: Boltwood or Weather Station
  - Dome: External Low Light Camera
  - Telescope: Internal Low Light Cameras
  - Computer & Associated Hardware: more cameras
    - want to see status lights for diagnostics

- Information from all these systems should be consolidated in one, easy to access location

Monitoring: All Sky Camera

- Integrating Video Camera (Stellacam III)
- clone of the camera at the MMT, software from CONCAM
- auto-iris lens + software adjusted gain, exposure
  - also works in daylight

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Observatory Layout

- Layout: where are telescopes, computers, & equipment?

- Computers, power supplies generate heat
  - design enclosure to limit thermal effects (i.e. wide dome slit)
  - or choose layout to move heat sources away from optics

- Ventilation system for enclosures
  - remove the heat that is generated near the telescopes
  - cool rapidly to nighttime ambient after daily solar heating

Observatory Layout

- Long signal cable runs are undesirable
  - electrical pickup, lightning concerns
  - USB cables nominally limited to 16 feet
    - so moving computers requires extenders (i.e. fiber optic)
    - increases complexity (3 cables, 2 boxes, 2 power supplies)

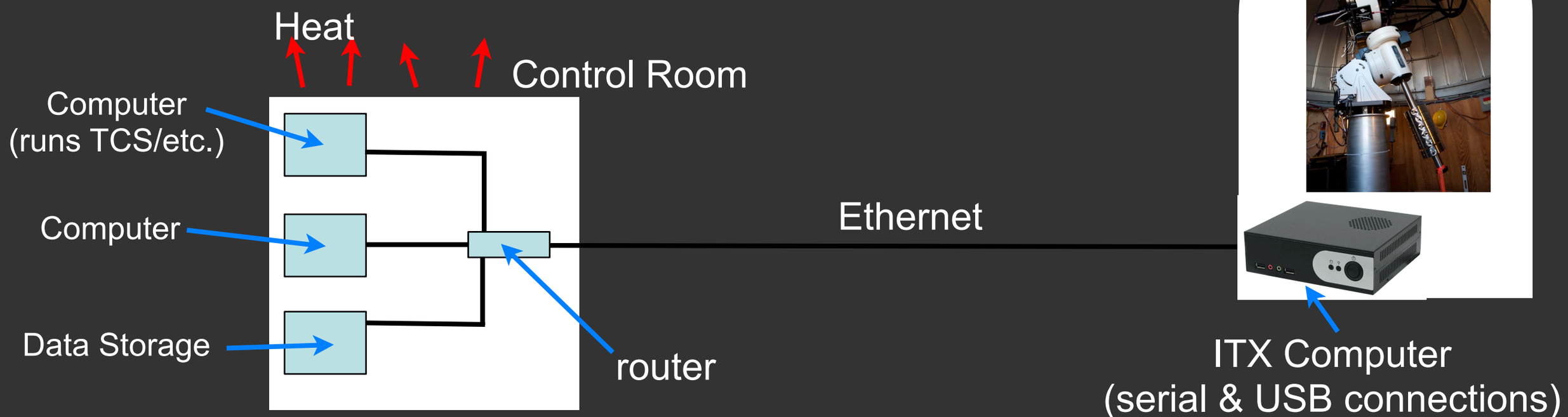
- Cables & Connectors
  - USB (non-positive connections)
    - thermal cycling, telescope motion can work them loose
  - serial (DB9), phone (RJ11), etc. are positive connectors

Computers

- Site environment may be non-optimal for computers
  - altitude -- hard drives are air cushioned
  - altitude -- more cosmic ray hits
  - temperature -- extremes out of standard operating range
- Reliable Computers
  - large systems: RAID & redundant power supplies
  - small systems: fanless, diskless
- Keep the Software Simple
  - the fewer programs running, the better
  - turn off OS features, services, daemons
  - separate observatory control, data storage, data processing
  - put security at firewall?

Control Systems

- Fault Tolerance: Rerouting of communication
  - minimize use of unreliable USB push-to-fit connectors
- Remote USB and Serial Ports
  - use small ITX machine locally
  - control computer runs all complicated software
  - use virtual machines as backups



Real Life Challenges

- everything takes longer than expected to implement, test, & debug

- funding cycle pressures often push us to non-optimal solutions
  - "*get it working now*" instead of "*get it working right*"

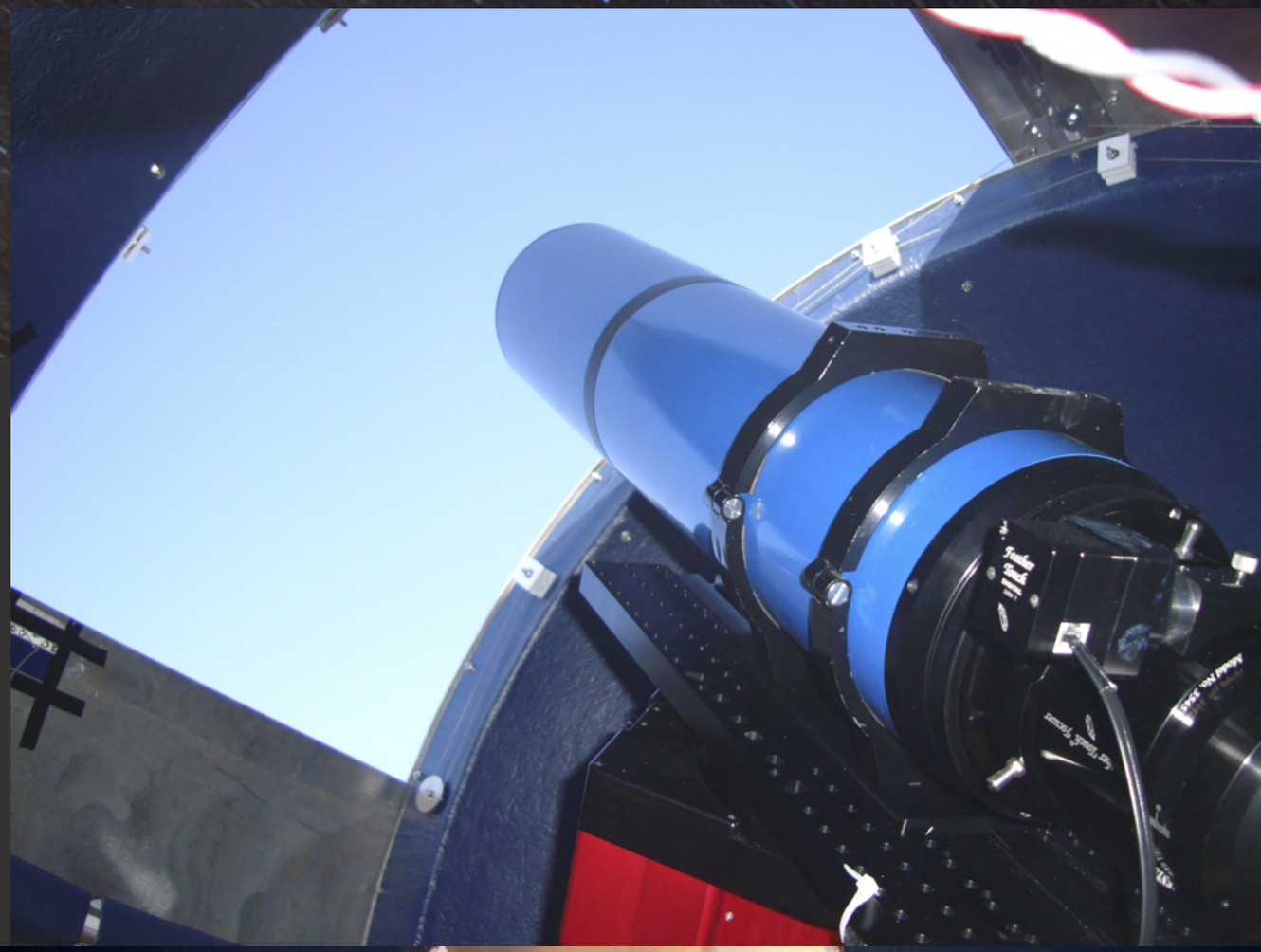
- operating costs are often more difficult to obtain than capital costs
  - this is one motivation for building an automated telescopes
  - must be considered in design of hardware

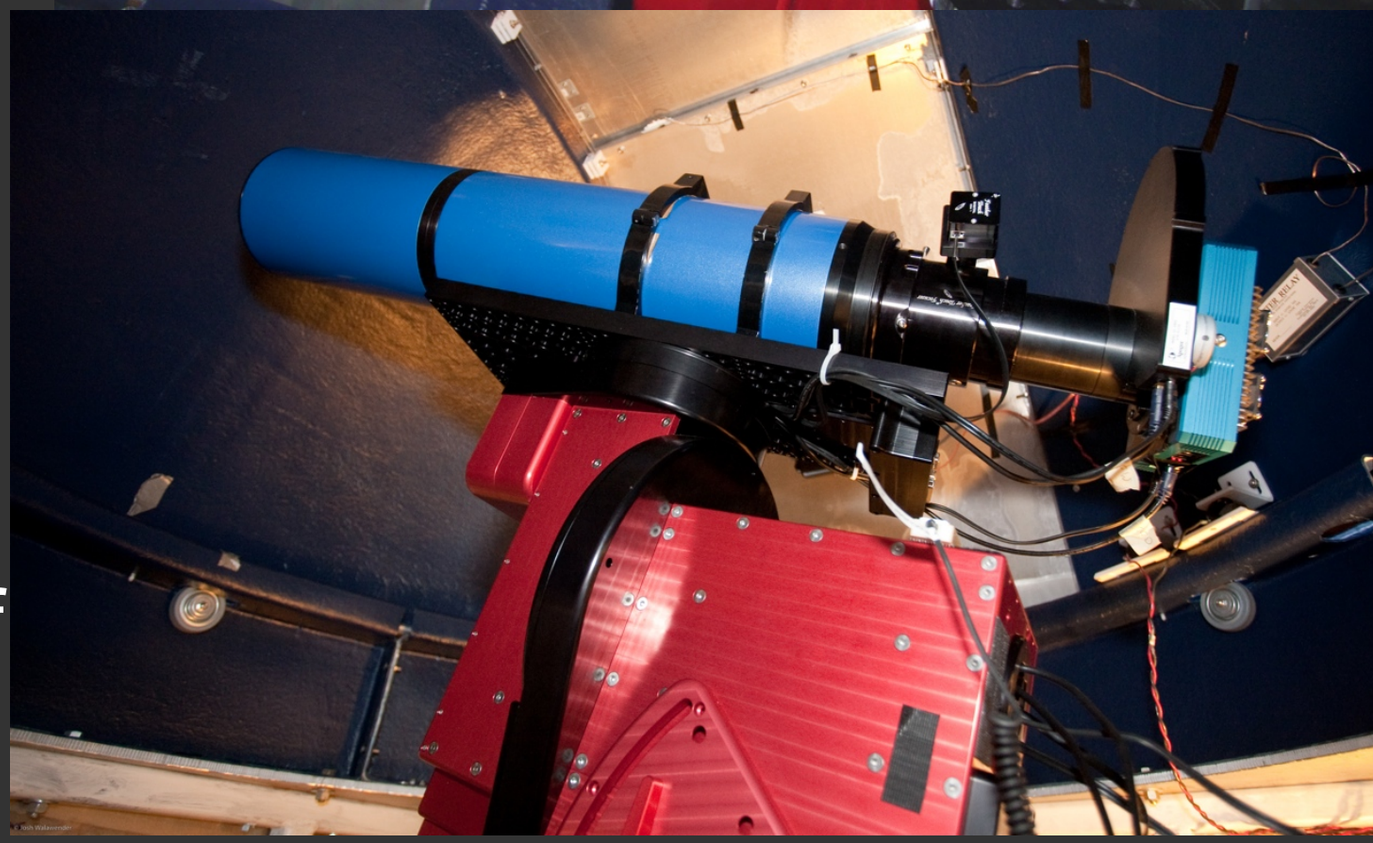
VYSOS-20

- 20 inch f/8.2 RCOS
  - ion milled optics
- Astro-Physics AP3600GTO “El Capitan” Mount
- Apogee Alta U16M CCD
  - 16 MP (4096x4096)
- Currently being commissioned

VYSOS-5

- Stellarvue SV135
  - 135mm f/5.4
  - dual-fluoro triplet
- Software Bisque Paramount
- Apogee Alta U16M CCD
  - 16 MP (4096x4096)
- Has collected 1.5 years of data



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