

## Scheduler Manual

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### 1. Overview

The LS4 scheduler reads in a plan of observations (aka "fields") from a text file, and sends commands to the control programs for the telescope (questctl) and the LS4 camera (ls4\_ccp) to implement the observations. The scheduler determines which fields will be observed and their order depending on codes in the observing plan and observational constraints specific to the type of observation.

On the highest level, the code flows as follows:

```
Read in and initialize observation plan.
```

```
Wait until sun goes down, dome opens, and telescope is ready to command.
```

```
While not yet morning twilight:
```

```
    if telescope ready:
```

```
        if stop requested:
            stop telescope tracking
```

```
        else if bad weather:
            stow the telescope and close dome
```

```
        else if dome is closed or scheduler is paused:
            wait 10 sec
```

```
        else:
            select next field to observe.
            Point telescope and take exposure.
```

```
    else:
        wait 10 sec
```

```
Stow telescope, close dome and exit
```

### 2. Observation Plan

Each line of an observation plan ("obsplan") specifies the following:

**ra, dec** : telescope pointing (hours, deg)

**expt** : exposure time (sec )

**shutter code** : ( explained below)

**n\_required** : required number of exposures

**interval** : requested exposure interval (sec)

**survey code** (explained below).

**comment** (extra info for reference purposes)

**Survey Codes** (integer from 0 to 4):

0: no survey (generic observation)

1: Trans-Neptunian Object survey

- 2: Supernova survey
- 3: Must-do high-priority code
- 4: Ligo event followup

**Shutter Codes** (upper or lower case):

- N: dark field (see note below)
- Y: sky field
- F: focus field
- P: pointing-calibration field
- E: evening twilight flat
- M: morning twilight flat
- L: dome flat

Note: darks with dec = -1, 0, 1 deg will be observed in evening twilight, dark time, and morning twilight, respectively. Otherwise, there is no time restriction.

### 3. Observation Selection

Before each observation, the scheduler updates the status of every planned observation. The relative status of the observations and their selection constraints determine the next observation to make.

**Selection Constraints**

- **pointing limits** (e.g. limiting airmass, hour angle, galactic latitude, moon separation)
- **exposure requirements** (expt, n\_required, interval)
- **observable sky** (visible area of night sky).
- **interruptions** (dome closed for weather or maintenance).
- **observation cadence** (minimum time between observations).
- **survey code** (survey-specific constraints)

**Field Descriptor**

Internally, the scheduler maintains a field descriptor for every planned observations. This records the current status and observing parameters (see "Field" structure in "scheduler.h"):

- **survey code** (from obsplan)
- **shutter code** (from obsplan)
- **status code** ( see descriptions below )
- **pointing info** (ra, dec, galactic lat, long, lunar separation)
- **exposure info** ( expt, n\_required, interval)
- **rise/set times** (UT hours and Julian Days `ut_rise`, `ut_set`, `jd_rise`, `jd_set`)
- **expected time of next exposure** (Julian Date `jd_next`).

- **number of completed exposures** (**n\_done**)
- **up time** before field sets or sun rises (**time\_up**)
- **completion time** for remaining observations (**time\_required**)
- **time left** before time\_required exceeds time\_up (**time\_left**)
- **completed exposure info** (**filename, ut, jd, lst, ha, am, actual\_expt**)
- **doable flag** (1/0 if the field will/won't be observable in the remaining time)

#### **status codes:**

**too\_late** : observable, but not enough time for remaining required exposures  
**not\_doable**: observations are not longer possible of this field  
**ready** : the field can be observed now  
**do\_now** : the field can be observed and is of highest priority

#### **Selection Algorithm**

##### **init\_fields** (start of night):

Initialize field descriptors for every observation.  
Set n\_observable to number of doable fields.

##### **get\_next\_field** (each time a new observation is made):

Loop through the field descriptors of every planned observation in two passes.

##### **Pass 1:**

##### **update\_field\_status:**

Set doable\_flag=0 and status\_code to "not\_doable" for all fields satisfying any of the following:

- now completed (n\_done = n\_required)
- outside observing limits
- not ready to be re-exposed

Update values in following tables:

##### **Indices of earliest doable fields meeting specific criteria:**

<u>Field Index</u>	<u>Field Criterion</u>
<b>i_min_do_now</b>	sky fields with do-now status
<b>i_min_dark</b>	dark fields with do-now status
<b>i_min_flat</b>	dome or sky flat

##### **Tallies of doable fields meeting specific criteria:**

<u>Tally Name</u>	<u>Field Criterion</u>
<b>n_ready_must_do</b>	ready status, must-do code
<b>n_late_must_do</b>	too-late status, must-do code
<b>n_ready</b>	ready status, not must-do code
<b>n_do_now</b>	do-now status, all survey codes
<b>n_late</b>	too-late status

Minimum values for parameters of fields meeting specific criteria

Minimum Name	Field Parameter	Field Criterion
<b>n_left_min_must-do</b>	n_remaining	ready status, must-do code
<b>n_left_min</b>	n_remaining	ready status, not must-do code

## Pass 2:

Consider each of following criteria (in order) until one is found with matching doable fields. For criteria 3, 4, and 5, select the earliest matching field from the obsplan. For criteria 1, 2 and 7, choose the field with the least time\_left. For criteria 8, choose the field with the most time left assuming (and exceeding 0).

criterion 1: **status = "ready" and survey\_code = "must-do"**

Criterion 2: **status = "too\_late" and survey\_code = "must-do"**<sup>1</sup>

Criterion 3: **status="do\_now" and shutter\_code = dome, evening, or morning flat**

Criterion 4: **status="do\_now" and shutter\_code = dark**

Criterion 5: **status="do\_now" and not (dark or flat)**

Criterion 6: **doable** and paired with previously observed field<sup>1,2</sup>

criterion 7: **status = "ready" and survey\_code not "must-do"**

criterion 8: **status = "too\_late" and survey\_code not "must-do"**<sup>1</sup>

Notes:

1. the considered fields will have their exposure interval shortened so that completion\_time = time\_up (all remaining exposures become observable)

2. paired fields are consecutive fields in the obsplan that are both sky exposures (shutter code "Y" ) and for which the separation in the sky parallel to the equator is less than a fixed interval (RA\_STEP0 = 0.05 deg). This is meant to fill the gaps between CCDs in the LSQ camera.

## 3. Observing Cadence

The cadence of the observations depends on the staging of 4 key operations:

- (1) exposure time (time shutter is open).
- (2) image readout time (~20 sec for dual-amp readout, ~40 sec for single-amp readout).
- (3) transfer time of the image data from the controllers to the host computer (~5 sec).
- (4) the time to slew and position the telescope and dome for the next observation (> 20 sec).

Three cadences are possible, but only cadence 1 is currently implemented.

## cadence 1. linear staging

The simplest way to stage the operations is one at a time.

expose -> readout -> transfer -> slew -> ....

**cadence 2. Parallel slew**

A faster cadence is achieved by parallel staging the telescope slew during the image readout and transfer:

```
expose -> readout -> transfer -> exposure -> readout -> transfer -> ...
      slew                                slew
```

### cadence 3. Parallel slew and transfer

The optimal cadence is achieved by parallel staging slew and transfer with readout and expose. This is possible because the camera controllers have multiple buffers in memory allowing transfer of previously read image data while new data are being read out:

```
expose -> readout -> expose -> readout -> expose -> readout -> ...
      slew      transfer      slew      transfer      slew
```