The International Dark-sky Association/Vatican Observatory Night-sky Brightness Monitor

Set-up and Description

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Introduction

The International Dark Sky Association (IDA http://www.dark-sky.org/) and Vatican Observatory (http://vaticanobservatory.org/) night-sky brightness monitor (NSBM) is a system designed for automated long-term monitoring of the night sky brightness. Measuring changes in night-sky brightness over time or location is important to document the effects of artificial lighting that can adversly affect scientific research, biological systems, and aspects of cultural heritage. Each NSBM system, which is built through a contract with Matrix Products Development (http://matrixpd.com), consists of an indoor base unit, which controls the system software and stores the data, and an outdoors head unit that employs two pointable brightness meters. The NSBM measures sky brightness every 60 seconds in an area of sky approximately 6 degrees in diameter and stores the results in files which may then be automatically emailed to a central site (at IDA) for storage.

This guide is intended to help users set-up, troubleshoot, and maintain the NSBMs. It also documents aspects of the system hardware and software.

System Components & Requirements

The **base unit** (see Fig. 1) consists of a 17x16x4 cm plastic box containing data storage and control software for the NSBM system along with a wireless transmitter for communications with the remote head unit. The base unit has a plug for a 9V DC 800mA power supply (such a power supply is provided for each base unit for use with 120V AC outlets). The base unit also has an input plug for an ethernet cable. The settings for the NSBM are controlled by filling in forms on WWW-like pages once connected to the IP address of the base unit. Finally, the base unit has an LCD display which displays the units operational status.

The **head unit** (see Fig. 2) is an approximately 40x40cm metal and plastic device designed to be mounted outdoors with its metal plate in a vertical position and solar panels oriented south or north in the direction of the prevailing sun. The head unit contains two sensors, sealed in metal cylinders with lenses to focus on the sky. The cylinders are plugged into light baffling tubes with bird guards on one end and are connected to the head unit electronics with cabling. The two sensors may be pointed in different directions, keeping in mind the restrictions on pointing

near the sun. The head unit electronics box (Fig. 3) contains a wireless transmitter/receiver and a 6.7V SLA battery which provides power during the night and is recharged in sunlight.

The **requirements** of the NSBM system are:

A weather-proof environment for the base unit, including power and an ethernet-based internet connection with DHCP to assign the system one IP address.

A mount for the head unit a short distance from the base unit (nominally 100m, but perhaps less depending on obstructions that may interfere with the wireless link).

Warnings

1. Do not point the sensors toward the sun. The head unit and baffling tubes should be mounted so that the sun is at least 10 degrees from the pointings at all times of the year.
2. Handle the electronics carefully. It is advisable to ship the head unit with the battery disconnected (cables from the battery can be unclipped from the head unit electronics).

Set-up Procedures

1. Connect the head unit to its ethernet connection followed by its power. When power is supplied the LCD display should display at least the firmware version found in its flash memory. It will cycle through other status indicators as they are set. At this time the head unit will request an IP address using DHCP. When one is found, this will be displayed on the LCD.
2. Plug in the SLA battery found in the head unit electronics box. If it is already plugged in, unplug it and replug to cycle the power. The battery charge may be low so it is helpful to put the solar panels in the sun for recharging.
3. If there is sufficient charge in the SLA battery, the LCD of the head unit will indicate that the wireless connection is established and will display a signal strength (provided that the head unit is sufficiently close). An RSSI of 50 is apparently sufficient signal strength.
4. Now use a computer to connect to the head unit using a web browser which is directed to the IP adress as an URL. E.g., http://256.256.256.256 where the IP address is the one in the head unit's LCD display. You will be prompted for a username and password

which are set to ‘dan’ and ‘sirius’. After a successful login, you should see the ‘readings page’ which displays the last photometric information from the head unit (when one exists). There are hypertext links at the bottom of the page to a ‘settings page’ and ‘calibrations page’.

5. Next go to the settings page. The NSBM calculates the time of sunrise and sunset because it switches between a nighttime operational mode with sensor readings at 60-second intervals and daytime mode with occasional readouts. Input your longitude and latitude in decimal numbers in the spaces provided (positive latitudes for north and for **west** of the meridian). Input your local time in 24-hour units and date and uncheck the NIST time look-up option. The NSBM using email (SMTP) to transmit its data back to users or a data server. To test this out, enter the IP address for your local SMTP server along with a username and password. Enter an email address for a user who will inspect the data (later the email address will be a centralized server for the worldwide NSBM system). You can also select how many of the 1-minute interval photometric samples to accumulate before sending the data to the recipient. To establish the new inputs, click the ‘Submit’ button.
6. There is a calibrations page with photometric calibration parameters set for each sensor with zeropoint established relative to a master sensor and temperature dependence taken from lab measurements. These should be set for each NSBM prior to shipping, but may be re-input here if needed. Again, to establish the new inputs, click the ‘Submit’ button.
7. When new settings are made which change the NSBM data collection, you must recycle the power on the head unit by unplugging and replugging the battery. You may also need to recycle the power on the base unit as well (by unplugging its power momentarily). Resupply power to the base unit prior and allow it time to establish an IP address before replugging in the head unit battery.
8. See the section on Operations in order to know what to expect when the system is operating normally.

Site Selection and Mounting

Ideally the NSBM should remain in the same location with the same orientation throughout its lifetime so site selection is important. Some requirements and considerations include:

1. There should be sufficient sunlight on the solar panels throughout the year with the solar panels pointed toward the equator.
2. The sky should be unobstructed with allowance for growth of vegetation in the area.

3. Local light sources which shine directly on the monitor should be avoided since the purpose of the system is normally to measure artificial light reflected from the sky.
4. Other local considerations apply. It is desireable to have easy access to the head unit since it will require periodic cleaning and access to the battery when it is being set up. You may also wish to avoid sources of dust contamination or prevailing winds. You will need to test the wireless signal strength to the base unit in its anticipated location. An RSSI signal strength of 70 is strong while 50 is sufficient.
5. You may choose to point one sensor near or at the zenith and the other at lower elevation (e.g. 20 degrees from the horizon) toward a light source of concern such as a city. Make sure that no pointing will be too close to the sun. Since the sun should be avoided by at least 10 degrees, at latitudes less than 34 degrees, zenith pointings must be avoided by tilting the sensor tubes with different holes in the elevation brackets which are spaced at 5-degree intervals.
6. The NSBM head units have holes on their mounting plates to accept bolts on a vertical post. Other holes could be drilled, but in any case mounting the plate against a broad, flat surface will help to prevent a twisting motion in the wind.

Operation Description

Under normal operations, the NSBM switches between a daytime and nighttime mode according to its calculated times of sunrise and sunset, allowing the sun to move some angle below the horizon before taking sky brightness measurements. The calculated sunrise and sunset times can be seen in the head unit's LCD display, but actually represent times at which the sun is some distance below the horizon. During nighttime mode, the NSBM measures the sky brightness for a one minute exposure and records this along with other information about the current usage, battery voltage, and temperatures. These data are transmitted by the wireless link to the head unit as well. If the wireless link is broken, the data are simply stored until it is re-established at which point they are automatically transmitted. The vital data are emailed to a recipient at intervals set in the settings page (the number of readings per email; ie. up to 100 readings may be sent per email which would mean data is emailed when 100 minutes' worth of data has accumulated).

The data email consist of files with lines containing data for each 1-minute reading, appearing similar to the following:

```
10 11/27/09 01:34:33  0 00 CE3EE1 18.866 19.201  0.000 6.28  -15  18.6  17.9    53
```

The columns of data represent:

1. Head unit number: A unique identifier integer that corresponds to the head unit (which contains two sensors that can be swapped in and out).
2. The local date in MM/DD/YY format.
3. The local time.
4. An integer error flag which when non-zero indicates and error. Data transmitted with an error appear to be retransmitted until the error flag reads 0.
5. An unused error flag data column?
6. A serial number for the base unit.
7. The sky brightness in mag/arcsec^2 from sensor #1. The sky brightness reads 0.000 when there is no signal or the sky is too bright for measurement.
8. The sky brightness in mag/arcsec^2 from sensor #2.
9. An unused data column?
10. The head unit battery voltage (full charge is near 6.7V)
11. The current (in mA) drawn by the head unit which is negative when the battery is being discharged as it will during the night. A current of -15mA is normal. When being recharged in sunlight, a positive current of several hundred mA is normal.
12. The temperature in Celcius of sensor #1.
13. The temperature in Celcius of sensor #2.
14. The RSSI signal strength for the wireless connection.

The readings page contains a similar line of data from the last measurement during normal operations. Things to check for include: (1) That the sunrise and sunset times are reasonable, (2) That when two sensors are pointed at the same patch of sky, sky brightness measurements are consistent, (3) That the battery is charged to a voltage near 6.7 after several hours of sunlight, (4) That most lines of data show zero-valued error flags, (5) That the nighttime power usage is normal with a current of approximately -15mA, (6) That the two temperatures are consistent.

Troubleshooting

If you see **inconsistent behavior when comparing the base unit's LCD display and the rest of the system**, try recycling the power on the head unit (unplugging then replugging battery). It may take a minute or so for the head unit to get the proper settings. If this fails, try recycling the power on the base unit as well as the head unit, making sure that when repowering the ethernet cord is connected then the base unit is powered up prior to the head unit.

If you **experience loss of data by the head unit while it is unpowered** the CR2032 type watch battery in the head unit might be at fault. This can be replaced by opening the head unit cover with a screwdriver, removing the Rabbit microprocessor module by taking off the nut and removing it from the socket. The battery can be popped out of its place by using a small screwdriver. Be careful not to bend any pins when removing the board.

If there is **no wireless connection** you will see no RSSI signal strength indicated in the scrolling LCD display on the head unit. This could be the result of a low-charged SLA battery in the head unit or too great a distance and/or obstructing objects between the base and head units. First of all, make sure to recharge the battery by placing the solar panels in sunlight for several hours. A sunny day should recharge the unit with enough power to last several nights in a row. Moving the head unit inside next to the base unit can resolve any questions about whether the battery power is sufficient, but the wireless signal is not getting through.

If the **sunrise and sunset times are incorrect**, the problem most likely lies in the settings page. It is a good idea to recheck the date, time, longitude and latitude making sure particularly that the signs are correct as described in the Set-up Procedures section. If that doesn't appear to be the problem, check that the changes made to the base unit are transmitted to the head unit by recyling the power on both as described above.

Maintenance

The NSBM system is designed to be a low maintenance system. The only routine maintenance anticipated is **regular cleaning of the optics**. To clean the optics, it is recommended that a solution of optics cleaner or other mild solvent such as alcohol be used along with a soft cloth. An easy place to find these items may be a drugstore or other location that sells eyeglass cleaning kits.

To access the optics which are at the end of the sealed cylindrical sensor housing, unclip the sensor housing from its light baffling tube. Some rinsing and careful wiping of the optics can clear away the accumulated dust.

Hardware Description

A description of some details will follow...

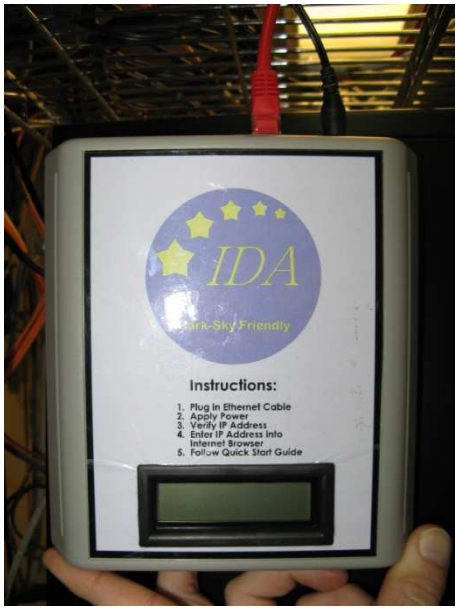

Fig. 1 – The base unit.

Fig. 2 – The head unit.

Fig. 3 – The head unit electronics.