Camera Control System Status

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CCS System Architect and CAM, SLAC

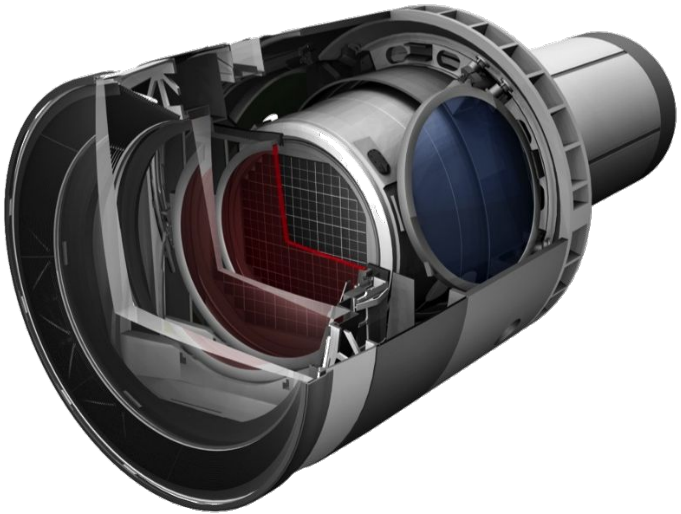
NSF/DOE Joint Status Review

August 2019

Outline

- Introduction and Scope
- Technical Status
- Recent Accomplishments & Notable Outcomes
  - Recent Accomplishments
    - Main Camera, AuxTel and ComCam
  - Remaining work and Challenges
  - Transition to Commissioning and Operations
- Risks and Mitigations Status
- Hazards
- Programmatic Status
  - Organizational Structure
  - Cost and Schedule Performance Status
  - Upcoming Major Milestones
- Summary
- Supporting Material
  - Key Documents
  - Past Review recommendations
  - BCR summaries

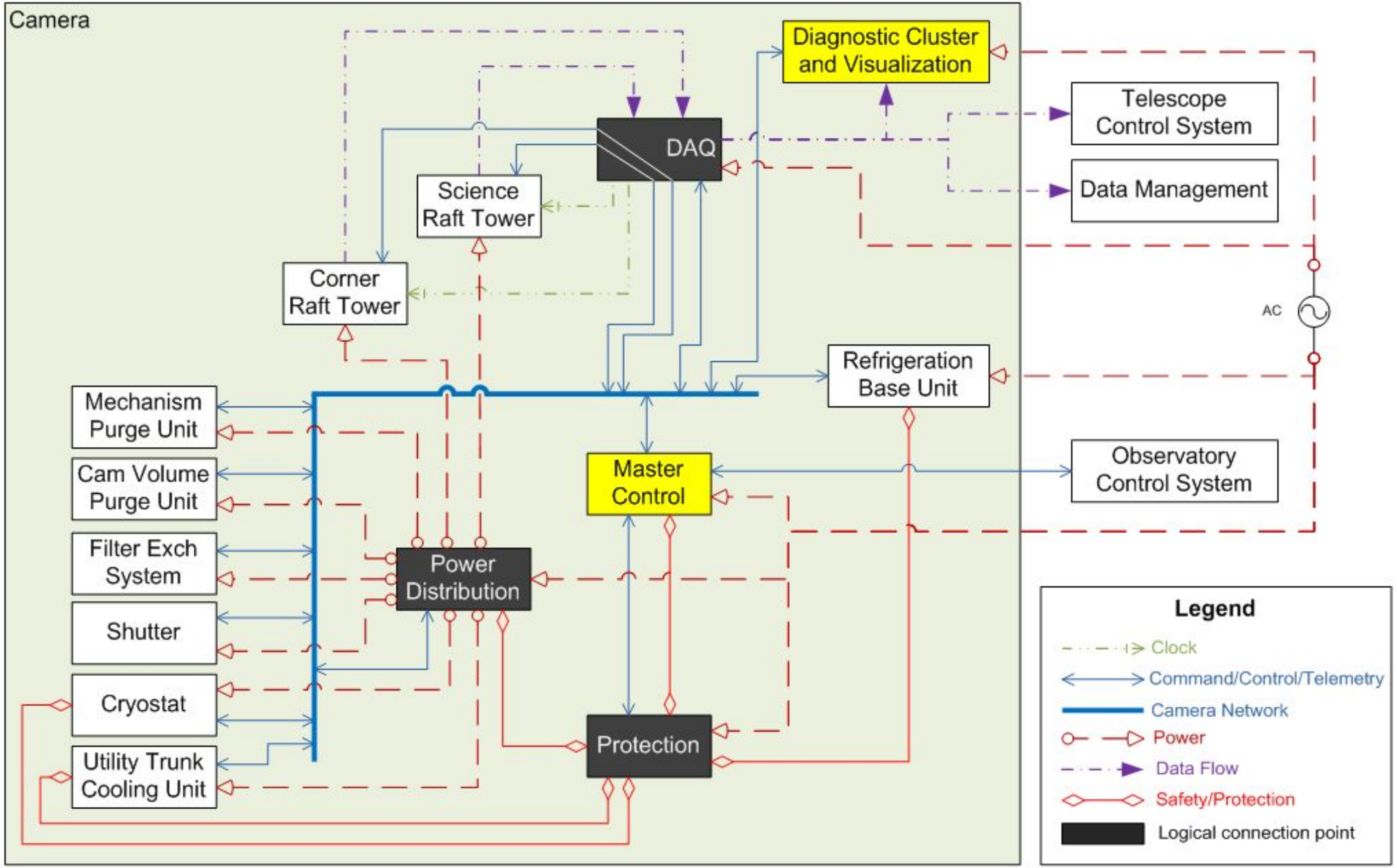
Introduction and Scope



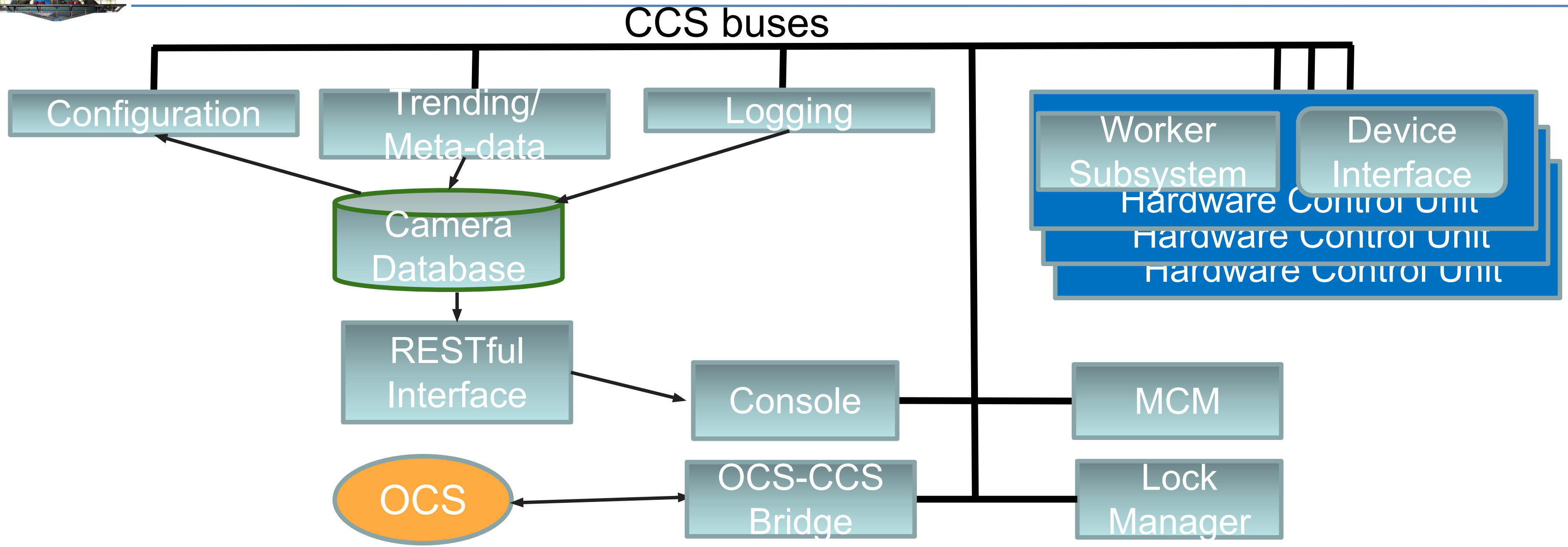
CCS Overview

- **The Camera Control System (CCS) is responsible for**
  - **Controlling, configuring and monitoring Camera subsystems**
  - **Communication with Observatory Control System (OCS)**
    - Receive commands and configuration
    - Sending command responses, events, status and trending data
  - **Camera diagnostic cluster and visualization**
  - **Camera engineering consoles**
- **Two main thrusts of development:**
  - **Test stands/prototypes/I&T (get early experience/feedback)**
    - All Camera subsystems have been initially developed as prototypes
      - Often used for testing performance of subsystem hardware "Test Stands"
    - The software used for these hardware prototypes is now becoming the production CCS subsystems shipped with the Camera
  - **Develop Camera interface to Observatory**
    - Pathfinder exercises (test observatory interfaces)
    - AuxTel (2017-2019), ComCam (2019-2020), Full Camera (2019-2021)

Camera Logical block diagram



CCS Architecture



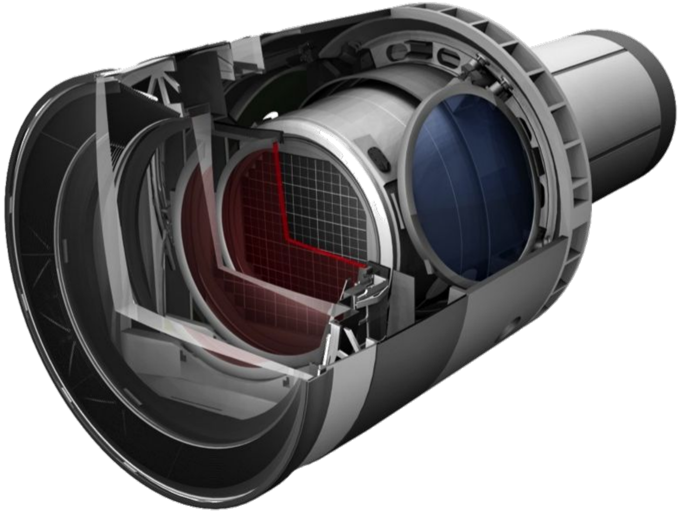
- **All modules use core CCS infrastructure written in Java**
  - **Core infrastructure provides communication protocol used by buses (jGroups)**
    - Command bus – used for commands/responses
    - Status bus – used for status messages, trending, arbitrary subsystem “meta-data”
    - Logging bus – logging messages (debug aid)
- **All modules run on Linux, either standard PC or embedded computer (Versalogic Lion and Advantech Uno)**

CCS interface to observatory (OCS)

- ICD (LSE-71) was extensively updated in 2018 to take into account changes in Observatory level documents LSE-209, LSE- 70
  - Commands remain largely unchanged
    - Lifecycle:
      - enterControl, exitControl, start <configuration>, standby, enable, disable
    - Operations:
      - initImage <deltaT>
      - takeImages <nImages> <exposure> <shutter> <science> <wavefront> <guider> <visit-name>
      - setFilter <filterSpec>
      - initGuiders <roiSpec>
    - Calibration:
      - clear <nClears>
      - startImage <shutter> <science> <wavefront> <guider> <visit-name> <timeout>
      - endImage
      - discardRows <nRows>
  - We anticipate additional requirements appearing during commissioning, and have planned for this

Large Synoptic Survey Telescope

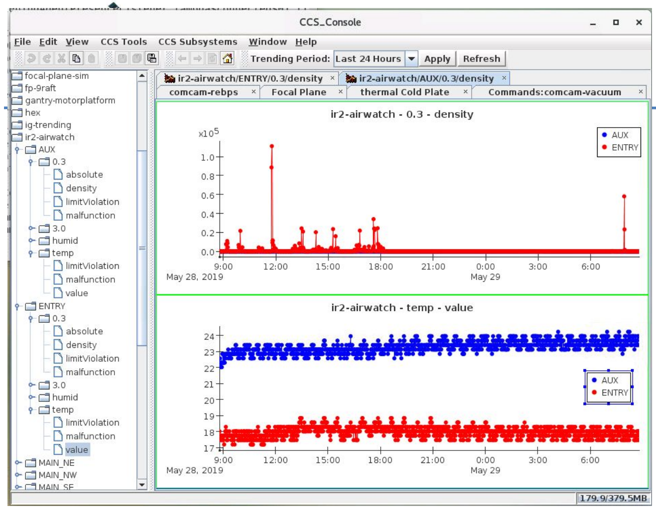
Technical Status

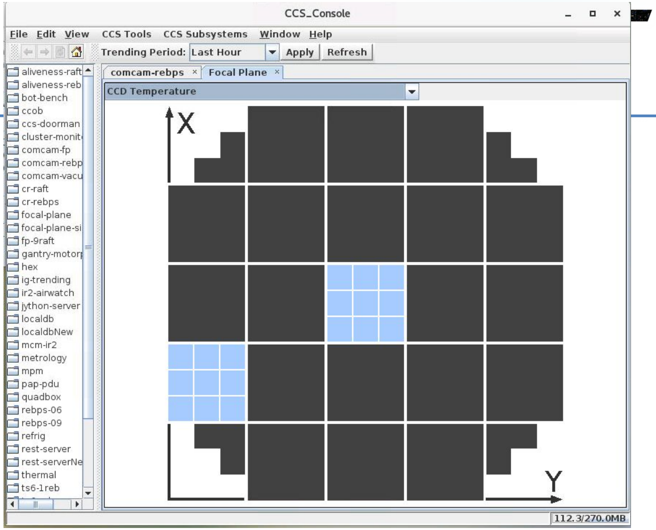


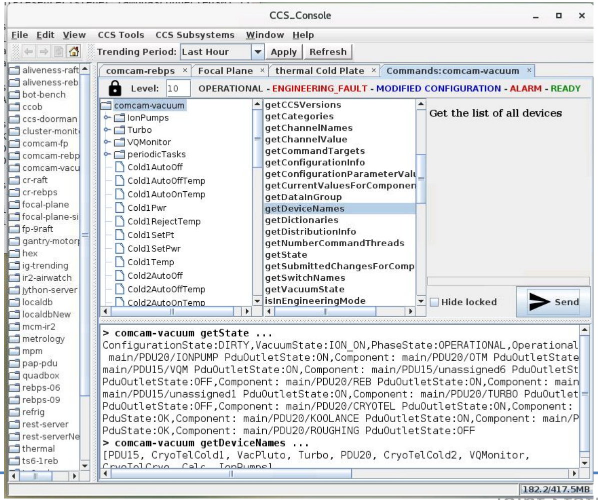
CCS Core Status

- **In use with test stands (BNL, SLAC, etc) for many years**
- **Deployed in Tucson for AuxTel for ~1 year**
- **Key features**
  - **Distributed communication system based on jGroups (multicast)**
  - **Command line interface (ccs-shell)**
  - **Graphical console (ccs-console)**
    - plugins to support subsystem specific functionality
  - **Python scripting (ccs-script) for debugging, automation, test-stands**
  - **Telemetry database records time-histories for monitored quantities**
    - Restful interface makes data available to:
      - CCS Console
      - Web based time history plotting tool
      - Other utilities (e.g. python scripts, jupyter etc)
  - **Configuration database (under development)**
    - Currently using .properties files stored in github until final system complete
  - **Lock manager (partially implemented)**
    - Allows local-control to be locked out when under observatory control

CCS Console


CCS_Console
File Edit View CCS Tools CCS Subsystems Window Help
Trending Period: Last 24 Hours Apply Refresh
ir2-airwatch/ENTRY/0.3/density
ir2-airwatch/AUX/0.3/density
comcam-rebps Focal Plane thermal Cold Plate Commands:comcam-vacuum
ir2-airwatch - 0.3 - density
AUX
ENTRY
May 28, 2019
May 29
ir2-airwatch - temp - value
179.9/379.5MB


CCS_Console
File Edit View CCS Tools CCS Subsystems Window Help
Trending Period: Last Hour Apply Refresh
comcam-rebps Focal Plane
CCD Temperature
X
Y
112.3/270.0MB


CCS_Console
File Edit View CCS Tools CCS Subsystems Window Help
Trending Period: Last Hour Apply Refresh
comcam-rebps Focal Plane thermal Cold Plate Commands:comcam-vacuum
Level: 10 OPERATIONAL - ENGINEERING_FAULT - MODIFIED CONFIGURATION - ALARM - READY
Get the list of all devices
Hide locked
Send
> comcam-vacuum getState ...
> comcam-vacuum getDeviceNames ...
182.2/417.5MB


CCS_Console
File Edit View CCS Tools CCS Subsystems Window Help
Trending Period: Last Hour Apply Refresh
comcam-rebps Focal Plane thermal Cold Plate
COLD PLATE RTD & TRIM HEATER STRINGS
VIEW THRU L3
TRIM HEATERS
ColdHtr 5 Power
ColdHtr 4 Power
ColdHtr 3 Power
ColdHtr 2 Power
ColdHtr 1 Power
ColdHtr 0 Power
TOTAL TRIM POWER: 0.0 W
Red=Protection RTD
127.9/271.5MB

CCS Web Trending tool

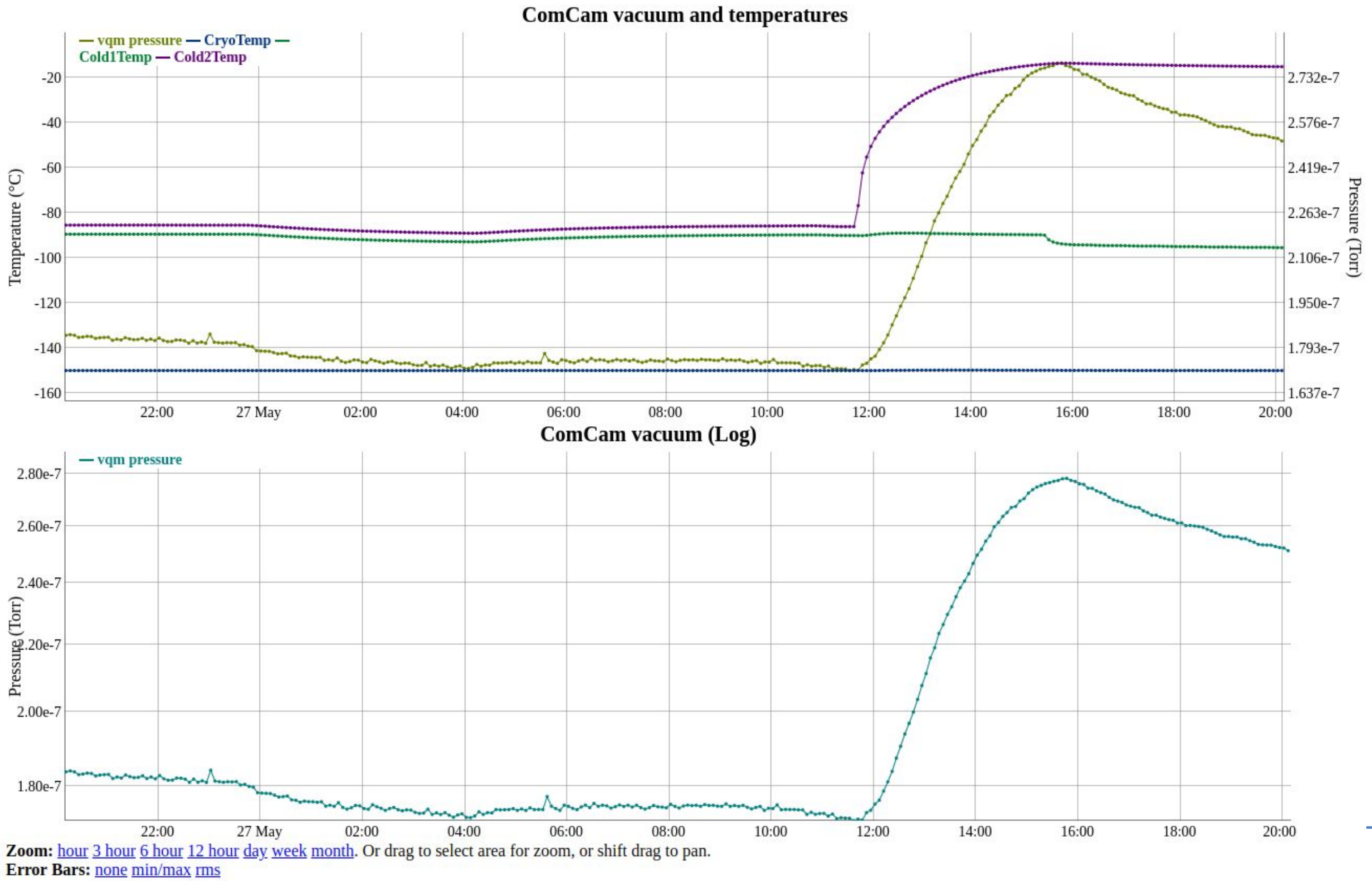


Image Visualization (quick view)

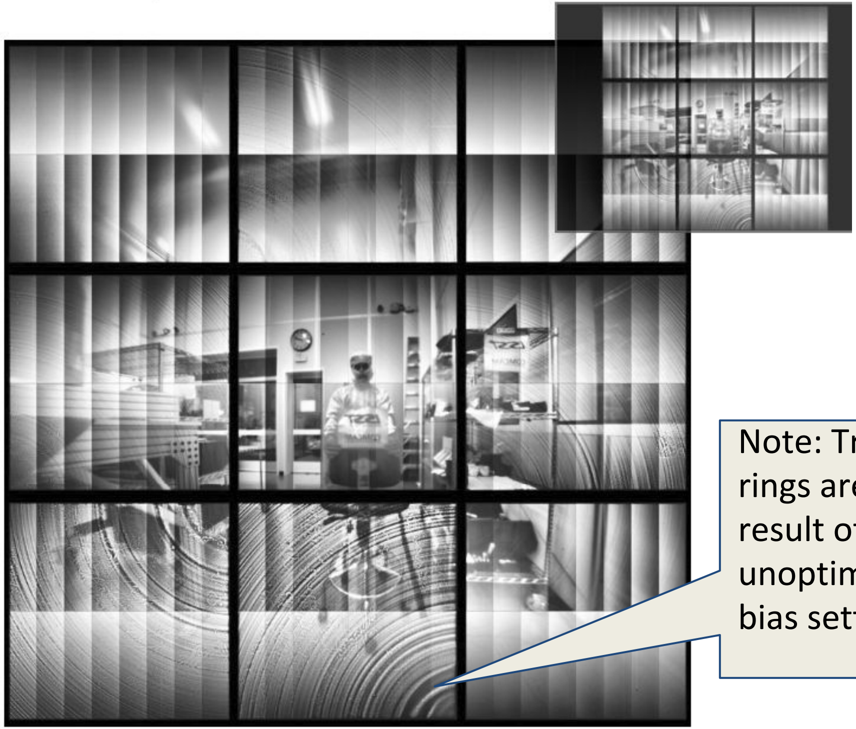
LSST Camera Image Viewer

Image: CC_C_20190306_000082 Raft: R22 Test Type: DARK Image Type: DARK

Run: Time: 2019-03-07T06:10:59

ComCam | Obs Day | Search...

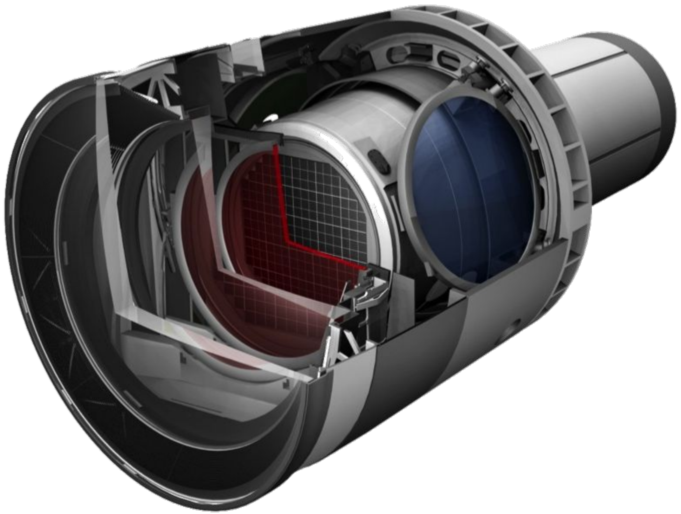
Obs Id	Image Type	Test Type	Obs Time	Rafts
Obs Day: 20190319 (60 images)				
Obs Day: 20190306 (98 images)				
CC_C_20190306_000001	BIAS	BIAS	2019-03-07T05:17:23	R22
CC_C_20190306_000002	BIAS	BIAS	2019-03-07T05:17:28	R22
CC_C_20190306_000003	BIAS	BIAS	2019-03-07T05:17:34	R22
CC_C_20190306_000004	BIAS	BIAS	2019-03-07T05:17:41	R22
CC_C_20190306_000005	BIAS	BIAS	2019-03-07T05:17:46	R22
CC_C_20190306_000006	BIAS	BIAS	2019-03-07T05:17:51	R22
CC_C_20190306_000007	BIAS	BIAS	2019-03-07T05:17:57	R22
CC_C_20190306_000008	BIAS	BIAS	2019-03-07T05:18:03	R22
CC_C_20190306_000009	BIAS	BIAS	2019-03-07T05:18:08	R22
CC_C_20190306_000010	BIAS	BIAS	2019-03-07T05:18:16	R22
CC_C_20190306_000011	BIAS	BIAS	2019-03-07T05:40:33	R22
CC_C_20190306_000012	BIAS	BIAS	2019-03-07T05:40:38	R22
CC_C_20190306_000013	BIAS	BIAS	2019-03-07T05:40:43	R22
CC_C_20190306_000014	BIAS	BIAS	2019-03-07T05:40:48	R22
CC_C_20190306_000015	BIAS	BIAS	2019-03-07T05:40:54	R22
CC_C_20190306_000016	BIAS	BIAS	2019-03-07T05:40:59	R22
CC_C_20190306_000017	BIAS	BIAS	2019-03-07T05:41:05	R22



Note: Tree rings are result off unoptimized bias settings

Try the preview…
https://lsst-camera-dev.slac.stanford.edu/FITSInfo/

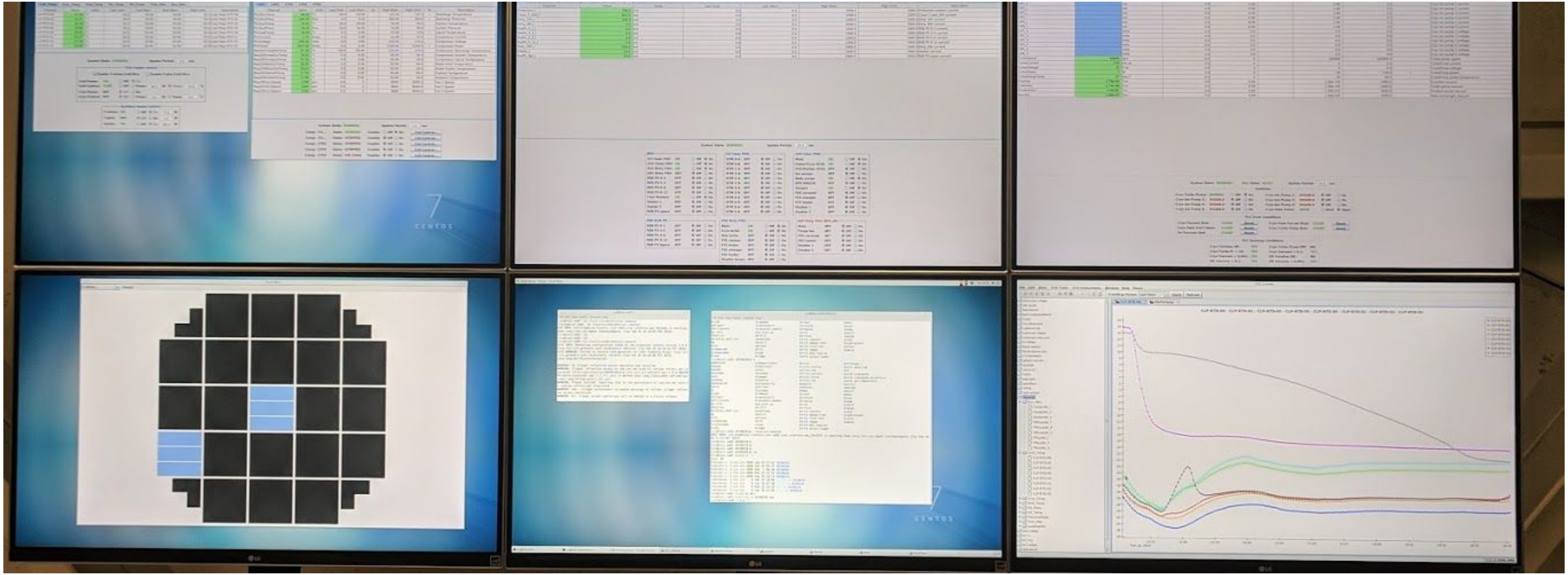
Recent Accomplishments & Notable Outcomes



BOT Test Stand

- **Major accomplishment was operation of BOT test stand in April/May 2019**
  - **2 Engineering Test Unit (ETU) rafts installed in cryostat**
  - **CCS controlled and monitored most camera subsystems**
    - DAQ (v1.5) and raft electronics boards (REBs)
    - Utility Trunk/Quadbox including REB power supplies
    - Refrigeration/Cryo systems
    - Various test heads (CCOB, flat-illuminator, etc)
      - Some mounted on movable BOT x-y stage
    - Controlled readout and generation of FITS files
      - Over 37,00 exposures (>500,000 FITS files) generated and analyzed
      - Mirrored to NCSA for future offline DM analysis
  - **Next step - "9 raft" BOT operations**
    - Will use DAQ (v4.0)

BOT Test Stand Operations



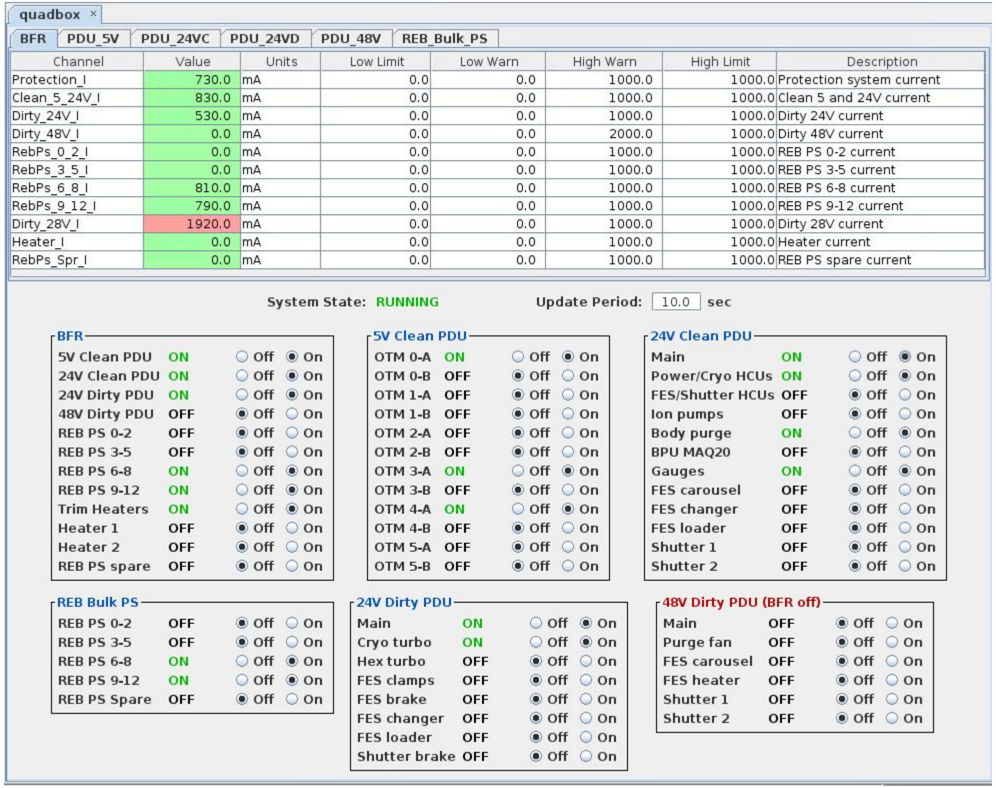
- **BOT operations controlled by running shifts in IR2 control room**
  - **Mimicking the way the camera will be operated in Chile**

Focal-plane subsystem

- Controls and Monitors all raft electronics boards
- Controls and Monitors CCDs, including PID loop for temperature control
- Loads sequencer and DACs in REB boards to control readout
- Handles image data received from DAQ
  - Generates FITS files for analysis on diagnostic cluster
    - Also archived to NCSA during BOT operations
  - Feeds image data to “quick-view” visualization system
  - Keeps database record for all images taken
- Provides specialized GUIs for monitoring health of all electronics/CCDs
- For “9-raft operations”
  - Will use DAQ v4.0 (essentially final DAQ API)
  - WIll split image processing across multiple nodes of diagnostic cluster
  - Parallelization of monitoring across multiple threads

QuadBox/Utility Trunk

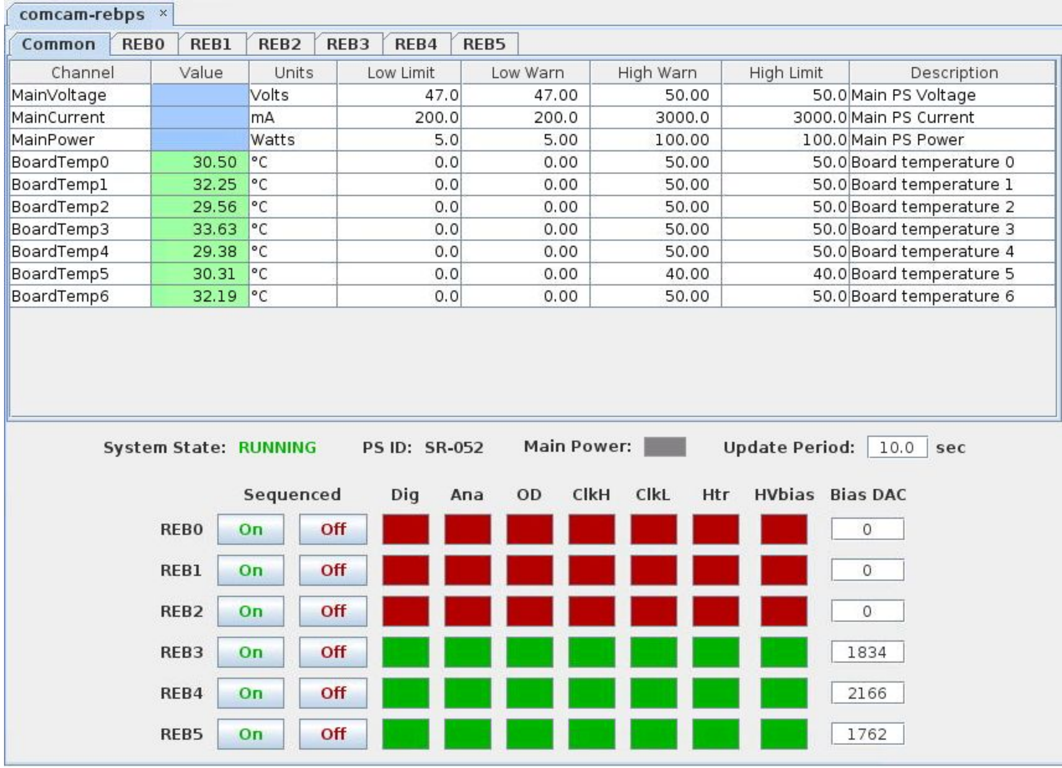
- Control of quadbox power systems in place
  - Quadbox for ComCam (similar but not identical) is under test
- Work remaining on testing of camera body/purge systems (for thermal control of various camera volumes)
  - Test electronics rack created, software being finalized, testing should be completed before end of August.



Channel	Value	Units	Low Limit	Low Warn	High Warn	High Limit	Description
Protection_I	730.0	mA	0.0	0.0	1000.0	1000.0	Protection system current
Clean_5_24V_I	830.0	mA	0.0	0.0	1000.0	1000.0	Clean 5 and 24V current
Dirty_24V_I	530.0	mA	0.0	0.0	1000.0	1000.0	Dirty 24V current
Dirty_48V_I	0.0	mA	0.0	0.0	2000.0	1000.0	Dirty 48V current
RebPs_0_2_I	0.0	mA	0.0	0.0	1000.0	1000.0	REB PS 0-2 current
RebPs_3_5_I	0.0	mA	0.0	0.0	1000.0	1000.0	REB PS 3-5 current
RebPs_6_8_I	810.0	mA	0.0	0.0	1000.0	1000.0	REB PS 6-8 current
RebPs_9_12_I	790.0	mA	0.0	0.0	1000.0	1000.0	REB PS 9-12 current
Dirty_28V_I	1920.0	mA	0.0	0.0	1000.0	1000.0	Dirty 28V current
Heater_I	0.0	mA	0.0	0.0	1000.0	1000.0	Heater current
RebPs_Spr_I	0.0	mA	0.0	0.0	1000.0	1000.0	REB PS spare current

REB Power Supply GUI

- REB power supply for control of electronics boards + CCDs
  - Prototype in use with test stands for several years
  - Production boards now in use in quadbox
  - CCS GUI currently has one page per supply
    - But wiring between power supplies and REBs is complex
- Improved GUI, for people who have not memorized the wiring diagram, nearly complete

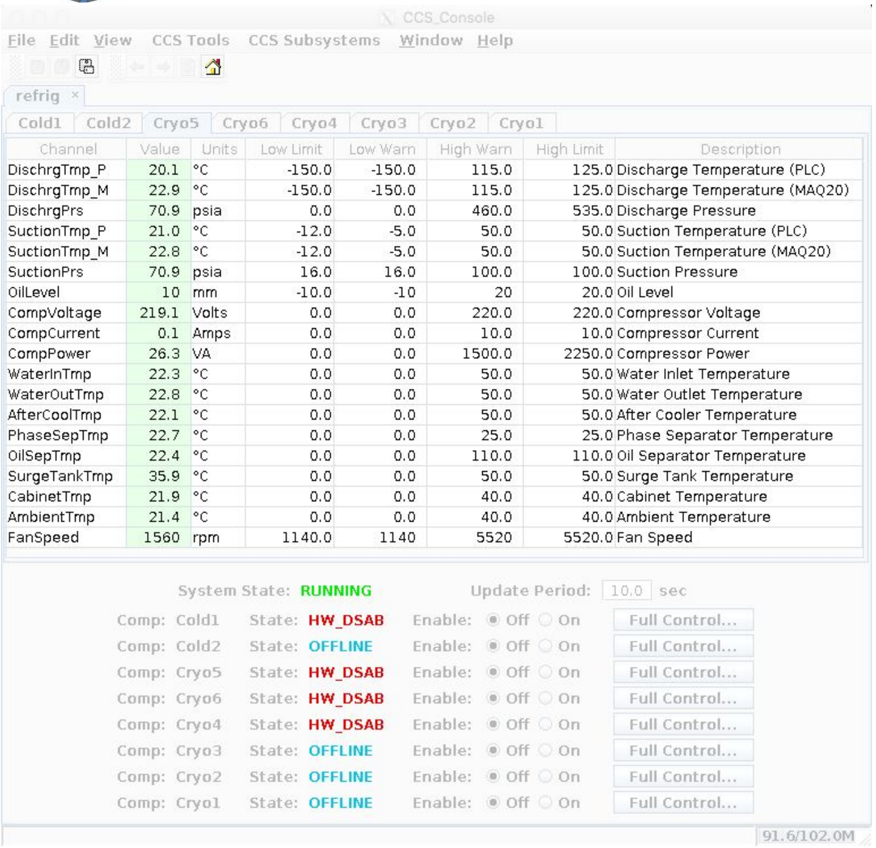


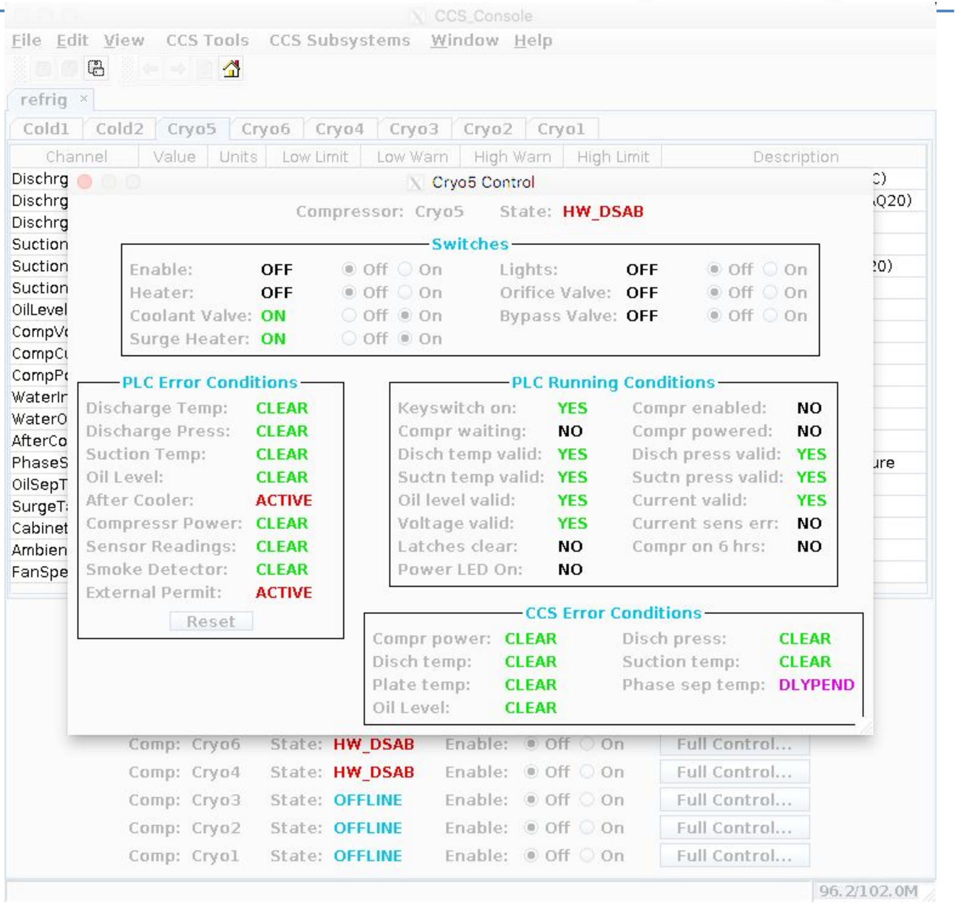
Channel	Value	Units	Low Limit	Low Warn	High Warn	High Limit	Description
MainVoltage		Volts	47.0	47.00	50.00	50.0	Main PS Voltage
MainCurrent		mA	200.0	200.0	3000.0	3000.0	Main PS Current
MainPower		Watts	5.0	5.00	100.00	100.0	Main PS Power
BoardTemp0	30.50	°C	0.0	0.00	50.00	50.0	Board temperature 0
BoardTemp1	32.25	°C	0.0	0.00	50.00	50.0	Board temperature 1
BoardTemp2	29.56	°C	0.0	0.00	50.00	50.0	Board temperature 2
BoardTemp3	33.63	°C	0.0	0.00	50.00	50.0	Board temperature 3
BoardTemp4	29.38	°C	0.0	0.00	50.00	50.0	Board temperature 4
BoardTemp5	30.31	°C	0.0	0.00	40.00	40.0	Board temperature 5
BoardTemp6	32.19	°C	0.0	0.00	50.00	50.0	Board temperature 6

Cryo/Refrigeration/Vacuum

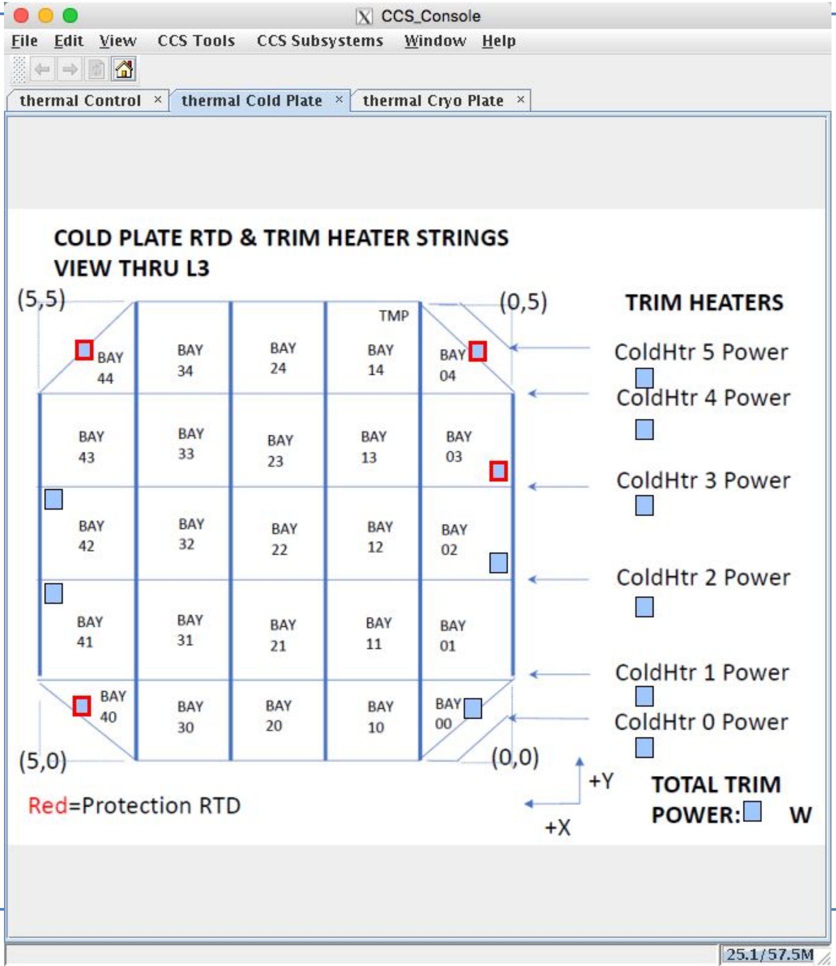
- **CCS provides full control and monitoring of the cryo/cold systems**
  - **3 CCS subsystems:**
    - The refrigeration subsystem (refrig) controls and monitors the two cold refrigeration compressors and six cryogenic compressors.
    - The heat exchanger subsystem (hex) monitors the corresponding two cold and six cryogenic heat exchangers.
    - The thermal subsystem (thermal) controls and monitors the trim heaters used to maintain the temperatures of the cold and cryogenic plates.
  - **In addition the vacuum subsystem provides:**
    - Control of turbo and ion pumps on the pump plate, plus pressure monitoring at various locations

Cryo/Refrigeration GUI

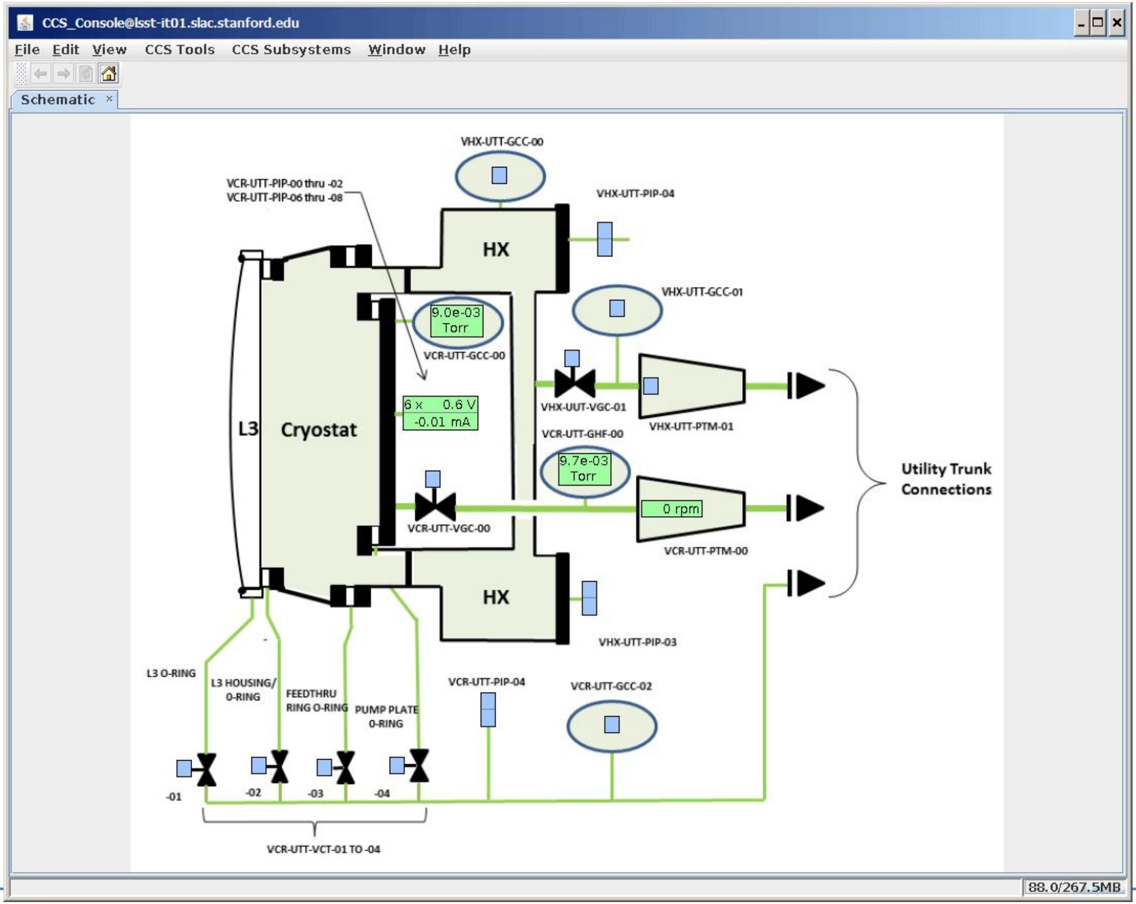




Thermal Subsystem Cold Plate GUI

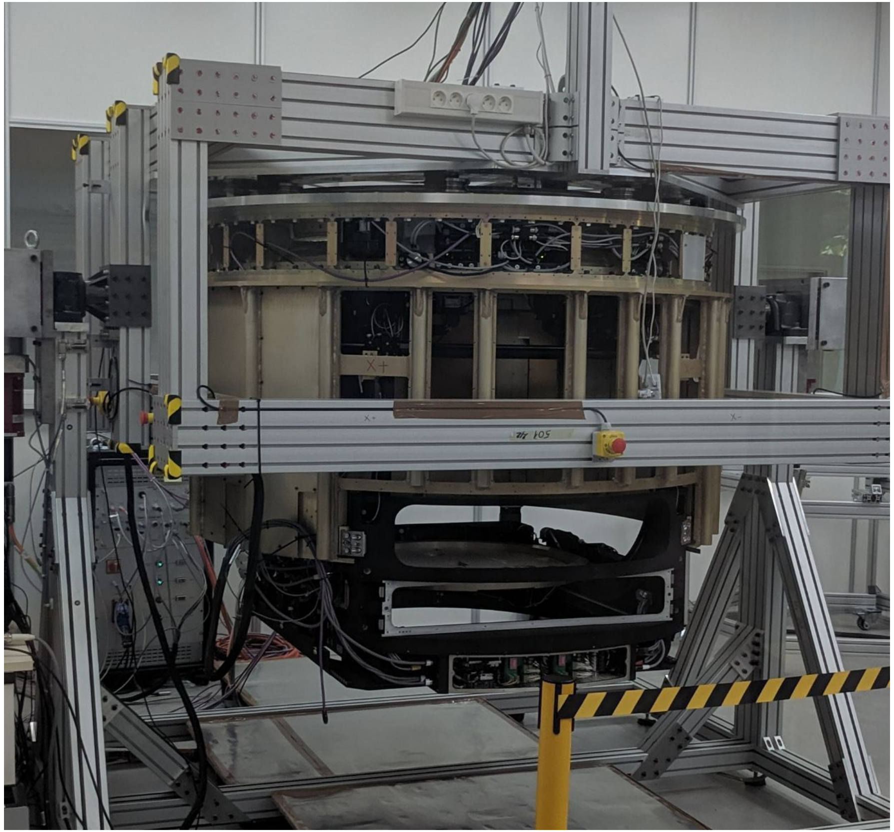


Pump Plate Monitoring GUI

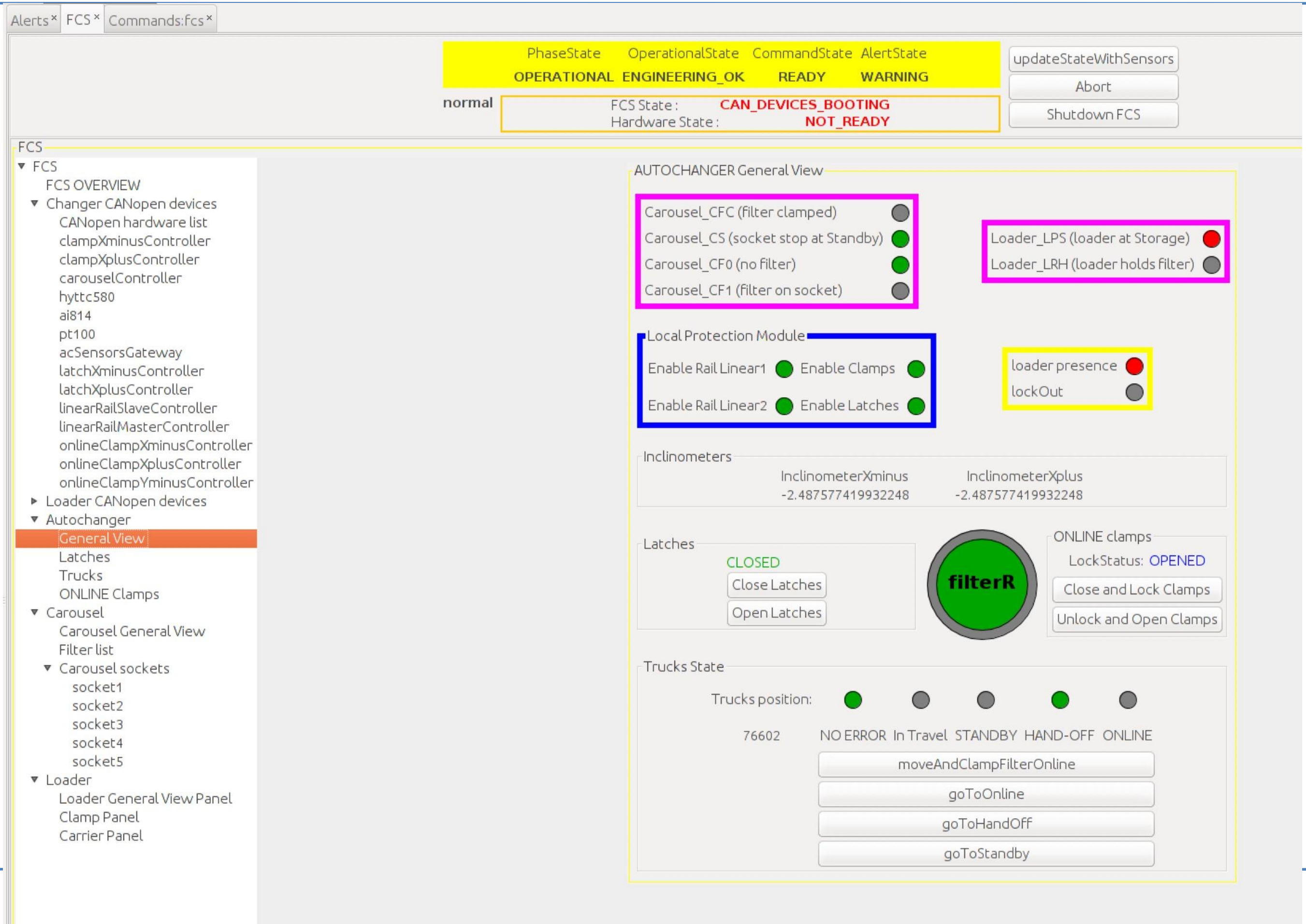


Filter Changer Subsystem (FCS)

- **Carousel, Auto Changer, and Loader all installed in Paris**
  - **CCS can operate each component independently or operate combined system (FCS)**
  - **Transfer of filters between carousel and auto changer under CCS control working**
    - Some remaining reliability issues being finalized
- **Activities when system arrives in SLAC clean room**
  - **Initial testing will be done with electronics (and experts) from Paris**
  - **HCU and canbus interface already exists in quadbox, and is functionally equivalent to custom electronics**



FCS GUI



Alerts
FCS
Commands:fcs
PhaseState OperationalState CommandState AlertState
OPERATIONAL ENGINEERING_OK READY WARNING
updateStateWithSensors
Abort
Shutdown FCS
normal
FCS State : CAN_DEVICES_BOOTING
Hardware State : NOT_READY
FCS
FCS
FCS OVERVIEW
Changer CANopen devices
CANopen hardware list
clampXminusController
clampXplusController
carouselController
hyttc580
ai814
pt100
acSensorsGateway
latchXminusController
latchXplusController
linearRailSlaveController
linearRailMasterController
onlineClampXminusController
onlineClampXplusController
onlineClampYminusController
Loader CANopen devices
Autochanger
General View
Latches
Trucks
ONLINE Clamps
Carousel
Carousel General View
Filter list
Carousel sockets
socket1
socket2
socket3
socket4
socket5
Loader
Loader General View Panel
Clamp Panel
Carrier Panel
AUTOCHANGER General View
Carousel_CFC (filter clamped)
Carousel_CS (socket stop at Standby)
Carousel_CF0 (no filter)
Carousel_CF1 (filter on socket)
Loader_LPS (loader at Storage)
Loader_LRH (loader holds filter)
Local Protection Module
Enable Rail Linear1
Enable Clamps
Enable Rail Linear2
Enable Latches
loader presence
lockOut
Inclinometers
InclinometerXminus
-2.487577419932248
InclinometerXplus
-2.487577419932248
Latches
CLOSED
Close Latches
Open Latches
filterR
ONLINE clamps
LockStatus: OPENED
Close and Lock Clamps
Unlock and Open Clamps
Trucks State
Trucks position:
76602
NO ERROR In Travel STANDBY HAND-OFF ONLINE
moveAndClampFilterOnline
goToOnline
goToHandOff
goToStandby

Shutter

- **Shutter hardware changed since early prototypes**
  - **Now uses Beckhoff controller**
    - TwinCAT 3 RT kernel under Windows Embedded Standard 7
      - Local EtherCAT bus
      - Motor control modules
      - Digital input modules
      - PTP module (64-bit, nanosecond precision)
    - Hall switches wired to EtherCAT I/O modules
      - Generates timestamp on change of state
  - **Has required complete rewrite of CCS driver, including developing a command protocol for communication between internal firmware programmed beckhoff state machine and externally visible CCS state machine**
    - Subsystem now complete and ready for combined CCS+firmware+hardware testing
    - Work still needed to adapt GUI to new subsystem functionality

AuxTel (not part of MIE project)

- AuxTel has been operating in Tucson since ? 2018
  - Single CCD operating using DAQ (v1.5), WREB and CCs
    - CCS controls DAQ, WREB and power supplies
      - Similar to full camera
    - CCS controls Bonn Shutter (similar to ComCam)
    - CCS monitors vacuuum and temperature
    - CCS controls Power distribution (via PDU)
  - DAQ data fed to DM similarly to main camera
    - DM Header Service and DM archiver service
  - Custom filter changer and shutter
    - Software developed and initial testing at SLAC complete
  - Master Control Module (MCM) and Observatory Control System interface (OCSBridge) operature similar to full camera
    - Invaluable it debugging interface between CCS, DM and OCS/TCS.
  - Will Ship to Chile before end of 2019

ComCam

- **For CCS ComCam represents an opportunity to test many camera components prior to shipping complete Camera**
  - **Single Raft (9 CCDs) operating in same mode as full camera**
    - Focal-plane subsystem, DAQ, REB power, CCD conditions
    - Vacuum and thermal systems similar to camera
  - **Custom filter changer and shutter**
    - Software developed and initial testing at SLAC complete
- **ComCam itself is now in Tucson**
  - **Aim to complete CCS installation for ComCam in Tucson in August**
- **Quadbox for ComCam is being finalized at SLAC (commissioning scope)**
  - **Will be integrated at Tucson in September**
- **Testing of integration with Observatory Control System**
  - **Scheduled for October->January 2020**

Work remaining and outstanding issues

- **Camera Subsystems with ongoing work**
  - **Shutter**
    - Full testing of combined CCS + Beckhoff firmware underway
  - **Camera Body**
    - Initial testing of Camera body temperature control loops now in progress
  - **Camera Rotator**
    - Controlled using OCS via reverse CCS->OCS bridge
  - **Readout of Full Focal Plane**
    - Daq 4.x was delivered at end of June, puts CCS control of readout from "9-raft" focal-plane on critical path
  - **Filter Changer and CCOB Wide beam projector**
    - Being developed by IN2P3 in france
  - **Integrated Camera operation with Master Control Module and OCS Bridge**

Work remaining and Outstanding Issues

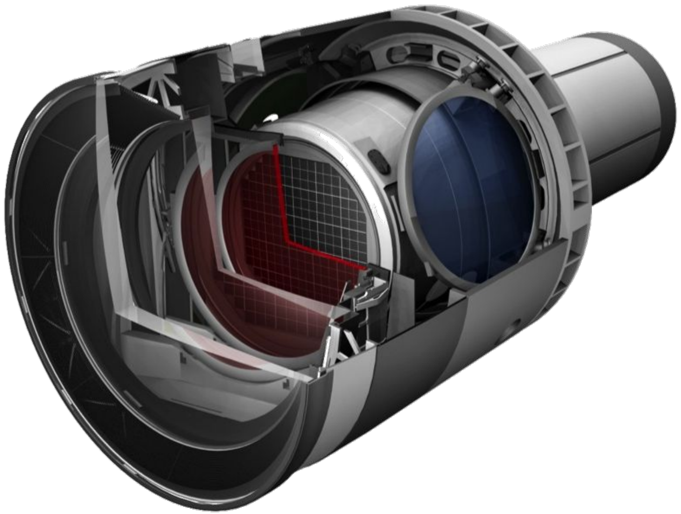
- **CCS Core**
  - Schedule for some work has been extended due to lack of manpower availability at IN2P3
    - Lock Manager implementation is not complete
      - Lock manager prevents different console/users from gaining access to system, and controls which commands users are authorized to issue.
      - This functionality is not critical until CCS is operating under OCS control for the full camera
      - Workaround: Take care in coordinating work between users
    - Configuration database
      - Currently we work around this by using .property files stored in github to provide equivalent functionality
        - » Missing features are time histories of configuration values and versioning of new configurations
  - Performance
    - Requirements on CCS stipulate <40ms overhead on image taking caused by message transport time.
      - Currently we have tails in message transport time which exceed this
      - Extensive diagnostics are being impemented to diagnose and fix this

Transition to commissioning and operations

- **CCS is already contributing to observatory commissioning:**
  - **Pathfinder/Early integration exercises**
  - **AuxTel operation in Tucson**
  - **ComCam operation at SLAC and (soon) in Tucson, then Chile**
  - **Refrigeration pathfinder on summit in Chile**
    - We will be installing first CCS servers to support this in September/October
    - We will be installing full set of CCS servers for ComCam/Main Camera before the end of 2019
      - See commissioning breakout session for updates on pathfinder
- **We expect a subset of CCS personnel to migrate to commissioning and then operations, to ensure continuity of support.**

Large Synoptic Survey Telescope

Risks and Mitigations



Definition of Risk and Risk Analysis

Risk can be defined as an undesirable event during project execution that negatively affects program goals for performance, cost or schedule.

- Risk management is the ***ongoing process*** of ***comprehensively assessing*** project risks.
- Camera Risk Management Plan (LCA-29-A) defines the methodology to manage our risks

Definition of Risk Probability

Pts	Likelihood of Occurrence	Approximate Probability	Description of Probability
1	Rare	<1%	Likelihood of occurrence is not credible
2	Unlikely	1-5%	Not reasonably expected to occur
3	Possible	5-25%	Possible, or difficult to assess the chance of occurrence
4	Likely	25-67%	Very likely that an adverse event will occur
5	Highly Probable	>67%	High probability that an adverse event will come to pass

Definition of Risk Impact

Pts	Severity of Impact	Description of Impact
Cost Impact		
1	Insignificant	Overrun of cost of < $30K, recoverable with project contingency
2	Minor	Overrun of cost of $30k - $200K, recoverable with project contingency
3	Moderate	Overrun of cost of 200k - $1.5M, with significant impact on contingency
4	High	Overrun of baseline cost of $1.5M - $10M, with re-baseline required
5	Critical	Overrun of baseline cost of >$10M, with project in jeopardy
Schedule Impact		
1	Insignificant	Degradation of schedule margin to project critical path by < 2 wks
2	Minor	Degradation of schedule margin to project critical path by 2 wks to 1.5 months
3	Moderate	Degradation of schedule margin to project critical path by 1.5 to 3 months
4	High	Degradation of schedule margin to project critical path by 3 to 6 months
5	Critical	Degradation of schedule margin to project critical path by > 6 months
Performance Impact		
1	Insignificant	No effect on ability to meet requirements; minor design changes needed
2	Minor	Minor excursion from subsystem requirement, but compensated elsewhere
3	Moderate	Level 2 and/or SRD design specification exceeded
4	High	Level 1 and/or SRD minimum specification exceeded
5	Critical	Unable to achieve any of the primary science missions

Risk Score

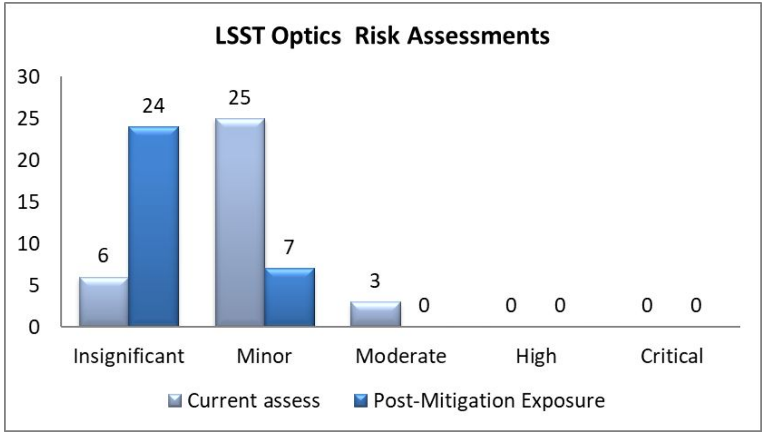
Total Impact					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Risk Probability	1	2	3	4	5

Risk Level
Critical
High
Moderate
Minor
Insignificant

- Quasi-quantitative process to assign objective values to probability of occurrence and impact of occurrence aspects of risk.
- Total Impact:
  (0.50*Cost Impact) +
  (0.33*Schedule Impact) +
  (0.33*Performance Impact)
- Risk Score:
  Risk Probability * Total Impact

Standardized risk management processes are used to manage CB&S risks

- Risks are tracked in the Camera Risk registry, Document LCA-29
- Risk exposure is assessed and tracked at regular intervals since 2010 (initial assessment)
- Actively planning mitigation to burn down risks and monitor progress
  - Current status: total risks identified
    - 35 risks are actively being mitigated
    - 11 are closed or accepted due to design changes or mitigation completion
- Mitigations are budgeted in the scope of work
- After budgeted mitigation (Post-Mitigation) is performed, residual risk is analyzed



Selected top risks are shown below:

- Opt-021: Selected filter coating vendor cannot meet specifications in a band (Moderate Risk)
  - Development contract will demonstrate all coatings well ahead of filter coating with 5 of 6 demonstrated to date
- Opt-039: Filter delivery (Moderate Risk)
  - Schedule contingency
  - First article planned
- Opt-001: Filter coating doesn't meet specifications (Moderate Risk)
  - Development contract will demonstrate all capability to deposit all coatings
  - First article coating will demonstrate readiness and capability
- Opt-026: L3 Doesn't meet centering requirement (Moderate Risk)
  - Test Window assembly test review
  - Testing of L3 barrel assembly

CCS active risks

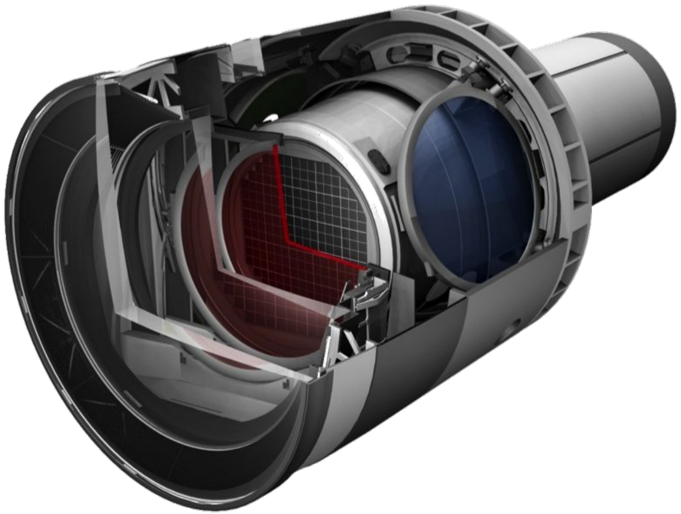
Risk Title	Risk Description	Current Exposure		Residual Exposure	
Contributed Labor	IF the CCS relies on substantial amounts of contributed labor and if that contributed labor fails to materialize, fails to deliver the expected software, or delivers software that does not meet the requirements THEN additional on-project manpower may be needed to compensate.	13	Moderate	9	Minor
Late scope changes	IF subsystems come with late changes to CCS interface scope, THEN CCS-provided software modifications will be required	10	Minor	6.7	Minor
Observatory visualization software	If an observatory wide plan for development of visualization software with required functionality and availability timescale suitable for use by the camera for I&T THEN the camera team may have to develop their own visualization system which may require more manpower than planned and/or provide less functionality than desired..	8	Minor	4.0	Insignificant
Sites adhering to data format standards	IF data formats and directory structures are not precisely defined and enforced, THEN conflicting data formats and directory structures make data curation and application of test algorithms difficult or impossible across testing sites.	8	Minor	2.3	Insignificant
Insufficient personnel	If CCS D&D lacks sufficient personnel, THEN some camera subsystem development will run behind schedule or over budget, and will not be tested properly before deployment.	6.0	Insignificant	5.0	Insignificant
Maintainability	IF technology choices become obsolete, or documentation is inadequate THEN the system cannot be properly maintained.	5.0	Insignificant	3.0	Insignificant
Communications latency	If communications response times do not meet requirements THEN camera performance may not meet the specified requirements.	4.5	Insignificant	1.5	Insignificant

CCS Risks Recently Retired/Accepted

Risk Title	Risk Description	Current Exposure		Residual Exposure	
eLog support from FNAL	If FNAL decides to terminate support for the eLOG, THEN an alternate system is needed or we take on the support	5.7	Insignificant	1.2	Insignificant

- **We have stopped using the FNAL eLog, content that used to be on eLog (and much more) has migrated to SLACK.**
- **No new risks Identified since last year**

Hazards



Hazard Analysis

Hazards can be defined as a failure of a component, system or function that could lead to personnel injury or damage to hardware.

- Hazards are NOT risks.

Hazard Severity Classification		
Class	**Description**	**Potential Consequences**
1	Catastrophic	Injury: may cause death or permanently-disabling injury
		Property damage: near-complete loss of camera system
		Environment: irreversible severe environmental damage
2	Critical	Injury: severe injury, occupational illness, or permanent partial disability
		Property damage: major damage to system; loss of major subsystem(s)
		Environment: significant reversible environmental damage
3	Marginal	Injury: minor injury or occupational illness
		Property damage: minor damage to camera or subsystem, recoverable with minimal impact on program
		Environment: mitigatible environmental damage, where restoration activities can be accomplished
4	Negligible	Injury: minor first aid treatment; personal health not affected
		Property damage: more than normal wear and tear; easily recoverable within scope of standard maintenance
		Environment: minimal environmental damage

Hazard Probability Level		
Level	**Frequency of Occurrence**	**Definition**
A	Frequent	Likely to occur often in the life of the Camera
B	Probable	Will occur several times in the life of the Camera
C	Possible	Likely to occur sometime in the life of the Camera
D	Remote	Unlikely but possible to occur in the life of the Camera
E	Improbable	So unlikely, it can be assumed occurrence may not be experienced

Mishap Risk Assessment		Severity			
		1—Catastrophic	2—Critical	3—Marginal	4—Negligible
Prboability	A—Frequent	1	3	7	13
	B—Probable	2	5	9	16
	C—Possible	4	6	11	18
	D—Remote	8	10	14	19
	E—Improbable	12	15	17	20

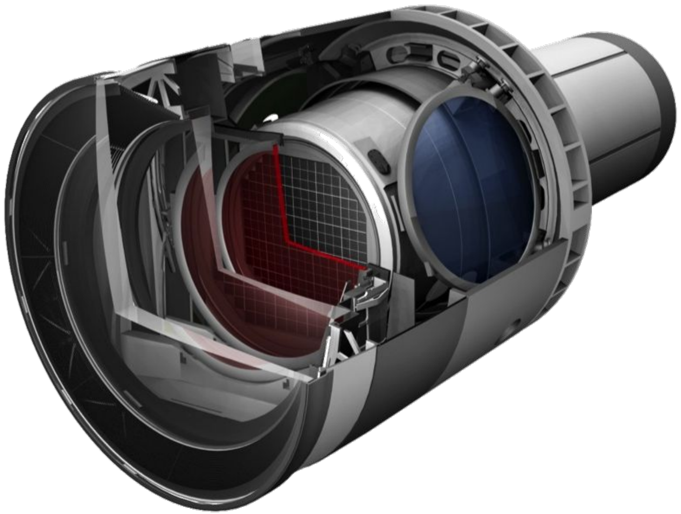
Mishap Risk Categories	
Risk Assessment Value	**Description**
1-5	High
6-9	Serious
10-17	Medium
18-20	Low

CCS Hazards (LCA-15)

ID	Description	Mitigation	Level	Verification
98	Erroneous commands could result in unsafe behavior by various Camera components	Implement **Camera Protection System** (CPS) independent of CCS to prevent erroneous commands from causing hazardous responses by subsystem hardware	Medium	Generate erroneous commands under controlled conditions to verify that CPS prevents execution. Write test suites to verify that internal CCS logic prevents generation of erroneous commands.

- **CCS has only one hazard**
- **CCS is designed to prevent erroneous behaviour independently of the Camera Protection System (CPS) -- while CCS is active it should never rely on the CPS**
    - **CCS can monitor state of CPS (so we know it has triggered)**
    - **CCS can issue resets to CPS (but these will be ignored if trigger still active)**
- **There have been no changes since PDR**

Programmatic Status



CCS Organization

CCS Management

- Éric Aubourg (APC) -- *CCS Physicist/Subsystem Lead*
- Tony Johnson (SLAC) -- *CCS System Architect and Cam*
- Stuart Marshall (SLAC) -- Camera Integration Scientist, *System Engineering, I&T*

CCS Core Infrastructure

- Alexandre Boucaud (APC) -- **Joined December 2018**, Core/Filter Changer
- Dmitry Onoprienko (SLAC) -- Consoles/Core
- Max Turri (SLAC) -- Developer Tools/Core

CCS Subsystem Support

- Homer Neal (SLAC) -- BNL Test Stands, Focal Plane, ComCam
- Owen Saxton (SLAC) -- Refrigeration/Rafts, AuxTel, DAQ, Quadbox, Camera Body
- Steve Tether (SLAC) -- Shutter, BOT/Integration Gantry
- Françoise Virieux (APC) -- Filter Changer
- Al Eisener (Santa Cruz) -- Test stand support, ComCam Filer Changer
- Farrukh Azfar (Oxford) + Babak Abi (Oxford) -- PTP and OCS-Bridge
- Guillaume Dargaud (Grenoble) -- CCOB

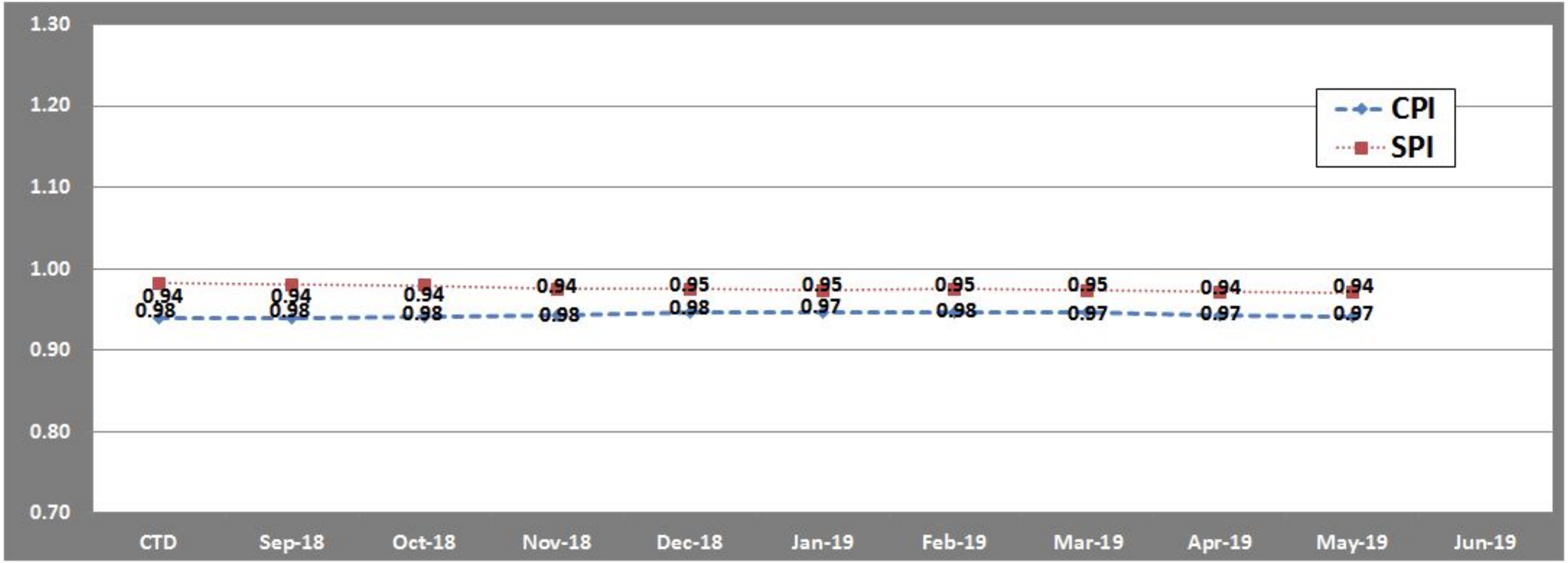
CCS Performance as of May 2019

- CCS cumulative SPI = 0.97
- CCS cumulative CPI = 0.94

Control Account	BCWS	BCWP	ACWP	SV	SPI	CV	CPI
3.07.01.01 CCS Integration & Management	$982,807	$982,807	$931,471	($0)	1.00	$51,336	1.06
3.07.01.02 CCS Core	$1,784,281	$1,846,054	$1,888,126	$61,773	1.03	($42,072)	0.98
3.07.01.03 CCS HCU	$1,843,440	$1,646,801	$1,933,568	($196,639)	0.89	($286,767)	0.85
Total	$4,610,527	$4,475,661	$4,753,165	($134,866)	0.97	($277,504)	0.94

CCS performance trend

- CCS performance very stable, not surprising since we are ~90% complete



Total Project ($K)	BCWS	$ 4,307	$ 4,354	$ 4,400	$ 4,450	$ 4,484	$ 4,516	$ 4,538	$ 4,561	$ 4,585	$ 4,611	$ 4,633
	BCWP	$ 4,230	$ 4,268	$ 4,308	$ 4,340	$ 4,374	$ 4,396	$ 4,426	$ 4,438	$ 4,456	$ 4,476	
	ACWP	$ 4,501	$ 4,542	$ 4,579	$ 4,604	$ 4,619	$ 4,644	$ 4,675	$ 4,694	$ 4,726	$ 4,753	
	CV	$ (272)	$ (274)	$ (271)	$ (264)	$ (246)	$ (248)	$ (249)	$ (256)	$ (270)	$ (278)	
	SV	$ (77)	$ (85)	$ (92)	$ (110)	$ (110)	$ (120)	$ (112)	$ (123)	$ (129)	$ (135)	
	CPI	0.94	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.94	0.94	
	SPI	0.98	0.98	0.98	0.98	0.98	0.97	0.98	0.97	0.97	0.97	

Variance Analysis

- **CCS HCUs -- cost variance: -$286,767**
  - **May 2019 The cost variance is caused by a combination of**
    - earlier standing army costs caused by delays of other subsystems which we are coupled to (Shutter, I&T, SR in particular)
    - less contributed labor than initially planned for, as documented in our 2016/17/18 EACs
    - requests for additional CCS functionality in the test stands, in particular the need to add additional safety features to test stands
    - more complexities in cryo/refrigeration and shutter subsystem than anticipated.
- **CCS HCUs -- schedule variance: -$196, 639**
  - **May 2019 The schedule variance is being caused mainly by waiting on other camera subsystems which are (or were) behind schedule. We are continuing to actively work with the shutter and camera body subsystem to complete the remaining work as quickly and efficiently as possible. The camera rotator which we have been waiting for is now available in IR2 and we have been making good progress in testing it. A full DAQ system with DAQ v4.x software is now available in IR2 which will enable us to complete work on full focal-plane readout by the summer.**

CCS estimate to complete status

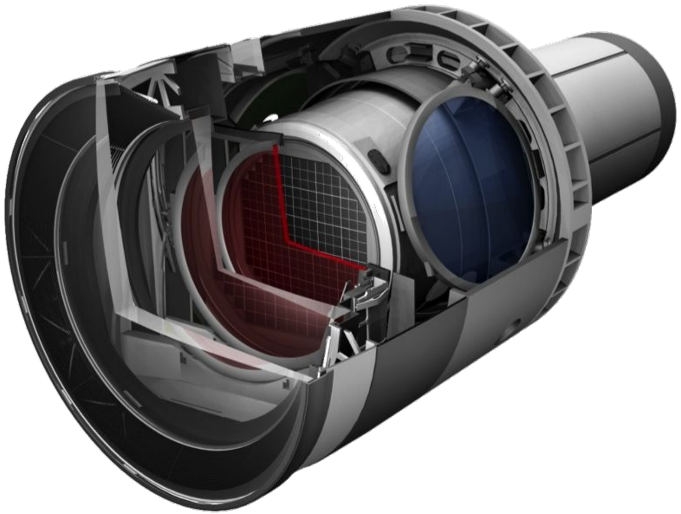
- Comprehensive estimate at completion performed on 10/2018 (performed yearly)
  - No significant updates to EAC this year

Control Account	BAC	EAC	VAC	% Comp
3.07.01.01 CCS Integration & Management	$1,083,374	$1,105,359	($21,984)	91%
3.07.01.02 CCS Core	$2,127,699	$2,015,296	$112,403	87%
3.07.01.03 CCS HCU	$1,843,440	$2,093,942	($250,502)	89%
Total	$5,054,513	$5,214,596	($160,083)	89%

EAC key drivers:

- CCS has had significant variances compared to the CD-3 baseline, but these are in line with the EAC estimate which we made in September 2016 and October 2017, and largely caused by the same issues:
  - Contributed manpower is less than anticipated at CD-3, resulting in increased cost
    - Departure of key developer Etienne Marin-Matholaz in Feb 2018.
      - Replaced by Alexandre Boucaud in November 2018, but need for APC group to concentrate on filter changer has prevented significant contribution to CCS code development
    - We have bought on new manpower from Oxford, Grenoble and Santa Cruz
  - Late requests for additional functionality, especially test stands
  - Delays in equipment availability from other subsystems, or late design changes

Summary

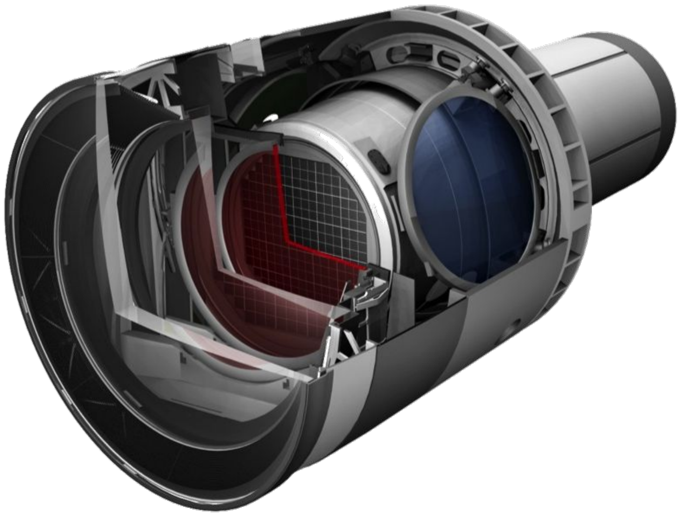


Summary

- In last year CCS has made major step forward in controlling
  - Many camera components in I&T cleanroom
  - ComCam initially at SLAC, very soon in Tucson
  - AuxTel in Tucson, including testing CCS/OCS interfaces
- Some camera work remains to be done, in particular integrated control of shutter+filter changer+utility trunk/cryo/camera
  - Schedule is in place for completing this work
  - CCS is on or close to critical path for several of these components
- Initial installation of CCS servers in Chile will occur before end of this year

Large Synoptic Survey Telescope

Supporting Material



Key Documents are Available on "Additional Docs" Tab in Confluence

- **Key Documents & Reviews for the corner raft subsystem can be found at (contact the camera point of contact for access):**
  - https://confluence.slac.stanford.edu/display/LSSTCAMREV/Home
- **This site contains:**
  - Project Documents
  - Design and Allocated Baseline Documents
    - Specifications
    - ICDs
    - Design Documents
  - Cost and Schedule Baseline
  - Design Reviews & Relevant Presentations
    - Preliminary Design Review
    - Other reviews
  - CCS Manuals