The objective of the Operations simulator (Opsim) is to provide a tested and validated scheduler for the LSST that will be delivered prior to the start of commissioning in 2019. To accomplish this, Opsim is required to be able to test and evaluate scheduling strategies that prioritize which fields the LSST should observe on time scales of a night and over the duration of the survey. This prioritization must account for prior observations, weather (current and predicted), visibility of the fields, overhead in reaching a field (e.g. slew time, and filter exchange time), observing overrides for targets of opportunity, scheduled and unscheduled down time, and the optimization of a broad range of science merit functions. The cadence generated by these scheduler algorithms must also meet the requirements laid out for the survey in the Science Requirements Document (SRD) and associated flow down documents.

To accomplish this objective Opsim is being designed as a framework; one that can simulated the LSST observatory environment and telemetry, and into which scheduling algorithms, that will subsequently be used by the Observatory Control System (OCS), can be integrated. The current requirements on Opsim are that it,

- provide a parameterized model for the observatory that describes the LSST opto-mechanical performance
- simulate the OCS telemetry streams that describe the state of the LSST system, the current and predicted weather, the astronomical sky conditions, prior observation history, and any override requests
- implement an API and communication model that is consistent with that used by the scheduler in the OCS.
- be capable of expressing and optimizing a broad range of technical and science metrics that have been provided by and/or vetted by the science community
- provide a framework for testing, validating and optimizing the scheduler module, and that can be installed and run by the science community

1 The development timeline for Opsim

Opsim development is phased to meet the needs of the project for the delivery of a tested and validated algorithm for scheduling the LSST prior to the start of commissioning. This includes the creation of the metrics and associated tools to evaluate the performance of the scheduler, a framework that generates the appropriate telemetry for the telescope, a pluggable scheduler that can be integrated with the OCS, the capability to generate sequences of simulated observations with different scheduling algorithms and configurations, and the ability for external users to be able to install and run Opsim and analyse its outputs.

1.1 FY2014 development

The FY2014 development focused on the first of these objectives; the ability to characterize and visualize the performance of a scheduler through the definition of a suite of science metrics. The prioritization of this component was driven by prior experience in scheduler development that stressed the need to be able to quantify how well an algorithm is performing through a set of cost functions or metrics, and for these metrics to be science-based, and developed and vetted either by the scientific community or in collaboration with the science community.

To accomplish this the Metric Analysis Framework (MAF) was created. MAF is an open-source python framework designed to provide a user-friendly, customizable, and easily-extensible set of tools for analyzing data sets from Opsim. The primary components of MAF are "metrics" (algorithms to analyze a given quantity of data), "slicers" (methods to subdivide lists of observations into smaller subsets that are appropriate for each metric), and database classes that can access and manipulate the outputs of Opsim runs. MAF was released to the LSST community in July 2014 and a tutorial session on the use of MAF was held during the 2014 cadence workshop.

1.2 FY2015 development

The current year of development (leading up to the 2015 cadence workshop) is focused on four areas: the refactoring of Opsim to provide a pluggable architecture that enables the Opsim scheduling code to be run by the OCS, the continued support of MAF and the enhancement of its capabilities for use by the science collaborations, the release of a new set of simulated cadence runs that can be analyzed with the MAF, and the delivery of Opsim to the LSST science community as a tool that they can install, configure, and run.

1.2.1 The refactoring of Opsim

The primary objective for 2015 is the redesigned of Opsim to change it from a monolithic simulation program into a modular simulator of the LSST environment and data streams together with an associated scheduler. Opsim will replicate the API's and communication layers expected for the OCS scheduler. Communication will be based on the DDS (Data Distribution Service) protocol used by the OCS. Modules within Opsim will simulate the telemetry for current weather and forecasts, previous observations, and observatory status and provide a dynamical model of the LSST. The design of Opsim will be such that the code developed for the scheduler module will be capable of being plugged directly into the OCS. Delivery of an initial implementation of the refactored simulator with a reduced set of telemetry streams is expected in July 2014.

1.2.2 Improvements in the scheduling algorithms

Concurrent with the redesign of Opsim will be the expansion of the available scheduler algorithms and cadences deployed by Opsim. The current assumption for the LSST has been a universal cadence in which all parts of the sky (defined to be the wide-fast-deep region) are observed with a similar cadence and pattern. A natural extension to this universal pattern is the "rolling cadence" where the region surveyed shifts as a function of time. This provides a denser time sampling for the survey at the cost of a shorter baseline in the temporal sampling. Opsim will be enhanced to support a rolling cadence (defined by regions on the sky or particular LSST pointings) with an expected delivery of March 2015

Extending beyond rolling cadence the current greedy algorithm deployed in Opsim will be enhanced with "look ahead". This enables the scheduler to determine whether a proposed sequence of visits to a field can be completed within the time available (e.g. a revisit is required in 45 minutes but astronomical twilight ends before the revisit can be completed). It is expected that look ahead should improve the efficiency of the scheduler (especially for observation later in the survey). Delivery of look ahead is scheduled for the summer 2015.

1.2.3 Optimization of "Auxliary" Proposals

Opsim currently uses one main proposal covering 18,000 square degrees where it attempts to deliver the SRD requested number of visits. Opsim can achieve the requested number of visits over the 18,000 square degrees in about 8 years, which leaves 20% of the survey time available for other survey strategies. Opsim currently implements non-Wide Fast Deep (WFD) science strategies with a variety of "auxiliary" proposals. One proposal covers the ecliptic north of the equator (NES) to better catalog NEOs and PHOs. One proposal, covers the celestial south pole (SCP) region to sample the Magellanic Clouds and various south pole cosmology survey regions. Another proposal covers the Galactic plane (GP) with many fewer visits than the WFD because of the confusion limit in these dense stellar regions. Finally, there are a number of different Deep Drilling proposals which request large numbers of visits to a few fields in a short amount of time to sample the time domain and sample very faint variability (high-z supernovae). A significant effort in 2015, will be to optimize the use of the 20% of time available for auxiliary proposals. The current Deep Drilling proposals are based on the efforts of the Deep Drilling Working Group, but more interaction should lead to evolution of these cadences. Efforts to optimize the science from the NES, SCP and GP areas will be made with input from the community, and an overall optimization of the time allocation between the various auxiliary proposals will be sought. It should be noted that continuing optimization of various rolling cadences may address many of the science issues addressed by the auxiliary proposals.

1.2.4 Support of the MAF and Opsim communities

Development and support of MAF for the project and science community will continue. This includes the creation of a repository for storing and accessing metrics designed by the science collaborations (see `https://github.com/LSST-nonproject/sims_maf_contrib`) and a mechanism by which user defined metrics will be incorporated automatically within the analysis of subsequent Opsim runs. The core metrics for the project will be extended to include SRD metrics that will capture the science and cadence requirements as defined within the SRD.

In February 2015 a new set of opsim runs will be released to the science collaborations using the latest version of Opsim (v3.2). These runs, collectively known as "Tier 1" are listed at `https://confluence.lsstcorp.org/display/SIM/Cadence+Workshop+Simulated+`

`Surveys`. They provide a set of runs of Opsim using the existing v3.2.1 scheduling algorithm where the parameterization of survey (e.g. integration time, airmass limits, number of pairs of visits etc) are modified. The outputs from the MAF will be released with the Tier 1 runs.

In July 2015 a further sequence of runs will be released using the "rolling cadence" scheduling algorithms. These, "Tier 2" runs will be used to evaluate how the size of the rolling cadence patches and their sampling as a function of region on the sky and time interval effect the baseline metrics. As part of the delivery of the Tier 2 cadence runs Opsim will be released to the community with instructions for how it can be installed, configured, and run.

1.2.5 Support of the cadence 2015 workshop

The simulation team will continue to support MAF and Opsim and its use by the science collaborations leading up to and through the 2015 cadence workshop.

1.3 Post-FY2015 development

Figure 1 provides a high level timeline for the development of Opsim and the scheduler through to early commissioning with ComCam. The development of the scheduler and Opsim is divided into three phases: refactoring to create an initial pluggable scheduler, development of the scheduler algorithms, optimization of the cadence for the LSST project. The expected deliverables from the project, and community are aligned with this schedule. Throughout this development yearly cadence workshops will be held where the current baseline cadences, status of the scheduler algorithms, and an evaluation of their properties will be presented to enable the community to evaluate the impact of the scheduler and cadences on specific science cases. These workshops would lead up to the publication of the proposed project cadence in mid-2018. At this point the project would establish a cadence committee who would evaluate this proposed cadence and its impact on LSST science. In Jan 2019 this cadence would be publish together with the report from the cadence evaluation committee for review by the broader science community.

Date	Opsim/Scheduler deliverables	Project Deliverables	Community deliverables	Opsim/ Scheduler work
Jan – Jul 2015	Start Opsim refactoring	Prototype baseline cadence	Deliver initial metrics	Opsim/Scheduler Refactoring
Aug – Dec 2015	Deliver ability to run Opsim	2015 Cadence workshop Evaluating rolling cadence and survey geometry	Baseline cadence modification proposals	
Jan – June 2016	End Opsim Initial Refactoring			
July – Dec 2016	First report on initial metrics performance and proposed baseline cadences	2016 Cadence workshop Evaluation of initial baseline cadence		
Jan – June 2107			Cadence proposals in new scheduler environment	Scheduler Development
July – Dec 2017	Second report on initial metrics performance and proposed baseline cadences	2017 Cadence workshop Delivery of iterated baseline cadence		
Jan – June 2018				
July – Dec 2018	Delivery of baseline cadence proposal	Setup cadence committee	Committee Evaluation	
Jan – June 2019		Publish baseline cadence	Community evaluation	Scheduler Optimization
July – Dec 2019				
Jan 2020		Observing		

Figure 1: Timeline for the development of Opsim and the scheduler including expected deliverables.