VERA C. RUBIN OBSERVATORY

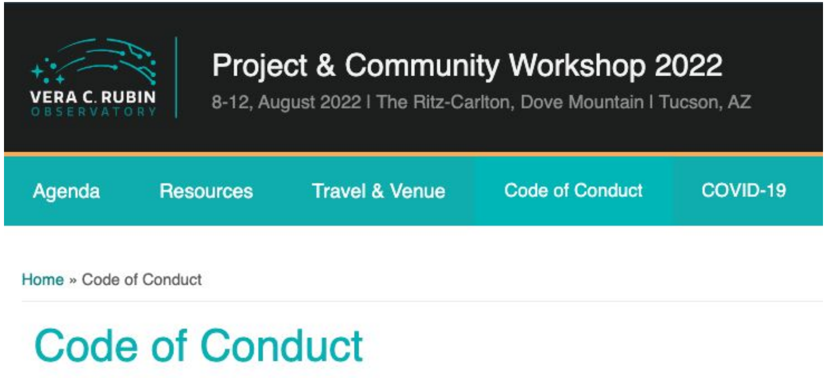
Strategy for System-level Science Verification and Validation

Keith Bechtol
Rubin Observatory System Verification and Validation Scientist

Rubin PCW
9 August 2022

NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

Friendly reminders - CoC & Covid



Harassment and unprofessional conduct (including the use of offensive language) of any kind is not permitted at any time and should be reported.

Rubin Observatory adheres to the principles of kindness, trust, respect, diversity, and inclusiveness in order to provide a learning environment that produces rigor and excellence.

Check name-tags for these contact comfort level stickers.

Thank you for masking indoors!

Use the confidential email rubin2022-covid@lists.lsst.org to request a test, report your test results, or ask questions.

Reporting bullying, harassment, or aggression.

The Rubin 2022 Organizing Committee has appointed designated contacts:

- Ranpal Gill (rgill@lsst.org)
- Andrew Connolly (ajc@astro.washington.edu)
- Melissa Graham (mlg3k@uw.edu)

Contact via email, Slack, or the Community Forum.

Friendly reminders - virtual participation

Virtual participants should be muted when they're not speaking.

In-person participants should speak into the room microphone(s), or the chair should repeat all questions into the microphone, so that the virtual participants can hear what is said.

In the Rubin2022_PCW Slack Space, all participants can use the session's channel for Q&A and discussion.

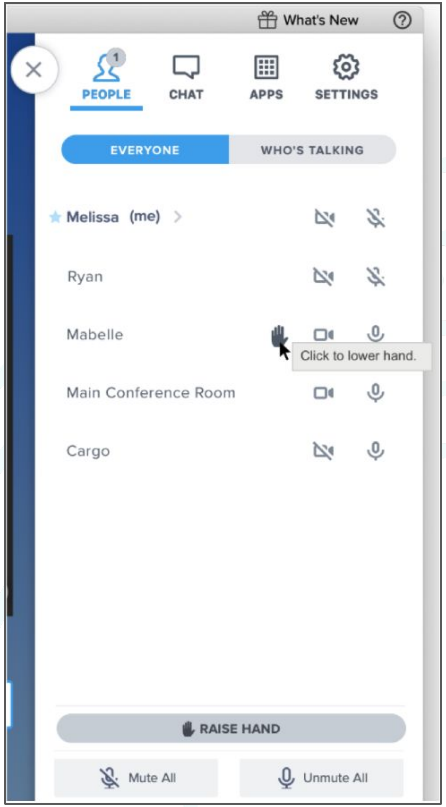
The channel name convention is, e.g.: #day1-mon-slot3a-intro-to-rubin

In BlueJeans, virtual participants should:

use the BlueJeans "raise hand" feature and wait for the moderator to call on you before speaking

or

use the BlueJeans chat functionality to ask questions or make comments.



Logistics

Session Chairs: Keith Bechtol

Slack Channel: #day2-tues-slot2e-science-verification

Monitoring slack for questions: <TBD>

BlueJeans Raise Hand: Please raise your hand in BlueJeans to ask a question. You will be called upon to unmute and ask your question by the chair.

BlueJeans Chat: **Will not be monitored**. Please post questions in Slack channel

Scribes: <TBD>, anyone who would like to add notes

Notes: Shared google doc for live notes (anyone with link can edit)

Objective of the session

Discuss a strategy for how to evaluate the scientific performance of the as-built Rubin Observatory using calibration and on-sky observations from ComCam and LSSTCam during the commissioning period, with a focus on demonstrating Operational Readiness.

Dedicated session “Onboarding for SIT-Com In-Kind Contributions” Tuesday afternoon @1:30-3:00

Dedicated session “Early Science w/ Rubin” Tuesday afternoon @3:30-5:00 to discuss science enabled by Rubin for its community through and including the first data release, Data Release 1 (DR1, first 6 months of LSST data)

Agenda

Overview of Science Verification Strategy (60 min)

- Deliverables
- Tooling
- Construction / Data Delivery Milestones
- On-sky Observations during Commissioning
- AuxTel Imaging Survey as Pathfinder
- QA Timescales
- Proposed Organization

Discussion (30 min)

Definitions

Verification: *Did we build what we said we would?*

- Checking that requirements are satisfied

Validation: *Does the thing we built do what we expect/want it to do?*

- Showing that science can be done with the data products

Characterization: *Do we understand why/how the thing works the way that it does?*

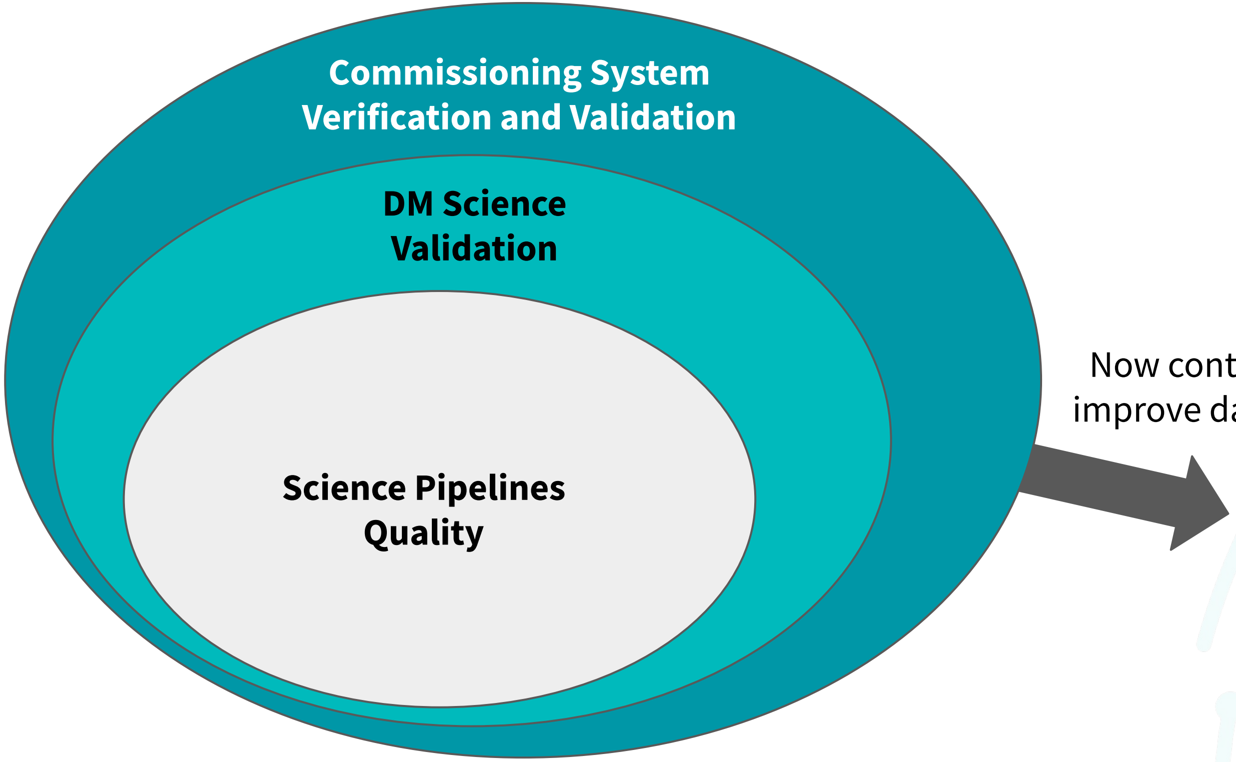
- Optimizing delivered data quality under a range of conditions

Quality Assurance of What?

- **Science Pipelines Quality:** (DMTN-085)
  - Are the pipelines in development performing as well as expected? Given a fixed set of images, how does one version of the pipelines perform compare to another to inform decisions. E.g. do I merge this ticket? Is this RC ok for production? Has a merged ticket caused an issue that needs investigation?
- **DM Science Validation:**
  - Assess that the as-built Data Management System meets the needs of the scientific community and other identified stakeholders. Final DM Science Validation will be carried out as part of commissioning.
- **Commissioning System Verification and Validation:**
  - Is the system capable of routinely acquiring raw pixel-level data that will support the science goals of the 10-year LSST survey? (e.g., throughput, delivered image quality, capability to calibrate)
  - Do we understand the distribution of delivered data quality and how **hardware, software, and observatory operations together** contribute to generating "science ready" data products
  - Can we produce the set of verification artifacts to demonstrate construction completeness and operational readiness?
- **Operations [System Performance] Validation and Verification:**
  - During operations, is the running system performing as expected; e.g. on tonight's data, or on the data release in production?

Borrowed from Yusra Al-Sayyad

Quality Assurance of What?



Now continuously monitor and improve data quality during LSST

Operations [System Performance] Validation and Verification

Borrowed from Yusra Al-Sayyad

Key Points

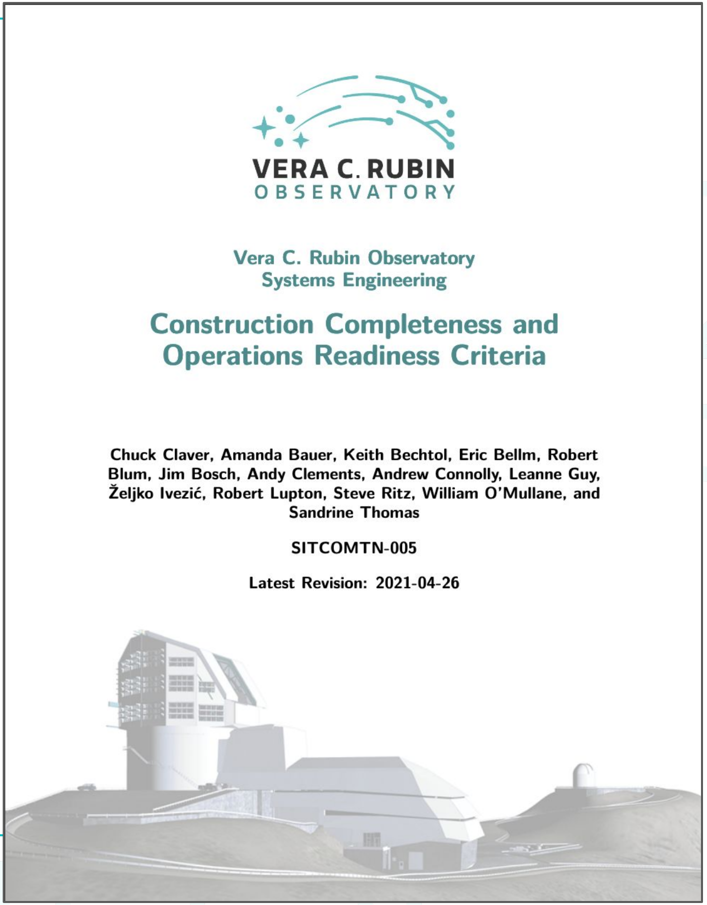
- Primarily deliverable is to provide evidence of a verified system performing according to specifications and ready to be handed over to LSST Operations
- Tight timeline for commissioning on-sky observations; preparation over the next year to automate science verification and validation studies and exercise workflows is necessary but not sufficient to meet our goals
- This activity will grow rapidly over the next two years; we will bring in expertise from individuals across Science Pipelines, DM V&V, Ops V&V, Systems Engineering, the subsystems, as well as in-kind contributors
- Propose organizing effort around a set of “science units” with groups responsible for reporting characterization of the data quality to inform commissioning, Science Pipelines development, and verification efforts

System-level science verification and validation deliverables

Construction Completeness and Operational Readiness Criteria

1) Verification of LSST System Requirements (LSE-29) and SRD (LPM-17) survey performance;
2) Verification of the Observatory System Specifications (LSE-30);
3) Verification of Data Process, Products and User Services;
4) Demonstrating Science Data Quality Assessment (SDQA);
5) Conduct a Science Validation Survey;
6) Demonstrate the system state is recorded and archived for each observation;
7) Verify Education and Public Outreach has met its requirements and construction scope;
8) Operational procedures and documented and accessible;
9) Provided a document record of the as-built system, modification and non-compliance;
10) Demonstrate Rubin Operations Team readiness

ls.st/sitcomtn-005



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Vera C. Rubin Observatory
Systems Engineering

Construction Completeness and Operations Readiness Criteria

Chuck Claver, Amanda Bauer, Keith Bechtol, Eric Bellm, Robert Blum, Jim Bosch, Andy Clements, Andrew Connolly, Leanne Guy, Željko Ivezić, Robert Lupton, Steve Ritz, William O'Mullane, and Sandrine Thomas

SITCOMTN-005

Latest Revision: 2021-04-26

Deliverables at Operational Readiness Review

- Verification of system-level requirements in LSR + OSS
  - Roughly 100-200 normative "science performance" requirements for which verification involves using data from science pixels
  - Detailed specifications, test plans and reports, final compliance status
  - Impact studies in cases of non-compliance
- Documented set of science verification and validation analysis software and visualization capabilities to provide to Operations
- Studies to inform LSST Operations based on commissioning on-sky observations, e.g.,
  - Correlating delivered data quality with environmental conditions / telemetry
  - Minimum number of visits and quality of visits to use for template generation for difference imaging
  - Dithering strategy in both WFD and Deep Drilling Fields
  - Visit definition as 2 x 15 sec snaps versus 1 x 30 sec
- Drafts of construction papers
- Additional publications and tech notes to document details
- Press images

Steps to Verify a typical OSS/LSR science performance requirement

- Rubin Observatory uses the Jira verification system (LVV project, see documentation)
- Requirements are decomposed into individual **verification elements** that have well defined specifications including pass/fail criteria
- All verification elements must have links to passed **test cases** (a single test case can cover multiple verification elements)
- The test cases can have links to the **documentation of the scientific evaluation methodology that must include a summary of the method and steps to verify the linked requirements**
- When stepping through test cases in a **test cycle**, we attach the evidence that specifications have been met, which could be accomplished by loading **metric values and diagnostic plots that have been generated using dedicated data analysis software outside the Jira system**

Science units focus on highlighted items
Work directly alongside with systems engineering on other parts

Steps to Verify a typical OSS/LSR science performance requirement

Key point:

The formal verification evidence should be captured in the verification system, but the scientific methodology and mechanisms to characterize and verify the requirement performance parameters do not have to be fully contained in the verification system; the evidence must be version controlled, and the link to the associated code repository, data, etc., must be static.

Science Verification and Validation Data Analysis Tooling

Resources

Rubin Observatory uses many data analysis and visualization tools

"Monitoring Pipeline quality overview" presentation from June 2022 DM Science Pipelines Bootcamp provides background on testing datasets, metrics, squash, chronograph, plot-navigator, and other tools – highly recommended!

For today, we highlight a few recent developments…

analysis_tools

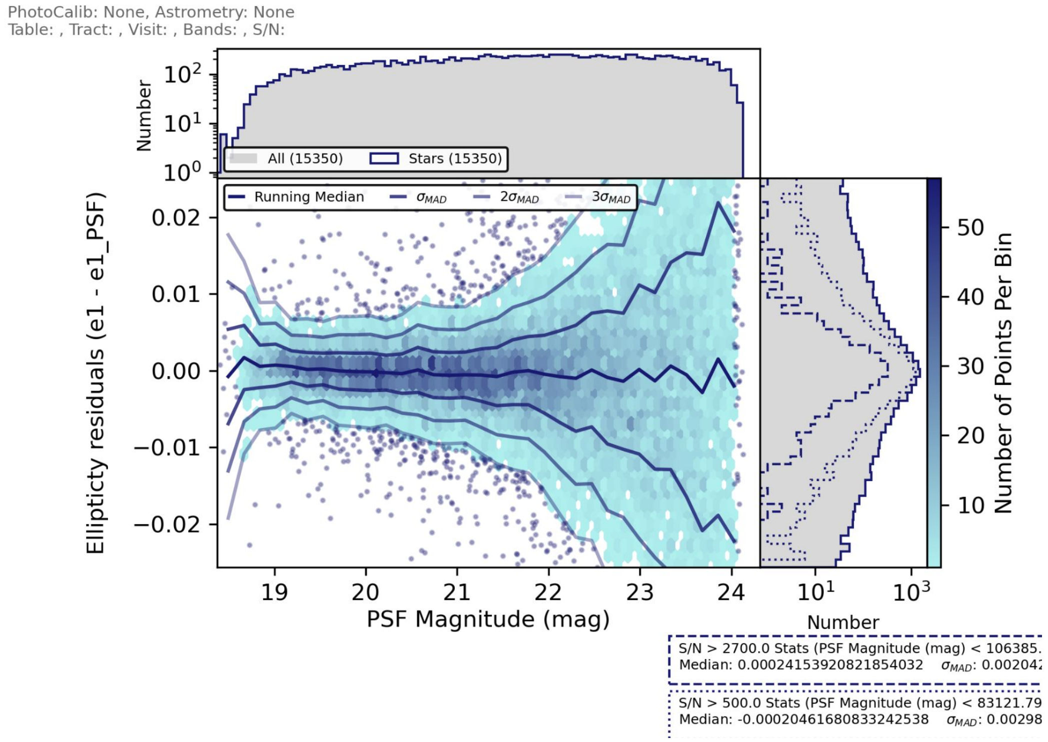
New analysis_tools python package is a refactor of faro and analysis_drp packages that provides both metric and plot generation functionality

- Run analyses as Tasks within data reduction pipeline, as part of a separate pipeline, or even standalone in a script/notebook
- More fully leverages middleware capabilities (e.g., high configurability, efficient grouping of analyses into quanta + smaller number of output files, ability to easily reconstitute input data products along with configuration that were used to generate a metric/plot)
- Modular design; potential to build customized analyses off base classes
- Analyses that run on per-visit source tables, per-tract object tables, per-tract associated sources, …

Sprint in July 2022 added example metrics + plots in multiple contexts; added to lsst_dstrib last week (w_2022_32)

Option to work through a tutorial notebook at the “Onboarding for SIT-Com In-Kind Contributions” session Tuesday 1:30-3:00 pm

analysis_tools example



plots and metric values generated with same underlying code as part of the same pipeline task

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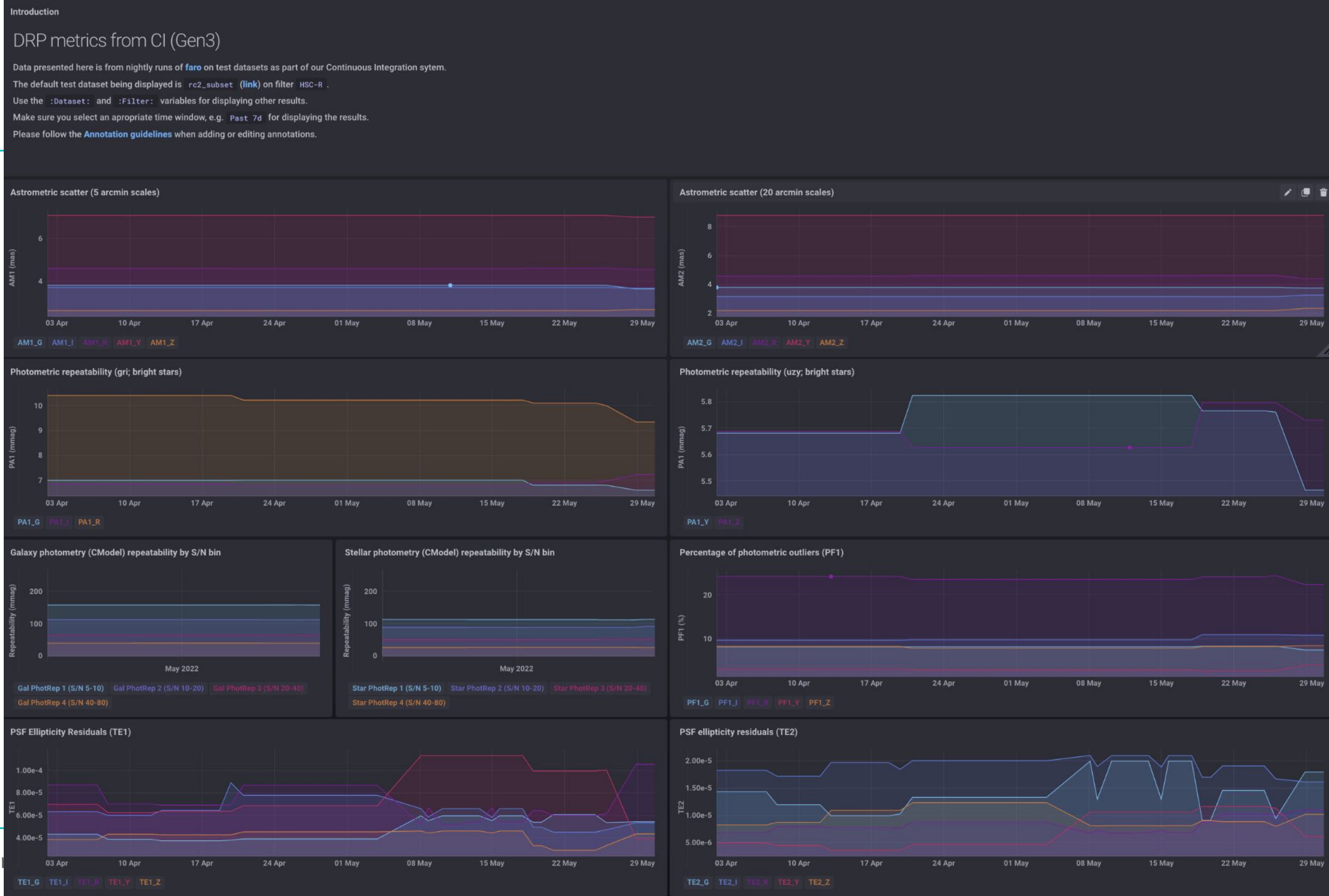
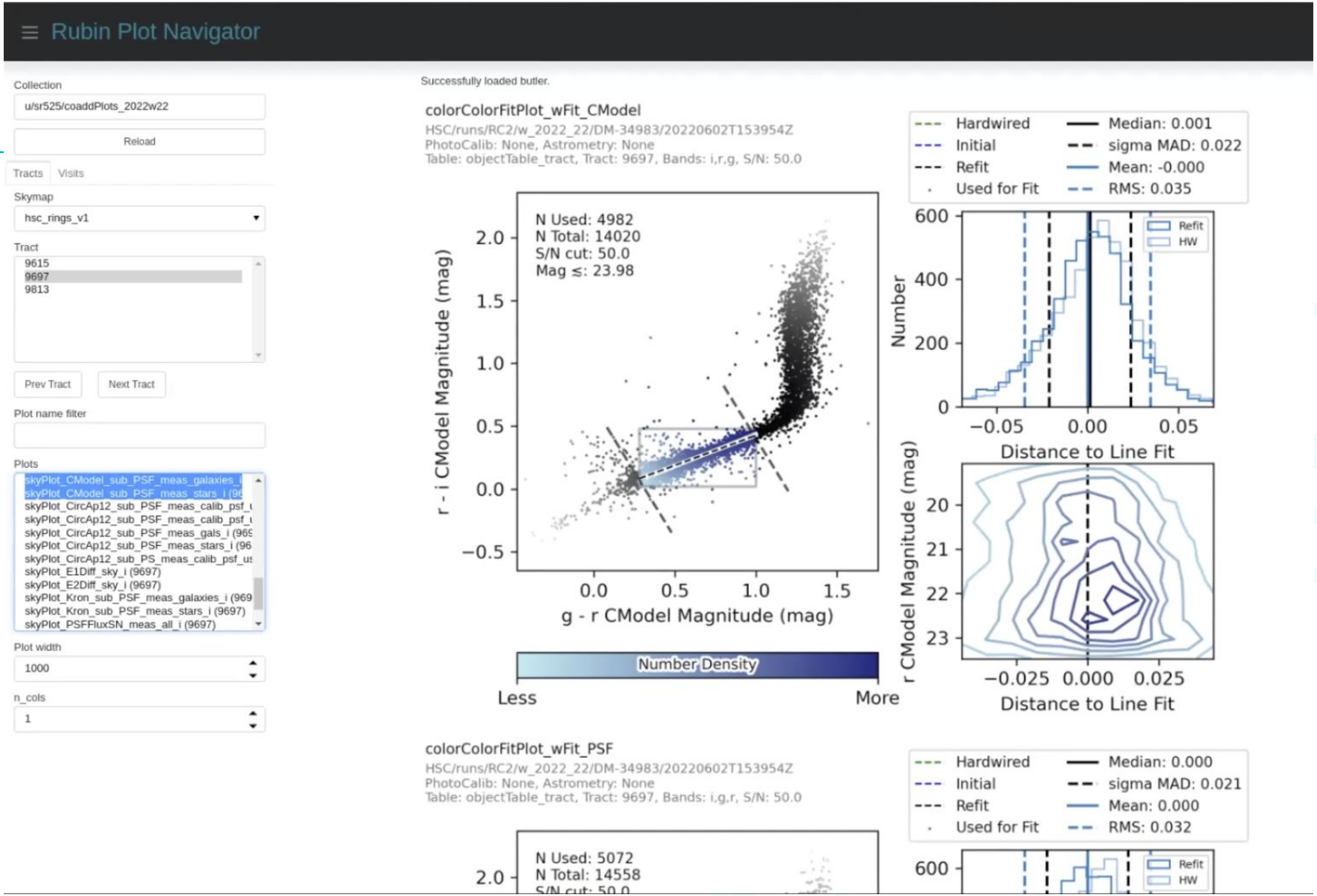
InfluxDB / Chronograph dashboard showing time evolution of a sample of metrics computed as part of the nightly builds on a small subset of the HSC RC2 dataset

During commissioning, we will also look at how data quality varies over time

Guy et al. 2022
[arXiv:2206.15447](https://arxiv.org/abs/2206.15447)



Screen shot of prototype plot navigator webpage demonstrating the capability to browse through a collection of automatically generation diagnostic plots stored in the Butler



Remarks

Contributing science performance metrics and plots to the analysis_tools package would make it possible to run these studies during commissioning and as part of the preparation of an LSST data release

This is one of the more direct ways for Science Collaborations to have an influence on science verification and validation prior to a major data release

The science performance metrics and plots are persisted alongside input data products with the Butler, and could be made available as part of a release

Science collaborations could also set up custom pipelines built upon analysis_tools base classes to support their science validation workflows

Construction / Data Delivery Milestones

Future Major (Celebratory) Milestones

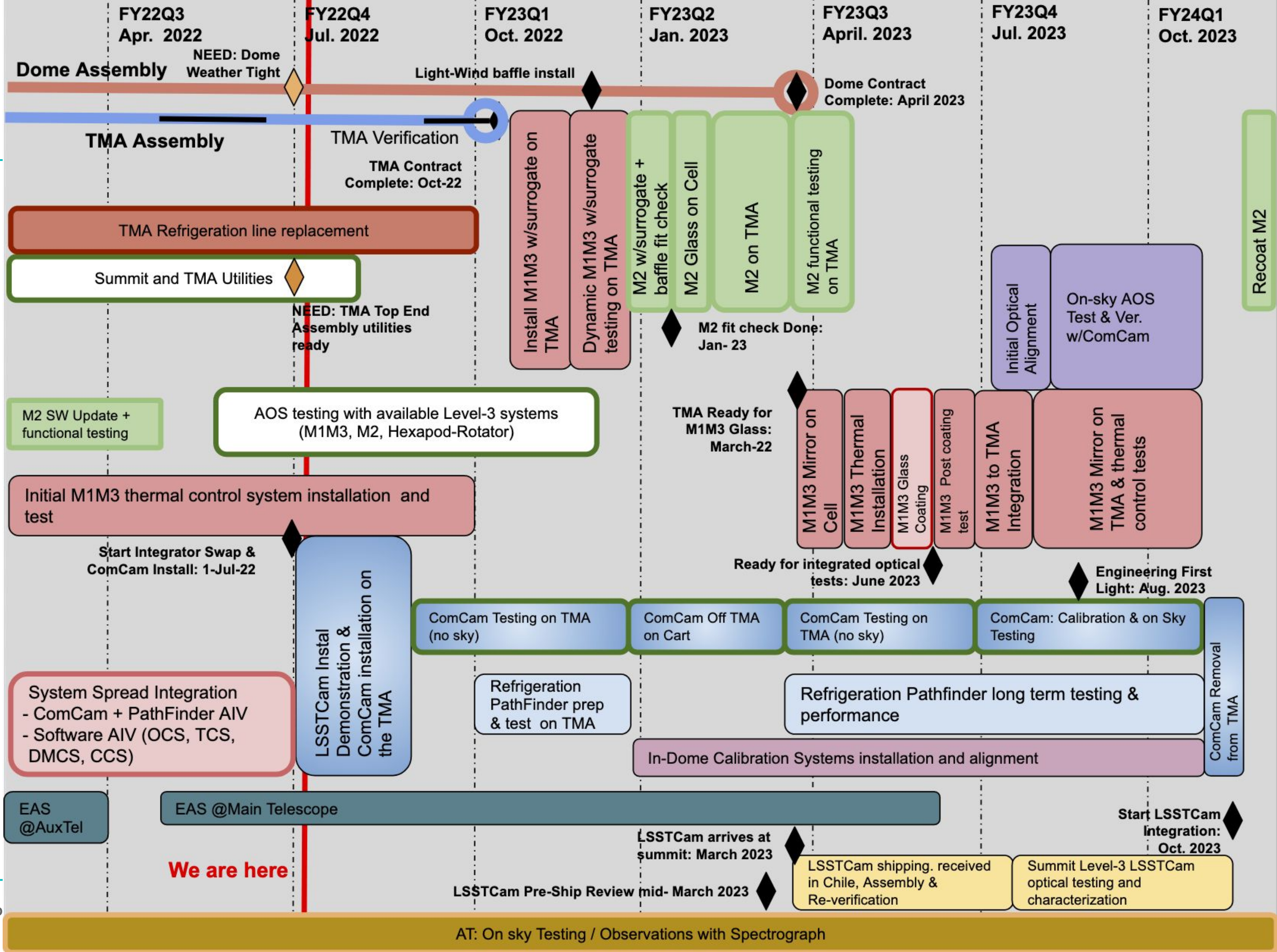
Celebratory Milestones: https://dmtn-232.lsst.io/

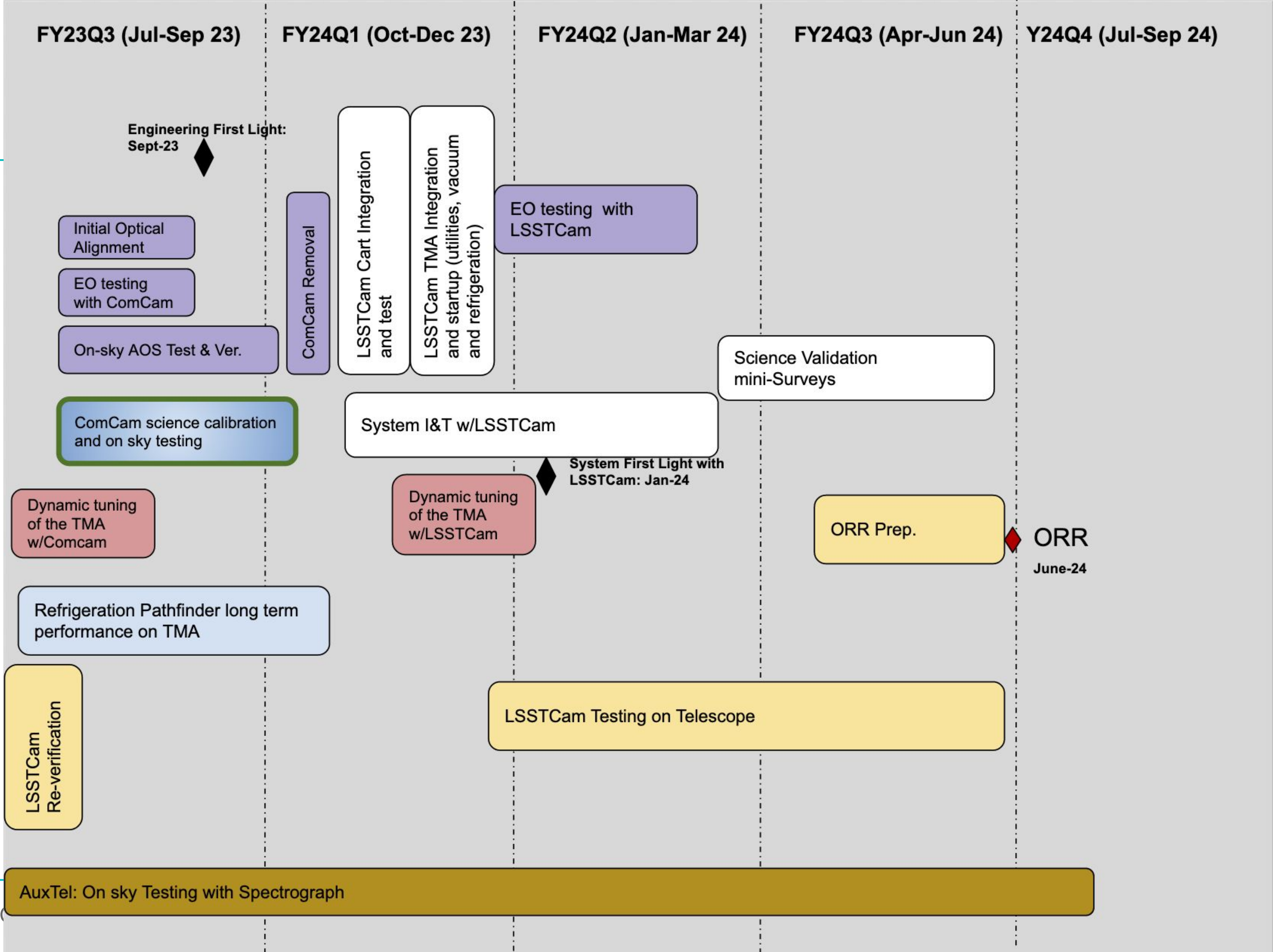
(synchronized ~monthly from P6 plan)

Current Forecast	Name
29-Sep-2022	TMA Contract Complete
30-Sep-2022	EPO Construction Finish
20-Mar-2023	COMP: Camera Pre-Ship Review at SLAC
28-Mar-2023	Dome Complete
17-May-2023	3-Mirror Optical System Ready for Testing
19-Jul-2023	Engineering First Light w/ComCam
05-Sep-2023	Camera Ready for Full System AI&T
14-Feb-2024	**System First Light**
11-Jun-2024	Test report: Final Pipelines Delivery
11-Jun-2024	Mini-Survey 2 Complete
18-Jun-2024	Operation Readiness Review Complete

Rubin Operations Top Milestones

- **2021-06-30** Deliver Data Preview 0.1 (DP0.1) (L1-RO-0040)
- **2022-06-30** Complete Delivery of Data Preview Zero (L1-RO-0050)
- **Apr 2024 - Jul 2024** Complete Delivery of Data Preview One (DP1) (L1-RO-0060) (= Optical testing on TMA complete + 6 months)
- **Jun 2024 - Oct 2024** ("Survey"/"Full") Operations Begins (L1-RO-0100) (= Operation Readiness Review Complete + 1 day)
- **Jun 2024 - Nov 2024** Survey Start (L1-RO-0110) (= ("Survey"/"Full") Operations Begins + 1 months)
- **Dec 2024 - Mar 2025** Complete Delivery of Data Preview Two (DP2) (L1-RO-0070) (= COMP: mini-Survey 2 Data Release Complete + 6 months)
- **Oct 2025 - Jan 2026** Complete Delivery of Data Release One (DR1) (L1-RO-0120) (= Survey Start + 12 months)


FY22Q3 Apr. 2022
FY22Q4 Jul. 2022
FY23Q1 Oct. 2022
FY23Q2 Jan. 2023
FY23Q3 April. 2023
FY23Q4 Jul. 2023
FY24Q1 Oct. 2023
Dome Assembly
NEED: Dome Weather Tight
Light-Wind baffle install
Dome Contract Complete: April 2023
TMA Assembly
TMA Verification
TMA Contract Complete: Oct-22
TMA Refrigeration line replacement
Summit and TMA Utilities
NEED: TMA Top End Assembly utilities ready
Install M1M3 w/surrogate on TMA
Dynamic M1M3 w/surrogate testing on TMA
M2 w/surrogate + baffle fit check
M2 Glass on Cell
M2 on TMA
M2 functional testing on TMA
M2 fit check Done: Jan- 23
Initial Optical Alignment
On-sky AOS Test & Ver. w/ComCam
Recoat M2
M2 SW Update + functional testing
AOS testing with available Level-3 systems (M1M3, M2, Hexapod-Rotator)
TMA Ready for M1M3 Glass: March-22
M1M3 Mirror on Cell
M1M3 Thermal Installation
M1M3 Glass Coating
M1M3 Post coating test
M1M3 to TMA Integration
M1M3 Mirror on TMA & thermal control tests
Initial M1M3 thermal control system installation and test
Start Integrator Swap & ComCam Install: 1-Jul-22
LSSTCam Instal Demonstration & ComCam installation on the TMA
Ready for integrated optical tests: June 2023
Engineering First Light: Aug. 2023
ComCam Testing on TMA (no sky)
ComCam Off TMA on Cart
ComCam Testing on TMA (no sky)
ComCam: Calibration & on Sky Testing
ComCam Removal from TMA
System Spread Integration
- ComCam + PathFinder AIV
- Software AIV (OCS, TCS, DMCS, CCS)
Refrigeration PathFinder prep & test on TMA
Refrigeration Pathfinder long term testing & performance
In-Dome Calibration Systems installation and alignment
EAS @AuxTel
EAS @Main Telescope
Start LSSTCam Integration: Oct. 2023
LSSTCam arrives at summit: March 2023
We are here
LSSTCam shipping. received in Chile, Assembly & Re-verification
Summit Level-3 LSSTCam optical testing and characterization
LSSTCam Pre-Ship Review mid- March 2023
AT: On sky Testing / Observations with Spectrograph



FY23Q3 (Jul-Sep 23)
FY24Q1 (Oct-Dec 23)
FY24Q2 (Jan-Mar 24)
FY24Q3 (Apr-Jun 24)
Y24Q4 (Jul-Sep 24)
Engineering First Light: Sept-23
Initial Optical Alignment
EO testing with ComCam
On-sky AOS Test & Ver.
ComCam Removal
LSSTCam Cart Integration and test
LSSTCam TMA Integration and startup (utilities, vacuum and refrigeration)
EO testing with LSSTCam
Science Validation mini-Surveys
ComCam science calibration and on sky testing
System I&T w/LSSTCam
System First Light with LSSTCam: Jan-24
Dynamic tuning of the TMA w/Comcam
Dynamic tuning of the TMA w/LSSTCam
ORR Prep.
ORR
June-24
Refrigeration Pathfinder long term performance on TMA
LSSTCam Re-verification
LSSTCam Testing on Telescope
AuxTel: On sky Testing with Spectrograph

Science Verification View of Commissioning

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering	System Optimization	Science Validation Survey(s)
EO testing	EO testing in-dome calibration systems	optical alignment pointing tests AOS look-up table initial science verification	tweaking control loops scheduler parameters observing efficiency and science performance over range of conditions	>30 days sustained observing exercising operations procedures continued science validation of coaddition and difference imaging
Level 3 System Integration Complete	**Ready for On-sky Testing**	**System "First Light"**	**Start Science Validation Surveys**	**Operations Readiness Review Complete**
LSSTCam reverification complete DM ready for bulk data collection	calibration products pipeline verified	routinely producing science grade images over the full field of view (FOV) verified system throughput, delivered image quality	verified applied of ISR for on-sky images verified visit-level PSF modeling, astrometric + photometric calibration	Science Pipelines delivered science verification complete

Prioritization of Commissioning SVV Studies

Fixed by the telescope, camera, and observing strategy

Potential to be continually improved through refinements of the Science Pipelines

Image quality (PSF profile, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies

Instrument signature removal

“System First Light” criteria

Visit-level PSF modeling, photometric, and astrometric calibration

Coaddition, difference imaging, deblending, galaxy photometry including shape measurement, moving object link-age, and proper motions

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Prioritization of Commissioning SVV Studies

Fixed by the telescope, camera, and observing strategy

Image quality (PSF profile, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies

Instrument signature removal

Entry threshold for starting SV survey(s)

Visit-level PSF modeling, photometric, and astrometric calibration

Coaddition, difference imaging, deblending, galaxy photometry including shape measurement, moving object link-age, and proper motions

Potential to be continually improved through refinements of the Science Pipelines

Prioritization of Commissioning SVV Studies

Fixed by the telescope, camera, and observing strategy

Image quality (PSF profile, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies

Instrument signature removal

Operations Readiness Review

Visit-level PSF modeling, photometric, and astrometric calibration

Coaddition, difference imaging, deblending, galaxy photometry including shape measurement, moving object link-age, and proper motions

Potential to be continually improved through refinements of the Science Pipelines

Tight Timeline for Science Verification Analyses

Test what we can as early as we can; maximize opportunities for iteration; automate as many analyses as possible

ComCam “first light” precedes LSSTCam “first light” by ~6 months

~4 months between LSSTCam “first light” and Operations Readiness Review; includes

- Observing
- Data processing
- Human brain cycles to interpret results, prioritize, ideate solutions
- Implement fixes, re-process data, re-analyze
- Document results

On-sky Observing Strategy during Commissioning

Managing Expectations

Data content from commissioning is a “shared risk” / “best effort” situation:

- **Rubin Observatory needs to prioritize technical and scientific verification of formal system requirements to demonstrate construction completeness in a timely fashion**
- The detailed schedule for on-sky commissioning observations is TBD
- The Commissioning Team has already been planning to acquire on-sky observations that would enable science validation studies for the four main LSST science drivers
  - Guidance from science community is welcome and appreciated to enhance opportunities for science validation studies based on commissioning data
- Commissioning observations are NOT an observing proposal / TAC process
- We cannot ensure that any particular observations will be taken during commissioning

Process so Far

Phase 1 (2020):

- LSST Community Post welcoming community input in the form of brief "commissioning notes"
- Parallel Session at PCW 2020, including 6 presentations from representatives of SCs
- Participated in workshops with individual SCs as requested
- Commissioning notes received from SSSC, TVS + SMWLV, Galaxies, SLSC, and DESC
    - Many well motivated concepts for scientific and technical investigations that could be done using commissioning data; summary presented in Parallel Session at PCW 2021
    - Several suggested fields are currently on target list for AuxTel imaging survey

Phase 2 (2023-):

- Project will produce menu of candidate target fields, considering community input
- Iterate details with community as needed closer to time of first light

Emergent Themes from Commissioning Notes

Datasets that could serve as a reference for characterizing the Wide-Fast-Deep (WFD) survey:

- Deep (10-year to 20-year LSST WFD equivalent exposure)
- High cadence over several contiguous hours to several consecutive nights
- Multi-band (*ugrizy*)
- Uniform depth

Many goals can be met with a series of LSSTCam pointings each with 1000-2000 visits across multiple bands with dense temporal sampling

- Unique dataset with high legacy value; complementary to the nominal WFD survey strategy and could serve as a valuable reference during early years of LSST
- Consider a few contiguous fields each comprised of a few LSSTCam pointings (with dithering)
- Suggested high-priority targets include DDFs, Outer Solar System pointing (e.g., OSSOS, DEEP), moderately dense stellar fields (not too much PSF overlap; low interstellar dust extinction)

Science Verification View of Commissioning

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering	System Optimization	Science Validation Survey(s)
EO testing	EO testing in-dome calibration systems	optical alignment pointing tests AOS look-up table initial science verification	tweaking control loops scheduler parameters observing efficiency and science performance over range of conditions	>30 days sustained observing exercising operations procedures continued science validation of coaddition and difference imaging
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LSSTCam reverification complete DM ready for bulk data collection	calibration products pipeline verified	routinely producing science grade images over the full field of view (FOV) verified system throughput, delivered image quality	verified applied of ISR for on-sky images verified visit-level PSF modeling, astrometric + photometric calibration	Science Pipelines delivered science verification complete

Commissioning Data Collection

ComCam

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering (~3 months)	System Optimization (~1 month)	
biases, darks, flats	suite of in-dome calibration	pointing, AOS testing star flats, dithering around bright stars, airmass scans	20-year LSST WFD equivalent depth, synthesizing LSSTCam FoV, prioritizing LSST DDF	**remove ComCam, install LSSTCam**

LSSTCam

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering (~3 months)	System Optimization (~1-2 months)	Science Validation Survey(s) (~1-2 months)
biases, darks, flats	suite of in-dome calibration	pointing, AOS star flats, dithering around bright stars, airmass scans	20-year LSST WFD equivalent depth in fields for extragalactic, Galactic, and Solar System science, ~100 deg^2 in multiple bands with dense temporal sampling	Menu includes increased coverage of LSST DDFs Pilot LSST WFD survey, ~1000 deg^2 in multiple bands to 1-2 year LSST equivalent depth Astrophysical targets / ToO

On-sky Engineering

Gradual transition from mostly engineering initially to mostly science-driven activities

From the first in-focus image on sky, we intend to push data through Science Pipelines and produce catalogs as well as diagnostic metrics and plots, with an initial emphasis on single-visit performance

In parallel with testing of telescope/camera, we will attempt to formally verify as many science performance requirements as possible

Example observations: star flats, dithering around bright stars to study scattered light, observations at a range of airmass, etc.

System Optimization

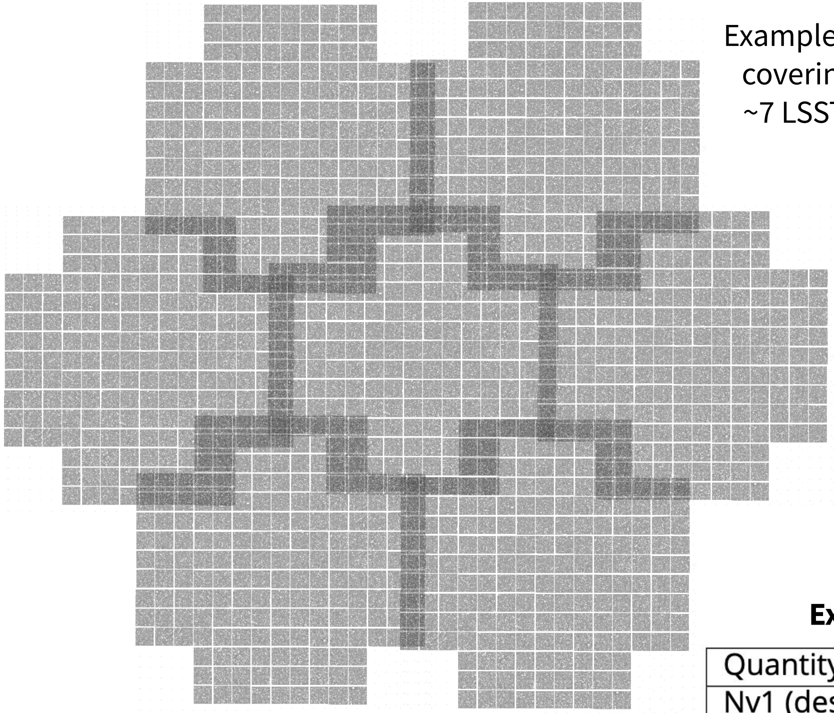
Mostly science driven activities with interspersed engineering; this phase represents the start of a sustained effort to characterize observatory performance

Emphasis on data processing through coaddition and difference imaging; first opportunity to explore the full science potential of Rubin Observatory

Data taking will be driven by the needs to complete formal science verification, and to produce datasets that will be of high scientific value to the LSST community

Example observations: deep fields (e.g., 20-year LSST Wide-Fast-Deep equivalent exposure) for extragalactic, Galactic, and Solar System science covering ~100 deg^2 in multiple bands with dense temporal sampling

System Optimization



Example contiguous field covering ~70 deg^2 with ~7 LSSTCam pointings

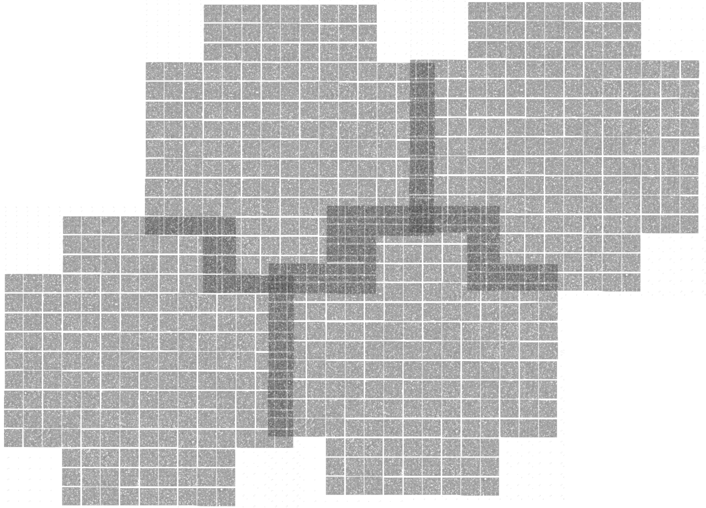
Obtain deep exposures in multiple bands in a few such contiguous fields aimed at extragalactic, SMWLV, and Solar system science cases, with rapid observing cadence to support time domain studies

Roughly 700-800 visits per night

Example 10-year LSST visit distribution across the survey footprint

Quantity	u	g	r	i	z	y
Nv1 (design spec.)	56 (2.2)	80 (2.4)	184 (2.8)	184 (2.8)	160 (2.8)	160 (2.8)
Idealized Depth	26.1	27.4	27.5	26.8	26.1	24.9

System Optimization



Example contiguous field covering ~40 deg^2 with ~4 LSSTCam pointings

Obtain deep exposures in multiple bands in a few such contiguous fields aimed at extragalactic, SMWLV, and Solar system science cases, with rapid observing cadence to support time domain studies

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Idealized Depth	26.1	27.4	27.5	26.8	26.1	24.9

Science Validation Surveys

>30 nights of sustained data taking to demonstrate that Rubin Observatory can smoothly transition to steady state LSST Operations

Example observations:

- Increased coverage of LSST Deep Drilling Fields
- Pilot LSST Wide-Fast-Deep survey covering to increase areal coverage, increase breadth of opportunities for science validation, and to begin generating templates for difference imaging
  - For example, ~1000 deg^2 in multiple bands to 1-2 year LSST equivalent exposure
- Astrophysical targets of interest
- Target-of-Opportunity tests

Next Steps

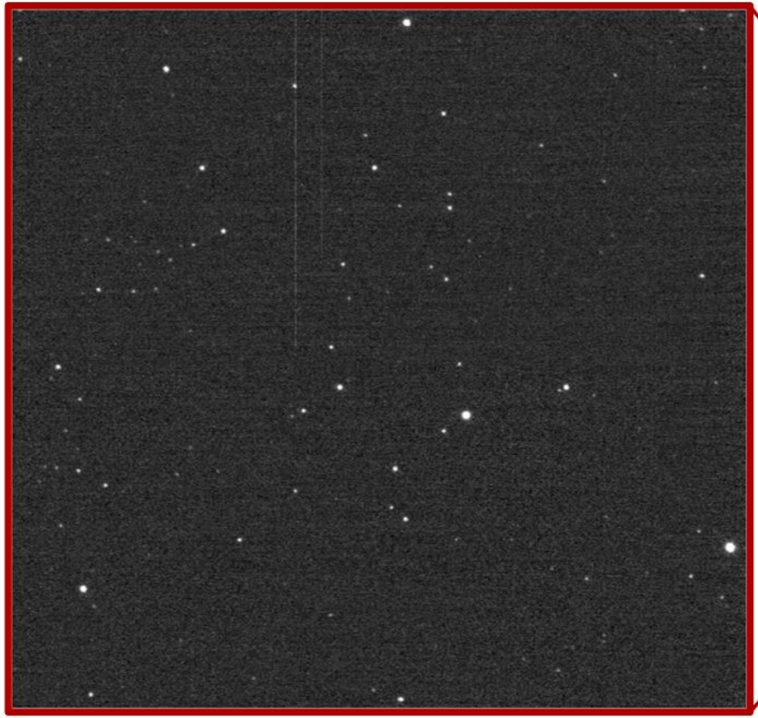
Roughly 3 months before ComCam goes on sky, we will begin detailed planning for on-sky observations taking into account the expected schedule and visibility of candidate fields during that season.

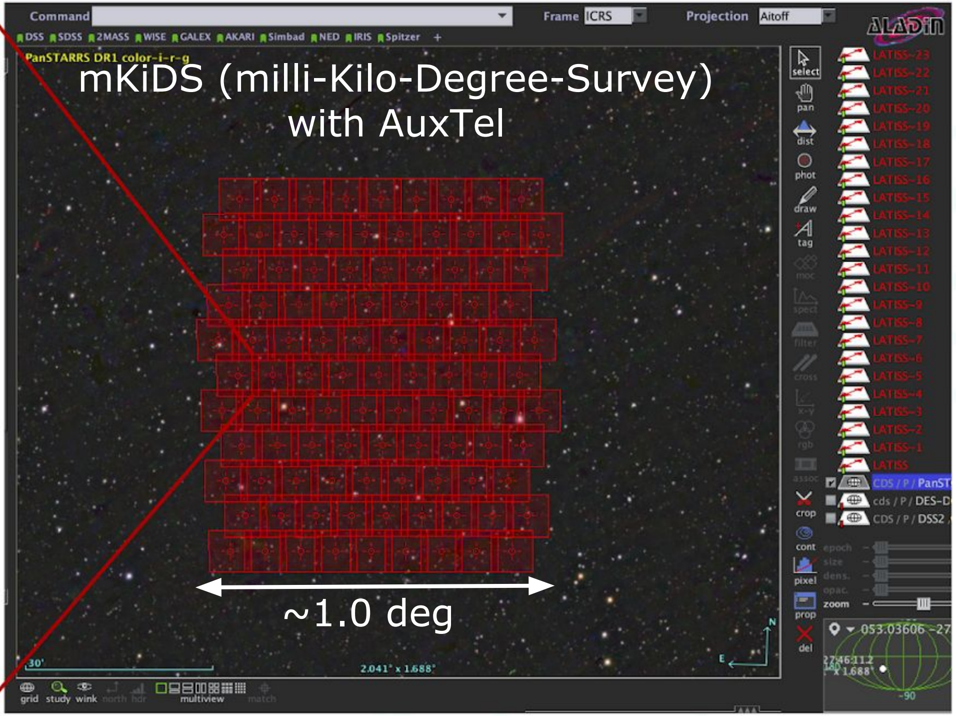
AuxTel Imaging Survey as Pathfinder

AuxTel Imaging Survey

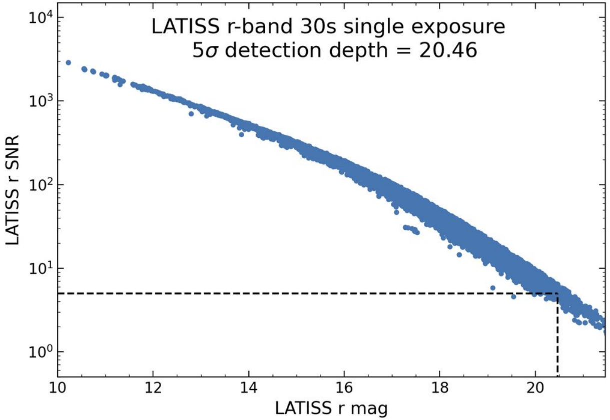
>5000 x 30 sec exposures in *gri* collected since Oct 2021

Johnny Esteves and Erik Dennihy

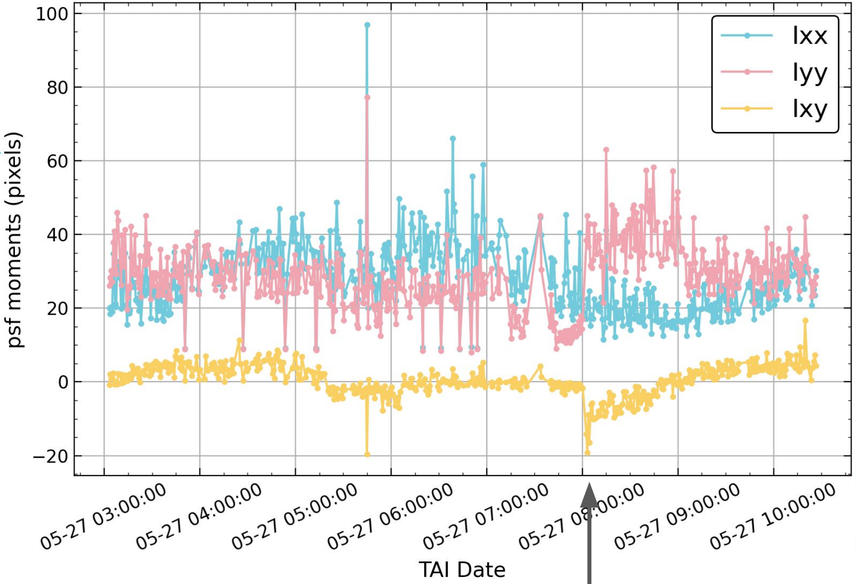




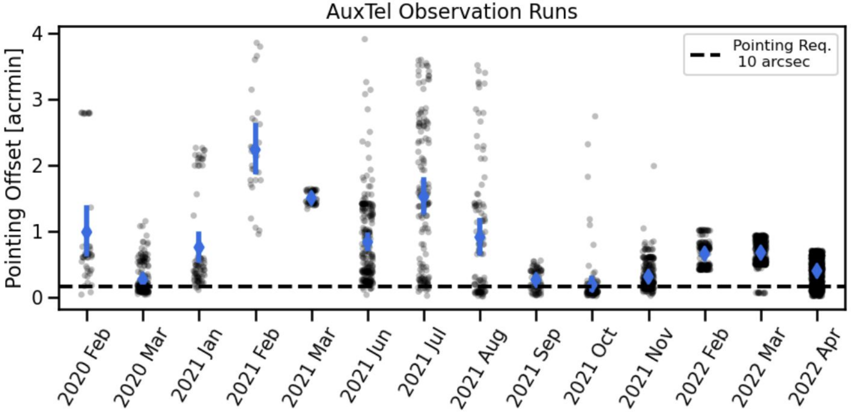
Example Analyses



First zeropoint and imaging depth estimates with AuxTel

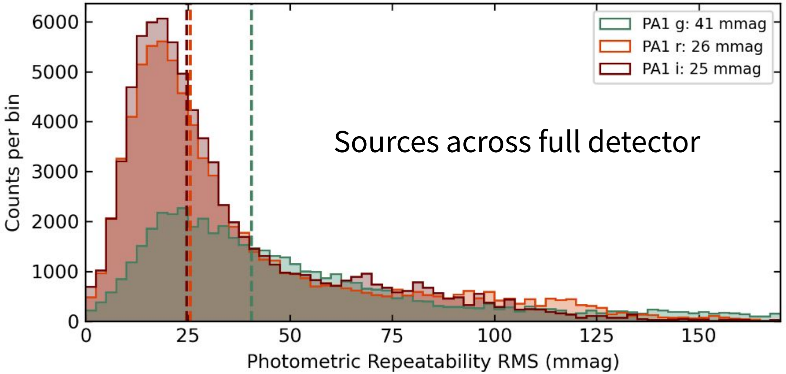


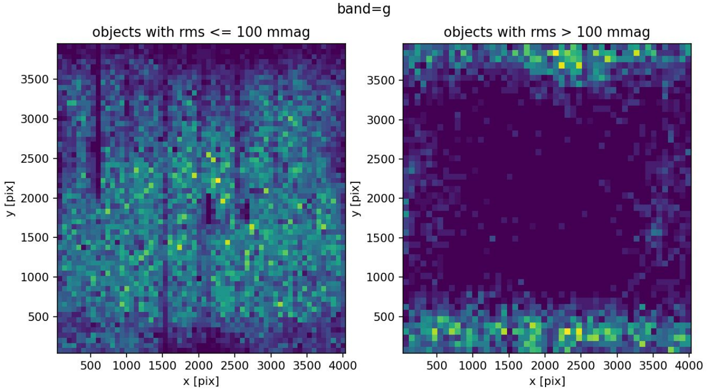
Large shift in PSF moment values at 08:00 coincident with a 180 deg slew in telescope azimuth



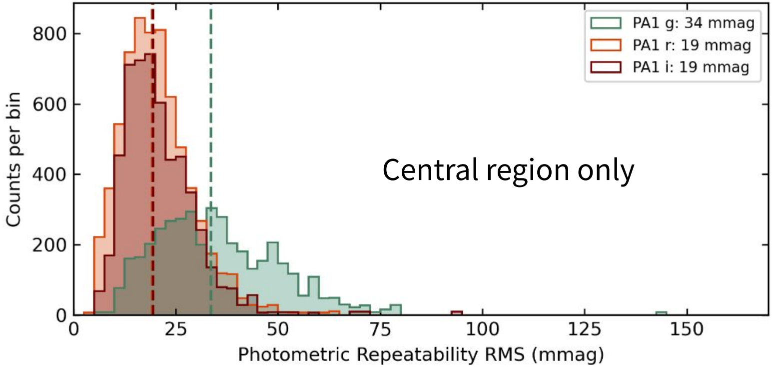
Telescope pointing offset measured by comparing to astrometric solution

Example of Metrics in Action





Photometric repeatability outliers are concentrated around edges of focal plane

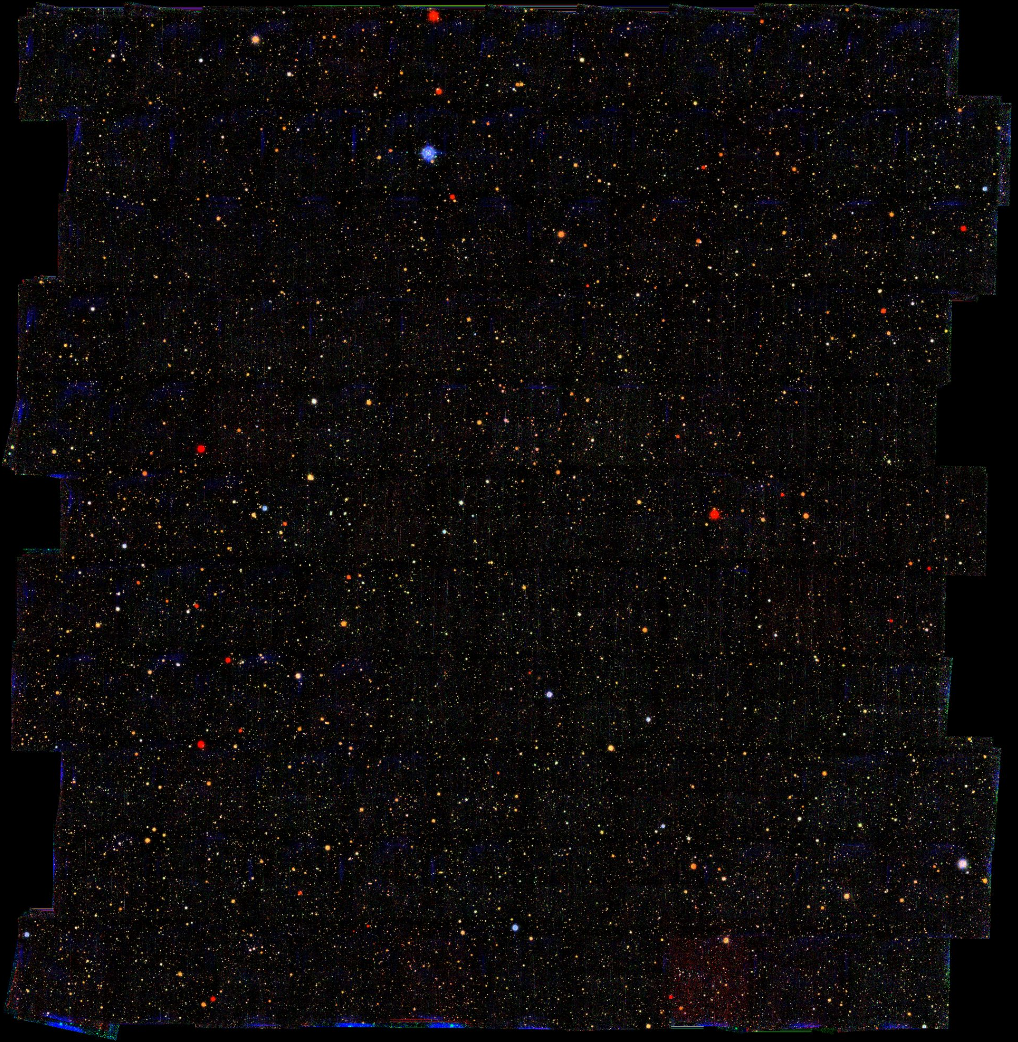


Outlier source photometric attributed to known vignetting and epoxy creep issue on current set of AuxTel filters (to be replaced)

One square-degree of the sky as seen by the Auxiliary Telescope, mapped using the same Feature Based Scheduling algorithm that will control the main telescope. The field is one of the original Harvard Standard Regions used to calibrate the Southern Sky (reference)

This co-added image combines more than 2500 exposures in three different filters (SDSS gri) collected between February and May of 2022.

Erik Dennihy, Merlin Fisher-Levine, Robert Lupton

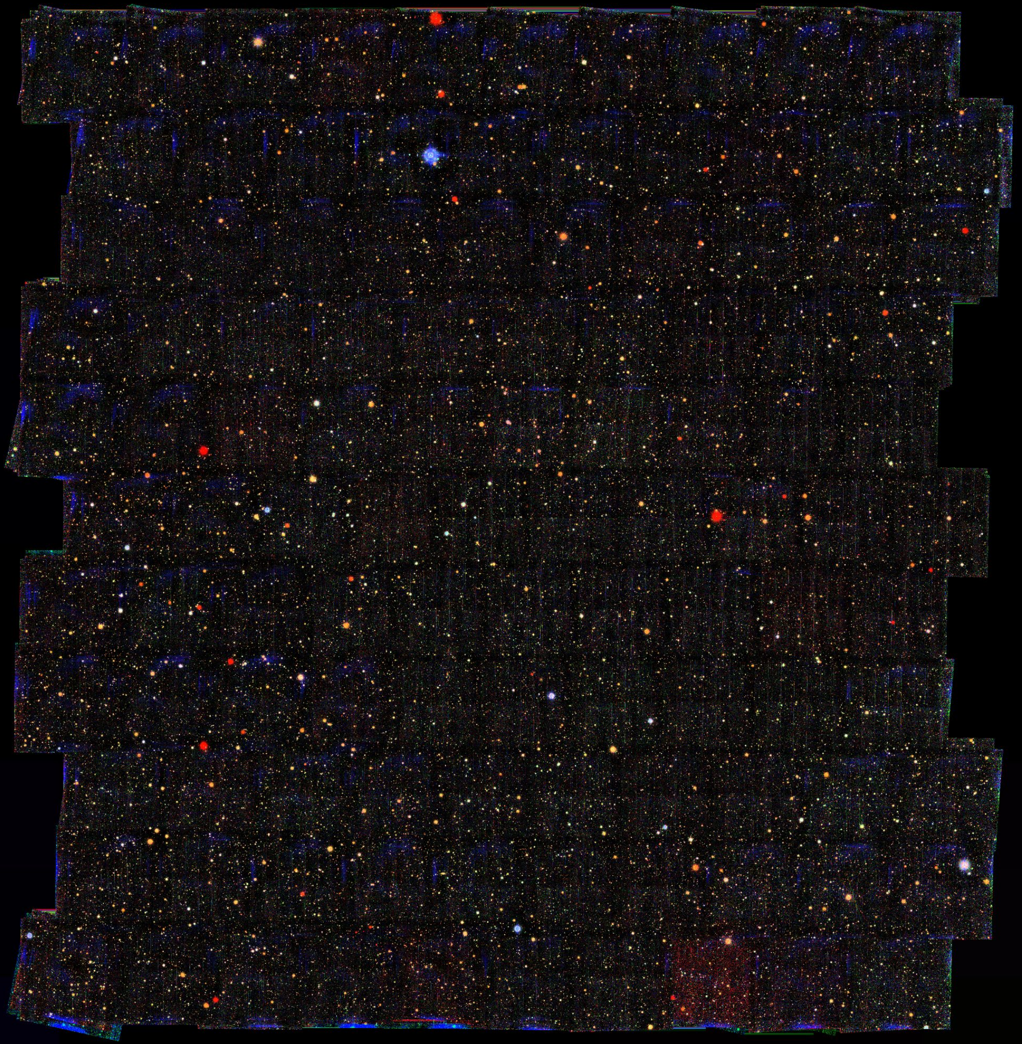


VERA C. RUBIN
OBSERVATORY

One square-degree of the sky as seen by the Auxiliary Telescope, mapped using the same Feature Based Scheduling algorithm that will control the main telescope. The field is one of the original Harvard Standard Regions used to calibrate the Southern Sky (reference)

This co-added image combines more than 2500 exposures in three different filters (SDSS gri) collected between February and May of 2022.

Same as previous image with increased stretch to pull out data quality features

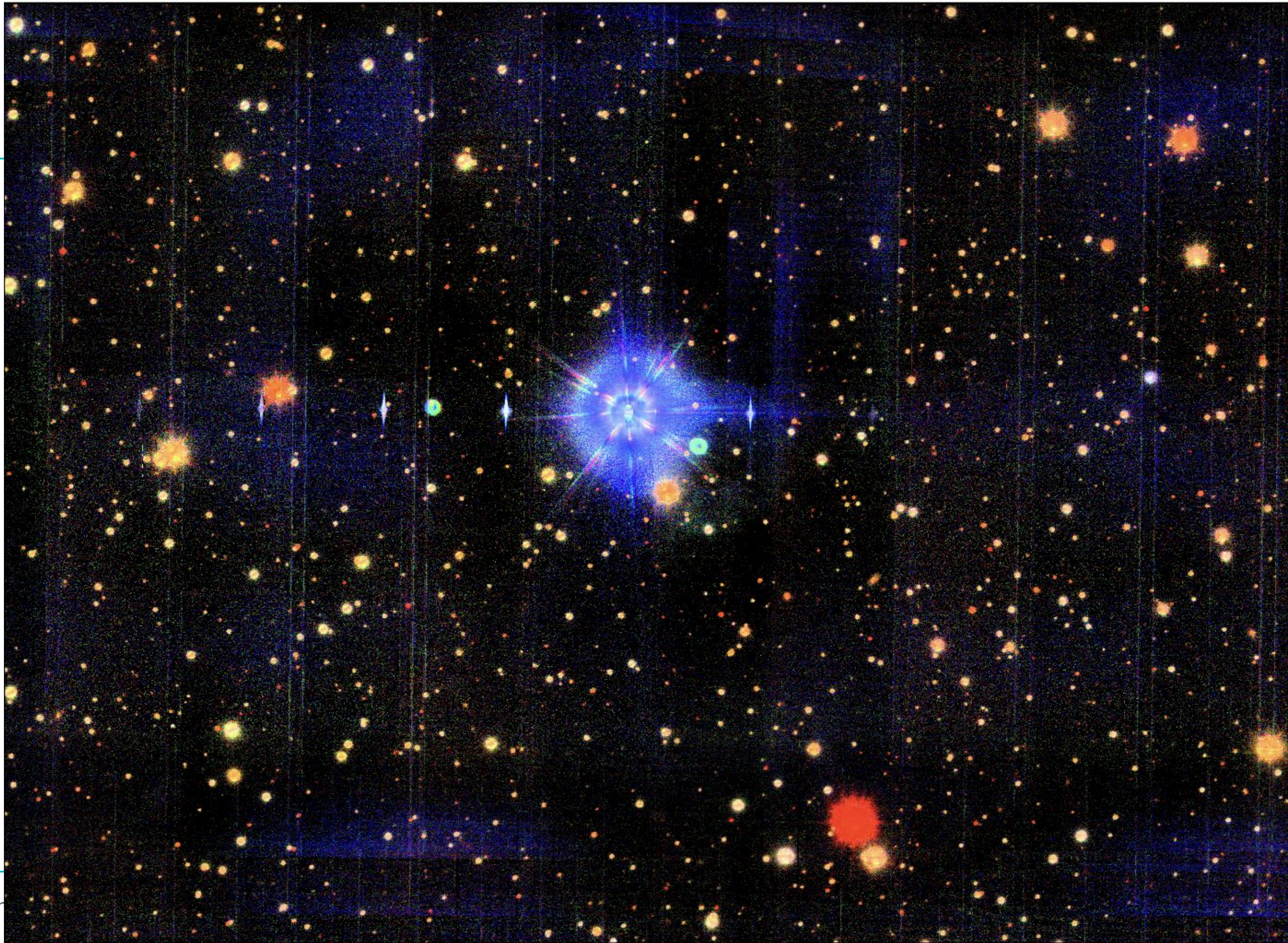


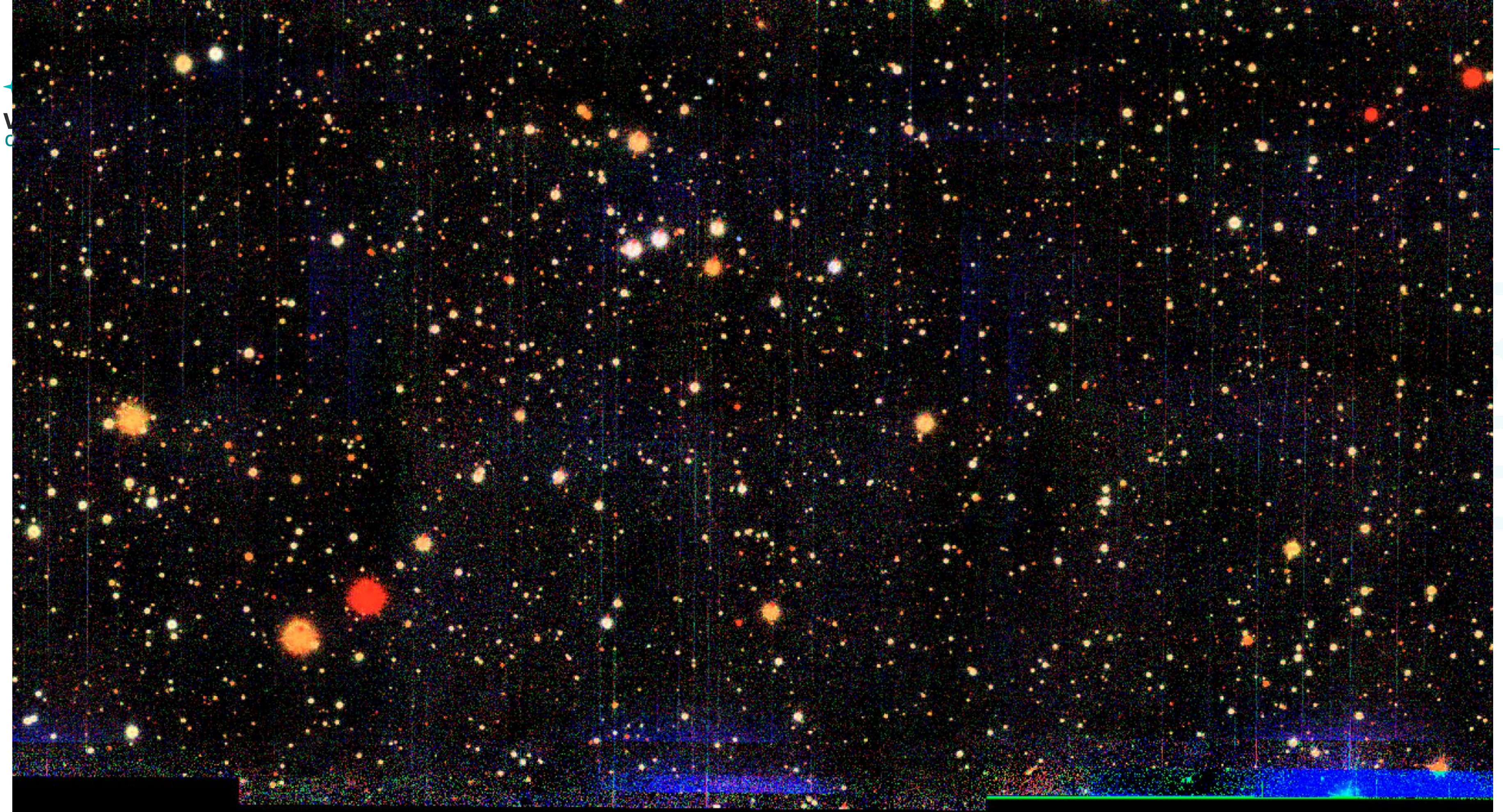
Erik Dennihy, Merlin Fisher-Levine, Robert Lupton

Oops! Crosstalk was turned off

Intermittent bad column

Background subtraction issues





Astrometry failures (notice offset small red dots in central region of image)

Timescales for Science Data Quality Analysis and “First-look” Infrastructure

Timescales for Data Quality Analysis

- Minutes
  - Supporting nighttime decision making at observatory
  - Monitoring of basic image health focused on hardware/system configuration
- Hours
  - Supporting daily work planning and prioritization
  - Optimizing system configuration, including telescope pointing and AOS
  - Initial science performance characterization for individual visits (e.g., identify subset of “survey quality” images that could be used to build coadds)
- Beyond 24 hours
  - Data processing: coadd processing and template generation
  - Investigating Science Pipeline algorithm performance (e.g., noise levels and PSF in deep coadds, deblending)
  - Deep dive and ad hoc investigations, exploring data processing configuration
  - Generating verification artifacts

Needed Functionality

- Summary QA reports of camera calibration products
- Summary QA displays of basic camera health for individual exposures during the night
- Automated “rapid analysis” Science Pipelines processing within 30-60 seconds (ideally faster)
    - Sufficient to measure high SNR stars
    - Interested in delivered image quality, throughput (e.g., zeropoint), background level
    - Information used to seed nightly reports
- Rendezvous science performance metrics with other telemetry data (database)
- Visualization tools to view performance over the full focal plane, trending over the night, trending with respect to telemetry
- Automated DRP single-frame processing within 24 hours
    - More comprehensive processing and science performance assessment of individual visits
- >24 hour timescales
    - Ability to select arbitrary subsets of images to build coadds and templates for difference imaging
    - Ability to reprocess with different Science Pipeline configurations

Possible implementation of “First-look” capabilities

- Computing
  - Camera Diagnostic Cluster used for basic camera health checks
  - Automated “rapid analysis” done on commissioning cluster in Chile (at summit or at base)
  - Automated DRP single-frame processing at USDF
- To the extent possible, most science performance metrics and visualizations are computed automatically as part of the Science Pipelines processing
  - Many basic data quality metrics are already computed as part of ComputeExposureSummaryStatsTask in calibration step of single-frame processing
- Visualization supporting nighttime operations
  - Exploratory trending is most easily done in Chronograf
  - Interactive visualization with Bokeh apps (e.g., more advanced trending, full focal plane visualization)
    - Can be embedded in LOVE; can be deployed multiple places
  - Tabular summary of basic per-visit data quality
- Science performance metrics go to [TBD database]
  - Envision both science performance metrics that are treated like telemetry (calculated and not touched) and metrics that could be updated to reflect improved understanding
- General commissioning data processing (e.g., coadds) and science verification and validation analyses at USDF
  - Data processing campaigns to support science verification and validation of the stability of calibrations, difference imaging, deep coadds, …

Where are we July 2023 (~ComCam on sky)?

- DMSR Priority 1a requirements verified using precursor datasets
- Routine AuxTel observing runs (approaching nightly?)
  - "Rapid analysis" pipeline runs within ~1 min at USDF and on summit, generating metrics that are pushed to database to be rendezvoused with EFD and displayed to observers
  - Auto-generated nightly reports with content populated by automated QA analyses
  - Executed DRP and AP test campaigns for AuxTel imaging
- Calibration bootstrap plan in place
  - Astrometric + photometric reference datasets vetted and ingested
- On-sky observing strategy / menu for ComCam with tested observing routines
- Ready to test all "first light" criteria (image quality, throughput, calibration, ISR)
  - Detailed test specifications + detailed test cases
  - Metrics for all normative requirements implemented with accompanying visualizations (e.g., analysis_tools)
  - External reference datasets vetted and ingested

Proposed Organization of System-level Science Verification and Validation Effort

Rubin Observatory Construction Org Chart

Ops ADs

Ops Director's Office
Director of Operations
Robert Blum

Deputy Director (NOIRLab)
Amanda Bauer

Deputy Director (SLAC)
Phil Marshall

Communications
Manager
Ranpal Gill

Project Director's Office
Director
Zeljko Ivezic

Deputy Director (AURA/NSF)
Sandrine Thomas

Deputy Director (SLAC/DOE)
Aaron Roodman

Project Science
Project Scientist
Steve Ritz

Deputy Project Scientist
Federica Bianco

Project Science Team

Project Advisors
Chief Scientist
Tony Tyson

Science Advisory Committee
Michael Strauss

Project Management Office
Project Manager
Victor Krabbendam

System Scientist
Chuck Claver

Deputy PM - Software & IT
William O'Mullane

Deputy PM - Camera Comm
Vincent Riot

Project Administration
Compliance & Quality Administrator
Veronica Kinnison

Project Controls
Kevin Long

Safety & Security
Head of Safety
Chuck Gessner

Site Safety Coordinator
Giovanni Corvetto

Information Security Officer
Iain Goodenow (Interim)

System Verification and Validation
Systems Engineering Manager
Austin Roberts

Science Validation Scientist
Keith Bechtol

Systems Integration
Observatory Scientist
Kevin Reil

Project Manager
TBD

System Commissioning
Commissioning Scientist
Robert Lupton

Project Manager
TBD

Data Management
Project Manager
William O'Mullane

Subsystem Scientist
Leanne Guy

Camera
Project Manager
Vincent Riot

Subsystem Scientist
Steve Ritz

Education & Public Outreach
Head of EPO
Lauren Corlies

EPO Deputy
Vacant

Telescope & Site
Project Manager
Jeff Barr

Subsystem Scientist
Sandrine Thomas

- Project Office
- Advisory
- Project Support
- Sub-systems
- Rubin Operations

Updated 3/2022

Human Resources for System-level Science Verification and Validation

Our people are our most valuable resource, including our ability to **function as a team**

There is no “extra reserve” of Rubin staff available to perform system-level science verification and validation data analyses

Rather, most of the staff who will be engaged in system-level science verification and validation activities are already wearing other hats for Rubin Observatory

In-kind contributors will bring additional scientific and technical expertise to diversify and enhance the effort

Proposed Organization

Goals of proposed organization:

- Focus on performance of the as-built system (rather than individual components)
- Ensure coverage of deliverables
- Motivate scientists + provide opportunities for visibility and leadership
- Create regular forum for detailed scientific/technical discussion
- Enable multiple science topics to be pursued in parallel
- Facilitate science validation / characterization beyond normative requirements
- Efficiently assign both planned work and emergent issues
- Incorporate expertise of in-kind contributors
- Match tasks to skill sets (e.g., let scientists focus on what they do best)

Proposed Organization

Organize effort around a set of **“Science Units”** that map onto system-level requirements and other construction completeness deliverables

Science Units are a way to spread the load of science verification and validation (data analysis + recommending observations + reporting issues)

⇒ Each normative requirement will be assigned to a science unit to ensure coverage, but the Units are NOT responsible for formal systems engineering aspects of verification

Each Science Unit has 1-2 leads (Rubin staff) to provide scientific leadership

Boundaries between Units are soft; individuals may contribute in multiple topics

Example Science Units

- Throughput for focused light
- Delivered image quality and PSF modeling
- Instrument signature removal / detector characterization
- Sky background / low surface brightness / ghosts and scattered light
- Photometric calibration
- Astrometric calibration / proper motions
- Survey performance / survey strategy optimization
- Object detection, quality flags, classification, survey property maps
- Difference image analysis – transient and variable objects
- Difference image analysis – Solar System objects
- Galaxy photometry / photo-z
- Weak lensing shear
- Crowded stellar fields
- Eyeball squad / beautiful images

Scope for Science Units

Each Science Unit will be given a charge:

- Develop **methods/algorithms for evaluating science performance** of the as-built system , including identifying needs for on-sky observations and external reference datasets, for a set of formal requirements from the OSS and LSR (list provided to each Topical Area)
- Assist Science Pipelines to **implement and test software to generate diagnostic metrics and plots**; develop additional code for specialized analyses
- **Suggest, prioritize, and perform ad hoc and science validation investigations** using on-sky commissioning data; report issues and recommend potential solutions and/or further studies
- **Document the results** in the form of tech notes and (sections of) construction papers

Science Units are NOT responsible for:

- Generating observing scripts
- Pushing commissioning data through Science Pipelines
- Implementing fixes to Science Pipelines to optimize performance / respond to data quality anomalies
- Producing the Data Previews
- Formal systems engineering aspects of verification / acceptance testing

Role of Science Unit Leads

- Provide **scientific leadership** to guide the development, implementation, and interpretation of science data analyses relevant to the Unit (see charge on previous slide)
- Report data quality analysis findings to a single meeting where overall commissioning priorities are discussed
  - Observatory commissioning
  - On-sky observing strategic and tactical planning
  - Science Pipelines development
  - Verification / systems engineering
- Offer the necessary support to empower their teammates to accomplish tasks
  - Most efficient if science unit leads are willing and able to provide coordination for the group

Role of Commissioning Science “Core Group”

- **Provide support to science unit leads to guide overall priorities and assist with coordination**
- Provide global oversight to ensure consistent approach and help to triage complex/emergent issues across the science units
- Provide support to in-kind contributions related to science validation
- Work with the Systems Engineering group to develop test plans and to complete formal acceptance testing (“witnessing”) around system-level science performance
- Synthesize needs for on-sky observations and data processing to Commissioning
- Coordinate with subsystems, as well as System Integration, Commissioning, and Operations
- Assemble and provide editorial oversight for Operations Readiness Review materials and construction papers related to the demonstrated science performance of the as-built system

Incorporating In-kind Contributions and Ex-Officio Groups

~30 in-kind contributing groups to SIT-Com comprising total of ~100 individuals (US, Chile, and international)

- Many of the SIT-Com in-kind contributions are related to science validation
- Summary spreadsheet with Rubin contacts
- Science Unit leads are natural “technical directors”

Several possible types of contributions (see Community post)

- *“Developer”* – making and reviewing PRs (see DM Developer Guide)
- *“Science pipelines advanced user”* – re-running Science Pipelines, reading source code, filing tickets
- *“Science data products user”* – accessing and analyzing data products; suggesting science validation analyses/methodology

Incorporating Ex Officio Members of Commissioning Team

Associate ex officio members of commissioning with relevant Science Unit

SCOC	⇒	Survey performance / survey strategy optimization
Photometric redshift	⇒	Galaxy photometry / photo-z
Alert brokers	⇒	Difference image analysis – transient and variable objects / Difference image analysis – Solar System objects

Priorities for Next Year

Commissioning Science Core Group:

- Work with SIT, COM, and subsystems to guide implementation of needed tooling and infrastructure for science performance evaluation of the integrated system
- Work with systems engineering group to prepare for formal verification (linkage to LVV project)

Science Units:

- Development of detailed test specifications for system-level verification
  - Drafting phase (start from existing plans, identify gaps that science validation can fill)
  - Document methodology in language accessible to science user
- Implement metrics and visualizations in analysis_tools and other software
- Utilize pathfinders for development and test
  - Precursor datasets (e.g., HSC, DECam, LSST DP0)
  - AuxTel spectroscopy and imaging

Next Steps

2022 Aug-Sep: collect feedback on proposed organization/strategy; issue draft charge for each Science Unit and contact individuals to serve as leads; complete onboarding of in-kind contributors

2022 Sep-Oct: Core Group holds initial meetings with Science Units to refine charge and make first work assignments (use Jira and Confluence work planning tools)

2022 Oct-Nov: Core Group begins hosting meeting series with a rotating focus through science units to ensure consistent approach, share knowledge across topics, and prioritize efforts

Mid 2023: as ComCam approaches start of on-sky engineering, anticipate that the cadence and format of meetings might shift to a more tactical approach; expect that Science Units will continue to be useful, but we are prepared to adapt as needed

Comments / Questions / Suggestions

Extras

Alternative Topical Areas Proposal

Consider an *alternative set of topical areas* based on **LSST Science Drivers**, e.g.,

- Dark Matter and Dark Energy
- Galaxy
- Time Domain
- Solar System

Pros: strong connection to science validation

Cons: potential to divide effort along Science Collaborations rather than taking a global view of the system; more challenging to map to deliverables; significant overlap between topical areas

Alternative Topical Areas Proposal

Consider an *alternative set of topical areas* based on **data products/algorithms**, e.g.,

- Instrument signature removal
- Single-visit performance
- Coaddition
- Difference imaging
- Deblending

Pros: maps closely to Science Pipelines expertise

Cons: more challenging for topics to proceed in parallel during commissioning, potentially more difficult for scientists to contribute, potentially more challenging to take system-wide view, science validation is de-emphasized/dispersed, potentially more challenging to coordinate as many science areas are involved in each topic