TELESCOPE AND CCD CAMERA

Operating Manual

Andrew Donnelly
Senior Research Project

Spring 2004

Chapter Summary

INSTRUCTIONS FOR THE OPERATION OF THE COMPUSTAR-14 TELESCOPE

The most important thing to remember abouit this system is that the telescope is **COMPUTER** controlled. You do not control the telescope! You instruct the computer. There is no need to touch the telescope unless something drastic, like a power failure during an observing session happens. In such a case, special procedures must be followed before bringing the telescope back into operation. Unless you have been trained in these procedures, simply turn off the telescope, close the dome, and report the problem the next day. Moving the telescope by hand can cause very expensive damage!

The axis of the optical assembly has been adjusted to be perpendicular to the declination axis of the telescope and the declination axis has been made perpendicular to the polar axis. These are now fixed by locating pins. As a result, automatic direction of the telescope can be accomplished with precision limitend only by uncontrollable factors such as flexure and atmospherec turbulence.

Each of the axes of the telescop si controlled by stepping motors driven by the computer. These move the telescope through worm gearing, providing motion, and position information simultaneously. The position of the telescope is set by these mortors within a fraction of the field of a low power eyepiece (about 8 arc-minutes). If the initializing procedures are followed carefully, and if synchronization is activated after any long slewing motion of the telescope, a finder telescope should never be required. Only the TEL-RAD finder is provided (there are two with four attachment points).

The heart of the system is an Intel 8052 microprocessor running at 12 MHz. This is an “imbedded microcontroller”, optimized for real time control operations. It has, onboard, 8Kby of ROM, 25 bytes of RAM, three 16 bit timers, and four bi-directional ports, providing 32 I/O lines. Eitghty Kby of EPROM contains the program and the catalog of stored celestial objects. An RS-232-C port is provided so that an external computer can run the telescope.

The computer communicates with the telescope through a Motor Controller Module, which drives the stepping motors in microsteps, with very strong impulses. The drives are preloaded and can be adjusted for optimum driving smoothness with minimum backlash. The visual observer should have no need of some of these features, which are particularly designed for photometry. This system eliminates the need for a separate tracking controller.

The system is also provided with a joystick controller which permits precision centering of the image after it is placed in the field of view by the computer. This joystick is of the proportional type so that the rate of movement of the telescope is proportional to the distance of the joystick from the central, neutral position. The joysitck has two buttons, one orange and one black, and which allow control of some computer functions. The orange button activates the synch command and the black one another command dependant on the mode of operation.

Before beginning it is important to note that the telescope session is NOT terminated by simply turning off the equipment. You MUST end each session with the END command, and turn off the power only after the telescope has completed its shut-down routine! The correct "park" position of the telescope is with the corrector plate pointing in toward the base and the black declination motor box on the side of the yoke toward the door onto the deck (Dec=-90, RA= 0). [See page ***{BLAH}*** for restoring the telescope to a proper parked position if it is not in such before you start your session.]

Another important command is the ABORT command. This will stop the action resulting from a faulty command. For example, if END were pressed when the eqipment placed on the back of the telescope could be damaged by the telescope's moving back to the "park" position, ABORT would save the equipment. Find the ABORT command before going on! ABORT terminates the command you chose by mistake, but the memory remains intact. You may continue as if nothing wrong had been entered. (However, do not use ABORT until the entire initialization sequence has been completed!)

NGF S Series Focuser Operation

The primary reason for the design of this focuser was image shift, inherent in the design of the Schmidt-Cassegrain telescope. Image shift is caused because one must move the primary mirror to achieve focus. The design is a modified "Craford" type of exceptional stability and smoothness. It is sturdily built but must be treated as a delicate precision instrument. This focuser hs been installed on the C-14 Telescope, replacing the former extension tube attached to the rear cell.

Operation

The draw tube should **only** be moved in or out by use of the Motor focus motor! Because it is hard anodized aluminum, directly pushing on the draw tube can wear a flat into the stainless stell drive shaft resulting in uneven travel. Also, you should not continue to run the motor after the end of travel has been reached as excessive wearing of the stainless steel shaft and the aluminum draw tube may occur. [Such damage is not covered under the warranty!] Never attempt to adjust the roller tensions.

The draw tube is moved in or out only by pressing one of the two red buttons on the hand unit. The motor speed can be changed by adjusting the variable speed knob. The hand unit operates on 2 AAA batteries. These batteries typically last a year. If the batter dies, use the SCT focus know for the rest of the session and inform whomever is in charge of telescope maintenance the next day.

Draw tube travel is limited to about 40mm, and is intended for fine adjustments. Coarse focus is obtained using the SCT focusing knob. At the beginning of each session, the fine focuser should be at the middle of its travel. The white line on the moving barrel should be barely visible.

Starting up

Remove the hand control unit from the cabinet or from the dome wall (depending on if the unit was properly stored during the last session) and plug the cord into the focusing unit.

Shutting down

Unplug hand control unit cord from the focuser and return the unit to the cabinet.

RECOVERY PROCEDURES

Safe Recovery from power failures and other misadventures which occur <u>during</u> a session

Althgouh mechanical resetting of the telescope must be done with special tools, there is a safe way to recover from most minor "disasters" **Never try mechanical resetting of the telescope position!** The following steps allow a safe recover:

1. Using a star map, locate a bright star near the zenith and find it in the sky. (The *Sky and Telescope* monthly chart shows the brightest stars and provides their names.) Locate this star in the attached list. (To help correlate list and star chart, positions to the nearest .5 h in RA and degree arc given for stars useful from our location)
2. Use SLEW:REF: [star number]:ENTER to point the telescope to the chosen star.
3. Use only the joystick to center the telescope on the star. (The dark key on the joystick may be used to change slewing speed.)
4. Press the Orange Key on the joystick to synchronize the telescope
5. These steps may ben then used with another bright star to confirm accuracy.

Resetting the "parked" postision if it is not correct, as defined on the second page of these instructions

1. If the telescope has not been turned on, follow the start-up procedures given above. Accept wherever the telescope is pointing in step 7 of the start-up procedures
2. Press END
3. When the telescope is parked, press ABORT
4. Using the joystick move the telescope to the <u>proper</u> parked position
5. Press SYNC (orange button on joystick)
6. Press END (Telescope should hardly move at all.
7. Turn off power to the telescope

CELESTRON-14 TELESCOPE OCULARS

Focal Length (mm)	Type	Visual Magnification	Measured Field (arc minutes)
7.4	Plössl	528	5
13	Plössl	301	9
26	Plössl	150	18
40	Plössl	98	22
9	Nagler	434	11
13	Nagler	301	17
20	Nagler	196	19
32	Erfle	122	31
55	Plössl	71	43

Computer Command Overview

These commands are described in detail in "Com pustar Reference, Detailed Commands"

Abort
Terminates whatever command is in progress, if any. Also initializes the optional joystick

Align
Used to fine tune the alignment of the polar axis of your telescope with the celestial pole and sync the coordinates of the computer with the sky. It is the second half of the BEGIN command, but can be repeated by itself for increased alignment accuracy

Begin
Used to begin each observing session. First, the Compustar asks for basic information (time,date,longitude, & latitude). Then it goes through the align sequence designed to help you quickly align the polar axis of your telescope with the celestial pole.

Disp
Displays selected information about the telescope, an object, or internal compustar values

End
Used after an observing session; returns the telescope to the "p arked" position

Field
Identifies the deep-sky object nearest the center of the field of view. If there are no CNGC objects within 30 arcminutes of the center of the field, then no object information is displayed

Look
Identical to the SCAN command except the telescope does not move, Information about each object is displayed

Next
Resumes execution of the most recent SCAN or LOOK command, moving to the next catalog object in the specified sequence.

Option
Used to permit expansion of the capabilities of the Compustar at a later date. For example, if a new accessory for the Compustar is developed, a new OPTION command may be needed to support it.

Rev
Used to reverse the counting direction of the Commpustar's built-in timer. It is also used to reverse the direction of motion caused by the motion control buttons or Joystick

Scan
Tells the Compustar to look through its internal CNGC catalog of deep-sky objects for those that satisfy criteria that you specify- and to slew to them sequentially

Set
Used to set a value used by the Compustar. It can be used to set the internal timer, time/date, longitude/latitude, epoch of celestial coordinates, or any of the parameters used by the SCAN and LOOK commands.

Slew
Causes the telescope to move rapidly to a specified object or coordinates.

Speed
Selects the speed range (SLEW, SET GUIDE) for the motion control buttons or joystick.

Timer
Toggles the Compustar's built-in timer on or off. The timer may be used for timing of photographic exposures.

CCD PHOTOMETRY EQUIPMENT LIST

Hardware:

1. CCD Camera: ST-7E (Class I)

   [01092946F] (ID number) [6.9 x 4.6 mm] (array dimensions) [9 x 9 μ] (pixel size) [765 x 510] (# of pixels) [11.9 x 7.9 arc minutes] (FOV at 8" f/10)

2. Focuser: Model Temp Compensating Focuser Model S (TCF-S),

   Optec Inc.

3. Computer: Dell Laptop (Windows XP)

   Dell Lattitude C640

   4-M CPU 2.4 GHz

512 MB RAM

CCD SOFTWARE

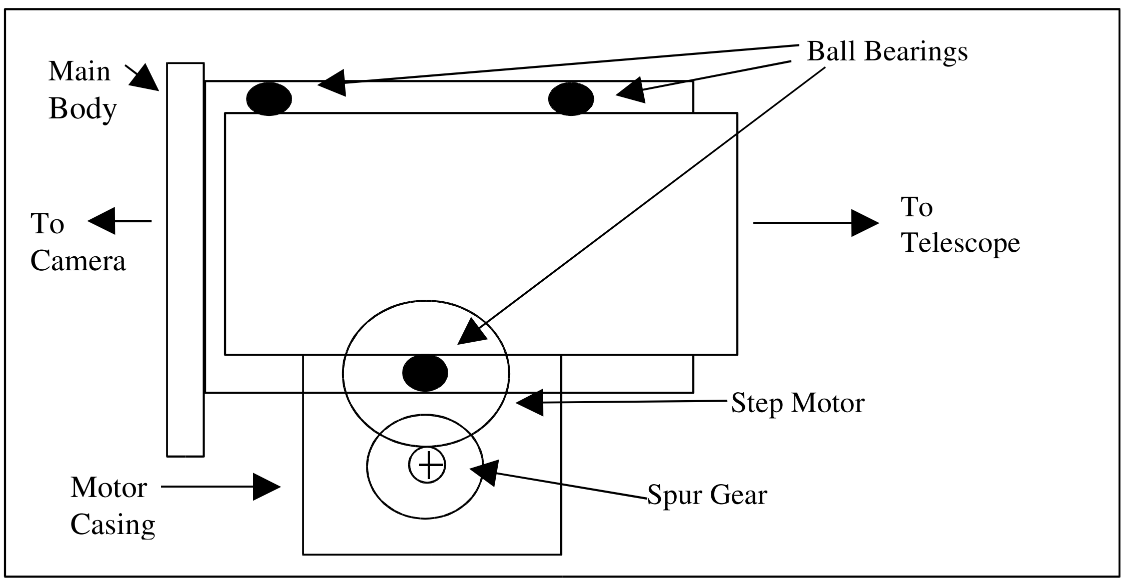
1. CCD Soft V. 5
   Image Processing & CCD Camera Control Software
   Copyright 2001 (Santa Barbara Instrument Group & Software Bisque Inc.
2. AIP_4WIN
   Astronomical Image Processing Softare
   Copyright 2000 (Willmann-Bell, Inc.)
3. SkyChart III
   Night Sky viewing software
   Copyright 2001 (Southern Stars Systems)

The Temperature Compensating Focuser TCF-S

Whereas it is not uncommon to see CCD's att ached directly to a telescope, our department has a more sophisticated system. This should be the second item with which you become quite familiar. The internal design is a little less interesting, but it is still important that you know not only its uses but also its structure to some degree.

The TCF uses a 2-inch ID drawtube. The drawtube is supported within a sturday cylinder by four ball bearing rollers and a stainless steel drive shaft. With a tremendous force of approximately 200 pounds, the shaft pushes the drawtube against the bearings. Rotating this drive shaft moves the drawtube a total distance of 0.6 inches.

The stepper motor (which controls the speed at which the focuser slides in and out) with a gear ratio of 50:1 has another drive shaft to which a 25 tooth spur gear is attached. The main drive shaft is attached to a 96 tooth drive gear. Thus, the total gear reduction from stepper motor to main drive shaft is 192:1. Each step from the motor moves the drawtube 0.000085 inches!



The motor and drive gears are protected in motor casing with covers to eliminate damage to the gears. The whole spur gear-step motor are a single machined part to assure proper alignment is maintained

The heart of the controller is a CMOS microcontroller. This device pulls very little power and can work within normal temperature ranges the focuser-camera system will feel.

The input power is from a DC power unit rated at 12V. The power control unit is well protected form surges and removes the possibility of failure within the highly sensitive focuser itself should anything happen.

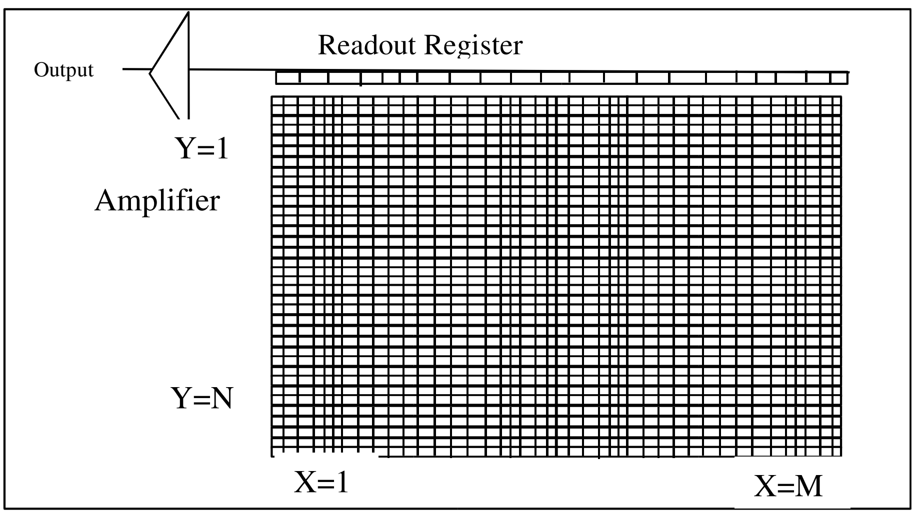
This focuser also happens to be a temperature control device (beyond that which the camera itself possesses). An electronic controller system monitors the telescope's tube temperature and compensates the focus accordingly. A small temperature probe is attached to the side of the telescope tube and monitors temperature with a resolution of 0.1^0 C. For our telescope, the focus will approximately 0.25 mm for every 1^0 C change in telescope temperature. It is not unusual during an observing session for the ambient temperature to change by as much as 10^0 C within the time span of a few hours. This change in focus due to temperature is a problem for regular sessions. So the TCF can not only change focus to accommodate for varying temperature, but it has two systems to cool the system. One is internal and once the focuser is plugged into the computer will drop the temperature of the system to 0^0 C. For the HOTTER, STEAMIER Williamsburg summers and falls, a secondary system is available in which a small tube is attached to the focuser and fed through a simple bucket of water which will be used as a heat sink to reduce strain on the main temperature controller.

The CCD ST7-E

CCD Introduction

What is a CCD you might ask? A CCD stands for "Charged Coupling Device". In essence it is a digital camera whose function is to track and photograph astronomical objects. Tom Elliott and James Janesick of JPL gives the best analogy for how they work.

> "Imagine an array of buckets covering a field. After a rainstorm, the buckets are sent by conveyor belts to a metering station where the amount of water in each bucket is measured. Then a computer would take these data and display a picture of how much rain fell on each part of the field. In a CCD the "raindrops" are photons, the "buckets" the pixels, the "conveyor belts" the CCD shift registers and the "metering system" an on-chip amplifier.

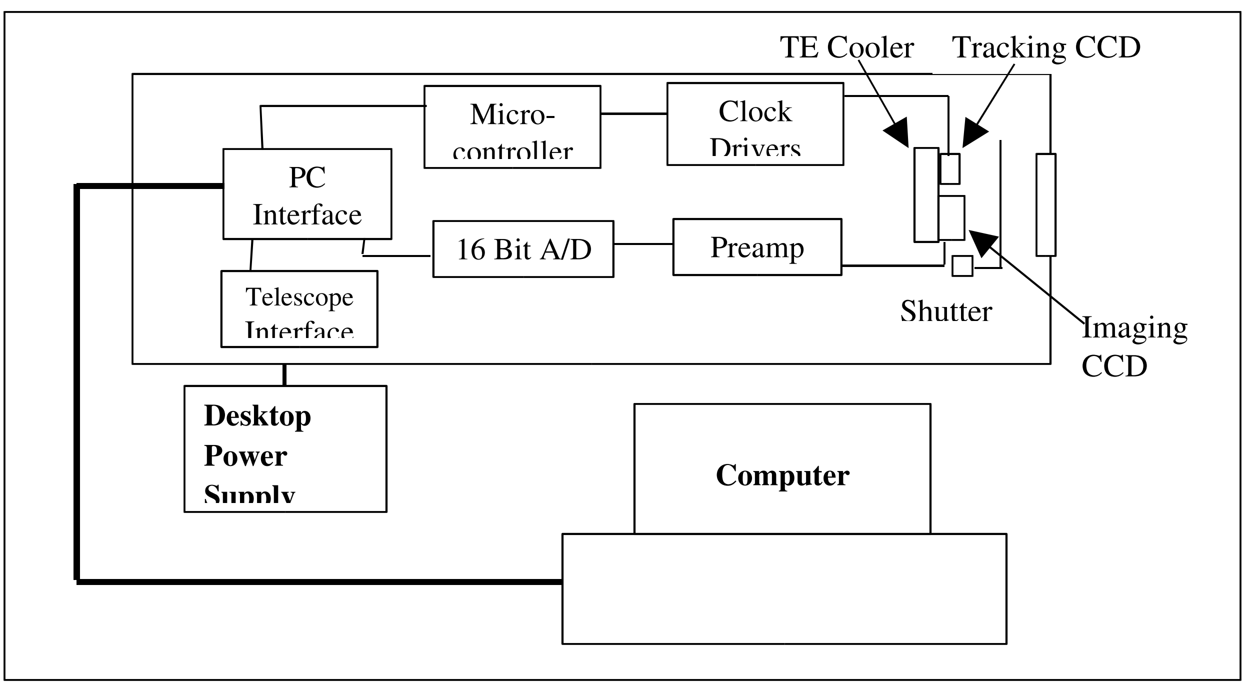


The CCD must perform four tasks in generating an image. These functions are 1) charge generation, 2)charge collection, 3) charge transfer, and 4) charge detection. The first operation relies on a physical process known as photoelectric effect- when photons or particles strikes certain materials, free electrons are liberated…In the second step, the photoelectrons are collected in the nearest discrete sites or pixels. The third operation, charge transfer, is accopmlished by manipulating the voltage in a systematic way so the signal electrons move down the vertical registers from one pixel to the next in a "conveyor belt" like fashion. At the end of each column is horizontal register of pixels. The register collects a line at a time and then transports the charge packets in a serial manner to an on-chip amplifier. The final step is when the packets are converted into output voltage."[1]

Hardware

The components of the CCD are as follows:

- The sensor, of which there are two, one is the imaging CCD, and the other is the trackig CCD for longer exposure shots
- Solid-State thermoelectric cooler. This device uses a cooling pump that sends heat to a sink
- Since the camera sits below 0º C, the heat pump sits in a dessicant that keeps humidity in device low
- Preamplifier
- Electromechanical shutter. The shutter allows taking dark frames by simply keeping shutter closed. This also is what accounts for the timer.
- Clock drivers which convert the logic-level signals to voltage levels required by the CCD internal chip.
- Analog to Digital Converter which digitaizes the data in the CCD for storage in the computer.
- External Power supply that provides +5V and + or – 12V to the camera.
- TTL level telescope interface port to control the telescope and the optional motorized color filter wheel.



[1] "History and Advancements of Large Area Array Scientific CCD Imagers", James Janesick, Tom Ellion. Jet Propulsion Laboratory, California Institute of Technology, CCD Advanced Development Group.

Dark Frames

Noise is a common problem with most any electronic device. It can reduce the validity of your pictures and therefore anything that can be done to reduce it, is a good thing. With that in mind, by subtracting a "Dark Frame" from the raw image, the noise will be reduced. A Dark Frame is merely an identical shot as the raw image, however the shutter remains closed and so you have a picture of what there would be had you not absorbed light from beyond. This will leave only an image of the thermal noise from the pixel array.

Flat Field Images

Still more can be done to reduce unwanted data from your raw image. The Flat Field command allows you to corret for the effects of nonuniform pixel response across the CCD array. A more in-depth description of the flat field effect can be found in the camera manual. But since it is usually beyond what would be needed for amateur or semi-professional work, it is of little concern. Especially due to the fact that its effects are only useful for shots longer than about a minute, which in CCD terms is a LONG TIME.

Computer Software forCamera Control and Image Processing

CCD SOFT V.5 –Camera Control Software

This is the software that while running, will manage all of the hardware you attach to it: Telescope, CCD, focuser. This software includes the following features:

- Acquire CCD Images-Fully automated imaging, including temperature control, autoguiding, multiple-exposure accumulation, dark frame acquisition, and color photography.
- Automatically focus your CCD camera-CCDSofts's @Focus technology, when combined with a compatible motorized focuser (such as the TCF-S), allows you to achieve focus quickly and simply.
- View images from a variety of file formats-CCDSoft can read and write to many file formats including: BMP, FITS, GIF, JPG, and TIF
- Create "slide show" of images-Browse as many images as you like, either manually, or using timer system
- Print your images
- Access RealSky targets-Display digitized sky survey images from the low or high compression formats (RealSky is a small program that comes with CCDSoft that not only is a sky guide, it also contains real images
- Perform professional level research-Search for comets, minor planets, or supernovas, generate reports for the Minor Planet Center, and even generate light curves of stars or minor planets.
- Integration with TheSky astronomy software-TheSky and CCDSoft have numerous integrated features

During observing sessions, this will be the software that you will be using because it controls the camera. Although it has processing software, the other software described in this manual will be more useful and it is recommended that you use that in lieu of the processing software contained in CCDSoft.

AIP_4WIN – Image Processing Software

This software allows much better manipulation of CCD images than that which is provided with CCDSoft and should be used instead. This software was designed in accordance with one of the top books for image processing, *The Hand book of Astronomical Image Processing*. This software includes the following features:

- Basic calibration – allows user to select one of many dark frames, average or take the median and prepare the master dark, which is then stored and used for all photos taken in a given observing session.
- Standard – performs dark subtraction and flat fielding. Allows creation of master dark, and master flat field. Creates flat-dark and uses as master for fine-tuned manipulation of images
- Advanced – Auto matches dark frames. Useful for most advanced calibration. Creates bias frame, dark frame, and flat field frame. *With bias frame time elapsed for master dark need not be the same as raw image when bias frames are integrated using this feature.*
- Display Statistical information on list of frames
- Create Histogram of image histories (in logarithmic scale)
- Can create Cross-Histogram- Displays a pixel by pixel comparison of two image histories
- Myriad of pixel to pixel features like; pixel math, pixel offsets, max pixel ranges, etc.
- Brighten or darken images, blur images, crop and center images

Starting a session

To start a session, after opening the dome, remove the covers from the optical elements of the telescope. Turn on the power supply and then switch on the Motor Controlled Module.

1. Press buttons marked OPT : 9 : 6 : ENTER (This bypasses polar alignment)
2. Press BEGIN (as you enter the requested information, the BACK key will permit you to correct any digits before you press ENTER. It acts like a PC's backspace key)
3. Enter GMT in HH:MM: SS format (Punctuation marks shown in the examples are not manuallyentered) Press ENTER
4. Enter year, month, day as requested, eg 2004 04 15. Press ENTER
5. Enter longitude 076.43 Press enter
6. Enter latitude 37.16 Stand clear and press ENTER
7. The telescope will slew to a reference star to identify of which will be displayed. Using the jostick, position the bright star in the center of the eyepiece field of view. Press ENTER
8. Turn on the TEL-RAD finders and check their mounting screws.

The telescope is now ready for use. The stored objects in the computer number over 7500, including all Messier objects, and all objects in the NGC catalogs, plus a catalog of reference stars and of interesting multiple stars.

For general purposes three methods are used to place objects in the field of the telescope; selection by catalog number, selection by celestial coordintes, and selection by slewing the telescope, using the joystick and the TEL-RAD finders to an easily visible object such as the moon or a planet. Three catalogs are availale designated by prefixes M,CNOC, and REF, for Messier, Computer new general catalog, and Referrence catalog, and Reference catalog, respectivlely. (In these operations, the black button on the joystick toggles between joystick controlled slewing speed ranges).

For example, to access the Andromeda Galaxy, press SLEW, M31,and ENTER (or SLEW, CONGC224, and ENTER)

For an object at RA. 13h 22.3m and Dec 12 deg. 22 minutes, enter SLEW, COORDS, 1322.3, ENTER, 1222

To use the joystick to acquire an easily seen objet, enter ABORT, SPEED, and SLEW, or use the black button to change slew speeed. Then use the joysitck to center the object

IMPORTANT: During any session it will help keep the telescope aligned if, after an object chosen from one of the internal catalogs is centered in the visual field, you press the orange key on the joystick this corrects alignment, as you move, for those uncontrollable errors due to flexure, etc. (Use this routine only when you are sure that the correct catalog entry of the object being viewed is displayed. If you are not sure, do NOT use the SYNCH command)!

Ending a Session

When the session is ended, turn off the TEL-RAD finders and press END. Wait until the telescope has moved to its "park" position.

[If and only if it moves to a position OTHER than the proper parked position, press ABORT. Use the joystick to move the telescope to the proper parked position. Press SYNC (Orange button on joystick). Then press END again.]

Then turn off the Motorl Controller Module and the Power Suppl. Put all covers ont eh optical systems and close the dome.

RECHECK THAT THE DOME IS CLOSED, THAT THE MOTOR CONTROL MODULE IS TURNED OFF, AND THAT THE POWER SUPPLY IS TURNED OFF. Secure the front dorr and lock the side door on leaving. Make sure the doors are LOCKED!

Procedure for use of the Charged Coupling Device (CCD)

1. Acquire the laptop from the shelf immediately inside the door on the 3rd floor
2. Head to the telescope, turn on as few red lights as possible once inside the dome
3. Initiate the starting sequence for the telescope and open the dome in preparation for slewing
4. Follow procedures provided on page 17 for starting the telescope and initial alignment
5. By either, reference number, or right ascension and declination align the telescope with the object that will eventually be photographed
6. Beginning with the eyepiece with the largest field of view, bring the object into focus until, while using the eyepiece with the lowest FOV, the object is focused as well as possible (realize that the FOV of the camera is even *less* than this)
7. Open the locked cabinet in the stand and remove all equipment including: the focuser, the camera, accompanying cords, and of course the mouse pad
8. Plug in main power strip and turn on, all power is to be routed through this device
9. Detach the eye piece and set on lower rack of stand
10. Open CCD case, and remove the focuser head
11. Attach the focuser head to the vacant spot where the eyepiece use to be
12. Now the main body of the focuser can be attached to the head using the mini screwdriver provided in the CCD case
13. The CCD itself is now attached to the bottom of the focuser, this is tightened with thumb screws attached to the focuser
14. The focuser requires three cords, they are attached, one is plugged into the main power strip, one is attached to the focuser, and the other will be attached to the back of the laptop
15. The CCD has two cords, one is the power cord, the other is the serial cable which is attached to the CCD and eventually to the back of the laptop
16. Now the laptop also has cords that must be attached before it is turned on:

a. Mouse
b. Ethernet cord which is then layed across to the far side where the Ethernet box is
c. Power cord
d. Focuser cord
e. CCD serial cable

17. Once all of these are firmly attached to the laptop, it can then be started
18. Like any other computer on campus it requires personal login name and password (using this will allow you to save your pictures separate from anyone else's)
19. Start the CCD Soft program, and open the camera setup window in preparation of your first picture
20. The first picture *should* still show your object centered *[Note: it is not out of the ordinary for the telescope to have shifted during this time, in a perfect world the telescope can be easily recentered by entering the RA and Declination. However if this does not work, which can happen as usually the recorded position and the actual position of the object can be different by a small amount, then you must slowly scan the area, taking pictures frequently until the object returns to the picture]*

21. Even a small movement can be enough to move the telescope ever so slightly, this is when the *art* of photometry begins to show, do not be concerned if you are unable to find your object right away, it is only through fine movement of the telescope can the object be found again.
22. Remember that because the eyepiece is no longer attached, only by taking photos can the content of the image be displayed, so using slow movements slew the telescope and retake the photo
23. Eventually you will find your object, and even though the object seemed in focus through the eyepiece, the sensitivity of the camera is much greater than your eye and so will seem out of focus. The CCD Soft program allows you to focus in small increments
24. This is another *art* in photometry, for doing this takes time and can be quite daunting, but once the object is as sharp as you can make it, the focuser and the software will then do fine adjustments that will further focus the object **[Note: The fine tuning is *minimal* so you must be as close as possible to focus for it to work]**
25. The photo should be taken multiple times and that will allow during manipulation of the data to get an average
26. These are your "raw" photos, you may now slew to your next object **[Note: I will at this time replace the eyepiece and use that to do rough adjustments and begin the process again once the object is as focused by eye as I can get it. If you don't do this, it the object may be so out of focus that it does not even show up when taking pictures]**

REFERENCE STARS

Ref. No.	Name	RA/ dec Hr/Deg	Ref. No.	Name	RA/dec
1	Alpheratz/ Alpha And	0/29	11	Polaris/Alpha UMi A	2.5/89
2	Caph/Beta Cas	0/59	12	Mira/Omicron Cet A	2.5/-3
3	Ankaa/Alpha Phe		13	Menkar/Alpha Cet	¾
4	Schedar/Alpha Cas	0.5/57	14	Algol/Beta Per	3/41
5	Diphda/Beta Cet		15	Mirfak/Alpha Per	3.5/50
6	Gamma Cas	1/61	16	Aldeberan/Alpha Tau A	4.5/17
7	Mirach/Beta And	1/36	17	Rigel/Beta Ori A	5/-8
8	Achernar/Alpha Eri		18	Capella/Alpha Aur AB	5.5/46
9	Almach/Gamma And A	2/42	19	Bellatrix/Gamma Ori	5.5/6
10	Hamal/Alpha Ari	2/23			

20	Elnath/Beta Tau	5.5/29	44	Iota Car	
21	Delta Ori A	5.5/0	45	Kappa Vel	
22	Alpha Lep		46	Alphard/Alpha Hya	
23	Alnilam/Epsilam Ori	5.5/-1	47	Regulus/Alpha Leo A	10/12
24	Alnitak/Zeta Ori A	5.5/-2	48	Gamma Leo AB	10.5/20
25	Kappa Ori		49	Merak/Beta Uma	11/56
26	Betelguese/Alpha Ori	6/7	50	Dubhe/Alpha UMa AB	33/62
27	Menkalinan/Beta Aur	6/45	51	Delta Leo	11/21
28	Beta CMa		52	Denebola/Beta Leo	12/15
29	Canopus/Alpha Car		53	Phecda/Gamma Uma	12/54
30	Alhena/Gama Gem	6.5/16	54	Delta Cen	
31	Sirius/Alpha CMa a	7/-17	55	Gienah/Gamma Crv	
32	Delta CMa		56	Acrux/Alpha Cru	
33	Eta CMa		57	Gacrux/Gamma Cru	
35	Castor/Alpha Gem A	7.5/32	58	Gamma Cenm AB	
36	Procyon/Alpha CMi A	7.5/5	59	Becrux/Beta Cru	
37	Pollux/Beta Gem	8/28	60	Alioth/Epsilon UMa	13/56
38	Zeta Pup		61	Mizar/Zeta UMa A	13.5/55
39	Gamma Vel A		62	Spica/Alpha Vir	13.5/-11
40	Avior/Epsilon Car		63	Epsilon Cen	
41	Delta Vel AB		64	Alkaid/Eta UMa	14/49
42	Suhail/Lamda Vel		65	Zeta Cen	
43	Miaplacidus/Beta Car		66	Hada/Beta Cen AB	

67	Menkent/Theta Cen		84	Kappa Sco	
68	Arcturus/Alpha Boo	14.5/19	85	Elranin/Gamma Dra	18/51
69	Eta Cen		86	Kaus Australis/e Sgr	
70	Rigil Kentaurus/a Cen		87	Vega/Alpha Lyr	18.5/39
71	Alpha Lup		88	Nunki/Sigma Sgr	19/-26
72	Izar/Epsilon Boo AB	15/27	89	Zata Sgr AB	
73	Kachob/Beta Umi	15/74	90	Altair/Alpha Aql	20/9
74	Alphecca/Alpha CrB	15.5/27	91	Gamma Cyg	20.5/40
75	Dschubba/Delta Sco A	16/-23	92	Deneb/Alpha Cyg	20.5/45
76	Antares/Alpha Sco A	16.5/-26	93	Gienah/Epsilon Cyg	21/34
77	Zeta Oph	16.5/-11	94	Alderamin/Alpha Cep	21/63
78	Atria/Alpha TrA		95	Enif/Epsilon Peg A	21.5/10
79	Epsilon Sco		96	Al Ni’ir/Alpha Gru	
80	Sabik/Eta Oph AB	17/-16	97	Beta Gru	
81	Shaula/Lambda Oph		98	Fomalhout/Alph a PsA	
82	Rasalhague/Alpha Oph	17.5/13	99	Scheat/Beta Peg	23/28
83	Theta Sco		100	Markab/Alpha Peg	23/15

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