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Remote Operated Scope Cover System

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Summary

A major problem with remote operated telescopes is that it is difficult to provide protection against dust entering the telescope when it is not in use. Even with a scope inside an observatory, some dust will penetrate and will reach the mirrors. In addition, while the main mirror is usually heated to prevent condensation (thus lengthening mirror coating life), the lack of a cover reduces the effectiveness of a main mirror heater as the mirror is continuously cooled by outside air thus requiring a higher heating power level. Lack of a cover also prevents a main mirror heater from protecting the secondary mirror from dewing and condensation. This paper describes the construction of a remotely operated telescope cover and the associated electronics. It includes an extensive discussion of the constraints embodied in the design.

Video of a test of the cover operation is available at
http://youtube.com/watch?v=CFZ7d2fD_RQ

General Description

The scope cover system as finally constructed is a series of motor actuated flaps. The flaps and motors are mounted on a ring that attaches to the outer end of the telescope. When the telescope is powered up, the cover automatically opens. When the telescope power is shut off, the cover automatically closes, using a small storage battery that was charged during the telescope operation. There is also provision for operating the cover manually using pushbuttons.

Design Constraints

The major constraints are in the physical space constraints to be met in this observatory. In other applications, the constraints will not be as severe as in this one, so the design decisions (eg., number and type of flaps) may be changed. This application was for an 18 in. Newtonian. The telescope tube is an octagon, 20in. ID, with walls 3/16in. thick at the open end. The telescope is on an equatorial mount and is housed in a dome observatory. As the telescope swings off to each side, the space between the end of the telescope and the inner surface of the dome is as little as 7-9 inches.

- Expense. Must be reasonably inexpensive (a few hundred dollars, max)

- Design Flexibility. It would be good to have a cover design that would operate with virtually any design of amateur telescope.
- Location. The cover should be on the end of the scope, not down with the primary mirror. This is to make the cover accessible for service, as well as to enclose the whole tube to control dust, and to provide thermal and dust protection for the secondary mirror.
- Weight. It is desirable to keep the weight low, preferably below 2 lb total
- Motive Power. Use model airplane servo motors to simplify the control system and to provide high torque at low expense
- Electrical Power. Must operate with minimal current drain, preferably from a small rechargeable battery
- Position. Cover system should operate at any scope position in dome. This sets limit on space available at the end of the scope, and also precludes any devices or mechanisms using the dome itself, or the wall or floor of the dome.
- Mode. Open when scope mount is powered up, close when scope mount is shut down. Specifically, I do not want external control or power or control computer to be necessary.
- Material. I prefer to use 1/8 plywood as it offers some physical protection and thermal isolation. Alternatives include carbon fiber, treated cardboard, or plastic. Metal can be too easily bent so is not suitable.
- Frame. The cover should be constructed on a removable frame so that it can be constructed and tested off the telescope.
- Optical. The flaps must fully retract so that they do not block the visual field.
- Extension. Rigid Open flaps must extend no more than 7 inches from the end of the scope at any time during open/close actions to allow the scope to open/close in any position in the dome. The edge of the frame to center is about 11inches, so the 7 in. limit requires some form of flexible cover or the use of articulated flaps (flaps hinged in the middle).
- Open Position. In the open position, the flaps must either be aligned with the tube (extending out front) or fold back against the outside of the tube. This is to avoid blocking the view of finders and other optical devices mounted on the side of the telescope. Flaps cannot fold inward due to presence of a Newtonian secondary mirror spider (or corrective lens in a S-C telescope).
- Tightness. The flaps should be reasonably tight and should present no direct openings for dust. This will require overlapping flaps, which in turn requires a defined sequence in opening and closing (first flap opened is the last to close).
- Flat. If feasible, the cover should be constructed of materials (translucent white) so that in the closed position it can be used as a reasonably good flat light source.

Alternative designs Considered

I examined a wide variety of designs. These included iris diaphragms (delicate, space consuming, difficult), accordion (complex, clumsy , side extensions on tube), fabric covers (side extensions on tube, how to gather cloth when open).

Particular Design

I prototyped three designs which, while promising, ultimately were not pursued.

The first was a series of eight flaps connected by a continuous flexible drive shaft (speedometer cable material). This would allow one motor to actuate all the flaps. However, the inevitable friction and stiffness in the system caused unacceptable variations in the degree of opening/closing around the octagon. In addition, there was no way a sequential opening/closing of the flaps could be done, thus preventing use of overlapping flaps. Finally, articulated flaps needed to meet the space constraints could not be powered by this system.

The second major design was to use two large flaps, with each being hinged limiting the extension to about 5.5 inches, and with linkage to articulate the flap as it opened to keep the extension less than 5.5 inches from the end of the telescope. While this design could work, it suffered from several problems

- The weight of the central section was rather large, requiring a large servo motor or use of lightweight materials.
- It was difficult to hold the flap in the open (extend outward from the end of the tube) as the telescope was moved in different positions because the holding power of the powered off servo motors was insufficient. Servo motors are all spur gear designs so unlike worm gear motors, their holding power is small. I considered keeping the servo motor powered; however, astronomy applications would require hundreds/thousands of hours per year and the motors would not likely support that service. Also, there would still be the issue of holding the flaps closed with the power off. Stepping motors offer high torque both in operation and holding (even power off); however, these are expensive and heavy, and require more complex drives. They also do not have inherent position sensing.
- Although the linkage used to operate the articulation did work fairly well, it proved unable to reliably move the articulated flap totally out of the optical path, particularly when working against gravity.

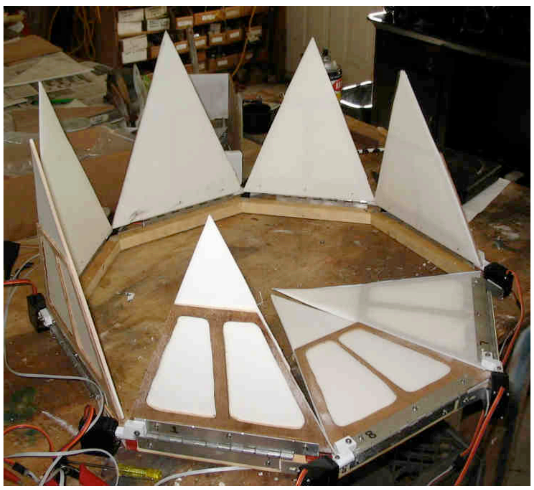
As in any design process, there are often theoretical solutions to any given problems, and it is up to the designer's judgment when these are worth pursuing, vs switching to a different design. In this case, after working extensively with the two flap design and seeing increasingly difficult problems, I switched to an eight flap design.

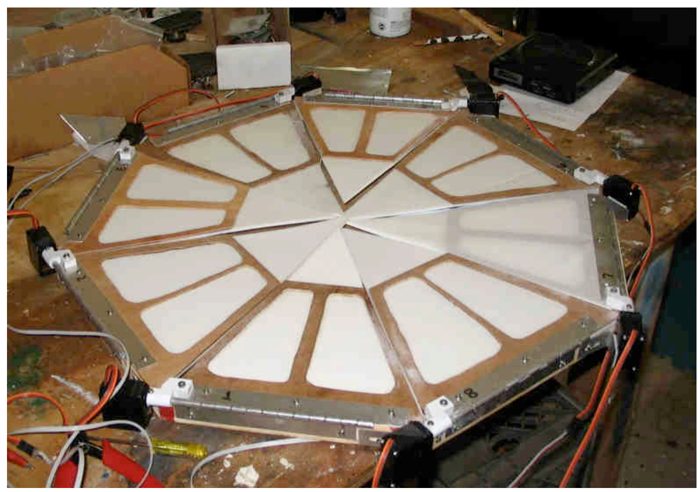
In the third prototype design, I used an eight articulated flap design. Each flap would have its own motor (so is more expensive and complex), but each flap is much lighter in weight, and the articulated portion (now a small triangle) is lighter yet. The standard servo motor can hold the flap in the correct position in all positions, even with power off.

The lighter weight of the articulated flap allowed the use of a lightweight spring loaded hinge. The hinge is custom made in about five minutes using standard piano hinge material and standard spring material. The hinge provides sufficient force to keep the flap extended. When the flap is being opened, a simple link made of 0.010 stainless steel cable running through HDPE bearings causes the articulated portion to fold down inside against the main portion of the flap. While this has proven reasonably simple to build and calibrate, and reliable in operation, working with the design made it clear that adjusting eight flaps to the precision required would be difficult, and it would be even more difficult to make it operate exactly as needed over the long run.

I finally chose an alternative that also uses eight flaps, each with its own servo motor. The flap is made of 1/8 in. thick closed cell polyethylene foam, so takes a plane (flat) form, but which is also highly flexible. For rigidity, the base of the flap is made of a skeleton of 1/8 in. plywood to which the foam flap is glued. Thus, when the tip of the opened flap strikes the inner surface of the dome, it simply bends out of the way without affecting the telescope drive.

The use of eight independent servo motors has allowed the controller to operate the flaps in any desired order, thus allowing a sequential opening/closing. In addition, each motor can be set for its own particular open/close position to allow for construction tolerances.





Electronics

The motors are controlled by a PIC microcontroller with a custom program. The controller box contains the battery and push buttons needed for operation. The controller sends open/close signals to each motor at an internally controlled rate. The controller mounts on the cover assembly, and has a single wire pair extending to the 12v scope power input (or to a 12v power supply from the 120VAC scope power).

The electronics operates from its own rechargeable battery, and is connected to the scope mount. When the mount is powered up, the on/off power not only tells the controller to openclose the flaps, but also provides recharge current as long as the mount is powerd.

Initial Operation and Calibration

When the telescope cover is first operated, each flap must be calibrated so that it opens/closes to the correct position. The system default sets the open and closed positions to approximately half way. After calibration, the controller will then remember the new settings. To return to the default settings, hold the Sequence button in while powering up from a totally cold start (battery and power disconnected for at least 10 sec).

To calibrate the flaps, after powering up, the "Sequence" button is pushed for three seconds starting the calibration sequence. This causes the flaps all to close as best they can, ie, to the default or to the most recent calibration.. Flap1 then opens to what it thinks is the open position. Using the Open/Close buttons, the operator trims the open position for Flap1. When satisfied, push the Sequence button to continue with Flap2. After all eight flaps are opened and calibrated, Flap8 then closes (last open, first closed) and the operator calibrates its proper closed position, and similarly with the remaining flaps. After Flap1 is closed and calibrated, the next Sequence button push finishes the process, storing the calibrations in the memory of the controller.

Although the default is eight flaps, the user can set a lesser number of flaps in the cover system, if desired. When setting the calibration of the open positions, when the final flap has been set (eg., number four), rather than push the Sequence button to advance, push both the Open and Close buttons. This will signal that the user has done the last flap, and will then advance to setting the Closed positions. To reset the flap number back to eight, re-establish the defaults as noted above.

Normal Operation

Here is the controller logic for normal operation:

- When the scope power is off, the controller is asleep. Actually, it is only dozing, watching for the scope power or for the user to push a button. The controller battery, after charging for 4-6 hours, can operate for over a month. If it does discharge, the controller will still respond to powering up the telescope (though about five hours of scope power on operation will be needed to fully charge the battery for the power off closing cycle).
- An LED pilot light signals the various operations. During standby, the LED will flash approximately every minute.
- When the scope power is turned on, the controller detects this and opens the cover.
- When the scope power is turned off, the controller detects this and closes the cover (if the scope has been powered on for at least 60sec--see below).
- When the controller responds to successive power on or power off signals, it will require that at least 60 sec pass before responding to another power on or off signal. Thus, if operating remote, and the user wishes to open the scope cover but with the scope powered off, (e.g., to take "flat" images), you can turn on the scope which triggers opening the cover. If you then turn off the scope within 60 sec the cover will stay open (the controller interprets the sequence as your command to leave the scope cover open). To then close the cover remotely, turn on the scope for more than 60 sec, then turn off the scope. This process provides remote control but avoids the need for yet another stand alone remote control system.

- Whether the scope power is off or on, and no matter how soon after the previous operation, the cover can be opened or closed by actuating the Open/Close buttons.
- You can change the speed of cover action. To do so, when in an Opening cycle, push the Open button while the controller transitions from one flap to the next to increase the speed (x2 for each transition), or push the Close button to decrease the speed (x 1/2 for each transition). You can also restore the default (slow) speed by restoring defaults.