CCS Support for I&T and Data Flow

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Large Synoptic Survey Telescope

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SLAC

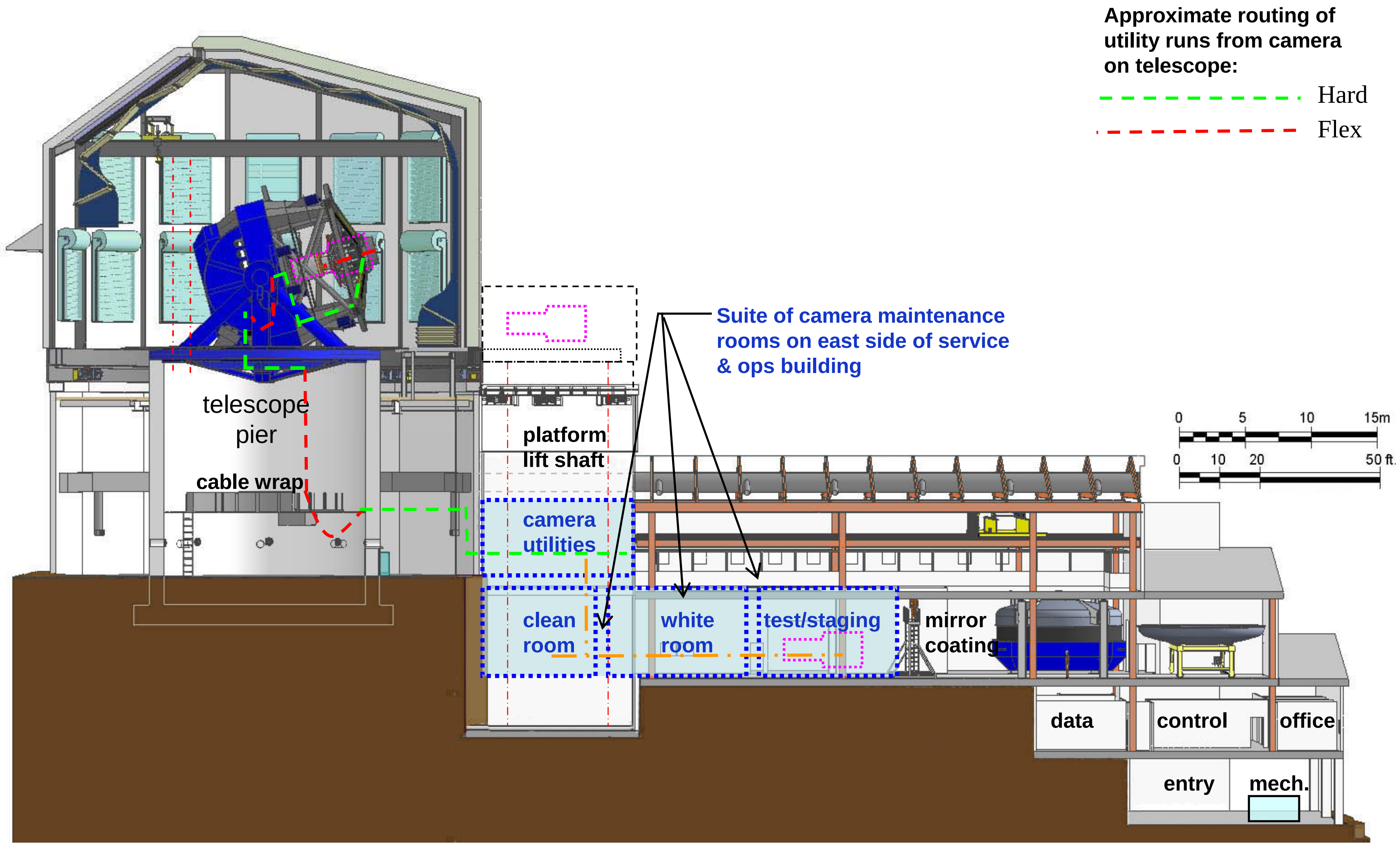
Outline

- CCS Definition
- CCS Scope
- Control Architecture
- Data Flow Architecture
- Topics and action items for discussion

Functionality of Controls and data acquisition

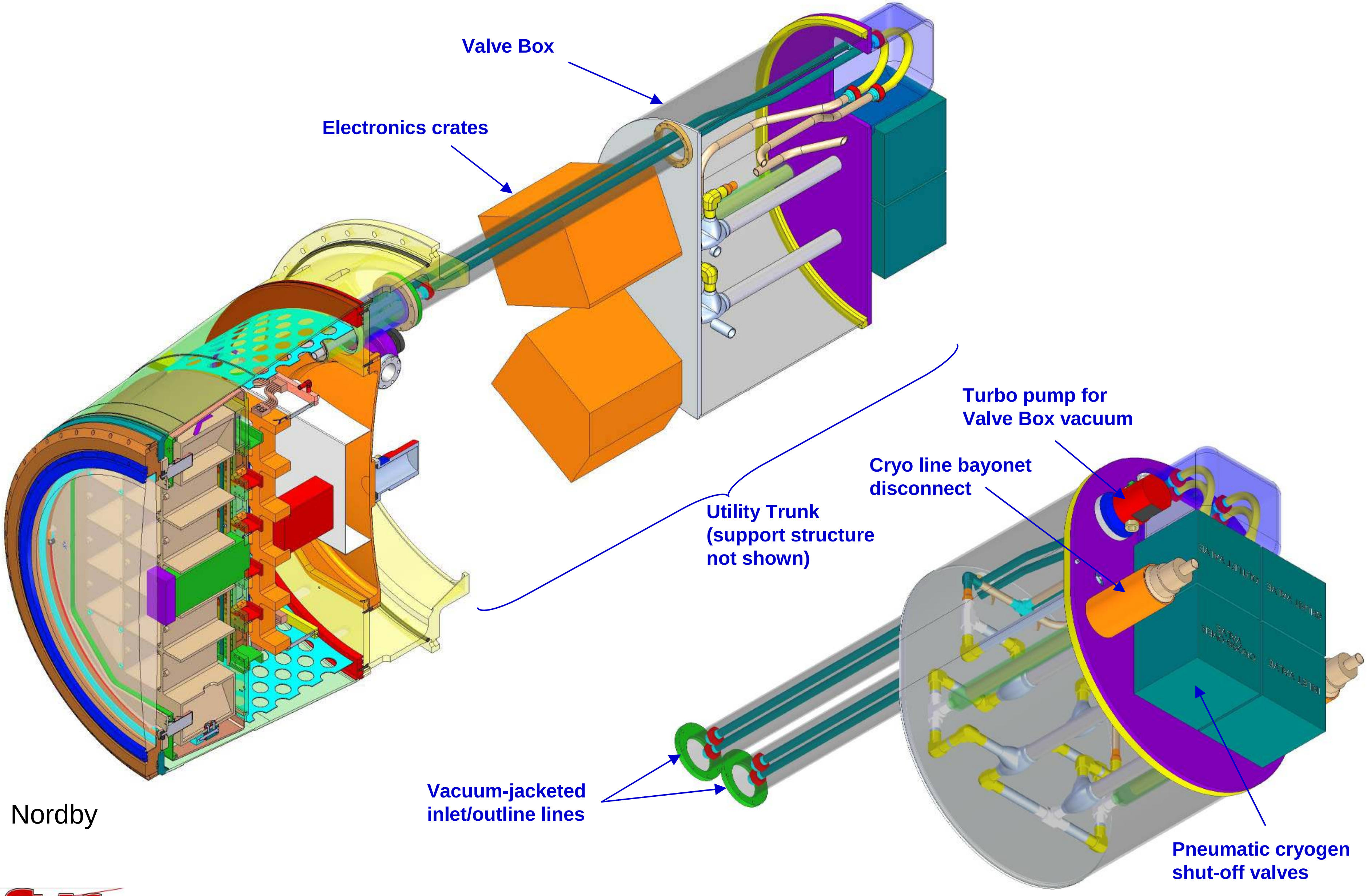
- Maintain the operational state of the camera
- Orchestrate the sequence of subsystem operations to affect data collection
- Report/publish the aggregate status of camera subsystems to Observatory
- Provide a command/control interface for Observatory Control
- Provide hardware/software necessary to receive and store raw camera data
- Provide access mechanisms for data retrieval by DM and any other downstream clients
- Provide additional command/control interfaces for engineering, testing
- Key point is that CCS has interactions and interfaces across all camera subsystems and with OCS, TCS, DM

Camera Systems Locations



Nordby

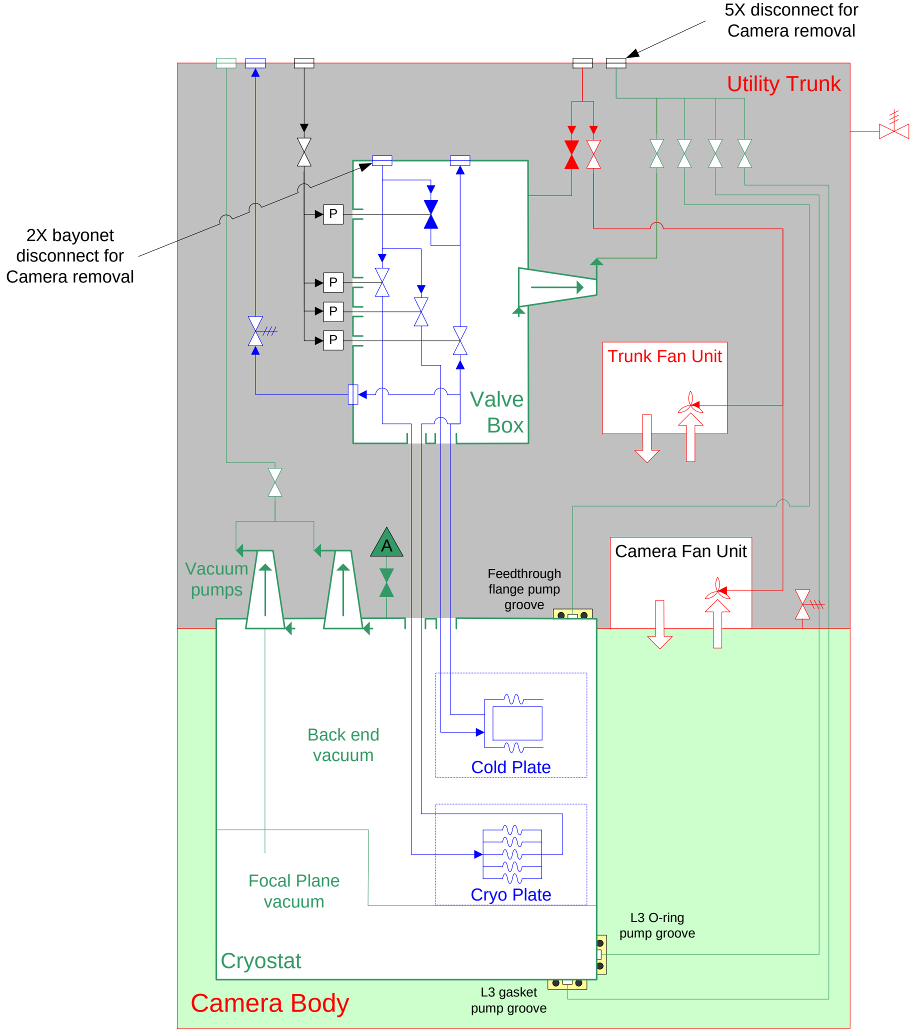
Valve Box and Utility Trunk



Nordby

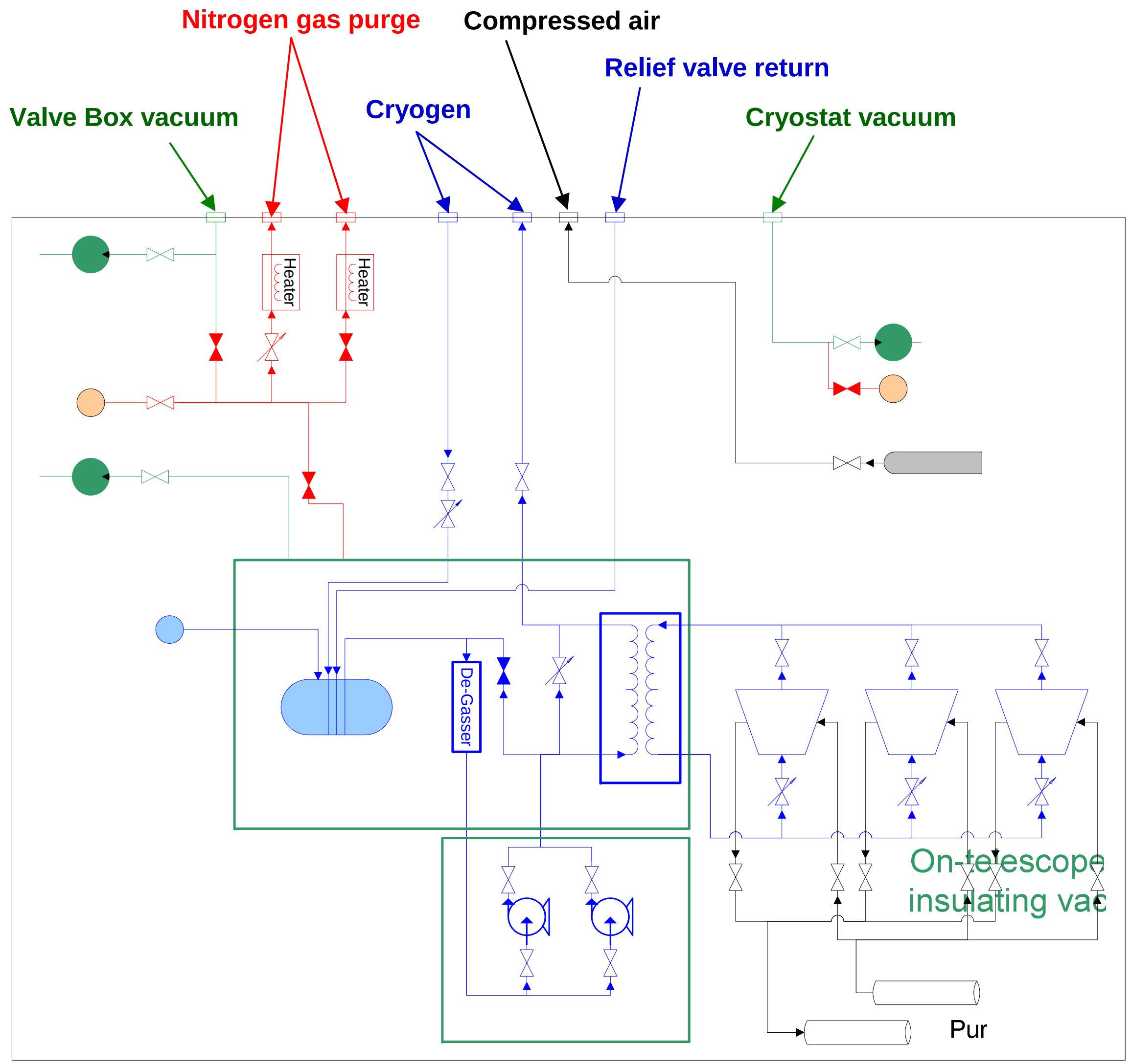
Utility Trunk Schematic

- Vacuum systems
- Cryogenic fluid controls
- Temperature regulation
- Power control
- Subsystem electronics packages



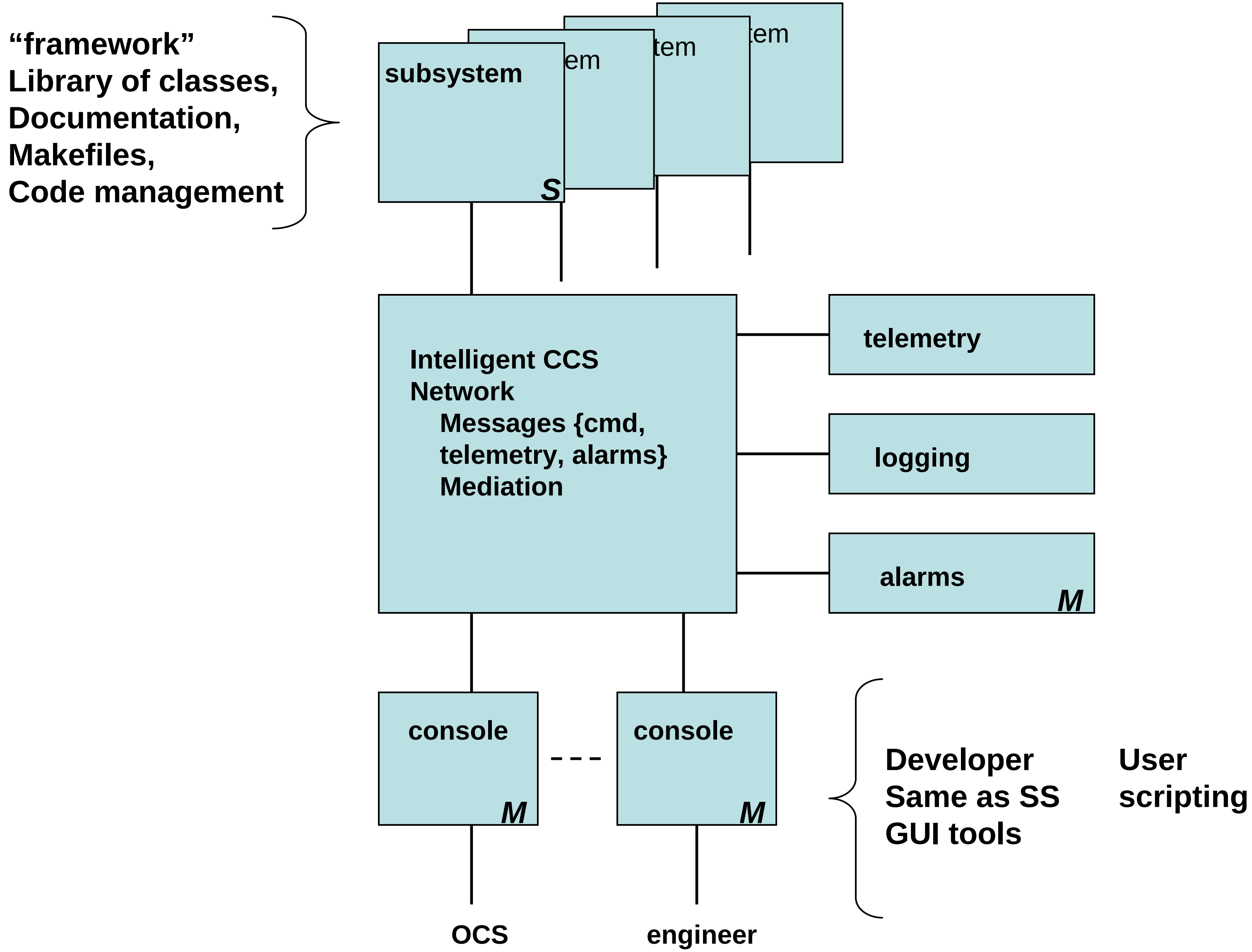
Utility Room Schematic

- Backing pumps
- Cyrogen fluid sources



N2
Nordby

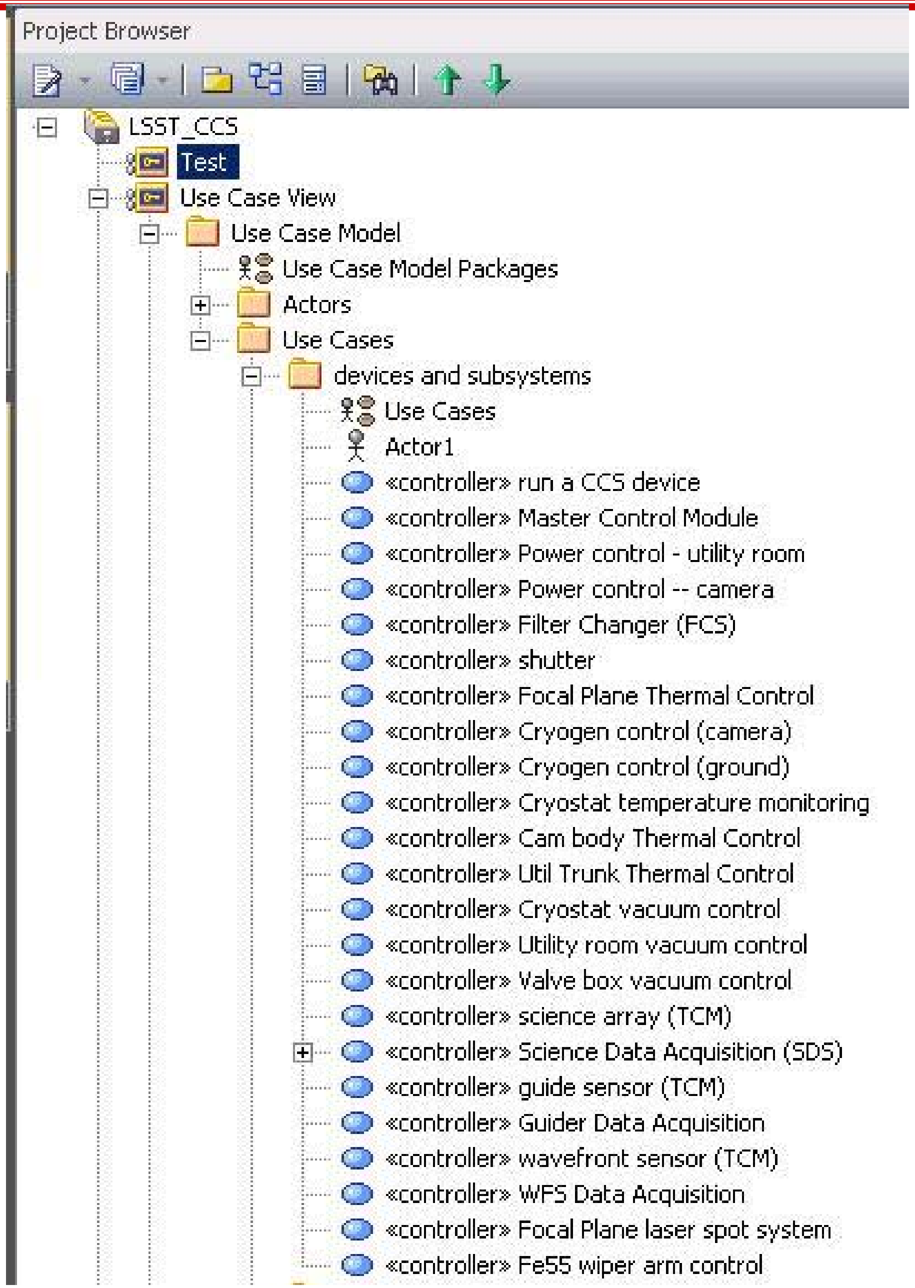
CCS Baseline Architecture



Defining Subsystems

Large Synoptic Survey Telescope

- Substantial updates from mechanical engineering team
- Additions include utilities transport, utility trunk evolution, off-telescope operations
- Review and re-parse subsystem definitions based on "subsystems are tightly coupled"
- Track definitions and functionality of subsystems in UML
- Each subsystem (CCS view) is based on a generic "controller" model



Defining Subsystems

Master Control Module

The MCM controls all other CCS subsystems via messages passed over tcp/ip networking on a private camera net. The MCM is the only "device" visible to the OCS and represents the camera as a whole.

Power control - utility room

This subsystem enables, monitors, sequences power sources which are in the ground utility room It includes switches, relays, and logic to provide appropriate sequencing and interlocks between power source In particular, we might not power the heat exchanger if the insulating vacuum system is not functioning.

Power control -- camera

This subsystem enables, monitors, sequences power sources which are in the utility trunk volume. It includes switches, relays, and logic to provide appropriate sequencing and interlocks between power sources.

Filter Changer (FCS)

Filter changer is self contained set of 5 filters, electromechanical motion devices and controller.

Defining Subsystems (cont'd)

Shutter

Assuming a two blade shutter instrumented for position vs. time measurements

Focal Plane Thermal Control

Controls the temperature of the focal plane assembly. It must monitor temperatures and heater settings in each of the 25 rafts. Inputs are temperatures reported by the science array via the TCM (or possibly the SDS) and output is to the RCM's via the TCM (or again possibly the SDS).

Cryogen control (camera)

Cryogen is delivered from the utility room to the valve box in the utility trunk. Actuated valves (at least 4) control the flow of cryogen to the cold plate (BEE heat sink) and the cryoplate (CCD/FEE heat sink). This system controls and monitors this flow. Sensors for air pressure (for actualted valves) and nitrogen gas purge may be needed. Temperature sensors in the lines, cold plates, and valve boxes are also likely.

The output temperatures from this system would be visible to the cryogen delivery system on the ground and could be used to bring the CCD temperature control system within the limits of the focal plane heaters.

Defining Subsystems (cont'd)

Cryogen control (ground)

Comprises 3polycold refrigeration systems, a pumping system, heat exchanger, storage reservoir, and round-trip transport lines. This system provides monitoring and control of this system as a whole. It must be able to start/stop and adjust these devices during operation.

Cryostat temperature monitoring

This system provides monitoring of all temperature sensors in the cryostat which are not part of the cryogen flow or science array systems.

Camera body Thermal Control

This is environmental control and monitoring of the camera body including all areas outside of the cryostat. In particular, this includes the L1/L2 chamber, the L3/shutter/filter zone and the carousel zone also.

The system consists of a temperature regulated supply (from the ground) of dry nitrogen gas feeding a fan coil unit with a supply/return line for chilled water. The fan coil circulates the dry N2 throughout the volume absorbing heat in chilled water coils.

Operation depends upon the supply of dry N2 (low pressure) and chilled water (telescope utility). Temperature sensors in the camera body skin and components will be inputs, with the system adjusting either fan speeds, or water flow rates to regulate the skin temperature of the system.

Defining Subsystems (cont'd)

Utility Trunk Thermal Control

This is environmental control and monitoring of the utility trunk.

The system consists of a temperature regulated supply (from the ground) of dry nitrogen gas feeding a fan coil unit with a supply/return line for chilled water. The fan coil circulates the dry N2 throughout the volume absorbing heat in the chilled water coil.

Operation depends upon the supply of dry N2 (low pressure) and chilled water (telescope utility). Temperature sensors in the utility trunk components will be inputs, with the system adjusting either fan speeds, or water flow rates to regulate the skin temperature of the system.

Cryostat vacuum control

Two turbo-pumps with backing from the utility room. Operation would assume the backing pumps are on (with verification). Two or more vacuum gauges and possibly an RGA would be used to monitor the vacuum quality. Interface to turbo pumps unknown at this time but may include health/safety data from the pump itself.

Defining Subsystems (cont'd)

Utility room vacuum control

The on-ground utility room vacuum system provides three distinct vacuum systems:
- backing vacuum for the cryostat
- backing vacuum for the valve box
- insulating vacuum for the cryogen supply system lower portion.

These systems will include some number of gauges and valves (manual) and also a N2 (nitrogen) gas purge supply with some monitoring.

Valve box vacuum control

This system comprises one turbo pump and some gauges and is backed by the utility room backing pump system (shared with the cryostat vacuum but they can be manually valved off).

Sensors/gauges for monitoring both the vacuum and the pump/valves would also be included in this system.

science array (TCM)

Timing and Control Module (TCM) distributes commands and timing to the ~21 raft controllers. The TCM delivers raft status to the CCS.

Defining Subsystems (cont'd)

Science Data Acquisition (SDS)

The SDS is the data acquisition and distribution system for science data. It receives the data stream from the CCDs, does preliminary processing, buffering and temporary storage of the science data. While under the control of the CCS, the SDS also provides services that are beyond and asynchronous with the camera readout.

guide sensor (TCM)

Timing and Control Module (TCM) distributes commands and timing to the 4 guide controllers. The subsystem module (this object) instantiates the states that represent the guider system.

Guider Data Acquisition

This is the portion of the SDS devoted to guiding. It nominally operates when the science array is integrating. Also, the real-time analysis of the guider data may take place in the SDS which then outputs offset parameters that the telescope control system uses to control the telescope tracking.

Defining Subsystems (cont'd)

Wavefront sensor (TCM)

Timing and Control Module (TCM) distributes commands and timing to the 4 guide controllers. The subsystem module (this object) instantiates the states that represent the guider system.

WFS Data Acquisition

The SDS is the data acquisition and distribution system for wavefront sensor data. It receives the data stream from the sensors, does preliminary processing, buffering and temporary storage of the wavefront. While under the control of the CCS, the SDS also provides services that are beyond and asynchronous with the camera readout. The primary client of this data is the telescope system. It is not expected to be routinely consumed by any other client.

Focal Plane laser spot system

This system consists of a set of laser sources and optics which project a fixed pattern onto the focal plane for in-situ calibration procedures. Control will essentially consist of just enable/disable and on/off.

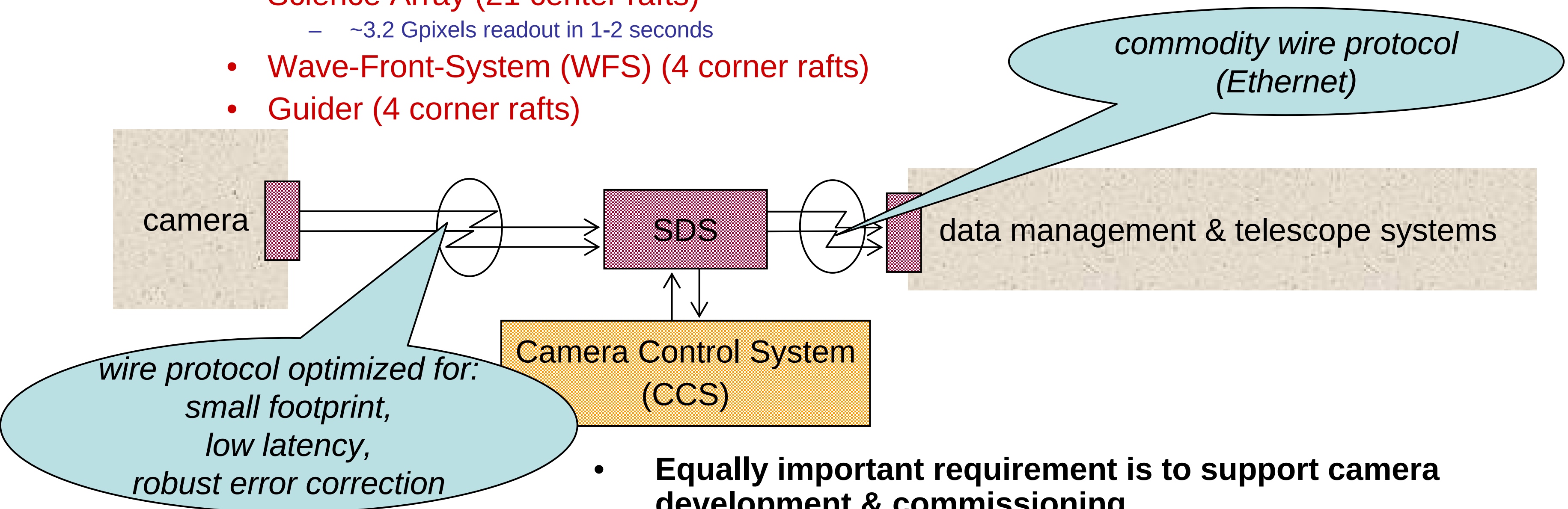
Fe55 wiper arm control

This system consists of the motion arm, motors, limit switches and locks which drive the Fe55 arms across the focal plane during calibration procedures.

Data Flow: Science DAQ System (SDS)

Processes, buffers & publishes science data to both telescope and DM systems

- Science Array (21 center rafts)
  - ~3.2 Gpixels readout in 1-2 seconds
- Wave-Front-System (WFS) (4 corner rafts)
- Guider (4 corner rafts)



- **Equally important requirement is to support camera development & commissioning**
  - **This means support for *test-stand activity*.**
- **Why is this support necessary?**
  - **reuse**
  - **allows early field testing**
  - **preserves across development, commissioning & *operation*:**
    - camera team's software investment (yours!)
    - camera operational experience (yours!)

Huffer

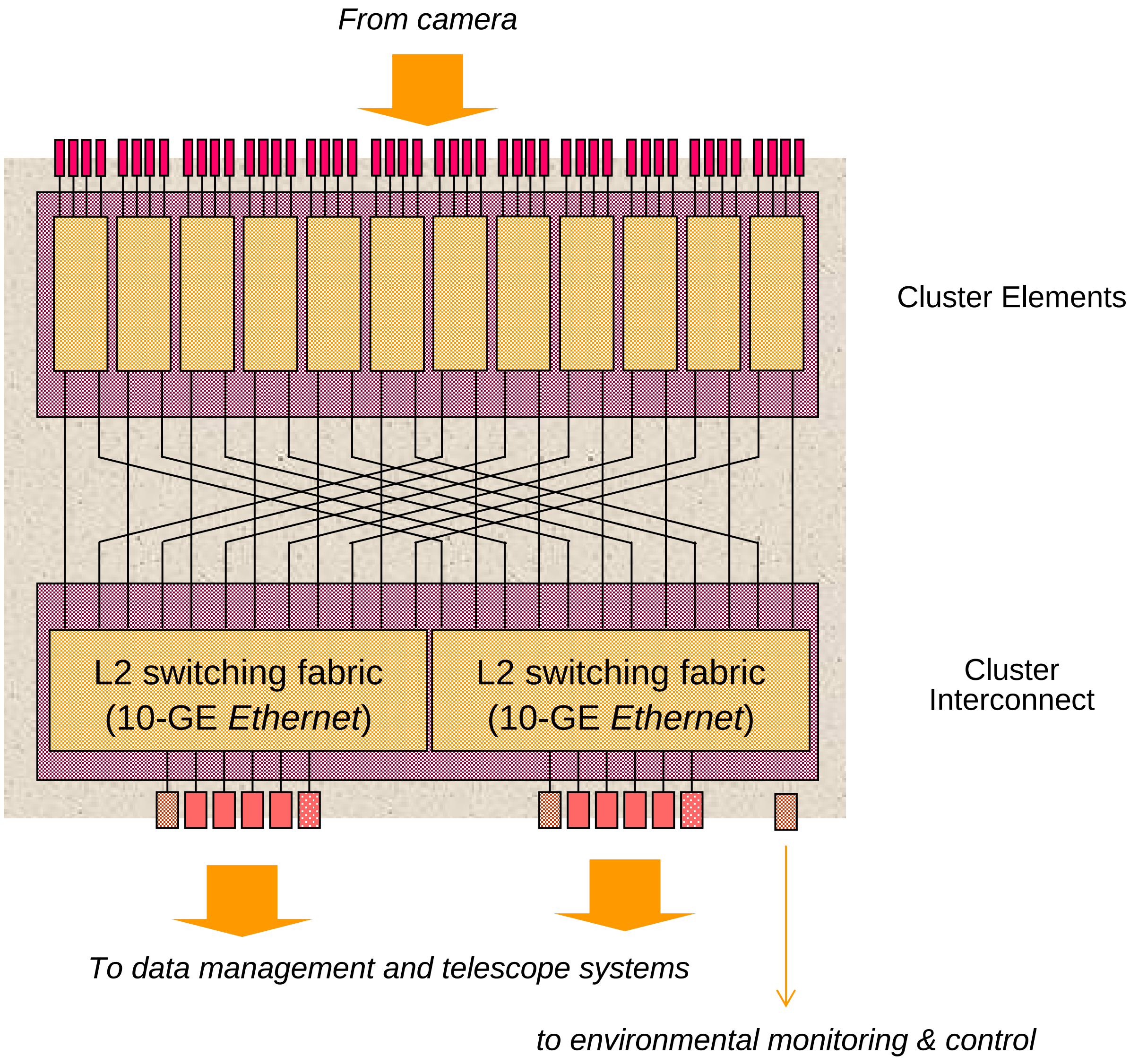
Modular Architecture

Cluster

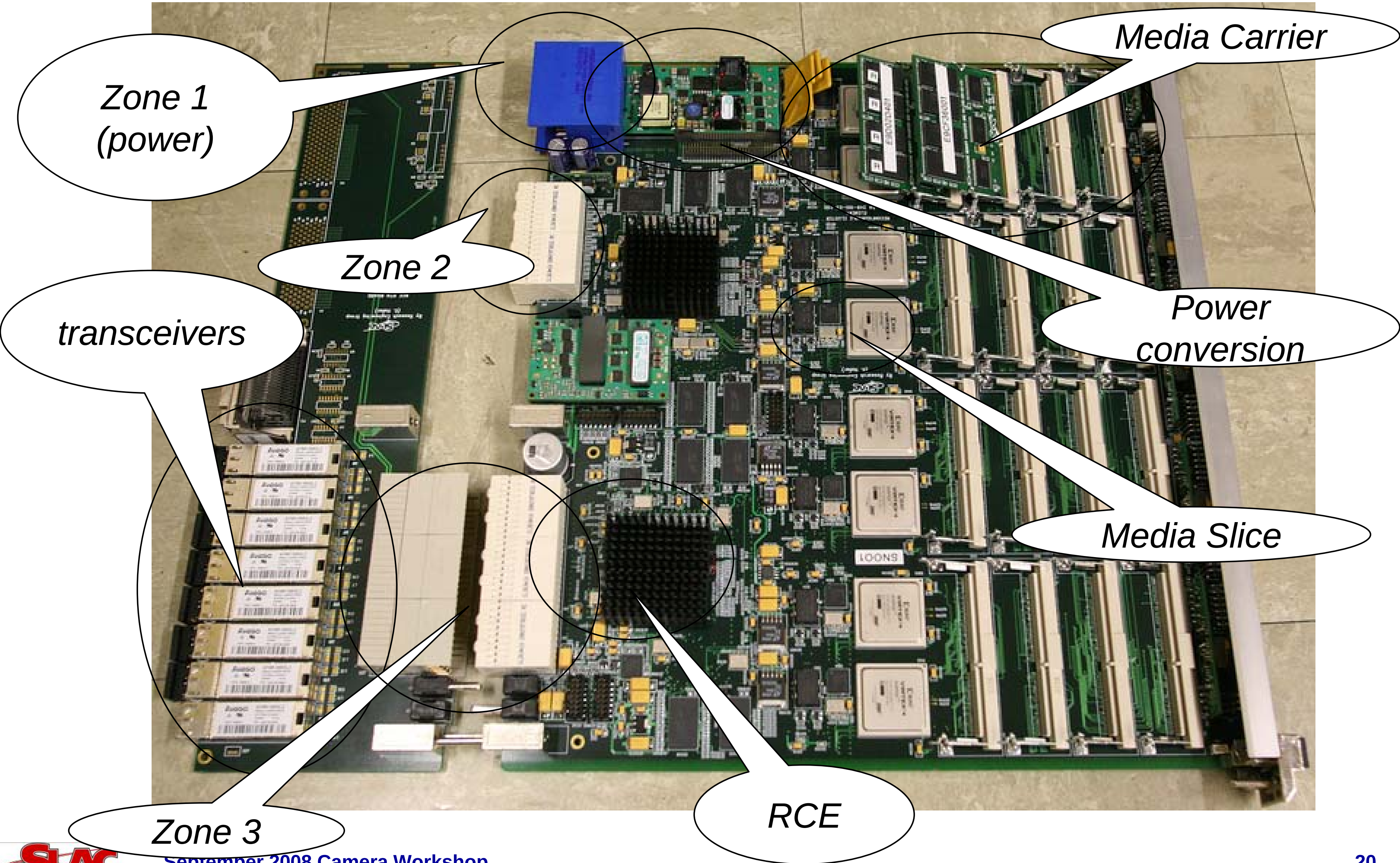
- **Contains up to 24 elements**
- **Elements are connected through a *Cluster Interconnect***
  - **Contains two *independent* switching fabrics:**
    - 10-Gbit *Ethernet* switching
    - fully managed (Layer-2)
    - cut-through (< 200 NS)

- **For each element:**
  - **One MAC is connected to one fabric, & its other MAC to a second fabric**
  - **allows prioritization of different traffic patterns types**

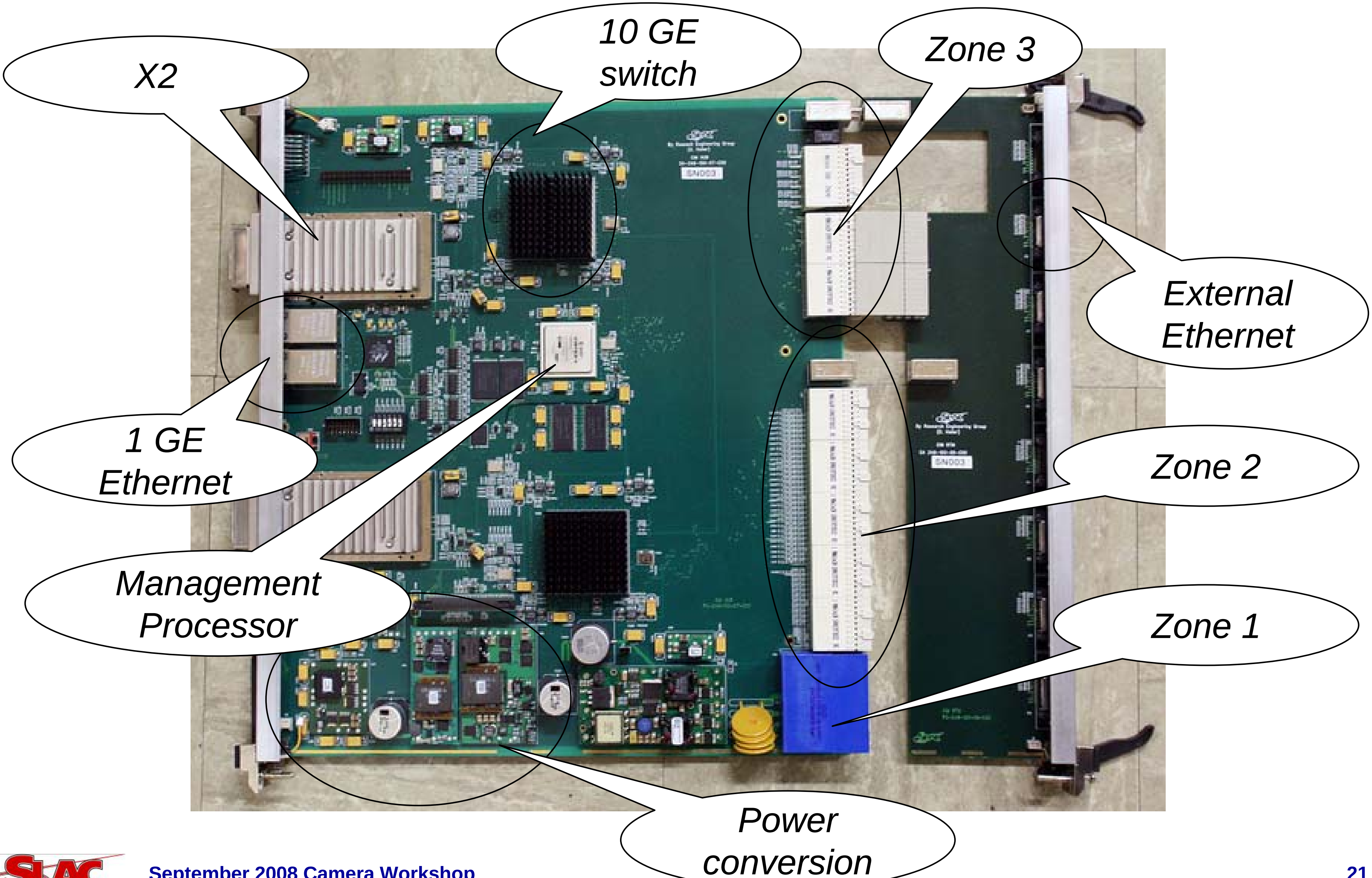
The cluster (12 elements)



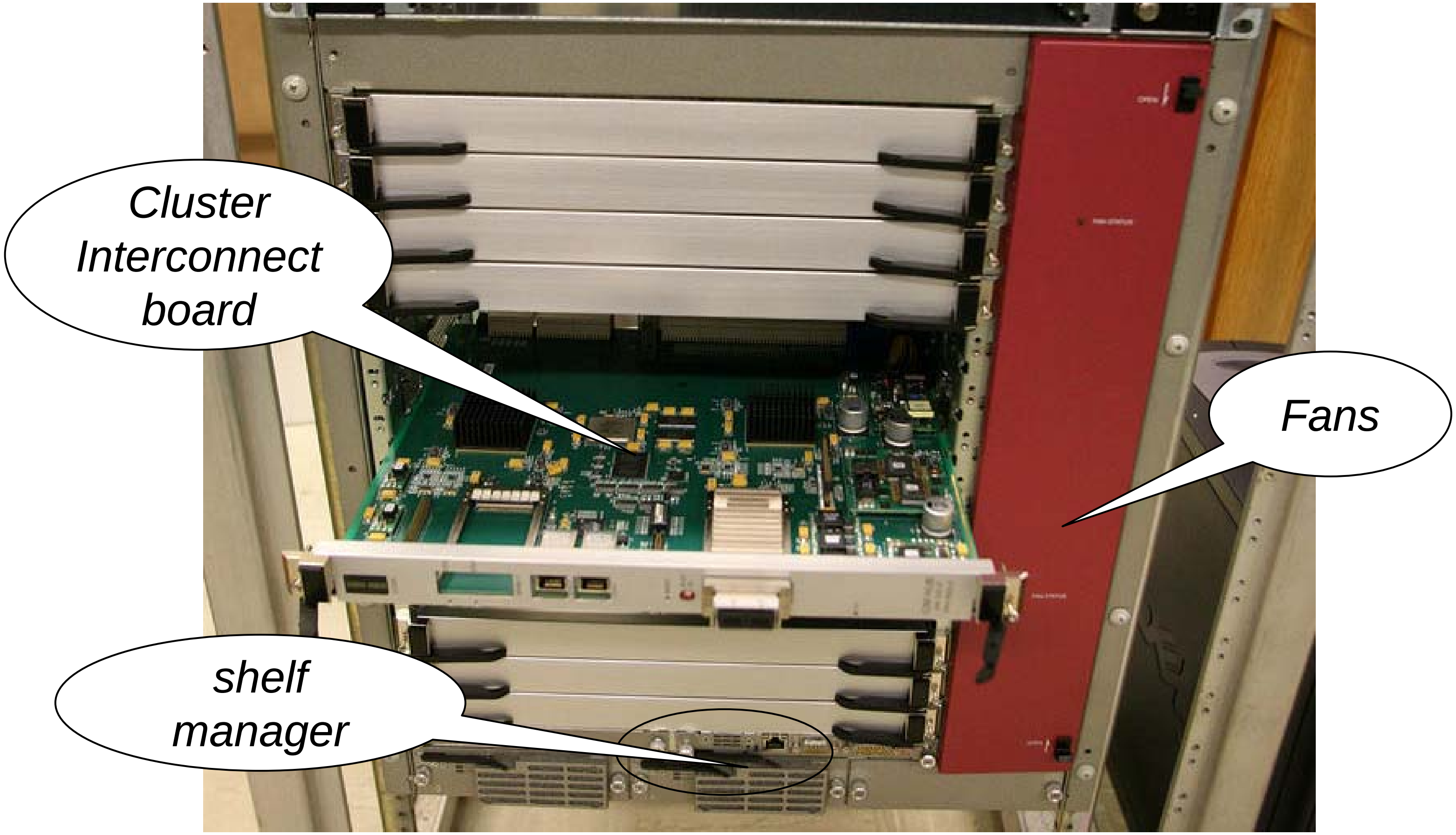
RCE board + RTM



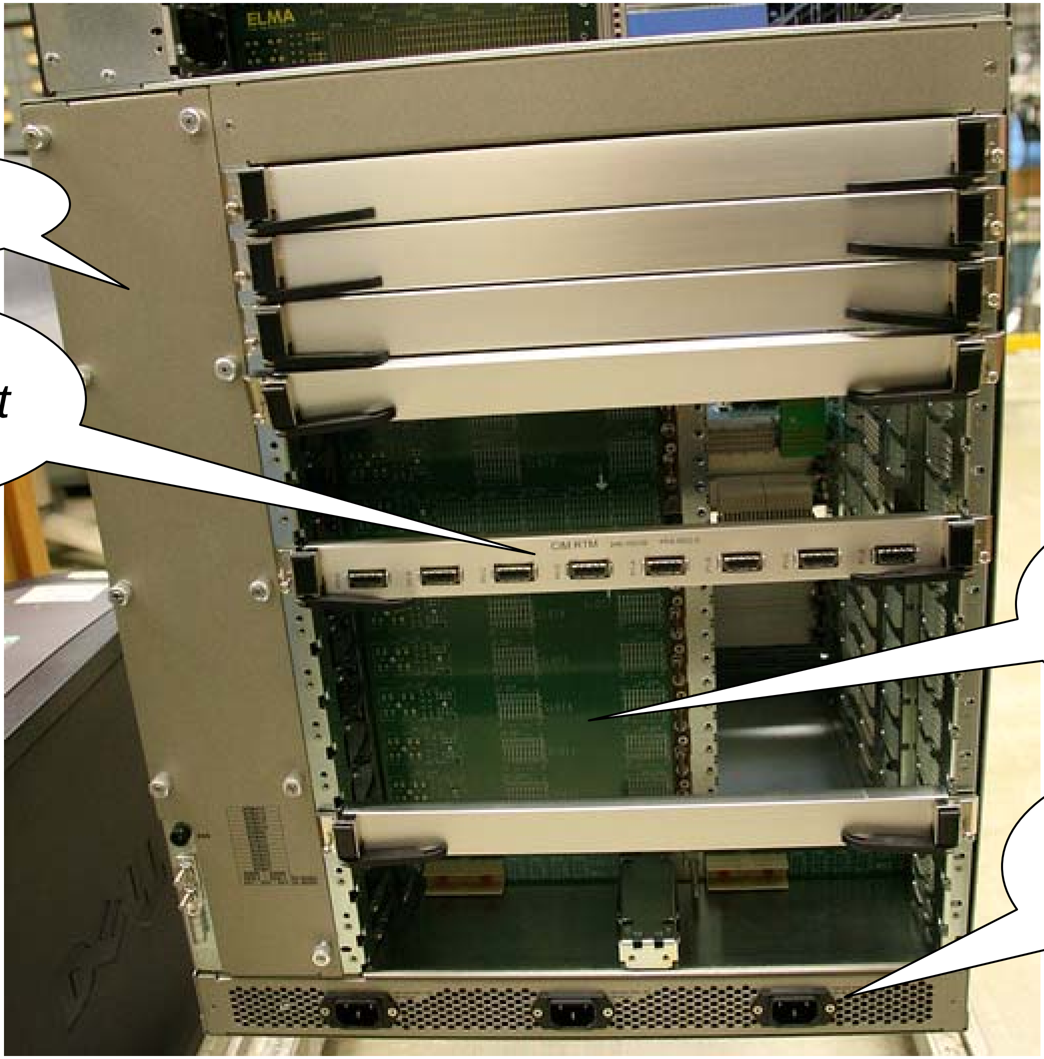
Cluster Interconnect board



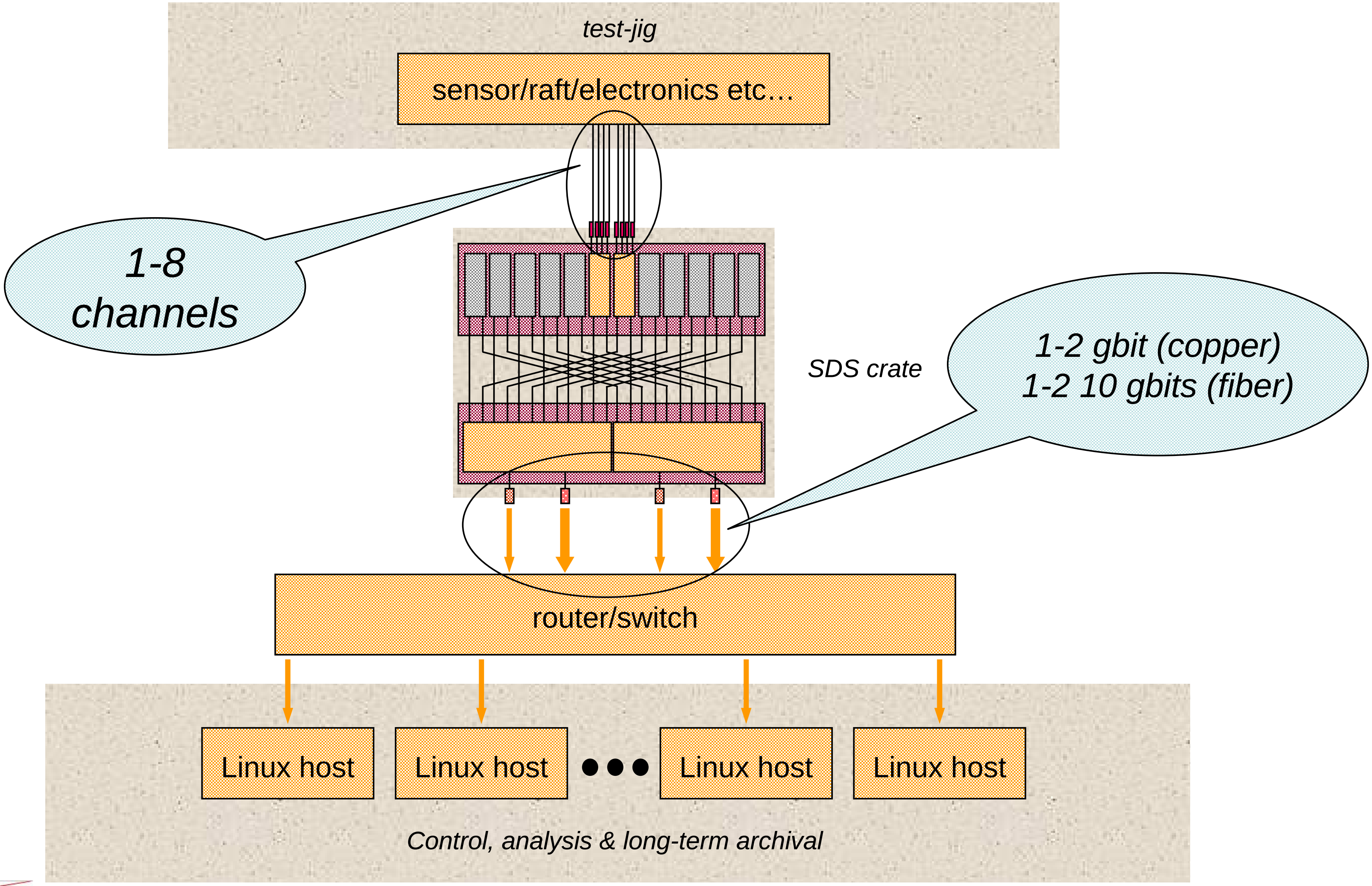
ATCA (horizontal) crate (front)



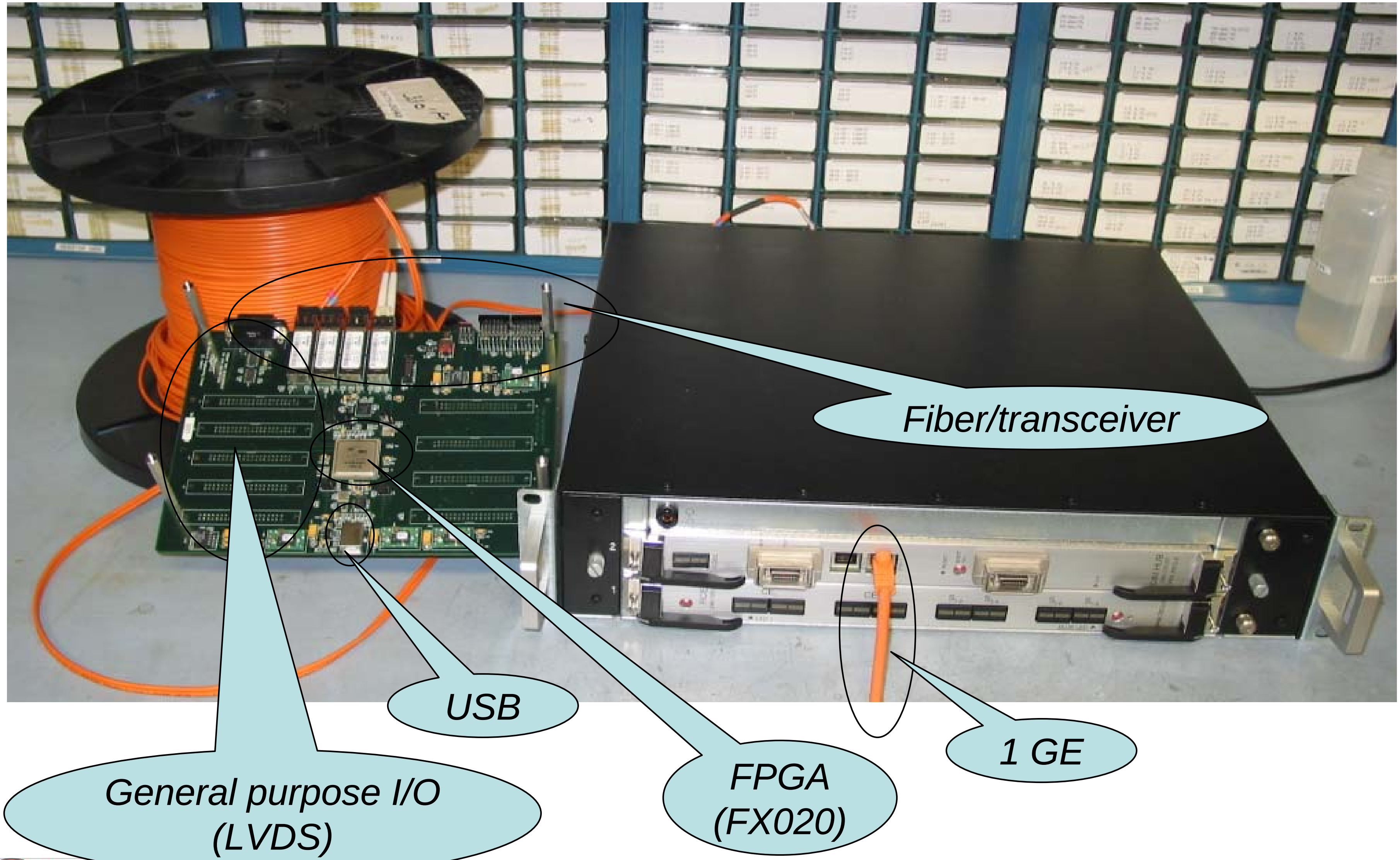
ATCA crate (back)



The test-stand crate configuration



Using the development board



Irreducible functions

- Convert read-out representation to physical representation
- Manage and perform electronics cross-talk correction
- Mount the server side of the client image interface
  - Stream data to DM
- Mount CCS interface
- Manage and perform image simulation
- Support In-situ monitoring & diagnostics
- Provide image buffering, used for…
  - "3 day" store
  - flow-control (client interface)
  - simulation
  - monitoring & diagnostics

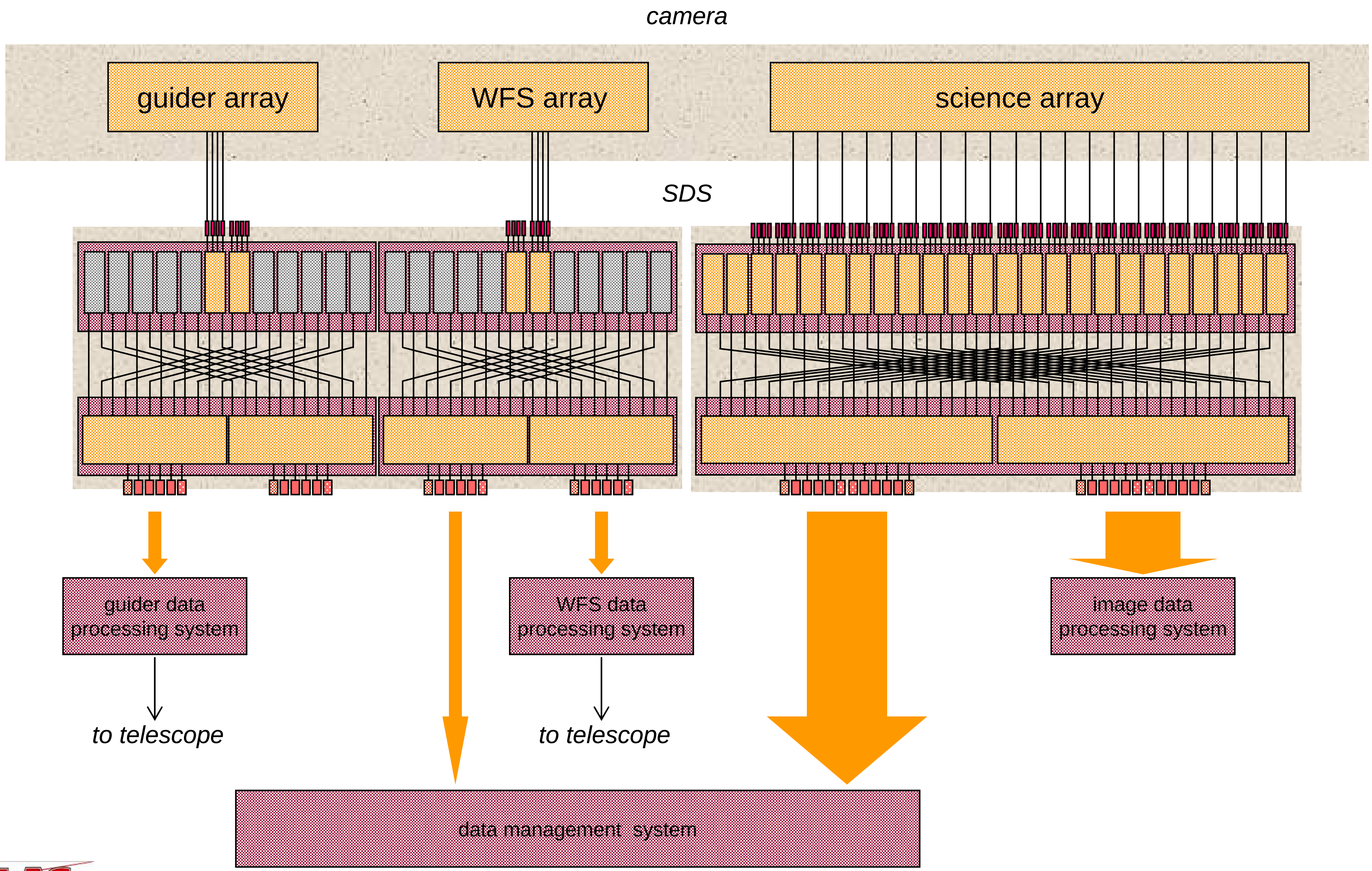
monitoring & diagnostics

- Principal purpose is to support camera development
  - sensors
  - electronics
- Scope definition, necessary capabilities will mature as camera develops
  - This is an interactive facility, not a batch facility
- Expect that these tools & applications will follow the camera & be part of its operation

- Implementation responsibility divided between SDS and processing farm
  - SDS provides:
    - image Buffering
    - data iteration & selection
  - Processing farm
    - control & management
    - visualization
- Data transfer may occur asynchronously with respect to DM streaming…

- Sizing and capability of processing farm must be able to scale with:
  - Size of sensor plant
  - Number of concurrent clients

The SDS & its *data* interfaces



SDS Summary

- **Architecture is now relatively mature**
  - **Functional prototypes are in-hand**
  - **Performance and scaling have been demonstrated to meet the performance requirements**
- **Focus has now shifted to the definition & development of the client interface. However:**
  - **A significant amount of interface work remains between camera electronics and the input side of the SDS**
  - **The specification (& implementation!) of necessary diagnostics is a work in progress**
    - A camera-centric activity, however…
    - observatory could well add to these requirements…
- **There is more then one SDS…**
  - **Support for “test-stands”**
  - **WFS & Guider activities**
  - **Full camera commissioning & operation**
    - “Building 33”
    - Mountain-top
  - **The SDS design is intended to encompass and support all these activities…**

Discussion

- Number and location of test-stands
- Software suite for LSST camera images?
  - Relation to DM
  - Evolution from testing/engineering to production/science
- Continuity of test protocols over time across multiple sites
- Management of CCD, raft, camera data from testing → operations
- Hardware, software and DB tools needed to manage the (non-production) camera data
- "Responsible person" for each subsystem as liason to CCS

Generic Ideas for Continued Discussion

- TCS/SOAR heritage where useful
- Subsystem boundaries defined by "tightly coupled"
- Implementing the event driven state machine model
- Communications:
  - Master/slave only
  - No peer-to-peer
  - Peer info via "subscription"???
- Network (tcp/ip) is only connection to subsystem
- CCS proxy modules vs. resident CCS code in subsystem.
- Use of EA and UML/SysML to document design
- CCS trac/svn site exists
- Supervision of a distributed set of processes on a distributed set of nodes:
  - Startup/shutdown
  - Logging
  - Debugging/tracing/snooping tools
  - Graphical tools for monitoring
  - Error handling/restarts
  - Links to "hardware protection system"