LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

Call for White Papers on LSST Cadence Optimization

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DRAFT

Abstract

The LSST community is invited to play a key role in the definition of LSST's Observing Strategy by submitting white papers to help refine the cadence of observation in the 'main survey' and fully define the use of the remaining 10% of available time, distributed among a variety of 'mini-surveys'.

The LSST Science Requirements Document (SRD) places minimal constraints on the observing strategy, recognizing that science evolves and that the initial (by now more than a decade old) survey strategy would have to be redefined closer to first light. With LSST first light expected in 2020, now is the time to undertake the final pre-commissioning planning for the initial LSST observing strategy. While the existing candidate baseline survey strategy has been primarily defined by the LSST Project, the final planning must be undertaken hand-in-hand with the community.

<summary of what must be kept, what is open to change, how much time 10-20%>

<combine white papers>

We are soliciting white papers to help plan these aspects of the LSST survey strategy. The deadline for these white papers is November 30, 2018.

Change Record

Version	Date	Description	Owner name
1	2018-06-30	First released version.	Željko Ivezić

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Call for White Papers on LSST Cadence Optimization

1 Introduction

The Large Synoptic Survey Telescope (LSST) will provide an unprecedented optical imaging dataset that will support investigations of our Solar System, Galaxy and Universe, across half the sky and over ten years of repeated observation. LSST observations will be scheduled automatically, with the scheduling algorithm designed to address all science goals and maximize observing efficiency for given observing constraints (please see Appendix C for a list of most relevant references describing LSST and its operations). LSST is constructing a flexible scheduling system that can respond to the unexpected and be re-optimized as the survey progresses.

Any implementation of LSST's 10-year observing strategy must meet the basic requirements described in the LSST Science Requirements Document (SRD[1]) for the core LSST science goals:

- constraining dark energy and dark matter,
- taking an inventory of the Solar System,
- exploring the transient optical sky, and
- mapping the Milky Way.

However, in practice, the SRD intentionally places minimal quantitative constraints on the observing strategy, primarily requiring:

- A footprint for the 'main survey' of at least 18,000 square degrees which must obtain at least 825 visits per field (see SRD Tables 22 and 23), which places a minimum constraint on the time required to complete the main survey. Simulated surveys indicate this means that the main survey typically requires 85–90% of the available time to reach this benchmark; even with scheduling improvements, it is unlikely that the goals of the main survey could be met with a time allocation significantly below 80%.

[1] The LSST Science Requirements Document (SRD) is available at http://ls.st/srd

- Parallax and proper motion accuracies of 3 mas and 1 mas/yr at $r = 24$, respectively (see SRD Table 26), which places a light constraint on distributing visits throughout the lifetime of the survey and throughout a season.
- Rapid revisits (40 seconds to 30 minutes) must be acquired over an area of at least 2000 square degrees (see SRD table 25) for very fast transient discovery; this requirement can usually be satisfied via field overlaps when surveying contiguous areas of sky.

This leaves significant flexibility in the detailed cadence of observations within the main survey footprint, including the distribution of visits within a season (or between seasons), the distribution between filters and the definition of a 'visit' itself. Furthermore, these constraints apply to the main survey, which is expected to require at most 90% of the observing time; the use of the remaining time in mini-surveys is not constrained in the SRD.

A brief introduction to the current candidate baseline survey strategy, expanded background of the primary LSST science goals, and concise descriptions of how these goals drive the basic survey strategy and data processing requirements are provided in the LSST Overview paper[2]. This current candidate baseline survey strategy, as represented in the reference survey simulation, includes the main survey and several candidate mini-surveys (for more details, please see Appendix A):

- The **main "wide-fast-deep" survey**, which covers $\sim$18,000 deg^2 of sky within equatorial declination range $-62° < \delta < +2°$, and excluding the central portion of the Galactic plane. Within the main survey, two visits[3] per field (in either the same or different filters) are acquired in each night, to allow identification of moving objects, rapidly varying transients, and improve the reliability of the alert stream. These pairs of visits are repeated every three to four nights throughout the period the field is visible in each year. Each field in the main survey receives about 825 visits throughout the ten years of the LSST survey, spread over the six LSST filters $ugrizy$. The quantitative SRD constraints on area coverage, number of visits, parallax and proper motion errors, and rapid-revisit rate (40 seconds – 30 minutes) apply to visits obtained in the main survey. In the current reference simulation, the main survey uses 86.4% of the available time.

[2] The LSST Overview paper is a living document available at http://ls.st/pif.

[3] A 'visit' here is an LSST default visit, which consists of back-to-back 15 sec exposures, for a total of 30 sec of on-sky exposure time. These back-to-back exposures are always in the same filter, separated only by the 2 second readout time.

- The **North Ecliptic Spur candidate mini survey** covers the area north of $\delta = +2^{\circ}$ to 10° north of the Ecliptic plane and is intended to observe the entire Ecliptic plane for purposes of inventorying the minor bodies in the Solar System. This area ($\sim$ 4160 deg^2) is observed on a schedule similar to the main survey, although with a smaller total number of visits per field and only in filters $griz$. As implemented in the current reference simulation, the North Ecliptic Spur mini-survey uses about 5.5% of the available time.

- The **Galactic Plane candidate mini survey** covers the central portion of the Galactic plane which is not included in the main survey, centered around $|l| = 0^{\circ}$ and covering $\sim$ 1860 deg^2. It is observed at a much reduced rate compared to the main survey, and with a smaller total number of observations per field (30 visits per field and per filter, in $ugrizy$), so as to provide astrometry and photometry of stars toward the galactic center but without reaching the confusion limit of the coadded images. There is no requirement for pairs of visits in each night in this area. As implemented in the current reference simulation, the Galactic Plane mini-survey uses about 1.6% of the available time.

- The **South Celestial Pole candidate mini-survey** covers the region south of the main survey, to the South Celestial Pole, $\sim$ 2315 deg^2, including the Magellanic Clouds. This mini survey is observed with a strategy similar to the Galactic Plane mini-survey, with 30 visits per field per filter in $ugrizy$, and without requiring pairs of visits. This provides coverage of the Magellanic clouds, but without committing extensive time as these fields are at high airmasses from the LSST site. As implemented in the current reference simulation, the South Celestial Pole mini-survey uses about 2.0% of the available time.

- The **Deep Drilling Field candidate mini-survey** is implemented as five specific field pointings $\sim$ 50 deg^2, which are observed with a much denser sampling rate. These fields are observed every three to four days, but in a sequence of multiple $grizy$ exposures during gray and bright time, and then multiple sequential u band exposures during dark time. The current deep drilling fields are aimed at extragalactic science, providing a 'gold sample' to calibrate the main survey, and to discover Type Ia supernovae. As implemented in the current reference simulation, the Deep Drilling Fields mini-survey uses about 4.6% of the available time.

Due to the desire for multi-wavelength precursor observations for the deep drilling fields, and the limited lifetime of relevant space-based observatories, the locations of four of the Deep Drilling fields have been finalized, while any remaining field locations have yet to be specified. The locations of these four deep fields were announced in 2012, as the result of a community driven process with the goal of obtaining multi-wavelength coverage by ground and space-based facilities some of which may not exist at the start of the LSST survey. These fields are intended to coincide with multi-wavelength surveys targeting the ELAIS-S1, XMM-LSS, Extended Chandra Deep Field-South, and COSMOS pointings. The cadence of observations within these (or any) deep drilling fields is not finalized, although the coadded depth may be expected to be at least one magnitude deeper than the LSST main survey in each filter.

Beyond the SRD constraints and commitment to the four deep drilling fields, the survey strategy as implemented in the candidate baseline above should not be considered guaranteed; for illustrative examples of some alternate survey strategies, please see Appendix C.3. All of the candidate mini-surveys and the cadence in the main survey will be re-evaluated on the basis of community input in the next step of planning for the initial LSST survey strategy. Much of the existing survey strategy has been based on a mix of community and project input, but the overall balance has been project-driven. The main purpose of this call for white papers is to solicit detailed input from the community interested in LSST science in order to design the optimum overall survey strategy.

1.1 Feedback from the community into the LSST survey strategy thus far

The LSST community is already playing a key role in the refinement of LSST's observing strategy by developing and analyzing metrics for quantifying the performance of simulated surveys generated by the LSST project. This work is being assembled in an open github community[4], in the form of a large cross-community survey evaluation paper titled 'Science-Driven Optimization of the LSST Survey Strategy'[5], which will be referred to here as the Community Observing Strategy Evaluation Paper (COSEP). Chapter 1 and 2 of the COSEP provide a useful overview of the considerations involved in modifying the LSST survey strategy, as well as more details of the baseline survey strategy and examples of some possible variations in survey strategy, implemented in various simulated surveys.

The COSEP explores the effects of relatively small changes to the LSST survey strategy on the detailed performance of the anticipated science investigations. The main lessons learned

[4] https://github.com/LSSTScienceCollaborations/ObservingStrategy
[5] The first version of this community observing strategy evaluation paper was published as arXiv:1708.04058 in August 2017.

from the first version of this paper are:

1. The LSST Project should simulate, analyze and optimize the rolling cadence idea (a non-uniform sampling in time in the wide-fast-deep survey designed to increase the frequency of observations for better coverage of variable phenomena on time scales of a few months, driven by supernovae, asteroids, and short-timescale stellar variability, at the cost of decreasing the frequency slightly at other times), and
2. The LSST Project should execute a systematic effort to further improve the ultimate LSST survey strategy (e.g., sky coverage optimization, u band depth optimization, mini surveys).

Through the end of construction and commissioning, the COSEP will remain a living document and the main vehicle for the community to broadly communicate to the LSST Project regarding the scientific repercussions of various observing strategies. The LSST Project Scientist will periodically synthesize and act on the results presented in this paper, making appropriate small modifications to the survey strategy in response, with support from the Project Science Team (PST), the Science Advisory Committee (SAC) and the future Survey Strategy Committee[6].

While the COSEP will continue to provide the means to update evaluations of the survey strategy, the white papers solicited in this call are intended to provide the LSST science community with an opportunity to propose more significant modifications of the LSST survey strategy, including expanding or eliminating various mini surveys. The performance evaluation components of the white papers solicited here will also be added to the COSEP, to provide a comprehensive reference point for survey strategy evaluation.

1.2 Motivation for this white paper call

Guided by the community input summarized in the COSEP and further advice from the Science Advisory Committee (SAC), the LSST Construction Project has decided to solicit detailed technical white papers for specific modifications of the current baseline survey strategy.

[6] The SAC will establish a Survey Strategy Committee to evaluate competing survey strategy proposals and to propose a general survey strategy for commissioning and operations. The committee will be comprised of both project and non-project personnel.

As discussed in more detail in Appendix A, analysis to date indicates that the baseline candidate survey strategy, while meeting the basic science requirements for the LSST survey, can be meaningfully improved[7] The LSST SRD provides minimal constraints on the survey strategy details because it recognized that science evolves and that the initial, by now more than a decade old, survey strategy will have to be re-optimized closer to first light. With LSST first light expected in 2020, now is the time to undertake the final pre-commissioning optimization[8] of the LSST baseline observing strategy. We seek science-driven input for cadence properties such as per-bandpass imaging depth, the sky coverage, temporal coverage, observing rules, etc., as summarized in Appendix A. Investigations of a limited number of such survey strategy modifications are reported in Chapter 2 from the COSEP (and discussed in various supplementary materials listed in Appendix C).

1.3 General guidelines

We solicit detailed white papers for specific modifications of the current baseline survey strategy, including both the main survey and the so-called "deep drilling fields" and mini surveys. There are no specific limitations on what kind of science programs will be considered, but please note that the primary four LSST science themes remain the cornerstones of the LSST survey and cannot be easily abandoned (the LSST SRD states that "the adopted observing strategy will not jeopardize the goals of any of the four main science themes").

The detailed cadence of visits in the main survey, the footprint for any other mini survey (except the location of the four pre-announced deep drilling fields), and the cadence or number of visits in any mini survey are open topics for optimization. The existence of a particular survey strategy for a given mini survey in the current baseline should not be taken to imply that it will be present in the same way in the final survey strategy.

Detailed white papers are also solicited for novel ideas, such as twilight observing (see Appendix A.6), as well as synergies with other major surveys (*e.g.*, WFIRST, Euclid). In addition, white papers for programs which leverage LSST's unique large étendue are more compelling than *e.g.,* single object investigations. At this time we are not soliciting proposals to optimize observations during the commissioning period.

[7] The current, as-simulated, baseline survey strategy is described in detail in Sections 1.1 and 2.3 in the COSEP.

[8] "Optimization" used here does not imply its strict mathematical meaning. We are attempting to create the best survey strategy possible, but this is not a formal optimization effort of an objective function in part because the concept of an "optimized" survey depends in part on a subjective weighting of different science goals.

Technical constraints imposed by the system and observing conditions are summarized in Appendix B. If a proposed dataset will require special processing, a plan to obtain necessary software and compute resources must be provided in the white paper. In cases that require more detail, or in case of specific questions not addressed in this document, please start a discussion at community.lsst.org[9].

The LSST Science Requirements Document states that "the adopted baseline design assumes a nominal 10-year duration with about 90% of the observing time allocated for the main LSST survey.", and further clarifies that "The remaining 10% of observing time will be used to obtain improved coverage of parameter space. . . ". While the detailed time allocation will eventually depend on currently unknown system performance parameters, it is unlikely that the goals of the main survey could be met with a time allocation significantly below 80%. In other words, it is plausible that the time allocated to programs other than the main survey could significantly exceed 10% (perhaps by as much as a factor of two), but no firm commitments beyond this statement of plausibility can be made at this time.

The data from any given specialized survey will be treated in exactly the same way as all LSST data: there is no special proprietary access for any subset of the data from LSST. Indeed, the final set of the so-called deep-drilling fields and other mini surveys may be based on an amalgam of ideas from different white papers; there will be no sense in which a survey strategy described in a given white paper must be accepted or rejected as-is.

1.4 Review process and timeline

The deadline for submitting white papers is November 30, 2018. For submission instructions, please see the next section.

Soon after the November 2018 submission deadline, members of the LSST Science Advisory Committee (SAC), with technical support from the Project, will triage the submitted white papers and decide which meet the criteria of scientific excellence and technical feasibility for further analysis (including suggestions for combining submitted ideas into single programs, and giving suggestions for maturation of the current notional extragalactic observing strategy). These criteria are discussed in Section 3.

[9] `https://community.lsst.org/c/sci/survey-strategy`

The input from the submitted white papers will be used to design multiple options in observing strategies and a Project team will generate simulated surveys based on these survey strategies. These multiple simulated surveys will address varying science drivers and will form a "menu" of possible survey strategies (e.g., a main survey with 18,000 deg^2 of sky coverage vs. sky coverage of 23,000 deg^2 to a somewhat shallower depth). The performance evaluation criteria submitted as part of the white papers and in the COSEP will be used to generate quantitative assessments to compare these strategies.

We anticipate that the list of observing strategies that will be simulated and analyzed (the "menu" above) will be available by April 2019. Simulated survey outputs and Metric Analysis Framework (MAF[10]) analyses will become available by the end of 2019.

An advisory report on these survey strategies will be prepared by the Project for the LSST SAC during early 2020, in a close collaboration between the Project and the Observing Strategy Github community and LSST Science Collaborations. The SAC will in turn advise the Project on the specific survey strategy to be used at the start of full LSST operations, as well as on guidelines for the strategy throughout all ten years of the survey. In developing their recommendations to the Director, the SAC will be guided by selection criteria set by the Project Science Team and discussed in Section 3 (*e.g.*, restrictions based on technical criteria, such as those discussed in Appendix B). The Director can further consult with the Project Science Team about the SAC survey strategy recommendations. A baseline simulation that reproduces the adopted strategy, and its detailed performance analysis, will be published in 2021. The start of LSST operations is anticipated in 2022.

An overall aim of the Project and all stakeholders is to make this process transparent to the community and to base all decisions on quantitative input and pre-defined criteria to the maximum extent possible. The Project will organize a dedicated session at the LSST 2018 All-hands meeting (Tucson, Aug 13-17) about this call for white papers, to further clarify details, exchange ideas, discuss simulated surveys, and coordinate teams that plan to submit white papers.

2 White paper submission guidelines

[10] https://sims-maf.lsst.io

2.1 Who can submit a white paper?

All members of the scientific community interested in LSST science can submit a white paper. We reiterate that the data from any given specialized survey will be treated exactly the same way as all LSST data: the authors of white papers will have no proprietary access to it. There will be no formal "acceptance" of proposed ideas; with the overall ranking priority advice provided to the Project by the Science Advisory Committee, the Project Team will implement a number of different strategies that will be used as quantitative input ("a menu of options") by the Science Advisory Committee when recommending strategy for the initial phase of the LSST survey.

2.2 Requested input

The current baseline survey strategy (as represented in the reference survey simulation) includes:

- the main Wide-Fast-Deep (WFD) survey,
- Northern Ecliptic Spur (NES) mini survey,
- Galactic Plane (GP) mini survey,
- South Celestial Pole (SCP) mini survey, and
- the Deep Drilling (DD) fields mini survey,

Quantitative, science-driven optimization input is requested for all of the above, as well as for survey strategy questions such as optimal visit exposure time, co-added per-bandpass imaging depth, the sky coverage, temporal coverage, observing rules, etc. For a detailed discussion, please see Appendix A. The existence of a particular mini survey, sequence of observations, or exposure time in the current baseline does not guarantee its existence in the same form in the final survey strategy.

In addition to existing surveys listed above, we also seek input on new mini survey ideas to replace and/or enhance the current programs, including special "Target of Opportunity" (ToO) programs. We also solicit novel ideas, such as twilight observing (see Appendix A.6), as well as observing synergies with other major surveys (e.g., WFIRST, Euclid).

We reiterate that that the observing time allocated to **all** the mini surveys (including DD fields) is "about" 10%, and is unlikely to exceed 20% of the total available observing time. We note that implementation details for mini surveys (especially DD fields) are coupled at some level to the main survey: more time for the former means less for the latter, and some of the design decisions for the latter affect the science case for the former. For example, some rolling cadence strategies for the main survey may allow some variable and transient science to happen that would otherwise be the focus of a deep drilling field, and changes in the main survey footprint will affect the definition of a Galactic Plane survey. The Project will provide additional alternative survey simulations with this call for white papers to help illustrate some of these potential crossovers.

2.3 TeX template for submission

Each proposed modification of the survey strategy must contain a Scientific Motivation, Technical Description, and Performance Evaluation section, instructions for which are expanded in the white paper submission template. The Scientific Motivation section is intended to explain why this survey strategy modification is important and what can be learned if the proposed observations were obtained, relative to some baseline. The Technical Description section details what observations are being requested and should provide enough detail to enable proper simulations[11] to be created, as well as additional information that can help in the process of combining similar but separate survey strategy modification requests. The Performance Evaluation section must contain methods to evaluate the effectiveness of the survey strategy modifications, particularly in light of the potential effect of survey strategy changes proposed in other white papers. It is unlikely that any proposed cadence modification suggested in white papers will be carried out in its "ideal" form; thus metrics (along with threshold values for these figures of merit) to evaluate the science performance of non-ideal simulations are crucial. The TeX submission template should help with further instructions for each of these areas.

The submission template requests each white paper to self-assign to one of the following categories:

- a specific observing strategy to enable specific time domain science, that is relatively agnostic to where the telescope is pointed (e.g., a science case enabled by relatively

[11] For more information on how survey simulations are created, please see the documentation on OpSim at http://sims-opsim.lsst.io.

deep precise time-resolved multi-color photometry).

- a specific pointing or set of pointings that is (relatively) agnostic of the detailed observing strategy or cadence, (e.g., a science case enabled by very deep precise multi-color photometry)
- an integrated program with science that hinges on the combination of pointing/detailed observing strategy combination (e.g., search for variable stars in the LMC/SMC).

If a specific white paper does not fit any of these categories, please state so.

The submission template and an example of the submission, with instructions about all the required information, can be found in the git repository hosted at lsst-pst/survey_strategy_wp[12]. The submission process includes the following steps:

1. Fork the repository using your (the PI's, or a selected collaborator's) Github account.
2. Clone the forked repository to your local machine.
3. Create a directory with the PI name as LASTNAME_FIRSTNAME_NUMBER, where NUMBER is a counter for multiple white papers submitted by the same person (or the case of two people with the same name).
4. Copy the template to the directory created in the last step.
5. Fill the latex template file with the white paper information. It is possible to make intermediate commits to keep track of the changes to the white paper and share it with collaborators.
6. Once the proposal is ready, make a Pull Request (PR) to the master branch of the main repository.
7. A team member will accept your PR, or contact you in case of problems.

For additional help or questions, please ask on LSST Community[13].

[12] https://github.com/lsst-pst/survey_strategy_wp
[13] http://community.lsst.org/c/sci

3 White paper ranking criteria

The ultimate LSST observing strategy will aim to deliver a cutting-edge data set to enable the four LSST's cornerstone scientific programs, while at the same time maximizing the science possible with specialized observing using about 10% of the total observing time.

We anticipate that the adopted observing strategy will be based on an amalgam of ideas from different white papers; therefore, there will be no formal "acceptance" or "rejection" of proposed ideas. The overall ranking priority advice provided to the Project by the Science Advisory Committee will be based on the following considerations:

- **Science** Importance and robustness of the proposed science program, including its match to the unique abilities of the LSST system, and its consistency with the main four LSST science themes. This could be a single strong science goal, synergies with other astronomical facilities, or a multitude of science goals enabled by the same survey strategy.
- **Feasibility** Programs must be feasible from the hardware and software point of view (see Appendix B), specifically including any special data processing required. The complexity of the program, in terms of additional requirements on hardware and software beyond the baseline requirements, will also be considered. The Project Science Team will conduct a technical check on submitted white papers.
- **Time requested** The amount of time (including overheads) required should be justified by the associated science.

As always, the science program properties such as importance and robustness are open to interpretation. It is inevitable that some science drivers will be in conflict, and even observing efficiency may not be defined in an absolute sense. The Project and the Science Advisory Committee will strive to make the white paper ranking process transparent to the maximum extent possible.

Acknowledgments: this document has greatly benefited from discussions between the LSST Project Science Team, the LSST Science Advisory Committee and Kem Cook, Phil Marshall, Steve Ridgway, Daniel Rothchild, Peter Yoachim and numerous other members of the LSST Science Collaborations.

A Examples of open survey strategy optimization questions

The quantitative optimization of the LSST observing strategy requires many detailed decisions to be made, often with only an indirect science justification, or with conflicting science drivers. The current most significant open questions and associated tradeoffs are listed below for the main survey and each mini survey. White papers are specifically encouraged to address these questions.

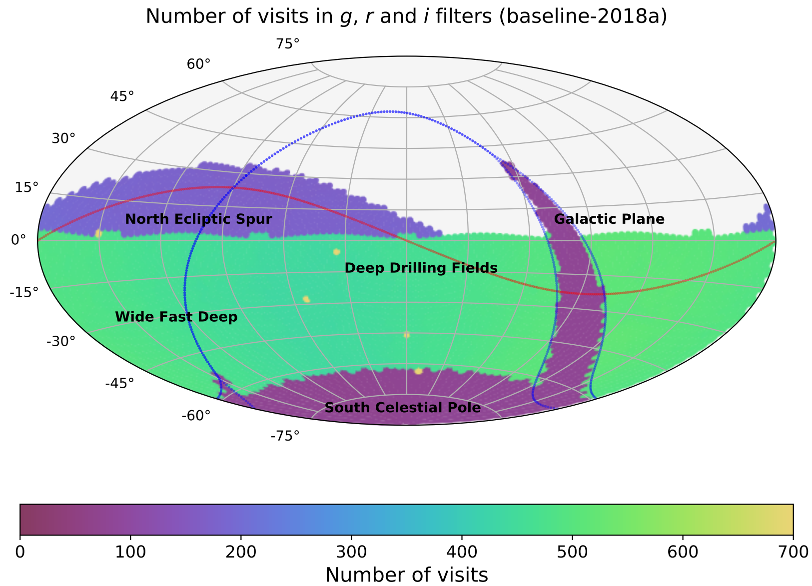

FIGURE 1: The current baseline survey includes the main Wide-Fast-Deep survey and four candidate mini surveys: the North Ecliptic Spur, the Galactic Plane, the South Celestial Pole, and the Deep Drilling fields. This figures demonstrates their footprint in the current baseline simulated survey and the number of visits in gri bands. We are seeking suggestions for modification of the survey strategy, especially suggestions for changes to the mini surveys.

A.1 The main Wide-Fast-Deep survey

The baseline survey strategy optimizes the amount of sky covered in any given night (subject to the constraint of gathering pairs of visits in each night), and allows the entire sky visible at any time of the year to be covered in about three nights. The basic strategy is designed to give roughly uniform coverage over the sky at any given time, and to reach the survey goals for measuring stellar parallax and proper motion, and the number of visits per field (825 visits, summed over the six filters). In the baseline implementation, the main survey covers about

18,000 deg^2 of high galactic latitude sky, and uses about 86% of the available observing time (based on current survey simulations).

Open questions and optimization options associated with the main survey are as follows:

- With the current declination boundaries at $\delta = -62^\circ$ and $\delta = +2^\circ$, the main survey area includes about 18,000 deg^2 (without the Galactic plane confusion zone, see Appendix A.3). These boundaries were set to optimize the number of detected galaxies and galaxies useful for cosmological studies. These galaxy counts stay within 5-10% of the current baseline values even with a much larger survey area. For example, Section 2.4 in the Observing Strategy white paper describes a simulated survey that covers 27,400 deg^2 to about 0.15 mag shallower co-added depth than in the baseline survey (the airmass limit is relaxed to 1.5 and declination boundaries are at $\delta = -78^\circ$ and $\delta = +18^\circ$, with the mean number of visits per field about 20% smaller that in the baseline survey). This trade-off between the sky coverage and co-added depth is still open to optimization and it is important to receive science-driven optimization arguments from all science programs. Note that the footprint should not drop below 18,000 deg^2 with fewer than 825 visits per field, due to design requirements listed in the Science Requirements Document.
- The observing time allocation per band (number of visits per filter) listed in the Science Requirements Document (Table 24) is given only as an illustration. Further optimization of this allocation for the main survey, and different fractional allocations for mini surveys, are likely possible.
- Concentrating a fraction of the observations for a given field into a shorter period of time (a.k.a. a "rolling cadence") can provide enhanced sampling rates over a part of the survey for a designated time, at the cost of reduced sampling rate the rest of the time (while maintaining the nominal total visit counts). While it is likely that science programs such as supernovae, asteroids, and short-timescale stellar variability would benefit from rolling cadence, detailed cadence parameters have not been optimized yet (*e.g.*, how much of the survey area to "roll" at once and how long to "roll" for, or whether to "roll" in right ascension or declination).
- The current baseline survey strategy obtains two visits per night (within 15-60 minutes) in order to enable easy linking of asteroid detections, and robust identification of rapid photometric transients. Whether the two visits on the same night should be obtained in the same filter or in different filters has not been decided yet (e.g., in the context of

photometric transients, same filters would provide a more accurate measurement of the brightness change, while different filters would provide a color constraint).

- The current strategy for the main survey which obtains two visits per night could be modified to obtain a single visit, or more than two visits, per night.
- The current baseline survey strategy assumes that a visit is composed of two 15-second exposures, the so-called snaps (2x15 sec visits). While 2x15 sec visits enable search for very rapid variability, and help with cosmic ray rejection, there are compelling technical arguments to adopt instead single-exposure 30 second visits, with observing efficiency being the main argument. Arguments for retaining the 2x15 sec visits would be very useful in further optimization of the main survey strategy.

White papers addressing all or some of these optimization efforts are strongly encouraged.

A.2 "Deep Drilling" fields

The Deep Drilling (DD) fields are single pointings that are observed in extended sequences. In the first call for white papers in 2011 on survey strategy optimization, the Project received 8 white papers from the community[14]. These proposals often include specific filter combinations to ensure that near-simultaneous color information is available for variable and transient objects. While science programs suggested in DD proposals are ideally well matched to the size of LSST field of view (9.6 deg^2), it is plausible that some programs may require several fields.

Four of the LSST DD fields have been selected and announced (Elias S1, XMM-LSS, Extended Chandra Deep Field-South, and COSMOS). It is guaranteed that they will be observed with deeper coverage and more frequent temporal sampling than the main survey fields, but details are still open. White papers detailing additional DD fields and their requirements are solicited with this call (a plausible but not prescriptive range is 5-10).

The observing sequences and coadded depths for these DD fields are not yet decided. The current baseline cadence includes sequences of $grizy$ observations during bright time, and sequences of u band observations during dark time. The large number of filter changes in the bright time sequences are inefficient and the large gap in multi-color sampling during dark

[14] These white papers are available from https://project.lsst.org/content/whitepapers32012

time is likely problematic for variable and transient characterization. White papers addressing improved cadences in the DD fields are desirable.

A.3 Galactic plane survey

The baseline main survey excludes observations at low Galactic latitudes, where the high stellar density leads to a confusion limit at much brighter magnitudes than those attained at high Galactic latitudes. Assuming median seeing, this confusion limit corresponds to a source density of about 1-2 million per deg^2. The current boundary of this "Galactic confusion zone" starts at $|b| = 10^\circ$ towards $l = 0^\circ$ and linearly drops to $b = 0^\circ$ at $l = 90^\circ$ and $l = 270^\circ$. Along this boundary, the confusion limit is reached at a depth of $i \sim 26$; therefore, the useful coadded depth is at least 1-2 magnitudes shallower than for the main survey and the total number of visits in this region is thus fewer. Within this boundary, the fraction of galaxies is only a few percent and an assumption that all sources are stars works quite well (simulations show that at most a few percent of sources are galaxies, whose counts are much smaller than in high galactic latitudes fields due to interstellar extinction). For example, the DECAPS survey generated a catalog with 2 billion sources in the Southern Galactic Plane to a depth of about $r = 23$ (with seeing around 1 arcsecond; Schlafly et al. 2018, arXiv:1710.01309). While the confusion limit is relevant for the coadded depth, time-domain studies using photometry from single images can still benefit from additional visits in this region.

As guidance, stellar count simulations with the TRILEGAL code (Girardi et al. 2005, arXiv:astro-ph/050404) show that to the depth of $r = 27.5$ there are about 4 billion stars in the main survey area, with another 13 billion stars in the Galactic confusion zone. Of the latter, about 6 billion are brighter than $r = 24.5$.

The current strawman implementation of the Galactic confusion zone coverage allocates 30 observations in each of the six filters. Detailed optimization of this strategy has not been done yet. In particular, science-driven input is needed for both "static science" programs (e.g., The Blanco DECam Bulge Survey, BDBS Collaboration; DECAPS survey) and time domain surveys (e.g., Gould 2013, arXiv:1304.3455). Crowding is not expected to significantly impact the quality of data products derived from difference images (i.e., Prompt products).

The footprint in the current baseline survey strategy extends to far north along the Galactic plane, to the region that can only be observed at relatively large airmass from the LSST site at Cerro Pachón ($X > 1.4$ at $\delta = +15^\circ$). Originally, this extension was designed to extend longitudinal coverage of the Galactic plane with Galactic structure studies in mind. With the advent of other surveys (e.g., Pan-STARRS and DECAPS), the reasons for obtaining these less efficient observations (due to unavoidable high airmass) are less compelling. Unless a strong case is made in submitted white papers, the Project is likely to limit the coverage of the Galactic plane to $\delta < +2°$.

A.4 Southern Celestial pole mini survey

Due to its southern declination limit ($\delta > -62°$), the main survey misses a large fraction of both the Magellanic Clouds. To allow coverage of the Large and Small Magellanic Clouds, the baseline survey strategy uses relaxed limits on airmass and seeing for the ∼2,000 deg^2 region around the South Celestial Pole, but with fewer observations than for the main survey.

Detailed optimization of this strategy has not been done yet. Given recent informative observations obtained by the SMASH survey (Nidever et al. 2017, arXiv:1701.00502), as well as calibration and legacy aspects of this mini survey, a white paper with more detailed cadence prescriptions (e.g., is it necessary to extend the coverage all the way to the South Celestial pole?) would greatly inform further cadence optimization.

A.5 Northern Ecliptic spur mini survey

The main survey footprint provides most of LSST's power for detecting Near Earth Objects (NEO) and TransNeptunian Objects (TNOs) and naturally incorporates the southern half of the Ecliptic within its 18,000 deg^2 sky area. The additional coverage of a crescent reaching to $+10$ degrees of the Northern Ecliptic plane in the North Ecliptic Spur (NES) mini survey provides observations of small bodies, particular TNOs, throughout the full range of ecliptic longitude. The baseline survey strategy covers this region using the $griz$ filters only, with about 300 visits per field and a cadence generally similar to that of the main survey (but with more relaxed limits on airmass and seeing due to the northern location of the fields). With fewer visits per field, it is not possible to maintain a complete main survey time sampling over the full ten years of the survey (previous simulations ended observations in the NES by approximately year seven; the current baseline simulation runs observations over the full ten years at the cost of a lower sampling rate). A more detailed and robust science-driven justification addressing both outer Solar System (e.g., sampling of the full longitudinal distribution of TNOs) and inner Solar System (e.g., light curve sampling for main-belt and NEO asteroids) populations is needed to maintain and optimize the observing strategy for this mini survey.

A.6 Twilight survey

LSST's short read-out time (2 sec) enables efficient taking of short-exposure images during twilight time that would otherwise go unused. Science drivers and technical details are discussed in Section 10.3 in the Observing Strategy white paper (arXiv:1708.04058); the former include a bright star survey for Galactic science, obtaining light curves for nearby supernovae, and observations of near-Earth asteroids towards so-called "sweet spots" (on the Ecliptic, at Solar elongations of $\sim 60°$). This cadence has not been simulated yet because a sufficiently detailed and accurate sky brightness model, that includes twilight effects, has become available only recently (Yoachim et al. 2016, Proc. SPIE, 9910-48, 99101A-1).

The Project plans to simulate twilight observing in late 2018. Assuming exposure times of 1 second (the stretch goal from the LSST Science Requirements Document, which is already met and corresponds to the Camera baseline requirement), the saturation limit would improve by about 3 mag relative to 15-sec exposures; in the r band from about $r = 16$ to $r = 13$, with about 1.5 mag loss of limiting depth. In morning twilight, the improvement in dynamic range of 1.5 mag would gradually diminish and eventually dynamic range would vanish as the sky brightness increases. About 20-30 minutes of additional observing time could be utilized during twilight before the dynamic brightness range becomes too small. Assuming 7-sec visits (1 sec exposure + 1 sec for shutter + 5 sec for read and slew), about 2,000 deg^2 of sky could be imaged in 25 minutes (assuming no filter changes). Alternatively, over 350 exposures (1 sec + 1 sec + 2 sec) of the same field could be obtained instead. Detailed strategies should consider limitations on the number of filter changes (see Appendix B.1). White papers addressing the science justification and strategies for using twilight time are desired.

The shortest exposure stretch goal in the Camera baseline requirements is set to 0.1 sec. Science-driven studies that would advocate pursuing this goal would be a welcome contribution to further system optimization; twilight observing could especially benefit from shorter exposures.

B Constraints on survey strategy imposed by the LSST system

B.1 Hardware constraints

Several hard constraints prevent observations in certain alt-az directions. The telescope altitude limit prevents observations at altitudes below 20°. As a consequence of the alt-az mount, there is also a zenith exclusion zone with a radius of 3.5°.

The LSST telescope mount uses direct drive motors and there should not be any mechanical limits on slewing from the mount. However, there are observing efficiency considerations: the minimum slew time (as soon as the telescope moves at all) is 3 seconds, due to readout (2s) plus settle time requirements (1s). Otherwise, the slew time depends on slew distance. Approximately[15], in the azimuth direction,

$$t^{Az}_{slew} = 0.66\,\mathrm{sec/deg} * \delta Az(\mathrm{deg}) + C^{Az} \tag{1}$$

$$t^{Az}_{slew}\mathrm{min} = 3\,\mathrm{sec} \tag{2}$$

where $C^{Az} = -2$ sec (this is negative because of dome crawl; however, the minimum slew time is still 3 seconds due to readout and telescope settle time). For slewing in altitude

$$t^{Alt}_{slew} = 0.57\,\mathrm{sec/deg} * \delta Alt(\mathrm{deg}) + C^{Alt}, \tag{3}$$

where $C^{Alt} = 3$ sec for slews below 9° and $C^{Alt} = 37$ sec for longer slews (because of the need to recompute optics corrections for slews larger than 9 degrees in altitude). The dome is assumed to crawl in the azimuth direction, but not in altitude. In the baseline simulated survey, about 2% of slews move in altitude more than 9°.

The shortest exposure time is assumed to be 1 second, with the shortest exposure stretch goal in the Camera baseline requirements set to 0.1 sec. For exposures shorter than about 10 sec, the seeing due to atmospheric turbulence may be harder to characterize (the profiles are more irregular) than for longer exposures, and moving objects may trail in long exposures (for more details see Section 5.1.4 in Jones et al. 2018; Icarus 303, 181). Short exposures will have a low observing efficiency due to the finite read-out time (2 sec).

There are important constraints on the filter exchange strategy. As the system is not yet completely built and characterized, the following represents current understanding, based on the design and on engineering judgement. As such, some of the details should be considered

[15] Precise values can be obtained using method "get_approximate_slewdelay" from ts.observatory.model

preliminary and subject to change. Expanded ranges could be possible if there are strong scientific motivations along with sufficient resources during operations.

- The filter change mechanism is designed to undergo a total of 100,000 changes over its lifetime (an average of about 17 changes per night of the survey, after accounting for necessary calibration activities).
- Each filter is designed to support up to 30,000 changes over its lifetime.
- A maintenance cycle to the filter exchange mechanism is anticipated, and this would nominally occur after 10,000 changes or one year, whichever is reached first.
- During a given observing night, the system could support as many changes involving the 5 filters loaded in the carousel as desired, without any practical limitation beyond the two-minute change interval (which consists of 90 seconds for the exchange plus up to 30 seconds to put the camera into the required orientation).
- Filter loader operations (swapping a filter in the carousel) will be done during daytime. The system is designed for 3000 loads over its lifetime.
- The currently implemented filter-swap strategy is to replace during the day one of the z or y by the u band at the start of dark time, when the lunar phase reaches 20%. The process is reversed at the end of dark time when the lunar phase is above the same threshold.

B.2 Software constraints

The LSST Science Requirements Document specifies that "As a general principle, the measurement errors for fundamental quantities, such as astrometry, photometry and image size, should not be dominated by algorithmic performance.". Data products that LSST will produce are described in LSST Data Products Definition Document (ls.st/dpdd) and more algorithmic detail is provided in LSST Data Management Science Pipelines Design document (ls.st/ldm-151).

The Project will not take formal responsibility for specialized data reduction algorithms needed to process data, including that taken in "non-standard" modes; detailed discussion is available in the Data Management and LSST Special Programs document (ls.st/dmtn-065) and should be perused when proposing non-standard observing sequences. In addition, we strongly recommend to white paper authors to consult Sections 5 and 6 in the LSST Data Products Definition Document. If a proposed dataset will require special processing, a plan to obtain necessary software and compute resources must be provided in the white paper.

There is an additional caveat regarding crowded field processing (see also Appendix A.3). A fraction of LSST imaging will cover areas of high object (mostly stellar) density, such as the Galactic plane, the Large and Small Magellanic Clouds, and a number of globular clusters (among others). LSST image processing and measurement software, although primarily designed to operate in non-crowded regions, is expected to perform well in areas of crowding. The current LSST applications development plan envisions making the deblender aware of Galactic longitude and latitude, and permitting it to use that information as a prior when deciding how to deblend objects. While not guaranteed to reach the accuracy or completeness of purpose-built crowded field photometry codes, we expect this approach will yield acceptable results even in areas of moderately high crowding.

The above discussion only pertains to processing of direct images. Crowding is not expected to significantly impact the quality of data products derived from difference images (i.e., Prompt products).

B.3 Observing efficiency constraints

The LSST Science Requirements Document "...assumes a nominal 10-year duration with about 90% of the observing time allocated for the main LSST survey.", and thus 10% of observing time is left for all other programs. However, if the system performs better than expected, or if science priorities change over time, it is conceivable that the 90% could be modified and become as low as perhaps 80%, with the observing time for other programs thus doubled. At this time, details are TBD but the Project is developing flexible scheduling procedures to enable such modifications. In the current baseline survey strategy, the main survey takes about 85% of the time.

We note that the uncertainty in our system performance estimates due to weather and solar activity is about 10%. In addition, the system has not been built yet and many hardware performance parameters are still taken at their design values.

Sustained observing, such as the main survey, with exposures much shorter than standard visits will result in diminished observing efficiency. Given total visit exposure time t_{vis} (30 sec for standard visits), with two exposures/readouts (snaps) per visit, and assuming a slew and settle time of 5 sec (also including the second readout), the observing efficiency can be computed as

$$\epsilon = \left(\frac{t_{vis}}{t_{vis} + 9\,\mathrm{sec}}\right). \tag{4}$$

To maintain efficiency losses below ~30% (i.e., at least below the limit set by the weather patterns), and to minimize the read noise impact, $t_{vis} > 20$ seconds is required for sustained observing.

Variations in exposure time for the main survey affect not only the limiting depth, but also the total number of acquired visits and revisit time because the total observing time is finite. For more detailed discussion of these tradeoffs, please peruse Section 2.2.2 in the Overview paper.

The number of filter changes (2 minutes per change) and size of slews also affects efficiency.

B.4 Limiting depth and uncertainty estimates

Methods for estimating individual image depth (5σ point source magnitude limits) for a given exposure time and other observing parameters are discussed in detail in Section 3.2 in the LSST Overview paper (see C.1). Tradeoffs between exposure time per visit, single-visit depth, the mean revisit time, and the total number of visits, as well as justification for the adopted standard exposure time of 30 sec, are discussed in Section 2.2 of the same paper. The improvement in measurement uncertainties as the survey progresses, as a function of time t, can be approximately summarized as follows.

The co-added depth (the 5σ depth for point sources), $m_5^{\mathrm{co-add}}$, scales with time as (see eq. 6 in the overview paper)

$$m_5^{\mathrm{co-add}} = m_5^{\mathrm{co-add,Final}} + 1.25\,\log_{10}\left(\frac{t}{10\,\mathrm{yrs}}\right) \tag{5}$$

where $m_5^{\mathrm{co-add,Final}}$ is the target depth achieved with the 10-year survey. With airmass and other losses taken into account, $m_5^{\mathrm{co-add,Final}} = 27.2$ for the r band in the baseline simulated survey.

The photometric errors (inverse signal-to-noise ratio) at the faint limit of the so-called "gold" galaxy sample (4 billion galaxies with $i < 25.3$ which will be used for cosmological programs, see Section 3.7.2 in the LSST Science Book), is computed from (see eq. 5 and Table 1 in the overview paper):

$$\sigma_{i=25} = 0.04 \left(\frac{t}{10\,\mathrm{yrs}}\right)^{-1/2} \mathrm{mag.} \tag{6}$$

The volume of the 5-dimensional color error space per source with $i = 25$, which controls the ability to classify sources using colors (including photometric redshift estimates for galaxies and star/quasar separation, for example) is computed assuming uncorrelated color errors, as proportional to $\sigma^5_{i=25}$, and normalized by the value corresponding to the 10-year survey.

The trigonometric parallax accuracy for a point source with r=24 (see section 3.3.3 in the overview paper) scales with time as

$$\sigma_{\pi} = 3.0 \left(\frac{t}{10\,\mathrm{yrs}}\right)^{-1/2} \mathrm{mas.} \tag{7}$$

The proper motion accuracy for a point source with r=24 (see section 3.2.3 in the overview paper) scales with time as

$$\sigma_{\mu} = 1.0 \left(\frac{t}{10\,\mathrm{yrs}}\right)^{-3/2} \mathrm{mas/yr.} \tag{8}$$

Note the very strong dependence of σ_μ on time ($t^{-1/2}$ comes from the increase in the square root of the number of visits, analogously to σ_π, and an additional t^{-1} from the linear increase in temporal baseline). In both expressions, the number of visits is assumed proportional to time, with a value of 825 corresponding to the main wide-fast-deep 10-year survey.

The behavior of these quantities as a function of time is summarized in Table 1. While the co-added depth and σ(i=25) rapidly improve during the first few years, several important quantities continue to show marked improvement between survey years 8 and 10: most notably, the color error volume per source for faint sources ($i = 25$) shrinks by a factor of 1.7. Substantial improvement is also seen for proper motions, with errors larger by 40%, after 8 years than at the end of the 10-year survey.

TABLE 1: Various science metrics as functions of survey duration.

Quantity	Year 1	Y3	Y5	Y8	Year 10
r_5 coadd[a]	26.0	26.5	26.8	27.1	27.2
$\sigma(i$=25)[b]	0.12	0.07	0.06	0.05	0.04
color vol.[c]	316	20	6	1.7	1
# of visits[d]	83	248	412	660	825
σ_π (r=24)[e]	9.5	5.5	4.2	3.3	3.0
σ_μ (r=24)[f]	32	6.1	2.8	1.4	1.0

[a] The co-added depth in the r band (AB, 5σ; point sources).
[b] The photometric error for a point source with $i = 25$.
[c] The volume of the 5-dimensional color error space, normalized by the final value.
[d] The number of visits per sky position (summed over all bands).
[e] The trigonometric parallax accuracy for a point source with r=24 (milliarcsec).
[f] The proper motion accuracy for a point source with r=24 (milliarcsec/yr).

C Supplementary materials

C.1 Useful publications and websites

Note that various websites and documents references here are still in development (if not an official LSST change control document).

The LSST Overview paper provides a short summary of the four primary science drivers, as well as the expected performance of LSST in terms of throughputs, and calibration. It also discusses high-level survey constraints and tradeoffs. Available as `http://ls.st/pif`

The the Community Observing Strategy Evaluation Paper is a community-driven paper describing a wide variety of science cases and their implications for survey strategy. This paper is primarily aimed at helping define the main (90%) wide-fast-deep survey. Available as `http://ls.st/3y1`

The LSST Science Requirements Document (SRD) describes the official requirements for LSST science deliverables. Section 3.4 is the most relevant for survey strategy, although other sections are relevant for telescope and camera performance such as throughputs and readout time. Available as `http://ls.st/srd`

The LSST Data Products Definition Document (DPDD) describes the data products that LSST will provide, with some high-level background on how they will be produced. If you want to know what will be contained in various catalogs, this is a good place to look. Available as `http://ls.st/dpdd`

The LSST Data Management Science Pipelines Design (LDM-151) document describes the LSST data management processing pipelines. This provides details of how and when images will be processed and catalogs will be generated, including information on the algorithms used in each processing stage. If you want to know more about the details of a value in an output catalog and how it will be calculated, this is the place to look. Available as `http://ls.st/ldm-151`

Documentation about OpSim (Operations Simulator, which consists of the Simulated Observatory Control System and Scheduler), including a high-level overview and description of scheduling options, is available at `http://sims-opsim.lsst.io`.

Documentation about MAF, including a high-level overview and descriptions of current standard metric analyses, is available at `http://sims-maf.lsst.io`.

The baseline simulated survey document describes the new features enabled in Opsim v4, as well as characteristics of the updated baseline simulated survey.

The outputs of MAF analyses for the new baseline survey, as well as runs demonstrating potential options for mini surveys and Deep Drilling fields (a subset of the runs described in Chapter 2 of the OSWP) are available online at `http://astro-lsst-01.astro.washington.edu:8080`.

A short description of the current Deep Drilling fields and links to further materials (including white papers submitted in response to the 2011 call for input on the DD strategy) are available on the LSST website at http://ls.st/57q. Additional posts on LSST Community can be found by searching for 'deep drilling'.

Additional information is available in the following presentations:

- "Overview of the LSST Observing Strategy" (Nov 16, 2015): `http://ls.st/4yh`
- "The LSST Deep-Drilling Fields: White Papers and Science Council Selected Fields" (Aug

15, 2016): `http://ls.st/wzy`

- "Observing Strategy White Paper Status Report" (Mar 5, 2017): `http://ls.st/zj2`
- "LSST Plans for Cadence Optimization" (May 30, 2017): `http://ls.st/ot2`
- "Special Programs" (Aug 15, 2017): `http://ls.st/10o`

C.2 Communication about the LSST survey strategy

The Project Scientist (Željko Ivezić, e-mail: ivezic at astro.washington.edu) is formally responsible for survey strategy optimization efforts and is the formal liaison between the community and the LSST Scheduler and Operations Simulation teams.

The LSST Science Advisory Committee (SAC) is charged with collecting and delivering various community input to the Project. Strategic and political issues about the LSST survey strategy should be communicated via the SAC (chair: Michael Strauss, strauss at astro.princeton.edu).

In addition to this call for white papers, the Community Observing Strategy Evaluation Paper[16] provides a coordinated mechanism for providing scientific input about survey strategy. LSST science collaborations are also official channels for communication with the LSST project — a Data Management liaisonFor the list, please see http://ls.st/uj6 is assigned to each Science Collaboration to answer specific questions about data products generated by the project.

An open, searchable resource for asking questions not addressed in this document is available on LSST Community, in the Science category, SurveyStrategy subcategory. Team members will monitor and respond in a timely manner to questions posted there. Please go to `http://community.lsst.org`

There is a mailing list available (email: lsst-survey-strategy at lsstcorp.org) to contact the survey strategy team in case of specific questions and/or concerns. Messages posted to the mailing list are broadcasted to the survey strategy team and archived.

Throughout the survey strategy design process there will be open community meetings. The first of these will be at the LSST All Hands Meeting 2018 in Tucson, AZ (August 13-17, 2018).

[16] A living document available at https://github.com/LSSTScienceCollaborations/ObservingStrategy

Note that our teams cannot support individuals or groups wishing to run the Operations Simulator themselves. It is not required that authors of white papers run the proposed simulations themselves. We will provide documentation on running OpSim, and docker images (as well as the source code) will be made available; however, the Project does not have resources to provide help desk facilities on this topic.

C.3 Additional Simulated Survey Strategies

By the time this call for white papers is officially released, we anticipate that we will provide a set of simulated surveys for the community to use as test cases. These simulated survey strategies will include (approximately):

- The baseline survey strategy, with the main survey having a 18,000 deg^2 footprint, the North Ecliptic Spur, South Celestial Pole, Galactic Plane and Deep Drilling minisurveys operating in the current example baseline survey strategy manner.
- A survey with a much larger main survey footprint (27,000 deg^2), defined by airmass limit $X < 1.5$ and declination limits $-78° < \delta < +18°$, and including only the Deep Drilling mini survey (and no other mini surveys).
- A survey strategy with "more visits": each visit being 20 sec long with a single exposure per visit, and 40 sec visits in the u band (and probably another similar survey with exposures of 40 sec and 60 sec, respectively).
- A survey similar to the current baseline, with the Galactic Plane at the main survey cadence (and the northern tip of the Galactic plane mini survey removed).
- A survey similar to the current baseline, but with additional Deep Drilling fields.
- A survey similar to the current baseline, but with a modified cadence for Deep Drilling fields (ideally: observe in only 3 filters per night, but with a shorter gap between nights; rotating among the 3 filters used in each night).
- "Rolling cadence" simulations of the main survey – concentrating observations in bands of declination in some simulations, and in bands of right ascension in other simulations.
- A survey similar to the current baseline, but obtaining pairs of visits in different filters (vs. the same filter).

- A survey similar to the current baseline, but only observing with single visits per night.
- A survey similar to the current baseline, but adding random target-of-opportunity trigger events.