Panoramic Survey Telescope
and
Rapid Response System

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Science Applications International Corporation
An Employee-Owned Company

MAUI HIGH PERFORMANCE COMPUTING CENTER

Pan-STARRS

Pan-STARRS March 2004 EOC Review
Presented to Pan-STARRS External Oversight Committee

Dr. Nicholas Kaiser	Principal Investigator
Dr. Thomas Dombeck	Project Manager

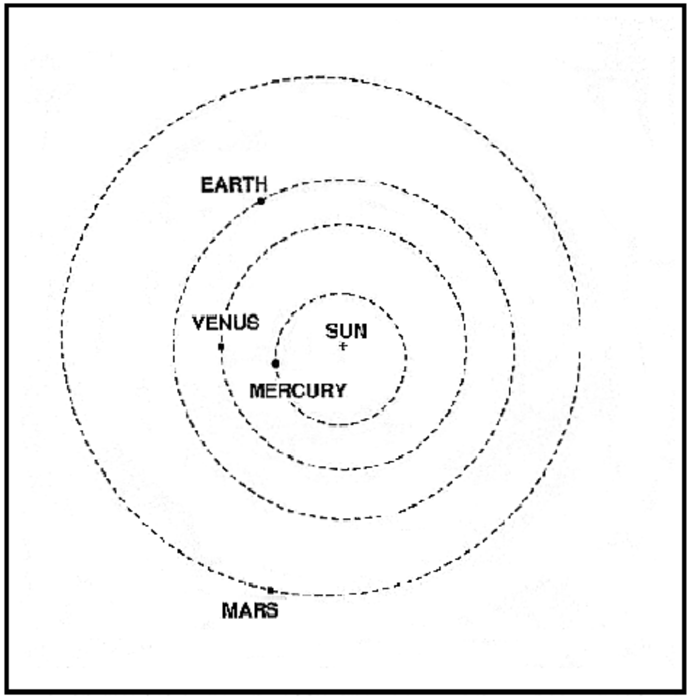
Background (cont.)

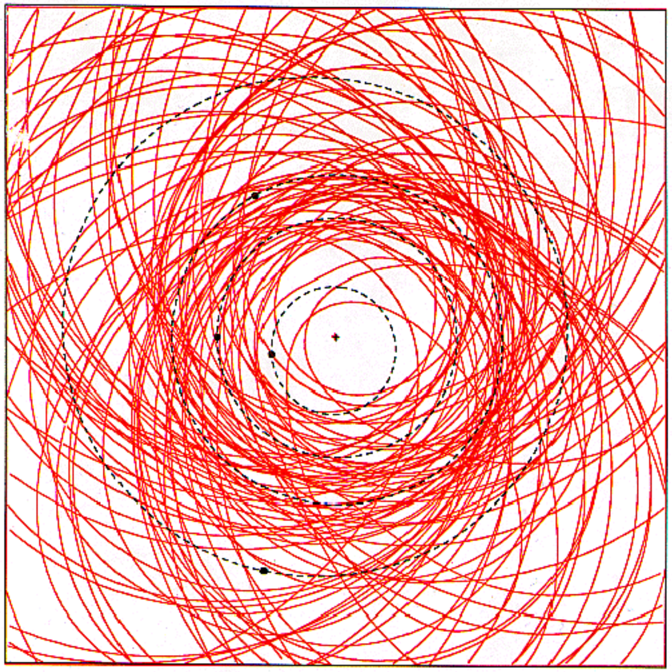
Science Opportunities

- Time domain astronomy :
  - Transients - SN, GRBs ...
  - Variability - QSOs, stars, extra-solar planets
  - Moving objects

    NEOs, TNOs, KBOs, comets...

    Parallax + proper motions in local solar neighborhood
- Static sky science - accumulated multicolor digital atlas :
  - Dark matter and dark energy from weak lensing
  - Evolution of structure
  - Birth of galaxies


EARTH
VENUS
SUN
MERCURY
MARS

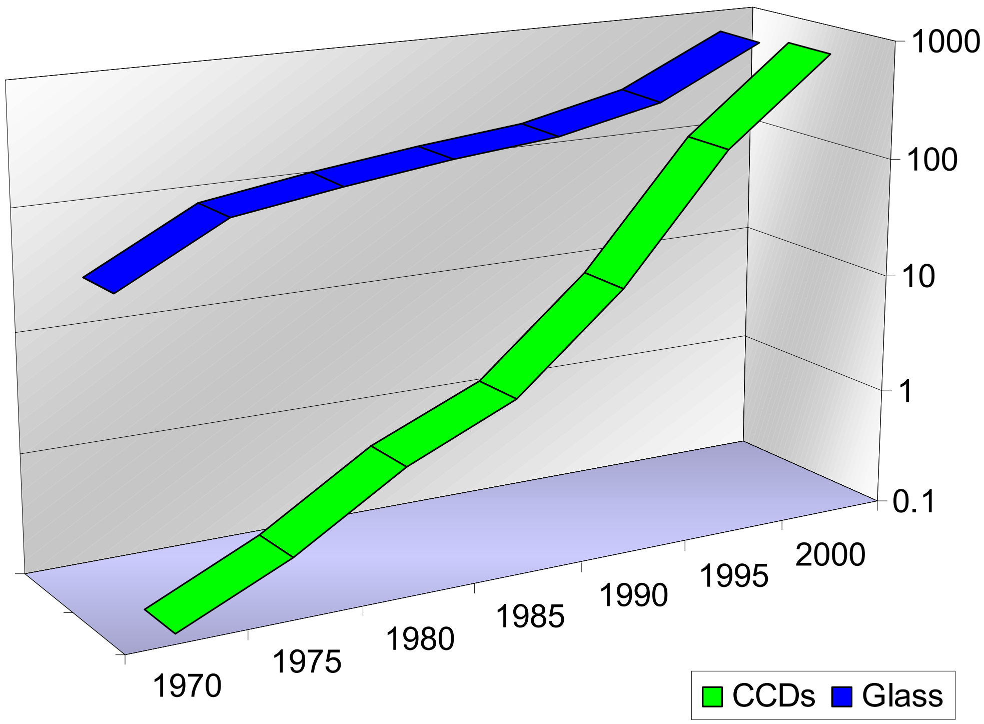


Background (cont.)

- Fundamental requirements
  - Collecting area × Field of View × Image quality
  - $A \Omega / \Delta\Omega$
- Possible designs
  - Monolithic - e.g. 8.4m DMT (a.k.a. LSST)
    - Challenge for telescope designers
  - Distributed apertures (Pan-STARRS)
    - Challenge for detector manufacturers

Trends

- Future dominated by detector improvements



- Moore's Law growth in CCD capabilities
- Gigapixel arrays on the horizon
- Improvements in computing and storage will track growth in data volume
- Investment in software is critical, and growing

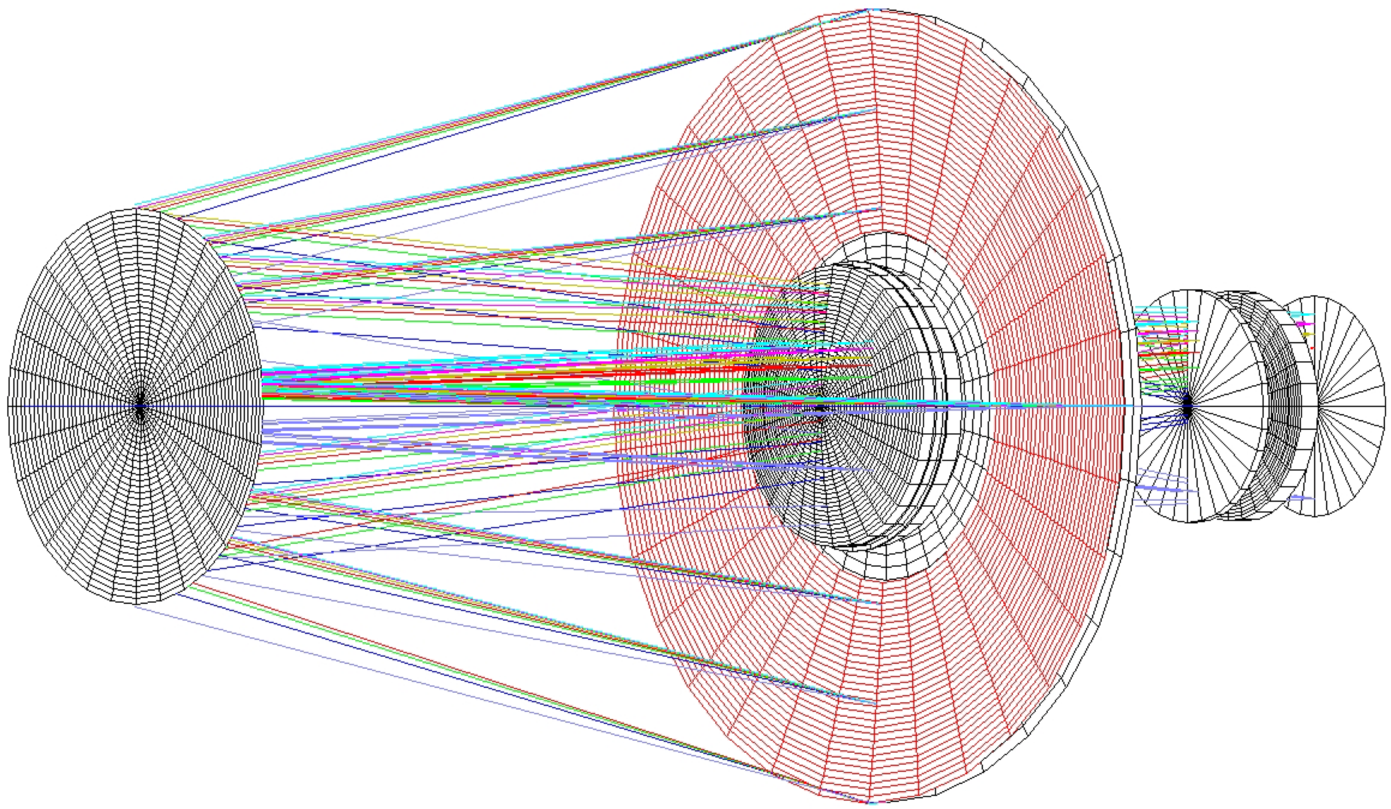
Total area of 3m+ telescopes in the world in m^2, total number of CCD pixels in Megapix, as a function of time. Growth over 25 years is a factor of 30 in glass, 3000 in pixels.

System Characteristics

Telescopes

- 4 × 1.8m f/4 with 7 square degree FOV
- Cassegrain with Wynne 3 element wide field corrector
- 6 filters (grizy + SS)
- Site options
  - Mauna Kea, replace 88" with common mount design
  - Haleakala, individual telescopes
  - Subject to site evaluation studies

Optical Design

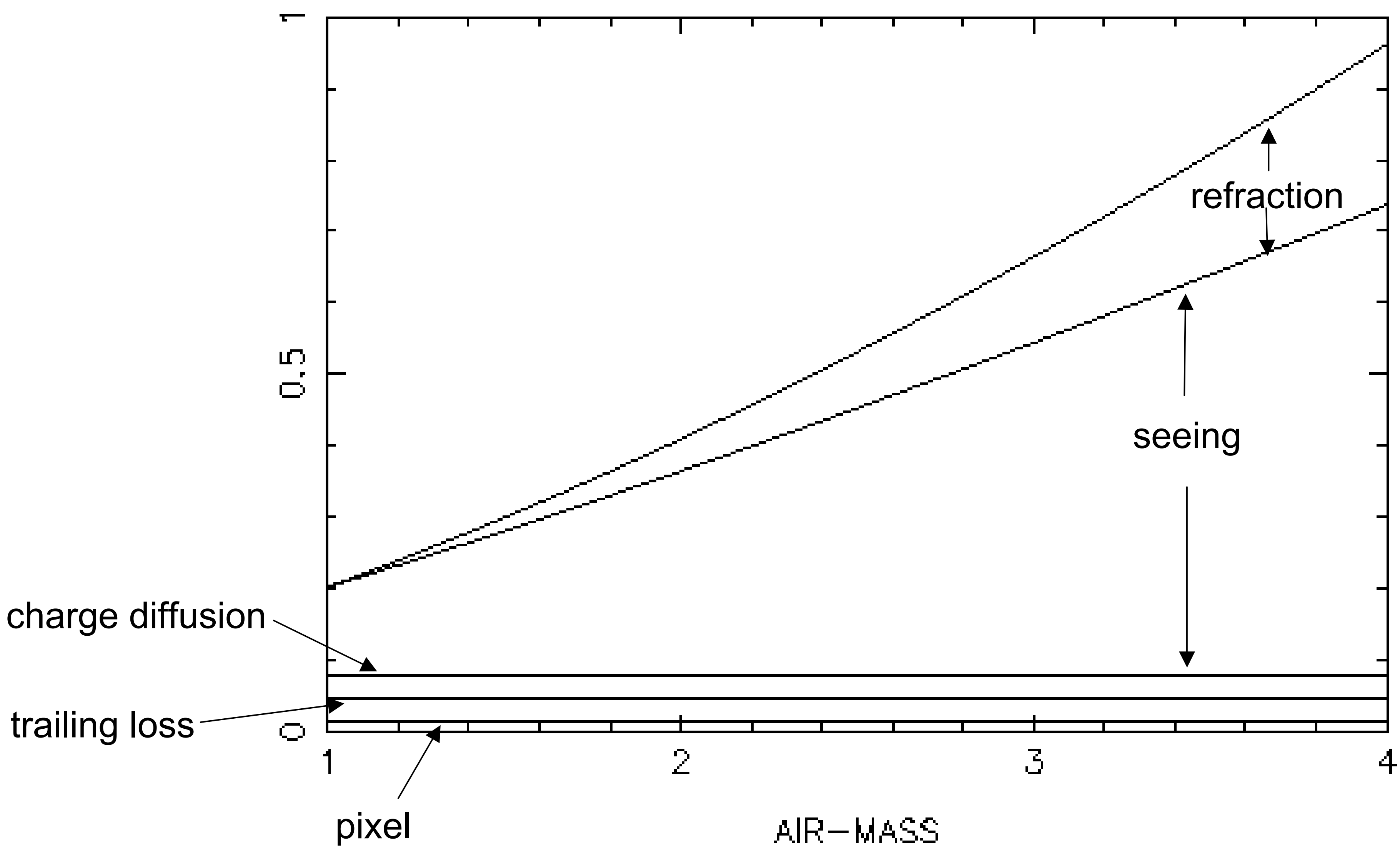


SOLID MODEL

PAN-STARRS FINAL 2
WED FEB 25 2004

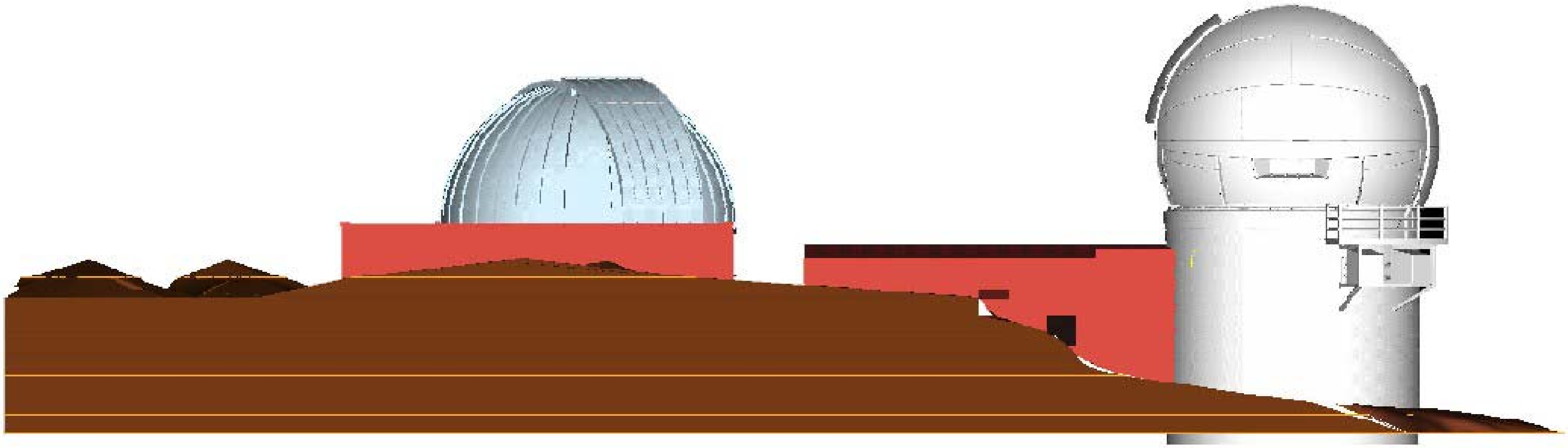
C:\ZEMAX\PAN-STARRS\PS-ADC-F-2A.ZMX
CONFIGURATION 1 OF 1

PSF Area vs. Air Mass



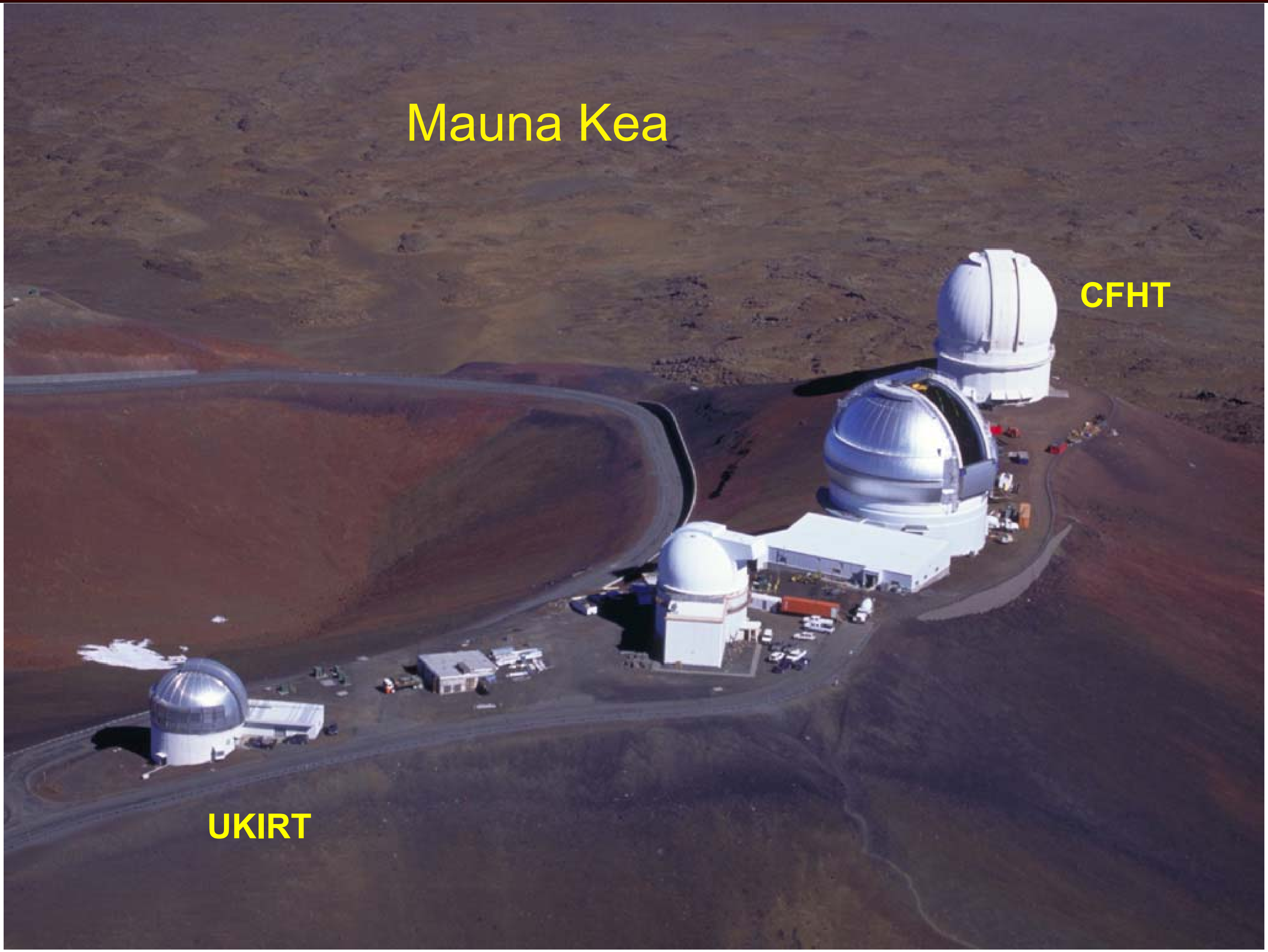
Haleakala High Altitude Observatory Site

Schematic of EOS Ice Dome as PS1 Dome

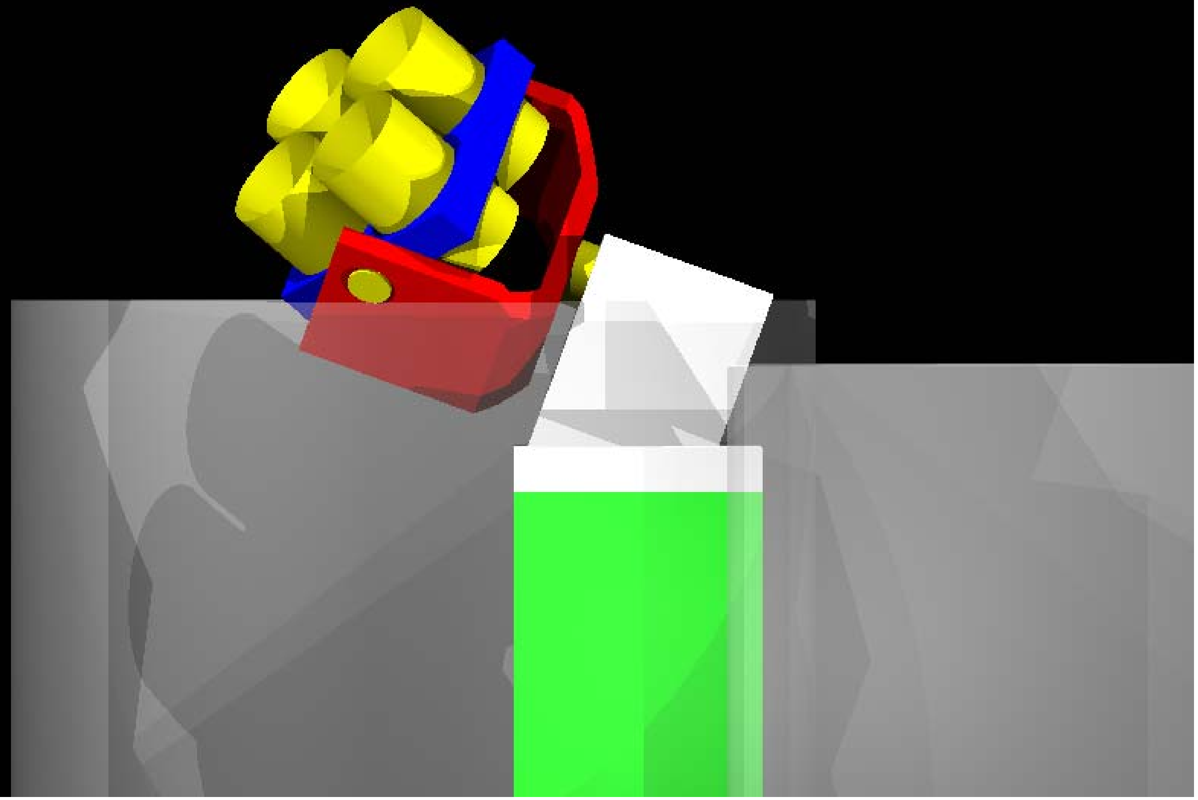


MAGNUM

PS1
EOS Ice Dome


Mauna Kea
CFHT
UKIRT

Common Mount



Design Goals

1. Reduce Detector Cost by Substantially Increasing Yield.
2. Fast Readout: Read Out Gigapixel Focalplane in 2 secs.
3. Provide On-Chip Guiding.
4. Minimize Effects of Bright Stars.
5. Remove Image Motion.

- *Above list is ranked in order of importance.*
- *Items 1-4 require the new "Array" technology.*
- *Item 5 requires OT pixels.*

System Characteristics

Detectors

- 10 and 12 micron pixel devices under test
- Charge diffusion scale < 6 micron
- Array of arrays

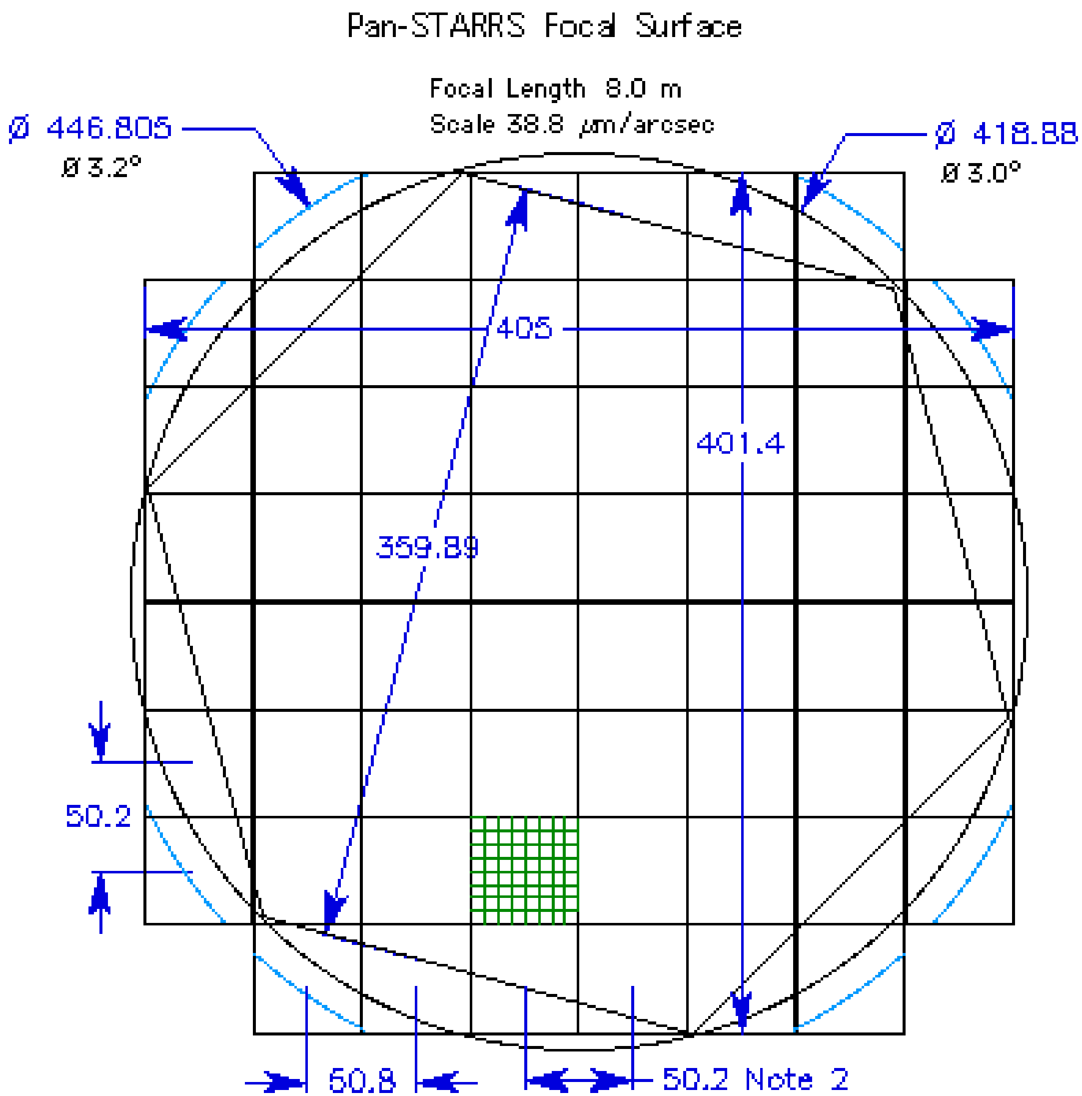
  1 FPA = 60 OTAs

  1 OTA = 64 cells

  Enhanced yield
- Few electron read noise at few seconds read time
- Near IR QE support (Y-band)

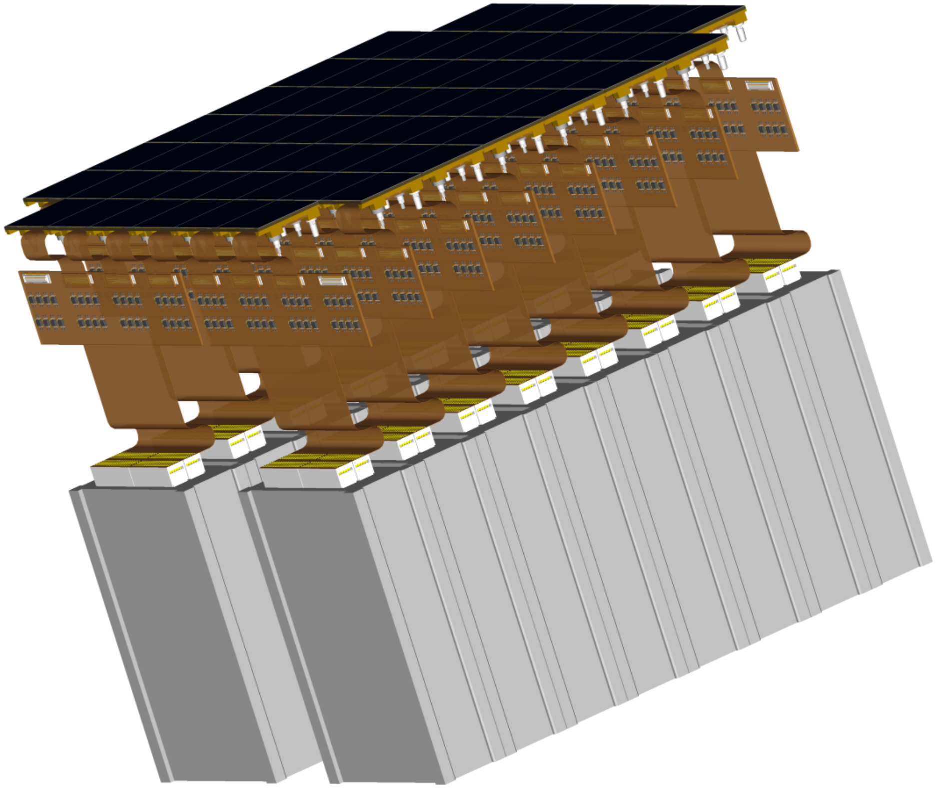
Camera Layout in Focal Plane

- Image size budget satisfied within ϕ3° circle.
- View of secondary unobstructed with ϕ3.2° circle.
- Inscribed hexagon has an area of 5.84 sq. deg.
- For the photometry, each of two 30 sec exposures will be offset such that the center of the second hexagon tiling map is at the vertices of the first, therefore having a half footprint overlap.
- For the astrometry, the six exposures will be distributed throughout 6 lunations to search for high proper motion stars.
- The pointing centers of each hexagonal tiling will be such as to maximize the field overlap.



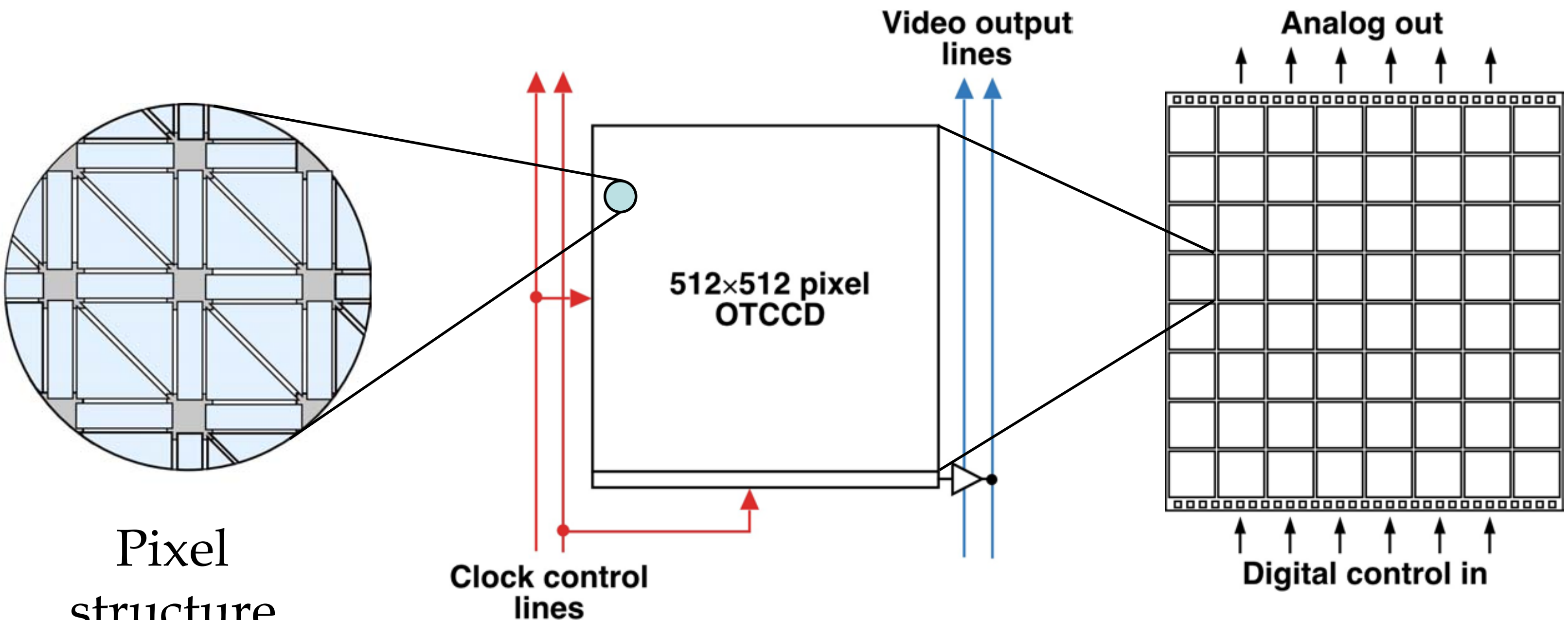
GPC Subsystems

- Detectors
- Cryostat, thermo-mechanics
- OTA mounting, electrical interface
- OTA controller
- Pixel server
- Software
- OTA testing



SOLUTION: The Orthogonal Transfer Array

- A new paradigm in large imagers.
- Partition a conventional large-area CCD imager into an array of independently addressable CCDs (cells).



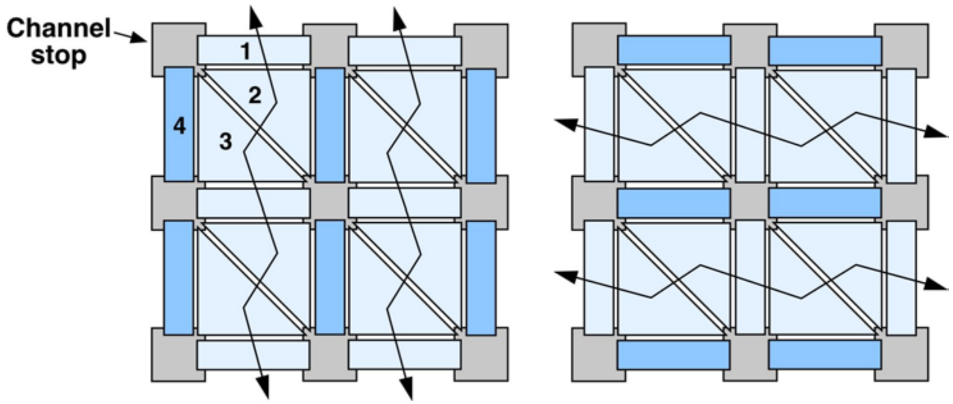
Pixel structure

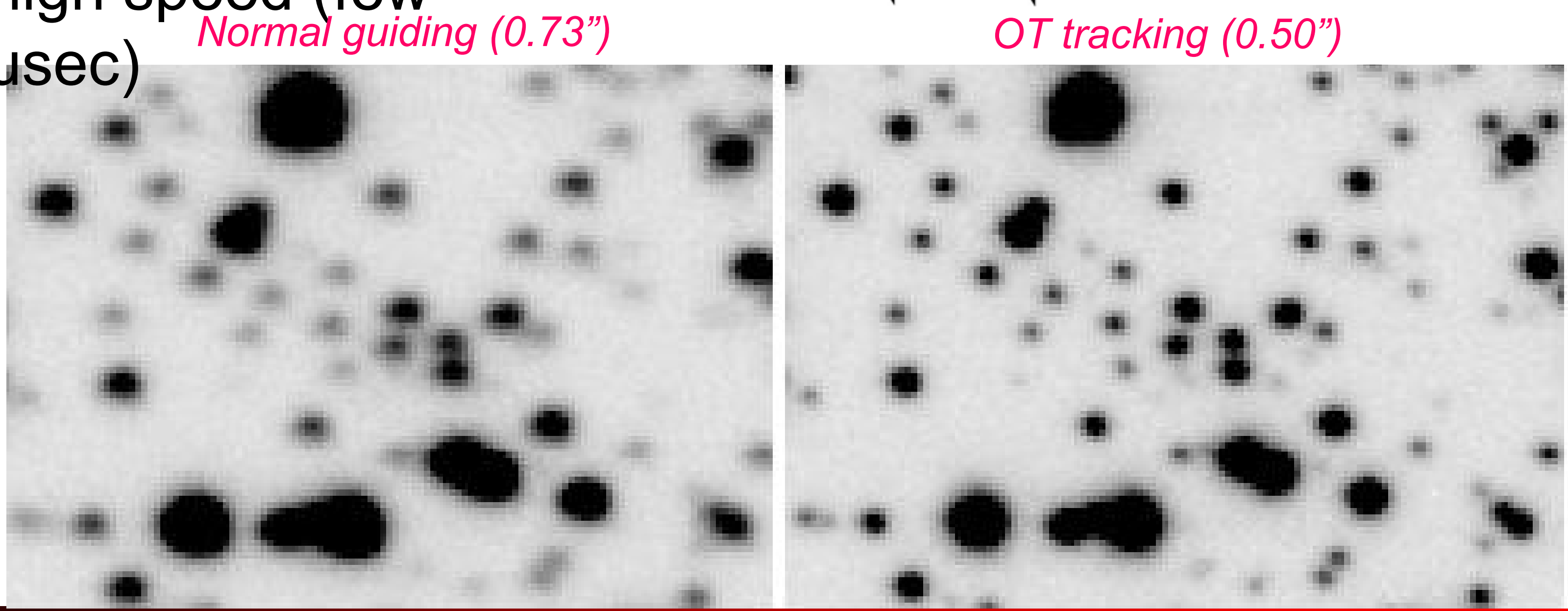
Independently Addressable Cell

OTA: 8x8 Array of Cells

Detector Details – Orthogonal Transfer

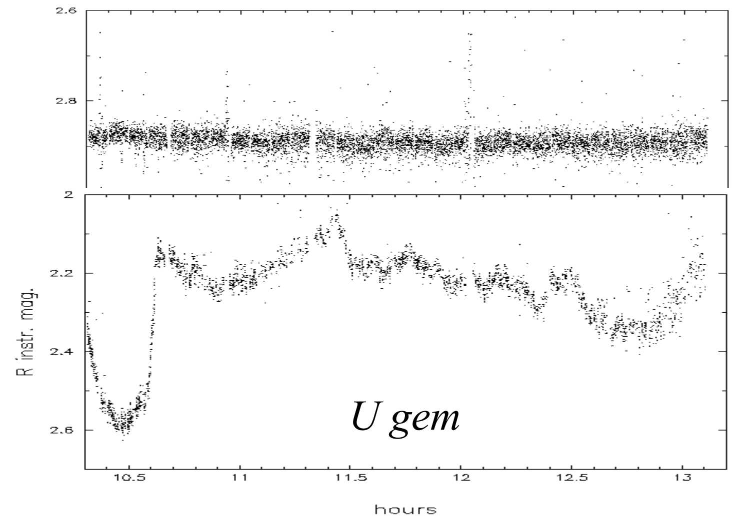
- Orthogonal Transfer
  - remove image motion
  - high speed (few usec)

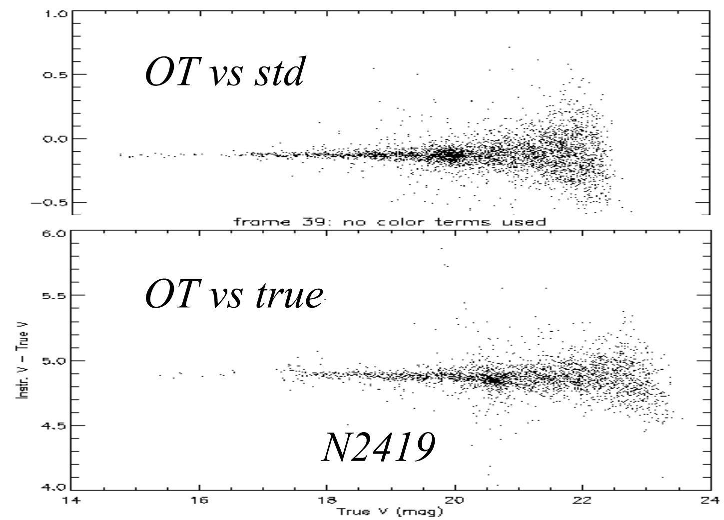




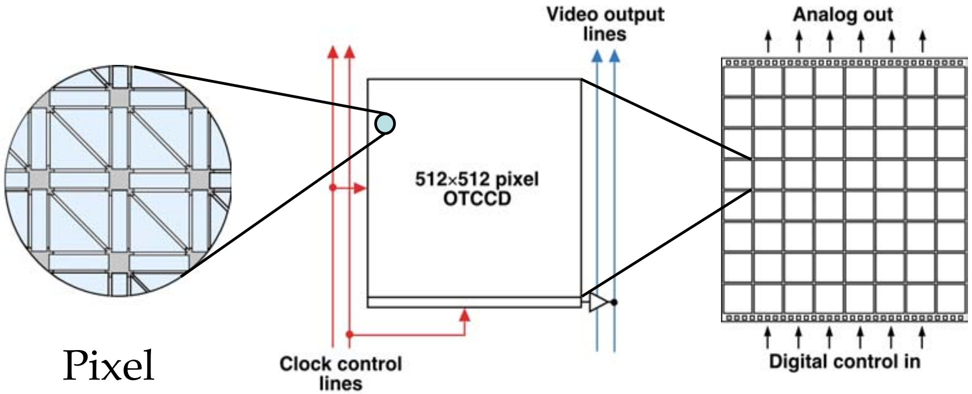
OTCCD Performance: On Sky

- Astrometry (Monet)
  - 1-D fit at 8 mas, 2-D fit at 5 mas: no problems with OT pixels
- Photometry (Howell)
  - "we expect that the OTCCDs used by Pan-STARRS will be able to provide relative photometric precisions of better than 2 mmag rms…"
- Photometry (Saha)
  - OT pixels perform as well as 3-ϕ, variations in psf from OT tracking do not hinder photometry.
- Science (Chambers)
  - "Image quality is *always* superior, and we have obtained the best optical images ever achieved with the 88-inch (0.45 arcsec FWHM in R band) ."
  - "Flat fielding is at least as good as 1 part in a 1000."





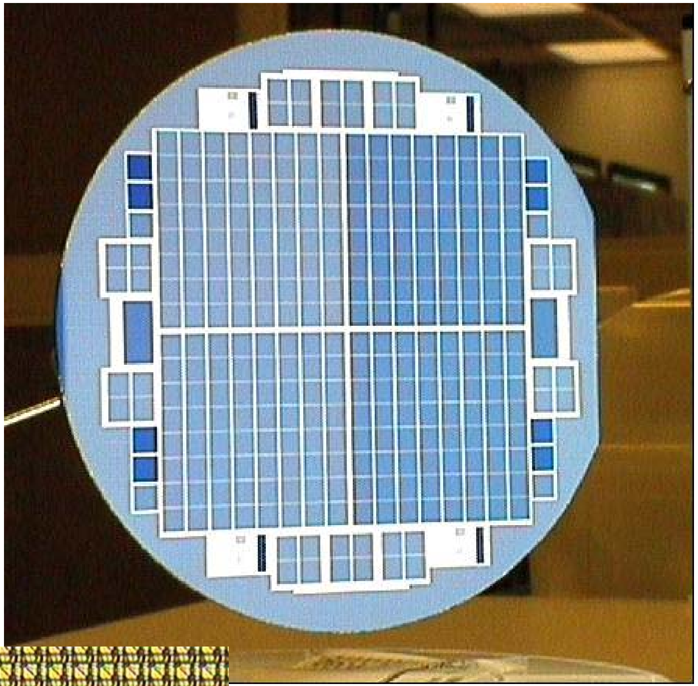
OTA: Lot 1 at Lincoln Lab

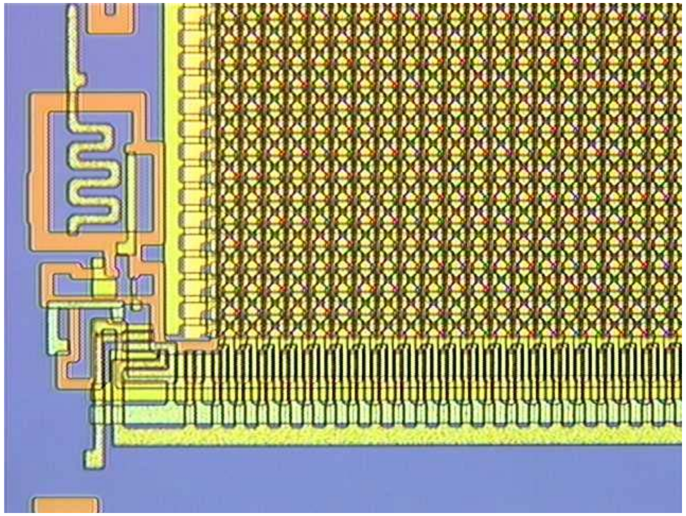


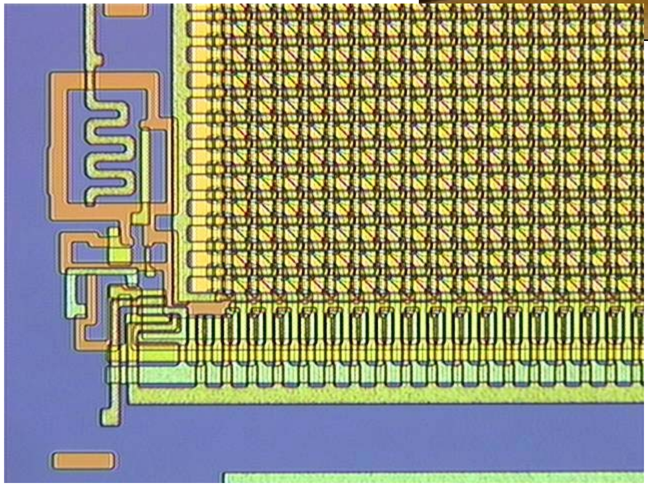
Pixel structure

Independently Addressable Cell

OTA:
8x8 Array of Cells







Maui High Performance Computing Center (MHPCC)

- Maintain image database (5 Peta-bytes)
- Database of all moving objects in the Solar System
- Process incoming new data
- Identify all previously unknown objects