Large Synoptic Survey Telescope

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Evaluating LSST Schedule Realizations

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How would one quantify and graphically represent the scientific performance of various scientific goals of a survey strategy? A simulated 10-year LSST observing schedule will produce 2.5x10^6 visits and in order to evaluate a simulated schedule, the project, collaborating scientists and team have defined tools called Merit Functions. Each Merit Function evaluates the success of a simulation in acquiring images with properties which characterize a specific parameter. Each Merit Function can be applied to a set of simulations, providing a single numerical value (a Metric) representative of the function and the simulation. The complete set of metric values can be used to quantitatively compare the performance of multiple simulated schedules. At present we are working with 6 groups of Merit Functions: Airmass, Astrometry, Early Good Images, Randomization, Solar System, Variables & Transients and Uniformity. The Metrics derived from the Merit Functions offer the possibility of comparing simulations quantitatively, within the context of defined functions. However, with dozens of metrics, it is still a challenge to present the results in a format that is both informative and objective. In this poster we show an early attempt to summarize the comparison of metric sets graphically.

How to Evaluate the Performance of a Large Time-domain Survey

A general purpose study of time-variability requires a complex tradeoff of performance in frequency, sampling pattern, sky coverage, filters, and other factors, and is subject to foreseeable but unpredictable weather, image quality and other constraints. The LSST Operations Simulator team has developed an effective and adaptable approach to schedule simulation, built on actual engineering design and measured site conditions.

For additional details on the Simulator functionality, please see the poster by C. Petry et al. in this session.

Merit Functions and Metrics

Each Merit Function evaluates the success of a simulation in acquiring images with properties which characterize a specific parameter (e.g. effective parallax baseline) relevant to one or more science/technical objectives (e.g. parallax precision). Merit Functions are not intended to give a direct measure of science value or productivity, but to be simply and intimately related to science requirements. Each Merit Function can be applied to a set of simulations, providing a single numerical value (a Metric) representative of the function and the simulation. The complete set of Metric values can be used to quantitatively compare the performance of one simulation with another.

Illustrations of Merit Functions, Metrics and comparison of simulations follow below, drawn from opsim3.61, the current reference survey simulated with the LSST Operations Simulator.

Astrometry

Two merit functions evaluate the distribution of visits for proper motion and parallax, and a third measures the correlation of parallax factor (project earth-sun distance) with hour angle, which can be problematic for parallax determination. The figure shows for each field the median parallax factor "differences" – i.e. the median difference in parallax factors for visits optimally paired. The associated metric is the mean value, or 0.92 AU, which may be compared to a nominal potential maximum of ~2 AU.

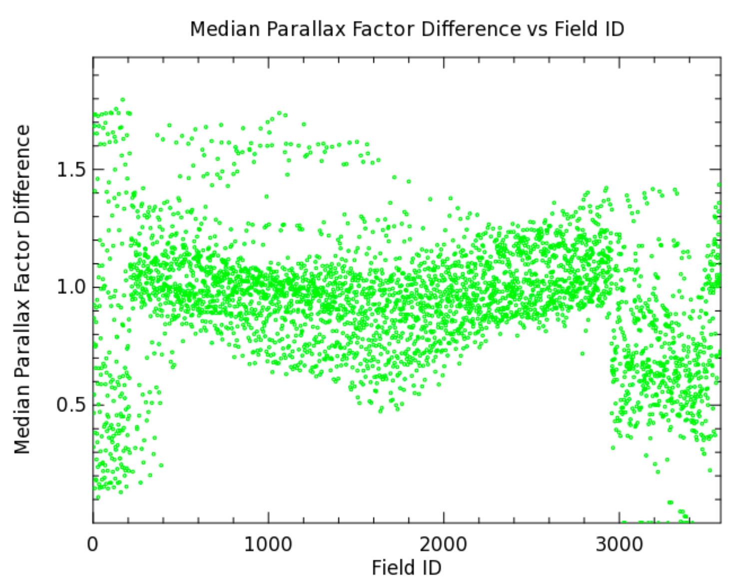
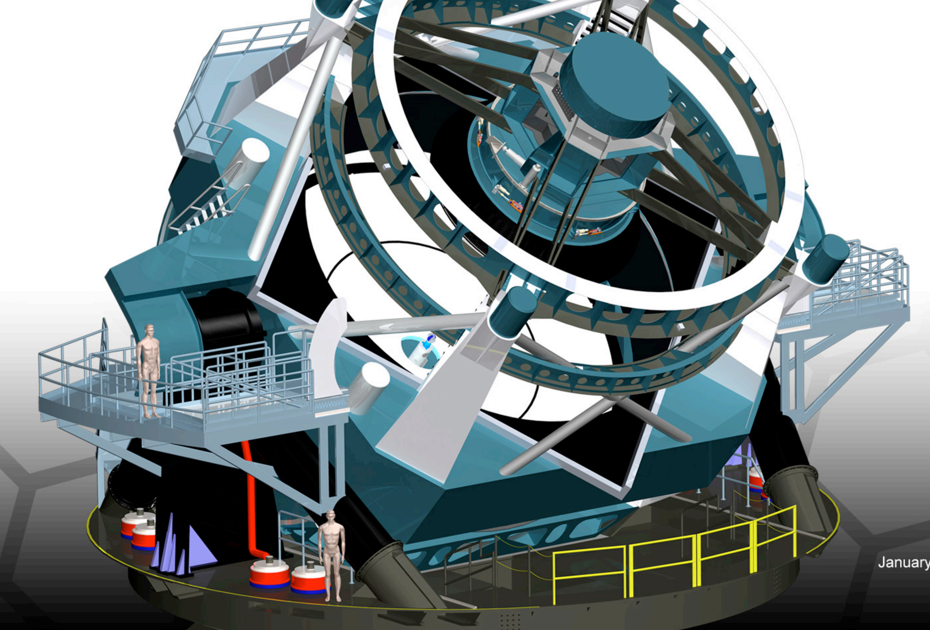


Figure 1: Mean parallax factor difference for each field. Note that low and high field numbers correspond to special programs in the South Polar Cap and the northern ecliptic, and do not share the cadence of the main Wide-Fast-Deep survey. This is also true for fields in the high density regions of the galactic plane, which have scattered mid-range field numbers.



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Solar System

Merit functions have been created to count groups of visits suitable for detection of moving objects and association of nightly tracklets for orbit determination. For this purpose, at least three appropriately spaced nights are required with appropriately spaced visit pairs on each night. The figure shows for each field the number of such groups based on 'griz' filters. The associated metric is the number of groups obtained for 50% of the fields, which is 97 groups.

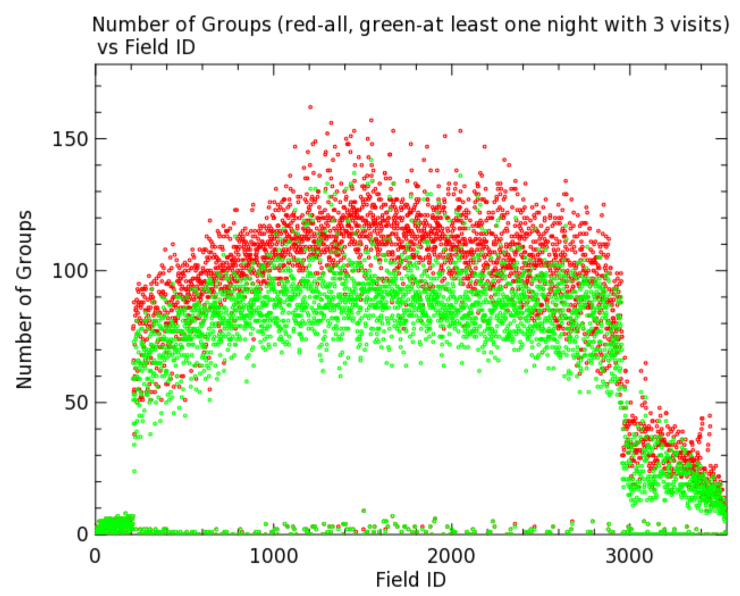

Figure 2: For each field, the figure shows the number of qualifying Groups obtained (red) and also the number with at least one night having 3 visits (green).

Airmass

The airmass of a visit is driven to transit values for optimum seeing and to larger values for some astrometric and field randomization goals. For convenience of comparison, we define "normalized airmass" as the airmass of a visit divided by the airmass of the field at transit. The figure shows the normalized airmass. The associated metric is the mean normalized airmass, in this case 1.15.

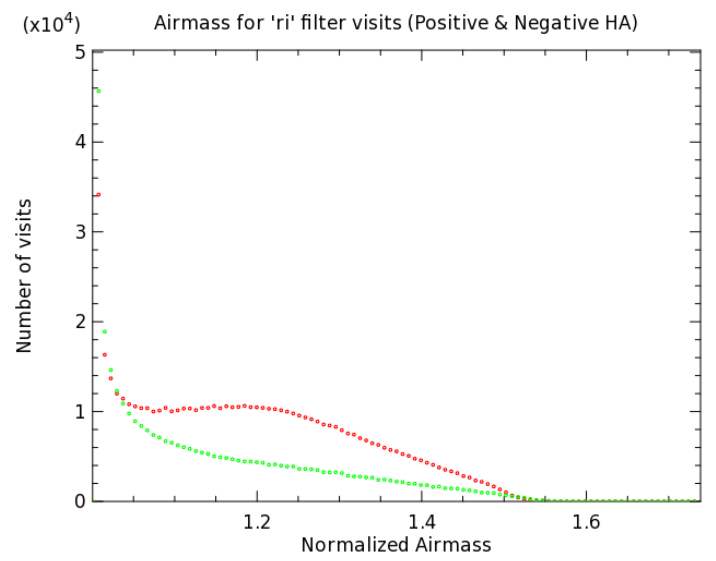

Figure 3: Normalized Airmass for all visits in all filters to the main survey fields. Note peaks near 1.0. Red curves correspond to visits west of meridian, indicating a tendency of the current simulation to chase fields into the west.

Early Good Seeing

Some science and technical goals will be best supported with early acquisition of good seeing images for all fields (e.g. photometric calibration closure, dense field deconvolution, detection of transients). The figure describes the best image quality obtained in survey fields. The associated metric is the median best delivered image quality. In this example, it is 0.52 arcsec after 1 year (vs. 0.48 after 3 years and 0.45 after 10 years).

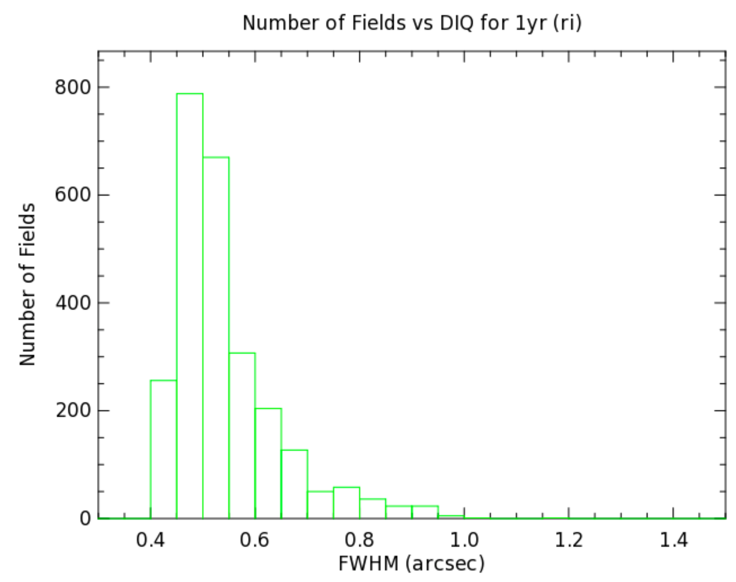

Figure. 4: The number of fields for which the best single image obtained in r or i filters is in the range of the histogram bins, after 1 year.

Variables and Transients

Five merit functions characterize the sampling of sources with a short revisit time, rapid acquisition of color information, the acquisition of well-sampled sequences, long sequences with minimal gaps, sequences well suited for supernova study, and proper sampling of periodic variables. The supernova case is shown here for illustration. Identification of supernovae are possible from a pair of visits, but scientific characterization will require a series of visits with appropriate timing. A field-night is a visit to a field which is in a suitable sequence of visits such that if there is a SN at t=0 that night, there will be a sequence of observations satisfying a specific set of requirements.

The figure shows (in red) the number of nights for which each field would have a suitable visit sequence, according to the following requirement: At least 7 visits in the range -20 < T < 60, one visit T<-5, one visit T > 30 (where T is the time relative to the SN time of peak brightness), no gap >15 days, and 4 or more filters. Successively more stringent requirements (14, 21 and 28 visits) are shown in the green, blue and pink histograms. An example Metric is the sum total of field-nights for 4 or more filters and 14 or more visits, in this case 157,092.

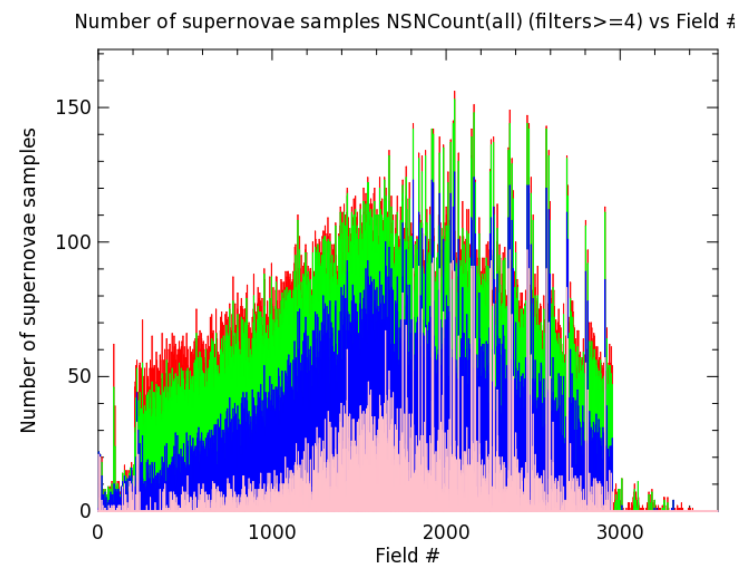

Figure 5: The number of days for each field for which supernovae at max would have good sampling, as described in the text. The peaks on the right are clumps associated with the deep drilling fields.

Uniformity

A number of Merit Functions evaluate the distribution of visits over the full length of the planned 10-year survey. For some purposes visit pairs are required; for other purposes it is important to minimize the length of temporal gaps. As an example, in order to properly close the photometric calibration grid it is useful to obtain multiple satisfactory data sets for all fields early in the survey with minimal spatial gaps.

The figure shows the number of visits obtained in the g filter for each field in the survey during the first year of operation. Specific quality criteria may be imposed – in this case visits with seeing poorer than 1.5 arcsec are not counted. A minimum of 3 visits in each filter is considered necessary for initial global closure of the calibration. There is a grid of associated Metrics for the 6 filters and various time intervals (e.g. first 1, 2 and 3 years).

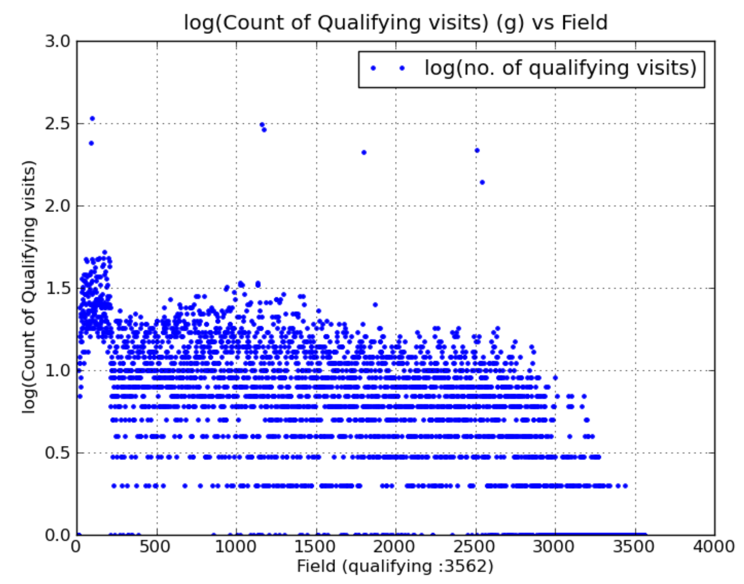

Figure 6: The number of qualifying visits in the g filter to each field during the first year of the simulated survey opsim3.61.

Randomization

To suppress image shape biases due to instrument or other systematic effects, it is desired to randomize a number of observing parameters. For example, the instrument parameter RotTelPos describes the angle between the telescope and the camera rotator. The peak at 180 deg occurs because the rotator is reset to that value at every filter change, but is otherwise allowed to wander quasi-randomly. The metric is the mean RMS distance from 180. In this case it is 51 deg, which may be compared to a value of 57.3 deg for a fully random distribution

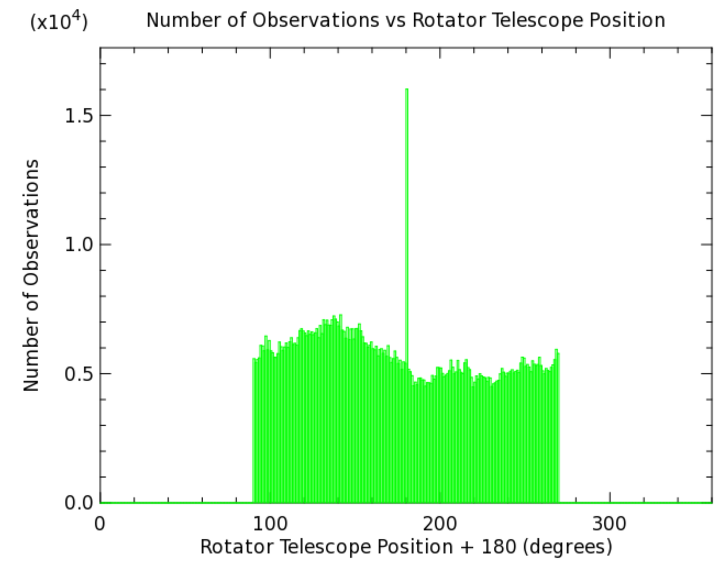

Figure 7: The value of the rotator angle (RotTelPos + 180) for all r and i visits to fields in the main survey, evaluated per visit to each field, and represented in a histogram by bins in angle.

How to Compare Schedule Realizations

The time-order sequencing of visits lends extreme complexity to schedule simulations, and makes comparison of two such realizations a challenge. The most satisfactory science solution, carrying out full analysis of simulated data, would be appropriate for a focused survey but is not realistic with a broadly purposed survey. The LSST Science Book alone lists hundreds of science goals.

The Merit Functions alone do not support comparison as each is a graphical representation of millions of data points. The Metrics derived from the Merit Functions offer the possibility of comparing simulations quantitatively, within the context of the defined functions. However, with dozens of metrics, it is still a challenge to present the results in a format that is both informative and objective.

In the figure below we show an early attempt to summarize the comparison of two metric sets graphically. Here the Metrics derived from simulation opsim2.5, designed to emphasize certain visit-pairs valuable for detecting near earth objects, is compared with the current reference simulation opsim3.61. Each of the opsim2.5 Metrics is normalized by the corresponding opsim3.61 Metric. The success in adding visit-pairs is obvious, as is a general reduction in other Metrics. Of course it is easy to improve a single Metric at the expense of others. A Simulator objective is to improve one or many without compromising performance elsewhere. A challenge is to interpret and weight the Metrics appropriately.

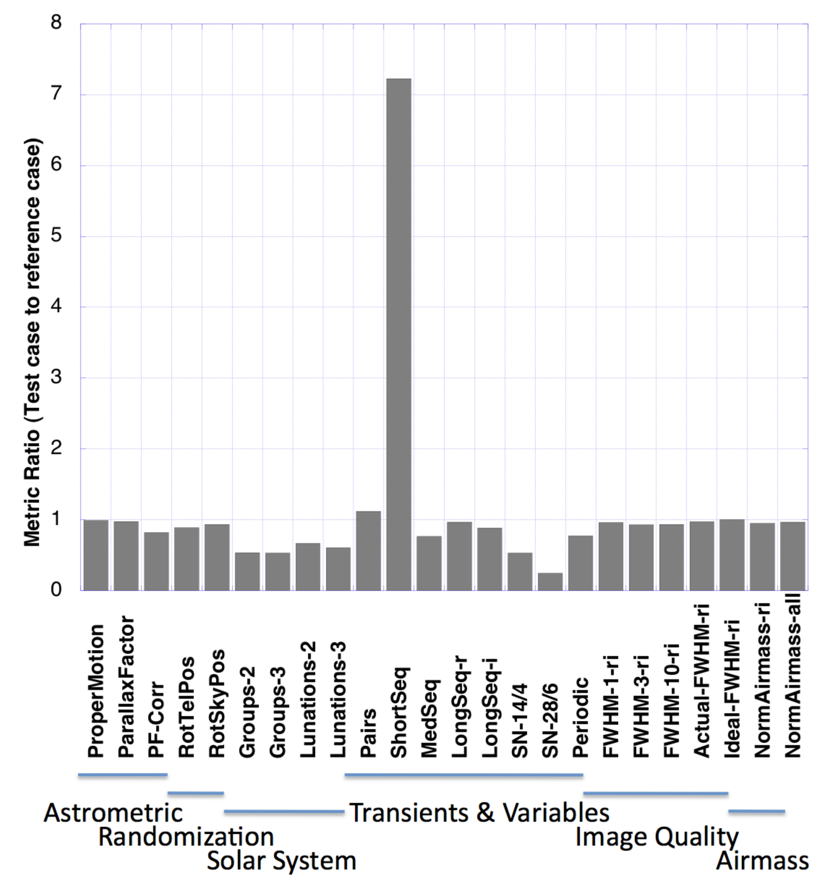

Figure 8: An example comparison of different simulations for each metric normalized by the current reference simulation (opsim3.61).

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