Time Domain Astronomy with the System

Time Domain Astronomy

- Targets of Opportunity
  - GRBs
  - SNe, etc
- Time Domain Surveys
  - Microlensing (SuperMACHO, MOA…)
  - SN Ia (Essence, CFH SNLS,…)
  - Solar System (Linear, DES,…)
  - Stellar variability (OGLE, …)

Producers and Consumers

- Surveys/Instruments Producing Alerts
  - SNLS, SM, Essence, OGLE, MOA
  - Future
    - Dark Energy Camera
    - PanSTARRS
    - LSST
- Response Facilities
  - Prompt, Raptor, ETC
  - Gemini, Keck, Magellan, VLT, etc

Time Domain Case Studies

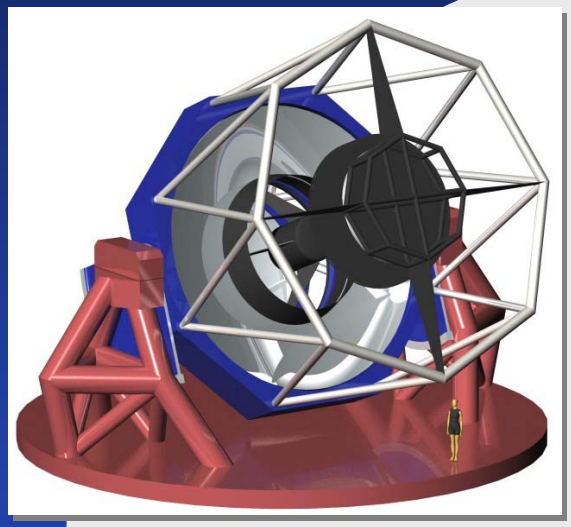
- SuperMACHO + ESSENCE
  - NOAO survey program on Blanco 4m
  - Follow up: Gemini, Magellan, Keck
  - NSF funding
  - Data public immediately,
    - Alerts in real time
    - Images available rapidly from NOAO archive

System-atic Challenges

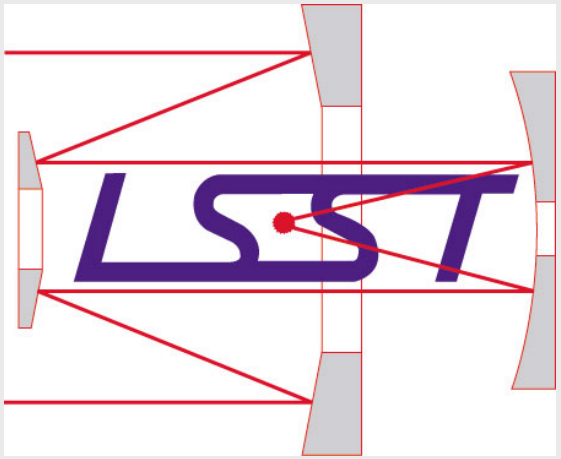
- Rapid Access
  - Image follow up
  - Spectroscopic follow up
- Long Term Access
  - Surveys can be long
  - Follow up tends to be short term
- Space/Ground System
  - Space to ground: GRBs
  - Ground to Space: SN Ia

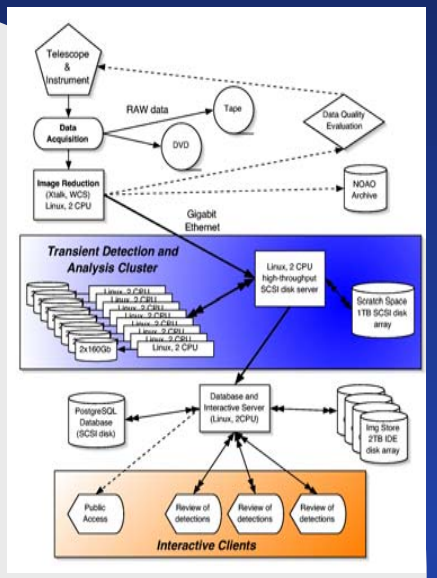
Time Domain *AND* Wide Field

Large-aperture Synoptic
Survey Telescope

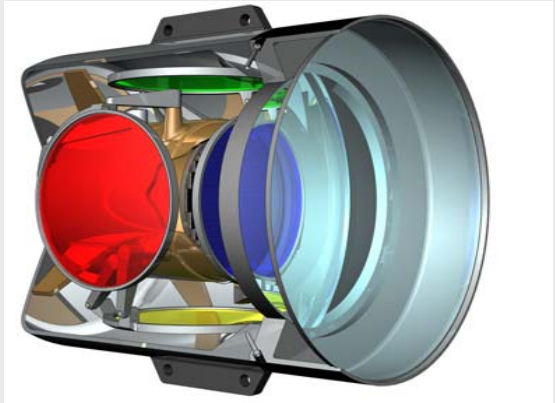


8 meter-class optics





18 Terabytes/night



2.8 Gpixel Detector

LSST Motivation

- Probe Dark Energy & Dark Matter
- Open the Time Window
  - Faint Transients (GRB, SN, …?)
  - Variability studies: stars, galaxies…
- Unprecedented Planetary Probes
  - NEO > 300m, KBO, Comets, debris

Requires: reach 24 V mag in <15 sec
over ~5-10 sq deg field

Massively Parallel Astrophysics

- Dark matter/dark energy via weak lensing
- Dark matter/dark energy via supernovae
- Galactic Structure encompassing local group
- Dense astrometry over 30000 sq.deg: rare moving objects
- Gamma Ray Bursts and transients to high redshift
- Gravitational micro-lensing
- Strong galaxy & cluster lensing: physics of dark matter
- Multi-image lensed SN time delays: separate test of cosmology
- Variable stars/galaxies: black hole accretion
- QSO time delays vs z: independent test of dark energy
- Optical bursters to 25 mag: the unknown
- 5-band 27 mag photometric survey: unprecedented volume
- Solar System Probes: Earth-crossing asteroids, Comets, TNOs

Figure of Merit

Area surveyed (number of objects found) to some SNR at some magnitude limit, per unit time:

Science goals

Apparatus & Eff.

$$\frac{N}{t} = \frac{\varphi_{obj}^{2}\, A\, \Omega\, QE\, \varepsilon}{(SNR)^{2} \varphi_{sky} (\delta\Omega)}$$

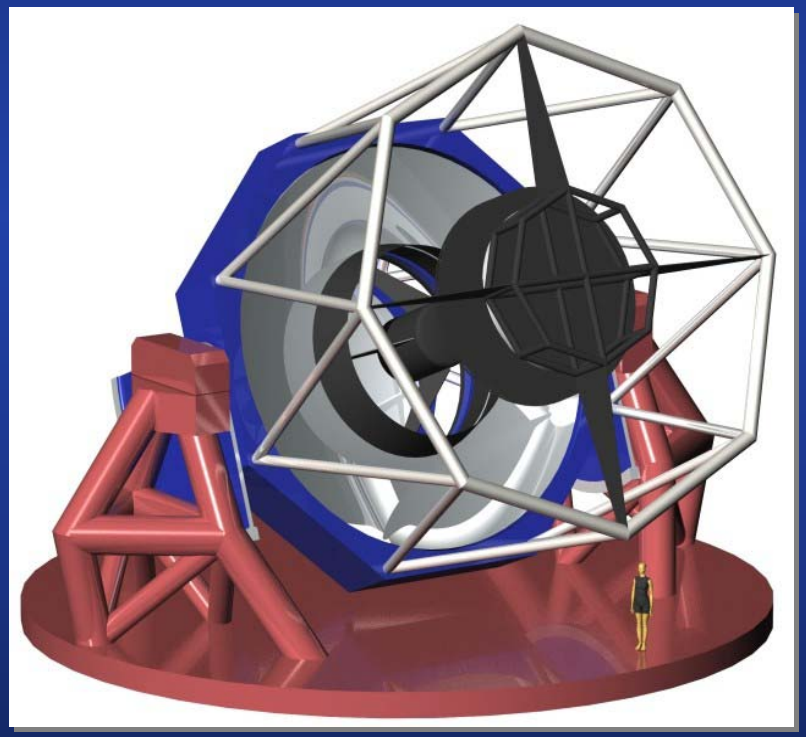
site & optics

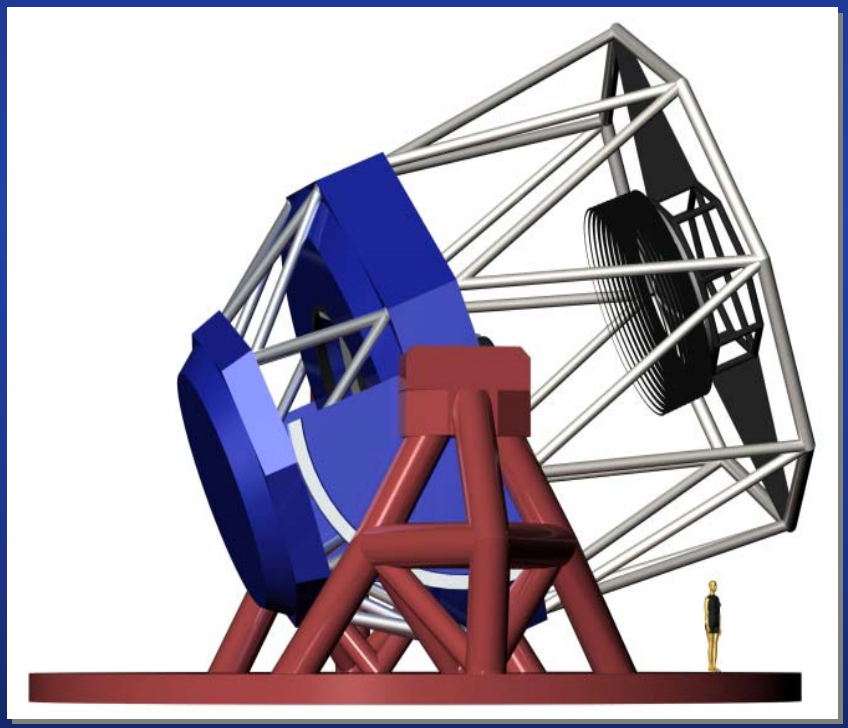
A – aperture **Ω – camera FOV** **QE – det. Eff.**

ε – observing eff. **Φsky – sky flux** **dΩ – seeing footprint**

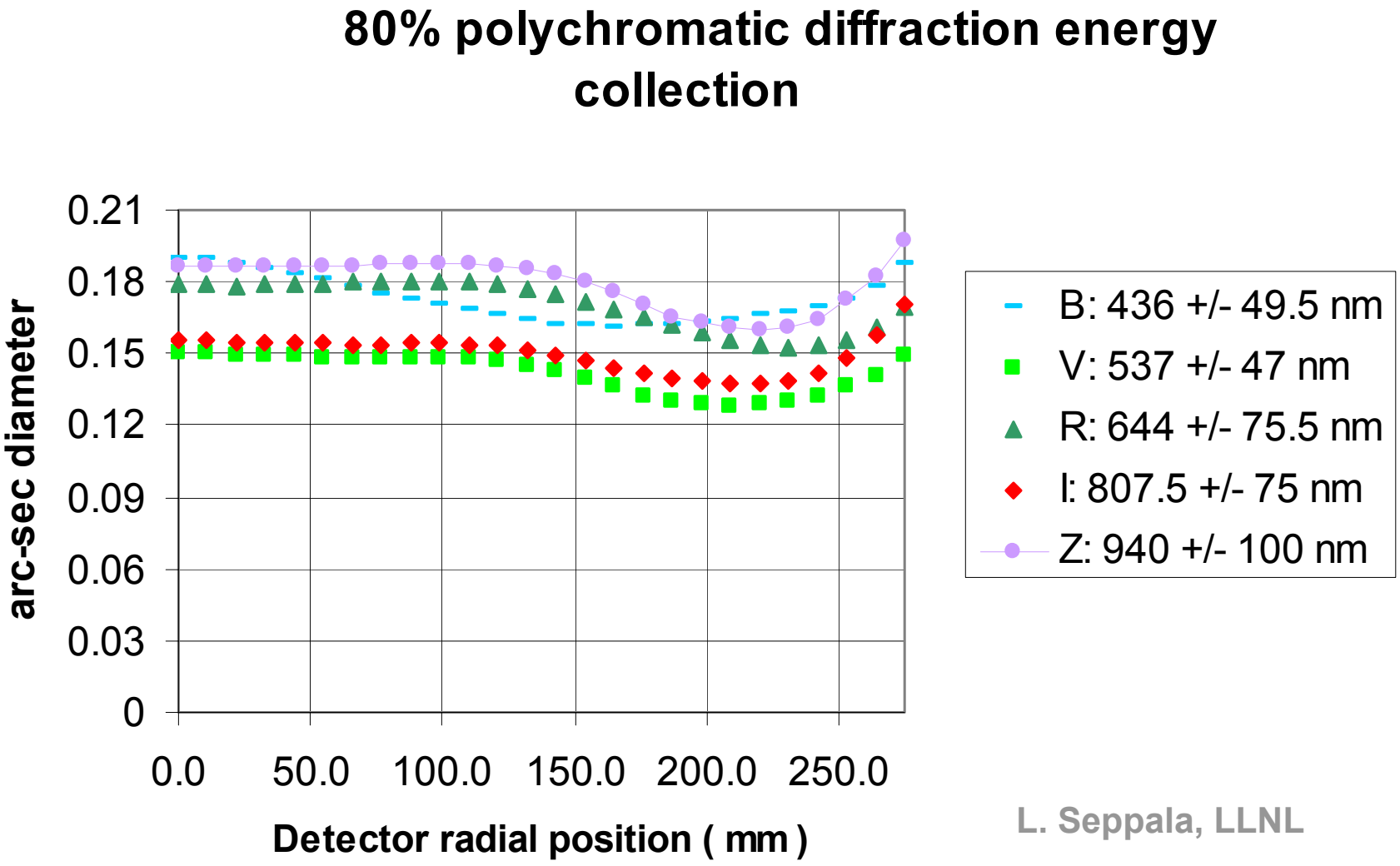
The LSST Telescope

$A\Omega = 270\text{-}330\ m^2\ deg^2$



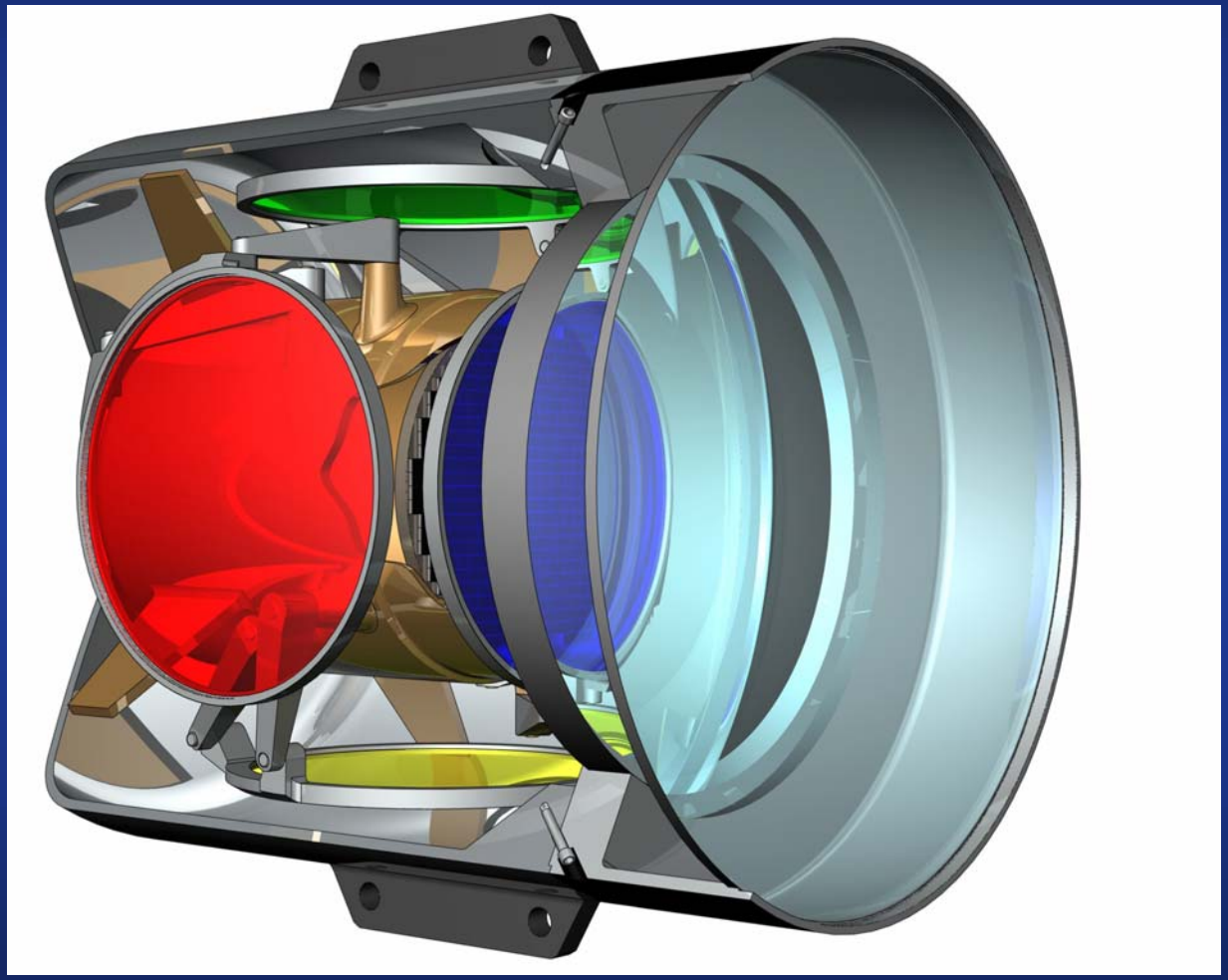


Crisp Images Over Entire Field



L. Seppala, LLNL

2.8 billion pixels



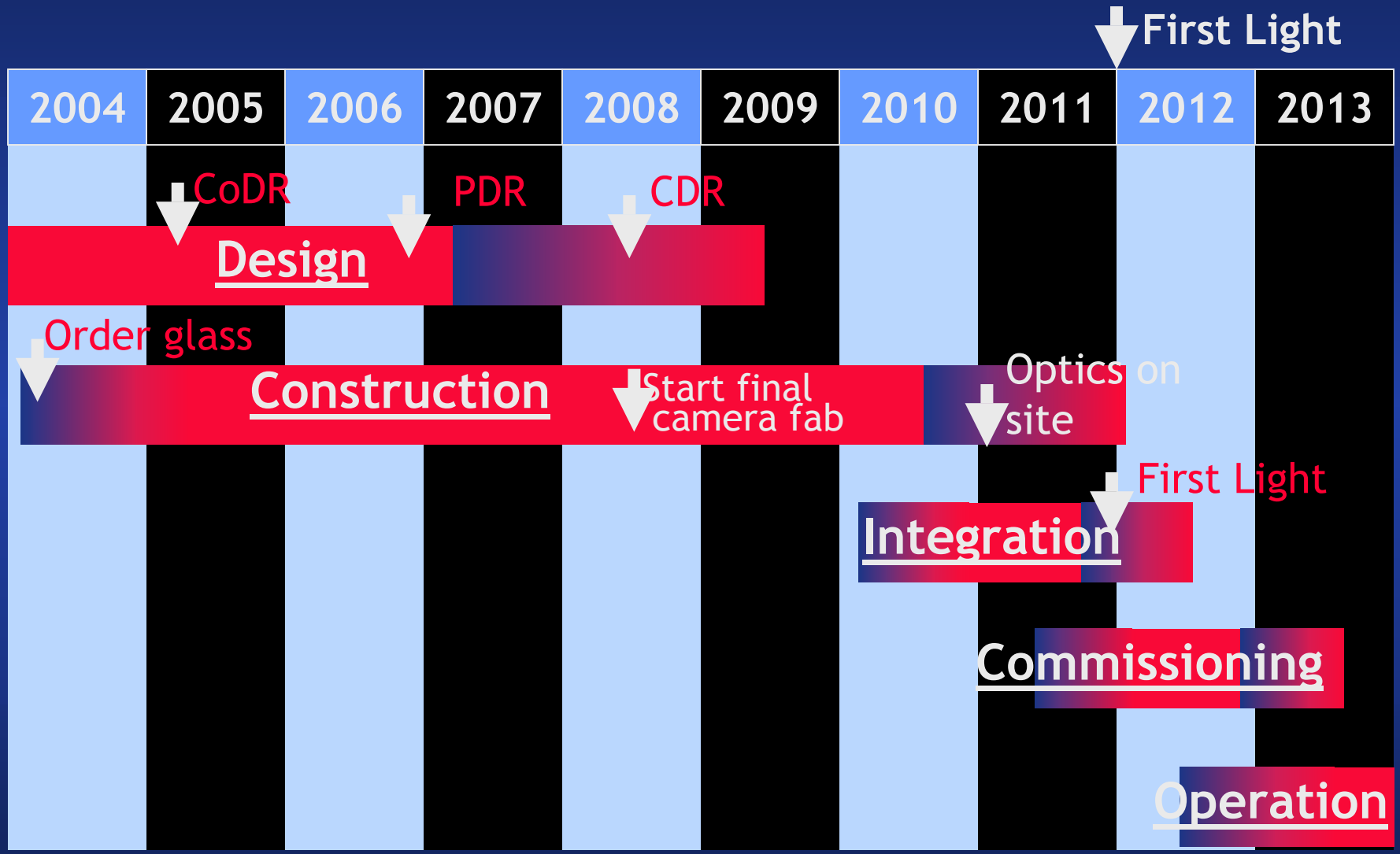
LSST Data Rates

- 2.8 billion pixels read out in less than 2 sec, every 12 sec
- 1 pixel = 2 Bytes (raw)
- Over 3 GBytes/sec peak raw data from camera
- Real-time processing and transient detection: < 10 sec
- Dynamic range: 4 Bytes / pixel
- > 0.6 GB/sec average in pipeline
- Real-time reduction requires ~ 50 Tflops peak
- Data rate is comparable to ATLAS on LHC.

LSST Data Products

- Real time alerts (~ 10 sec latency)
- Catalogs in database(s)
  - Photometric: < 1%
  - Astrometric: ~ 10 mas
- Images:
  - Time series (all saved)
  - Deep co-additions
  - Difference images
- Public access to all

LSST schedule has first-light at the end of 2011



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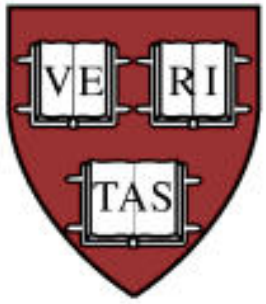

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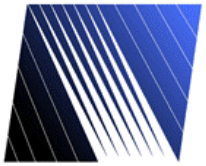

NCSA