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DIRECT IMAGING WITH THE GEC CAMERA

at the

NICKEL TELESCOPE

This manual is to be used

in conjunction with the

Nickel Telescope User's Manuel (LOTR 36)

by

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Acknowledgement

I am particularly indebted to Richard Stover and Lloyd Robinson for patiently answering my questions. If I got it all wrong, it is certainly no fault of theirs.

CHAPTER I. INTRODUCTION

This manual is by no means self contained. In addition to this, you will need to read LOTR 36, the **Nickel Telescope User's Manual.**

There is a choice of two independent data taking systems for use with the CCD camera. The older system uses the PDP-8I computer, and at the time of writing it still presents several nice features not yet available with the new LSI-11 system, including a very nice log stretch to enhance low contrast features in the display, and an easy to use focus routine. The PDP system is described in LOTR 28, **The CCD Data-Taking System.** LOTR 28 was not written by me, but by Tod Lauer, and hence is a model of clarity and full of useful information. This system is no longer supported and I recommend it only as a backup if the LSI-11 should fail. I won't discuss the PDP-8 system further here.

The LSI-11 system is the one to use, because it is being currently supported and is growing and developing. The LSI-11 system is described in two manuals. The data taking process is described in **The CCD Data-Taking System** by Richard Stover (do not confuse it with Tod Lauer's manual of [unfortunately] the same title). The data manipulation routines are documented in the **LSI-11 Vista User's Guide** by Don Terndrup and Richard Stover.

The LSI-11 data-taking system is menu driven. That is, the options are presented to you on the terminal screen, so generally you simply select what you wish to do from the screen. Once you have read the manual so you understand what the options are, you will find the system very easy to use and largely self explanatory.

The Vista data reduction programs are more complex, and are organized quite differently in that it is a command-driven system. Efficient use of Vista depends much more on remembering command codes and how to use them. This apparent disadvantage is partially offset by greater inherent flexibility and by excellent documentation, both in the form of the Vista manual and in instantly available help commands at the computer terminal.

The main point of the last two paragraphs is to motivate you to do your homework with the appropriate manuals before you come to the telescope. It will really pay off.

You might like to read some more general references about CCDs. Here are a few randomly selected ones which you might find interesting or even useful:

1. **Low Light Level Detectors for Astronomy,** Eccles, Sim and Tritton, Cambridge Univ. Press, 1983. See Chapter 8, "Solid State Imaging Detectors," pg. 158 ff. (A few older references are given at the end of the chapter.)

2. "CCDs," by Roger Lynds, in **Symposium on Recent Advances in Observational Astronomy,** 1981, pg. 31-38.

3. "The Lick Observatory Charge-Coupled Device (CCD) and Controller," by Lloyd Robinson in **Solid State Imagers for Astronomy,** *SPIE,* Vol. 290, 1981, pp. 124-129. (Lick Observatory Bulletin 891).

4. "CCD Use at Lick Observatory," by T. R. Lauer and a cast of thousands, Lick Observatory Bulletin 970 (1984).

5. "CCDs: Their Cause and Cure," by George Djorgovski, in Borucki and Young (eds.) **Proceedings of the NASA/SDSU Workshop on Improvements in Photometry,** 1984. NASA Conference Publication 2350, pp. 152-176.

CHAPTER II. DESCRIPTION of the CCD CAMERA

"The Camera" is a black anodized aluminum box, about 20" on a side, which hangs at the cassegrain focus of the telescope.

The standard position angle of the tub for the CCD puts the access door for the camera on the west side. Opening the access door with the two knobs at the upper left and right corners will reveal the simplicity of the camera. The camera box is mounted offset a few inches from the optical axis. As you look in the access door, the telescope beam enters from the top left, strikes the diagonal mirror on the bottom left, and is reflected to the right, through the filter wheel, through the shutter, and into the side-looking, gold anodized dewar, where it focuses onto the chip.

The dewar has a T-fitting in the top to which filling and overflow hoses are connected. On the side of the dewar is a brass valve with a black knob – the vacuum valve.

- **CAUTION:** *Never, ever open the vacuum valve!*

The dewar is held in place by a dovetail clamp on the right-hand wall of the camera box. Access to the hand-screw for the clamp is by a small door just below the dewar on the bottom of the camera. Unscrew the locking screw for this door to gain access to the clamp handle. You may have to rock the dewar a bit in the dovetail in order to get it out. After clamping the dewar in place, be very sure to refasten the dewar clamp access door shut in order to prevent light leaks.

On the back side of the dewar is a flat aluminum box which contains readout and preamp electronics for the chip. Three cables attach to it. The large connector on the left (as seen when mounted) is for the control cable that provides the operating signals between the chip and the controller (see reference 3 in the previous section for details). Next to it is a coax connector for the signal cable that is separate from the control cable in order to reduce noise pickup. On the right is another coax connector that conveys the shutter signal to the "Uniblitz" shutter power supply. The Uniblitz is also mounted on the dewar, so generally there is no reason to disconnect the cable between it and the electronics box. Leaving it connected reduces the chance of inadvertently confusing the signal and shutter connections later. The Uniblitz is also left connected to the shutter, so all that is normally necessary to connect for the shutter is to plug the 110 V shutter power cord into the socket on the right wall of the camera. Proper operation of the Uniblitz requires that the power be on (obviously), and (not so obviously) that the shutter open/closed switch be on **closed.** If the shutter switch is on open, the shutter will be locked open, and the computer cannot control it. The shutter switch is useful to make a quick manual check of the shutter (the solenoid makes a loud click), but of course will not prove that the computer is controlling it correctly.

Only one other wire connects the dewar to the camera, but it is an essential one. That is the red ground wire that goes from the dewar to the camera case. The connector just pulls apart. Do not forget to reconnect it.

To summarize what is necessary to remove the dewar: **turn off the controller**, remove the baffle (see below), disconnect 4 cables: 110 V to shutter box, control, signal, and ground cables.

- **CAUTION:** *Never connect or disconnect the cables from the CCD electronics box (control cable, signal cable) unless the CCD controller is turned off. The electronics are quite sensitive.*

When replacing the dewar, it is all the way in when the dewar side of the dovetail is about 1/2" in past the front edge of the fixed camera box portion of the dovetail. If the dewar is not all the way in, the optical axis may not intersect the chip.

The cables from the CCD controller are attached to the camera by connectors on the bottom of the camera housing. The weight of the cables should not be on the connectors, but instead should be carried by a strap hung from the bottom of the camera.

When the dewar is out of the camera, a small port on the south wall of the camera allows one to peer in on the optical axis at the diagonal mirror. This might be useful if you are having a lot of trouble detecting any object with the chip, but it is very unlikely that you will use it. Note that a quicker and easier approach to seeing if light is reaching the camera is to hold a white card in the beam above the camera diagonal mirror, which will allow you to see an out of focus 2nd or 3rd mag star even if you are only slightly dark adapted.

A baffle fits between the filter wheel and the shutter. It is a sliding fit between its slotted mounting bracket and the retaining screw on the bottom of the camera. The bracket slides underneath the washer on the retaining screw. It usually takes some wiggling to get it seated properly.

The filter wheel is keyed to its shaft, and is locked onto the shaft by a small black thumbscrew (do not lose it!). The filter position zero point is read by a microswitch near the bottom rim of the wheel. The easiest part of the camera to harm is this microswitch, especially when remounting the filter wheel. It is essential to hold the switch in the depressed position in order to slide the wheel past it without breaking it. The wheel is just hard enough to slide in so that you might forget to keep the switch depressed. It is equally important not to touch the filters as you struggle with the filter wheel. For three-handed people this task is much easier. Power to the filter wheel stepping motor comes from a small supply on the lower left corner of the outside left wall of the camera. Turn off the power supply before removing the filter wheel. When you replace the the wheel, be absolutely sure to replace the black thumbscrew to hold it on.

The dark slide is gold anodized and sticks out of the left wall of the camera at the top. Usually you will only pull it at the beginning of the evening and close it at the end of the night, since the shutter keeps light off the chip between exposures.

A black tube inside the camera at the front left houses a flat field lamp. To use it, plug the brown cord hanging outside of the left wall of the camera into a 110 volt source on the telescope tub. With the dark slide **in**, point the lamp at the white spot on the bottom side of the dark slide. The CCD will see light scattered from the white spot. Do not forget to unplug (turn off) the light when done!

CHAPTER III. USING IT

When you arrive, the configuration should be that the camera is mounted on the telescope, and the dewar has been pumped down by the dome crew. Liquid air or nitrogen will be available in the dome. Unless you have made special arrangements with the prior observer, the controller will be on but cooling will not have begun.

1. Cooling. The dewar can be filled in place with liquid nitrogen (N_2) - there is no need to remove it from the camera. There is an important caution about filling the dewar with nitrogen. Never, ever, even in your most macabre nightmares, should you consider connecting the N_2 line to the valved spigot on the dewar. That valve is the vacuum valve, and should be dealt with only by the dome crew. Liquid nitrogen is introduced into the dewar through the "T" fitting at the top of the dewar, and no valve (on the dewar) is involved.

In order to fill the dewar, place the large (50 liter) N_2 container close to the camera on the dome floor, with the telescope pointed approximately to the zenith. Locate the transfer tube (2 ft brass pipe with two $\sim$ 8 ft hoses attached) and insert it into the storage container. The short red hose section near the top of the transfer tube serves as a seal and must fit securely over the neck of the storage container, since the container will be pressurized. The lower of the two hoses from the liquid air storage dewar will fit onto the hose fitting with a black valve handle that is on the west side of the south pier of the telescope about a foot above the floor. The top hose from the storage container can be joined to the thinner of the two short hoses on the T fitting at the top of the CCD dewar. The thicker hose at the CCD is the discharge (overflow) hose. If you wish, you may pass both hoses from the CCD dewar through two small (normally plugged) holes in the upper right hand corner of the north wall of the camera - most people do not bother.

When that is all set up, open the valve near the base of the telescope. That will allow dry N_2 to pressurize the storage dewar, which will then force liquid N_2 into the CCD dewar. If everything is hooked up correctly, frost will begin to form on the hose between the dewars in a few seconds. For the first few minutes the system will "chugg," until everything gets cold enough for the liquid to begin to flow into the CCD dewar. At that point, chugging will stop, and the dewar will fill in only 2 or 3 more minutes. Let the flow continue until liquid begins to spurt out of the overflow pipe (keep it pointed out of the camera!). Then **quickly** disconnect the pressurization hose for the storage dewar, either at the storage dewar end or at the telescope end, and close the valve for the dry N_2 at the base of the telescope. If you only close the valve but do not disconnect the hose, flow will continue for a while into the CCD dewar as the pressure bleeds off. Disconnecting the hose releases the pressure and stops the flow. Another way to release the pressure is to pull the red hose and T fitting up off of the storage container. If you do that, do it very carefully so that the residual pressure in the storage dewar does not splash liquid N_2 on you. In any case, be careful not to crack the hoses, which will now be frozen solid.

Use the heatgun from the dome wall cabinet to soften the plastic pipes, then disconnect the refill line between the storage dewar and the CCD input pipe. Move the storage dewar away from the center of the dome floor.

The hoses and T fitting on the CCD dewar will have frost on them and will be very stiff. Use the heat gun to evaporate the frost, and paper towels to finish drying things off. When the hoses are dry, position them inside the camera box so they will not flop into the light-path or foul the shutter or filter wheel. Always be careful of the front-surface diagonal mirror inside the camera box.

How do you know when to refill the dewar? The hold time for the coolant varies, depending especially on how good the vacuum is. It should last at least 8 hours, and maybe 12, if the vacuum is good. Of course, it is best not to run out of N_2, so try to anticipate it if you can. A conservative N_2 plan would be to refill before starting in the evening, then top it off at midnight, dawn, and after lunch.

The hold time will gradually decrease as the vacuum is lost due to leakage and outgassing. A dewar pumping will usually last for a few days before it is needed again. If the dewar starts to get visible condensation on the outside ("sweats"), or if the time grows too short between required N_2 refills, then it is time for a pump. Do not attempt it yourself. Ask the dome crew to do it (perhaps via a message to the 120-inch TA).

It will not do any harm if the CCD dewar runs out of liquid air. The converse, however, is **not** true.

- **CAUTION:** *Do not leave coolant in the CCD dewar if the controller will be off for an extended period. If it will be more than, say, one-half hour, dump out the coolant.*

2. CCD Controller. The CCD controller contains most of the electronics to interface between the CCD and the computer system, and to monitor and control the temperature of the CCD. It is mounted in a rack on the east side of the telescope yoke. It will only very rarely be necessary to touch it, but every time you walk by, it is worth a glance at the temperature readout. The small LED display in the upper right-hand corner shows the temperature near the chip in degrees Celsius, and when it is fully cooled that temperature should be -145°C. It does not matter if it is not exactly -145°, but whatever it is should be stable to ± 0.1°C. If the temperature drifts up, you are probably out of liquid air. If it drifts down below a temperature which has been stable, then the temperature controller has probably failed (recall the earlier caution about letting the temperature get too low).

The controller is nearly always left correctly set up. However, here is what to check. Power on, fans on, exposure off. Do not reset the controller during an exposure cycle; the software takes care of that. The rotary function switch must be on "PDP-8 control" (yes, even if it is really LSI-11 control). If the micropressor is happy, the green light, incorrectly labelled "contrast," will be on (I have never seen it off).

The last thing to know about the controller is that the heater current may be read out by selecting "low" or "high" with the selector knob just beneath the LED temperature readout. It should read zero during initial cooling, until the temperature starts to be stabilized by the heater near -145°C. A typical current reading when the temperature is stable is about 0.5 with the switch on "low." If the temperature reaches, say -150°C, and no current is being drawn, get help immediately.

3. TV and CCD Orientations. The orientations of the sky on the TV and on the CCD chip are somewhat arbitrary, since the telescope tub may be rotated to any desired position angle (see LOTR 36, page 8 and note that the tub is now balanced for rotation with the CCD camera). Since both the TV and the CCD are fixed with respect to the tub, their relative orientations are also fixed.

The standard position angle for the CCD camera (that is, the position angle at which the dome crew will mount it at the beginning of each run) puts the camera access door on the west side of the camera. In this position, the cardinal directions are along rows and columns on the chip; N is at the left, and E is at the top. Notice that this requires an E-W flip to correspond to a normal finder chart. On the TV, directions are slantwise; north is at the upper left, and east is lower left, so a normal chart works fine. This is true if, as is usually the case, the inverting switch on the lower right corner of the TV panel is in the "reverse" position (the switch causes a top-to-bottom flip of the TV image).

4. Diagonal Mirror and TV Offsets. For CCD camera use, the usual full-surface diagonal mirror inside the tub is replaced with one which has a hole on the optical axis, so light may pass through to the chip. The mirror is tilted slightly, so that a field near the edge of the mirror reaches the TV for acquisition of the object to be imaged.

This arrangement generates a few differences from the ordinary TV procedure. When initially setting up the telescope, it is necessary to put a bright focus star at the correct position in the finder so that it will appear in the TV field. The finder field position will not be the same as it will be for the ITS, since the CCD system uses the tilted diagonal just described. Look in the User's Logbook for the most recent description of what position in the finder grid reticle corresponds to the TV center with the CCD. (If you find a significantly different position, please record it in the log for observers who follow you.) Then find the star with the TV, center it in the field, and reset the telescope coordinate readouts. Then refer again to the User's Log to find the offset in R.A. and Dec that will move the telescope so as to move the image from the TV to the CCD. Set up the slit change offset routine available on the PET computer, using "change to left slit" for TV to CCD, and "change to right slit" for CCD to TV, then try it - usually you will get the star somewhere on the CCD. Try a one-second CCD exposure to see where it is. (Remember that the TV field is 2 or 3 times larger than the CCD field, so if you are not lucky you may have to move the telescope around a bit, say one arcminute in each direction.) When you locate the reference star, maneuver the telescope so as to get the star onto the center of the chip, then offset back to the TV and carefully mark the position on the TV which corresponds to the center of the CCD, for the offsets you used. Usually that is good enough. If for some reason (compulsion?) you want the center of the chip to correspond to the center of the TV, you will of course need to touch up the offsets. Usually it is not worth doing that, but if you have done a particularly careful job, please update the User's Log.

The diagonal mirror control in the control room is always left in the "in" position for CCD use.

5. Focus. It is necessary to get a bunch of things all focused at once. The folding flat relay mirrors for the TV (see pg. 10 of LOTR 36 - but of course you have already memorized everything in LOTR 36) should be preset by the dome crew so that TV and CCD foci very nearly coincide. If you wish to check the folding flat position, open the small black hatch in the side of the tub, and it should measure 1 7/8" from the black handle on the relay mirror assembly to the outside wall of the tub.

When you acquire a bright star at the beginning of the evening, after you have reset the telescope position readouts and set up the TV-to-CCD offsets, you will want to focus the telescope onto the CCD. Take a series of test exposures for various telescope focus readings. Record to disc only, and use a small window on the CCD, perhaps 50 x 50. Then use the itv routine from Vista, and cut through the center of each image to produce either row or column plots. For each focus setting, count the number of pixels at FWHM in the star image. Finally, reset the focus to that which produced the smallest image. If all is normal, this will be at least very close to the focus setting for the best TV images. Any differences are normally small enough to be ignored.

The best telescope focus seems to stay nearly the same for long periods. See the pencil notations on the rack panel near the focus readout, and/or the User's Log, for the latest scoop, and then check it.

The CCD is sensitive to focus, in the sense that a difference of only a few units at the focus readout will obviously affect the image size. Be sure to take out the backlash in the focusing screw by making all focus changes from lower to higher numbers, starting from 10 or 20 units below the desired setting. Be sure not to touch it up at the end, in the reverse direction.

6. Filters. The filter holder has spaces for six 2" round or square filters, held in by split rings. The clear aperture is 45 mm, and filters up to 10 mm thick can be accommodated.

The filter normally provided at time of writing is the Spinrad "night sky" filter that passes from $\lambda\lambda$6000 - 7700 (thus it has slightly more blue response than its 120-inch "cousin"). This is a red interference filter which is usually in the wheel. This filter is very useful for direct imaging. It blocks most of the artificial night sky lines (NaD and Hg) to the blue of λ6000, as well as the worst of the band emission $>\lambda$7700. Also available are BVI filters on the Cambridge System. They are:

					$\sim \lambda$(nm)		
FILTER	COMPOSITION	$\sim$ % T_{max}	1%	50%	center	50%	1%
B	BG-18 (1 mm)	40	363	385	425	466	547
	+GG-385 (2 mm)						
	+BG-12 (1 mm)						
V	BG-18 (2 mm)	65	478	495	539	584	650
	+GG-495 (2 mm)						
I	RG-9 (3 mm)	98	700	730	800	1100	$\gg$

These filters were donated to us by Dr. Dave Hanes of Queens University, Kingston, Ontario.

At the present time (Fall 1985), several groups in the UC system are purchasing interference filters for CCD use, so it might be worth checking around before rushing out to buy your own.

Please be very careful in handling filters. In particular, do <u>not</u> attempt to clean any filter that is not your own. Many filters have delicate coatings, the accidental removal of which may greatly reduce their efficiency as well as changing their spectral response, and interference filters are susceptible to separation. It is best to leave cleaning to the appropriate specialist.

7. Baseline. You will notice that even a very short dark exposure will produce a significant DN (digital number) level at each pixel in the resulting frame. This is because a fixed constant is added to each pixel, in order to eliminate any possibility of noise produced in the readout process from resulting in a negative DN level. If the added constant is, for example, 16 DN, noise will produce both positive and negative excursions, so you will probably find 16 $\pm$ a couple of DN's in a dark frame.

Also during readout, each row may receive a small accidental offset, which is the same for each pixel in that row, but varies from row to row.

Both of the above are corrected by use of a bookkeeping column on the chip, which is the last column on the right. It sometimes appears on a displayed image as a bright edge, depending on the bit select used for the display (see the data taking and Vista manuals for more about the bit select). The baseline correction is easily made in the reduction using the Vista command "bl", but is more commonly accomplished as part of the autoflat routine (see next section). This baseline correction removes, to first order, additive errors in the resulting frame. If you want to know more, see the writeup for the bl command in the Vista manual.

8. Flat Fields. Flat fields are one of the trickier aspects of CCD use. They are used to remove both small scale (high frequency and pixel-to-pixel) sensitivity variations as well as large scale (low frequency) non-uniformities. Multiplicative errors are removed (again to first order) by dividing a baselined data frame by baselined flat field frame (followed by renormalization). The baseline and flat field corrections are easily done in Vista by a user-friendly procedure called "autoflat."

There are a number of different options available for flat field sources. You must make your own choice in light of your observational goals. For some projects it will not make much difference which method you use, while for others it may be critical.

The first possibility is to use the flat field lamp built into the camera, as was described on page 8. This is not a popular option, because the illumination is very non-uniform, leading to large intensity gradients at the chip. However, it may be convenient as a way to just get light onto the chip, for example if the weather is very bad and the dome is leaking so you do not want to open the mirror cover.

Second, you might use the white windscreen or the white spot on the inside of the shutter. This requires pointing the telescope to it and opening the mirror cover. There are various options for illuminating it. They are:

a. Room lights. They are pretty bright, but blue compared to the sky.

b . Secondary lights. On the east arm of the yoke is a black rack panel with a toggle switch for selecting either one or two lamps mounted on the secondary ring. They are also bluer than the sky, and do not illuminate the white spot uniformly, although it is so totally out of focus that by the time the light reaches the CCD, this illumination is much more uniform than you might expect.

c. Gooseneck secondary light. This somewhat tacky arrangement is perhaps best. It requires plugging the brown zip cord from the gooseneck lamp taped to the secondary into the Power Designs power supply, and setting the lamp current for the color temperature that you like. A recommended setting is ~ 1.5 amps when using the Spinrad filter. This gives a rough match to the color of the night sky (roughly K-star colored). The connector on the power supply should be connected to the ± DC jacks.

The third general option for flat fields is to do them on the sky, which is, oddly enough, the most nearly sky-colored source. A 15-minute exposure with the Spinrad filter on a dark (to avoid scattered light problems) blank patch of sky will give sufficient signal for the VAX reduction software to fit a smoothed surface (high signal/noise at each pixel is not required).

The paper by Djorgovski mentioned in Chapter I contains some interesting remarks on flat fielding. A consultation with your local software guru may be useful in choosing your approach.

9. Saturation. The 12-bit A-D converter allows a maximum of $\sim$ 4K digital numbers (DN's) for the readout. For the GEC chip, the usable well depth is thus about 65,000 electrons. Saturation will not physically damage the chip, but severe saturation may result in subsequent problems due to after images and/or bleeding of the charge back into the wells over a period of time. The best thing is to avoid grossly overexposing, perhaps by taking an initial short exposure in order to scale the exposure time. In case of an overexposure, if you are worried about possible after images, take a dark frame to check it. In case of a <u>very</u> severe overexposure (which should not happen anyway) you may have to wait a few hours for all of the charge to leak away.

10. Logsheets. The tape header contains pretty complete information on each exposure, especially if you keep the object name and remarks up to date. Still, it is useful to have a paper log sheet as well, particularly to keep track of image numbers on the disk and tape for ease of recalling them. Three possible formats are bound into the end of this booklet for you to copy if you wish. Note that you must come to the telescope with your own logsheets - there usually are <u>not</u> ones available in the control room.

11. Tapes. One-half inch nine track tapes may be purchased from the 120-inch electronics staff. You can get about 85 full-size frames on a 2400′ tape. For many purposes, it is best not to record the full image. It is usually most convenient to record to both disc and tape. In case of tape drive failure, you can continue with the disc alone and transfer it to a tape later. But leave a conspicuous note so the disc will not get erased!

12. Scratch Frames. Frames not written to disk or tape are stored as frame 999 on the data disk until written over by a subsequent image.

13. A Note on Vista. Vista will seem much more useful to you if you learn to set up procedures. A procedure is a short named program, usually just a sequence of Vista commands you wish to execute repeatedly. I emphasize this here just because setting up procedures is discussed right at the end of the Vista manual, so if you are like me, you may never get to it in the normal course of events.*

Similarly, be sure to look at the "alias" command, which is quite handy for lazy people (like me).

* "So why is this note at the end of your manual?" – Richard Stover

CCD CHARACTERISTICS

Mfr/Type	GEC P8601/A
Construction	Thick, front illluminated
Rows × Columns	576 × 385
Pixel Size	
Microns	22[a]
Arcsecs	0.26
Full Field Size (arcsec)	150×100
Long Dimension Orientation[b]	EW
Electrons/DN	15.7
Readout Noise (electrons rms)	23.5 (~1.5 DNs)
Operating Temperature	−145 C[c]
Peak QE	35-40% @ ~ 8000 Å
Spectral Range	~ 4000 Å to > 1 μ
Secs to detect 20th mag	~ 1000[d]
Sky counts in 1000 secs	~ 50 [d]

[a]There is no deadspace between pixels.

[b]With some inconvenience, this may be reset by the observer.

[c]At room temperature, even a one-second dark frame will be saturated.

[d]With Spinrad night-sky filter.

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CCD Log Sheet

page____ of____

DATE: ____________________ PROGRAM: ____________________

CCD: ____________________ OBSERVER: ____________________

DATA TAPE: ________________

Obs	Object	Filter	Exp	H.A.	Comments

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CCD Log Sheet

page_____ of_____

DATE: ____________________ PROGRAM: ____________________

CCD: ____________________ OBSERVER: ____________________

DATA TAPE: ____________________

Obs	Object	Filter	Exp	H.A.	Comments