Simulating a Survey: The Operations Simulator

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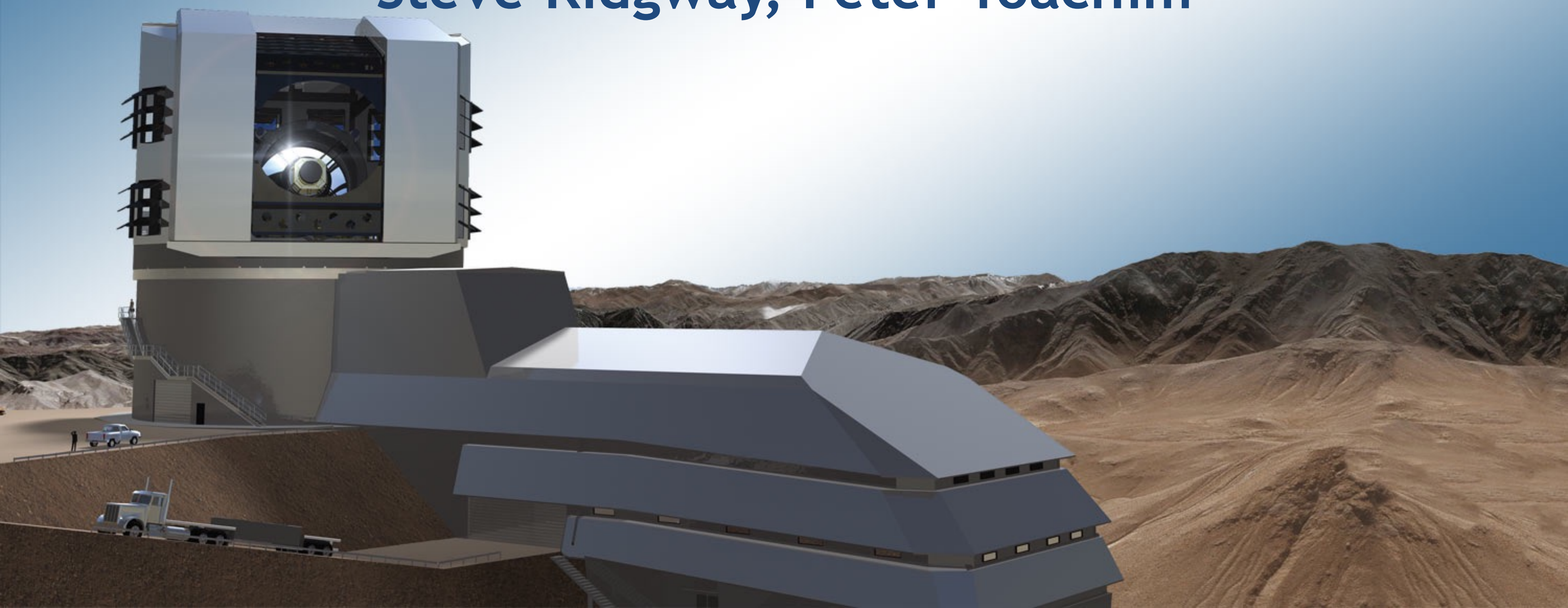


Survey strategy drives much of our science

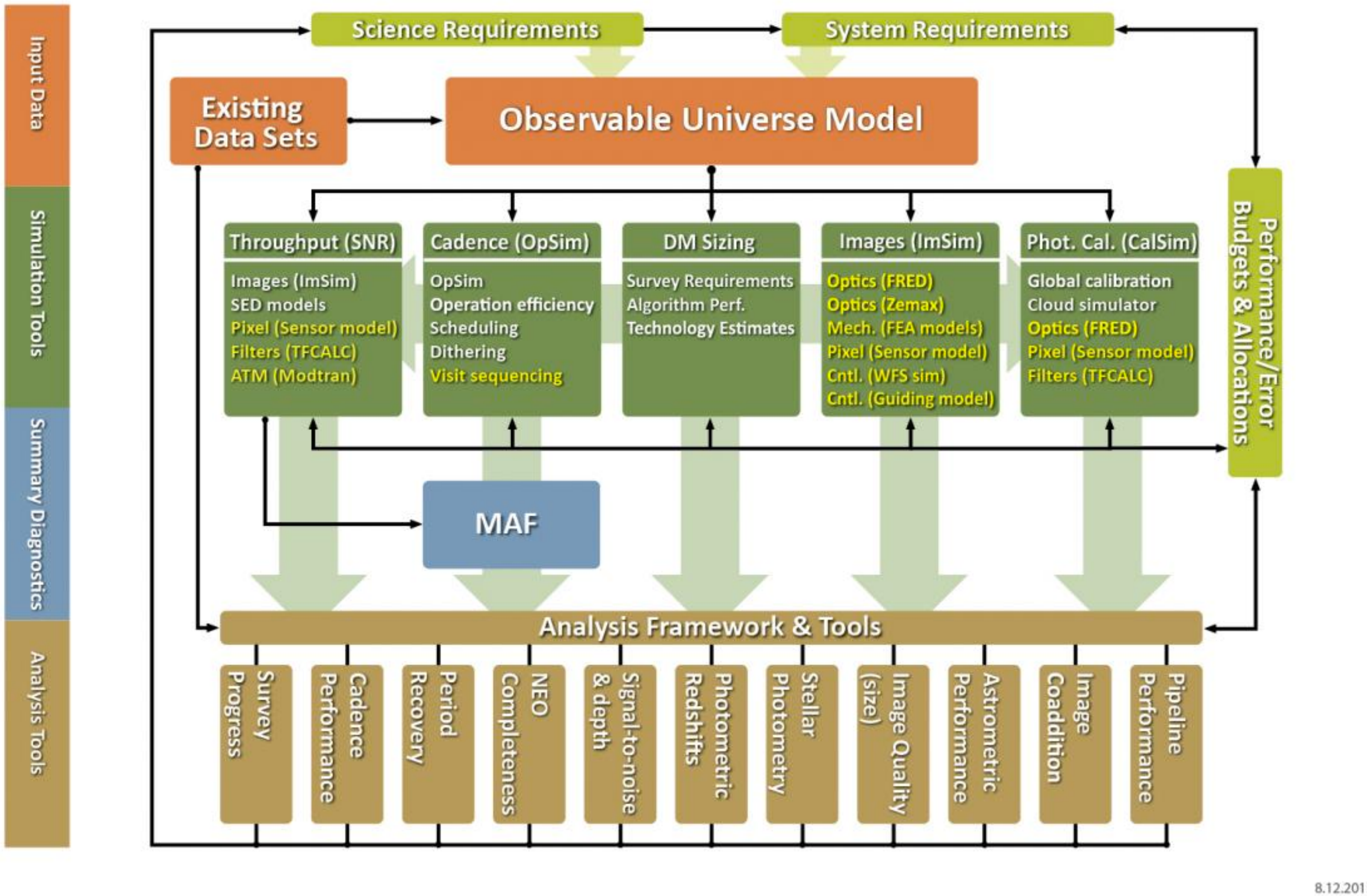
- The LSST supports a broad range of science objectives
- Many of these science objectives are driven by how we sample the sky (e.g. SN light curves, proper motion accuracy)
- Cadence is set by these competing science proposals, sky brightness, weather, engineering performance, visibility of the survey fields
- Optimization of such a survey is an open and active areas for research and evaluation

You will be disappointed by whatever strategy is implemented (probably). You should try to move beyond this and understand what your science will really need.

Science performance through "metrics"

- What is your science goal?
  - e.g. a measurement of H_0 from strong lensing
- Qualitatively, how does the survey strategy impact this science?
  - accurate time delays of days-weeks are needed, and they have to be inferred from long, but noisy, sparsely-sampled light curves
- Quantitatively, how does your science depend on the survey strategy? Are there simple quantities - metrics - that allow you to give approximate answers to this?
  - how does the time delay measurement degrade as you change the sampling of the light curve; the depth per visit, the season length, or the campaign length.

LSST Simulation Ecosystem



Defining performance

Data Management (aka DM): Take a bunch of raw images and process them to make catalogs

- **Photon Simulator (aka PhoSim)**: Simulate LSST images by tracing photons
- **Catalog Simulator (aka CatSim)**: A realistic catalog of objects LSST could observe (Stars, galaxies, etc)
- **Calibration Simulation (aka CalSim)**: Uber-cal for LSST
- **Operations Simulator (aka OpSim)**: Simulate the operations of the telescope (motion of the motors) as well as the scheduling of observations.
- **Metric Analysis Framework (MAF)**: Analyze and visualize how well an astronomical survey performs.

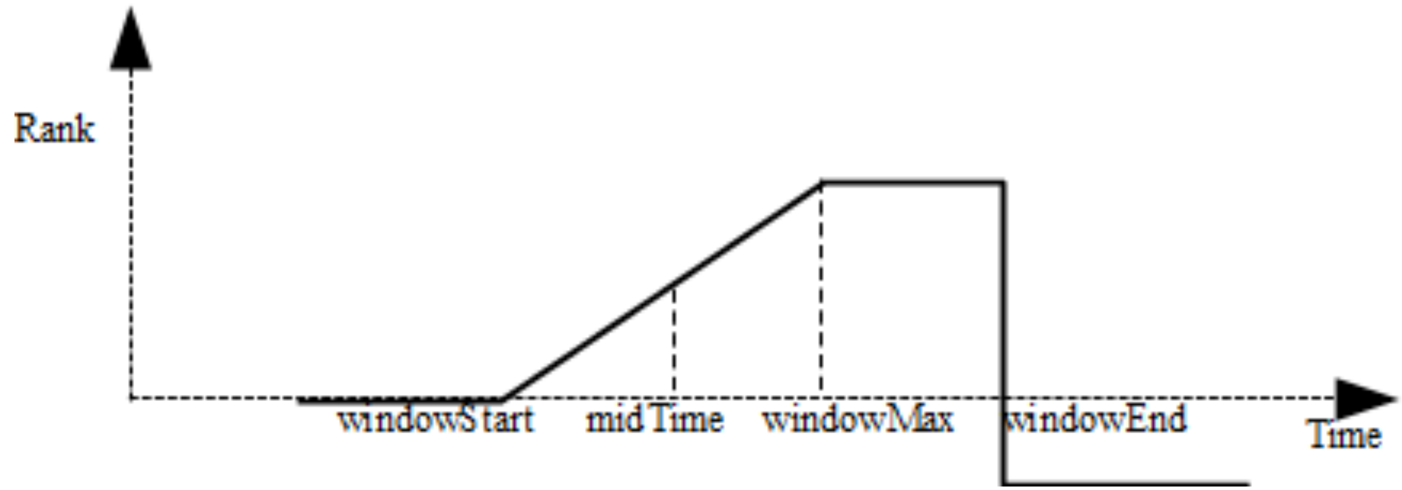
We hope we can approximate a few of those components when doing the scheduling strategy optimization

OpSim: an adaptive simulation tool

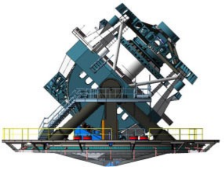
- High fidelity model for limitations and operational overheads of telescope and instrument
- Ephemeris: time windows when a particular observation is possible – predictable time constraints
- `Models' for observing restrictions placed by weather and other downtime
- Optimization methods and algorithms that make operational decisions that maximally deliver the desiderata given the constraints of telescope, instrument and environment
- Mechanism(s) for specifying science driven desiderata
- Metrics Analysis Framework:
  – tools that help diagnose the mechanics of the simulator in delivering the desiderata and can be used to develop figures of merit, metrics, and other representational forms
  – Tools that will be deployed to the community

Optimizing time constraints

- Basic parameter: time window for visit intervals



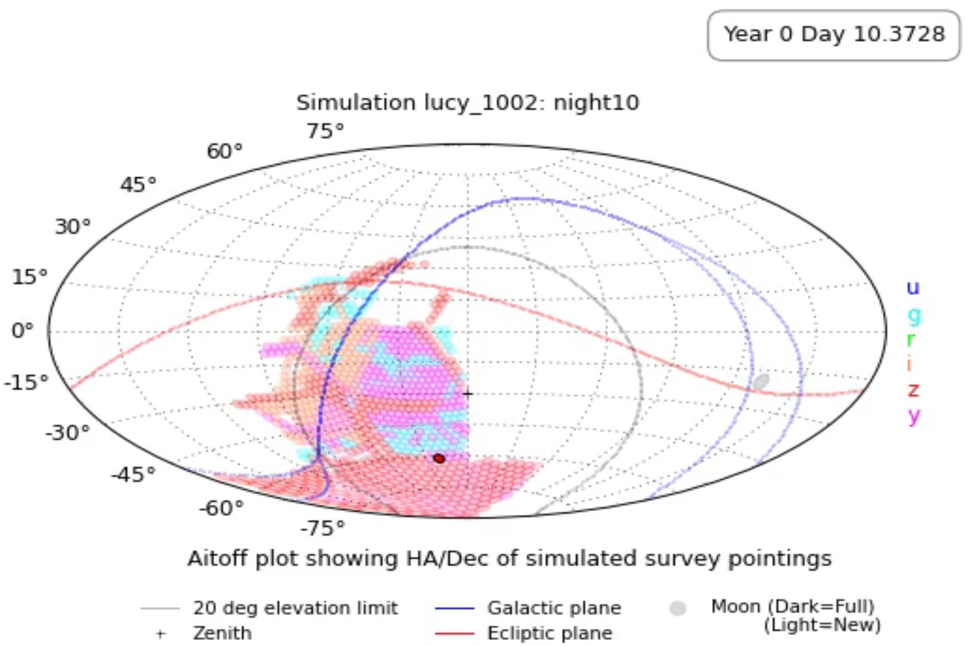
- Each field has a sequence of visits with time intervals.
- **This rank envelope promotes visits as close to the desired intervals as target competition allows**

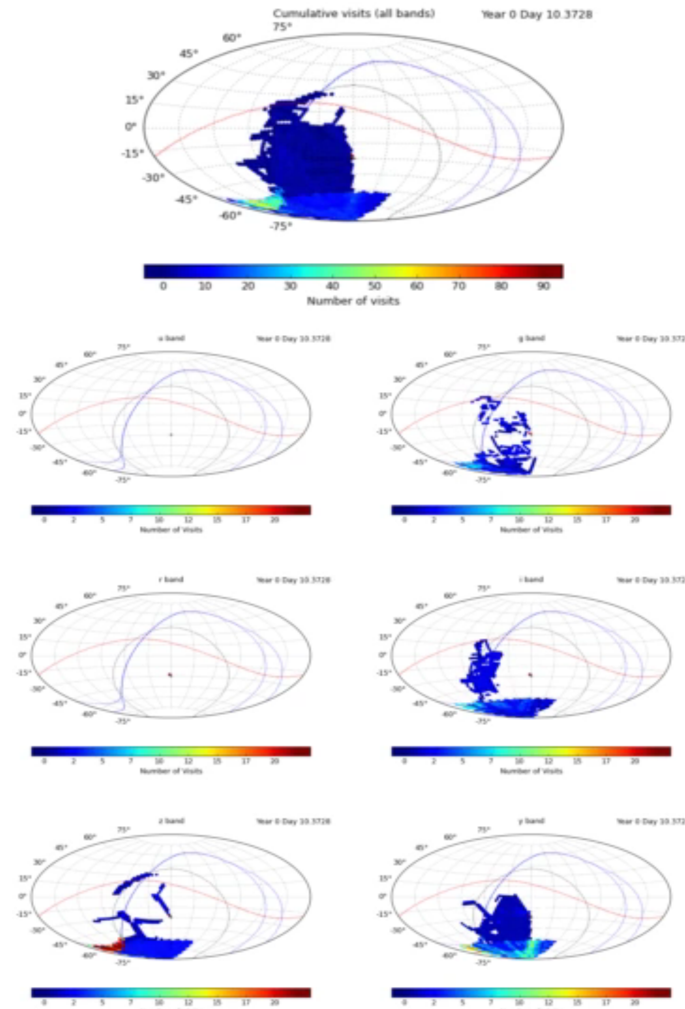


OpsSim “scheduler”

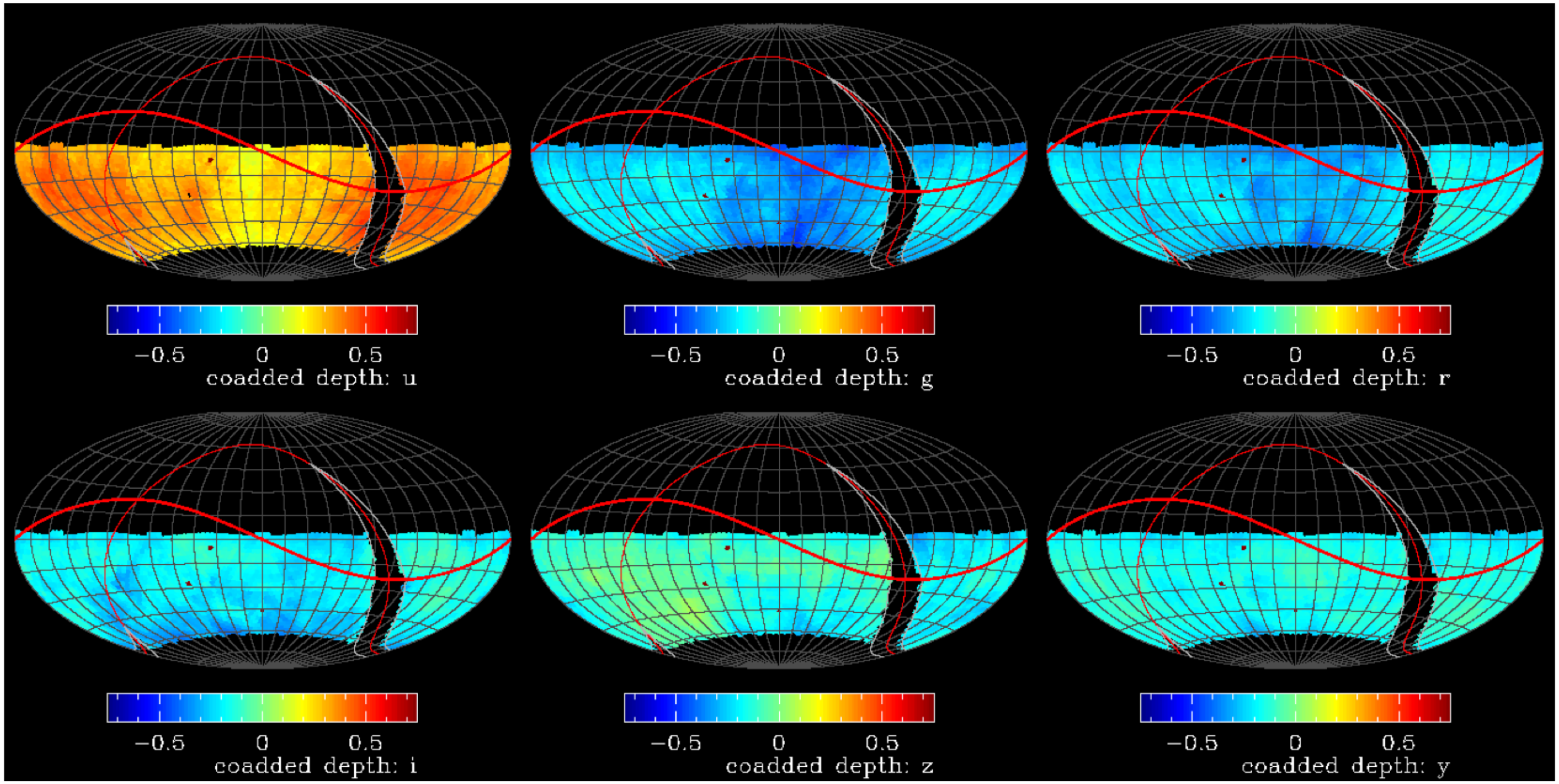
- Prototype implementation (greedy algorithm)
  - Each science proposal selects candidate targets that comply with requirements for airmass, sky-brightness and seeing.
  - Each proposal computes the scientific merit for each target according to distribution and cadence requirements.
  - The observation scheduler combines all the targets and computes slew cost for each one
  - Computes the overall rank and selects the best
  - **Search all fields and select one with the highest weight**
  - **Objective function optimizes the total number of visits**

Observing the sky





OpSim v3.3: a simulated survey(s)



The Operations Simulator output

- What 2.5 million LSST visits might look like.
  - Pointings on the sky, filter, and their timestamp
  - Weather, cloud, sky brightness, seeing for the observation
  - Scheduled and unscheduled down time
  - A scheduler that balances several science goals
- OpSim scheduler based on “Proposals”
  - Wide-Fast-Deep (“the main survey”): 18,000 sq deg
  - North Ecliptic Spur: Solar system objects
  - Deep Drilling Fields: ~6 deep fields
  - Galactic Plane
  - South Celestial Pole

What ideas can we exploration

- Changes in the definition of the survey area
- Change the total number of visits
- Changing the number of pairs of visits per night
- Changes in the proposal definitions
- Airmass and observing limits
- Integration times by filter

- Dithering (though MAF)
- Focal plane geometry (through MAF)

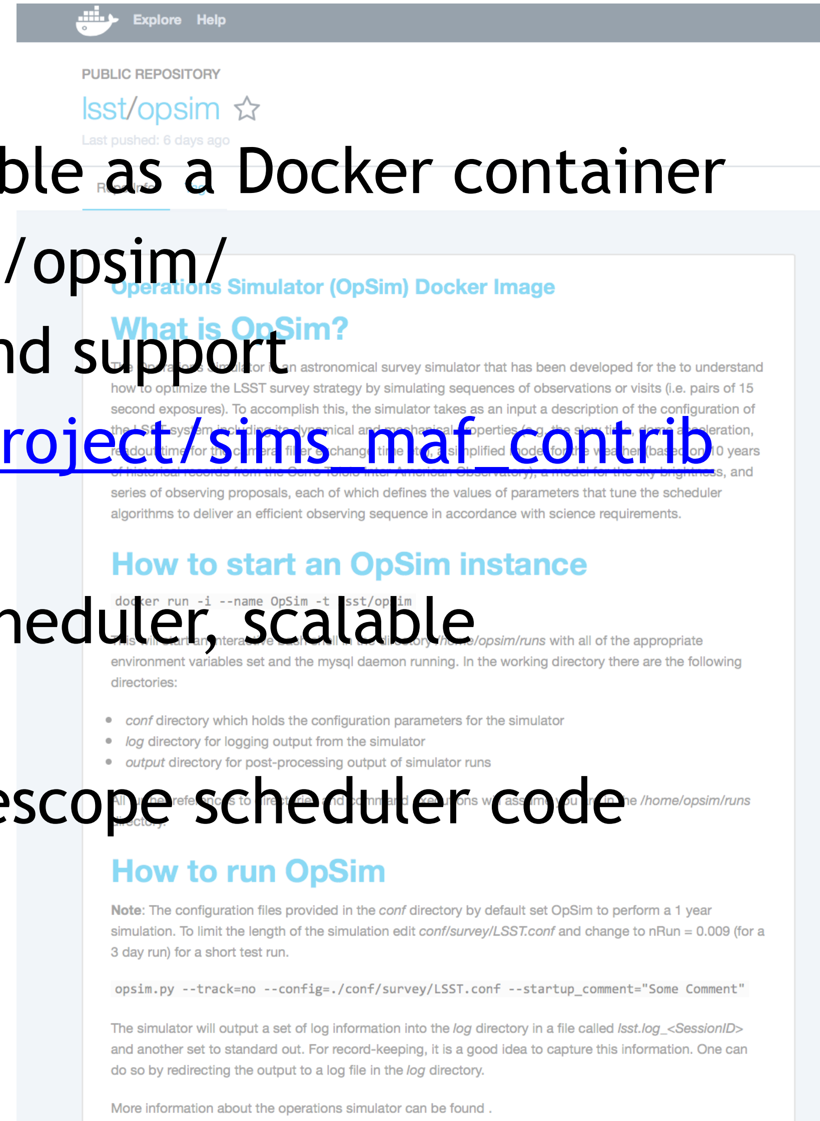
Surveys that exist

Setup	Simulation Name	Description of the Survey Setup
0	enigma_1189	Modern Version of the Baseline Cadence A candidate replacement simulation for the current Baseline Cadence (opsim3.61) produced with the latest version (v3.2.1) of the Operations Simulation (OpSim) code. The following adjustments have been made: includes Science Council approved Deep Drilling fields; Wide-Fast-Deep (WFD) design specification for areal coverage (18,000 deg) & WFD "boosted visits" = 75, 105, 240, 240, 210, 210 for u, g, r, i, z, & y filters where g, r, i and z visits are collected in pairs separated by about 30 minutes; includes revised scheduled downtime as well as random downtime; minAlt = 20 deg; MinDistance2Moon = 30 deg. Note that SRD design visits = 56, 80, 184, 184, 160, 160 for u, g, r, i, z, & y filters.
1	ops2_1098	Uniform cadence (WFD), which asks for visits in pairs, and no other proposal.
2	ops2_1093	Only uniform cadence (WFD), but does not require pairs of visits.
3	kraken_1033	As the baseline cadence (Setup 0), but does not require pairs of visits.
4	enigma_1271 enigma_1266	As the baseline cadence, but requests 3 visits per Wide-Fast-Deep field chosen instead of 2 visits, using the same window function for both 1-2 visits and 2-3 visits. As the baseline cadence, but requests 4 visits per Wide-Fast-Deep field.
5	kraken_1034	As the baseline cadence, except that the u-band exposure time is 60 sec instead of 30 sec.; Nvisit for the u-band remains the same.
6	kraken_1035	As the baseline cadence, except that the u-band exposure time is 60 sec instead of 30 sec; Nvisit for the u-band is decreased by a factor of 2.
7	kraken_1036	As the baseline cadence, except for a shorter visit exposure time: 20 sec instead of 30 sec. Deep drilling proposal has visits based on 30sec exposure due to code issues.
8	kraken_1037	As the baseline cadence, except for a longer visit exposure time: 60 sec instead of 30 sec.
9	ops2_1092	Pan-STARRS-like Cadence This is the uniform cadence, and no other proposal, keeping pairs of visits, but increase the area to include everything with Dec <+15 deg (about 27,400 deg2), and keeping the default airmass limit of 1.5.
10	kraken_1038	As the baseline cadence, except for the more relaxed airmass limit of 2.0 instead of 1.5.
11	ops2_1096	As Setup1 (uniform cadence with no other proposal), except for the more relaxed airmass limit of 2.0 instead of 1.5.
12	ops2_1097	As Setup 1 (uniform cadence with no other proposal), except for the more stringent airmass limit of 1.3 instead of 1.5.

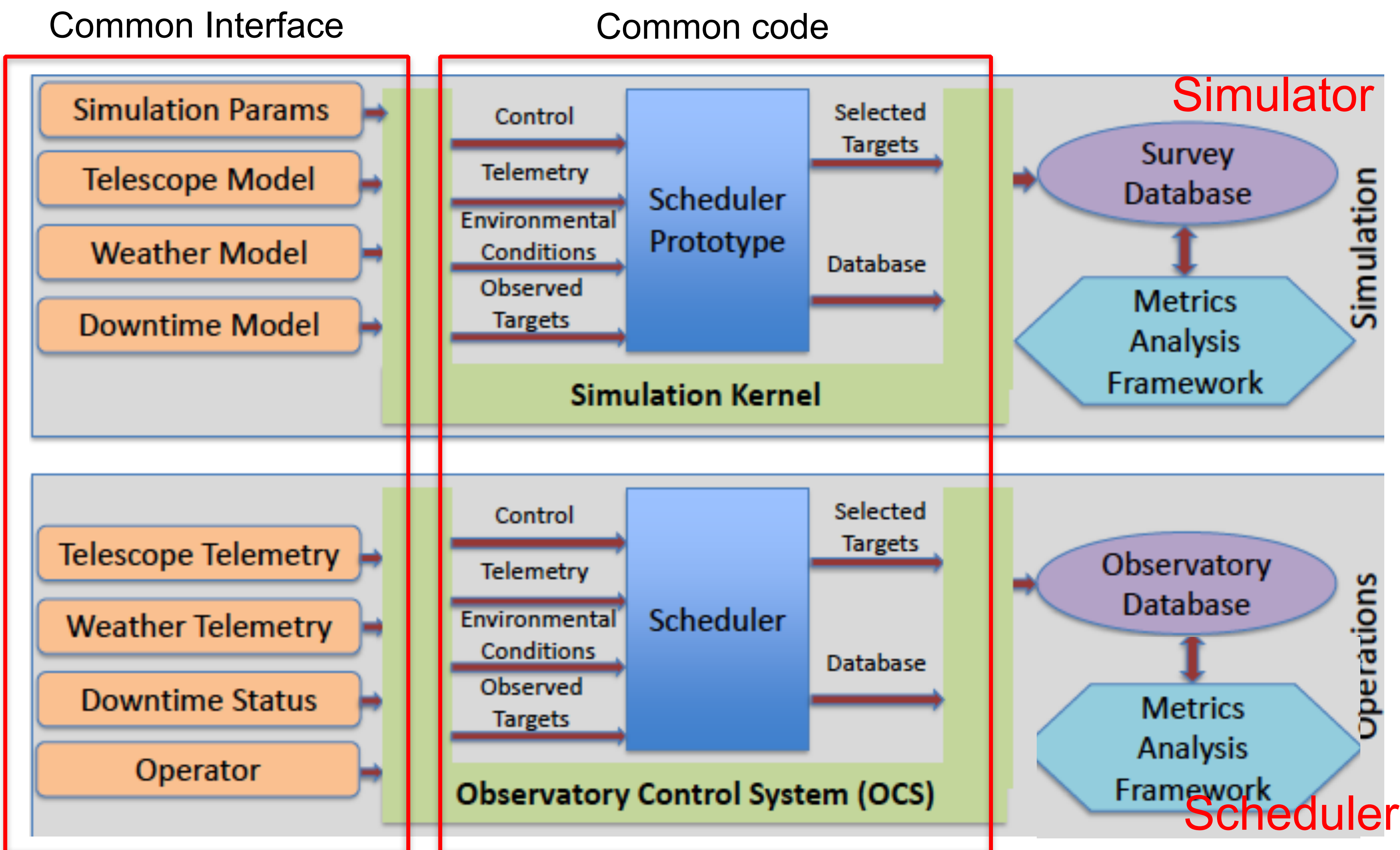
http://ls.st/p1r~

Status and future plans

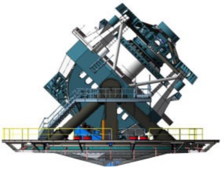
- Release of OpSim
  - Promised for June 2015. Available as a Docker container
  - https://hub.docker.com/r/lsst/opsim/
- Continued development of MAF and support
  - https://github.com/LSST-nonproject/sims_maf_contrib
- Development of v4
  - Modular, simulated OCS and scheduler, scalable
  - Initial delivery Aug 2016
  - This will eventually be the telescope scheduler code
  - Limited support for v3.3



Scheduler/simulator Interface



Go write down your ideas and pseudo code (or code)



Opsim

- What it is
- What does
- How it currently works
  - What ideas explorations can it support
  - What cant it – editing the code
- What happens next
  - What are your expectations

You should worry less about how we solve it scheduler vs how your science performance is impacted and what desiderata we should be considering

Metrics are important

Does survey strategy matter?

- Examples of questions you might want to address:
  - the amount of sky coverage (as a function of season)
  - the sampling of the galactic plane including number of bands and over what timescale (can we take all u-band in one year)
  - how many bands must be observed to start getting out science
  - what signal-to-noise is required within each band for your science (e.g. photometric depth for photoz)
  - for transient science what measurements are needed to determine how well you can discover a transient (e.g. time sampling of observations - pairs, triplets, n-tuples)
  - for transients and variability what metric would be used to define how well you can characterize/classify a source (e.g. number of colors over what period)
  - and so on….