SSSC Update

Meg Schwamb
(Queen's University Belfast)
@megschwamb

Legacy Survey of Space and Time
Solar System Science Collaboration

Image Credit: Rubin Observatory/NSF/AURA

5+ million Solar System objects, 1+ billion observations!

	Currently Known	LSST Discoveries	Typical number of observations
Near Earth Objects (NEOs)	~20,000	200,000	(D>250m) 60
Main Belt Asteroids (MBAs)	~650,000	6,000,000	(D>500m) 200
Jupiter Trojans	~7000	280,000	(D>2km) 300
TransNeptunian Objects (TNOs) + Scattered Disk Objects (SDOs)	~3000	40,000	(D>200km) 450
Comets	~3000	10,000	?
Interstellar Objects (ISOs)	2	10	?

See http://ls.st/Document-29545

Slide Credit: Mario Jurić

LSST Solar System Science Collaboration (SSSC)


Meg Schwamb & David Trilling
SSSC Co-Chairs


Darin Ragozzine & Gal Sarid
Publication Coordinators


Colin Orion Chandler & Agata Rożek
Early Career Representatives

Active objects Working Group (Lead: Cyrielle Opitom): broadly consisting of all categories of activity in the minor planet populations: short period comets, long period comets, main belt comets, impact- or rotationally-generated active asteroids,etc

Community software/infrastructure development Working Group (Lead: Henry Hsieh): broadly consisting of people interested in helping build databases, software packages, etc to be used by the Solar System community on LSST data

Inner Solar System Working Group (Lead: Siegfried Eggl): broadly consisting of the main belt, Mars/Jupiter Trojans, and Jupiter irregular satellites

NEOs (Near Earth Objects) and Interstellar Objects Working Group (Lead: Sarah Greenstreet): broadly consisting of objects on orbits inward of or diffusing inward from the main belt as well as interstellar objects temporarily residing in the Solar System

Outer Solar System Working Group (Lead: Michele Bannister): broadly consisting of KBOs, Centaurs, Oort cloud, Saturn/Neptune/Uranus Trojans, and Saturn/Neptune/Uranus irregular satellites

Cross Science Collaborations Equity, Diversity, and Inclusion Committee

Laura Inno
(Parthenope University of Naples)

What has the SSSC Done since the last Sprint?

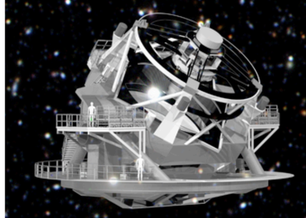
Advocating for Incremental Templates

To handle alert generation outside the template building process attached to the annual DRP, the Construction project initiated a change request to include incremental templates in the DM system workflow. This change has been accepted and is now part of the baselined DM project in constructiom. A summary of the changes is the following:

- LCR-2273: Construct Image Differencing Templates Outside DRP, new requirement 1.4.6 Template Coadds ID: DMS-REQ-0280, The DMS shall periodically create Template Images in each of the u,g,r,i,z,y passbands. Templates may be constructed as part of executing the Data Release Production payload, or by a separate execution of the Template Generation payload. Prior to their availability from Data Releases these coadds shall be created incrementally when sufficient data passing relevant quality criteria is available.
- To enable artifact rejection, templates will be built with at least three images in year one, and five in subsequent years. (Rubin OSS-REQ-0158)
- Once a template is produced for a sky position and filter it will not be replaced until the next Data Release to avoid repeated baseline changes.
- Templates are not necessarily built from the first N images that are collected.

Now encoded in the Rubin Observatory Plans for an Early Science Program Document

https://rtn-011.lsst.io/



Preparing for Astrophysics with LSST

Transients & Variable Stars *Stars, Milky Way & Local Volume* *Solar System Science Collaborations*

Community awards managed by LCO

With support from HEISING-SIMONS FOUNDATION

Preparing for Astrophysics with LSST is a new research and community-building initiative for members of three participating Rubin Science Collaborations: Transients and Variable Stars (TVS), Stars, Milky Way and Local Volume (SMWLV) and the Solar System Science Collaboration (SSSC).

More information on the goals of this program can be found in our overview page, and details of each program element can be found by exploring here.

Working Group Telecons

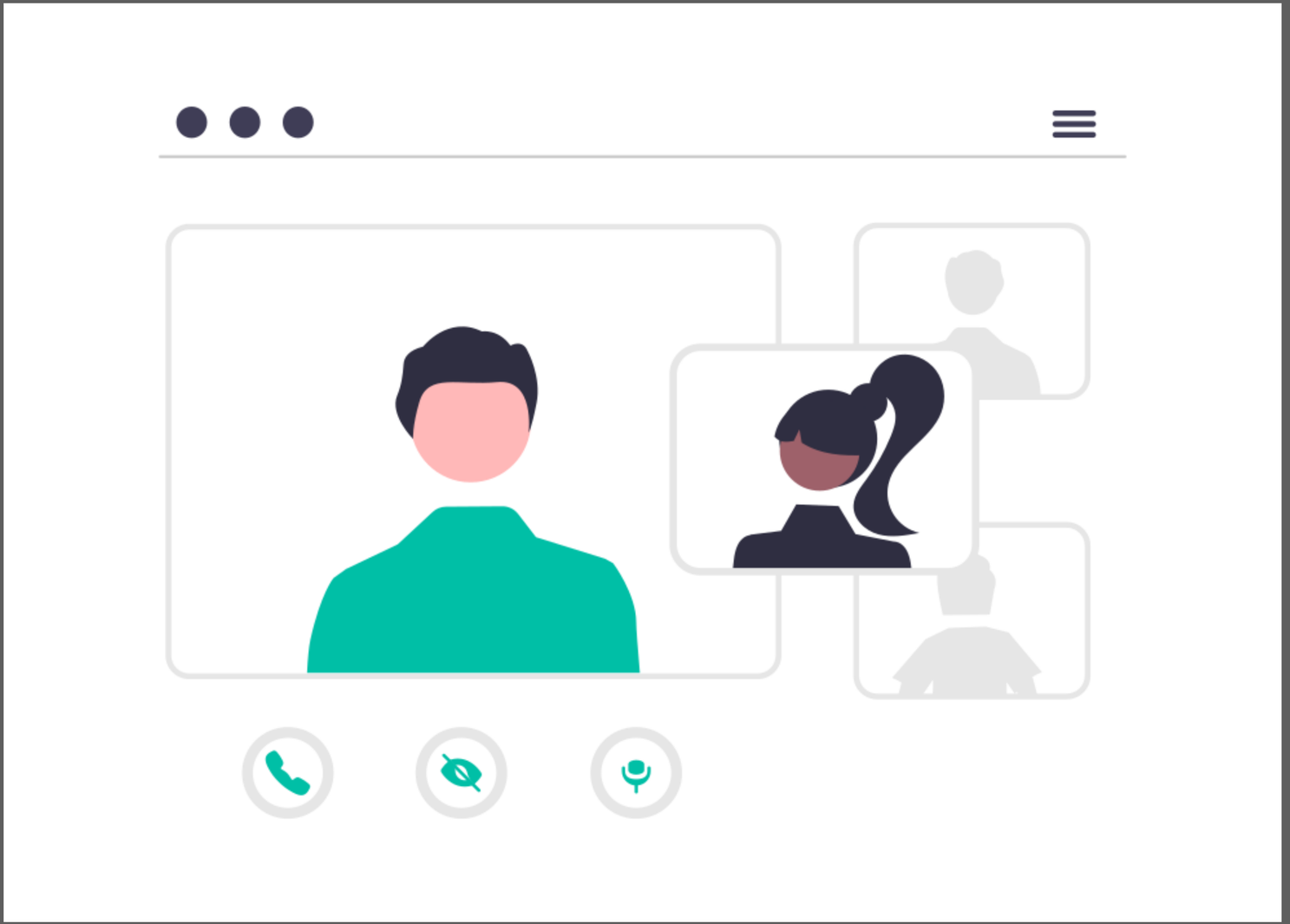
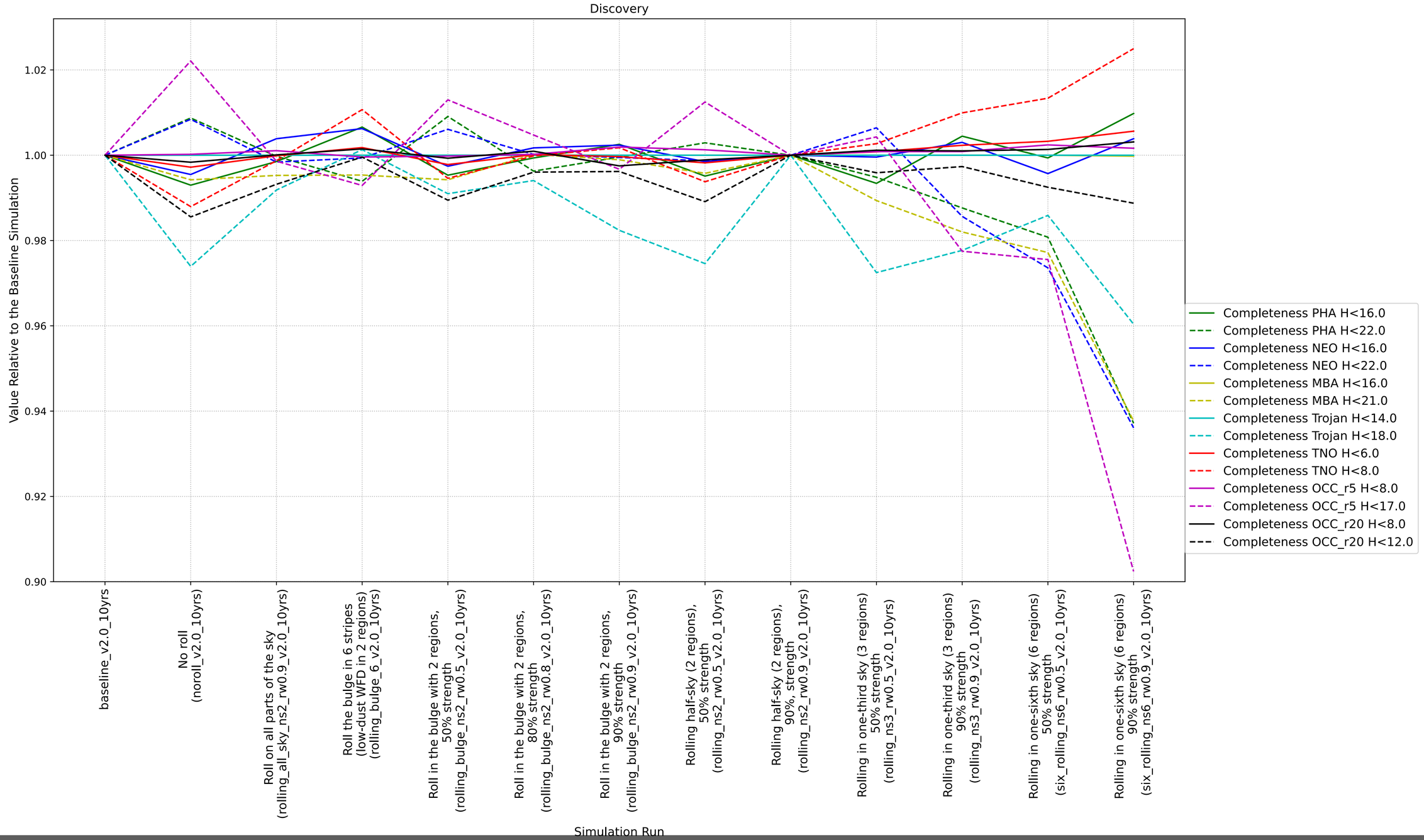


Image credit: https://undraw.co/

Giving Input on LSST Cadence Decision

Image Credit: Lynne Jones; Video Credit: Last Week Tonight with John Oliver


Discovery
Value Relative to the Baseline Simulation
1.02
1.00
0.98
0.96
0.94
0.92
0.90
baseline_v2.0_10yrs
No roll
(noroll_v2.0_10yrs)
Roll on all parts of the sky
(rolling_all_sky_ns2_rw0.9_v2.0_10yrs)
Roll the bulge in 6 stripes
(low-dust WFD in 2 regions)
(rolling_bulge_6_v2.0_10yrs)
Roll in the bulge with 2 regions,
50% strength
(rolling_bulge_ns2_rw0.5_v2.0_10yrs)
Roll in the bulge with 2 regions,
80% strength
(rolling_bulge_ns2_rw0.8_v2.0_10yrs)
Roll in the bulge with 2 regions,
90% strength
(rolling_bulge_ns2_rw0.9_v2.0_10yrs)
Rolling half-sky (2 regions),
50% strength
(rolling_ns2_rw0.5_v2.0_10yrs)
Rolling half-sky (2 regions),
90%, strength
(rolling_ns2_rw0.9_v2.0_10yrs)
Rolling in one-third sky (3 regions)
50% strength
(rolling_ns3_rw0.5_v2.0_10yrs)
Rolling in one-third sky (3 regions)
90% strength
(rolling_ns3_rw0.9_v2.0_10yrs)
Rolling in one-sixth sky (6 regions)
50% strength
(six_rolling_ns6_rw0.5_v2.0_10yrs)
Rolling in one-sixth sky (6 regions)
90% strength
(six_rolling_ns6_rw0.9_v2.0_10yrs)
Simulation Run
Completeness PHA H<16.0
Completeness PHA H<22.0
Completeness NEO H<16.0
Completeness NEO H<22.0
Completeness MBA H<16.0
Completeness MBA H<21.0
Completeness Trojan H<14.0
Completeness Trojan H<18.0
Completeness TNO H<6.0
Completeness TNO H<8.0
Completeness OCC_r5 H<8.0
Completeness OCC_r5 H<17.0
Completeness OCC_r20 H<8.0
Completeness OCC_r20 H<12.0

Responded to the Cadence Note Call

Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) Solar System Science Collaboration (SSSC) Cadence Note

Meg Schwamb[1], Michele Bannister, Bryce T. Bolin, Rosemary Dorsey, Henry Hsieh, Lynne Jones, Laura Inno, Tim Lister, Colin Snodgrass, Sarah Greenstreet, Cyrielle Opitom, Kat Volk, Siegfried Eggl, Michael S. P. Kelley, Steve Chesley, Wes Fraser, Alan Fitzsimmons, Mario Jurić, William J. Oldroyd, Robert Seaman, and Michael Solontoi

For the LSST SSSC

http://lsst-sssc.github.io/Files/SSSC_cadence_note.pdf

Feedback after the SCOC Meeting

SSSC 2nd SCOC workshop Post Reflections

Baseline 2.0 Simulation: Overall, the SSSC supports the recommendations in the draft cadence report and the suite of simulations to explore further refinements of the LSST cadence. We ask the SCOC to use our decision tree outlined in our Cadence Note for evaluating the simulated 1.5-1.7 simulations when considering the v2.0 simulations. We have some concern over the slight decrease in Solar System detections in Baseline 2.0. This may be due to the change in low galactic latitude coverage within the WFD. We note that the MAF Solar System detection estimates do not account for stellar crowding in the galactic plane, so the metric is overly optimistic in these regions. We ask the scheduler team to work with the SSSC to investigate the cause of this, to better understand how future changes/tweaks to the 2.0 cadence will further impact the number of faint Solar System detections.

Revised Footprint: The SSSC is happy with the revised footprint. The Northern Ecliptic Spur (NES) continues to be our highest priority request. We have yet to explore the simulations with varying NES observations as the MAF Solar System metrics are still being run. We plan to provide feedback in January via our SCOC liaison.

Micro-Surveys - We fully understand the reasoning behind implementing in Year 2 the micro-surveys, such as the Near-Sun Twilight NEO Survey. We are pleased that the Solar System twilight micro-survey is being further explored by the SCOC. We strongly advocate for including this twilight survey in the final cadence. We note that any fraction of observing time that can be dedicated to this will produce niche science (see the SSSC Cadence Note).

TOO Programs and "Nano-Surveys" - We encourage the SCOC and Rubin Operations to

http://lsst-sssc.github.io/Files/SSSC_mini_cadence_note_Nov_2021.pdf

Unsolicited feedback to SCOC on all v2

We provide a brief summary of the SSSC's review of the v2.0 cadence simulations. The SSSC applied the same strategy used in our cadence note and our response to the SCOC November 2022 workshop. Comparing the metrics to the relevant baseline cadence or within a simulation family, reductions in relevant metrics (discovery and light curve inversion) larger than ~5% for Near Earth Objects (NEOs), Trans-Neptunian Objects (TNOs), Main-Belt Asteroids (MBAs) Potentially Hazardous Asteroids (PHAs), and comets were deemed unsuitable. We allow wider swings in the metrics for Jupiter Trojans based on the expected science and their localized positions on sky which will make them very sensitive to cadence modifications. Like our previous cadence note, we provide a silver, green, red label for each of the v2.0 simulations in the linked spreadsheet.

New Baseline: The Baseline 2.0 is satisfactory for the SSSC's science goals. The Inclusion of more of the Northern Ecliptic Spur in the Wide-Fast-Deep (WFD) footprint is welcome.

Filter distribution (bluer_ and long_u families): We prefer the baseline filter allocation over any of the shift to bluer filter allocations simulated. Most of the families with bluer filters (bluer_indxXX,, long_uXX) are worse for Solar System objects than the baseline, especially for the light curve metric. In terms of modifying u-band exposures, we prefer the v2.0 baseline, but the long_u2_ is a good compromise and the least bad for solar system metrics, as long as it is not done simultaneously to any of the bluer_indxXX options.

Presto Color (presto_gapXX, presto_gapXX_mix, and presto_half families): The presto

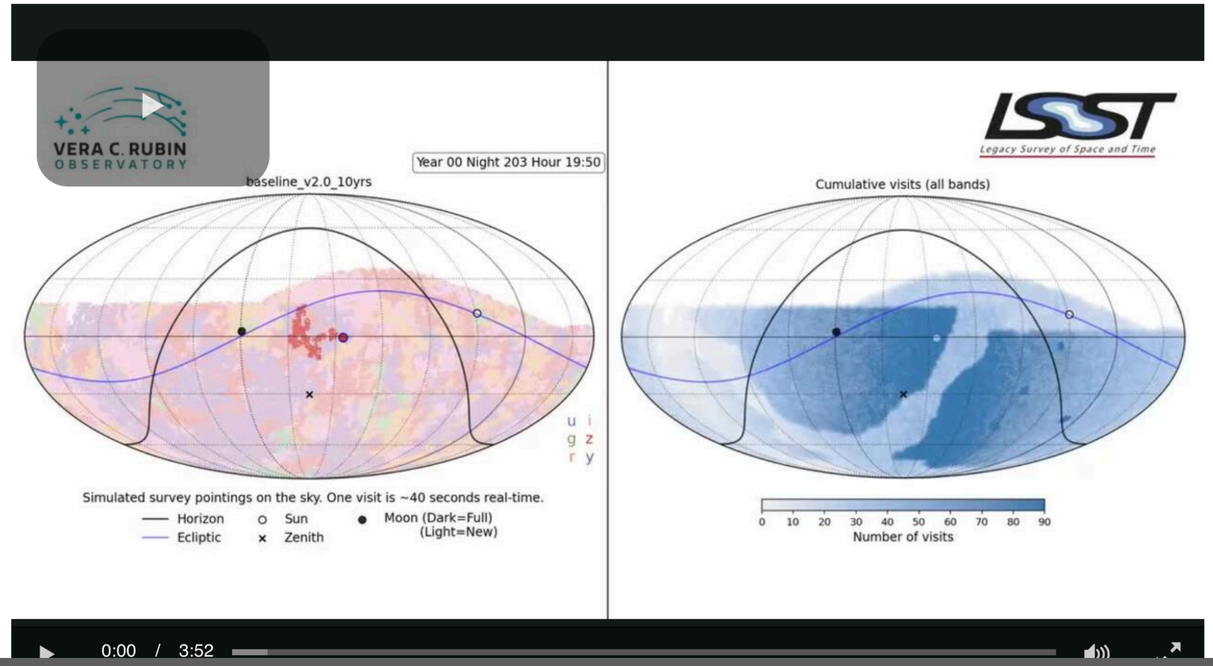
http://lsst-sssc.github.io/Files/SSSC_V2.0_Cadence_Simulations_Key_Points.pdf

Cadence Group is now drafting the LSST Cadence ApJS Focus Issue

THE ASTROPHYSICAL JOURNAL
SUPPLEMENT SERIES

Rubin LSST Survey Strategy Optimization

PI: Federica Bianco



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The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will provide unprecedented data that will be made available to all US and Chilean scientists and to international member scientists for a diverse range of astrophysical investigations, from cosmology to solar system studies and from stellar astrophysics to transients to galaxy evolution. In any synoptic survey such as this one, the choice of cadence—the pattern in which the telescope moves across the sky and periodically revisits each field—is of vital importance in maximizing the scientific utility of the data. Yet, identifying the optimal cadence for a broad range of scientific goals is a challenge. As part of the survey design and characterization process, Rubin Observatory involved the LSST science community by soliciting Cadence White Papers and Cadence Notes. Peer-reviewed journal articles describing scientific investigations that motivate and support these notes are published in this focus issue as a record of the factors which influenced survey design, and for guidance for future surveys that may confront many of the same issues faced by Rubin Observatory.

OPEN ACCESS

Optimization of the Observing Cadence for the Rubin Observatory Legacy Survey of Space and Time: A Pioneering Process of Community-focused Experimental Design

Federica B. Bianco *et al* 2022 *ApJS* **258** 1

+ Open abstract View article PDF

OPEN ACCESS

Preparing to Discover the Unknown with Rubin LSST: Time Domain

Xiaolong Li *et al* 2022 *ApJS* **258** 2

+ Open abstract View article PDF

OPEN ACCESS

Blazar Variability with the Vera C. Rubin Legacy Survey of Space and Time

Cadence Group is now drafting the LSST Cadence ApJS Focus Issue

Tuning the Legacy Survey of Space and Time (LSST) Observing Strategy for Solar System Science

Megan E. Schwamb [1], R. Lynne Jones [2,3], Peter Yoachim [2], Plus Others, [2] Kathryn Volk [4], and Tim Lister [5]

[1] *Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, UK*

[2] *Department of Astronomy, University of Washington, Box 351580, Seattle, WA 98195-1580, USA*

[3] *DIRAC Institute, Department of Astronomy, University of Washington, 3910 15th Avenue NE, Seattle, WA 98195, USA*

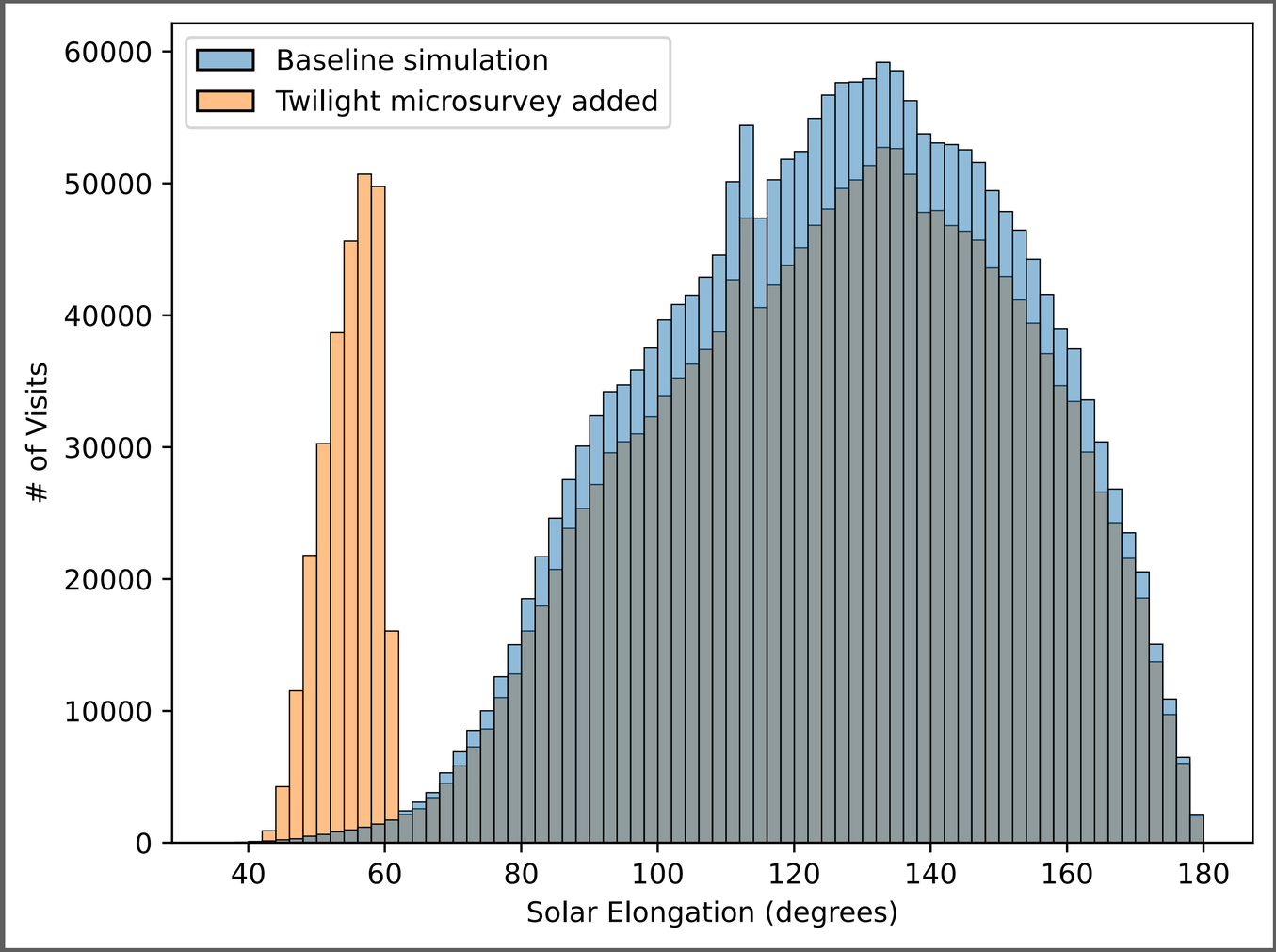
[4] *Lunar and Planetary Laboratory, University of Arizona, 1629 E University Blvd, Tucson, AZ 85721, USA*

[5] *Las Cumbres Observatory, 6740 Cortona Drive Suite 102, Goleta, CA 93117, USA*

ABSTRACT

In 2024, the Vera C. Rubin Observatory is planned to start science operations for the Legacy Survey of Space and Time (LSST). This multi-band wide-field synoptic survey is going to transform our view of the Solar System, with the discovery and monitoring of over 5 million planetesimals. The final survey strategy chosen for LSST has direct implications on the discoverability and characterization of Solar System minor planets and passing interstellar objects. Inventorying the Solar System is just one of the four

Low Solar Elongation Angle Solar System Twilight Survey



- Very short exposures might not be possible
- Current iterations impact WFD so this needs to be revised

THE SCOC TIMELINE IS SUBJECT TO CHANGE, THIS VERSION IS FROM OCTOBER 2021:

- Nov 16-17, 2021: the 2nd SCOC workshop
- Dec 15, 2021: finalized Phase 1 SCOC recommendation publicly available
- Mar 1, 2022: simulations of the recommended strategy available (with detailed baseline variations to enable fine tuning of the baseline cadence)
- Summer 2022: draft Phase 2 SCOC recommendation available, the 3rd workshop to fine-tune the recommended baseline strategy, including start of "early science optimization" discussions **Workshop moved to Fall 2022**
- Dec 15, 2022: the simulation of the adopted observing strategy (the new baseline for starting LSST) produced and made publicly available; finalized Phase 2 SCOC recommendation delivered to the Rubin Observatory Operations Director **No plane to move this deadline back into 2023**
- Apr 1, 2023: the observing strategy fixed and implemented in the Scheduler and the Observatory Control Software (note: this date is exactly one year before currently anticipated start of operations)
- Dec 15, 2023: SCOC, informed by system performance estimates from the commissioning team, recommends baseline strategy modifications to address "early science optimization"

What's Next for the SSSC?

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Continued SSSC feedback on SCOC decisions

What is Early Science?

What to do in the first ~3-6 months of operations

The SCOC would operate by consensus to the extent possible. But formal votes would be taken at major decision points:

- Development of an initial 10-year survey strategy plan, and drafting the report describing that plan.
- Development of an “Early Science” plan
- Recommendations of significant changes in survey strategy during operations.

Pushing on Early Science

We have been advocating to just start the LSST survey when asked to contribute a few slides to last year's PCW, but no formal input requested yet from the SCOC.

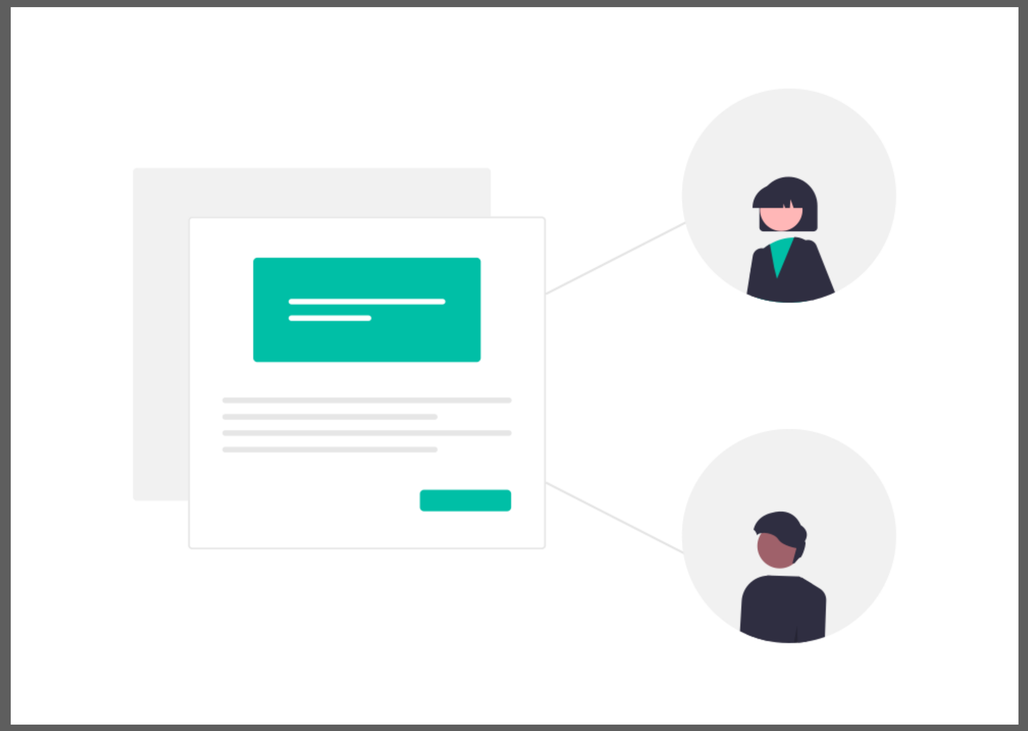
Is a Research Note of the AAS a good way to give feedback?

Co-Chair Election Up-Coming

Nominations due later in June. Voting later in the Summer

Image credit: https://undraw.co/

Developing an external expert membership class for a small number of people without data rights who could provide some unique contributions to the SSSC (subject to adoption by the collaboration)



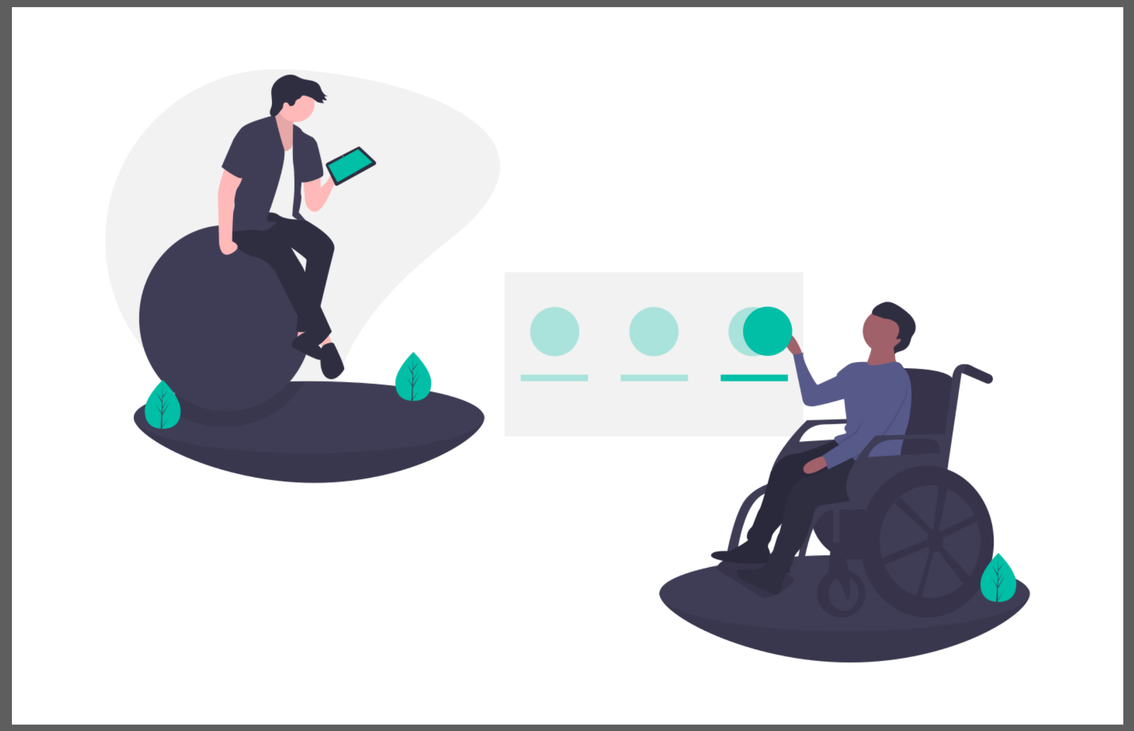
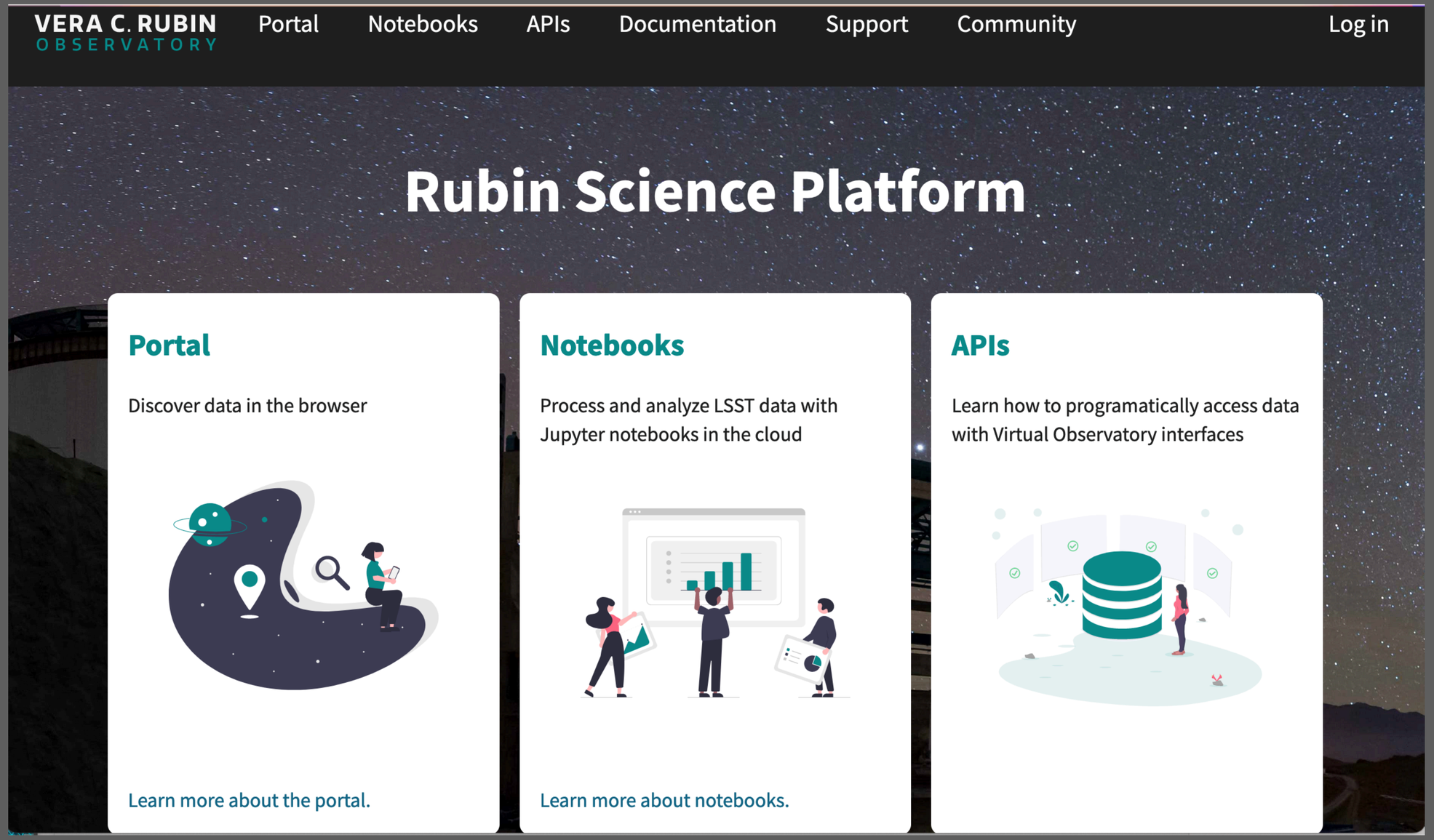


Image credit: https://undraw.co/

Figuring Out What We Need in the Rubin Science Platform



International In-Kind Contributions

The SSSC has been awarded 0.75 FTE of in-kind contribution software developer pool time to develop a Solar System forced photometry tool and enhancing the sbpy package

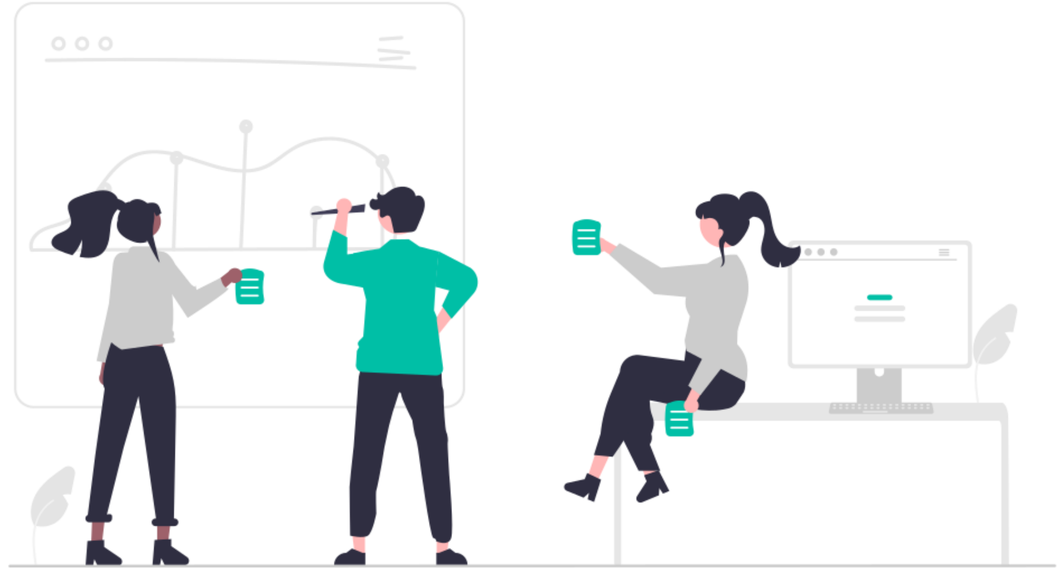
A few other specific SSSC international in-kind contributions, are planned/spinning up. There are mainly focused on software development.

Looking longer term: Commissioning Data

Rest of these dates is shifting ~4-6 months

Rubin Data Releases	Sep 2021	Jun 2022	Mar 2023	Dec 2023	Dec 2024	Sep 2025
	DP0.1	DP0.2	DP1	DP2	DR1	DR2
Data Product	DC2 Simulated Sky Survey	Reprocessed DC2 Survey	ComCam On-Sky Data	LSSTCam On-Sky Data	LSST Early Science Data	LSST Year 1 Data
DRP Processed Visit Images and Visit Catalogs	☑	☑	☑	☑	☑	☑
DRP Coadded Images	☑	☑	☑	☑	☑	☑
DRP Object and ForcedSource Catalogs	☑	☑	☑	☑	☑	☑
DRP Difference Images and DIASources	☐	☑	☑	☑	☑	☑
DRP DIAObject Catalogs	☐	☑	☑	☑	☑	☑
PP Processed Visit Images	☐	☐	☑	☑	☑	☑
PP Difference Images	☐	☐	☑	☑	☑	☑
PP Catalogs (DIASources, DIAObjects, DIAForcedSources)	☐	☐	☑	☑	☑	☑
PP Alerts (Canned)	☐	☐	☑	☑	☑	☑
PP Alerts (Live, Brokered)	☐	☐	☐	☑	☑	☑
PP SSP Catalogs	☐	☐	☑	☑	☑	☑
DRP SSP Catalogs	☐	☐	☐	☐	☑	☑

Facilitating Conversations and Connecting SSSC Members during the last 2 years of time to prepare before the start of LSST data



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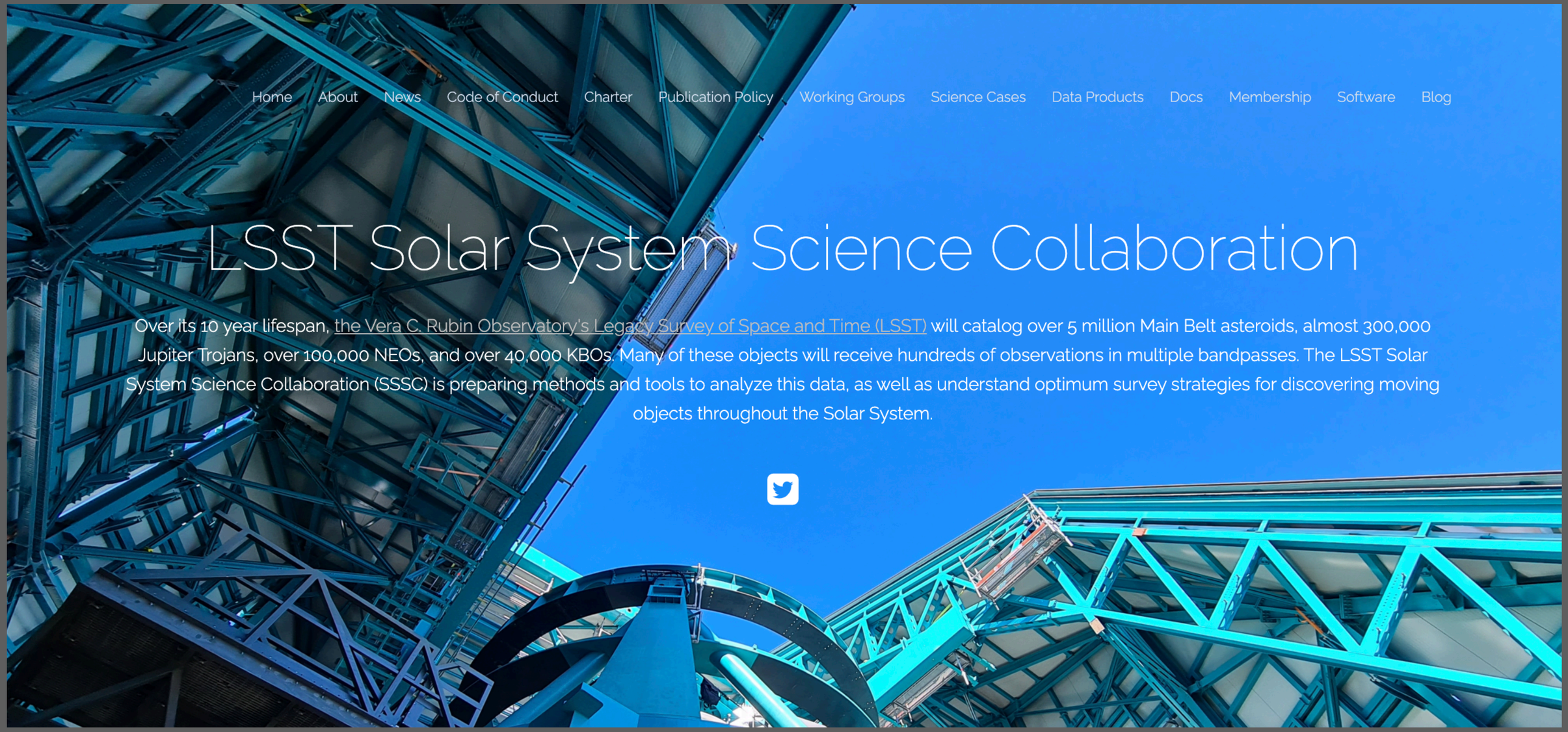
More details can be found on the SSSC's webpage



www.lsstsssc.org