Subject: LDT Boresight Cameras
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This document describes the planning and design for one or more boresight cameras for the Lowell Discovery Telescope (LDT). The current thought is to place such camera(s) in the top-ring assembly behind the M2 support structure, where it would be out of the beam path.

1 Background

As an advanced modern large-aperture telescope, the LDT should have all available tools on hand to help provide the maximum scientific output from a given night of observing. Existing tools, such as on-site weather information and sensors of all types placed on and around the telescope, provide good support for this goal, but currently LDT does not have means for directly measuring the astronomical observing conditions. A boresight camera or cameras can provide ancillary data to provide context for the main science data being collected by the telescope and to allow for intranight observation planning based on current conditions.

The current configuration of the telescope's top-ring assembly, which supports the secondary mirror (M2) and dome flat calibration lamps, has _____ m^3 of available volume *behind* M2 that is out of the main beampath. This design document describes the science justification for a boresight camera complex, the science and technical requirements thereof, and then delves into the design criteria and so forth.

2 Science Justification

There are three main science drivers for constructing and installing a boresight camera complex at LDT. The first is to provide context for the science data being collected by the instrument(s) on the cassegrain instrument cube. Night sky brightness estimates from the boresight camera can be used to provide detection threshold estimates for photometry. By using multiple bandpasses in the visible, estimates of the opacity can be obtained that can inform de-redenning of data sets. Having a camera in the complex with sufficient plate scale to measure stellar profiles can provide an independent measure of the seeing to compare with that found at the instrument cube. Finally, the ability to spot satellites nearing the main telescope FOV can (if paired with the ability to pause exposures) limit the damage to scientific observations from these reflective objects.

The second science driver is to allow for intranight observation planning based on current conditions. Although LDT operates in a classical rather than queue mode, observers themselves may choose to alter their night plan to maximize the scientific return of their telescope time. In the visible portion of the spectrum opacity, sky brightness, and seeing can play a role in choosing targets or organizing an observing run. It is even conceivable that simply having access to such realtime information would encourage observers to create observing lists or programs that can tolerate different atmospheric conditions. If, in the future, the LDT does transition (even partially) to a queue mode, these measurements are critical for ensuring the best science. Inclusion of a NIR camera in the boresight complex could allow for s direct estimate of the water column along the line of sight, appraising infrared observers of the level of absorption to be expected.

Longterm sky monitoring is the third science driver for the boresight camera complex. It will be possible to develop season-to-season and year-to-year models for atmospheric opacity, night sky brightness, and precipitable water vapor. Longterm monitoring has been established for many of the environmental conditions at the site, as well as for items such as the telescope pointing model. We are in the process of analyzing longterm trends in LMI image quality, as defined by stellar FWHM. Data from a boresight camera complex would add to this collection of understanding about the longterm trends at the LDT site. Furthermore, the correlation of sky measurements from a boresight camera complex with other environmental measurements can provide a basis for predictive modeling and observation planning.

3 Science Requirements

The boresight camera complex shall be able to:

- Measure the atmospheric opacity in realtime by comparing stellar photometry in different bandpasses.
- Measure the night sky brightness in one or more bandpasses.
- Provide an independent measure of the seeing at the top of the telescope.
- Provide warning of satellites or other bright phenomena approaching the telescope FOV.
- Estimate the water vapor content of the atmosphere along the line of sight.

4 Technical Requirements

Okay, here's a first stab at this:

- Opacity: 2-color visible bandpasses. Possibly easiest with 2 separate cameras (identical setups modulo the bandpass filter) to minimize mechanical motions and provide realtime comparisons. Wide-field camera preferred to provide context over many square degrees.

- Night sky brightness: One of both of the 2-color visible bandpasses from above can be used to measure the sky brightness. Wide-field camera can provide a broader estimate to remove issues with localized nebulosity, etc.
- Seeing: Separate camera with sufficient plate scale to resolve stellar profiles.
- Satellites: One or more of the wide-field visible cameras.
- PWV: Near-infrared (J or H) camera to measure the background flux at the edge of OH bands to estimate the water vapor content of the atmosphere.

Technology:

- CCD vs CMOS detectors? Need to investigate where the wind is blowing in terms of performance, cost, maintenance, and long-term support.
- Near-IR detectors / filters? What is the FOV requirement for the NIR camera?
- Telescope / Lens needed for each of the 4 separate cameras? Something about 400mm - 1000mm lens.

5 Design Criteria

TBD.

6 Vendor Quotes

TBD.

7 Technical Design

TBD.