The LSST Commissioning Plan

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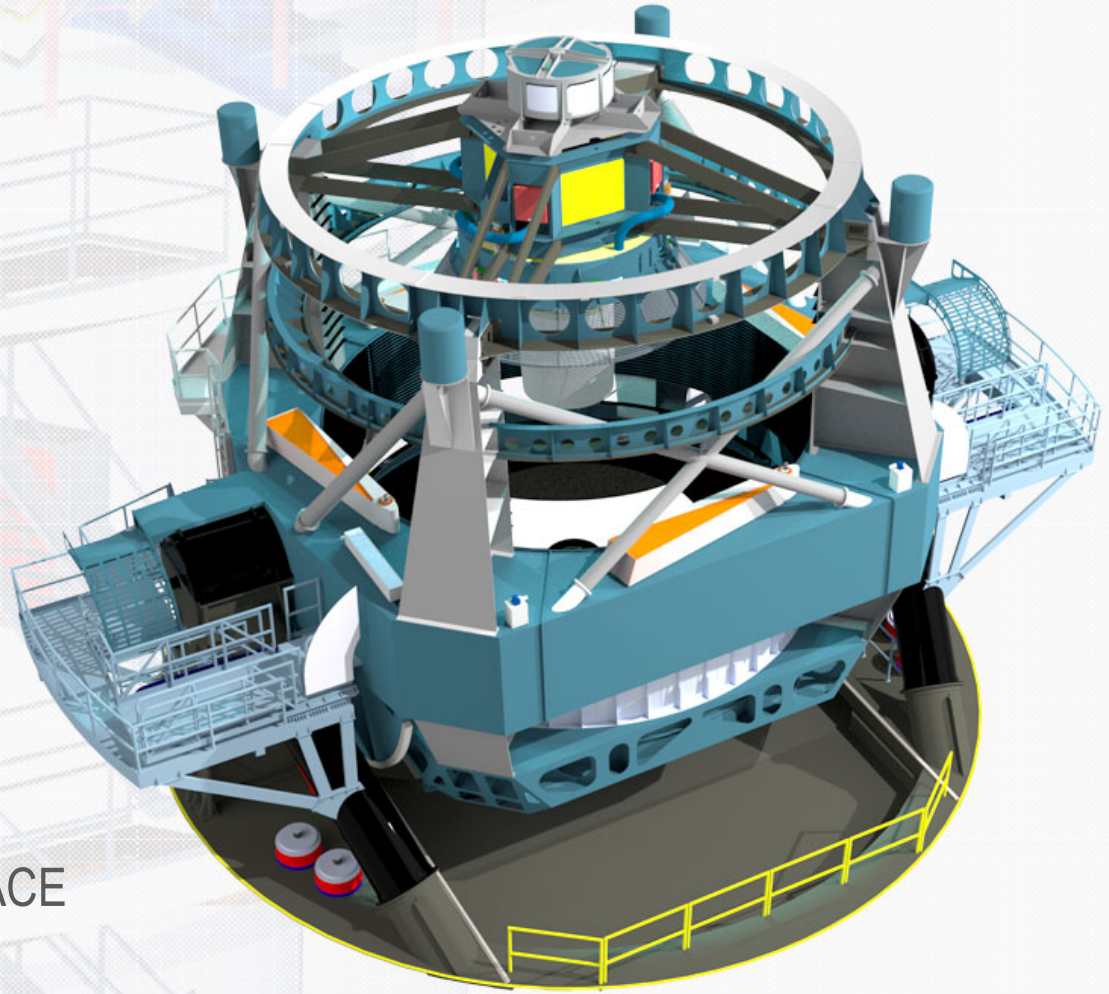


LSST SAC FACE-2-FACE

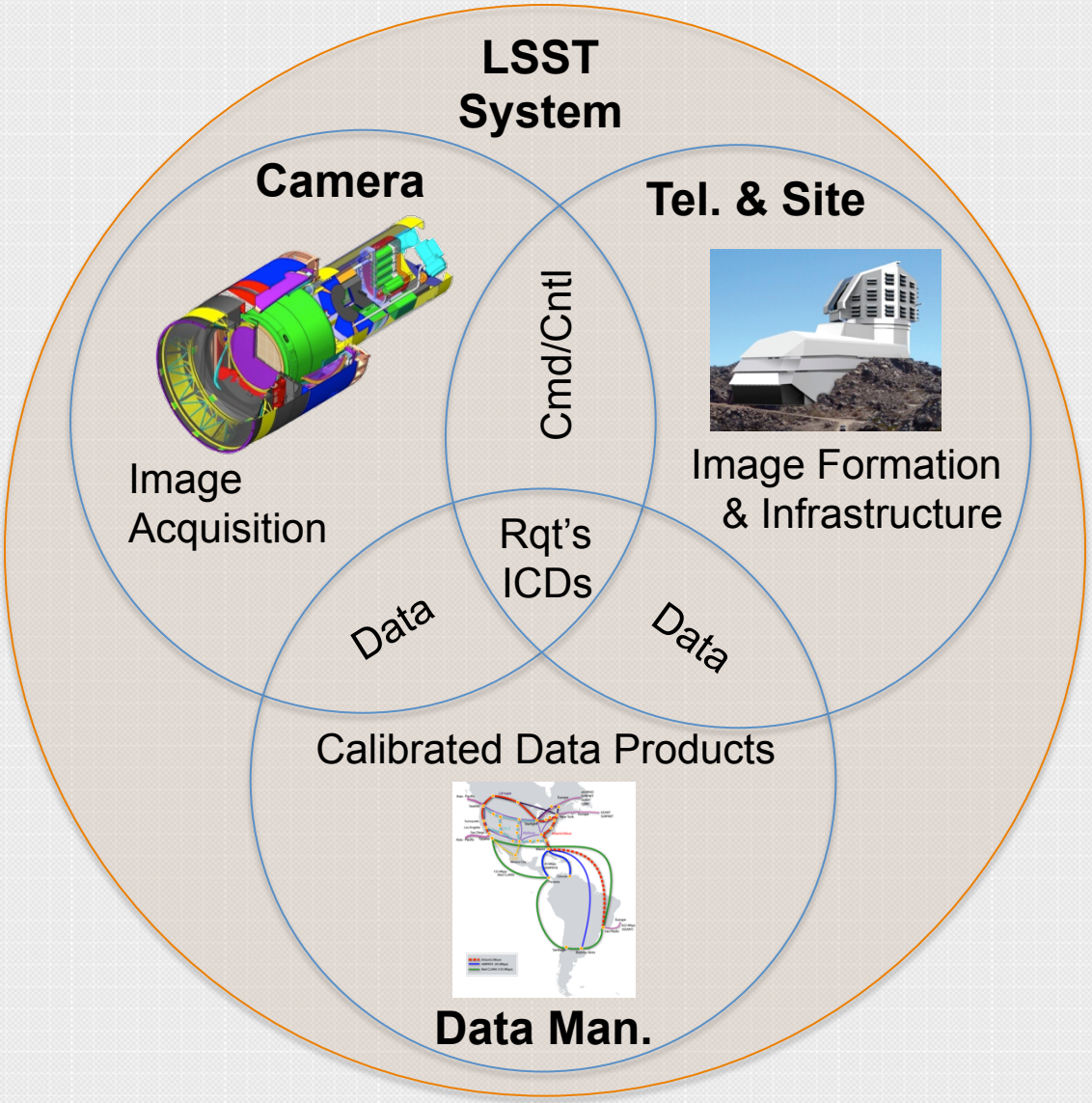
April 7, 2014

The LSST Commissioning Plan

- Scope of Commissioning defined by 3 Functional Objectives
- An Overview of the LSST Commissioning Plan
- Engaging the Community

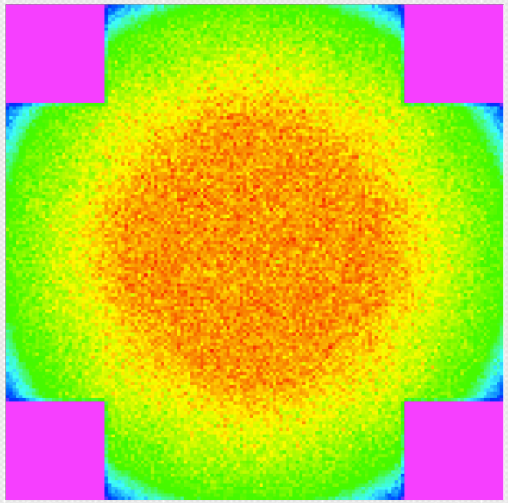
LSST Commissioning Plan document is LSE-79

Commissioning ties the individual elements together technically forming an operational system

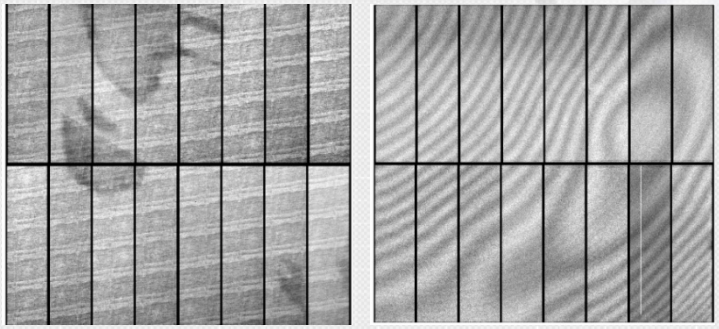


In commissioning we will characterize and document the as-built system performance

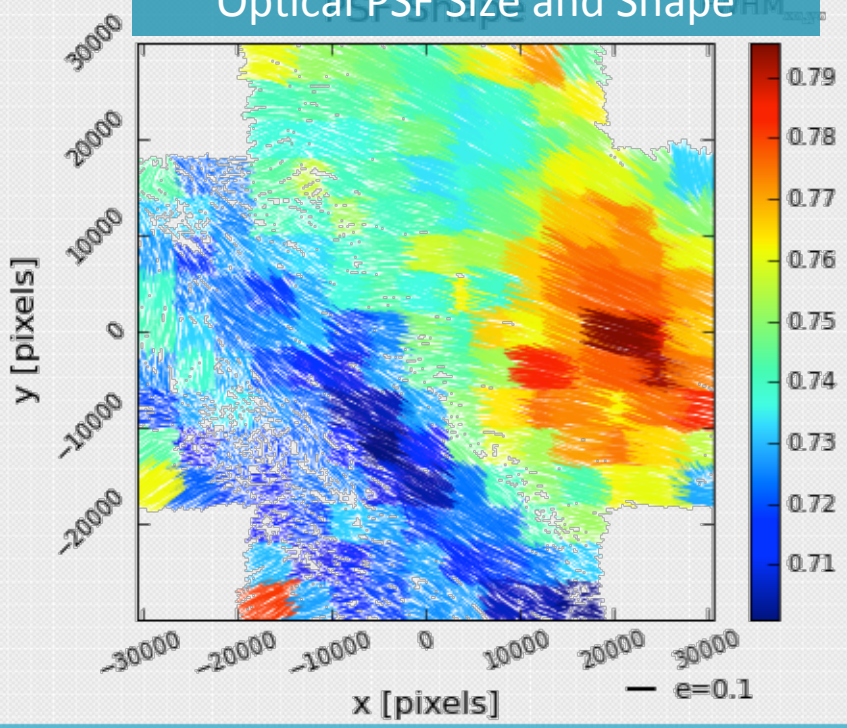
System Spatial Response



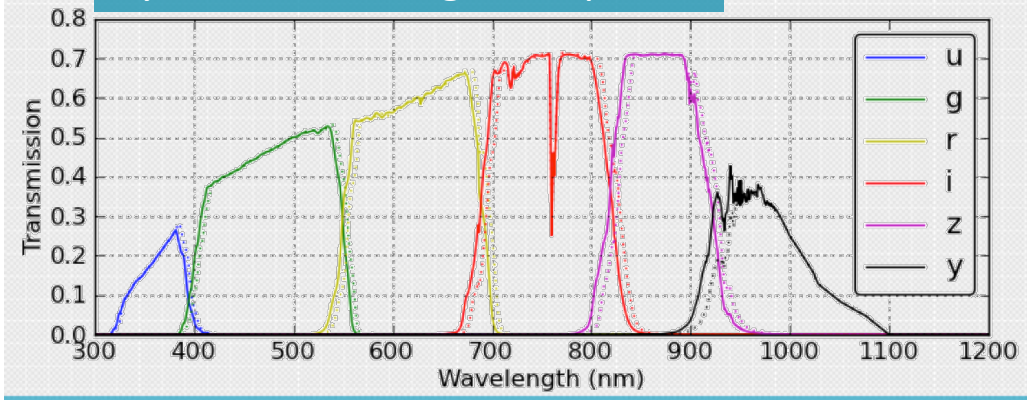
Sensor Features



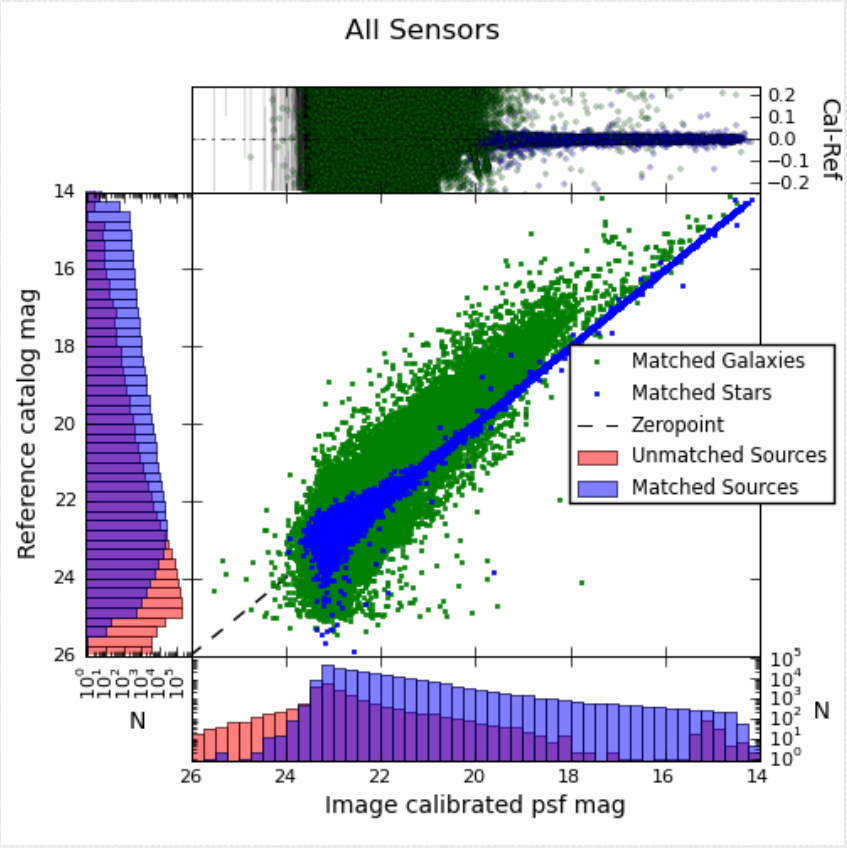
Optical PSF Size and Shape

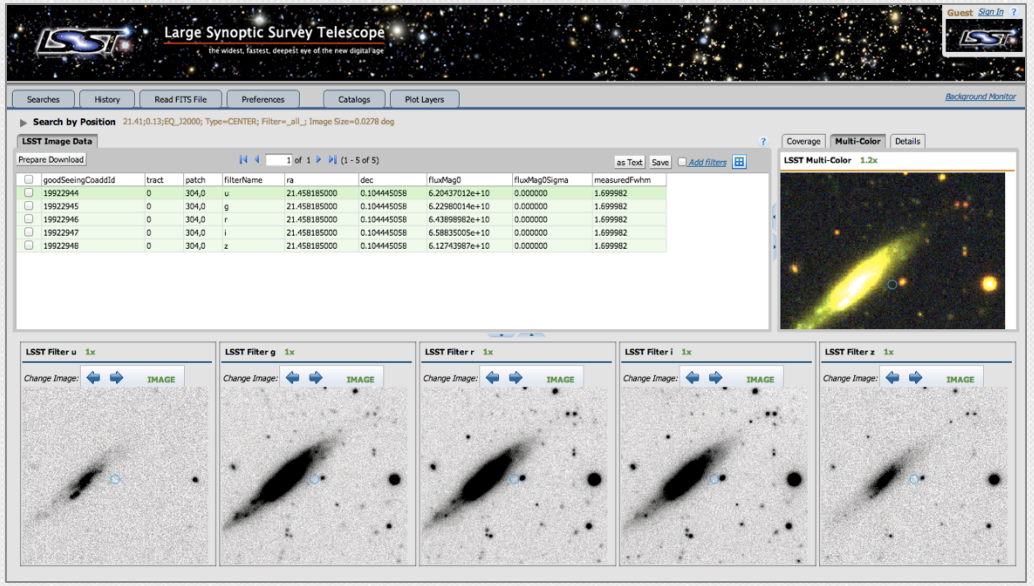


System Wavelength Response



Commissioning will conclude with data quality assessment of calibrated data products usable for science





Data will be accessible through the LSST Science User Interface.

Zero point fit and star/galaxy photometry

SDQA tools currently in place.

Other requirements for Operation Readiness

- The project team shall demonstrate that the integrated LSST system can collect and process time-domain Level 1 data products, including the generation and distribution of alerts;
- The project team shall demonstrate that the integrated LSST system can monitor and assess the quality of the data as it is being collected;
- The project team shall demonstrate that relevant metadata are being collected and archived;
- The project team shall deliver a complete set of documented operational procedures and supporting technical documents needed to operate the LSST as a scientific facility for the purpose of conducting a 10-year survey; and
- The project team shall deliver all reports documenting the as-built hardware and software including: drawings, source code, modifications, compliance exceptions, and recommendations for improvement.

Commissioning Management Structure

- **Project Director and Manager** maintains overall authority on all commissioning activities, budget and schedule.
- **LSST safety staff** continues their role to ensure all activities are conducted safely; particularly for the on-site activities at the Summit Facility.
- **Systems Engineering Manager and Systems Scientist** are responsible for the commissioning effort, including planning, prioritizing, coordinating the day-to-day commissioning activities, and functional supervision of assigned staff.
- **Subsystem Managers** continue to provide administrative supervision to personnel assigned to the commissioning team and responsibility for remaining construction activities not associated with commissioning.
- **Chilean Site Manager** supervises logistic and administrative operations of work carried out in Chile at the Summit and Base Facilities.

The composition of the Project Commissioning Team

The technical team is drawn from existing personnel in each of the 3 subsystems and functionally assigned to Systems Engineering and managed as a single group.

DOE operations is expected to support ~20 FTE (scientific & technical) assigned to Systems Engineering for Commissioning by MOU.

The science team has both existing personnel and new hires.

New hires include:

- 3 scientist + 3 postDocs
- 1 rotating scientist position
- Telescope operator (for 3 total)

Project Office continues administrative support

	Early Sys. I&T FY20	Full Sys. I&T FY21	Science Ver. FY22
Com. Scientists	5.3	8.7	11.3
DM Scientists	3.5	4.5	3.9
TS Scientists	2.2	2.5	2.7
Science Team Total	10.8	14.7	16.0
Engineering	7.0	6.2	6.8
Technicians	5.2	6.0	7.6
SW Engineering	11.4	12.1	8.6
Technical Team Total	23.7	24.4	22.9
Commissioning Total	34.4	39.1	38.9

MREFC supported FTEs by fiscal year assigned to the Commissioning Phase

Commissioning plan is in 3+ Phases

Staged subsystem acceptance testing

- Telescope & site with ComCam – **Oct. 2019**
- Camera system at summit – **Aug. 2020**
- DMS Archive Center at NCSA – **Aug. 2020**

– Early System Integration & Test with ComCam

- 6 months planned testing
- 4 additional months available if needed

– Full System Integration & Tests – Camera + Telescope + DMS

- 7 months to verify complete LSST system functionality

– Science Verification & Operations Readiness Demonstration

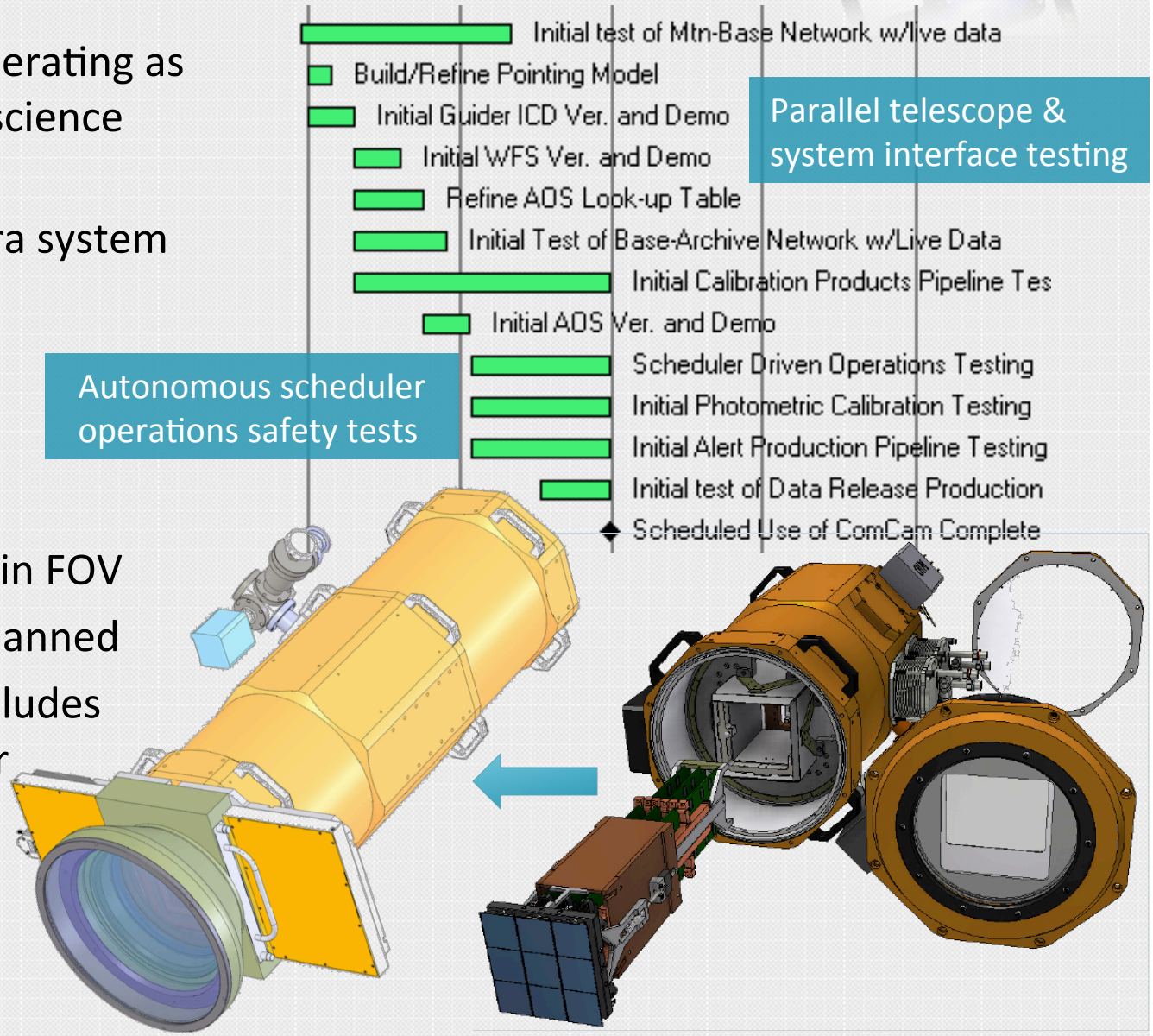
- 5 months to characterize and demonstrate science performance and operations readiness

Objectives in each of the 3 Commissioning phases guides detailed planning

- 6 month (min) early System I&T with ComCam
  - Interface testing
  - Initial Telescope and Active Optics Control Testing
  - Calibration Operations and Cal. Data Products Pipeline Processing
  - Scheduler Driven Operations Testing
  - DM Algorithm development
  - Procedure definition
- 7 month Camera-Telescope-DM integration
  - Final system interface verification
  - Telescope-Camera Integration and Test
  - DM Pipeline testing with Full FPA Data
  - OSS requirements verification
- 5 month Science Verification
  - Mini Surveys to characterize SRD performance
  - LSR requirements verification and characterization
  - Operations Readiness and Verification using initial survey cadence

Early System I&T activities with ComCam

- A single raft camera operating as a surrogate of the full science camera.
- Utilizes as many Camera system interfaces as possible:
  - CCS-OCS
  - SDS-DM
  - WDS-TCS
  - GDS-TCS
- Corrector for ~40 arcmin FOV
- 6 Filters - u-g-r-i-z-y planned
- Telescope interface includes Camera mass simulator



Early testing of DMS release 8.0 w/live ComCam data

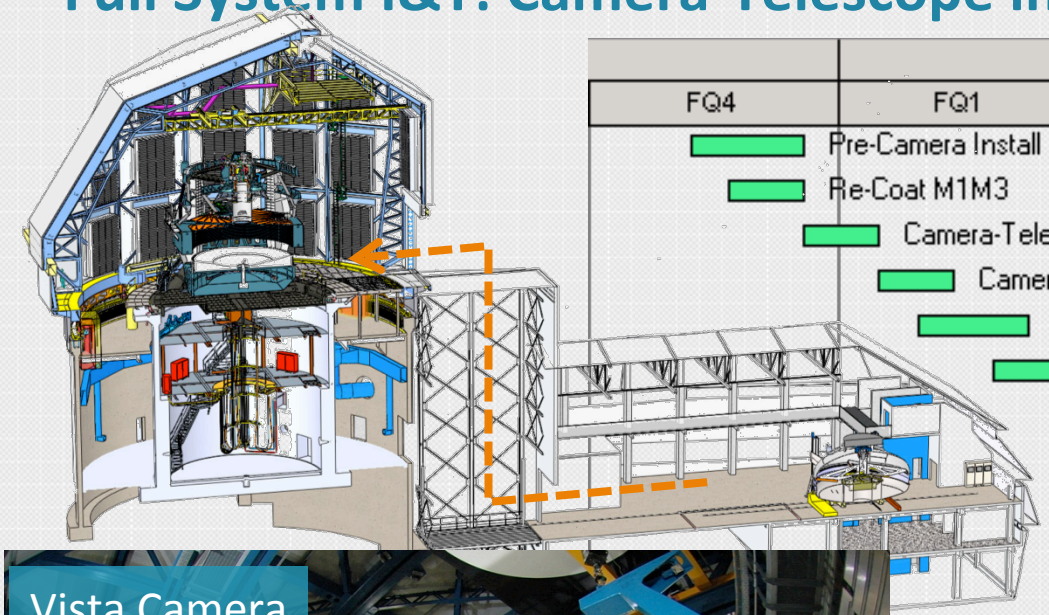
Release	R8.0/8.1 - Commissioning Camera ready Complete 8/31/18
SDQA	Collect and compute metrics for algorithms below. Visualization and exploration of telemetry, catalog, and image data in support of nightly observing. (LSE-63 Level 1 DQA)
L3 Toolkit	Testable for science user usability of DM stack
Calibration Products Production	Master flat production from monochromatic flats. Estimation of telescope-camera bandpasses from monochromatic flats. Derivation of atmospheric models.
Alert Production	Image Processing, Single Frame Measurement, Association of DIASources to DIAObjects, Association of DIAObjects with Objects, Image differencing with images incorporating as-built sensor characteristics, Image differencing of crowded fields, DIAObject characterization from DIASources, NightMOPS, DayMops (not parallelized or running at scale)
Data Release Production	Set up and solve the least squares system for photometric self calibration (20% DR1 scale), PSF estimation at SRD specification level, Capability to build coadds in crowded fields, Multi-coadd deblending and association, Simultaneous generation of multiple coadds, Deep Detection, Model fitting of blended objects, Computational performance enhancements
Science User Interface and Analysis Tools	SUI testable for science user usability of Data Products
Science Data Archive and Application Services	Construct Catalogs, Database Administration, Database User Management, Load Tables, SQL and non-SQL Query, Scan Queries, Shared Scan Queries, Image and File Archive, Data Access Client Framework, Data Definition Client Framework, Application Services
Data Management Control System	Configure, Catch-Up Archiver, OCS startIntegration, Archive Image, OCS nextVisit, Manage Production Phase Execution, Resource Management

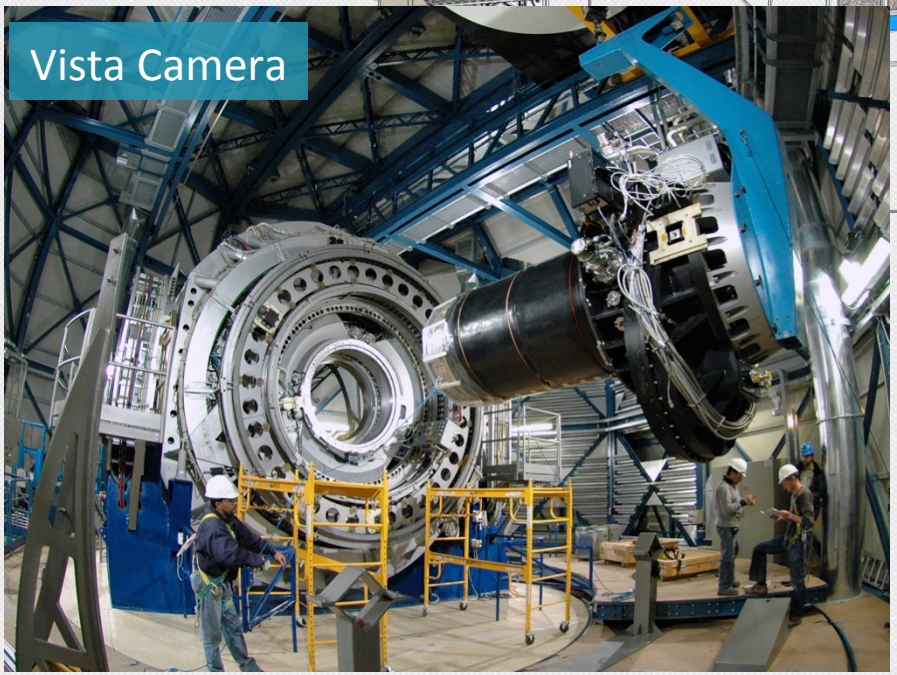
Data Management Pipeline Performance Verification with ComCam

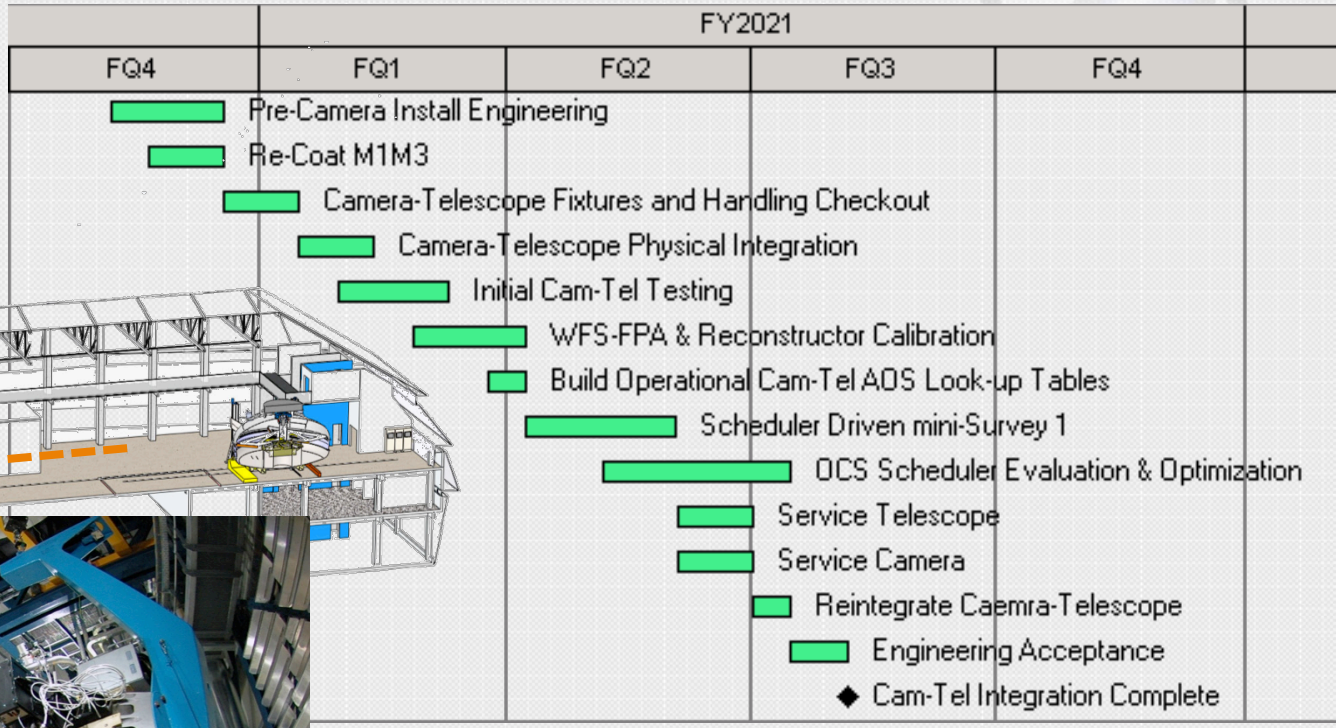
Calibration (WBS 02C.01.02.04)	Single Frame Processing (WBS 02C.03.01)
Cross-talk matrix derivation (on-sky and off-sky data, Master bias construction, Master dark frame construction, Defect mask construction, Broadband flat field acquisition, Master flat production from monochromatic flats. *Estimation of telescope-camera bandpasses from monochromatic flats, Reduction of calibration telescope spectra, Derivation of atmospheric models, Auxilliary telescope pipeline end-to-end test*	*ISR removal (defects, dark, flat, bias), Source detection and measurement of PSF flux, aperture flux, adaptive moments. WCS determination, single-visit astrometry accuracy. Snap processing (CR detection and removal). Deblender performance. Measurement (flux, shape, astrometry) quality at chip edges and near bloom stop. Multi-CCD sky background detemination. Cross-talk removal (intra-raft). Recognition and retention of trails (moving objects) in visit creation.*
Alert Production Pipelines (WBS 02C.03.*)	**Level 2 Pipelines (WBS 02C.03.*)**
Building difference imaging templates, Refinement of selection criteria and strategy for building templates, Differencing an image against a deeper template, Source detection on difference images, Verification of false positive rates, Measurement of PSF Flux and adaptive moments on the diffim, Forced photometry on difference of exposures comprising a visit, Fitting dipole sources on diffims, Detection and masking of artifacts, Detection and minimization of artifacts due to imperfect image registration, Trailed source model fit, Forced photometry on images and difference image, Image differencing of crowded fields, DIAObject characterization from DIASources, variability characterization, *NightMOPS validation, Level 1 database partial throughput validation, Data Management Control System partial validation, End-to-end test of diffim pipeline, Alert Generation Pipeline validation*	*Verify background-matched coadds, PSF, non-PSF matched, and chi^2. PSF Flux and Aperture photometry on coadds, Model fitting using CoaddPSF (Stackfit, greedy PSF), Coadd source characterization, Simultaneous generation of multiple coadds, Deblending and source association given multiple coadds, Deblending in crowded fields (crowded field photometry), Capability to build coadds in crowded fields, Insertion and recovery of simulated sources, Morphological star-galaxy separation*

A sample of Data Management functionality testable with ComCam

Full System I&T: Camera-Telescope integration





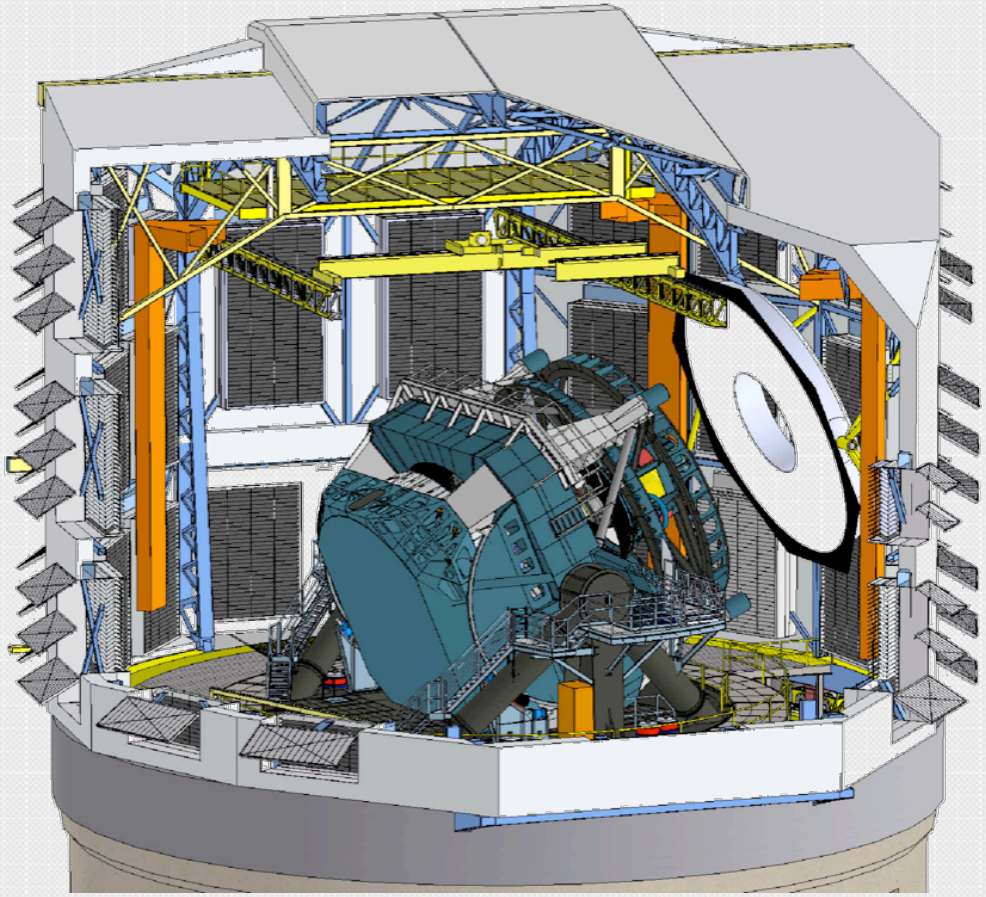


Camera-Telescope integration focus includes:

- Physical installation and basic functional checkout
- Final calibration and verification of active optics system
- Integrated system requirements verification (OSS)
- Functional interactions with scheduler driven observing

Initial Camera-Telescope characterization is done prior to on-sky measurements

- Mechanical Tests
  - Horizon to zenith displacements using laser tracker
  - Update hexapod look-up tables
- Functional Tests
  - Filter swap
  - Maintenance procedures
- System Characterization
  - Photon transfer functions to verify amplifier noise and linearity
  - Shutter timing and repeatability
  - System response by filter with narrow band flat images
  - Broadband flats for each filter
  - Shutter leakage tests
  - … and many other tests

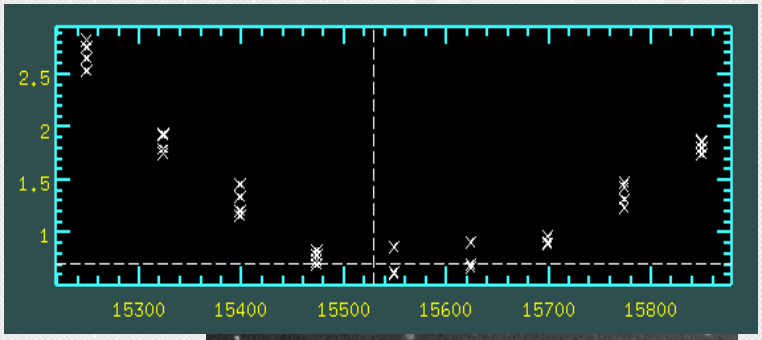


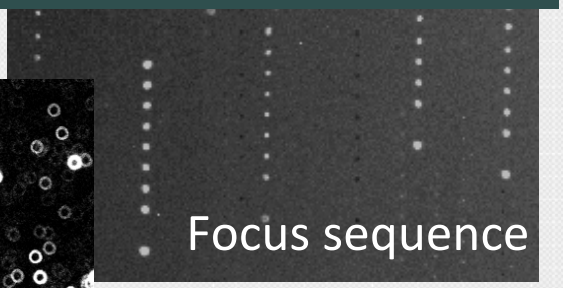
All image data will be processed through the DM pipelines.

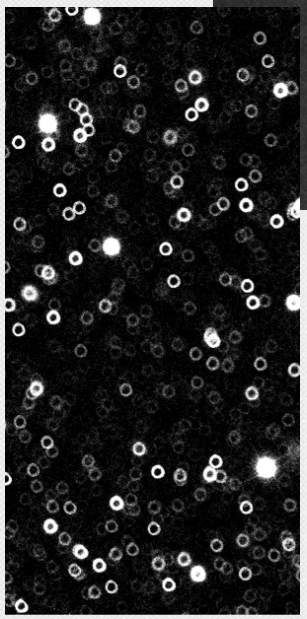
Initial On-sky Camera-Telescope activities will focus on active optics control

- Establish initial camera-telescope alignment and update control look-up tables
  - Laser tracker maps camera – hexapod / rotator deflection versus elevation angle
  - Focus sequence images to determine best fit plane with respect to FPA; adjust hexapod control to minimize residuals as a function of telescope elevation.

- Build the active optics look-up tables for the full field of vied using Camera Science FPA as a wavefront sensor
  - Intra and Extra focal images over the full FOV using hexapod to set defocus distance (~ ±5-10mm);
  - Determine mean wavefront error for each of the 189 sensors;
  - Determine Camera and M2 alignment and M1M3 and M2 surface corrections
  - Determine elevation, azimuth, and other dependencies for look-up tables







Intra/Extra focal images for wavefront sensing

All image data will be processed through the DM pipelines.

Examples of early data sets that will test and characterize the DM Pipelines

- Further characterization of the camera-telescope instrumental signature
  - **Illumination Correction Determination**: dense (~ >50% overlap) image rastering over spans 3-4 FOV, fit photometry for fixed pattern
  - **"Super Flats"**: median filtered images stacks leaving only sky, verify illumination correction after correction for tangent plane projection
  - **Ghost Image Validation**: Raster bright star over field to measure ghost surface brightness versus field angle
  - **Scattered Light Performance**: Measure changes in sky background from image sequences versus lunar angle to optical axis and azimuth orientation
  - **Astrometric WCS determination**: Raster common field across each detector, also provides initial photometric color term determination.

- Additional early data to DM pipelines
  - **Fixed Airmass Systematics**: Repeated observations of celestial pole field, at different rotations;
  - **Performance Repeatability**: High temporally sampled single fields to test image quality stability, and photometric / astrometric repeatability
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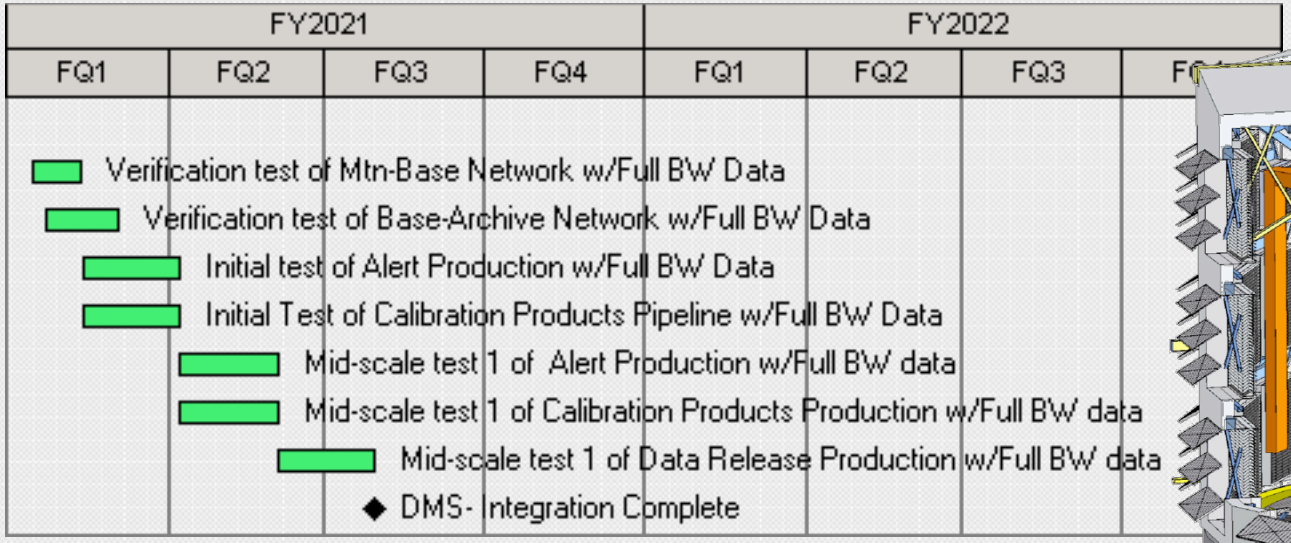
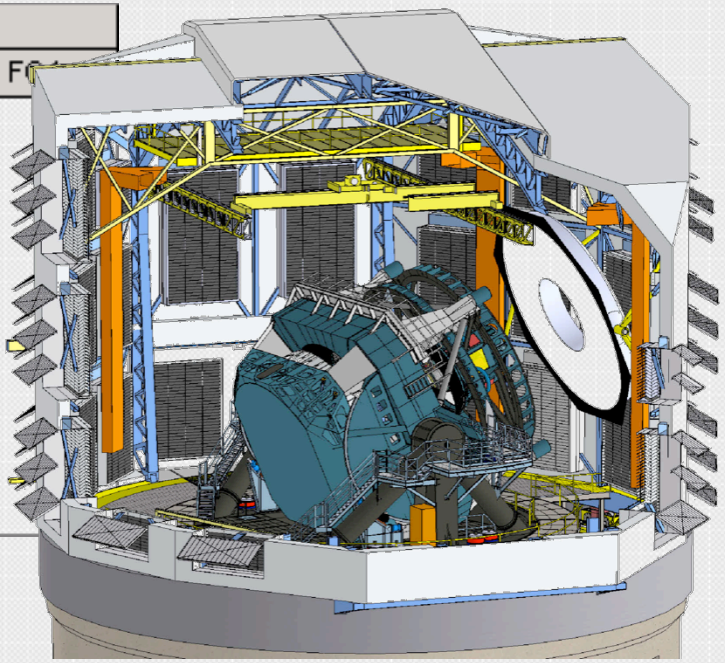
  - **Transparency Correction**: Observations of celestial pole field though different amounts and kinds of clouds, to verify how well we suppress transparency variations

Full System I&T: Data Management processing full FPA images



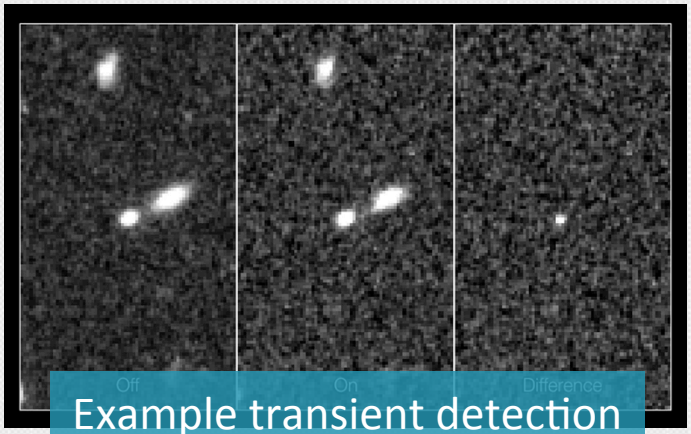


Calibration Products pipeline test & verification

- Spatial response from dome screen measurements
- System wavelength response from mono-chromatic dome screen measurements
- Sensor characteristics from dome screen measurements

Alert Production test & verification

- Instrumental signature removal
- Image differencing
- Transient detection and characterization.

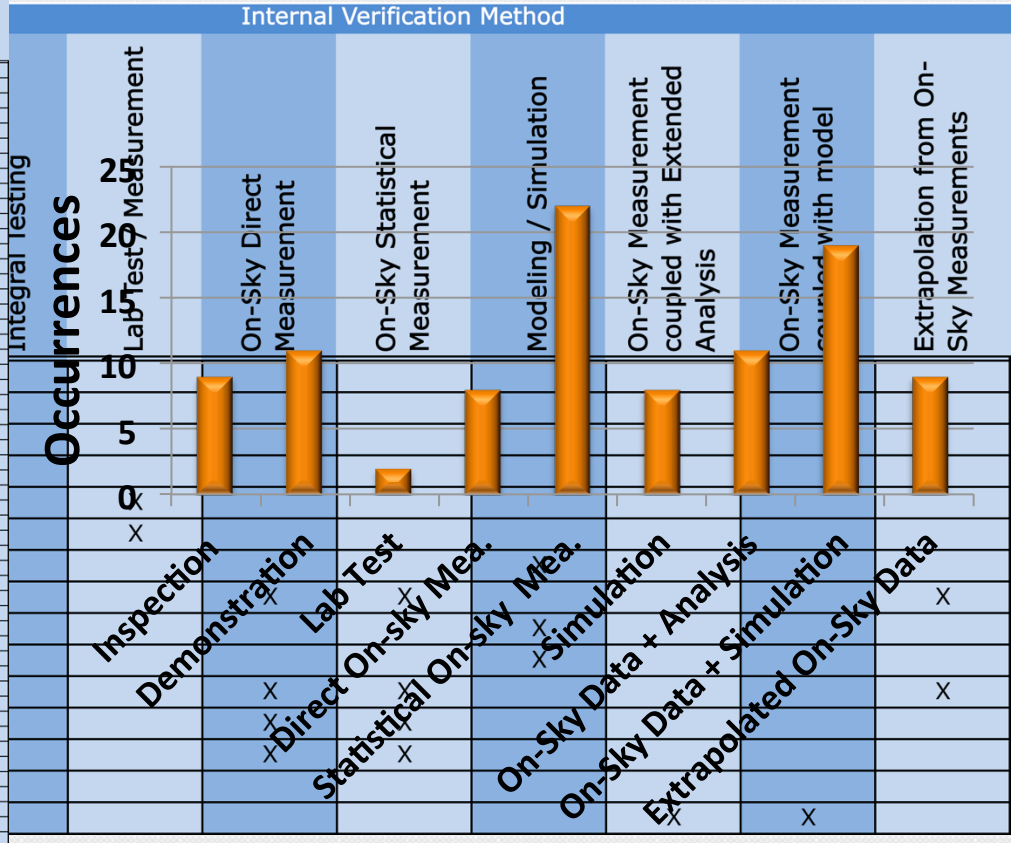


Example transient detection

LSR/SRD verification matrix will be filled in with compliance & characterization data at ORR

LSE-79

Requirement Title	LSR/SRD Variable	Internal Verification Method: Inspection / Specification	Demonstration / Integral Testing	Lab Test / Measurement	On-Sky Direct Measurement	On-Sky Statistical Measurement	Modeling / Simulation	On-Sky Measurement coupled with Extended Analysis	On-Sky Measurement coupled with model	Extrapolation from On-Sky Measurements
Single Image Performance										
Filter Complement (ugrizy)		X								
Number of Filters	Nfilters	X								
Filter Change Time	Tfmax		X							
Filter out of band	Fleak		X	X						
	FleakTot		X	X						
Filter Temporal Stability							X			
r-Band Reference Depth	D1				X	X				X
	DF1		X				X			
	Z1		X				X			
Filter depths (ugrizy)	DB1_filt				X	X				X
Variation of depth over FOV	DF2				X	X				
	Z2				X	X				
Minimum Exposure Time	Etmin	X	X							
Delivered Image Quality	S1							X	X	
	SF1					X				
	SX					X				
Image budget at Airmass=2	SXE							X	X	
Pixel Size	pixSize	X							X	
Image Spatial Profile	SRn							X	X	
Image Ellipticity Distribution	SE1					X			X	
	EF1					X				
	SE2					X				
Photometric Repeatability	PA1					X			X	
	PF1					X			X	
	PA2					X			X	
Photometric Spatial Uniformity	PA3					X		X		
	PF2					X				
	PA4					X				
Photometric Band-to-band calibration	PA5(u)						X	X	X	
Absolute Photometry	PA6				X				X	
Relative Astrometry	AM1,2,3					X		X		
	AF1,2,3					X				
	AD1,2,3					X				
Crossband Relative Astrometry	AB1					X		X	X	
	ABF1					X				
	AB2					X				
Absolute Astrometry	AA1					X			X	
Time Recording Accuracy	TACREL	X	X							
	TACABS	X	X							
Full Survey Performance										
Sky Area	Asky	X					X			
Total Number of Visits (10-year)	Nv1						X			X
Visit Distribution	Nv1_filt						X			X
Idealize Stacked depth										
Distribution of Visits in Time	RVA1						X			X
Astrometric Parallax	SIGpara				X				X	
y-band Parallax	SIGparaRed				X				X	
Proper Motion	SIGpm				X				X	
Ellipticity Residual Correlations	TE1							X	X	X
	TE2							X	X	X
	TE3							X	X	X
	TE4							X	X	X
Data Release Cadence	DRT1	X	X							
Transient Alert Latency	OTT1	X	X							
Number of transients	transN		X							



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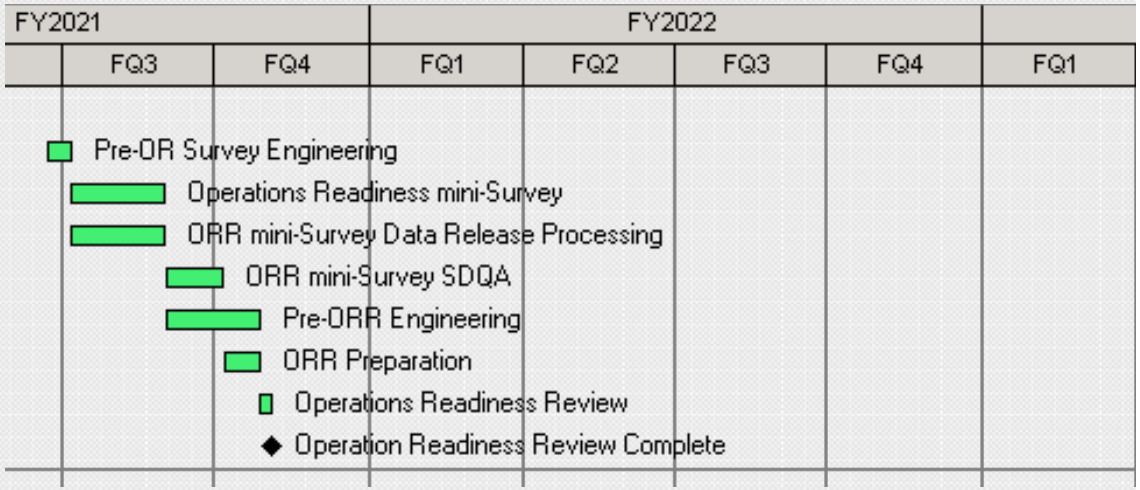
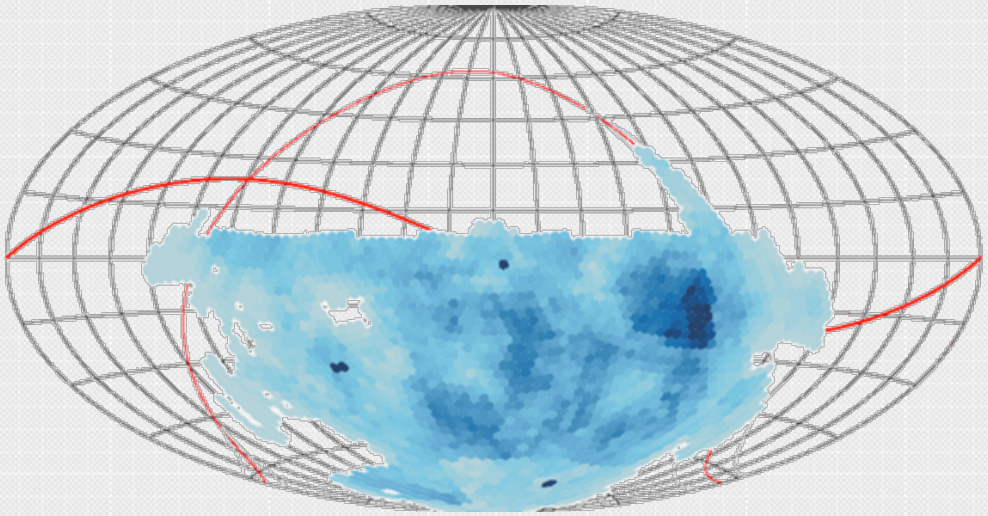
Commissioning concludes with an Operations Readiness mini-survey

Science verification focuses on characterizing the system performance properties defined in the LSR/SRD.

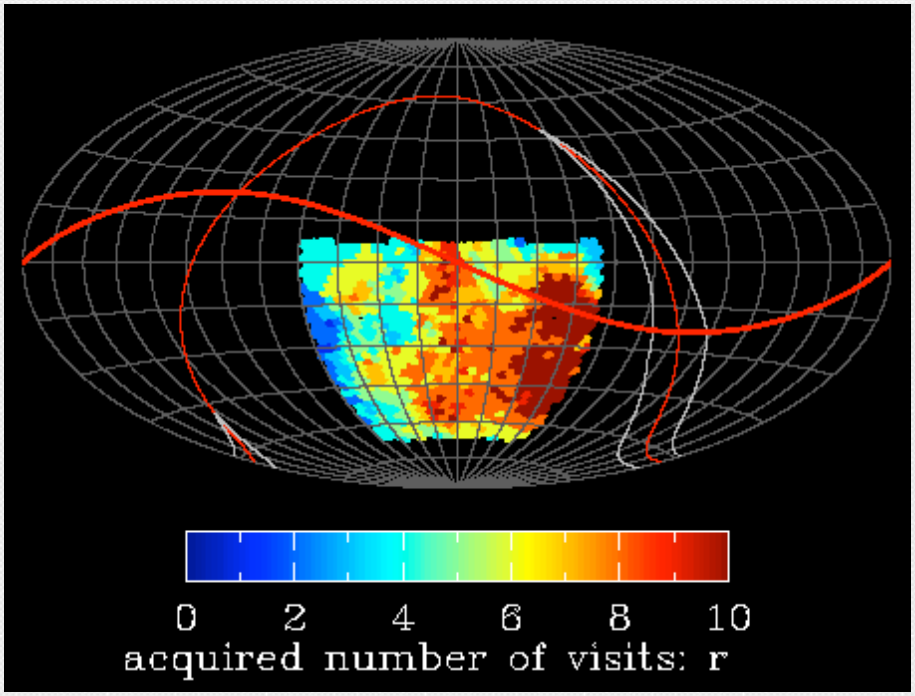
Verification matrix filled in with compliance and characterization data.

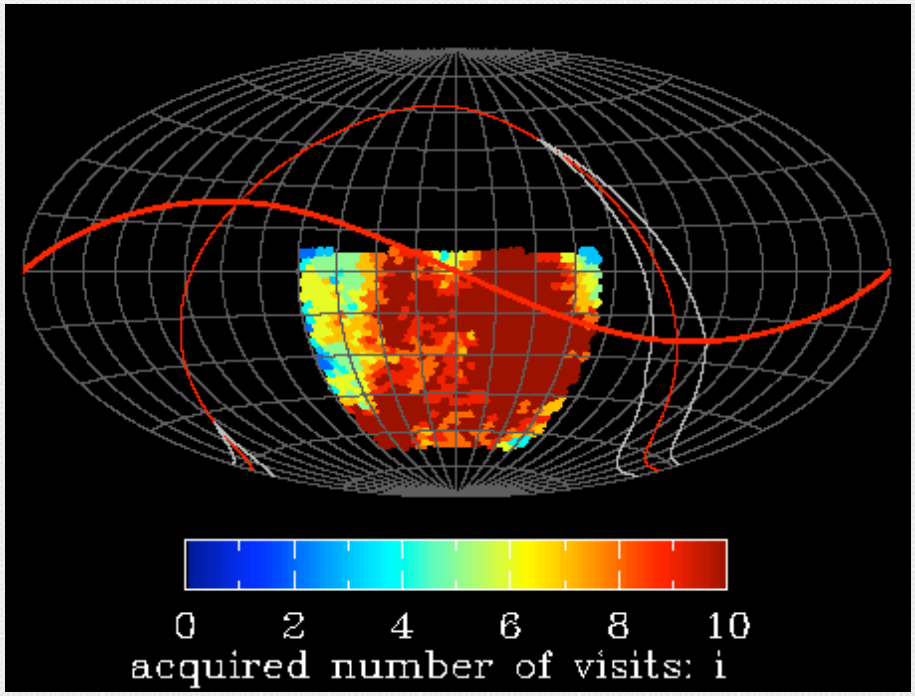




Example sky coverage from an Operations Readiness mini-Survey

30 day OpsSim example of a 2-color mini-Survey





Following ORR the final mini-survey would be released to the general community to initiate science operations.

An extended Commissioning Team will engage the community

- The Project will issue a call for proposals to participate in the "Joint" Commissioning Team. Proposals are required to show:
  - The proposed work will provide valuable feedback to the Commissioning team;
  - Lead to higher data quality at the start of operations; and
  - The PI and team are capable and have the resources to carry out the proposed analysis in a timely way.

- The participants will work with the project to develop the observing plans by suggesting
  - Specific areas on the sky
  - Targeted observations with special cadences
  - Mini-survey designs

An extended Commissioning Team will engage the community

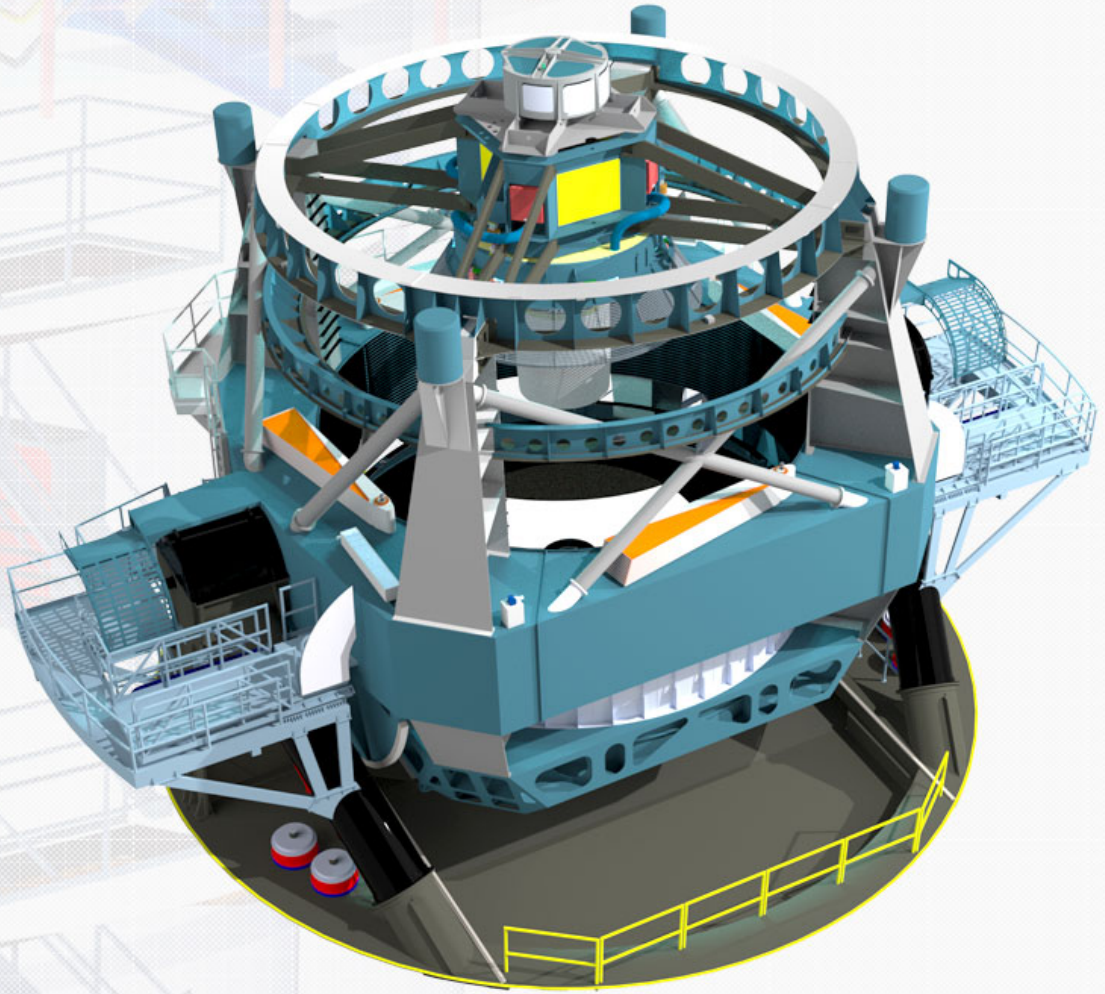
- Project team must stay focused on technical commissioning tasks and system characterization
- Community team is expected to collaborate with the project to provide value added scientific analysis of commissioning data
- General release of the commissioning data will be subject to an internal vetting and review process (TBD).

Commissioning Planning and Review

- Over the next two years a detailed Commissioning plan will be assembled and will include:
  - Specific verification tests, procedures and acceptance criteria
  - Initial observation sequences and mini-survey designs
  - Simulations of key commissioning activities using project tools.

- A review of the Commissioning Plan is expected sometime in 2016

End of Presentation



Description Summaries

Proposed Observations

(Provide a brief description of the objectives, tests; cadence, and analysis)

Proposed Tests and Objectives:

(Provide a brief description of the objectives, tests; cadence, and analysis)

Desired Cadence:

(Provide a description of the observation cadence including exposure times, revisit interval etc…)