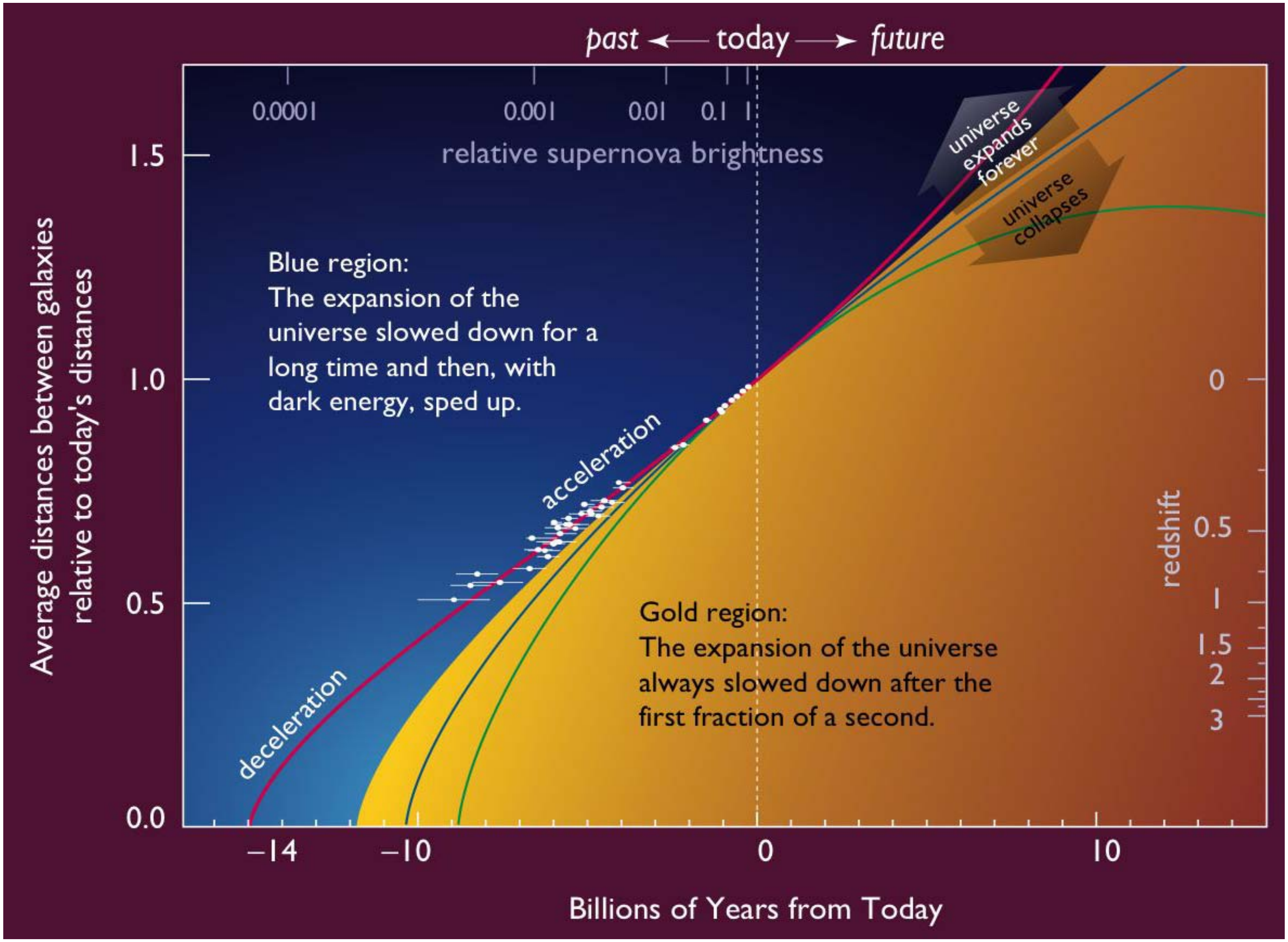
Realtime Computing and Dark Energy Experiments

Klaus Honscheid
The Ohio State University
Real Time 07, Fermilab

A few words on Dark Energy



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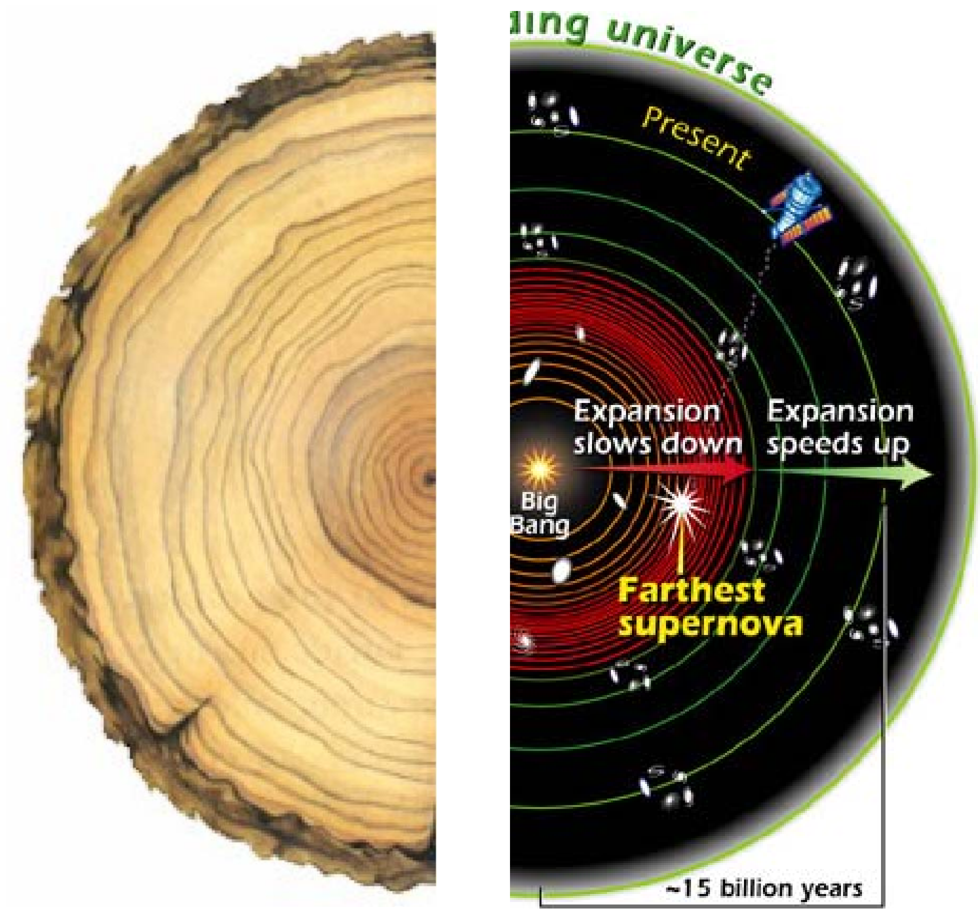
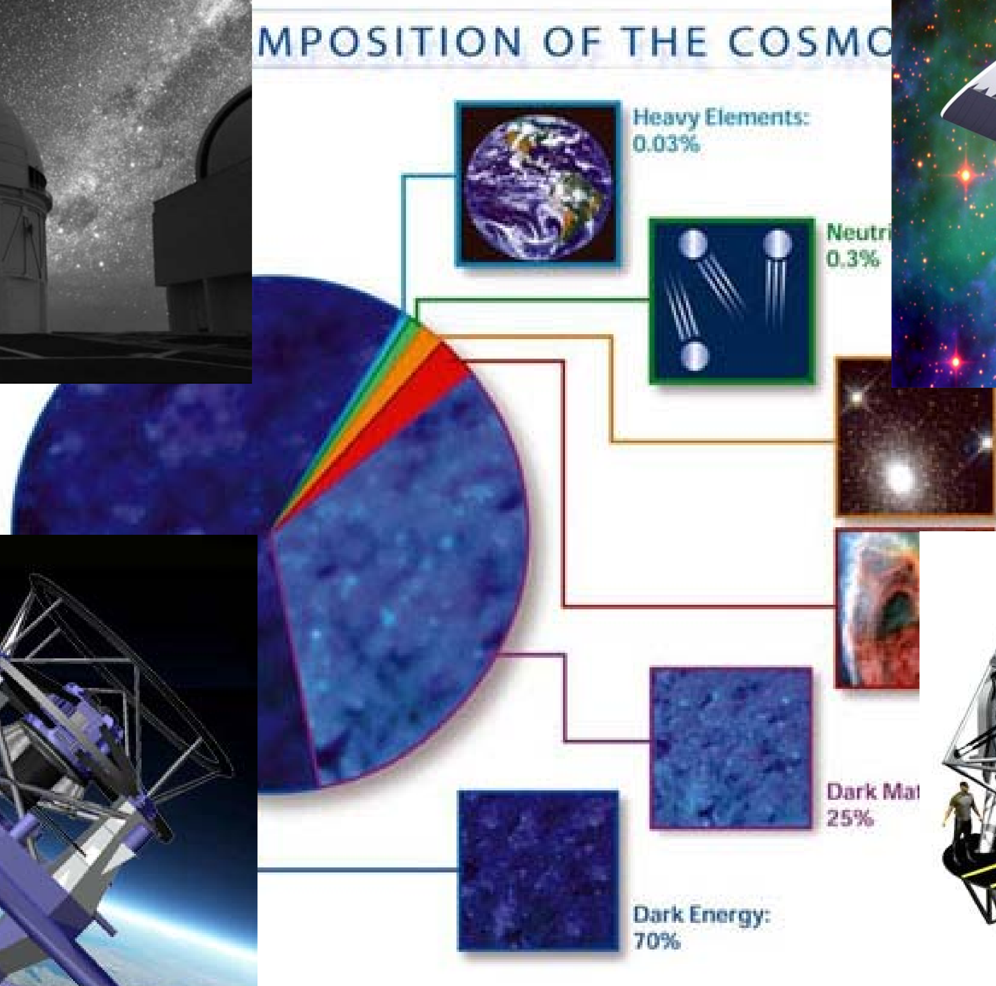
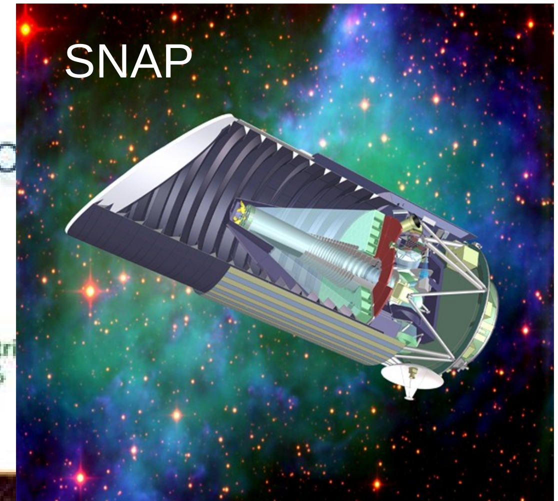
A few words on Dark Energy



The subtle slowing down and speeding up of the expansion, of distances with time: a(t), maps out cosmic history like tree rings map out the Earth's climate history. **(Courtesy of E. Linder)**

95% of the Universe is Unknown





Pan Starrs

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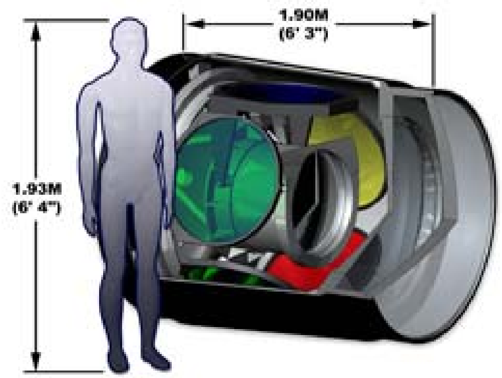
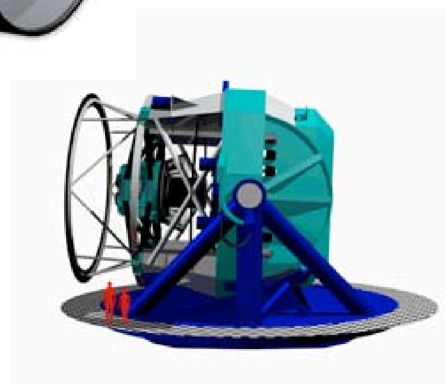
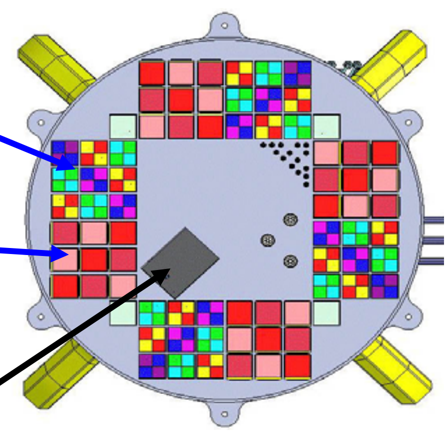
LSST and SNAP





201 CCDs (4kx4k) for a total of 3.2 Giga-Pixels



36 CCDs
(~443 Megapixels)

NIR
(~151 Megapixels)

Spectrograph port

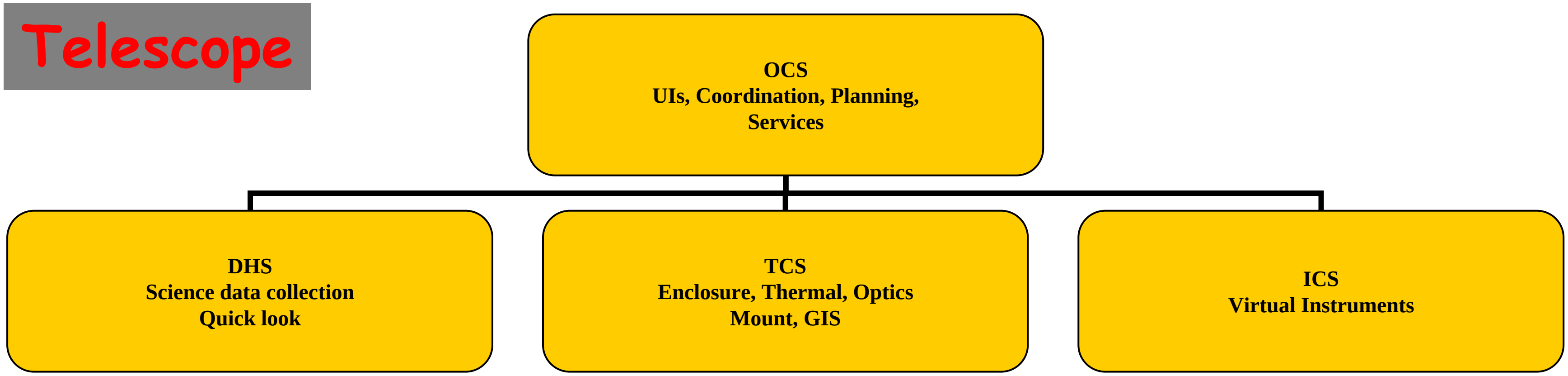
Outline

- DE DAQ vs. HE DAQ
- Front End Electronics
- Dataflow
- Control and Communication
- Data Management
- Summary

DE vs. HE Architecture

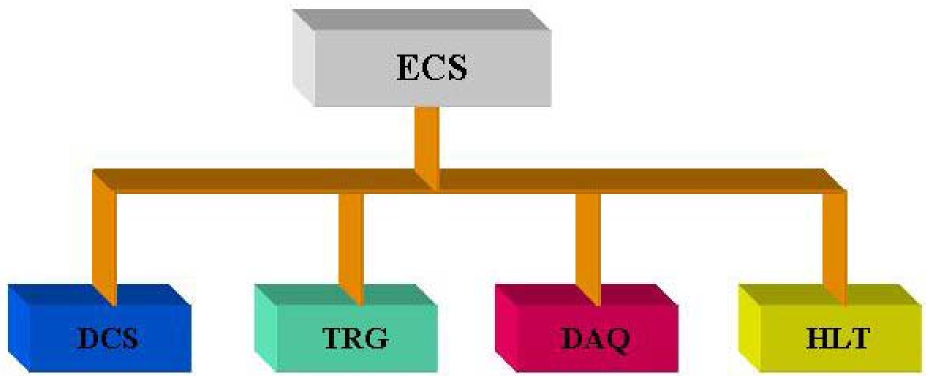
Telescope

Observatory Control System



Data Handling Telescope Control Camera Control

Detector (Alice)



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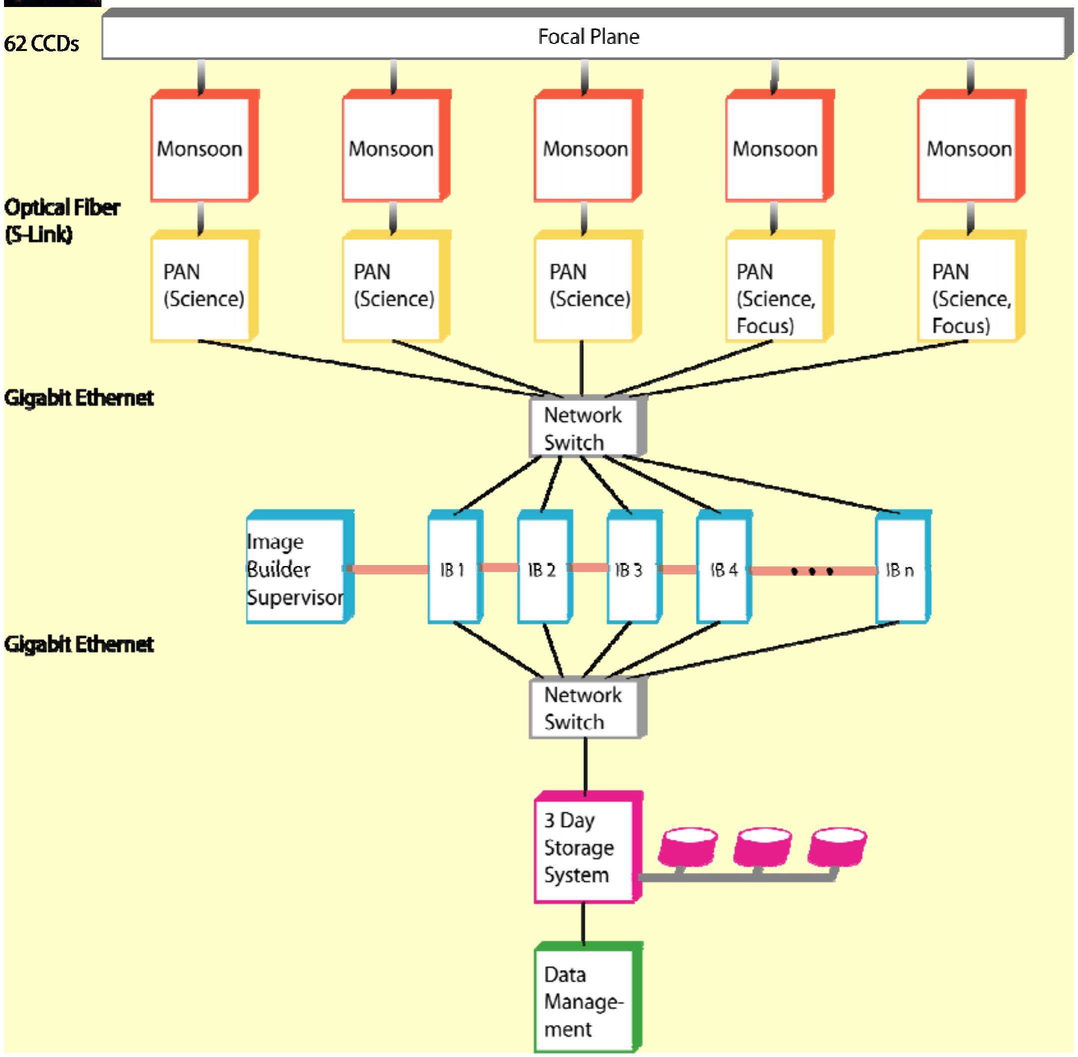
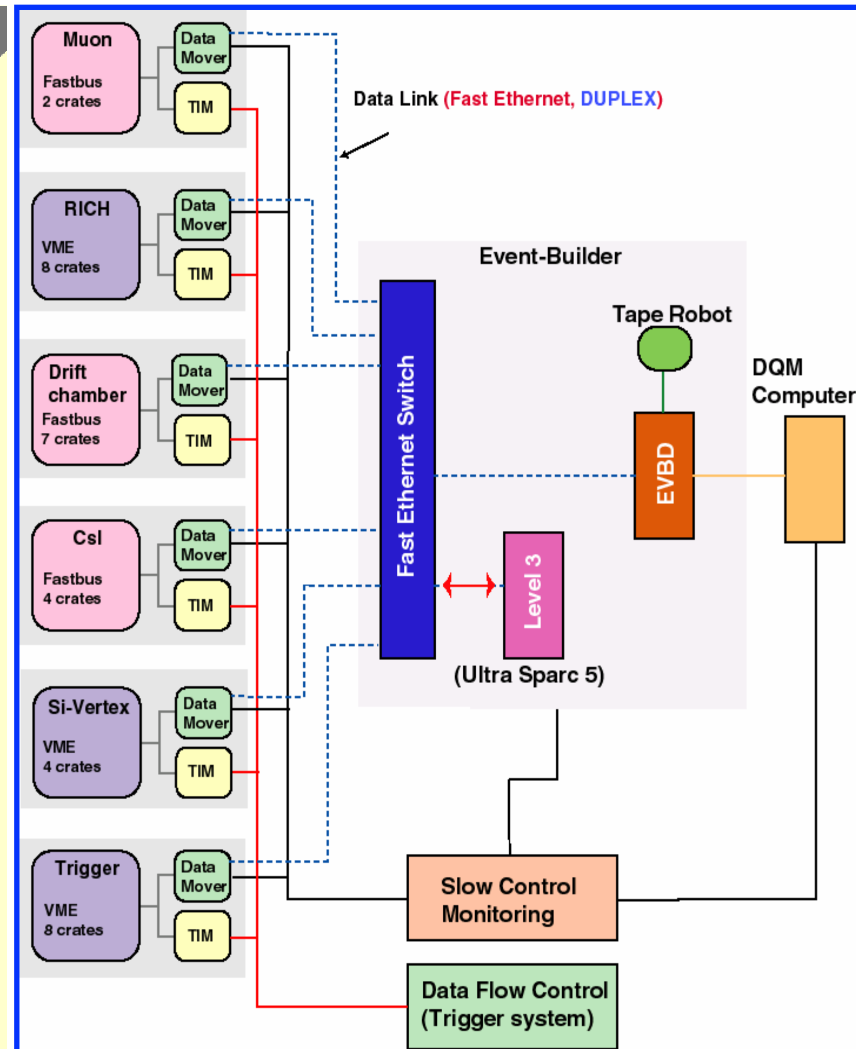
Dataflow Architecture

DES Camera



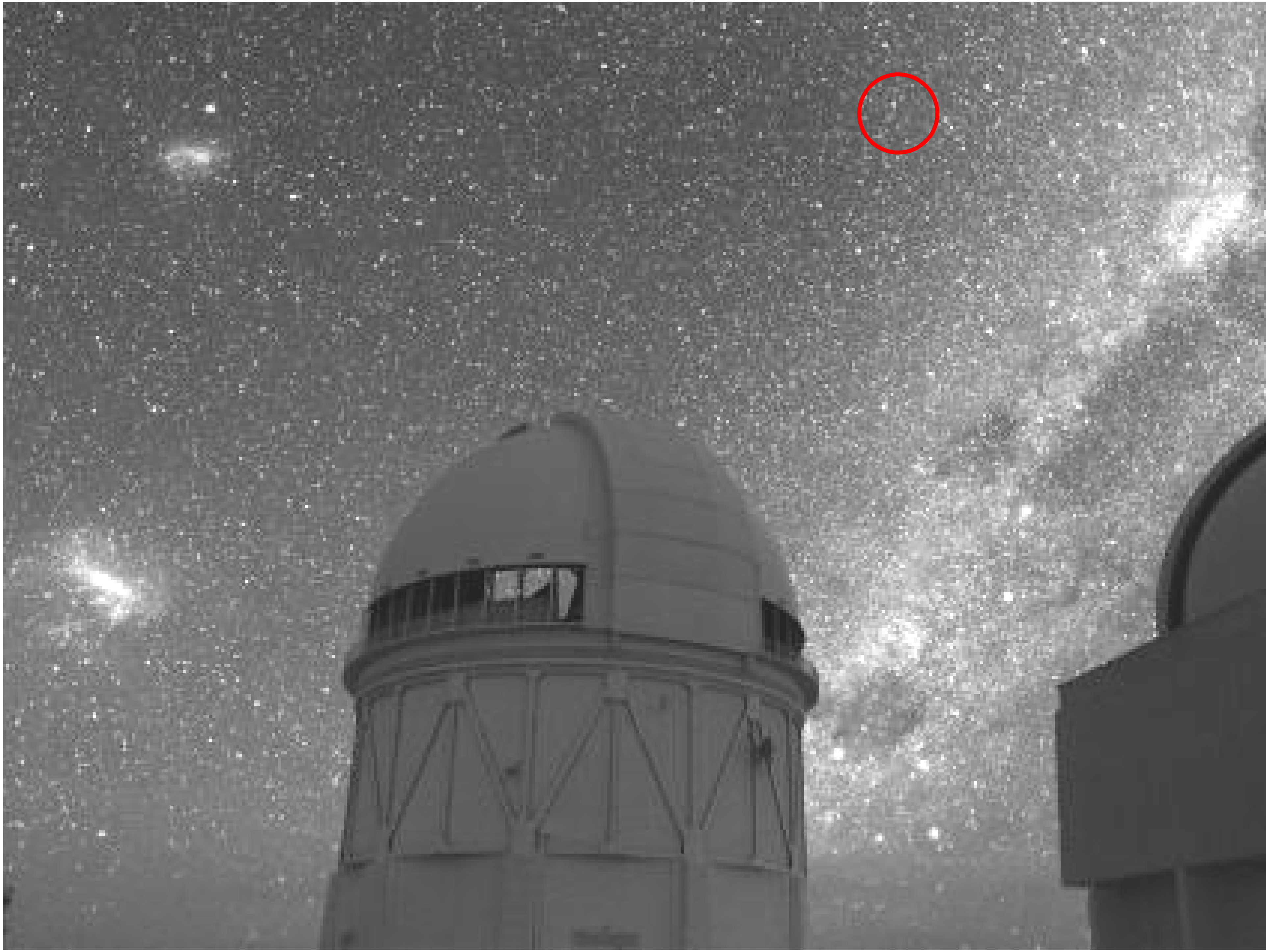
CLEO III Detector



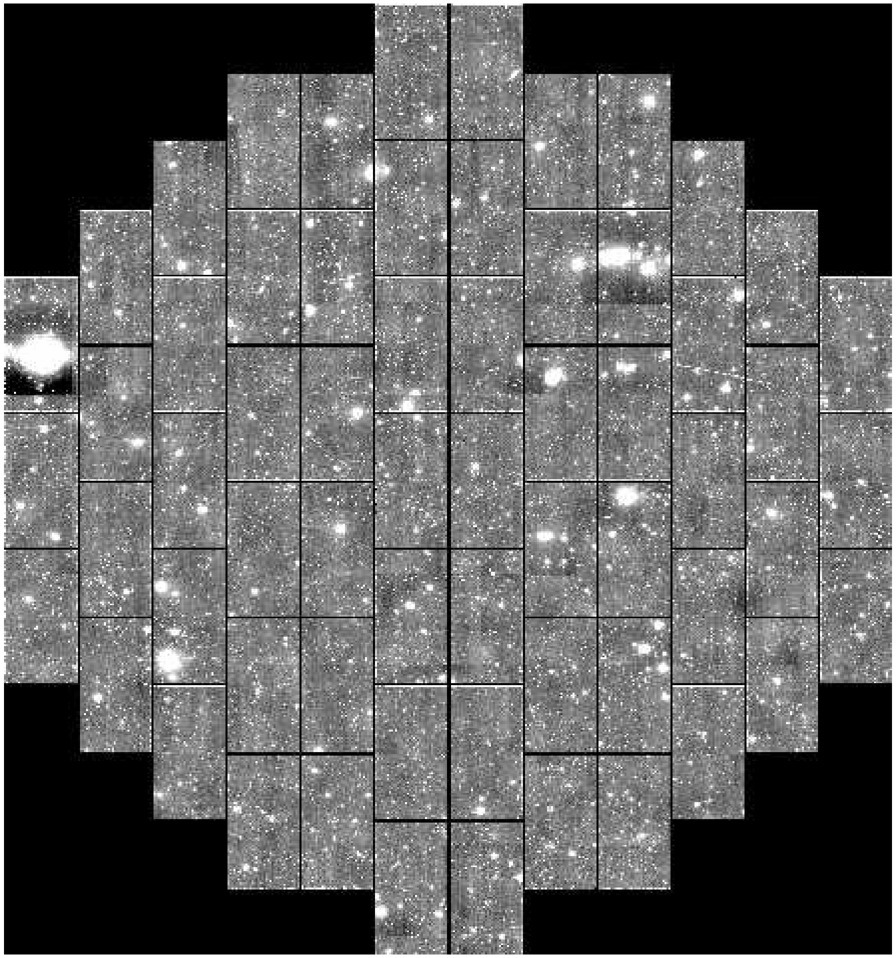
Typical Data Rates

Telescope	Data Rate	Data size (per night)	Detector	Data Rate (raw)	Data Size (per day)
DES	0.7 Gbs	0.3 TB	BaBar	5 Gbs	0.3 TB
SNAP	300 Mbs	0.3 TB	CDF/D0	100 Gbs	~0.8 TB
LSST	26 Gbs	~5 TB	LHC	800 Gbs	~8 TB

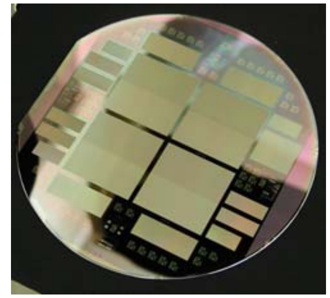
Zero Suppression Trigger



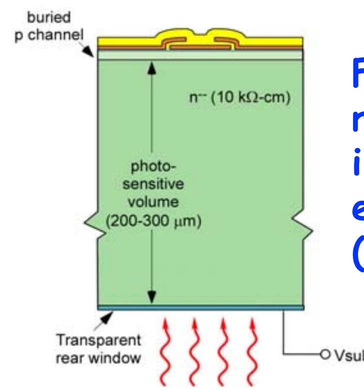
Front End Electronics



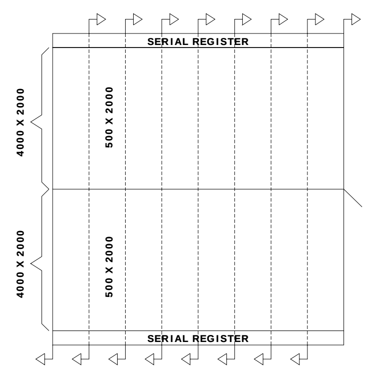
DES Focal Plane with simulated image (62 LBNL CCDs)



4 SNAP CCDs (LBNL)
3.5kx3.5k, 10.5 μm pixels



Fully depleted, high resistivity, back illuminated CCD with extended QE (1000 μm) (LBNL)



Multiple output ports for faster Read-out (LSST)

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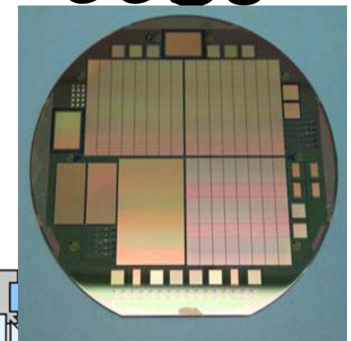
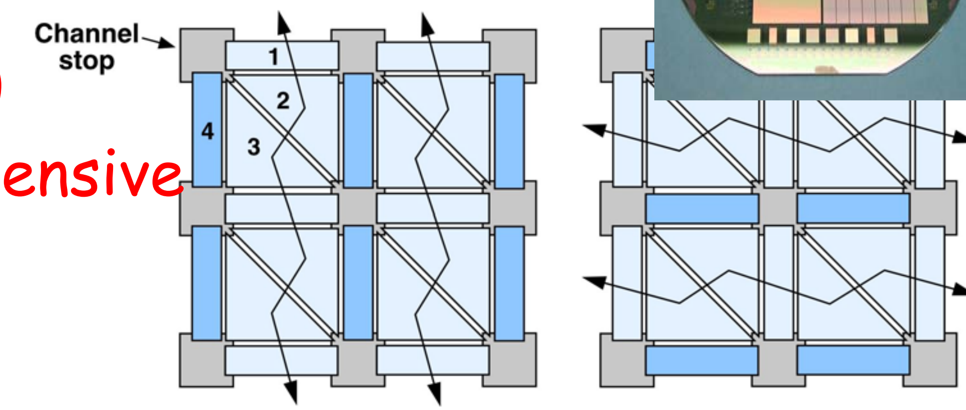
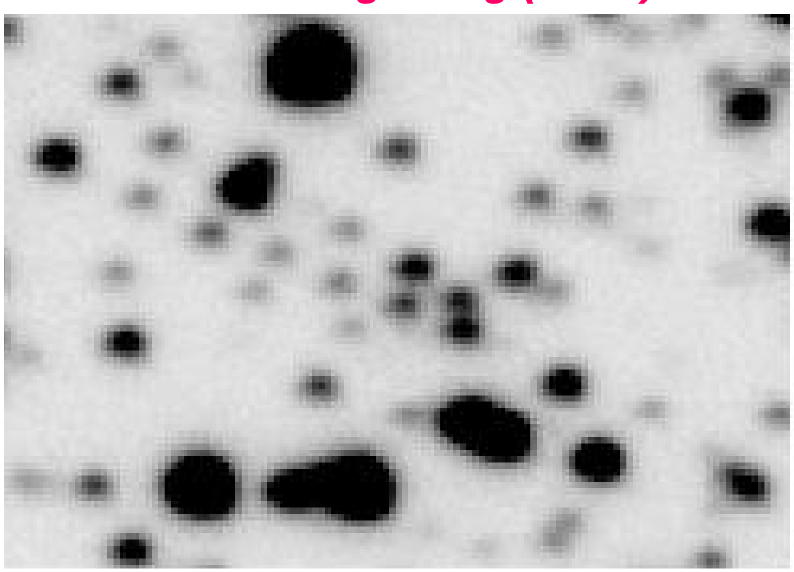
Orthogonal Transfer CCDs



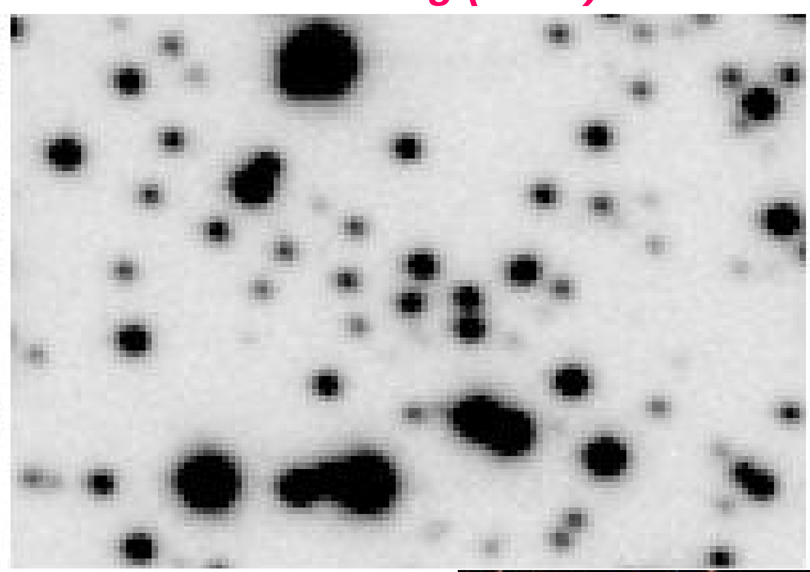
- Orthogonal Transfer CCD
  - remove image motion
  - high speed (~10 usec)
  - Better yield, less expensive
  - Pan Starrs, Wiyn



Normal guiding (0.73")



OT tracking (0.50")



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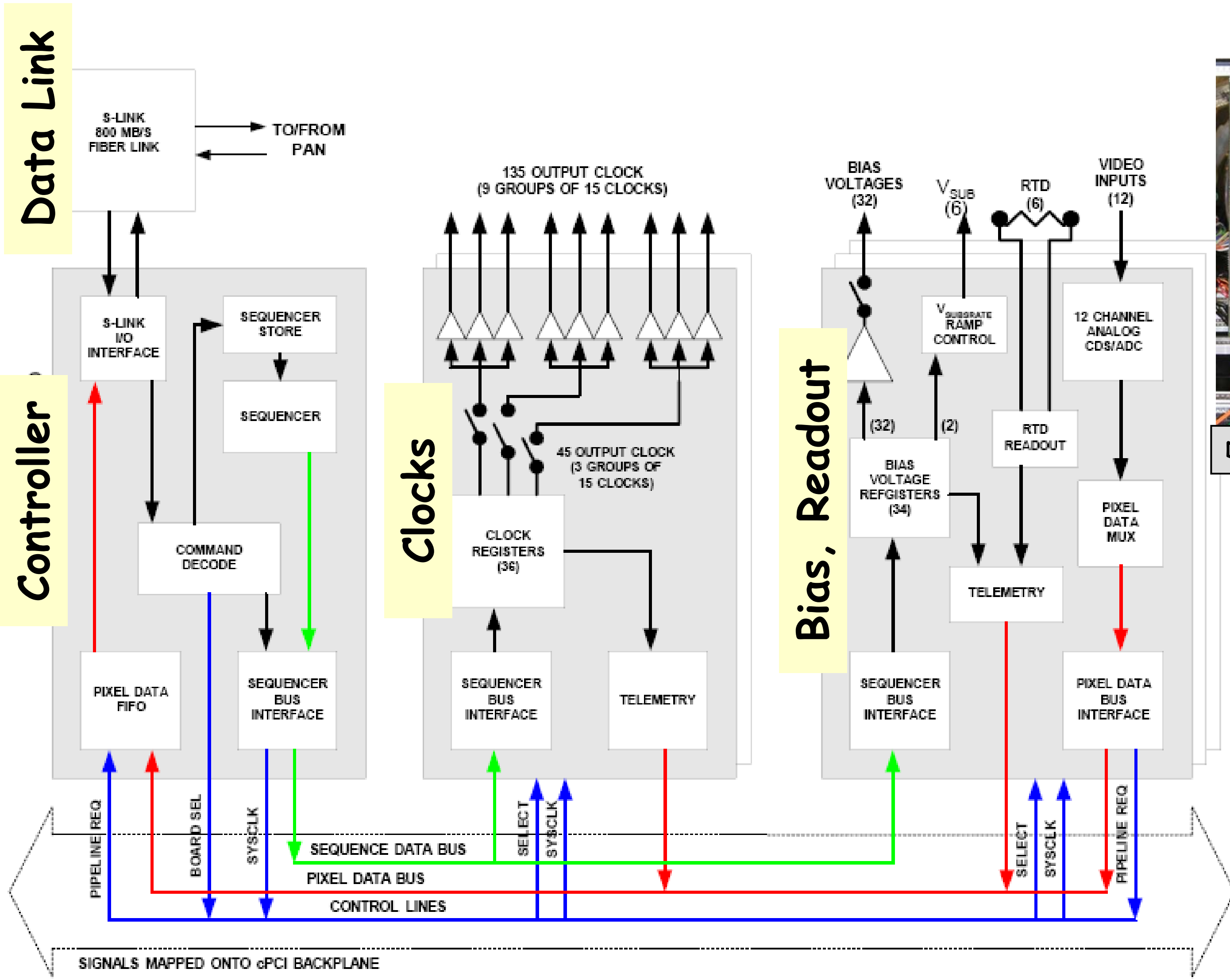
DECam Monsoon Block Diagram

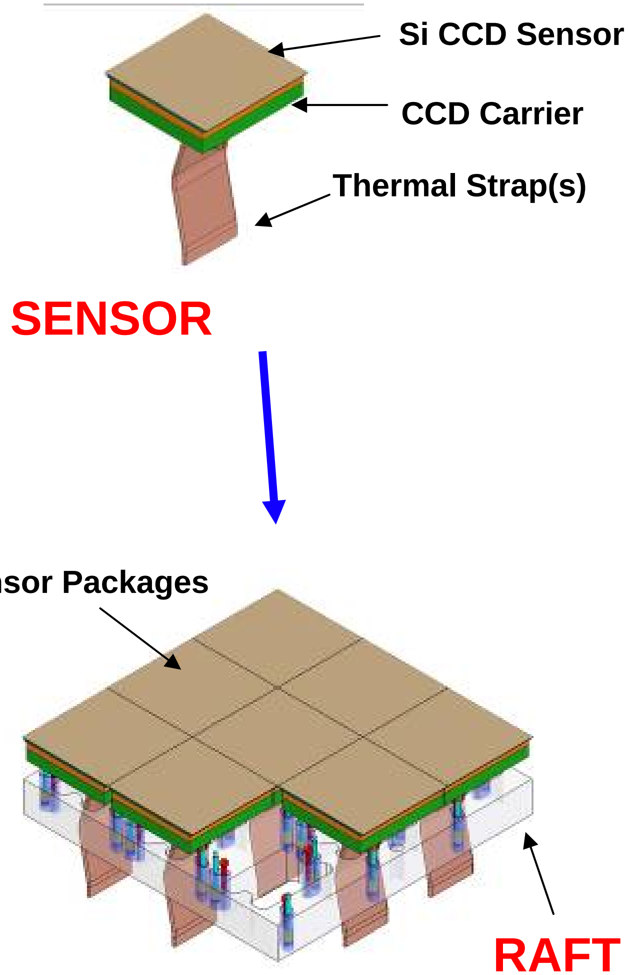


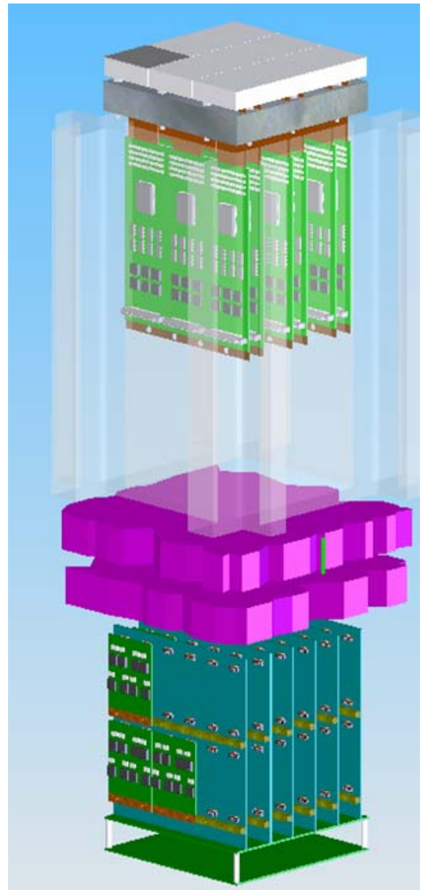
Developed by NOAO

DARK ENERGY SURVEY

Typical readout rate: 250k-pixels/s @ <10e- rms noise

LSST CCDs & Electronics





← 3 x 3 array of 16 MP sensors
16 output ports each → 144 video channels

← FEE package
- ← Dual Slope Integrator ASICs
- ← Clock Driver ASICs
- ← support circuitry

← Flex cable interconnect

← Cold plate

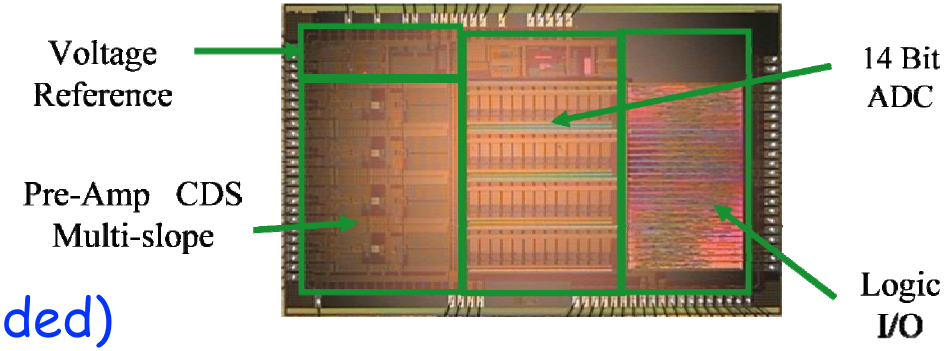
← Cool plate

← BEE package
- ← 144 ADC channels
- ← local data formatting
- ← optical fiber to DAQ

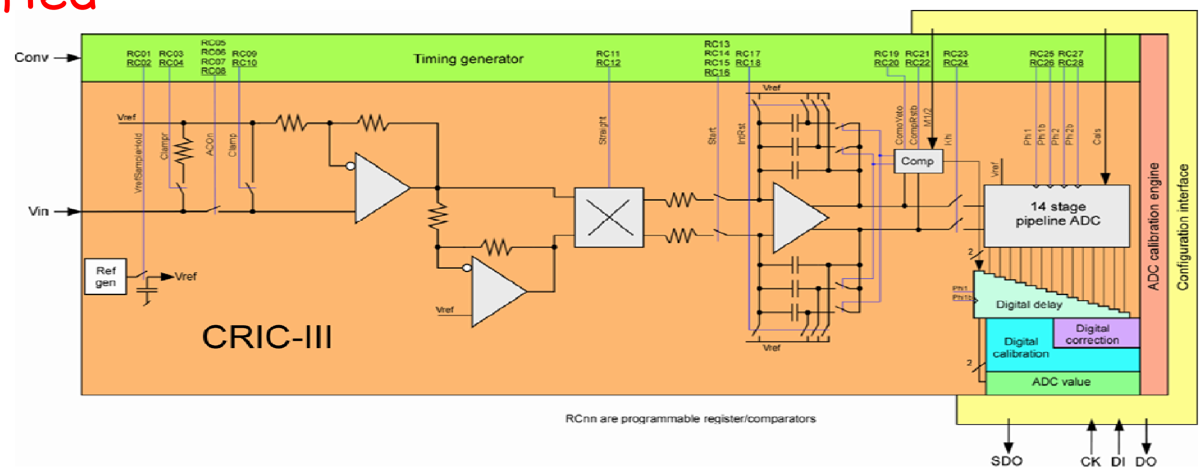
- 201 CCDs with 3.2 GPixel
- Readout time < 2 seconds, data rate 3.2 GBytes/s

It's even harder in Space (SNAP)

- Custom chips for clocks, readout, bias
- Multi range, dual slope integrator
- Correlated Double Sampling
- 14 bit ADC



- Radiation tolerant:
  10 kRad ionization (well shielded)
- Low power: ≈ 200mJ/image/channel ≈ 10mW/channel
- Space qualified
- Compact



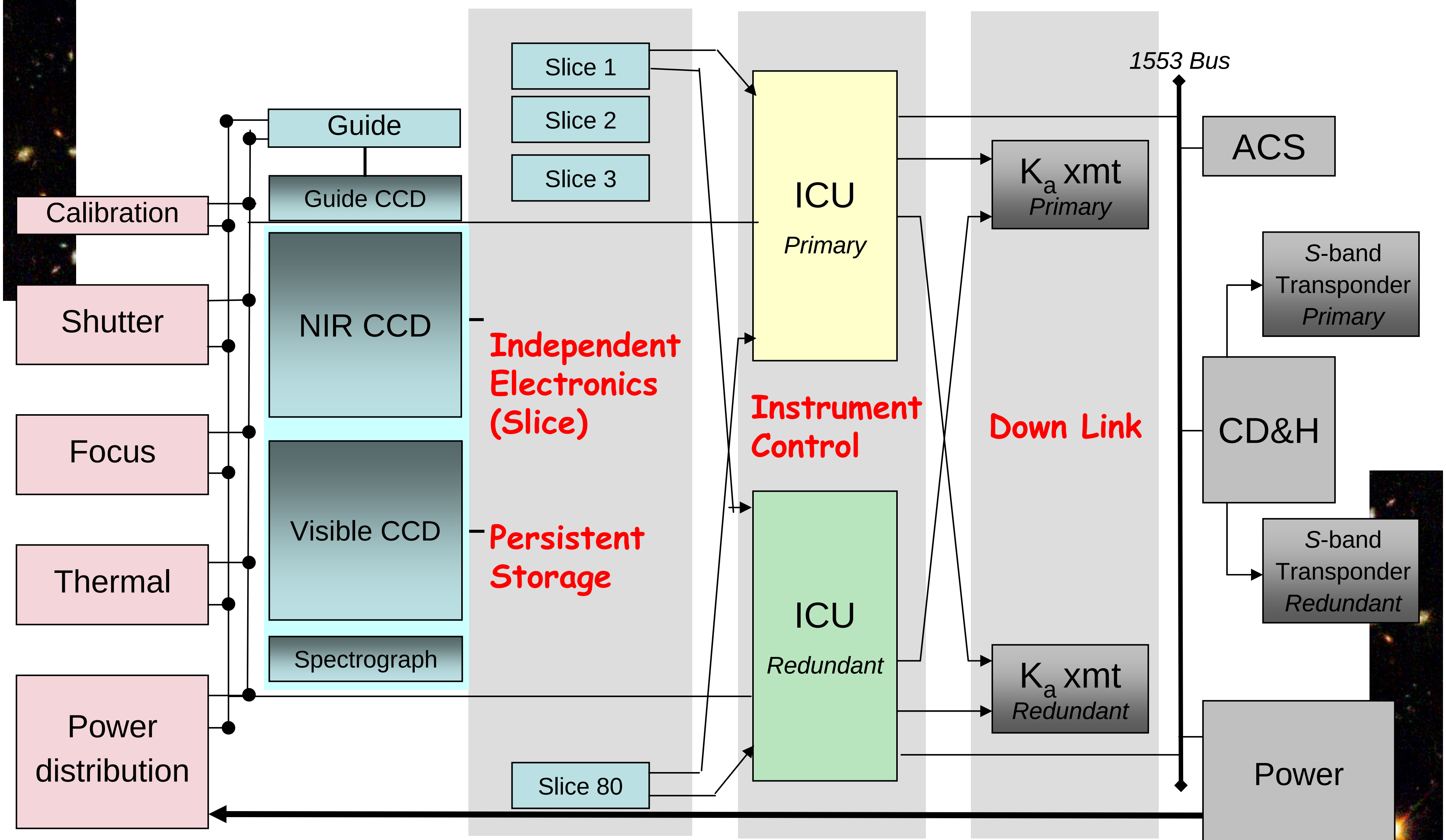
SNAP

Data Flow Considerations

Let's look at SNAP because space makes it different

- *Data Volume*
  - The instrument contains 36 visible CCDs, 36 NIR detectors
  - Each with 3.5k x 3.5k pixels, 16 bits
  - Approx. 1 GByte per exposure
  - 300 second exposure time, 30 second readout time
  - Approx 300 exposures or 300 GBytes per day
- Uptime (for down link)
  - About 1-2 hours contact out every 24
  - Random disturbances (e.g. weather)
- *Compressed data are sent to ground*
  - Compression can reduce the data by a factor of 2
- Down-link bandwidth
  - ~300M bits/second

SNAP Observatory



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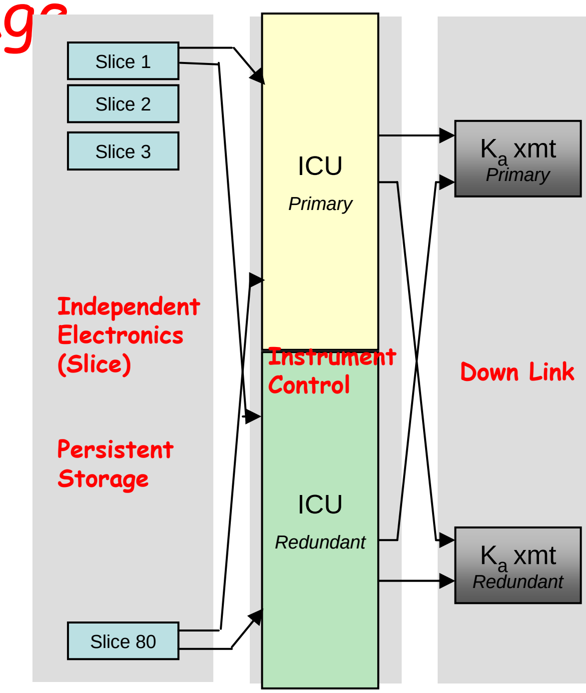
After H. Heetderks

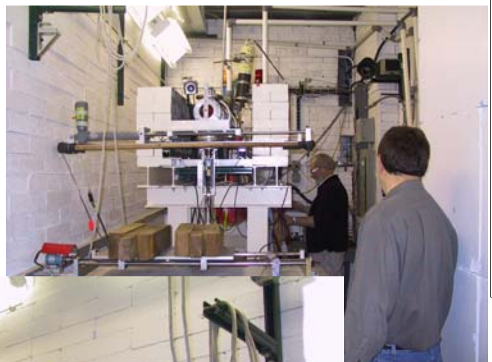
SNAP Observatory

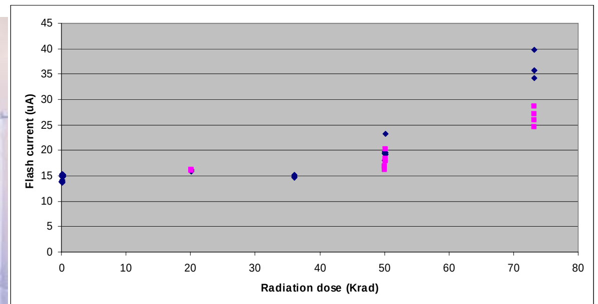
- Redundancy
  - Avoid single point of failure
  - Backup units for critical systems
- Uptime of data link
  - Onboard persistent storage
  - Data compression
  - Error correction
- Power, Size
- Radiation Hardness



Flash radiation studies

- Radiation studies (200 MeV p) suggest flash may be appropriate
- Implementation concept suggests requirements can be met
- Future work includes finishing radiation analysis and work towards other aspects of space qualification (see A. Prosser's talk this afternoon)





Quiescent current rises after ~50Krads. Failures significant above that dose. SEUs observed at a low rate.

Two beam exposures to 200 MeV protons at Indiana Univ cyclotron 20-80 Krads explored

original concept

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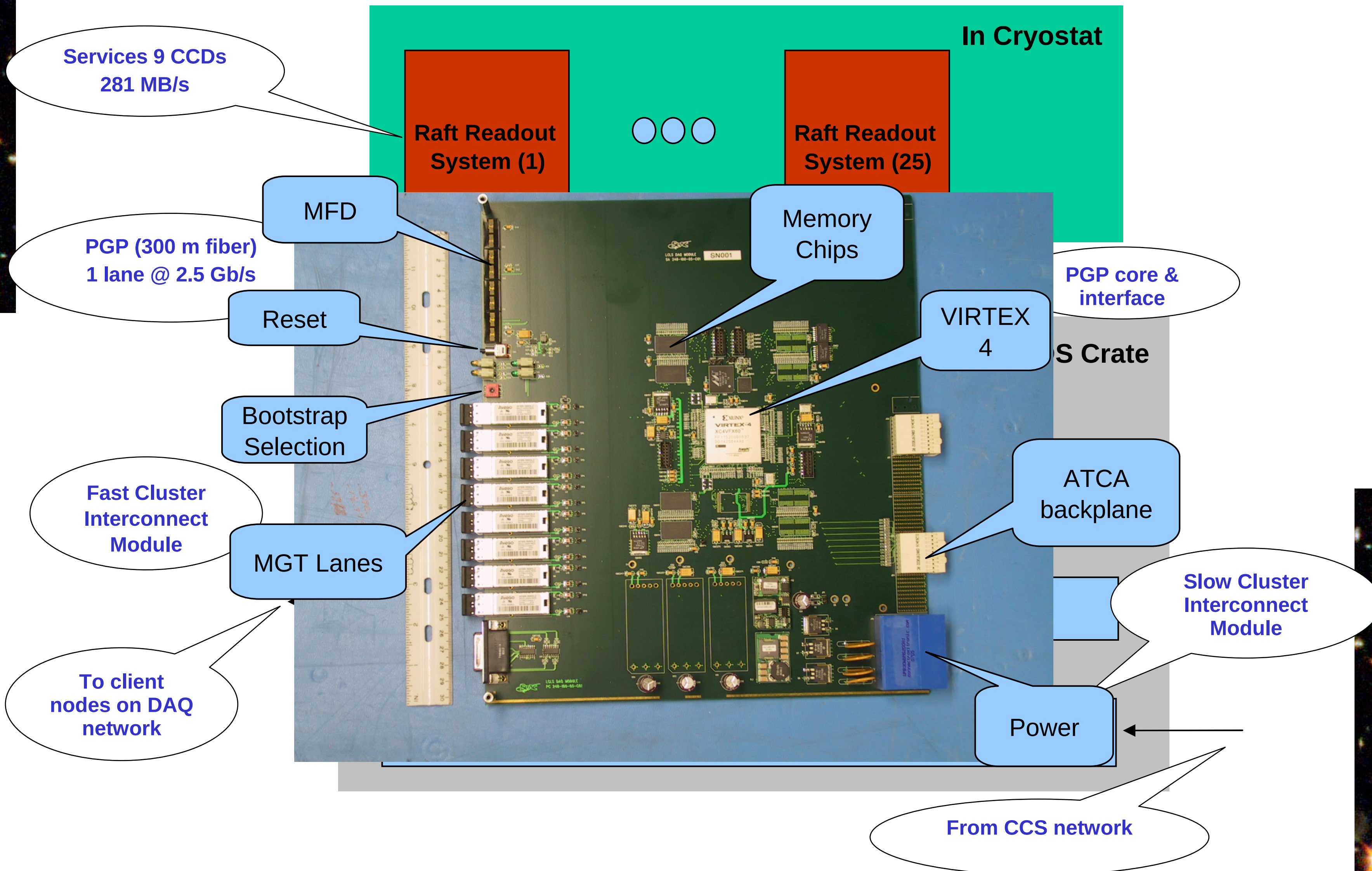
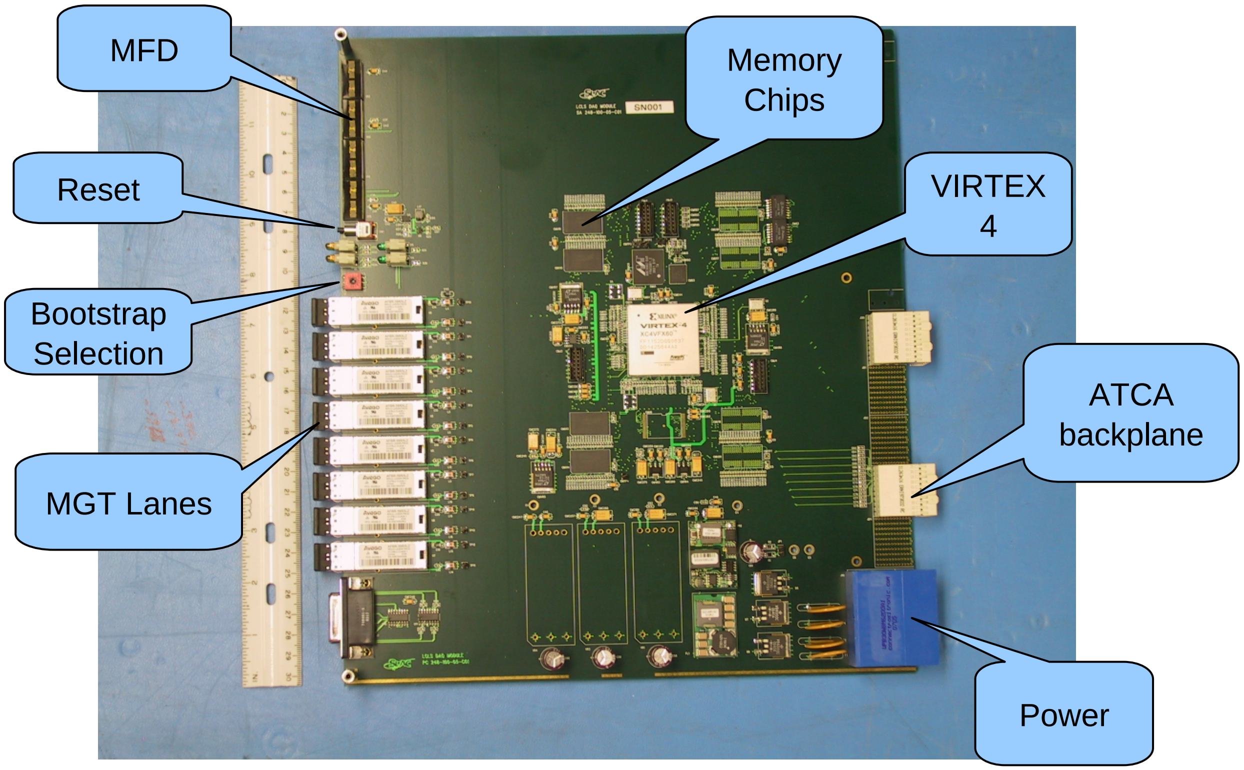
LSST Dataflow system

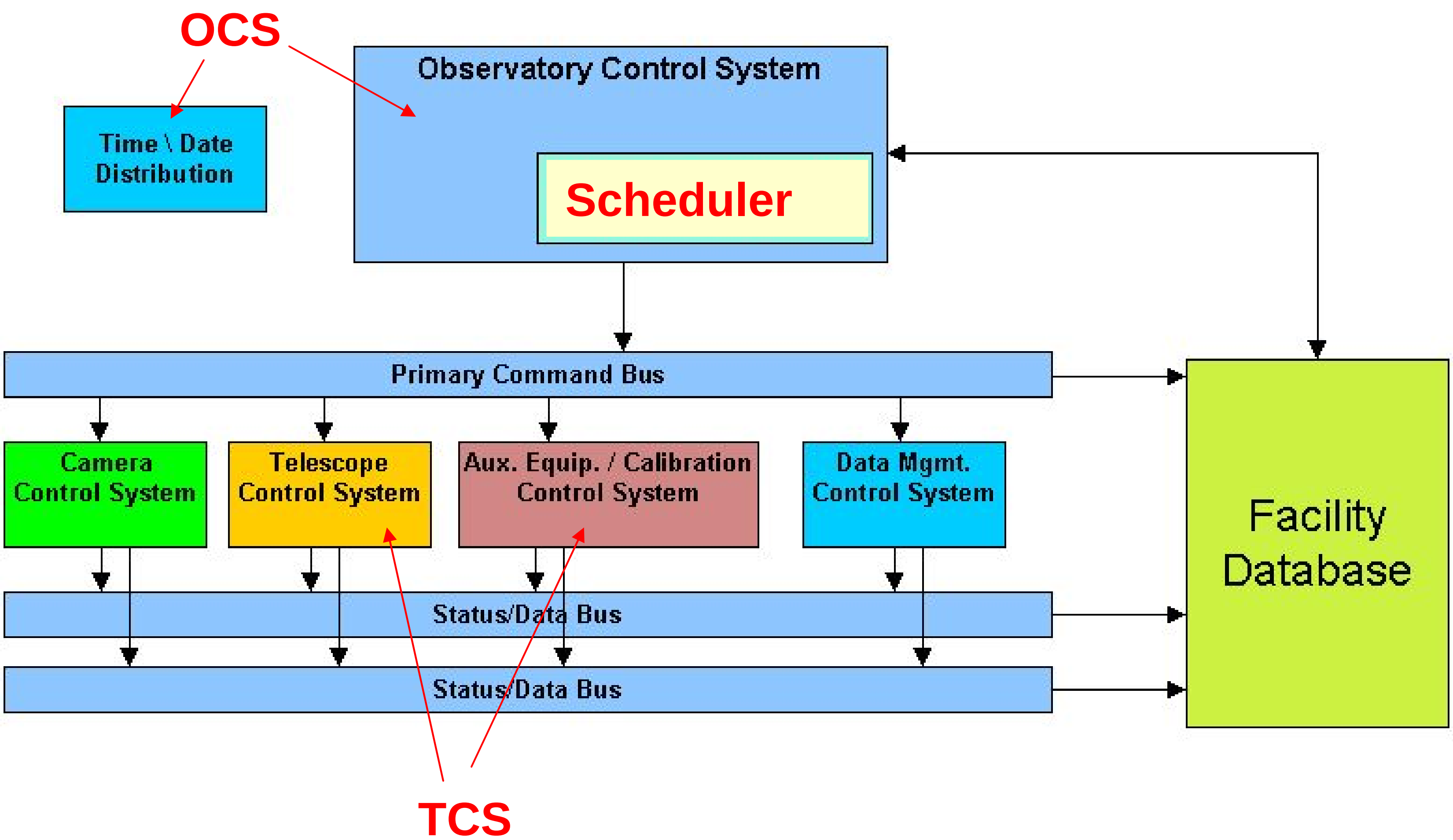


Courtesy of A. Perazzo

LSST Dataflow system



Controls and Communications



Typical Architecture (LSST)

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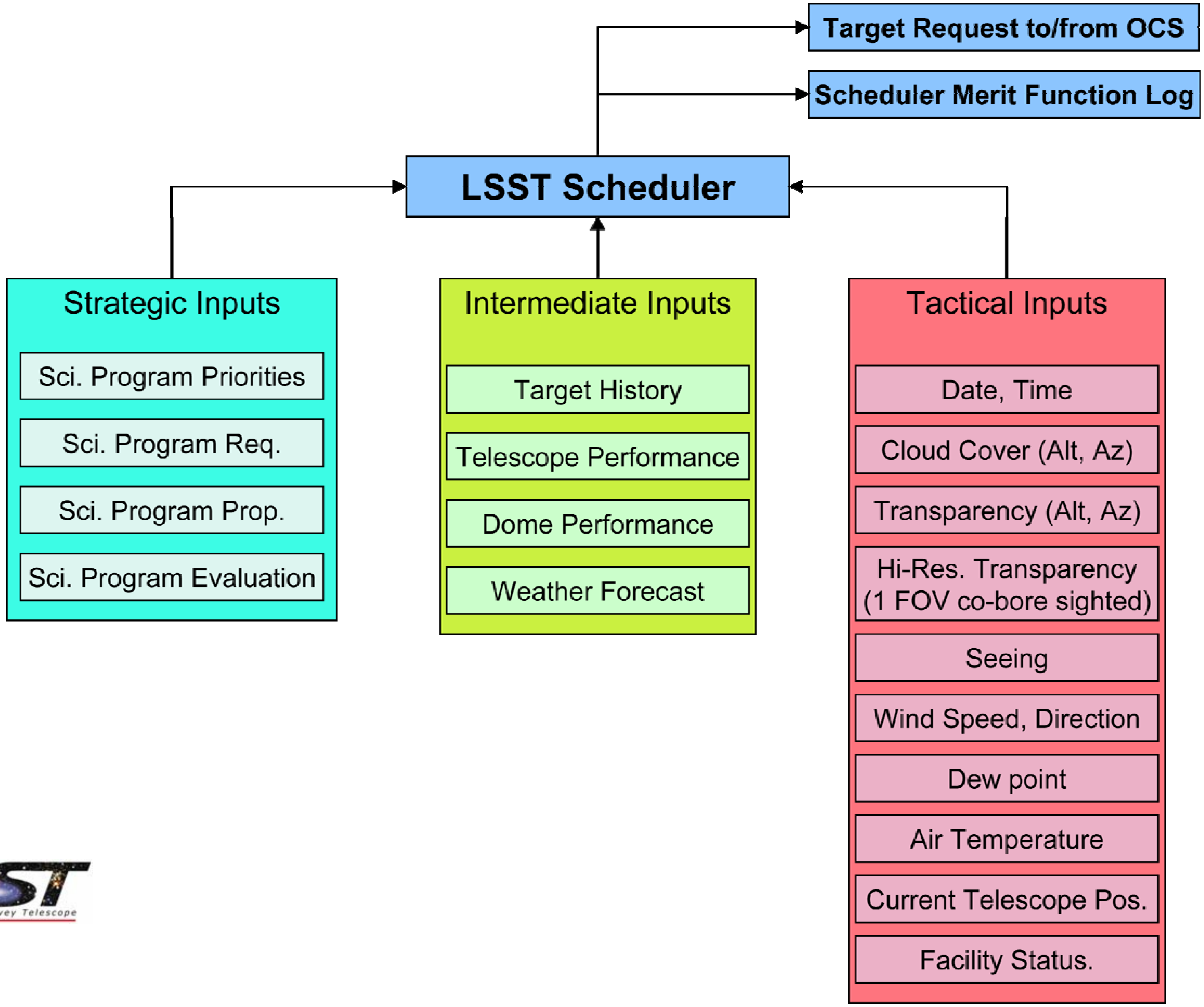
Expert Control: The Scheduler



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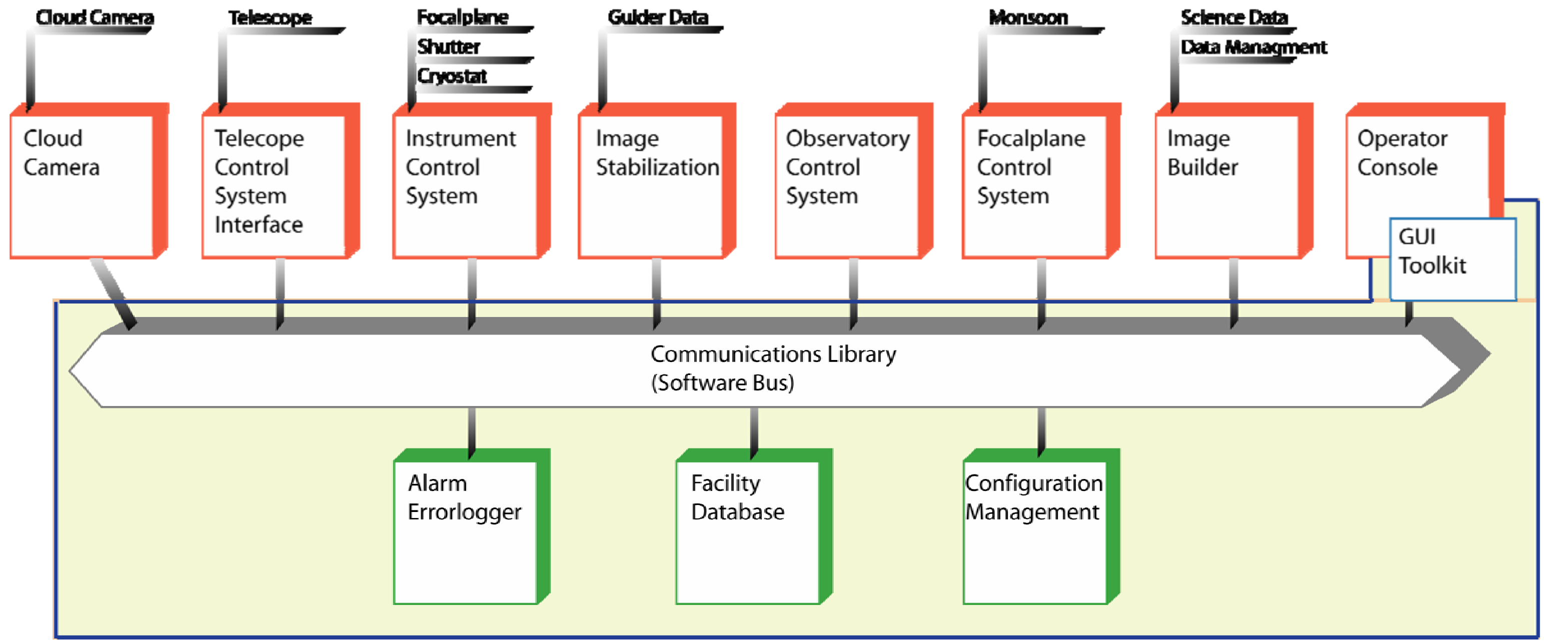
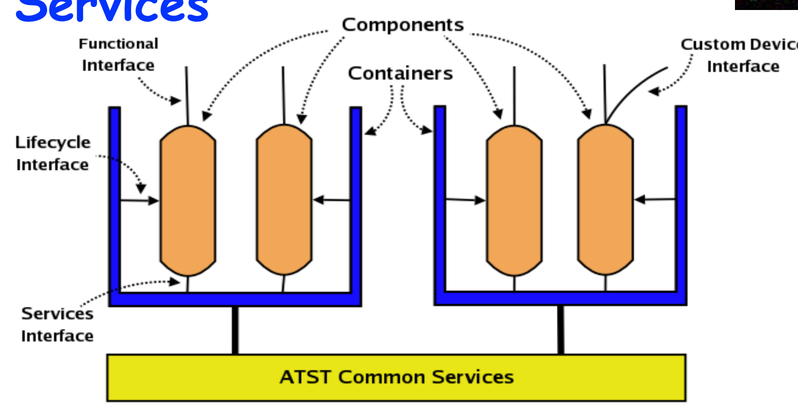
Common Services



Software Infrastructure provides Common Services

- Logging
- Persistent Storage
- Alarm and Error Handling
- Messages, Commands, Events
- Configuration, Connection



➡ **Messaging Layer**
Component/Container Model (Wampler et al, ATST)

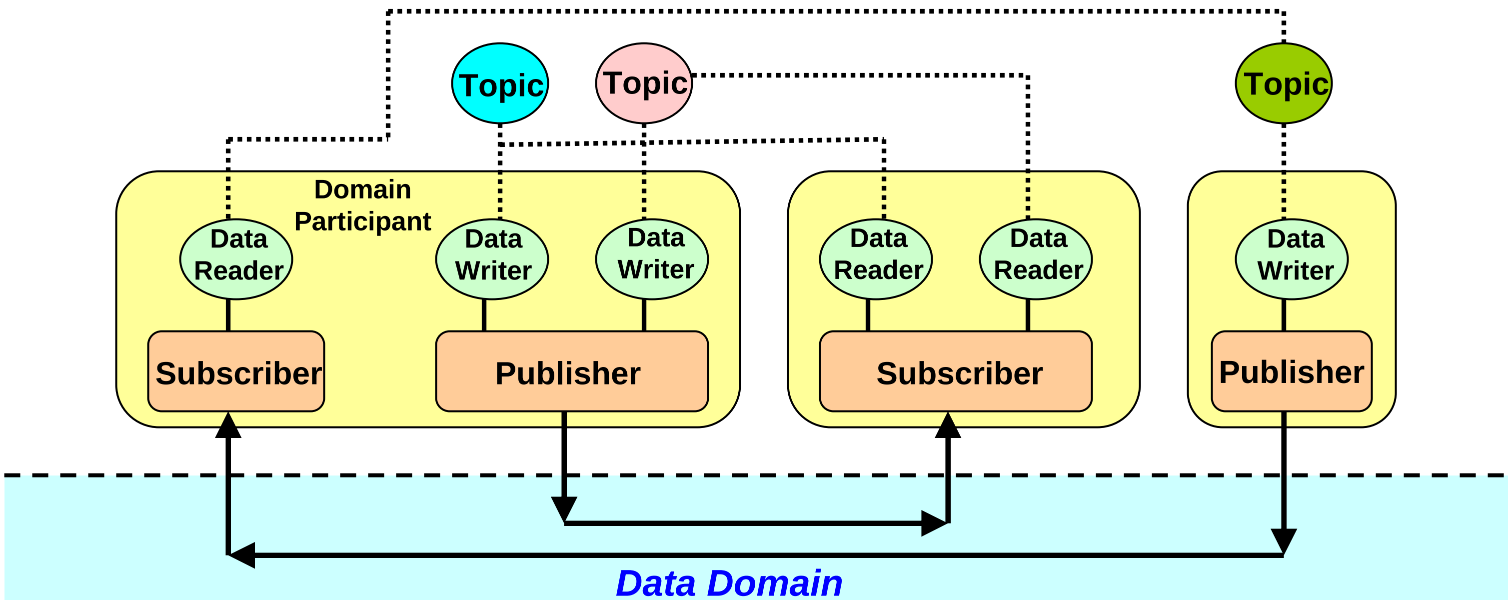
Implementations

	Network	Transport	Interface	GUI
ALMA	Ethernet	CORBA	IDL	Java/Swing
Gemini	Ethernet	Epics	Epics	Tcl/Tk
SOAR	Ethernet	Sockets	SCLN	Labview
DES	Ethernet	Sockets	SML/SCLN	Labview
LSST	Ethernet	DDS	DDS/IDL	Tbd
SNAP	SPI like	VxWorks		n.a.

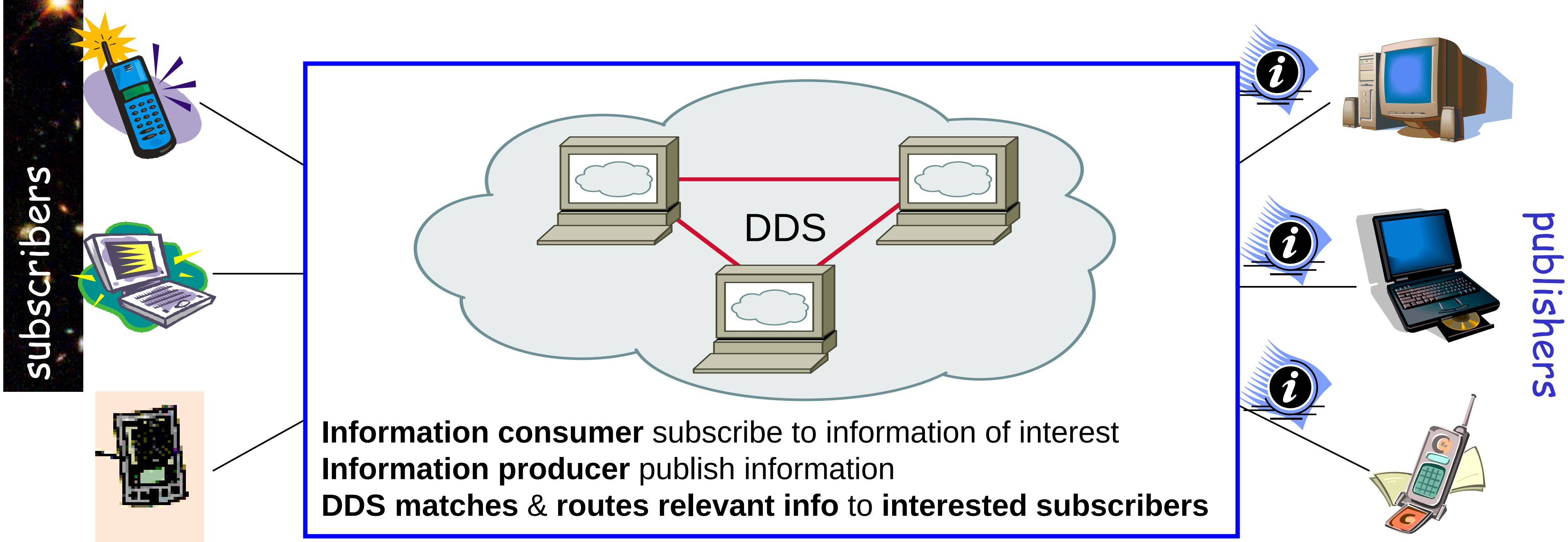
(adapted from S. Wampler)

Data Distribution Service

- Search for technology to handle control requirements and telemetry requirements, in a distributed environment.
- Publish-Subscribe paradigm.
- Subscribe to a topic and publish or receive data.
- No need to make a special request for every piece of data.
- OMG DDS standard released. Implemented by RTI as NDDS.



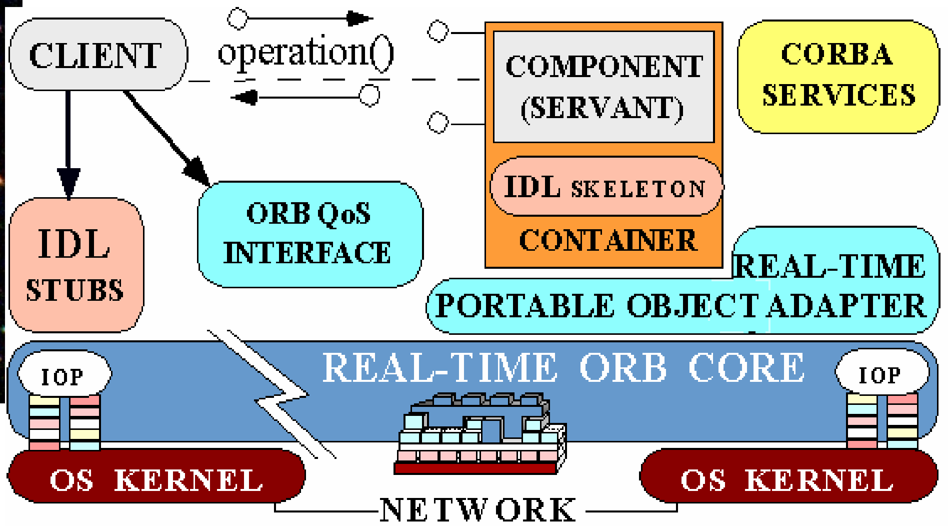
Summary of key DDS PS features

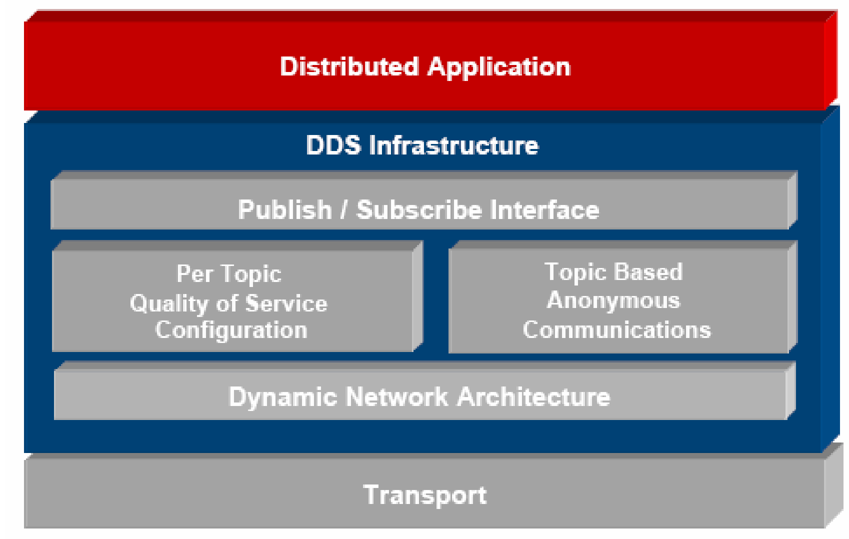


- Efficient Publish/Subscribe interfaces
- QoS suitable for real-time systems
  - deadlines, levels of reliability, latency, resource usage, time-based filter
- Listener & wait-based data access suits different application styles
- Support for content-based subscriptions
- Support for data-ownership
- Support for history & persistence of data-modifications

Courtesy of D. Schmidt

Comparing CORBA with DDS





***Distributed* object**
- Client/server
- Remote method calls
- Reliable transport

Best for
- Remote command processing
- File transfer
- Synchronous transactions

***Distributed* data**
- Publish/subscribe
- Multicast data
- Configurable QoS

Best for
- Quick dissemination to many no
- Dynamic nets
- Flexible delivery requirements

DDS & CORBA address different needs

Complex systems often need both…

Courtesy of D. Schmidt

Data Management

Long-Haul Communications

Base to Archive and Archive to Data Centers Networks are 10 gigabits/second protected clear channel fiber optics, with protocols optimized for bulk data transfer

Archive/Data Access Centers

[In the United States] Nightly Data Pipelines and Data Products and the Science Data Archive are hosted here. Supercomputers capable of 60 teraflops provide analytical processing, re-processing, and community data access via Virtual Observatory interfaces to a 7 petabytes/year archive.

Base Facility

[In Chile] Nightly Data Pipelines and Products are hosted here on 25 teraflops class supercomputers to provide primary data reduction and transient alert generation in under 60 seconds.

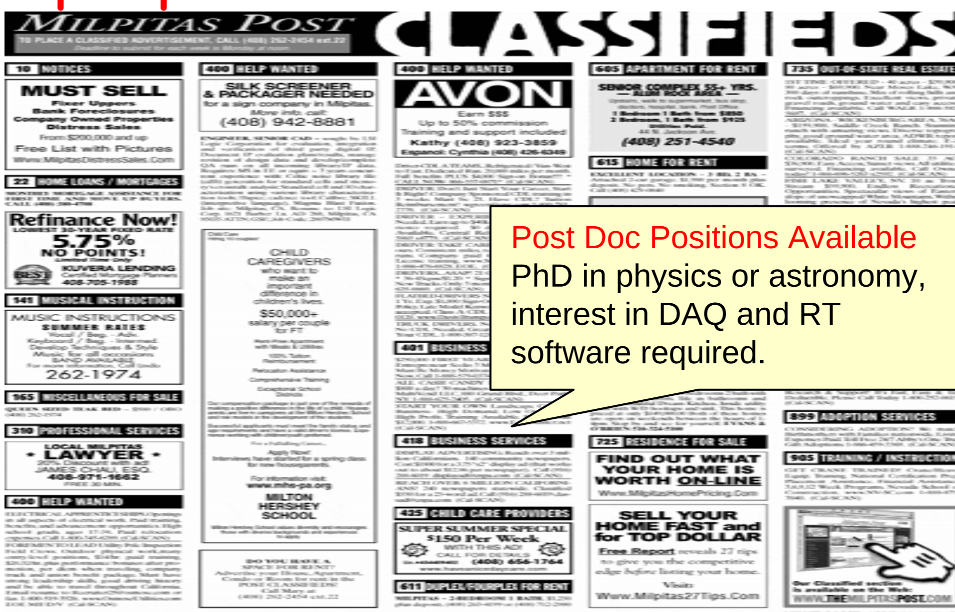
Mountain Site

[In Chile] Data acquisition from the Camera Subsystem and the Observatory Control System, with read-out 6 GB image in 2 seconds and data transfer to the Base at 10 gigabits/second.

Courtesy of T. Schalk

Summary and Conclusion

- Dark Energy science requires large scale surveys
- Large scale surveys require
  - Dedicated instruments (Giga-pixel CCD cameras)
  - Large(r) collaborations
  - State of the art computing and software technology
  - Good people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10 NOTICES
MUST SELL
400 HELP WANTED
SILK SCREENER & PACKAGER NEEDED
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AVON
Kathy (408) 923-3859
605 APARTMENT FOR RENT
(408) 251-4540
615 HOME FOR RENT
735 OUT-OF-STATE REAL ESTATE
22 HOME LOANS / MORTGAGES
Refinance Now!
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NO POINTS!
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141 MUSICAL INSTRUCTION
MUSIC INSTRUCTIONS
262-1974
CHILD CAREGIVERS
365 MISCELLANEOUS FOR SALE
310 PROFESSIONAL SERVICES
LAWYER
408-971-1662
400 HELP WANTED
MILTON HERSHEY SCHOOL
401 BUSINESS
410 BUSINESS SERVICES
425 CHILD CARE PROVIDERS
SUPER SUMMER SPECIAL
$150 Per Week
611 DUPLEX/FOURPLEX FOR RENT
725 RESIDENCE FOR SALE
FIND OUT WHAT YOUR HOME IS WORTH ON-LINE
SELL YOUR HOME FAST and for TOP DOLLAR
899 ADOPTION SERVICES
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> Post Doc Positions Available
> PhD in physics or astronomy, interest in DAQ and RT software required.

Special thanks to
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