Suggested Projects for Near-Space Engineering Students

We have identified two objectives that the near-space engineering projects could help us pursue. The primary scientific goal is to measure the sky brightness in various optical bands of astronomical interest (particularly the g, r, i, z, y bands of the Pan-STARRS survey) as a function of balloon altitude. A secondary goal would be to create a time-lapse video demonstrating the dramatic darkening of the sky and the emergence of stars against that background. Each of these goals involves the development of several subsystems, each of which could make a good engineering project for a team of two or three students.

A photometer suitable for measuring sky brightness could consist of an f/1 objective lens focused on a low-dark current photodiode through a suitable bandpass filter. An analysis of the probability of a bright star contaminating the photometer's field of view indicates that a field of approximately 2 degrees is a good choice. A low-dark-current photodiode 1mm square at the focus of a lens of 25mm EFL, gives a field opening angle of 2.3 degrees or 5.3 square degrees field area. A smaller, less expensive photodiode (e.g. Osram SHF-229) will also do well. Such a diode is 0.56 mm square, giving an opening angle of 1.26 deg (1.26 square degrees) with a 25mm lens. An f/1 lens of this focal length is practical to procure inexpensively and is compact and lightweight. The lens does not need to be a high-quality photographic objective; a simple plano-convex lens will do (e.g. All Electronics LNS-34).

Photometer Design Thoughts

1. The photometer telescope need not be precisely collimated, although accurate focusing at infinity will maximize sensitivity. It might be practical to defocus just slightly to make the device less sensitive to further defocusing due to temperature extremes occurring during the flight.

2. Direct solar radiation must not enter the telescope. If the telescope is aimed at 45 degrees from the zenith, and the flight takes place in early morning before sun rises to an altitude of 45 degrees, it should be easy to design a baffle that will keep the photometer objective shaded. In addition, the telescope can be placed at the bottom of a relatively long tube that will block stray and scattered light from contaminating the signal. The telescope focal length is only an inch, and the objective lens diameter is only an inch, so a six-inch long sunshade tube would be easy to implement and very effective.

3. For optimum accuracy, the photodiode must be cooled to as low a temperature as possible. Cooling will minimize both dark current and dark current noise, thereby increasing the effective sensitivity of the instrument. It may be practical to cool the photodiode with a cold finger extending from a radiator on the top of the package. This radiator must "see" the cold sky, not the hot sun. But again, the sun elevation will be low, so a simple baffle will shade the radiator from the sun while exposing it to the sky overhead.

4. It would be very useful to record the temperature of the photodiode so that temperature

effects can be taken into account in data analysis.

5. The photodiode input integrator must operate with low noise and extremely low input bias current.

6. The dynamic range of the instrument will need to be very large. One way to achieve a large dynamic range is to vary the integration time. By using a variable integration time and measuring (very precisely) the time required to integrate up to chosen threshold voltages of the integrator output, it is possible to achieve very precise results with a low-resolution ADC. The integrator reset switch must not introduce any leakage current into the integrator. A reed relay is better than an FET switch.

7. It might be a good idea to incorporate two photodiodes in the system--an active detector exposed to incoming light, and a reference detector in thermal equilibrium with the active diode but masked off. The reference signal would be useful for subtracting dark current and amplifier bias current from the data.

Suggested breakdown of photometer modules for parallel development

1. The telescope. Optics, mountings, baffling, thermal control components.

2. Instrumentation front end. This is a decidedly non-trivial electronics challenge!

3. Data acquisition and storage system.

4. System integration.

Other systems for development

1. ***Imaging system.*** Aim a video camera at 45 degrees and either grab a frame every second or so, or grab a minute of video every few minutes. A full 2-3 hours of video may be too much to record. A monochrome camera with appropriate filter would simulate astronomical observation and will provide better sensitivity. Different engineering teams could provide imagery in different optical bands. One challenge with video cameras is that their exposure time is generally limited to 1/60 second in order to maintain the video frame rate. This exposure time doesn't reveal stars very effectively. A camera capable of long single-frame exposures would be much better.

2. ***Inertial stabilization system.*** The photometer does not need a stable platform (as long as it doesn't swing enough to see the sun!), but imaging will require a reasonably stable platform. Spinning could be nulled--or at least dramatically reduced--with a motor driving an inertia wheel servoed to a MEMS gyro (e.g. Analog Devices ADIS16080). The armature of the motor may provide enough angular momentum to cancel package spin. There are now inexpensive magnetometer modules (e.g. Honeywell HMC2003) that can be used to derive a magnetic

heading for either stabilizing the platform or recording platform orientation as a function of time.

Another useful trick would be to try simply damping the motion with a vessel loosely packed with some mesh material and filled with a viscous fluid. A sail attached to the package might work to damp motion aerodynamically.

3. ***Motion measurement system.*** Inexpensive MEMS accelerometers could be used to measure wind buffet.

4. ***Instrument control and data management system.*** The various subsystems will need to be controlled as they perform their tasks, and data will need to be collected and stored. A single-board computer with a flash disk system, frame grabbers, ADC, DIO, and so forth will need to be provided, integrated, and programmed.