VERA C. RUBIN OBSERVATORY

Rubin Operations Status

National Astronomy Meeting, 2023 Cardiff

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NSF NOIR Lab AURA SLAC U.S. DEPARTMENT OF ENERGY

Highlights

- Project Status and Progress
- Schedule and plans update
- DP0 continues well. Planning increment as DP0.3 for summer. Solar system catalog.
- In-Kind Program
- Rubin-Euclid
- Satellites
- Rubin Observatory Sustainability
- Education and Public Outreach

The UK is a key partner in Rubin Observatory Operations and major contributor to planning for and eventually doing LSST science. Thank you!

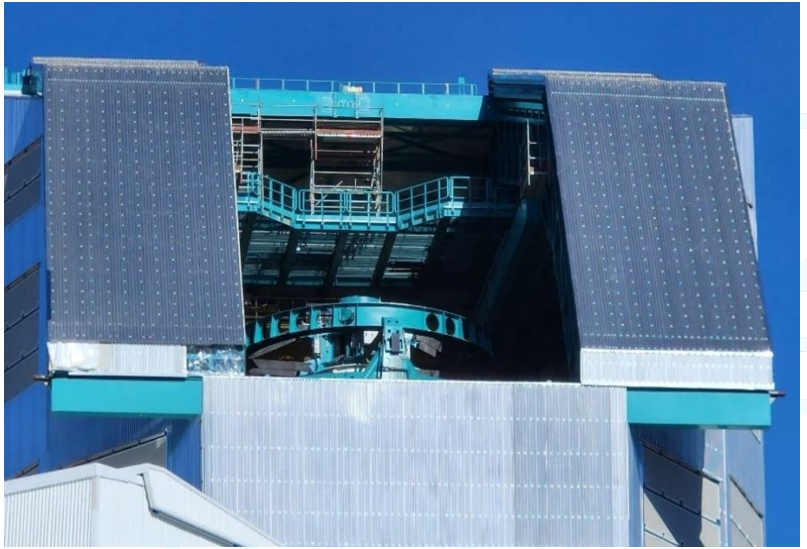
Construction Progress

We took formal control of the TMA in March ‘23.

The Dome is making good progress too, **but the work will continue until next year.**

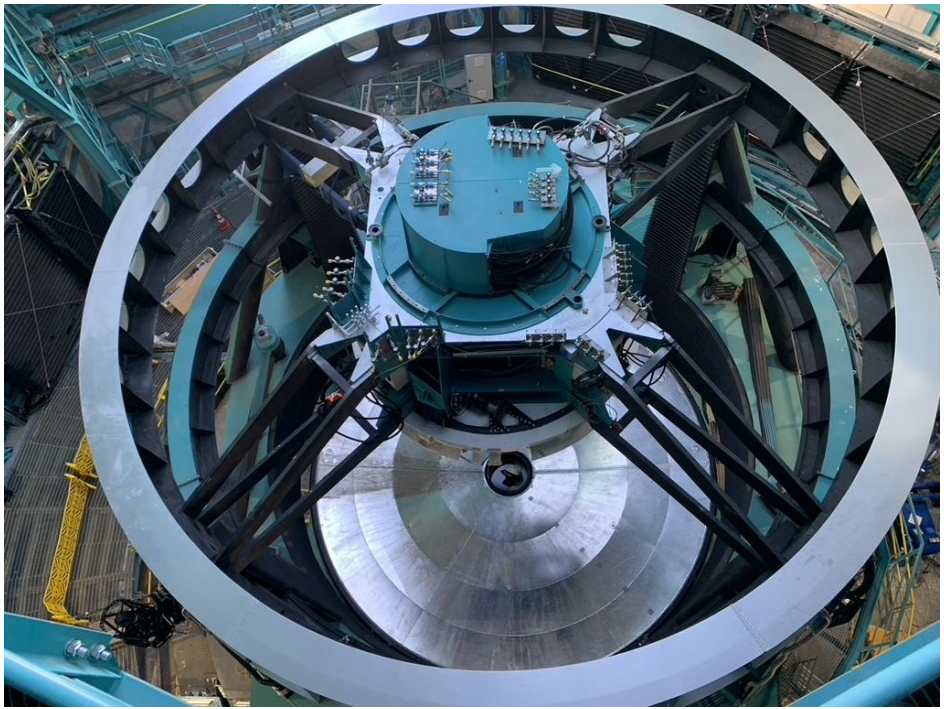
The LSST camera is cold and in the last round of testing at SLAC. **Planning shipment to Chile in October ‘23.**

Data Management team is effectively already in commissioning phase (and some operations).

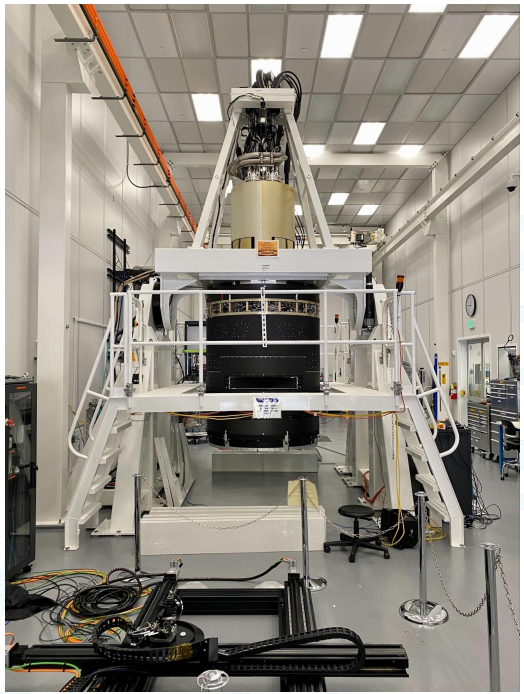


The Integration team is keeping track of schedule updates to **optimize both the use of space and resources**. Similarly, the commissioning team is working on refining the observatory validation plan, with a focus on **efficiency on and off sky**.

Current Configuration: “a functioning telescope”



Camera undergoing final testing



Slide Credit A. Roodman

Rubin Timeline (https://dmtn-232.lsst.io/)

***2023, a key year** for full system integration and commissioning!*

TMA Handoff to Rubin

LSSTCam testing, *now*

October 2023 : Arrival of LSSTCam on the summit

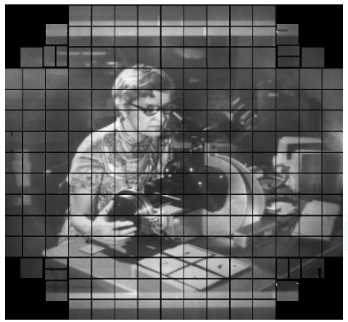
TMA nighttime testing *now*; Mirrors I&T on TMA

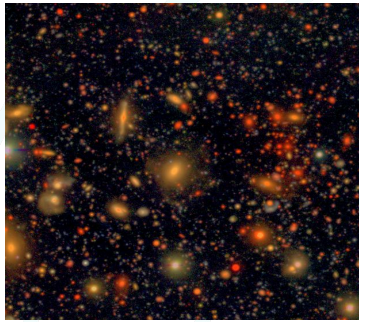
System First Light ~ October 2024.

Dec: Final pipeline delivery

LSST starts FY25

2023 **2024** **2025**





The COSMOS field seen by Hyper Suprime-Cam, courtesy of the HSC Collaboration, R. Lupton, and N. Lust.

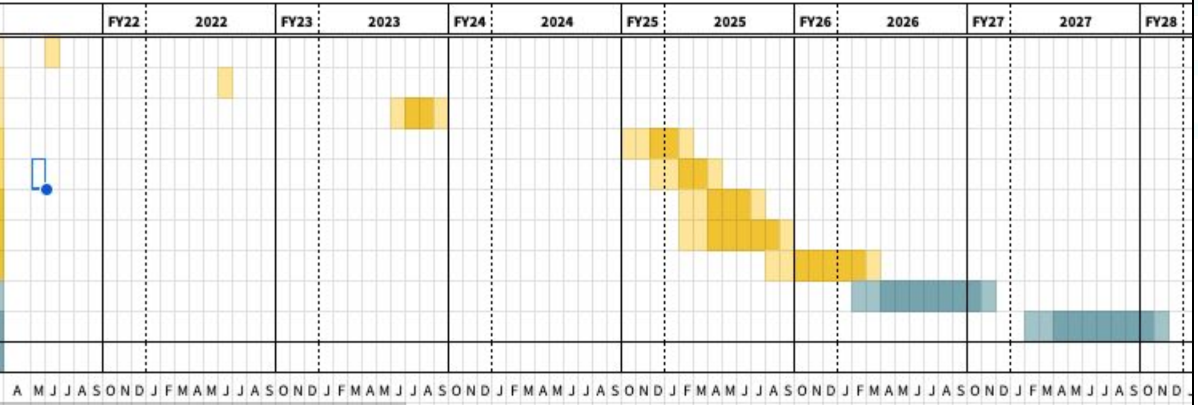
Project Schedule Update

- New forecast finish. As of April this year, February, 2025. Planning for ~5 months contingency on project. Expect Operations phase begins in “mid 2025.”
- Start of Full/Survey Operations planning date: June 01, 2025 (not the start of LSST!)

Rubin Operations Survey and Data Release Timeline

Nominal LSST Survey Start Date: June 2025

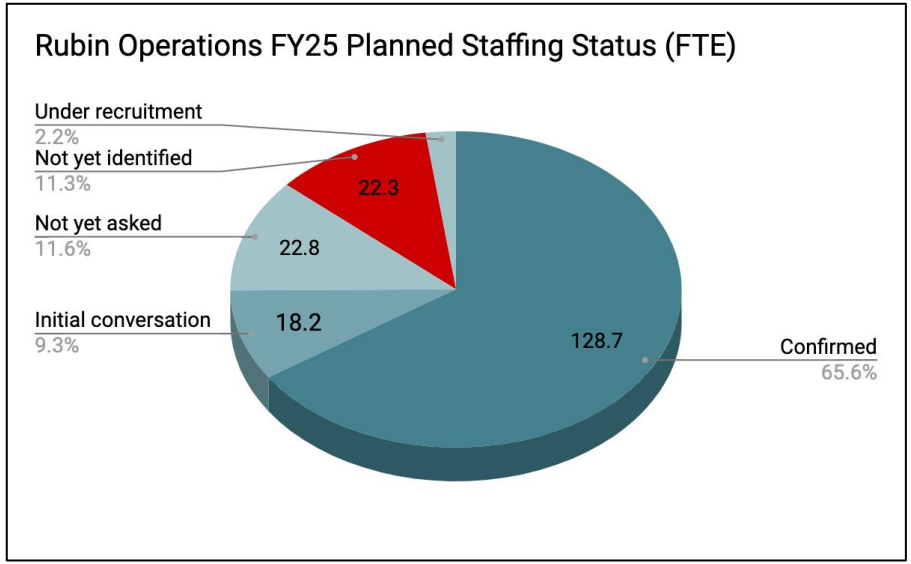
Event		Date	Milestone Date
DP0.1	DC2 Simulated Sky Survey	June 2021	2021-06-30
DP0.2	Reprocessed DC2 Survey	June 2022	2022-06-30
DP0.3	Solar System PPDB Simulation	Jun 2023 - Sep 2023	2023-07-31
FL	System First Light	Oct 2024 - Feb 2025	2024-12-23
DP1	First Light LSSTCam Data	Dec 2024 - Apr 2025	2025-02-22
OPS	Start of Operations	Feb 2025 - Jul 2025	2025-06-01
SVY	Start of Survey	Feb 2025 - Sep 2025	2025-06-27
DP2	LSSTCam Science Validation Data	Aug 2025 - Mar 2026	2025-11-26
DR1	LSST First 6 Months Data	Feb 2026 - Nov 2026	2026-06-27
DR2	LSST Year 1 Data	Feb 2027 - Nov 2027	2027-06-27
DR3	LSST Year 2 Data	Feb 2028 - Sep 2028	2028-06-27



Current Date

Staffing plan

- Staffing is a key readiness element (including from LSST: UK for the UK Data Facility)
- We are making progress on filling roles with new hires and new recruits from NOIRLab/SLAC:



Status March, 2023

Survey Cadence Optimization

- Phase 2 recommendation (V3 of baseline; see ls.st/pstn-055), released in December 2022.
- Optimization to continue throughout pre-Operations and LSST period
- There are 9 remaining important aspects of the cadence to resolve. SCOC is working on this now.

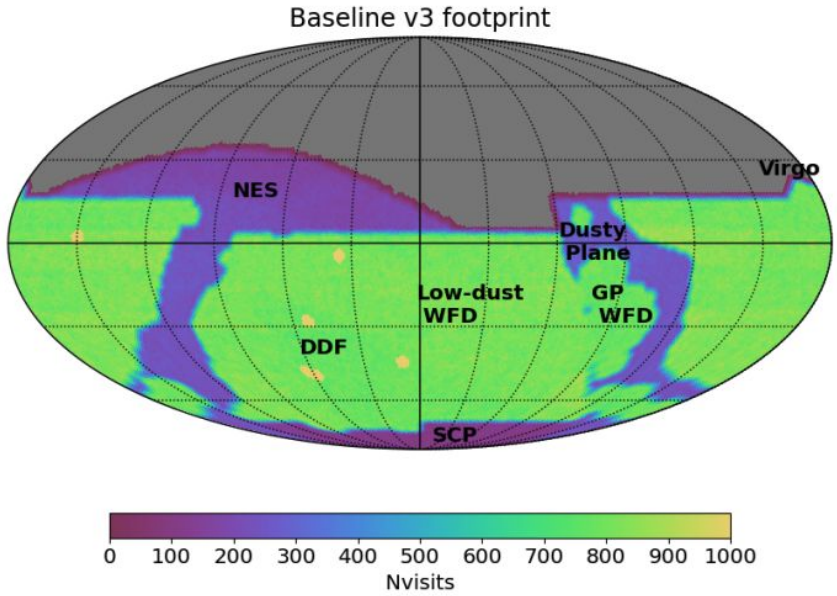


Figure 11: Number of visits per pointing in all filters for baseline_v3. The color bar saturates at 1000. The Virgo cluster is visible on the right of the map, in the Northern hemisphere.

Remaining 9 items for SCOC

See ls.st/pstn-055

SWAPPING FILTERS (u, z, y vs u, z; also visit pairs)

ROLLING CADENCE (uniformity concerns)

GALACTIC PLANE FOOTPRINT AND FILTER BALANCE (extent and filter balance)

REBALANCE EXPOSURE TIME (save time in some filters)

DDF CADENCE (“optimize” intranight cadence)

ToO workshop (community input/workshop)

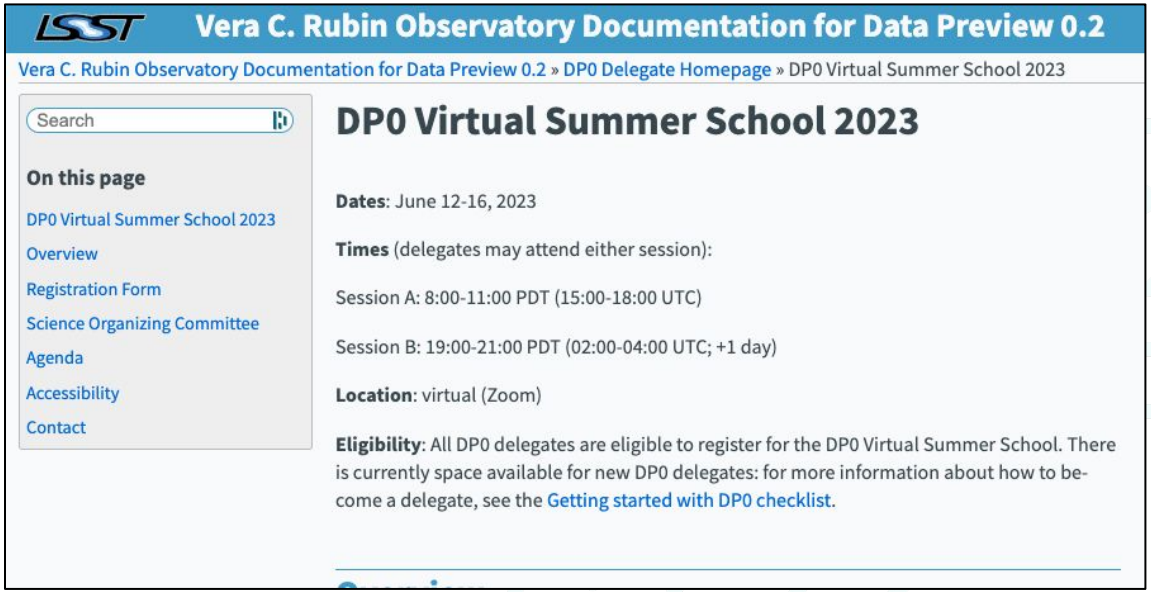
EARLY SCIENCE (year one program, template generation)

EUCLID COORDINATION (coordination in EDFS)

1x30 vs 2x15 EXPOSURES (need on-sky data)

Data preview 0

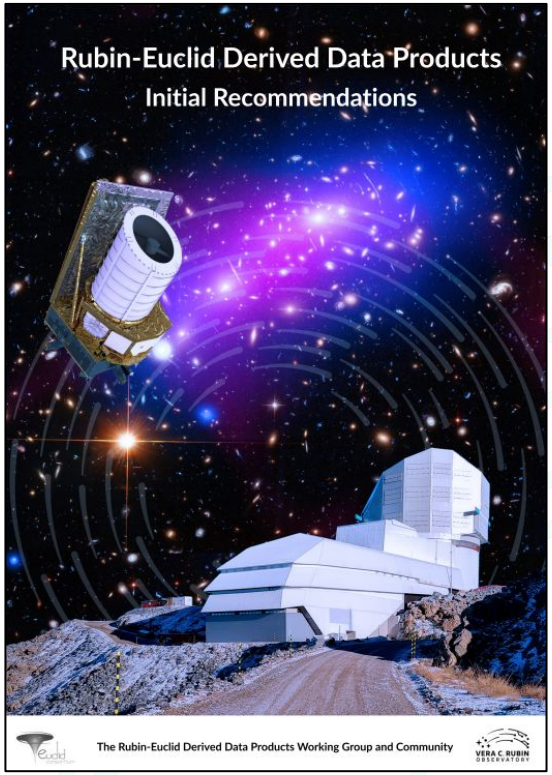
- Continue to support DP0.2 with up to 600 delegates on Google Cloud deployment of the Rubin Science Platform.
- Rubin Summer Data Science School based on DP0.2, June 12 - 16
- Expanding DP0 to include Solar System simulated object catalog (new data product, not addition to DP0.2)



*DP0.3 for community late July, Early August; see **C. Williams** talk next.*

Rubin Euclid Collaboration (good satellite problem)

- Extensive Community based, Science Based program to define derived data products from Rubin+Euclid
- Independently, Rubin agreed to observe in the Euclid Deep Field South. Euclid and Rubin agreed (MOU) to sharing data from both surveys with both communities.
- Now working on implementation phase of larger DDP program (letter of intent). Requires additional resources beyond either projects currently funded plans.

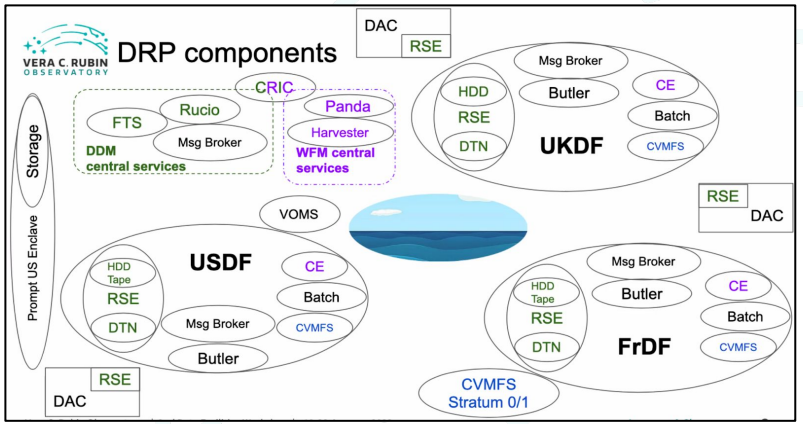


In-Kind Program

- Data Rights Agreements (DRA) now in final development. With lawyers (ack!) at AURA and SLAC.
- Each Program subject to DRA with either SLAC or AURA. Several have contributions that require both flavors. Both have ~same terms and conditions.
- Signed DRAs are now getting critical for several programs to get funding.
- We completed annual review last winter for contributions that have begun (at their own risk).
- Major data processing contributions from UK:LSST and France (IN2P3) are subject to DOE level agreements (annex to existing international agreements).

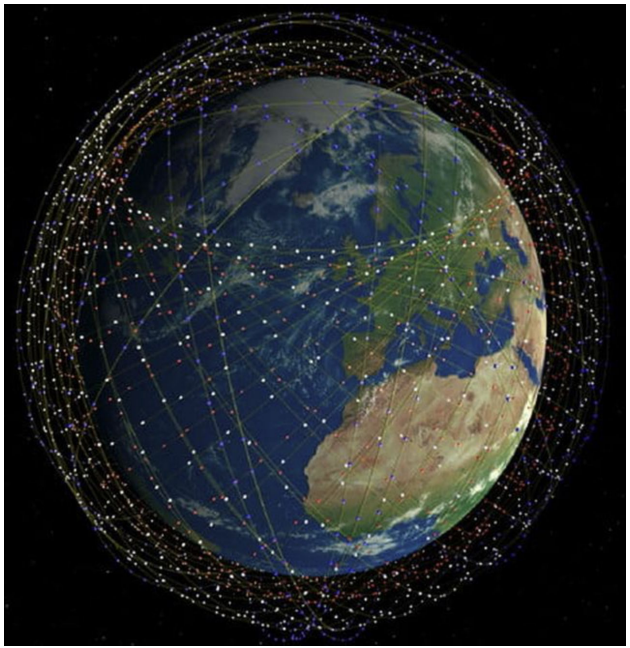
Preparing for DRP: SLAC, France, UK

- Multi-site testing/scaling work is underway, via increasingly complex stages
  - Start with job submission to central PanDA server from each site, to be executed at those sites (done)
  - Expand to central submission (done - no issues running 3k cores per site)
  - Use Rucio/FTS to move input/output files among sites
    - Rucio-butler integration about to be tested
  - Test scaling up numbers of simultaneous processes and volume of data
- Routine HSC reprocessing in progress at the USDF for months now
  - Engagement of Campaign Mgmt, Pipelines and Infrastructure groups
  - Pipelines group started a full HSC PDR2 multi-site reprocessing
    - Single epoch processing at the USDF
    - Coadds to be done multisite
- Rucio and PanDA servers installed at SLAC; in final testing
  - FTS3 server at SLAC being installed; using a server in the UK in the meantime



Impact of LEO Satellite Constellations on Rubin Observatory and LSST science

Željko Ivezić, with Tony Tyson, Meredith Rawls, Peter Yoachim and the Rubin team



https://www.universetoday.com/156383/starlink-satellites-are-still-bright/

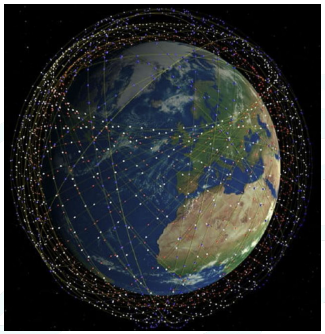
Impact of LEO Satellite Constellations on Rubin Observatory and LSST science

Quantitative assessment depends on several imperfectly known quantities:

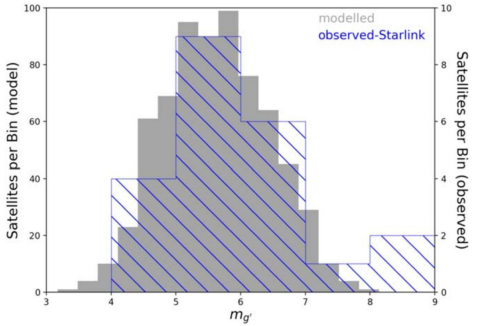
1) The number of satellites and their orbital distribution

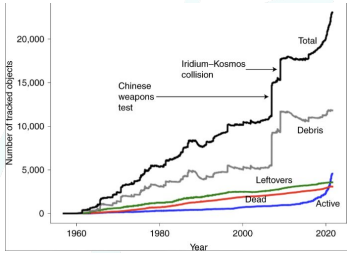
2) The satellite brightness distribution

3) Impact on
   LSST images
   and
   mitigation

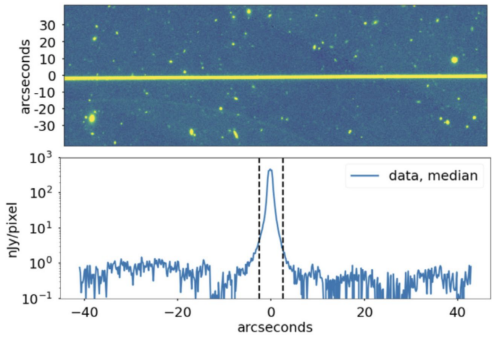


Lawler, Boley, & Rein





I. Hasan, J.A. Tyson, C. Saunders et al.



Summary (from Rubin/LSST point of view)

With tens of thousands of LEOsats, generally ***no combination of mitigations can completely avoid the impacts of the satellite trails*** on LSST science programs.

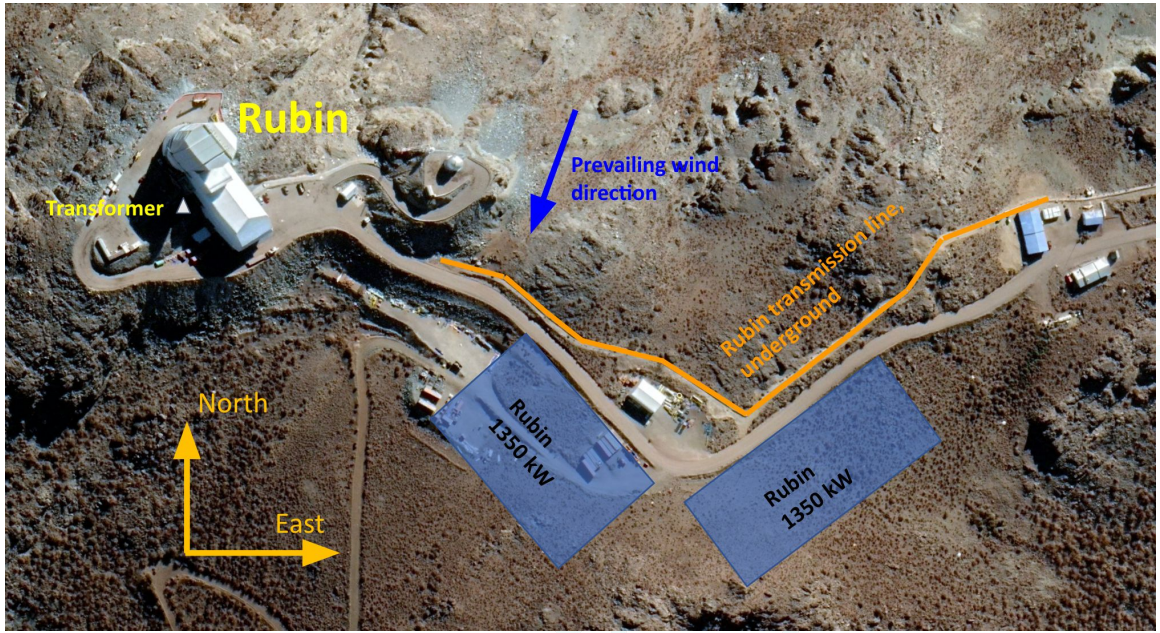
However, current predictions of the impact correspond to a **“nuisance”** that we have to plan for (~1% of pixels lost), rather than a ”catastrophic” impact (>10% of pixels lost).

We need to continue to **constructively** communicate with satellite providers.

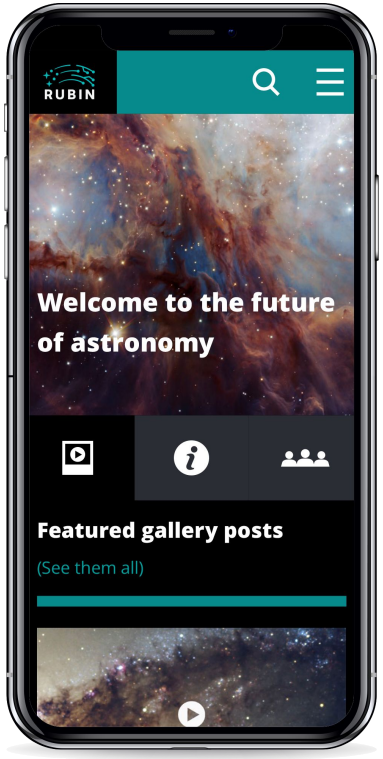
Not time to panic.

NOIRLab Sustainability - Rubin Extension

- New supplemental proposal to NSF submitted; led by NOIRLab (builds on current large investment)
- Goal: Pachón Carbon Neutral
- Supplement Covers 40% of Rubin use, one half of ultimate 2x1350 KW system proposed
- Accounts for 1400 tons CO2
- Engineering, site, PM, hardware $4.2M
- Engage local university engineering students



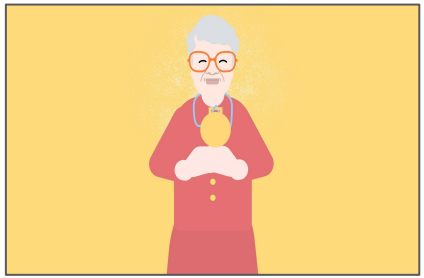
EPO Program is active in Operations!

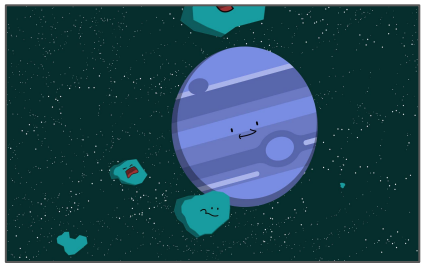


Website live:
rubinobservatory.org

Initial Public launch on social media in Jan/Feb 2023, continuing to build engagement.

Animated videos on YouTube, available in English and Spanish

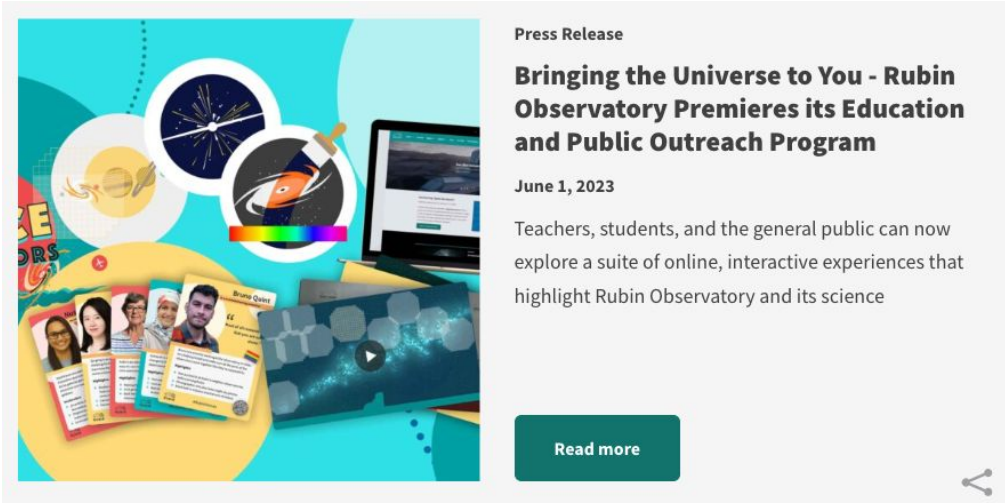




Try for a high score at spacesurveyors.app

Education & Public Outreach

- New content regularly posted to News, Events, Rubin Voices, and Education sections
- Final versions of the Surveying the Solar System and Expanding Universe formal education investigations released
- Internal testing of Citizen Science Principal Investigator workflows and notebooks (LSST: UK connection)
- So far in FY23, social media accounts published 467 posts, reaching 255,540 users and growing



Summary

- Planning survey start in mid 2025
- Data Preview 0 continues successful development of Ops team and community. Adding Solar System catalog as DP0.3
- Satellites impact is frustratingly hard to pin down. Direct impact seems manageable, but systematics not understood.
- In-kind program is active and growing. Progress in DRAs is slow but progressing
- Continuing to further develop Sustainability program for Rubin Observatory and NOIRLab
- EPO active in Operations

End of Presentation

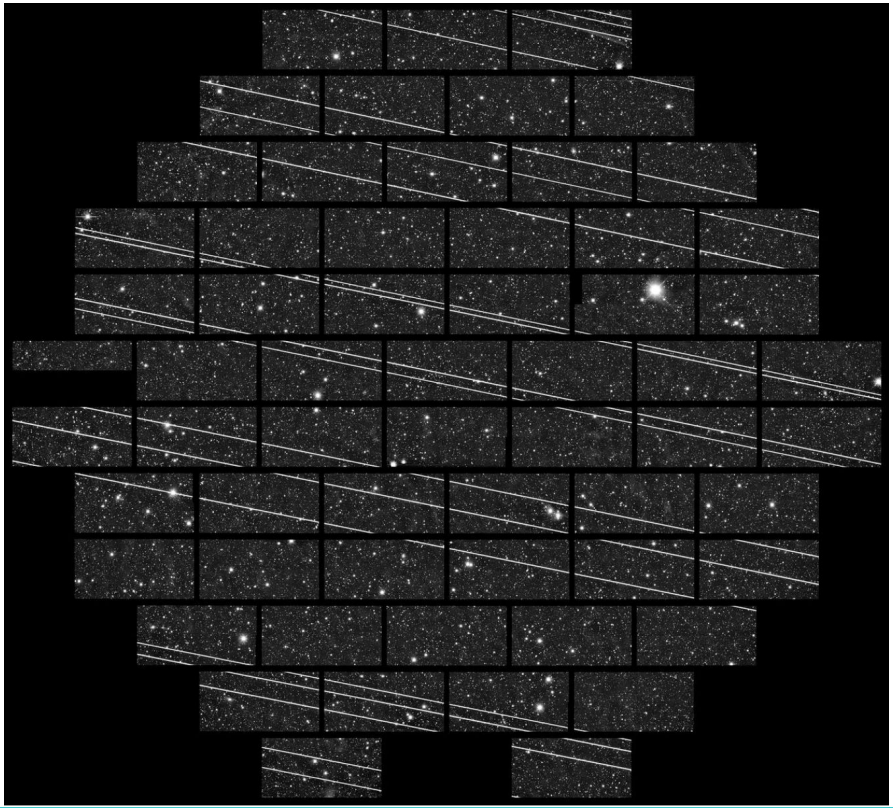
Detail Slides

Satellite Summary (from Rubin/LSST point of view)

- Assume much less than 10% lost etendue (requires bright trails mitigated by vendors).
- However: Science impact at tails of distributions.

  Rare detections. Rare alerts.
- Impact on Rubin science depends on science goal.
- Undertake full science simulations with systematics.
- Working with SpaceX on brightness: ConOps + scattered light simulations.

Low-Earth orbit satellite constellations



DECam image: 333 sec exposure, 19 Starlink streaks (Clara Martínez-Vázquez and Cliff Johnson)

How bad is that?

A few points to make:

- at that time, satellites were still much closer to the observer then when in their final orbits (the so-called “at station”)
- LSST visit is ~10 times shorter and the FOV is somewhat larger: ~2-3 streaks
- there are many other quantitative details that need to be taken into account...

So, really, **how bad are these satellite constellations for LSST?**

1) The number of satellites and their orbital distribution

The Astronomical Journal, 160:226 (13pp), 2020 November

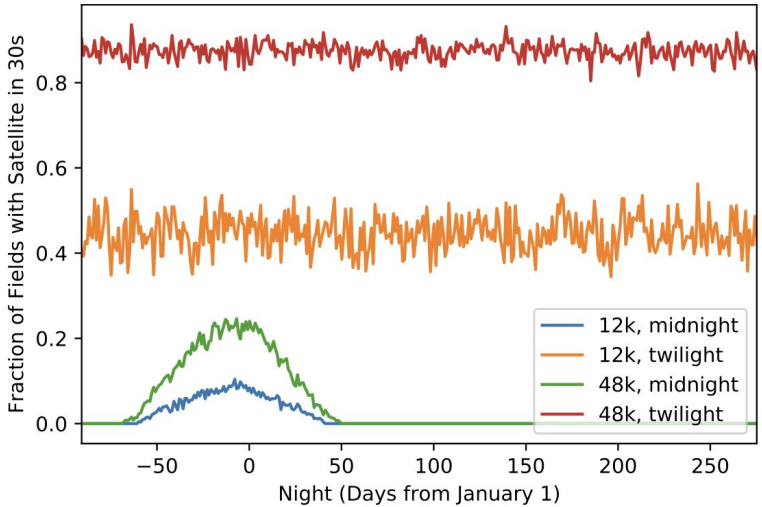
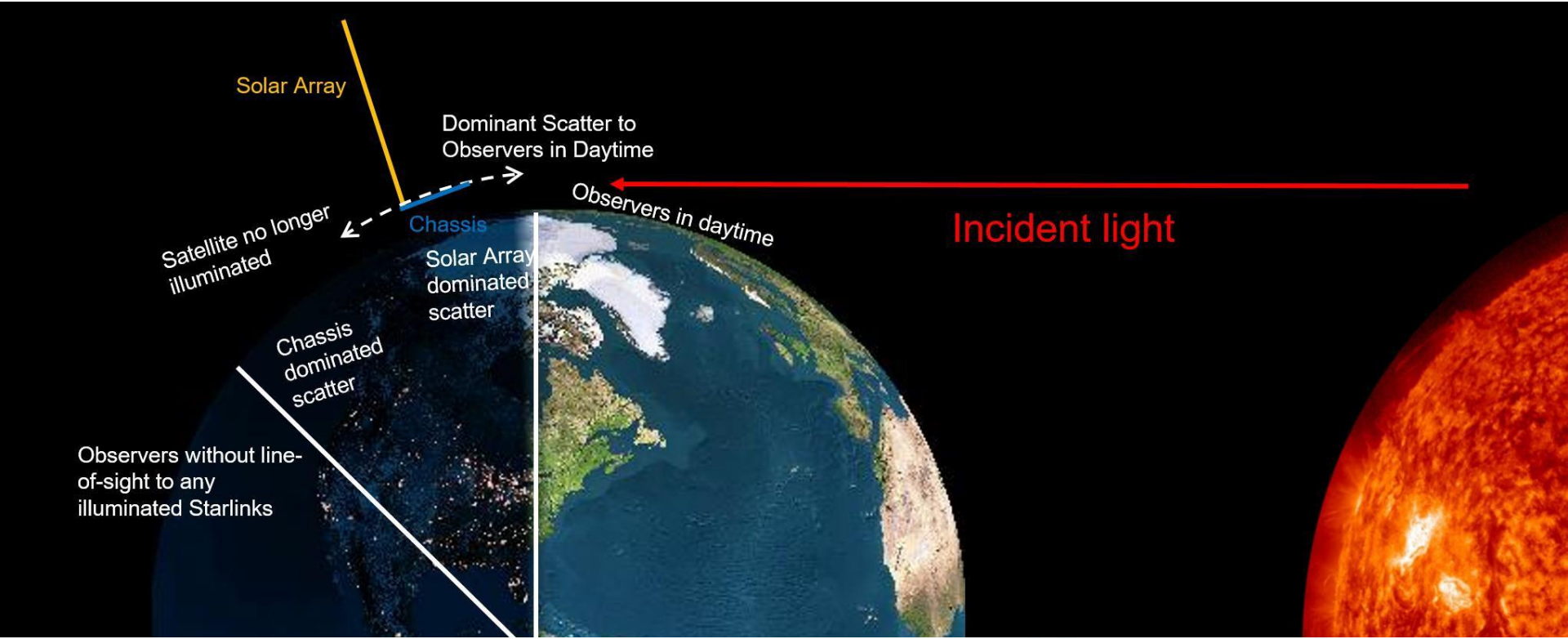


Figure 1. The LSST observing scheduler was simulated for one year under two assumptions for numbers of LEOsats. Shown here is the fraction of exposures with a satellite present vs. night (number of days from January 1) at −12 to −18 deg twilight and at astronomical midnight. Between 40% and 90% of exposures in normal twilight operations have an illuminated satellite trail. At midnight, the fraction of exposures with at least one satellite trail is 10%–20% during Chilean summer, and it drops to zero during Chilean winter.

- With 50k satellites, for Rubin/LSST:
  - close to 1 trail/FOV in twilight
  - at midnight, from 0 (winter) to 0.1-0.2 trail/FOV (summer)
  - with 1 arcmin mask width, about **0.3%** of all LSST pixels would be masked
- Details depend on:
  - orbital parameters
  - altitude distribution
  - satellite “ConOps”
  - mask width, which depends on science
  - variability, glints, ...

We already have simulation tools developed by the Rubin team (Peter Yoachim et al.)

2) The satellite brightness distribution



2) The satellite brightness distribution

- It turns out that satellites with a stationary magnitude of **~6.5-7 or fainter** would **not** be detected by unaided human eye, and would **not** saturate Rubin detectors

- The first generation of Starlink satellites (v1) have brightness of ~5-6 mag; SpaceX team is trying to make them fainter and they recently made some technological breakthroughs (dielectric Bragg mirrors, with specular optical reflection but transparent at long wavelengths used for communication) and improved space-qualified “black paint”) but we **don’t have yet** “at station” brightness measurements for this v2 batch

- SpaceX is open to sharing their technological advances with other satellite providers

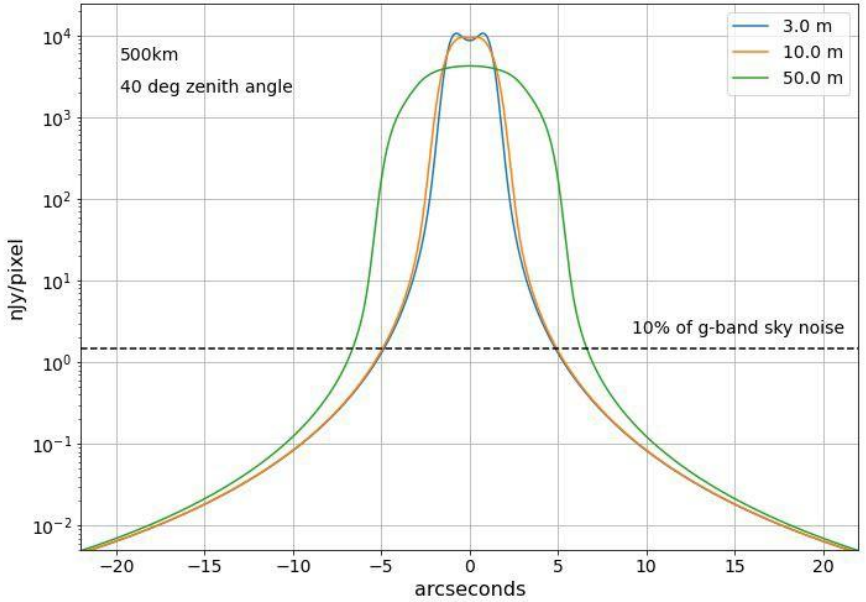
We are all hopeful that mature satellite constellations will reach >7 mag.

3) Impact on LSST images and mitigation

Data Management team has developed code to detect and mask satellite trails.

Each satellite trail requires a unique mask.
It depends on:

- Apparent brightness
- Size of satellite reflective elements
- Telescope primary mirror size (satellites are “out of focus”)
- Orbital height
- Seeing



Simulated satellite trail profiles for 3 differently sized satellites as observed by the Rubin Observatory.
Nourbakhsh et al (in prep)

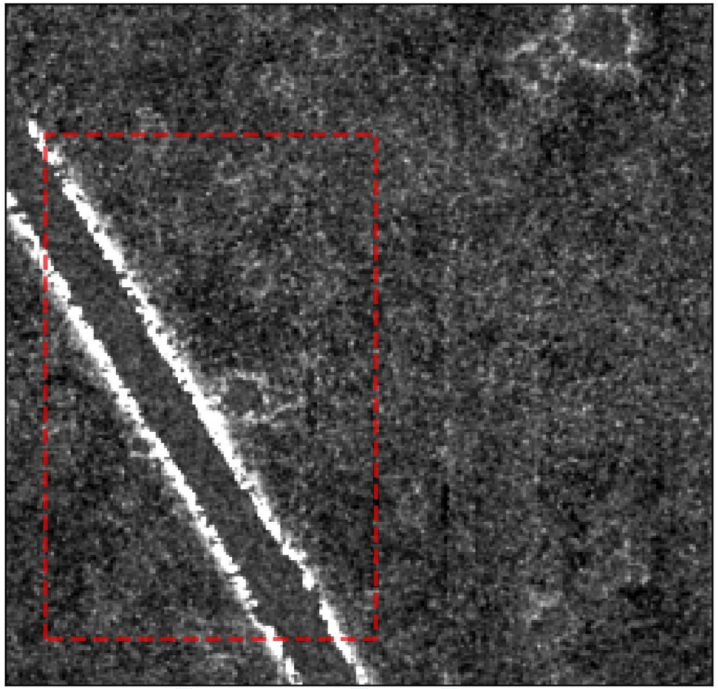
3) Impact on LSST images and mitigation

The Rubin Data Management team has already developed and tested code to detect and mask satellite trails.

Incomplete masking of satellite trails can cause systematic effects:

- Residual spill-over light.
- Lines of “bogus galaxy detections”.

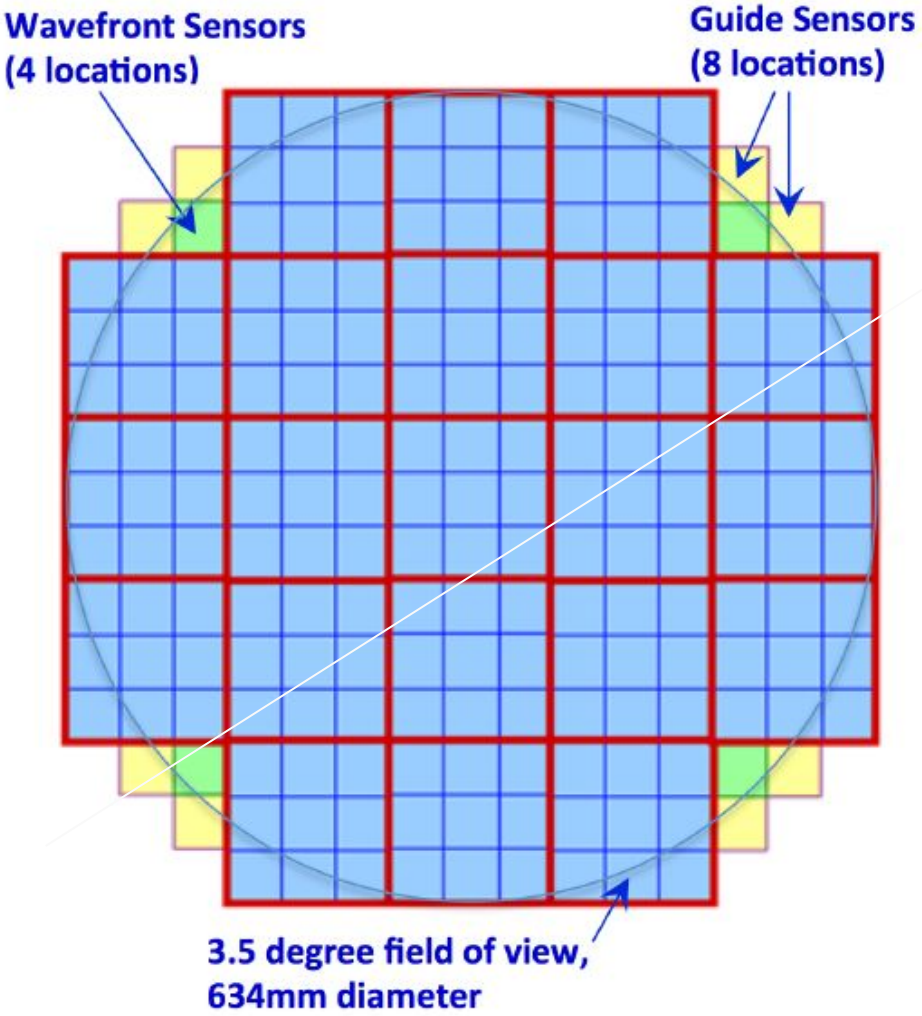
Also, potential cross-talk problems...



Satellite trail in a coadd image masked using a 40-arcsecond wide mask. For details, see Hasan et al (2022)

LEOsat Mitigation Challenges

- Streaks
  - CCD non-linear crosstalk
  - Streak masking residuals
- Variability & Glints
- Bogus events
- Brightness mitigations by industry

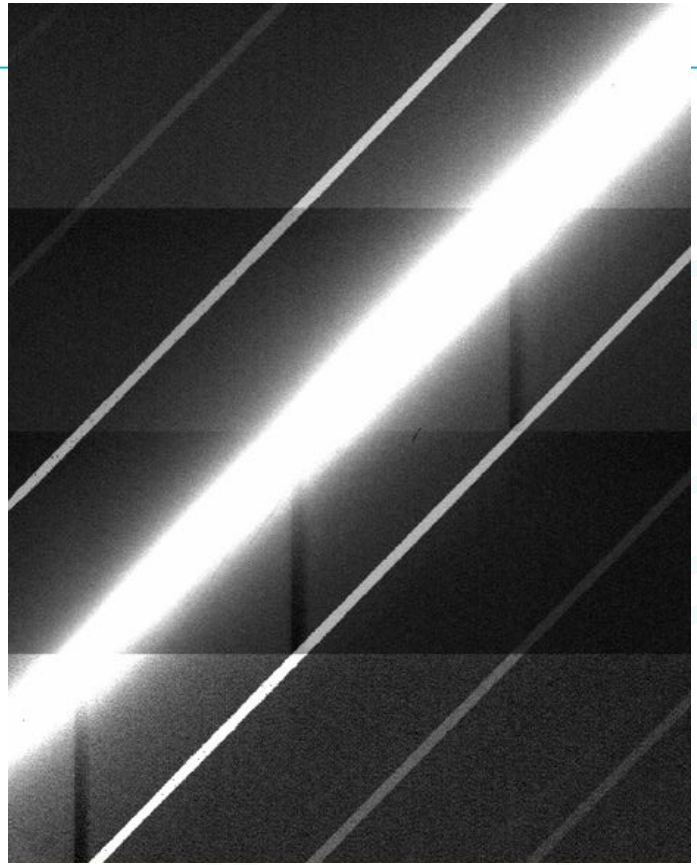


Each CCD is split into 16 segments, each with its own output amplifier

Bright satellite trail in the Rubin Observatory camera induces image artifacts

Electronic crosstalk between output amplifiers on 16 segments

Non-linear with intensity!

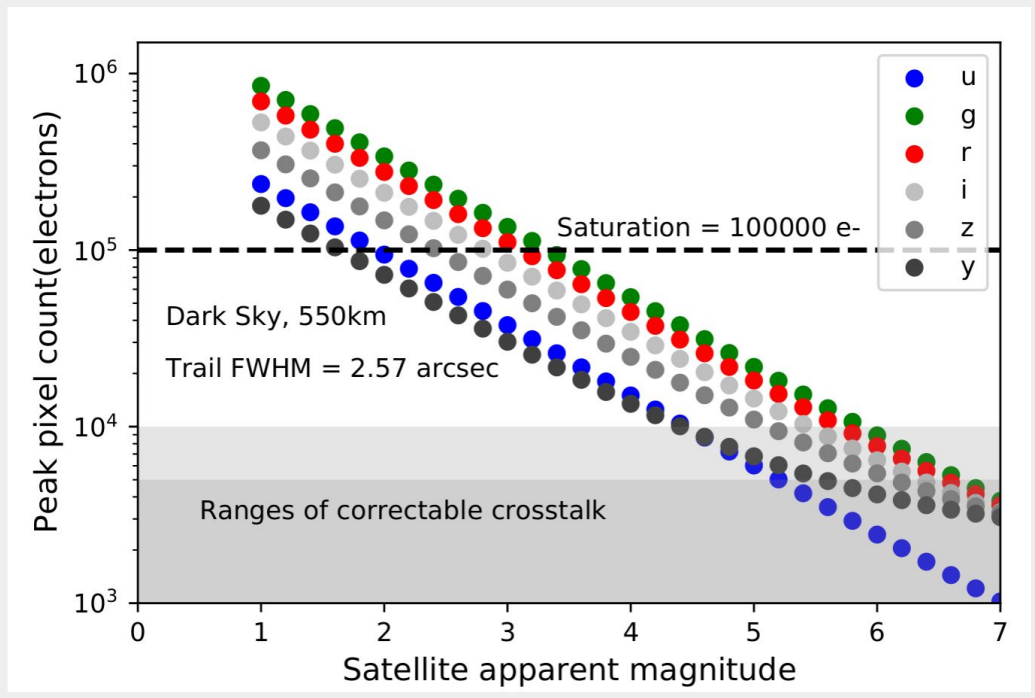


Correctability vs Flux

A non-linear crosstalk algorithm must correct to several electrons precision in 100 frame co-add.

At 6.5 *g* mag, a 10% error on any crosstalk coefficient could create a false faint galaxy image in a co-add.

Clearly, fainter satellites are needed



Vendor efforts

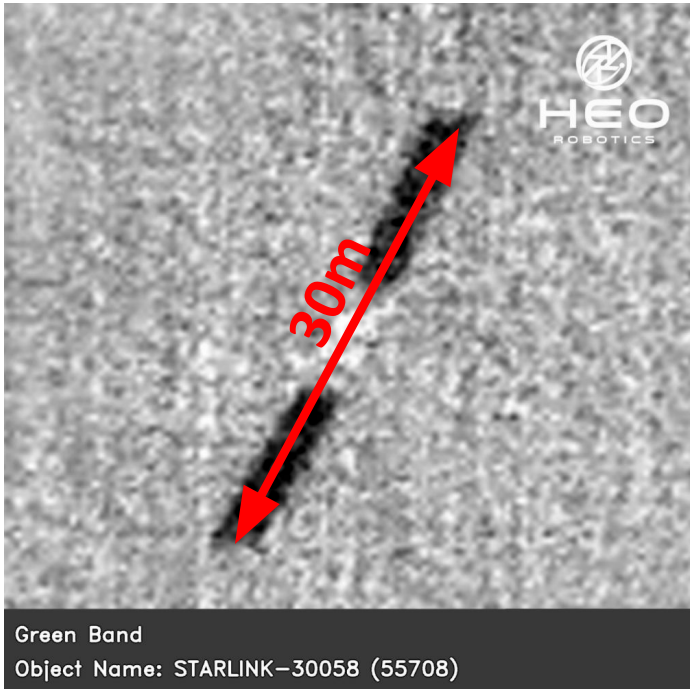
- SpaceX is working with the astronomical community to reduce the light pollution effects on optical astronomy
- Making the spacecraft 10 times darker enables removal of most satellite trail crosstalk residuals in the LSSTCam
- However, *even if that works*, evidence of the main satellite trails will clearly be in the data – complicating data analysis, and limiting discoveries

http://ls.st/satcon

AST-SpaceMobile

Bluewalker3 small scale prototype.

Starlink V2-mini



Starlink V2 is 50m long.