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# Large Synoptic Survey Telescope (LSST)

Scheduler Requirements

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# Scheduler Requirements

# Summary and Scope

A broad, general, fundamental and formal requirement for LSST is to execute an efficient and effective survey. This imposes functional requirements on the Scheduler algorithms and on the Observatory Control System which utilizes them. The system must execute “a universal cadence that would result in a common database of observations to be used by all science programs”. In this document, the Scheduler requirements are founded on the basis of Scheduler objectives, developed to respond to a discrete set of use cases.

The survey must be “optimized against local environmental conditions”, and must “adapt … according to the external environmental conditions”. These requirements implicitly assume timely availability of environmental and related information to the Scheduler, and these impose derivative requirements on the Scheduler. The Scheduler requirements are obtained from the OCS Scheduler Requirements, the Observatory System Specifications, part of the OCS Requirements document, and inferred from the Science Requirements Document.

Most of the Scheduler requirements are also represented in the Operations Simulator Requirements document, but formulated to utilize archival data, models, or other substitutes for real-time telemetry and status.

# Definitions of Terms

**Delivered Image Quality (DIQ) –** a measure of the image profile as recorded in the FOV, incorporating all atmospheric, telescope, and detection effects – the full width at half maximum (FWHM) in arc-seconds, or other measure TBD

**Field** – for simulation purposes, and in discussion here, the available LSST sky is described by a list of fields, each similar in size to the LSST FOV – in survey scheduling, the LSST pointings may be dithered about these positions, or otherwise differ from the field description

**Input latency –** as used here, input latency refers to the elapsed time between a change in a physical quantity, control information or datum, and the time when the data stream carrying that change is available to the Scheduler

**OCS –** Observatory Control System, which, among other tasks, accepts visit sequence requests from the Scheduler

**Operations Simulator –** A tool which simulates the software environment of the OCS, in order to test and develop the Scheduler; inputs available to the OCS as telemetry must be simulated in the operations simulator

**Proposal** – a parameter set describing a spatial region and an observing requirement, passed to the Scheduler for automatic scheduling

**Scheduler –** The collection of code which selects the pointing sequence for the survey; this code unit is employed in the operations simulator and also in the OCS

**Scheduling queue –** the Scheduler will enter fields into a queue, with a lead time of 1—2 visits, to enable the OCS to optimally set dome motions – it is assumed here that this queue can be interrupted by the Scheduler if necessary

**Scheduling latency** – as used here, scheduling latency refers to the elapsed time between a change in the input data available to the Scheduler, and when a visit is initiated commanded by a (possibly revised) schedule based on that data

**Telescope/Survey operator** – the responsible person or persons monitoring facility and survey performance in real-time, whether on-site or remotely

**Visit** – A schedule consists of a sequence of pointings, also called visits; a “Standard Visit” consists of two back-to-back 15-second exposures separated by the 2-second readout of the first image and having the last readout in parallel with the re-pointing to the next visit. In some circumstances, the next visit may be to the same field. The exposure time and readout time are current nominal and subject to modification

# Reference Documents

“LSST Observatory System Specifications” (LSE-30)

“LSST Observatory Control System Requirements” (LSE-62)

”LSST Operations Concepts” (TBD?)

“LSST System Requirements” (LSE-29)

“LSST Operations Simulator Requirements” (Doc-15320)

LSST Science book, http://www.lsst.org/files/docs/sciencebook/SB\_Whole.pdf

LSST: From Science Drivers to Reference Design and Anticipated Data Products, Ivezić et al., 2008, arXiv0805.2366I, http://lsst.org/files/docs/overviewV2.0.pdf

Inputs to OCS Required to Execute LSST Scheduling (Document-16283)

The LSST System Science Requirements Document (LPM-17), <http://www.lsst.org/files/docs/SRD.pdf>}

# Scheduler Requirements

# Introduction

## Introduction

This document collects the requirements placed on the Schedulerby the Science Requirements Document. Many of these requirements are flowed down through the Observatory Control System and the Observatory System requirements. Others are derived from science-based observing requirements traceable directly to the Science Requirements Document. This document collects Scheduler Objectives, Scheduler Use Cases, and Scheduler Requirements.

This document has been constructed by merger of requirement sets, and there is some redundancy in the following requirements. In the event of apparent inconsistency in requirements herein, the more stringent will be held valid.

This document is expected to be under version control.

## Purpose

The Scheduler objectives have been previously compiled in the proposed Observatory Control System requirements (LSE-62).. These objectives cover the functional aspects of LSST observation operations, requiring that observations be scheduled in the most efficient manner, modulo the scientific priorities of the survey. The following subset of proposed OCS requirements documents the flow of Scheduler objectives from the Science Requirements Document.

The functional Scheduler requirements above leave open the question of exactly how to maximize the scientific impact, and what adjustables are needed to conduct the LSST observing campaign that delivers the “best” science.

Owing to the breadth of the requirements for efficiency and optimization of the LSST science performance, other works have informed this document. An ad hoc working group of scientists and engineers explored the science-based requirements for LSST scheduling. This study took into account the participants’ extensive experience in real-world imaging surveys from ground-based telescopes, including how the facility/instrument performance and the evolving environmental conditions trade against survey objectives and survey optimization. Their report, “Science Requirements for LSST Scheduling” (Document-16199) is referenced here as a source of additional motivation for and discussion of some of the topics treated below.

Much of the progress of OpSim has been (and continues to be) research in how to maximize the scientific margin. Version-3 steers the OpSim architecture to address also the Scheduler Requirements, so that OpSim is configured, from here on forward, as the prototype for the Scheduler. The Operations Simulator Requirements document is included here by reference as a source of additional explanation for the following topics.

The foregoing sources have been utilized to generate the collected Scheduler science requirements. These are grouped as intrinsic requirements, and input-based requirements.

Scheduler Objectives

The Scheduler objectives are derived directly from the Science Requirements Document – specifically, to respond to the need for “a universal cadence that would result in a common database of observations to be used by all science programs”. The Scheduler shall provide an observing program consisting of a sequence of telescope pointings and data acquisition cycles suitable for automated operations. The observing program will be optimized for key science, general science use, and observing efficiency, according to rules or scoring defined and approved by LSST science management and implemented under the supervision of the Schedule Scientist.

Many of the high level Scheduler objectives have already been concisely formulated as OCS requirements.Scheduler Use Cases

The Scheduler use cases describe the detailed scenarios in which the Scheduler objectives, listed above, must be achieved, including normal operations, and expected and unexpected deviations from normal. The use cases compiled here are based on material presented at the 2013 All Hands (Document-16406), expanded to include the information recommended by Alistair Cockburn in “Writing Effective Use Cases”. The use cases are based on the circumstances, events and conditions that may be expected to accompany observatory on-sky operations. The Stakeholders are not described for each entry, since these are in all cases the operations staff and the scientific community.

# Overall Description

tbd

# Specific Requirements

## Inputs

### Science proposals coded for Scheduler

**ID: OCS-input-01**

**Specification**: All required information describing the needed science observations shall be input to the OCS/Scheduler. Input latency – one day or as needed.

**Discussion**: Science requirements are presented to the Scheduler in the form of proposals. Each proposal encodes all requirements relevant to scheduling, including visit/filter counts, image quality and depth, cadence, and any proposal-specific Scheduler parameters. Parameters currently utilized are listed in a series of documents at:

<http://www.noao.edu/lsst/opsim/docs/simulator/configuration.html>

(Note: the above URL is not active as of this writing)

**Use in Scheduler:** The science proposals can be entered as one of several different standard proposal types, each of which is defined for convenience of implementation. The proposals and proposal types are implementation tools, do not map uniquely to science objectives, and do not describe all science or observing details.

### Scheduler algorithm/parameters

**ID: OCS\_input-02**

**Specification**: Scheduler control parameters shall be input to the OCS/Scheduler. Input latency – one day or as needed.

**Discussion:** The performance of the Scheduler algorithm(s) depends on the configuration file-based parameters, which include descriptions of hardware performance, and weights and switches controlling Scheduler operation. While a single parameter set is expected to serve automatic scheduling under typical conditions, it is possible that for some conditions (unexpected instrument failure modes or observing conditions) it will be necessary to swap to a different Scheduler performance model during an observing session.

**Use in Scheduler:** The scientific performance of the Scheduler operation is controlled primarily by the configuration parameters, which describe the sky areas to be surveyed, the required observations, the cadences, and the weights to be employed in scheduling. The Scheduler bases its selections on a detailed model of telescope performance, which is also described by configuration parameters.

### Scheduled Target of Opportunity (TOO)

**ID: OCS\_input-03**

**Specification**: TOO observations with sufficient lead time shall be pre-scheduled. Input latency – one day or as needed.

**Discussion:** TOO observations may be accommodated. In some cases, the observations will not be so time-critical as to require automated interruption of the normal scheduling process (typically 24+ hour lead time). For these the relevant information will be input to the OCS/Scheduler prior to the observing session, e.g. as new proposals, and will be queued by the Scheduler.

**Use in Scheduler:** Pre-scheduled TOO observations will be represented in the Scheduler by proposals, possibly of a new proposal type. Each will be active for specified duration(s) with its own requirements and weights. These will be defined prior to the nightly start of observing , and will be “competed” with the standard proposal mix.

### Unscheduled Target of Opportunity (UTOO)

**ID: OCS\_input-04**

**Specification**: The Scheduler shall accept planned (but unscheduled) TOO’s as they are communicated. Input latency – less than 1 minute; Scheduling latency – less than 2 minutes.

**Discussion:** UTOO observations may be accommodated, based on prior or standing TAC/Director approval. Owing to the urgency of some UTOO observations, the process of inputing to the OCS/Scheduler will be automated, have a latency no greater than the 60 seconds, and will interrupt the on-going schedule with substituted observations. Following completion of the UTOO, the Scheduler will resume normal activity.

**Use in Scheduler:** Un-scheduled TOO observations will not be processed in competition with the standard proposal mix. They will be processed at highest priority, interrupting the proposal queue at the earliest moment possible after receipt of an authorized observation definition. The required observations will be carried out in the shortest possible time.

### Operating status

**ID: OCS\_input-05**

**Specification**: The operating status shall be available to the Scheduler. Input latency – less than 1 seconds.

**Discussion:** The operational status of the facility will be available to the Scheduler, indicating the current state, which might include (ready, pending, closed) and possibly other information. [Note: the complete status description will be defined elsewhere in LSST documentation, viz. future Technical Operations Document.]

**Use in Scheduler:** When “ready” the Scheduler will operate in normal scheduling mode, issuing observation requests at a normal cadence. When the status is “pending”, the Scheduler will repeatedly update its observation request. When observing is not “ready” or “pending”, the Scheduler will be inactive.

**Default in absence of input:** Scheduler will pause when status Is not “ready”

### Filter in Use

**ID: OCS\_input-06**

**Specification**: The identity of the filter in use shall be available to the Scheduler. Input latency – less than 1 seconds.

**Use in Scheduler**: The Scheduler will update its instrument description with the current filter information.

**Default in absence of input:** Last commanded position assumed.

### Filters Available

**ID: OCS\_input-07**

**Specification**: The identity of the filters available shall be available to the Scheduler. Input latency – less than 15 seconds.

**Discussion:** the selection of available filers will change when the 6th filter is swapped, or when any filters are withdrawn for any reason. Typical change interval will be weeks.

**Use in Scheduler:** The Scheduler will update its instrument description with the available filter information.

**Default in absence of input:** All filters available assumed.

### Current Camera Rotator Position

**ID: OCS\_input-08**

**Specification**: The current camera rotator position shall be available to the Scheduler. Input latency – less than 1 seconds.

**Use in Scheduler:** The Scheduler will update its instrument description with the current rotator information.

**Default in absence of input:** Last commanded position assumed.

### Restrictions on Pointing

**ID: OCS\_input-09**

**Specification**: The current facility restrictions on pointing shall be available to the Scheduler. Input latency – less than 15 seconds.

**Discussion**: Pointing restrictions (including telescope, dome, cable wrap information) are parameters in the Scheduler that must be updated any time that the telescope operational limits change. The restrictions currently implemented, along with other configuration parameters, are described at <http://www.noao.edu/lsst/opsim/docs/simulator/>

**Use in Scheduler:** The Scheduler will update its instrument description with the pointing restriction information.

**Default in absence of input:** Scheduler will pause.

### Focal Plane Description

**ID: OCS\_input-10**

**Specification**: The description of the LSST active focal plane shall be available to the Scheduler. Input latency – 1 day or as needed.

**Discussion:** The LSST focal plane is complex and performance of parts of it may vary. Information about the focal plane, particularly about changes which impact science throughput, may be useful to the Scheduler. A useful description would be a map of relative performance, showing both full and partial failures. [Viz. Camera-DM ICD.]

**Use in Scheduler:** The Scheduler will maintain several focal plane performance descriptors, at least including:

* Fractional effective area relative to nominal (i.e. reduced to account for any inactive chips or rafts).
* Noise degradation as fractional increase in median detector read noise over active focal plane area relative to nominal.

This information may be used to temporarily adjust the priority of some proposals or some observations.

**Default in absence of input:** Full focal plane operation assumed.

### Telescope Performance Status Assessment

**ID: OCS\_input-11**

**Specification**: The telescope performance status assessment shall be available to the Scheduler. Input latency – one hour.

**Discussion:** Following OCS requirement **OSS-REQ-0029**, the performance of actual telescope scheduling relative to the requested scheduling will be assessed at least every hour. The result of this assessment will be available to the Scheduler. In the event of deteriorated performance, some issues, such as mechanical model parameters, may possibly be adjusted automatically. Some may require engineering intervention. In any case, immediate alert to the telescope/survey operator will be required. [The Scheduler itself may carry out performance assessments, and results of such analysis will be made available to other telescope systems.]

**Use in Scheduler:** There will be a tolerance (initially 20%) for basic functions (slew, settling, filter change. For performance within tolerance but systematically differing from the model, scale factors will be applied to the model to provide approximate corrections. For performance outside tolerance in any parameter, a protocol for notification and operator intervention will be initiated.

**Default in absence of input:** Nominal operation and performance assumed.

### Downtime Schedule

**ID: OCS\_input-12**

**Specification**: The current project schedule for downtime shall be available to the Scheduler. This will include downtime scheduled on short notice due to operations or other issues. Input latency – 1 day or as needed.

**Use in Scheduler:** The downtime schedule is an essential component of Scheduler look-ahead algorithms.

**Default in absence of input:** Now downtime considered in look-ahead.

### Guider/AOS Data Stream/Performance

**ID: OCS\_input-13**

**Specification**: Performance data from the guider and AOS shall be available to the Scheduler. Input latency – 2 second.

**Discussion:** information about the wavefront quality direct from the guider/AO systems may be useful for detecting failed observations due to certain anomalies as much as one minute before this information will become available from data pipeline processing. Guider (tracking) performance characterization should be provided as rms and peak telescope pointing error with respect to the guide stars, and also fractional rms aperture flux variations, during current shutter open. Wavefront performance should be available as rms and peak of the sum of all terms of higher order than tilt.

**Use in Scheduler:** Tolerances for tilt and wavefront error will be established based on recent history and minimum requirements for the current visit. If the conditions fail either tolerance by more than 10%, the exposure shall be flagged as failed and will be available for re-scheduling.

**Default in absence of input:** Nominal performance assumed.

### Weather Forecast

Weather forecast data will be made available to the Scheduler as it becomes available. This will be useful in determining the probability that observations can be acquired at various times in the future – this information is essential to Scheduler look-ahead.

### Precipitation Forecast

**ID: OCS\_input-14**

**Specification**: The forecast for amount of precipitation vs time shall be available to the Scheduler. Input latency – one hour.

**Use in Scheduler:** In scheduling look-ahead, time periods with predicted precipitation will be given a weight of 0.0.

**Default in absence of input:** Forecast of clear weather assumed.

### Cloud Forecast

**ID: OCS\_input-15**

**Specification**: The forecast for cloudiness vs time shall be available to the Scheduler. Input latency – one hour.

**Discussion:** Useful information about clouds includes the fractional sky cover, altitude, and cloud type, as typically available from aviation forecasts.

**Use in Scheduler:** In scheduling look-ahead, time periods with clouds will be given a weight equal to the predicted fractional cloud cover.

**Default in absence of input:** Forecast of clear weather assumed.

### Forecast for Passage of Fronts

**ID: OCS\_input-16**

**Specification**: The forecast for passage of fronts shall be available to the Scheduler. Input latency – one hour.

**Discussion:** As weather fronts are commonly associated with turbulent conditions, this information can be useful in projecting the probability of obtaining useful data.

**Use in Scheduler:** In scheduling look-ahead, time periods with predicted passage of fronts will be given a weight reduced by a factor of 0.8.

**Default in absence of input:** Forecast of clear weather assumed.

### Temperature and Rate of Change with Time

**ID: OCS\_input-17**

**Specification**: The forecast for the ambient temperature and temperature change shall be available to the Scheduler. Input latency – one hour.

**Discussion:** Temperature and temperature changes may strongly impact dome seeing.

**Use in Scheduler:** In scheduling look-ahead, time periods with predicted temperature gradient greater than 1 degree Centigrade per hour will be given weight reduced by a factor of 0.8.

**Default in absence of input:** Stable temperatures assumed.

### Wind Speed and Directions

**ID: OCS\_input-18**

**Specification**: The forecast for the wind and wind direction shall be available to the Scheduler. Input latency – one hour.

**Discussion:** Local wind is associated with turbulence, poor seeing, and telescope wind shake, hence is an important predictor of observing conditions. Winds aloft (vertical profile of wind speed and direction) is a major contributor to the apparent motion of clouds.

**Use in Scheduler:** In scheduling look-ahead, time periods with wind speed exceeding 40 kph will be given weight reduced by a factor of 0.8, time periods with wind speed exceeding 60 kph will be given weight reduced by a factor of 0.5, and time periods with wind speed exceeding 70 kph will be given weight reduced to 0.0. (Numbers to be updated based on experience.)

**Default in absence of input:** Forecast of acceptable wind speeds assumed.

### Precipitable Water Vapor

**ID: OCS\_input-19**

**Specification**: The forecast of precipitable water vapour shall be available to the Scheduler. Input latency - one hour.

**Discussion**: The water vapour in the telescope line of sight will impact the thoughput of the z and y filters, and variations in the water vapour will complicate photometric calibrations.

**Use in Scheduler:** In scheduling look-ahead, time periods with high or varying water vapour will be given weight reduced by 0.8.

**Default in absence of input:** Forecast of normal water vapour for season assumed.

### Current Meteorology

Telemetry from local sensors will stream readings on local atmospheric parameters that impact observing conditions.

### Cloud Cover

**ID: OCS\_input-20**

**Specification**: The current cloud cover over the observatory shall be available to the Scheduler. Input latency – one minute.

**Discussion**: The bulk cloud cover is an indicator of the kind of scheduling input required to provide an optimized program. In the case of minimal cloud cover, it may suffice to avoid cloudy regions, and maintain high efficiency, whereas during heavier cloud cover it may be necessary to hunt for useful zones, with lower efficiency, or possibly switch to a back-up program. Transparency, including transparency through thin clouds, is specified elsewhere.

**Use in Scheduler:** If current cloud cover is greater than zero the Scheduler will take into account the instantaneous cloud distribution in determining which portions of the sky are available for observation. If the current cloud cover is greater than 50%, or are moving rapidly, the Scheduler will notify the operator, who will have the option of switching to a back-up observing plan.

**Default in absence of input:** Zero cloud cover assumed.

### Environmental Temperature Sensors

**ID: OCS\_input-21**

**Specification**: A variety of temperature data streams shall be available to the Scheduler. Input latency – one minute.

**Discussion:** Temperature drifts and differentials are a good predictor of the incidence of dome seeing, and combined with wind information may allow optimizing of the field selection to minimize the impact of dome seeing. For example, if the primary mirror is warmer than the ambient air, the best image quality may be obtained by orienting the dome to allow a moderate wind to sweep away turbulent cells.

**Use in Scheduler:** In scheduling look-ahead, if the mirror temperature is more than 1.0 degrees Centigrade greater than the ambient dome temperature, the next 1 hour of observing time will be given a weight reduced by a factor of 0.8.

**Default in absence of input:** Stable temperatures assumed.

### Wind

**ID: OCS\_input-21**

**Specification**: The external wind speed, direction, RMS and peak values, and the dome interior wind speed, shall be available to the Scheduler. Input latency – one minute.

**Discussion:** Wind information for the free atmosphere will help to optimize field selection with respect to potential wind buffeting – for example by selecting fields that orient the dome to protect the telescope. The wind speed inside the dome will provide additional information on the success of wind palliative efforts.

**Use in Scheduler:** In scheduling look-ahead, if the current wind speed is greater than 40 kilometers per hour, all parts of the sky which require exposing the telescope to direct wind buffeting will be given a weight reduced to 0.0.

**Default in absence of input:** Pause within 10 minutes pending operator intervention to override.

### Sky Conditions

Sky conditions provide the strongest variable constraint on data quality, and are subject to rapid stochastic variations. The sky conditions will be tracked by several observatory resources, including an all-sky photometric camera, a photometric monitoring telescope, and a DIMM seeing monitor. These instruments will provide data streams which, in general, will require analysis to provide the useful sky condition measures needed for scheduling.

The Scheduler inputs will be derived from a combination of current measurements, combined with models and analysis. The localization of the modelling and analysis may be within the OCS/Scheduler, based on raw data inputs, or external, with only final results transmitted to the OCS/Scheduler.

### Free atmosphere seeing

**ID: OCS\_input-22**

**Specification**: The current free atmosphere seeing along one sight-line shall be available to the Scheduler. Input latency – one minute.

**Discussion:** The free atmosphere seeing, as from a DIMM, is a reference point for the delivered image quality. If the delivered image quality is significantly inferior, more judicious selection of fields may ameliorate the effect. The CTIO RoboDIMM (<http://www.ctio.noao.edu/telescopes/dimm/dimm.html>) is a satisfactory model for the minimal instrumentation, with a data product approximating the zenith-equivalent r band seeing and a cadence of no greater than 1 minute.

**Use in Scheduler:** In scheduling, the selection of pointings depends on the required and available image quality. The DIMM offers reference for the current free atmosphere, which can be used to predict the observed image quality in any filter and at any zenith distance. If the predicted image quality based on the DIMM and the observed image quality from the data pipeline differ by more then 10%, the operator will be notified. S(he) will have the option of reducing the weight of parts of the sky, e.g. the parts in the windward quadrant. This will also serve as an alert to possible system malfunction.

**Default in absence of input:** Median image quality assumed.

### All-sky Sky brightness

**ID: OCS\_input-23**

**Specification**: A calibrated all-sky map of the sky brightness in at least one of the gri filters shall be available to the Scheduler. Input latency – two minutes.

**Discussion:** Sky brightness provides a systematic background, limiting deep imagery. It is extremely variable, both systematically due to lunar phase, and irregularly depending on clouds, atmospheric aerosol and particulate content and solar/geomagnetic activity. A continuous direct calibration of the sky brightness is essential to evaluate and to update in real time the Scheduler sky brightness model to predict current and near future conditions with the best possible confidence. The back-scatter of moonlight off thin clouds makes a big difference, and changes quite rapidly. The Scheduler requires sky brightness estimates in all 6 bands with spatial resolution of 30 arcminutes and precision and accuracy of 0.1 mag rms in all bands. Brightness in bands not monitored by an all-sky camera will be estimated numerically from the bands which are observed.

**Use in Scheduler:** In scheduling, the selection of pointings depends on the required and actual sky brightness. If the sky brightness based on the all-sky monitor and the observed sky brightness from the data pipeline differ by more then 10%, the operator will be notified. S(he) will have the option of reducing the weight of parts of the sky, e.g. the dusk or dawn horizon, or within a specified angle of the moon.

**Default in absence of input:** Median sky brightness assumed.

### All-sky Transparency

**ID: OCS\_input-24**

**Specification**: An all-sky map of the atmospheric transparency in at least one of the gri filters shall be available to the Scheduler. Input latency – two minutes.

**Discussion:** Atmospheric transparency contributes to limiting the depth of imagery, and variations in transparency complicate photometric calibrations. It is irregularly variable, depending on atmospheric aerosol and particulate content. A continuously available map of transparency is needed for selecting fields, and the time history of transparency is a useful discriminant for photometric/non-photometric conditions.

Atmospheric transparency information in ugriz will be required with a temporal cadence of not less than 2 minutes, an input latency not to exceed 2 minutes, and an angular resolution of 30 arcminutes. Units are magnitudes of extinction, assuming an AB-flat source SED. This will include (on the basis of measurements or validated models) all sources of extinction, including clouds, aerosols, Rayleigh scattering, and molecular absorption including water vapor. The required precision of the attenuation estimates is 0.05 magnitudes rms) in griz and 0.1 mag in u and y.

**Use in Scheduler:** In scheduling, the selection of pointings depends on the required and available 5-sigma detection limit. The transparency is a factor in the calculation of the 5-sigma detection limit.

**Default in absence of input:** Median transparency assumed.

### All-sky Photometric Quality

**ID: OCS\_input-25**

**Specification**: An all-sky map of the photometric quality as a function of position on the sky, in at least one visible filter, shall be available to the Scheduler. Input latency – 15 minutes.

**Discussion:** Both relative and absolute photometric quality are essential parameters in the LSST survey. Both may be inferred to some degree from the stability of all-sky transparency. This can be estimated from photometry on an all-sky grid of bright stars. The spatial variation in transparency at constant zenith distance in rms magnitudes, as a function of zenith distance, will be provided as a measure of photometric uniformity across the sky, and the temporal trend of these numbers in magnitudes per hour will be used as a measure of photometric stability.

**Use in Scheduler:** In Scheduler look-ahead, time periods with photometric variability at constant zenith distance greater than 0.007 will be given weight reduced by 0.8.

**Default in absence of input:** Normal good photometric stability assumed.

### Data Pipeline Quick Look and Data Quality Processing

Under most circumstances, the most reliable indicator of the conditions expected in the near future will be the conditions in the recent past. The actual data acquired in the most recent observation will reflect the impact of all those conditions, including all the effects discussed in the above draft requirements. Rapid return of pipeline processing results as input to the OCS/Scheduler will be essential and invaluable.

### Delivered Image Quality (DIQ)

**ID: OCS\_input-26**

**Specification**: The median DIQ from the most recent image, with associated observing parameters, shall be available to the Scheduler. Input latency – one minute.

**Discussion:** The report on the DIQ should include seeing FWHM, which reveals primarily the effects of the atmosphere, and the image shape, described by ellipticity, which reflects the performance of the fixed and active optics. Some of this information will be a function of the position on the focal plane, and how to represent is TBD.

**Use in Scheduler:** In scheduling, the selection of pointings depends on the required and available image quality and on the 5-sigma detection limit. The image quality is a factor in the calculation of the 5-sigma detection limit.

**Default in absence of input:** Median image quality assumed.

### Sky brightness

**OCS\_input-27**

**Specification**: The median sky brightness in the most recent image, with associated observing parameters, shall be available to the Scheduler. Input latency – one minute.

**Discussion:** The observed sky brightness will vary across the focal plane, owing to the vignetting function. The brightness will be expressed by its vignetting-corrected median value, in magnitudes per arcsecond squared, and its rms about the vignetted value.

**Use in Scheduler:** If the rms sky brightness is greater than 0.1 magnitudes, the observation will be tagged as failed. In Scheduler look-ahead, time periods with sky brightness rms greater than 0.005 will be given weight reduced by 0.8.

**Default in absence of input:** Median sky brightness assumed.

### Transparency

**ID: OCS\_input-28**

**Specification**: The transparency across the FOV inferred from the most recent image, with associated observing parameters, shall be available to the Scheduler. Input latency – one minute.

**Discussion:** The transparency and its fluctuations will complicate photometric calibrations and limit their success. The use of difference images for detection of alerts will facilitate the measurement of transparency and its variations across the FOV. The pattern of temporal variation of the former will be indicative of the potential for absolute calibrations, and of the latter will be particularly valuable for evaluating the quality of the relative calibration. The apparent transparency will vary across the focal plane, but probably can be represented by a simple parameterization of the vignetting function, TBD. The value of the parameter, in magnitude, and its RMS value across the focal plane, will be available.

**Use in Scheduler:** If the rms transparency is greater than 0.1 magnitudes, the observation will be tagged as failed. In Scheduler look-ahead, time periods with transparency rms greater than 0.005 will be given weight reduced by 0.8.

**Default in absence of input:** Median transparency assumed.

### Success of Current Exposure

**ID: OCS\_input-29**

**Specification**: A success/fail flag shall be available for the current exposure. Input latency – 2 seconds and 1 minute.

**Discussion:** Immediate identification of a failed observation will enable the Scheduler to reset the priority of the observation while the telescope is still pointing in the near vicinity of the field, increasing the probability that the schedule sequence will self-repair immediately. The Scheduler may implement an “instant” repeat decision, possibly science proposal dependent. In the case of a failed visit, the fail notification will be issued within 2 seconds. In the case of a successful visit, basic figures of merit will be provided within 1 minute. The information provided will include preliminary characterization of the data during alert processing. This must include measures of image size (arc-seconds) and shape (ellipticity), limiting magnitude (m5), and sky brightness. In the event that observing is interrupted for more than 5 minutes, with scheduled visits in the observing queue but unobserved, these will be reported as failed.

**Use in Scheduler:**  For each failed observation, the observing history will be corrected to reflect this fact immediately, allowing the Scheduler to include the a re-observation as one of the candidate observations for the next addition to the visit queue.

**Default in absence of input:** Successful exposure assumed.

### Operator Anomaly Flag

**ID: OCS\_input-30**

**Specification**: The telescope/survey operator can trigger an observation anomaly flag which shall be available to the Scheduler. Input latency – 2 seconds

**Discussion:** The operator initiated anomaly notification will be recorded with the visit metadata. It will not trigger Scheduler action unless so pre-programmed in the Scheduler (TBD)

**Use in Scheduler:** Operator intervention will be noted in the observing record, with explanatory information.

**Default in absence of input:** No anomaly assumed.

### List of Visits

**ID: OCS\_input-31**

**Specification**: A list of attempted visits for the duration of the survey shall be available to the Scheduler. Input latency – 2 seconds and 1 minute.

**Discussion:** The Scheduler will have access to the catalogue of completed visits integrated over the entire survey, up to and including the previous night, with associated data quality information. As soon as a visit is completed, if there is no known anomaly, it will be posted as conditionally successful. When a report from the DM pipeline is received ~1 minute later, the status will be updated to either confirmed successful or confirmed failed. It will also be possible to later change success flags if updated information becomes available.

**Use in Scheduler:** The observing history is a basic input to the Scheduler, and it will be updated with new information, both prior to a new observing session, and as possible during an observing session.

**Default in absence of input:** If an out-of-date history is available, use it as basis for scheduling. If no history is available, revert to designated backup programs.

## Outputs

tbd

### Next Target

### Scheduling meta data

## Functional Requirements

### Observatory Model

The Scheduler shall include an observatory model to estimate the slew delay time to any potential target. The model shall include the relevant elements of the observatory that participate in the slewing from to a target, and shall describe them in the necessary detail to compute the contribution to the delay time.

Discussion:

* Mount Altitude: for mount altitude axis a second-order model is considered. There is a lower limit and a higher limit for the telescope altitude position, a constant acceleration, a maximum speed and a constant deceleration. The speed limit, acceleration and deceleration are the same for both directions, and are independent from the azimuth position.
* Mount Azimuth: for mount azimuth axis a second-order model is considered, constant acceleration and deceleration with a maximum speed, all the same for both directions. A cable-wrap is included in the model, allowing a range of movements for more than a full circle. An absolute minimum limit and an absolute maximum limit are defined (-270 and +270 degrees), and the absolute azimuth moves in this range. For some target positions there are 2 possibilities, the closest to the current absolute position is chosen for determining the distance and direction for the delay computation.
* Rotator Angle: for mount rotator axis a second-order model is considered. The absolute angle limits allow a range of half circle, the limits are -90 and +90 degrees. Besides the parameters minimum angle, maximum angle, acceleration, deceleration and maximum speed, this component has an additional one, “follow sky”, which controls the orientation of the image. If this parameter is enabled, the target angle for the rotator will follow the parallactic angle to put North up (or down according to the range possibilities). If this parameter is disabled, the rotator angle is left where it is during the slew, but it tracks during the exposure.
* Dome Azimuth: for dome azimuth axis a second-order model is considered, with its own maximum speed, constant acceleration and deceleration, with no cable-wrap limits.
* Dome Altitude: for dome altitude axis a second-order model is considered, with its own maximum speed, constant acceleration and deceleration.
* Telescope Optics Correction: For the active optics corrections model, no coordinates for active components are tracked. A very simple model computes the time delay to adjust the optics as a function of the altitude slew in the telescope. There are 2 components in this model: the open-loop corrections and the closed-loop corrections. Both delay components need to be added because the eventual closed-loop correction is always executed after the open-loop correction. For the open-loop corrections model, the assumption is that correcting from the look-up tables is fast enough or not needed during tracking, so there is a penalty only when correcting for the slew. This penalty is modelled as a constant rate in time/altitude-angle-distance for the whole altitude range. For the closed-loop corrections, the supposition is that there is a first range of altitude-angle-distance (between 0 and a defined *limit1*) for which no correction is needed. There is a second range (between *limit1* and *limit2*) for which a single exposure is needed for the correction, adding a penalty of a constant delay time. Finally there is a third range (between *limit2* and 90 degrees) for which 2 consecutive corrections are needed producing a longer delay time.
* Settle Time: The settle time is a constant delay applied to every slew and accounts for damping the possible vibrations in the mount.
* Filter Change: If the target filter is different than the current filter position, a constant delay is applied for this stage.
* Readout: This is the delay in the readout for the previous exposure, considered part of the following slew.

### Sky Brightness model

The Scheduler shall contain a sky brightness model for dark time and twilight.

Discussion: the sky model provides the expected brightness level for every field in the present and evaluated future times for look-ahead capabilities.

### Scheduler History

The Scheduler shall maintain a complete history of the past schedule of actual visits.

Discussion: the internal history of visits is independent from the external Engineering Facility Database. This internal history keeps not only the visit parameters from the observation point of view, it also carries metadata produced by the relevant science proposals that are of interest to rank new targets in the present and the future.

### Science Proposals

The scheduler shall incorporate multiple science proposals for targets generation.

Discussion: The science proposals are the objects whose role is to propose targets to the Scheduler at each observation moment, giving a numeric rank to each candidate target according to their own agendas. Each proposal has its own scientific objective and individual characteristics.

* Area Distribution Proposals: This type of proposal is designed to get an even distribution of observations on a sky region. The Weak Lensing survey is implemented from this type. The parameters are basically the number of visits per filter that are requested for each field in the region. It gives more ranking to the more needed field-filter combinations.



If look ahead information is available and used, then the following self-balancing equations are used:

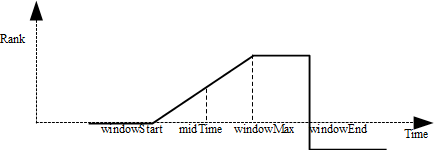


**availableTime** is the addition of the future time windows when the target (field-filter) is visible for the science program.

**targetMerit** gives a normalized range of values

Boost factor

* Transient Proposals: This type of proposal is designed to work with transient targets, in which the fields need a sequence of observations at a given set of time intervals. Every field in the specified sky region has its own sequence independent from the others. An event in this context is an observation of the field that has to be performed during specific time limits given by the scheduling requirements of the sequence, and with a filter to be determined by the particular algorithm of the proposal.



### Sequences behavior

The Scheduler shall implement the following variants on the behavior of the sequences for the transient proposals.

#### Basic Sequence

There shall be a sequence for each field in the defined region for the proposal. The sequence is defined by a filter, the number of visits to complete the sequence, a time interval between observations, and time window parameters for the tolerance.

#### Maximum number of missed observations

Each sequence is allowed to miss a defined number of visits. If there are more missed events than this threshold, the sequence is declared lost.

#### Restart Sequence

There shall be a flag for restarting a complete sequence, and a flag for restarting a lost sequence.

#### Alternate area distribution with tuples collection

There shall be a type of sequence that collects visits in tuples. The first observation of the tuple shall obey an area distribution equation for its rank, and the subsequent observations of the tuple shall obey a time window equation for its rank.

#### Subsequences

There shall be a type of sequence that is composed of several subsequences for each field running in parallel. Each sub-sequence is defined by a number of events with a fixed time interval, a filter, its own time-window parameters and limit for missed events. They all run independently proposing field-filter combinations until all of them are complete or any of them is lost, declaring in either case the end of the whole sequence.

#### Deep drilling sequences

There shall be a special case of sequence that allow the schedule of back-to-back visits.

### Cost function

### Deterministic look ahead

### Self balancing proposal progress

The Scheduler shall include the optional usage of self balancing factors to promote the least advanced science proposals against the ones that have achieved higher progress.

### Warm start capability

**ID: SCH-Int-4**

**Specification:** A warm start capability shall enable swapping from one scheduling algorithm to another during the night, automatically according to prescribed criteria, or by operator intervention.

**Discussion:** Under a change of scheduling algorithm, the existing queue of planned observations (~1-2 minutes in length) will normally not be cleared, and the schedule additions will be added to the existing queue.

### Scripted cadences

**ID: SCH-Int-5**

**Specification:** The Scheduler shall be able to accept scripted cadences which bypass the scheduling algorithm and execute a prescribed series of visits, slews, filter changes, camera rotations, etc.

**Discussion:** Scripted cadences will be required for a variety of commissioning, testing and calibration functions, and may be a suitable way of implementing deep-drilling and some other mini-surveys and target of opportunity events.

### Dithering

**ID: SCH-Int-6**

**Requirement:** The Scheduler shall be able to implement dithering of visit pointings.

**Discussion:** The LSST visit pointings are defined with respect to a standard grid of sky coordinates. The survey will optionally execute the survey with visits pointing a locations displaced (dithered) from the nominal field centers. The algorithm for this dithering will be explored with post-processing of simulated data, and possibly will not be implemented in the operations simulator algorithm.

### Operation in Event of Input Failure

**ID: OCS-input-00**

**Specification**: In the event of failure of any expected input, the Scheduler will continue to operate with appropriate defaults.

**Discussion**: An expected input can fail due to lack of data, or due to data outside expected ranges. In either case, the operator will be notified, and the Scheduler will default to pre-defined values. For certain input failure conditions, automatic operation may be paused pending operator intervention. Specific defaults are described in some of the following requirements.

## Performance Requirements

tbd

## Attributes

### Multiple scheduling algorithms

**ID: SCH-Int-3**

**Specification:**The Scheduler shall support multiple scheduling algorithms that are consistent with the inputs, outputs, and functions described in this document.

**Discussion:** Very likely, different algorithms will be utilized for non-optimal conditions, such as low transparency or high sky brightness. Also, the main algorithm(s) will likely evolve during the survey.

### Operations Simulator

**ID: SCH-Int-1**

**Specification:** The Scheduler shall accommodate scheduling algorithm modules developed and tested in the operations simulator.

**Discussion:** Algorithm development and testing will continue in parallel with the Scheduler development. Therefore the simulator and Scheduler must be designed to enable transfer of algorithms from one to the other.

### Implicit Scheduler requirements inherited from the simulator

**ID: SCH-Int-2**

**Specification:** Requirements for the operations simulator are also based on the flow down of requirements described above. Since the Scheduler must utilize the simulator scheduling algorithms, it must also support the simulator configuration parameters and inputs, differing in that the simulator uses models or historical data, whereas the Scheduler has access to current actual data.

**Discussion:** The intention is that all simulator scheduling functionality and optimization will be available in the Scheduler.

### Operation in Event of Input Failure

**ID: OCS-input-00**

**Specification**: In the event of failure of any expected input, the Scheduler shall continue to operate with appropriate defaults.

**Discussion**: An expected input can fail due to lack of data, or due to data outside expected ranges. In either case, the operator will be notified, and the Scheduler will default to pre-defined values. For certain input failure conditions, automatic operation may be paused pending operator intervention. Specific defaults are described in some of the following requirements.

### Global Survey Optimization

**ID: SCH-REQ**

**Specification**: The operations management structure shall provide a process for review of Scheduler performance and specification of Scheduler parameters (or equivalently metrics and metric weights) which will be utilized to balance science and technical performance with respect to multiple requirements.

**Discussion:** The requirements above refer to the optimization of individual survey performance measures that cannot always be maximized simultaneously. The adjudication of competing requirements is essentially a political process, and this will be provided specifically for the Scheduler.

# Appendix A – Scheduler Use Cases

## Normal Observing Operations

### Universal Cadence

* **Primary actor**: acting observing manager
* **Preconditions**: facilities, environmental conditions and astronomical conditions are suitable for initiation of normal operations
* **Guarantees (postconditions)**: automated observing begins
* **Trigger**: initiation of observing, normally at evening twilight
* **Main success scenario**: automated observing continues without interruption

### Deep Drilling

* **Primary actor**: acting observing manager
* **Preconditions**: facilities, environmental conditions and astronomical conditions are suitable for initiation of deep drilling proposal
* **Guarantees (postconditions)**: deep drilling observing on a field begins
* **Trigger**: auto-triggered by scheduler
* Main success scenario: deep drilling sequence for one field completes, and system returns to Use Case 1.0, normal observing

## Recovery

### Recovery from Lost Observation

* **Primary actor**: acting observing manager
* **Preconditions**: an observation has been lost
* **Guarantees (postconditions)**: observing history updated for any data loss; scheduler parameters reset as needed; automated observing continues
* **Trigger**: loss of data determined by internal system performance checks, or has failed 60-second DM quality control
* **Main success scenario**: automated observing continues with immediate repeat or non-repeat of observation determined by normal scheduler algorithms

### Warm Restart

* **Primary actor**: acting observing manager
* **Preconditions**: normal observing has been paused
* **Guarantees (postconditions)**: observing history updated for any data loss; scheduler parameters reset as needed; automated observing continues
* **Trigger**: automated scheduler-driven observing interrupted
* **Main success scenario**: automated observing continues with continuation of interrupted sequences determined by regular scheduler algorithms.

## Target of Opportunity (TOO)

### Predefined TOO

* **Primary actor**: acting observing manager
* **Preconditions**: a TOO has been pre-approved, with an associated priority, and an observing script pre-defined, to be held pending an appropriate trigger
* **Guarantees (postconditions)**: current observing activity will be interrupted immediately or following completion of the current observation or sequence (depending on an urgency flag), telescope will slew to requested field, and the TOO sequence will execute
* **Trigger**: an alert trigger has been received, probably automatic, but possibly by observing manager interrupt
* **Main success scenario**: TOO sequence is initiated within requested time window, sequence is completed, and automated observing resumes with continuation of interrupted sequences determined by regular scheduler algorithms.

### Unexpected TOO

* **Primary actor**: acting observing manager
* **Preconditions**: an unexpected TOO observation is requested with appropriate approval authority for targets and fields
* **Guarantees (postconditions)**: current observing activity will be interrupted immediately or following completion of the current observation or sequence (depending on an urgency flag), telescope will slew to requested field, and the TOO sequence will execute
* **Trigger**: human intervention
* **Main success scenario**: TOO sequence is initiated within requested time window, sequence is completed, and automated observing resumes with continuation of interrupted sequences determined by regular scheduler algorithms.

## New or Revised Observing Program

It is likely that the Scheduler will be modified many times during the survey, including adjustment of algorithms and parameters and addition or deletion of observing proposals.

### Modification of Scheduler

* **Primary actor**: operations scientist
* **Preconditions**: changes to the scheduler algorithms, parameters, or other components have been developed and approved for installation
* **Guarantees (postconditions)**: the modified Scheduler will begin operation with all history, status and other necessary information from the old Scheduler
* **Trigger**: project and science management decision
* **Main success scenario**: automated observing resumes with continuation of interrupted sequences determined by regular scheduler algorithms.

## Backup Programs

### Reduced Data Quality

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: data quality is significantly reduced due to conditions, most likely reduced transparency or poor seeing, which are below the requirements of all regular observing scenarios
* **Guarantees (postconditions)**: the Scheduler will shift to an alternate program which has been foreseen for the conditions, or if none, will pause operations
* **Trigger**: observing manager decision
* **Main success scenario**: during low quality conditions, backup programs which can make use of the data are activated

### All Fields Complete

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: the requirements for one or more observing proposals have been completely fulfilled, and at some time there are no requests for observations from primary programs – secondary programs will have been predefined for this circumstance
* **Guarantees (postconditions)**: the Scheduler will continue observations without interruption for approved secondary program(s)
* **Trigger**: insufficient primary programs to fill observing queue
* **Main success scenario**: optimized use of on-sky time will continue after the completion of key project requirements

## System Failure

### Filter Not Available

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: one or more filters is not available; the Scheduler design foresees this possibility
* **Guarantees (postconditions)**: the Scheduler will continue to carry out an optimized observing program based on the available filters
* **Trigger**: filter changer failure or withdrawal of filter from operation
* **Main success scenario**: standard scheduler algorithms continue to carry out correct optimization with reduced filter set

### Image Quality Low

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: data quality is significantly reduced due to technical failure, e.g. due to incorrect function of optics supports or active optics; the Scheduler design foresees this possibility
* **Guarantees (postconditions)**: the Scheduler will continue operations for several levels of degraded image quality, unless it exceeds an agreed limit
* **Trigger**: image quality reported by DM, and decision by acting observing manager
* **Main success scenario**: appropriate Scheduler performance is ensured, either automatically, or with human intervention

### Detector Partial Failure

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: part of the focal plane fails; the Scheduler design foresees this possibility
* **Guarantees (postconditions)**: the Scheduler will continue operations for partial failure
* **Trigger**: focal plane failure reported by DM or detector engineering
* **Main success scenario**: appropriate Scheduler performance is ensured, either automatically, or with human intervention

### Reduced Operations Efficiency

* **Primary actor**: acting observing manager and scheduler scientist
* **Preconditions**: operations efficiency is reduced and expected to remain so for an extended period of time
* **Guarantees (postconditions)**: the Scheduler will continue to optimize operations for the current level of performance
* **Trigger**: OCS analysis of observation timing, and engineering analysis and report
* **Main success scenario**: Scheduler parameters describing telescope system parameters will be adjusted, and Scheduler algorithms will correctly optimize observing under the performance limitations

# Appendix B – Higher Level Scheduler Requirements

## Observatory System Specifications

### Environmental Optimization

**ID: OSS-REQ-0026**

**Specification:** The survey scheduling shall be optimized against local environmental conditions to maximize the survey's scientific return. This optimization shall include the ability to adjust filters based on seeing conditions, the ability to avoid clouds with predefined opacity, and adjust to constraints derived from wind direction.

### Scheduling Assessment

**ID: OSS-REQ-0029**

**Specification:** The survey scheduling shall be adjustable based on periodic assessment of performance. This shall be done down to periods of 1 hour throughout the night and shall be based on actual accomplishments compared to objectives and current system technical performance.

### Survey History Record

**ID: OSS-REQ-0030**

**Specification:** The LSST Scheduler shall maintain an independent record of all past observations and shall include Data Quality Assessment parameters determined by evaluation of the imaging data. Input latency – 1 day for daily catalog and 1 minute for new visits.

Discussion: This catalog is derived from the DM archive, updated daily with results of DM processing of the previous nights, and updated every 30 seconds (refresh time) based on scheduled observing and DM pipeline analysis (1 minute elapsed time after completion of visit).

## OCS Requirements for Scheduler

### Schedule Survey

**ID:OCS-REQ-0007**

**Specification:** The OCS shall contain an automatic Scheduler, which organizes the outstanding observations in a way that optimizes observing time and achievement of the specified science goals.

**Discussion:** The science goals are described in terms of science programs. The OCS Scheduler includes these science programs as software components, with a high level of flexibility in order to be capable of implementing the particular cadence and distribution of each one of them. Scripting capabilities and adaptive parameters are also considered to cope with special purpose observations in the survey, and potential changes of the survey baseline definition.

### Fully Automatic Scheduling

**ID:OCS-REQ-0008**

**Specification:** The OCS shall be capable of scheduling and operating the sequence of observations in a fully automated fashion during an entire night.

**Discussion:** The OCS obtains all the relevant information from the science programs priorities, history of observations, environmental conditions/forecasts and subsystems states in order to build the schedule and conduct the survey automatically.

### Obtain Candidate Observations Automatically

**ID:OCS-REQ-0009**

**Specification:** The OCS Scheduler shall generate the list of candidate target observations for a visit in a fully automated fashion.

**Discussion:** The science programs running in the OCS Scheduler will provide each one with its own list of targets that are allowed to be observed and are also in need of visits. This group of lists is merged by the Scheduler to produce a single list of candidate targets for the next visit.

### Rank Candidates

**ID:OCS-REQ-0010**

**Specification:** The OCS Scheduler shall evaluate the list of possible candidate targets with a numerical rank, based on the history of observations and goals of the active science programs, in order to consider the benefits of all the options in the scheduling algorithm.

**Discussion:** Each science program contributes with its own list of ranked targets according to the parameters for depth, filters, time interval distribution and specific cadence requirements. The Scheduler then takes these ranks into account when assembling the single ranked list of targets according to their scientific priority for the next visit.

### Optimize Observing Time

**ID:OCS-REQ-0011**

**Specification:** The OCS Scheduler shall organize the sequence of observations optimizing the time spent collecting data.

**Discussion:** The natural way of achieving optimum observing time is by minimizing time spent slewing and changing filters. This objective will sometimes go in the opposite interest of the science goals for some science programs, and it is the job of the OCS Scheduler to make the best balance between the two for the time span of the survey.

### Maximize Science Programs

**ID:OCS-REQ-0012**

**Specification:** The OCS Scheduler shall pursue the maximum goals achievement for each science program.

**Discussion:** The OCS Scheduler balances the attention given to each science program in order to obtain scientific profit of each visit, trying also to find targets that satisfy multiple science programs simultaneously.

### Minimize Slew Time

**ID:OCS-REQ-0013**

**Specification:** The OCS Scheduler shall minimize the time spent in slewing and maximize the shutter open time.

**Discussion:** The OCS Scheduler considers the cost of observing the next visit. The cost is the time needed from the end of the current visit to reconfigure the observatory for starting the next visit. This is the time to be spent slewing the telescope, slewing the dome, changing the filter and preparing the camera for the exposures. The accumulation of these times during the night are to be minimized by improving the rank of targets with shorter slews.

### Estimate Slew Delay for Candidate Observations

**ID:OCS-REQ-0014**

**Specification:** The OCS Scheduler shall estimate the slew delay time from the current state of the observatory to the position of each possible next target, in order to consider the cost of all the options in the scheduling algorithm.

**Discussion:** The slew delay is evaluated for each target in the aggregated list of candidates, and this time is considered along with the scientific rank in order to build the final ranked list of candidate targets for automatically choosing the next visit.

### Dynamic Adaptation to Changing Conditions

**ID:OCS-REQ-0015**

**Specification:** The OCS Scheduler shall constantly adapt the sequence of observations in real time, according to the external environmental conditions and the particular requirements of sky quality of the outstanding observations in the active science programs.

**Discussion:** This short term adaptation must be in balance with the long term goals for the survey. Telemetry from the environment is key for this requirement. Weather conditions are accounted for in the ranking process of the targets.

### Schedule Science Programs

**ID:OCS-REQ-0016**

**Specification:** The OCS Scheduler shall propose target observations according to the goals and parameters of the science programs described in the Observatory System Specifications.

**Discussion:** The OCS Scheduler shall select the best observation target sequence from the list of possible candidates, considering the benefit for the active science programs and the time cost of following that particular sequence.

### Keep Track of Each Science Program Progress

**ID:OCS-REQ-0017**

**Specification:** The OCS Scheduler shall keep track of the detailed progress of each science program.

**Discussion:** In order to rank a particular sky field for the next visit, each science program needs to consider the number of visits granted for that field, the sequence of filters and the time distribution achieved so far, and evaluate those parameters for computing the science value for that particular field in the next visit opportunity.

### Observations Database

**ID:OCS-REQ-0018**

**Specification:** The OCS shall keep a detailed observations database with the complete history of observations with their parameters and environmental conditions under which they were taken.

**Discussion:** This observations database is utilized for ranking the future visits and also for building automatic and on-demand reports about the survey progress, globally and for each science program.

### Schedule Calibration and Maintenance Programs

**ID:OCS-REQ-0019**

**Specification:** The OCS shall schedule calibration and maintenance programs, according to the baseline plans. These programs shall allow automatic, scripted or manual observations according to the specific operational needs.

**Discussion:** During calibration and maintenance the OCS Scheduler works in a similar fashion, replacing the science programs by calibration or maintenance programs.

### Update Survey Parameters

**ID:OCS-REQ-0020**

**Specification:** The OCS provides the interface to allow the updating of the Scheduler parameters following the analysis of the survey progress by the survey managers.

**Discussion:** The OCS Scheduler shall have a set of parameters that control the survey operation, such as active science programs, relative priorities, ranking factors, time limits, sky brightness ranges, etc. These parameters can be adjusted by the survey scientists and engineers after analyzing the survey progress reports.

### Image Processing Control

**ID:OCS-REQ-0021**

**Specification:** The OCS shall inform the Data Management System in advance of the image acquisition of the needed processing related the specific image type.

**Discussion:** This requirement ensures that the Data Management operating at the Base Facility has advance notice of the type of image(s) that are being acquired. This is to inform the Data Management system of the type of processing it needs to perform on the images as they are obtained.