SkyCam
Functional Requirements Document (FRD)

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v0.5: Initial outline, text, and figures.

Purpose of this document

The purpose of this document is to provide functional requirements for a proposed 10 micron all-sky cloud camera to be placed at CTIO to support the Dark Energy Survey.

Terminology

APO: Apache Point Observatory[1]
ARC: Astrophysical Research Corporation
DECam: Dark Energy Camera
DES: Dark Energy Survey
DIMM: Differential Image Motion Monitor
IRSC: Infra-Red Sky Camera[2]
SDSS: Sloan Digital Sky Survey[3]
TASCA: Tololo All-Sky CAmera[4]

Functional Overview

The SkyCam system should:

1. image the full sky at a wavelength of ~10 microns once every 30 seconds throughout the course of nightly operations of the Blanco 4.0m telescope,
2. process the images in real-time,
3. output in real-time a GIF version of the processed image to a webpage,
4. output in real-time a quantitative diagnostic indicating the cloudiness of the sky (e.g., the rms of the pixel values from the most recent processed image) to a web-accessible graph and to an archival database,
5. create an animation based upon the processed images from the past hour to detect cloud

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[1] http://www.apo.nmsu.edu/
[2] http://www.ctio.noao.edu/telescopes/dimm/dimm.html
[3] http://www.sdss.org/
[4] http://www.ctio.noao.edu/~david/tasca.htm

movement and output the animation to a webpage,
6. create an animation based upon the full night's processed images at the end of each night, and
7. archive the raw and processed FITS images, processed GIF files, the full-night animation to a web-accessible directory.

These functional requirements are based upon the actual functionality of the APO IRSC, which, in its current incarnation, has been operating successfully since 2001.[5]

Context

In order to make optimal use of the DECam for the Dark Energy Survey (DES), observations of standard star fields will be sparse in the time domain. Therefore, it will be difficult to ascertain how photometric a given observation is, especially in the first year of observations when tilings will still be few in number. Therefore, it is necessary to use an independent method of determining the sky conditions. At APO, a 10 micron all-sky camera is used to determine the photometric quality both for SDSS and for ARC3.5m observations, and has proven hugely successful for this purpose.

At CTIO, a Differential Image Motion Monitor (RoboDIMM), an optical all-sky camera (TASCA), a Multiple-Aperture Scintillation Sensor (MASS), and a weather station all help to monitor sky conditions. These all have their own individual strengths and weaknesses in determining the photometric conditions over the full sky. A 10 micron all-sky camera (SkyCam) will provide an essential addition to this suite of monitoring tools.

Processing Outline

TBD.

Data Products

TBD.

Implementation

We recommend implementing a duplicate of the current incarnation of the Apache Point Observatory Infra-Red Sky Camera (IRSC). This is a well-tested system, and relatively inexpensive (on the order of $15,000 in total for parts, which includes the price of the mid-IR video camera.) The following discussion draws heavily upon the APO IRSC documentation website, which is at http://hoggpt.apo.nmsu.edu/irsc/irsc_doc/ .

The APO IRSC uses a Raytheon Thermal-Eye 300A[6] mid-IR detector suspended above a hyperbolic aluminum mirror (see Figs. 1 & 2). This camera, which works similarly to a low-resolution surveillance video camera, images the full sky down to the horizon at a rate of 30 Hz (i.e., 30 images per second). A standard, off-the-shelf video framegrabber digitizes this video output. The resultant images are co-added and then made available for display in 30 second intervals. These raw FITS images are then further processed to mask out the camera's support

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[5] http://hoggpt.apo.nmsu.edu/irsc/tonight/

[6] Note that Raytheon no longer manufactures the Thermal-Eye 300A. A similar product, however, is the Raytheon Thermal-Eye 300D, which is described at http://www.raytheoninfrared.com/productcatalog/prodItem25.html and at http://www.raytheoninfrared.com/admin/file/300D_elec_9.pdf .

structures, and the brightness and standard deviation of the sky is then calculated. The images are converted to PGM/GIF image format for display on the web, and the positions of the SDSS 2.5m and the ARC 3.5m telescope pointings as well as an alt-az grid is overlaid on each image (Figs. 3 & 4). The webpage also displays running graphs of the sky brightness and the sky standard deviation.
The sky standard deviation is robust in determining structure in the sky images (i.e., in detecting clouds, even light cirrus.)

The greatest advantage of the Raytheon 300 series camera is that it outputs images at 10 micron wavelengths at video rates with a reasonably good response. A disadvantage to this camera is that it has built-in autonormalizing and autoscaling functions, which confound methods of properly calibrating the sky brightness Nevertheless, the sky brightness can still be used for diagnostic purposes and therefore it is plotted along with the standard deviation to watch cloud cover trends throughout the night. Figure 5 shows an example of both plots; in the sky standard deviation plot, the horizontal green line indicates the empirically determined value below which conditions are photometric.

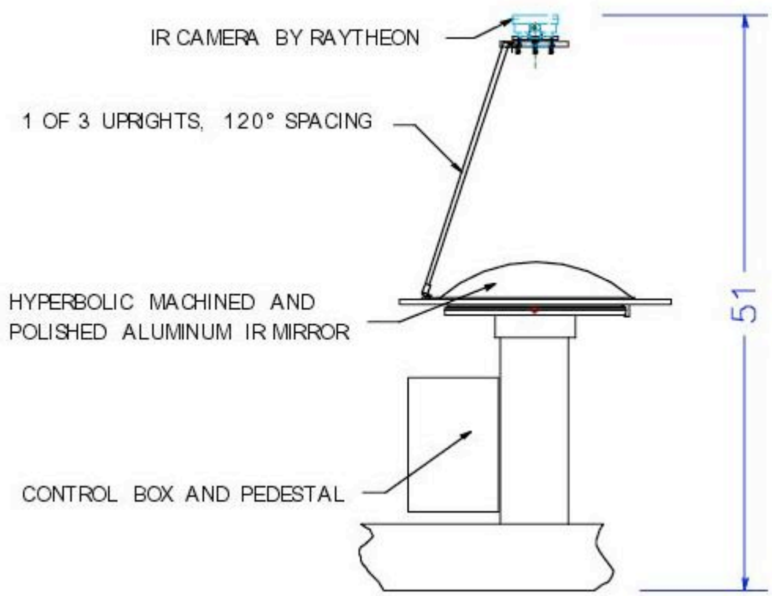

Fig. 1: Design of the current APO IRSC, commissioned in 2001.

Fig. 2: A photograph of the APO IRSC.

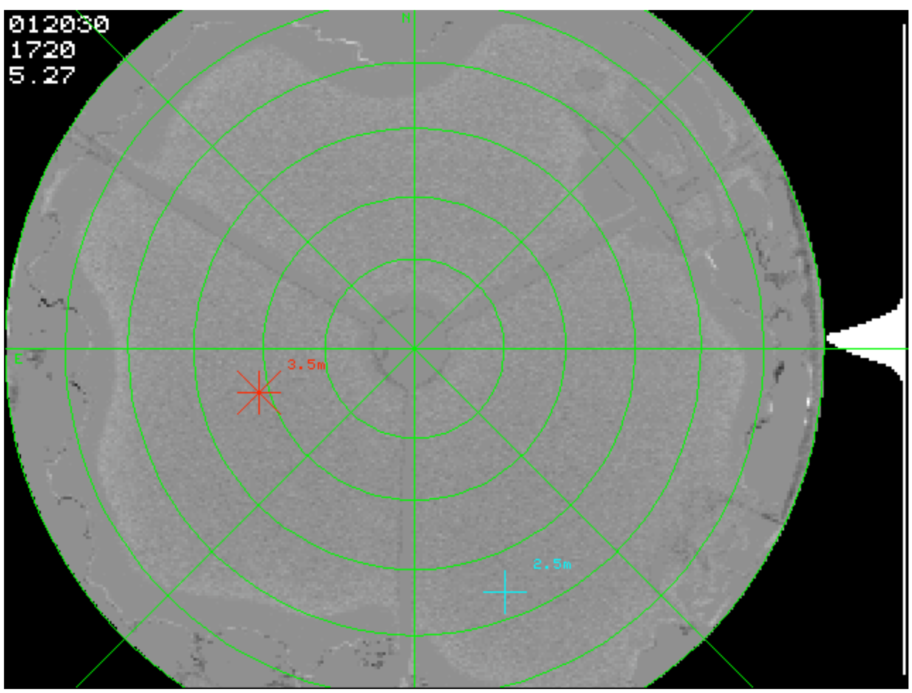

Fig. 3: A processed all-sky image from the APO IRSC under photometric conditions.

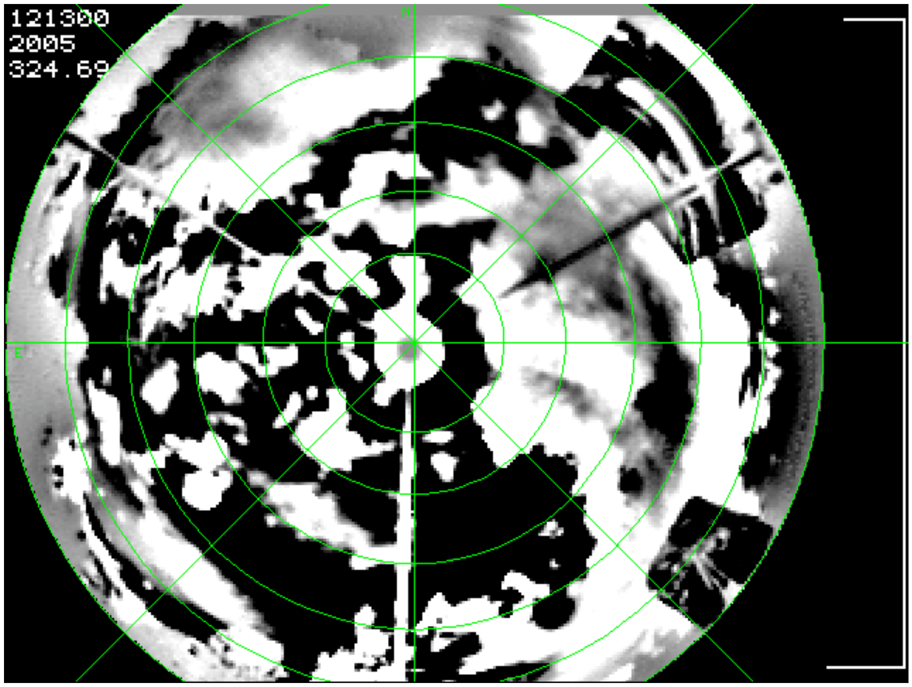

Fig. 4: A processed all-sky image from the APO IRSC under non-photometric conditions.

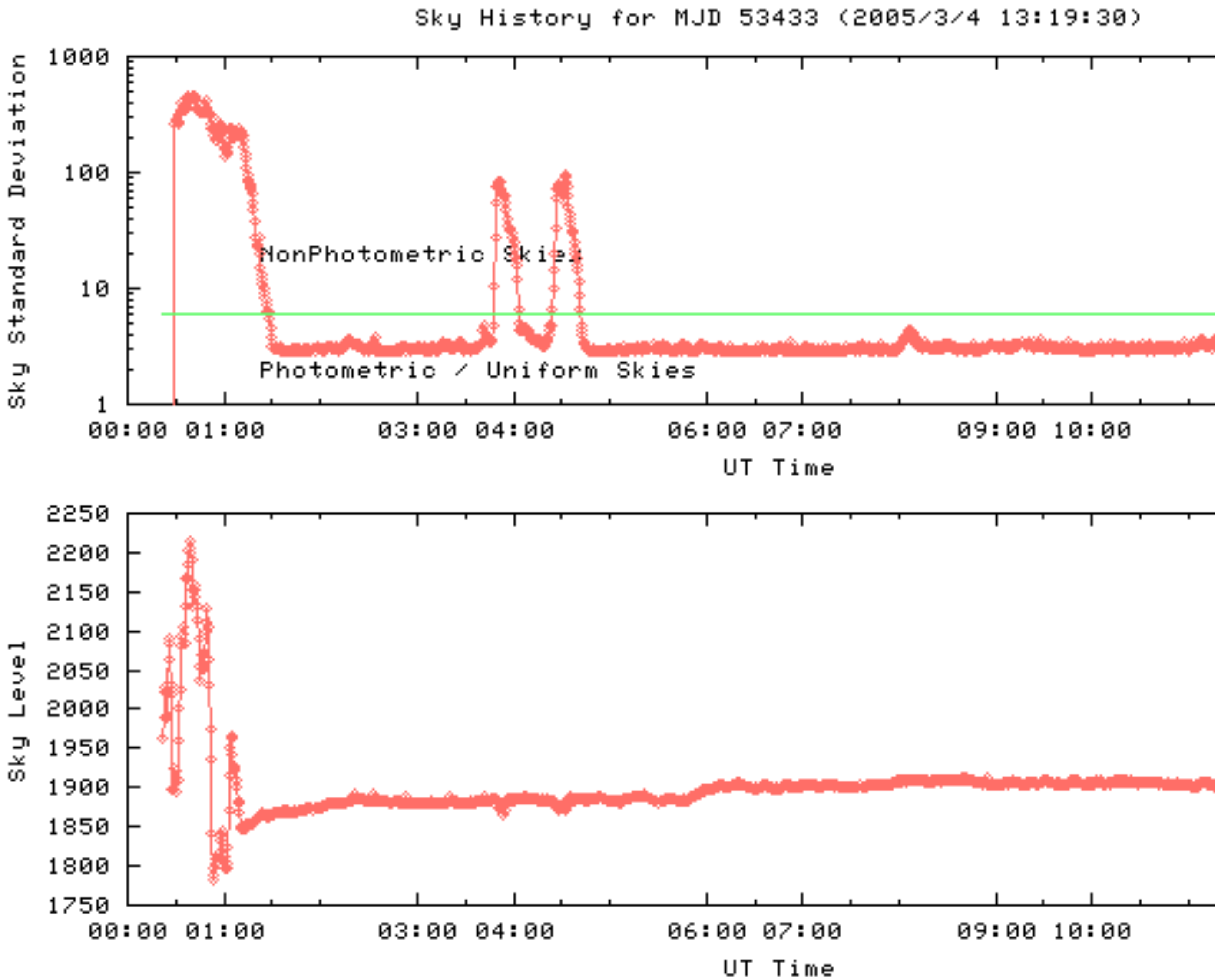

Fig. 5: The standard deviation of the pixel values of the all-sky image vs. time (top) and the sky level vs. time (bottom) for the night of MJD 53433. The horizontal green line in the upper plot indicates the empirically determined value separating photometric and non-photometric conditions. An mpeg movie of the cleaned all-sky images for this night can be found at http://hoggpt.apo.nmsu.edu/irsc/movies/53411.mpg .