# Eye Tracking System Instruction Manual

## Model 504
## Pan/Tilt Optics

MANUAL VERSION 2.1

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# 1 INTRODUCTION

The Model 504, remote eye tracker is designed to accurately measure a person's pupil diameter and point of gaze on a stationary (room fixed) scene space. The measurement is displayed as a cursor or set of cross hairs superimposed on the image from a scene camera or other video source showing the subject's field of view, and may also be recorded digitally on the eye tracker Interface PC, or exported as a real time serial data stream to an external device. Instrument specifications are summarized in section 9.

The auto-focus eye camera and eye illuminator are contained in a pan/tilt module that automatically moves the camera and illuminator in both azimuth and elevation to follow the motions of a subject's head.

A PC serves as the user interface with the eye tracker, and as a digital data recording device.

A general system description is provided in section 2 of this manual followed by unpacking and installation instructions in section 3. User interface software is described in section 4, followed by detailed operating instructions in section 5, specification of system interface ports in section 6, and explanation of the basic theory of operation in section 7. Section 8 will be useful for fault diagnosis should there be any problem with system function. Formal specifications are provided in section 9.

The model 504 Eye Tracker is a turnkey research tool that comes with many standard features. A variety of options are available which enhance its performance. The specific requirements of a given application may require some of the options briefly described in section 2.3.

# 2 GENERAL SYSTEM DESCRIPTION

The Model 504 eye tracker with an optional magnetic head tracker is illustrated schematically in Figure 2-1. The eye is illuminated by the beam from near infrared LED's on the pan/tilt optics module. An auto-focusing lens system in the pan/tilt module focuses a telephoto image of the eye onto a solid state video sensor (eye camera). The pan/tilt mechanism can rotate both the illumination source and eye imaging components in azimuth (pan) and elevation (tilt) in order to follow the eye as the subject moves about. A second solid state camera (scene camera) may be focused on the scene being viewed by the subject. Both cameras are connected to the model 5000 control unit.

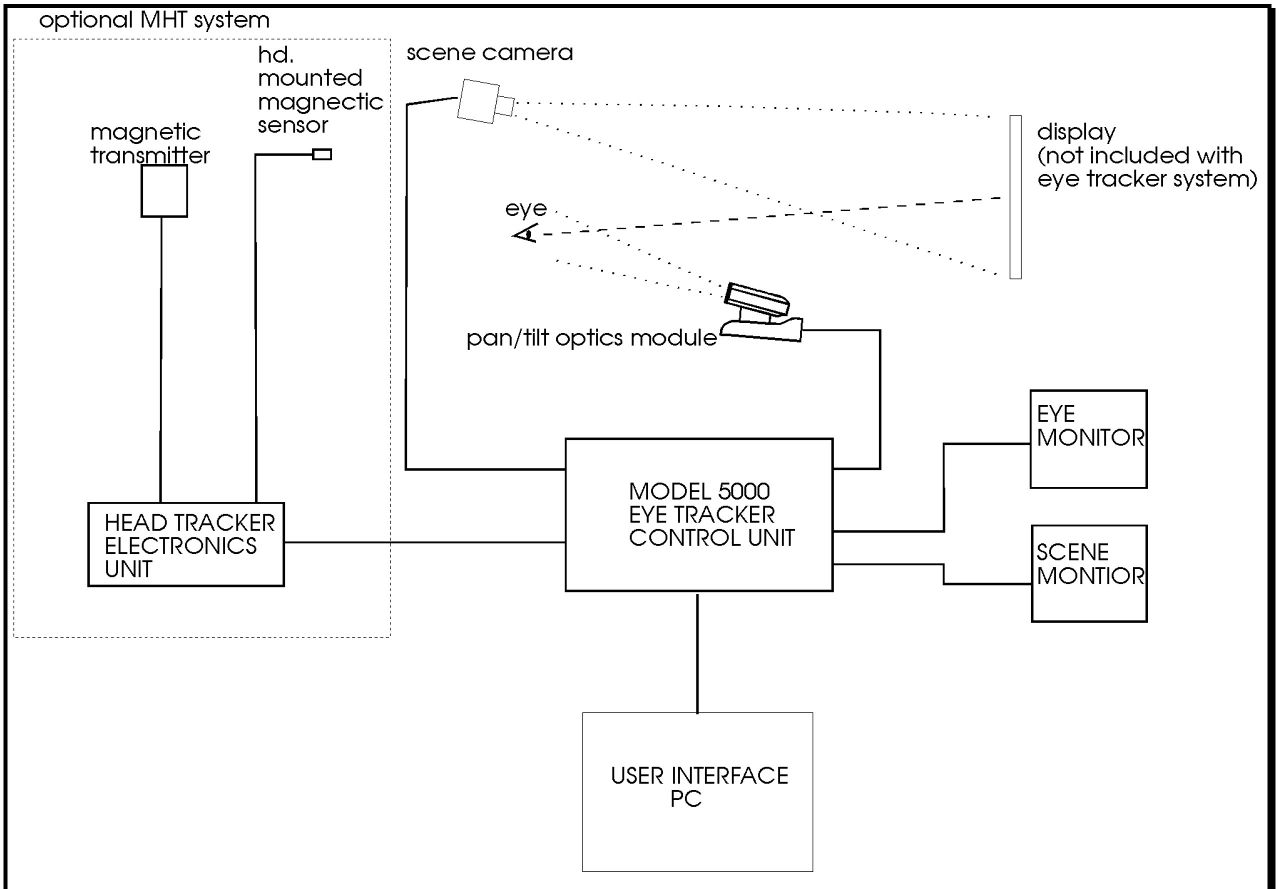



Figure 2-1. Schematic showing model 504 eye tracking system with optional magnetic head tracker

An alternate configuration shown in figure 2-2 assumes that the subject will be viewing a computer monitor, a uses a scan converter (in place of the scene camera) to produce a video copy of the display viewed by the subject.

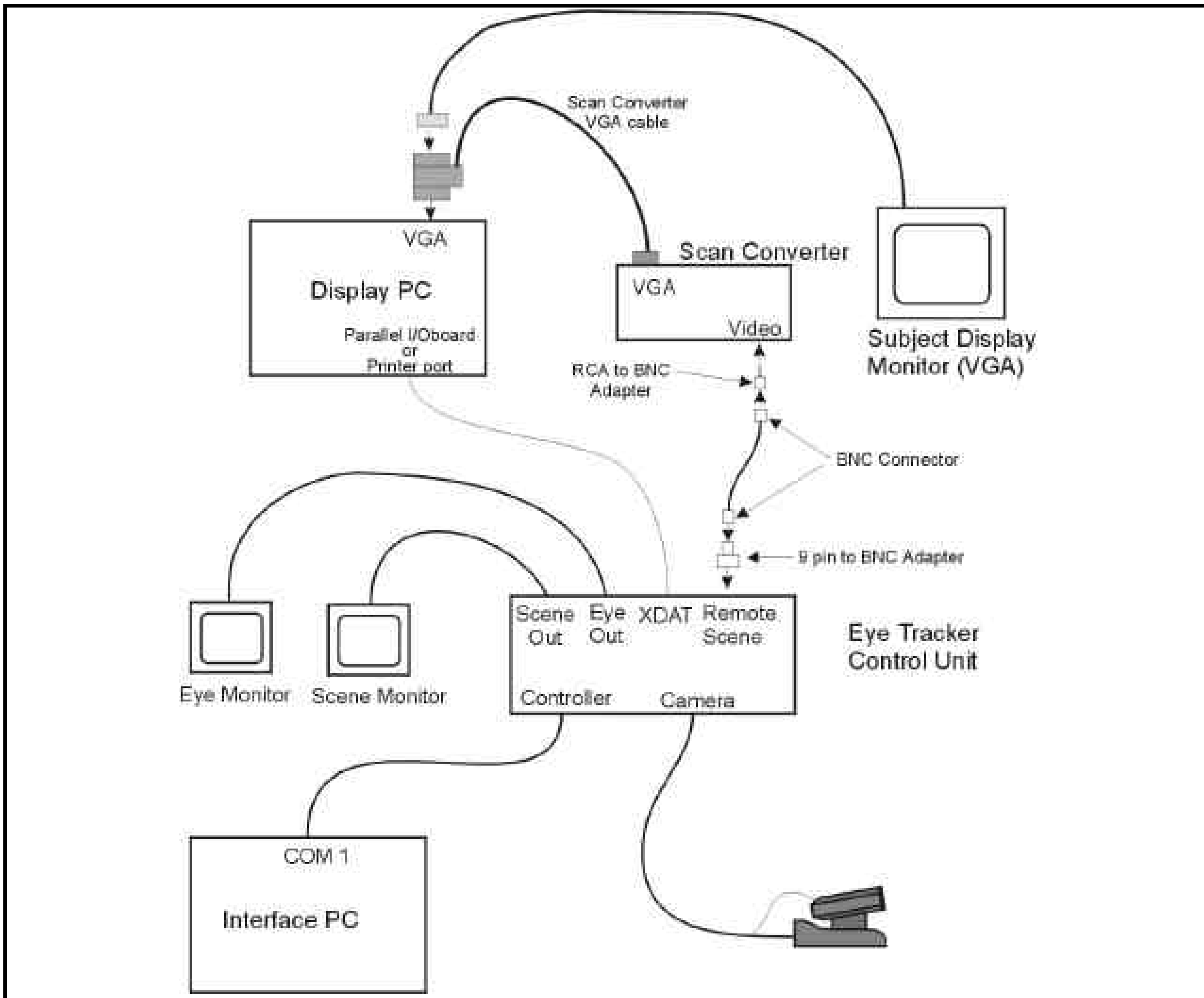



Figure 2-2. Model 504 with scan converter instead of scene camera (optional magnetic head tracker not shown)

The model 5000 control unit processes the eye camera signal to extract the elements of interest (pupil and reflection of the light source on the cornea) and computes both pupil diameter and line of gaze. These data are displayed and output to external data ports. For a discussion of the principles used to determine eye line of gaze see Section 7, Theory of Operation.

The model 5000 control unit also controls the pan/tilt mechanism, using pupil recognition information to determine appropriate pan and tilt commands to keep the pupil image centered. A magnetic head tracker, which provides position information even when eyes are closed or out of the camera field of view, can be used to assist in automatic pan/tilt tracking. A small remote control unit provided with the pan/tilt module can be used to manually position the pan/tilt mechanism.

Pupil and corneal reflection outlines and center cross hairs are displayed on the pupil monitor over the video image of the eye. Eye line of gaze with respect to the helmet is displayed as a cursor or set of cross hairs superimposed on the scene camera video image.

Calibration commands and most other interaction with the operator take place through the Eye Tracker Interface PC terminal. Data may also be recorded on the Interface PC hard disk, and processed later by user written programs or by ASL's data analysis programs (EYENAL option).

The standard model 504 consists of the listed below:

- Model 5000 control unit and plug in power supply
- Pan/tilt optics eye camera optics module.
- Scene camera with tripod, or scan converter
- Two video monitors (one for the eye image and one for the scene image)
- Cables for connecting the model 5000 control unit to the Interface PC, to the pan/tilt optics and scene camera, and to the two monitors.

A minimum system configuration should include all of these items; plus a PC with minimum specifications as described in section 2.1.5. Monitors with video cables may, if desired, be provided by the user instead of by ASL. Figure 2-3 shows the standard model 504 components. Note that a scan converter is often substituted for the scene camera if subjects will be viewing a computer monitor display.

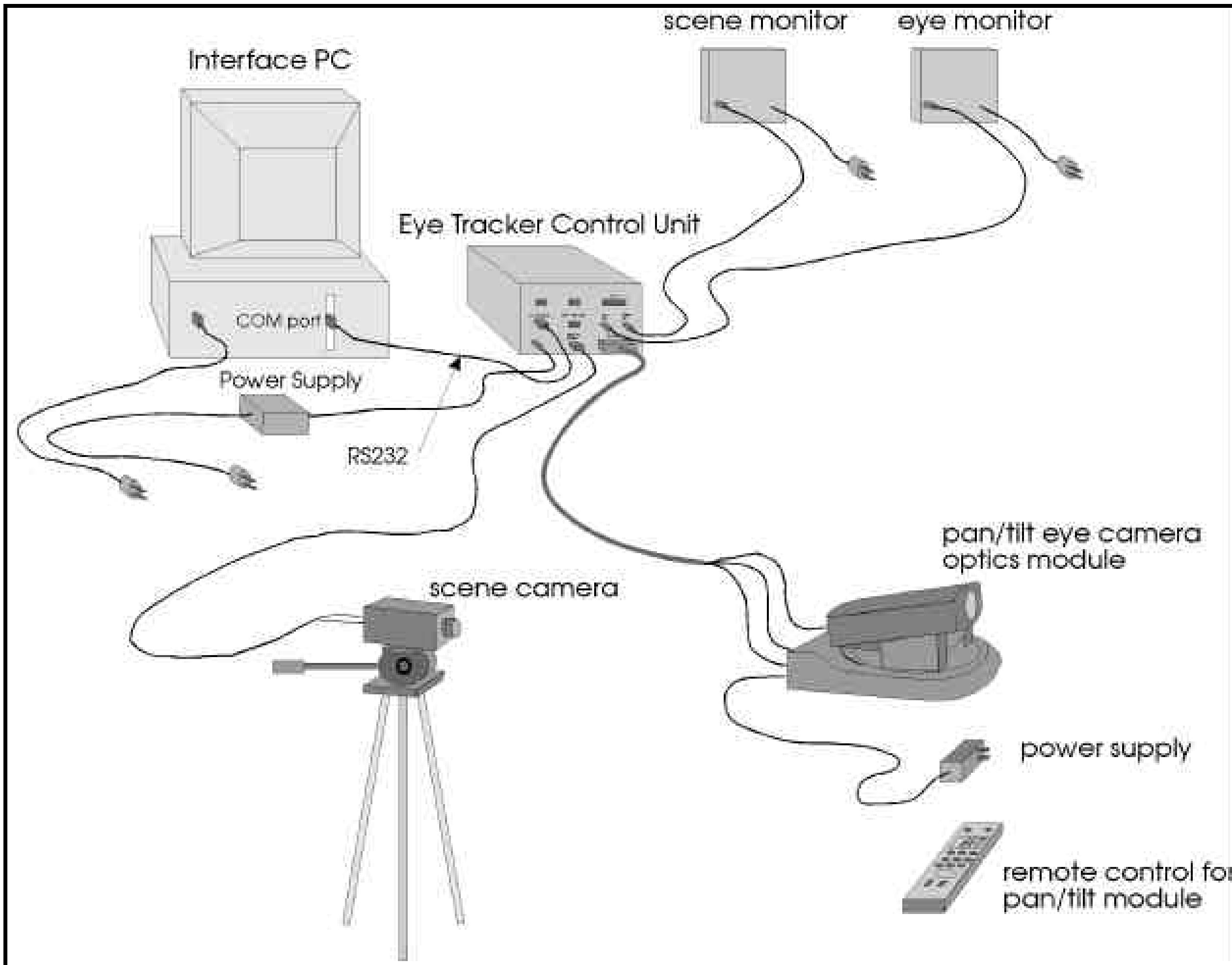



Figure 2-3. Standard components of model 504 eye tracker

## 2.1 Major Assemblies

### 2.1.1 Pan/Tilt eye camera optics module

The pan/tilt module is shown in figure 2-3. It normally rests on a horizontal surface (E.g. table top), but can also mount to a tripod. A ring of near infrared LED's around the lens opening provides eye illumination. A main power switch, and all the necessary connectors are located on the base (non moving) platform rear panel, accept for the illuminator power connector which is located at the rear of the moving platform. A separate power supply connects to a DC power input connector on the rear panel and plugs into a standard AC wall outlet. A IR remote control unit provides manual control for pan/tilt positioning, lens focus and zoom, and various other features built into the pan/tilt camera. The eye camera video output is 60 Hz (NTSC) or 50 Hz (PAL) composite video format depending upon the video standard in the destination country.

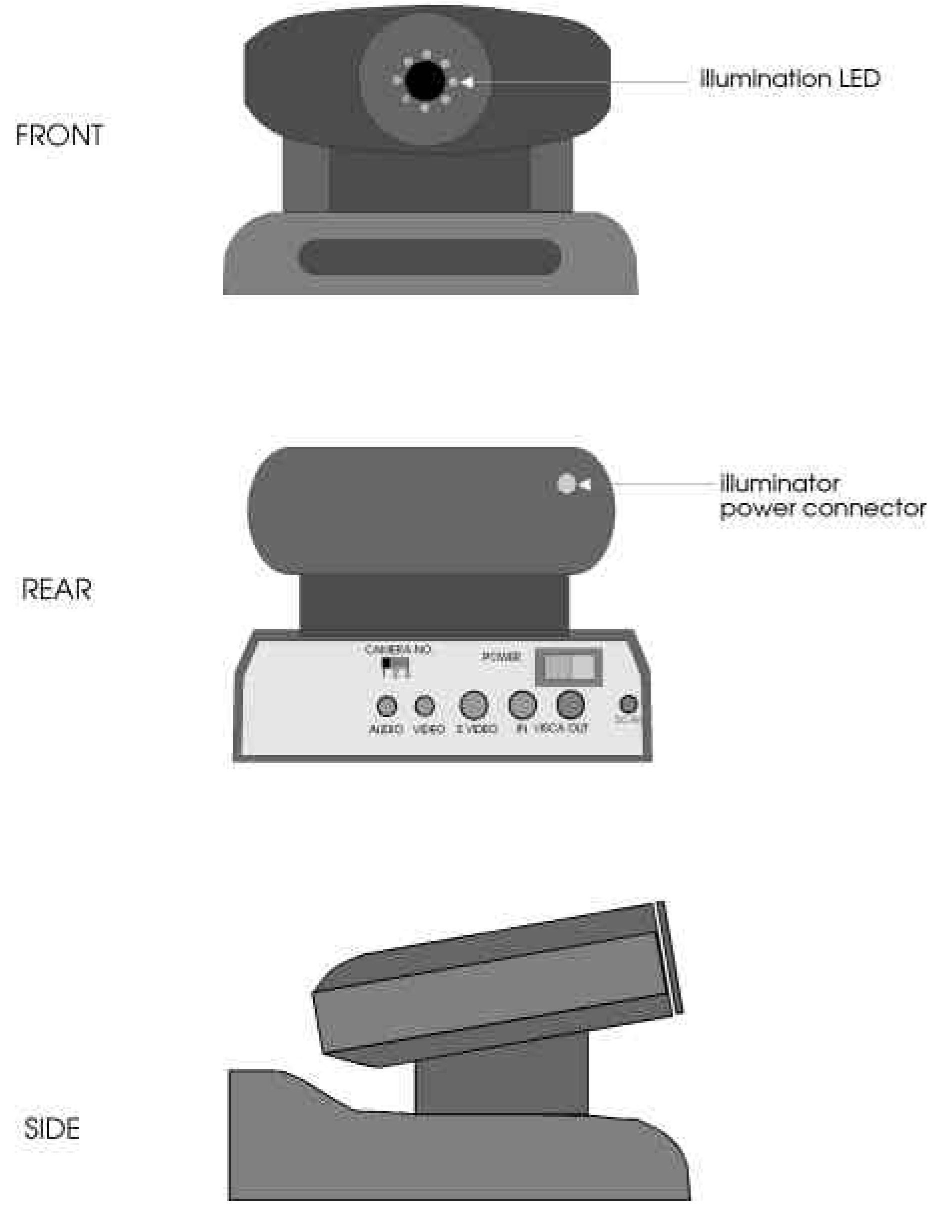



Figure 2-4. Pan/Tilt eye camera optics module.

The pan/tilt mechanism provides about 100° of pan angle and 25° of tilt capability. It may often be necessary to tilt the base of the unit to achieve the necessary camera view angle range and a removable knob is provided for this purpose. The tilt knob screws into a "¼- 20" hole in the unit base plate and, when in place, can be adjusted to hold the front of the base plate between 1.25 and 1.5 inches above the table surface (see figure 2-4). The same mounting hole can be used to fasten the unit to a tripod.

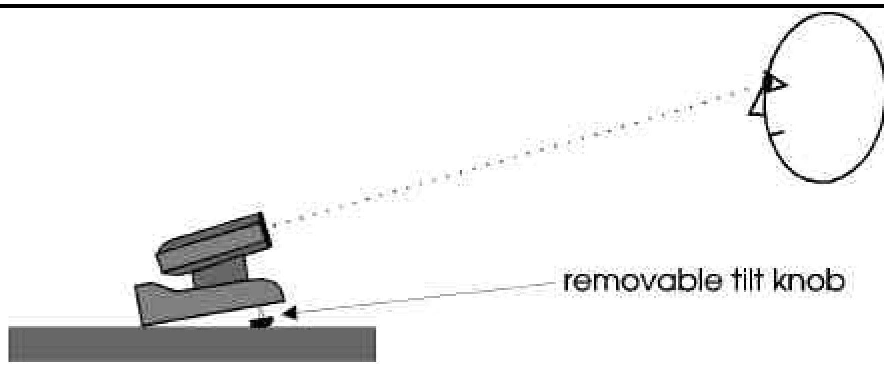



Figure 2-5. Pan/tilt module with tilt knob installed

The camera has an auto-focusing lens and a zoom function. As configured for eye tracking, the zoom setting actually controls the range over which the camera can be focused. At maximum zoom magnification the camera will auto focus over a range of from about 18 to 24 inches. As zoom magnification is decreased, focus distances increase. The maximum distance at which the eye tracker can be used effectively is about 40 inches from the camera to the eye.

The pan and tilt position, as well as some other pan/tilt module functions, can be manually adjusted from a hand held remote control unit. The remote control is an IR emitting device and must be pointed towards the front of the pan/tilt module when used. Pan/tilt functions can also be controlled from the Eye Tracker Interface program described in section 4.

### 2.1.2 Floor Mounted Scene Camera (FMSC) or Scan Converter

The scene camera is used to produce a video image of the same scene the subject views. This video scene image provides the reference frame for the eye point of gaze measurement. The color scene camera provided by ASL as part of the standard model 504 system, is powered directly from the model 5000 control unit, is equipped with an 8 mm lens, and includes a standard photography tripod to support the camera. The scene camera video output is 60 Hz (NTSC) or 50 Hz (PAL) composite video format depending upon the video standard in the destination country.

Alternately, if eye tracking subject's will be looking at a computer screen, the system may include a scan converter in place of the scene camera. The scan converter converts the VGA computer screen image (being viewed by the subject) to a composite video signal (either NTSC or PAL standard) which can be input to the eye tracker control unit as the scene video image. The scan converter is powered by its own external AC supply.

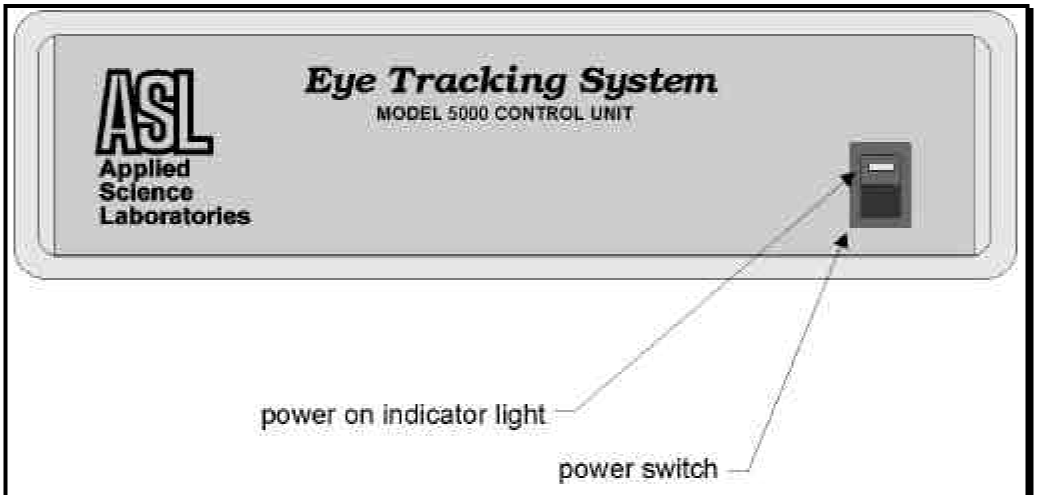



Figure 2-6. Model 5000 Eye Tracker Control Unit front panel

### 2.1.3 Model 5000 Eye Tracking System Control Unit

The model 5000 control unit measures 3.25" h x 10.0" w x 10.25" d and weighs 4.5 lb., and includes an external 12VDC power supply. The unit front panel (figure 2-5) contains a power switch and the rear panel (figure 2-6) contains all necessary connectors. Basic use of the device requires the connectors labeled “Controller”, “Camera”, “Remote Scene”, “Eye Out”, “Scene Out”, and “12V DC IN”. These are the connections to the Interface PC; the eye camera, pan/tilt mechanism and illuminator; scene camera; eye monitor; scene monitor; and the DC power supply respectively. Other connectors support various options or secondary functions such as communications with a head tracker and data output to an external device. The “HMO/PT” slide switch should be in the “P/T” position for use with pan/tilt optics.

The control unit houses the processing board that receives video from eye and scene cameras,

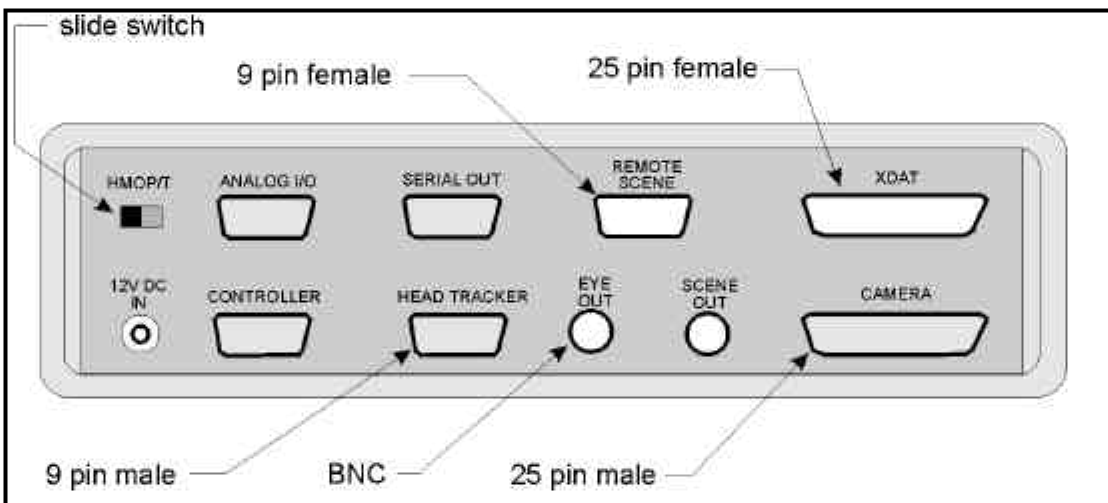



Figure 2-7. Model 5000 Eye Tracker Control Unit rear panel

recognizes features in the video eye image and computes line of gaze, communicates with the Interface PC, controls the pan/tilt mechanism, and superimposes feedback outlines, cross hairs, and cursors on the eye and scene video signals for monitor display. When an optional magnetic head tracker is used, this processing board also communicates with the head tracker and can use the head position data to assist with control of the pan/tilt mechanism.

### 2.1.4 Monitors

The standard system includes two video monitors, one for the eye image and a second for the scene image. If the scene monitor is provided by ASL it may sometimes be equipped with a switch marked "normal/reverse". This is primarily for use with head mounted optics (model 501 eye tracker systems). If a monitor is equipped with this switch, keep the switch in the "normal" position for use with the model 504 system.

If monitors are supplied by the user, note that video cables must also be supplied. The monitor(s) may be black and white or color and must accept a standard EIA (black and white) or NTSC (color) composite video signal (CCIR or PAL if 50 Hz cameras are being used).

The eye monitor displays the image from the eye camera. When the eye tracker is functioning properly, a white outline is superimposed over the image recognized as the pupil and a black outline is superimposed on the image recognized as the corneal reflection (CR). A white set of cross hairs designates the center of the pupil and a black set designates the CR center.

The scene monitor presents a video image of the scene being viewed by the subject, with a cursor or set of cross hairs superimposed to indicate the subject's point of gaze.

### 2.1.5 Eye Tracker Interface PC (Controller)

A computer may be supplied by ASL as part of a series 5000 eye tracking system, but is usually supplied by the user. The computer serves as the user interface device and as a data-recording device. ASL always supplies an Eye Tracker Interface program, which runs on this computer, and it is a required part of the system.

System requirements for the Interface PC are an IBM compatible PC capable of operation with Windows 95, Windows 98, Windows NT, or DOS. *Note, however, that a computer that can run only DOS is limited to using only the DOS version of ASL's Eye Tracker Interface Program.* The computer must also have available COM1 or COM2 serial ports using standard interrupts and device addresses. The minimum recommended system is a 200 MHz Pentium, but slower systems will probably work adequately as well. In these cases consult ASL

### 2.1.6 Software

The EYEPOS software package necessary to operate the eye tracker and record data is provided as a standard part of a series 5000 eye tracker. The EYEPOS software is included on a CD ROM, labeled "EyeTracker Software", or on a floppy disk labeled "EYEPOS". Also included on the CD

ROM or on a set of floppy disks is the EYENAL data analysis software, which includes a “CONVERT” function to convert binary data files to ASCII, and ACCESS software to allow access to binary data files from user written C programs.

## 2.2 Interface Description

The Eye Tracker Interface PC is connected to the model 5000 control unit with an serial RS232 cable from COM1 on the PC to the “Controller” connector on the model 5000 control unit. If an optional magnetic head tracker is being used it interfaces with a serial (RS232) connection to the model 5000 control unit connector labeled “Head Tracker”. Real time serial (RS232) data can be exported to an external device via the model 5000 control unit connector labeled “Serial Out” (the interface protocol is described in section 6). The video images from either the scene or pupil monitor may also be video taped.

The port labeled XDAT on the model 5000 control unit may be used to input parallel digital data from an external device, for recording on the Eye Tracker Interface PC along with gaze data.

## 2.3 Options

Described below are some additional components and software options, available from ASL, which may further enhance system operation.

### 2.3.1 Mobile Eye Tracker Control Unit (model 5000M)

The Mobile Control Unit measures 2.6"h x 10.1"w x 8"d and weighs only 3.25 lbs. The power switch with pilot light, the “Camera” connector, the “Remote Scene” connector, and the Scene Out and Eye Out monitor connectors are located on the front panel. The “Controller”, “DC In”, “XDAT”, “Head Tracker”, and “Serial Out” connectors, as well as the “HMO Pan/Tilt” slide switch are located on the rear panel. A 12VDC power supply unit is included, but a battery with 12VDC output and at least a 25 Watt capacity may be used instead.

The portable control unit is small enough and light enough to be carried by the subject in back pack or fanny pack, but does not support analog data output.

### 2.3.2 Magnetic Head Tracking Hardware (MHT)

The magnetic head tracking option (MHT) is a small unit that determines head position and orientation with good accuracy in six degrees of freedom. The head tracker output can be recorded independently of the eye tracker by a host computer or by the Eye Tracker Interface PC. When used with the model 504 eye tracker system, the head tracker can be used by the model 5000 control unit to assist in determining positions for the pan/tilt mechanism..

Head position is measured in six degrees of freedom at distances of up to 36 inches from the reference source (precise value depends upon model head tracker used). The unit consists of a control unit, a transmitter module (reference), and a small sensor (or receiver) which is attached to a Velcro head band worn by the subject. Nylon screws are provided for mounting the magnetic transmitter module. A cable is also provided to connect the MHT control unit to the "Head Tracker" port on the model 5000 Eye Tracker Control Unit.

The magnetic head tracker performance can be affected by large pieces of nearby metal or anything else that causes magnetic field distortion. Consult ASL for details.

# 3 INSTALLATION

## 3.1 Unpacking and Assembly

### 3.1.1 Control Unit

Locate the model 5000 Eye Tracker Control Unit and unwrap the protective material. Be sure that the power switch on the front panel is in the OFF (down) position. For use with pan/tilt optics, be sure that the slide switch on the rear panel is in the “P/T” position.

Locate the 12VDC power supply module and connect it to the “DC Power” connector on the Control Unit. Connect the other side to an AC power outlet. The power supply is input rated for 100 - 240 VDC, 50 or 60 Hz. The LED on the Control Unit front panel should remain off until the power switch is switched on.

### 3.1.2 Pan Tilt Optics

The pan tilt module will be in a small box within one of the large shipping boxes. It is packed in protective foam along with a 13.5 VDC power supply, remote control, and the removable tilt knob. Place optics module on a flat surface or, if it will be mounted to a tripod, fasten it to the tripod using the “1/4 - 20” hole under the nonmoving base. Be sure the power switch is in the off position. Connect the 13.5 VDC supply to the “DC IN” connector.

### 3.1.3 Scene Camera

If the scene camera (FMSC) was ordered from ASL, locate the scene camera in one of the shipping boxes. Locate the scene camera lens. If the lens is not already mounted to the camera, it will probably be in a amall marked "accessories". Locate the scene camera tripod and adjustable tripod head. The tripod will usually be in the manufacturer's box within one of the two-foot cube boxes. Using the mounting screw on the tripod head, mount the scene camera on the tripod. The handle on the tripod head, which turns to loosen and tighten, may be used to position the camera.

### 3.1.4 Scan Converter

If a scan converter was ordered from ASL, find the Scan converter box, carefully unpack the components and place them near the computer and monitor that is to provide the VGA display that the subject will look at. Note that use of the scan converter is appropriate only if the eye tracker subjects will be looking at VGA computer display. There is no mechanical assembly required, and cable connections are described in the “Interconnections” section (section 3.3.5).

### 3.1.5 Eye Tracker Interface PC

If the Eye Tracker Interface PC has been supplied by ASL, locate the computer, monitor, keyboard, and mouse, and assemble in the usual fashion. If supplied by ASL, the computer will have eye tracker software pre-installed. Software installation and operation procedures are discussed further on. It is assumed that the user is familiar with standard PC assembly and operation. If not, please consult ASL.

### 3.1.6 Magnetic Head Tracker (optional)

The magnetic head tracker (MHT) unit comes individually packaged. The package contains a control box, a source module with cable and connector, a sensor module with cable and connector, and a manual with one or more floppy disks. The MHT system may be either an Ascension "Flock of Birds" or a Polhemus "FASTRAK" or "ISOTRAK" type system. Consult ASL for comparative details.

The MHT transmitter (source) module must be mounted to a stable, nonmetallic surface using the nylon screws provided. Placement of the transmitter is discussed in the following section.

It is suggested that the transmitter be mounted so that it will be just above and behind the subject's head; and so that when the subject's head is in the nominal center (or average) position, the sensor will be about 10-12 inches from the source. If possible the source should be oriented such that the x axis is directed toward the subject and so that the y axis points down. It is also very important that the transmitter be rigidly supported, since any motion of the transmitter will introduce an error in the data.

## 3.2 Component Placement

### 3.2.1 Optics and Scene

The standard placement of the pan tilt module and resulting "measurable field of view" is shown in Figure 3-1. The measurable field of view is shown in another way by figure 3-2. Note that the measurable field extends symmetrically to either side the pan/tilt camera and above the pan/tilt camera, but only a small distance below the camera. This is because the upper eye lid begins to occlude the camera's view of the eye when the subject looks below the eye camera. For this reason the pan/tilt camera module should ideally be placed near the bottom of, or below, the desired field of view, but near the horizontal center of the desired field of view. Such an arrangement minimizes eyelid occlusion of the pupil and provides left to right symmetry. It is possible, however, to put the optics unit at many different positions, and less than ideal positioning may sometimes be required for a particular application or experiment. Figures 3-3, 3-4, and 3-5 show typical component placement when the subject will be viewing a computer monitor.

The optics unit may be placed anywhere so long as the following constraints are observed.

1. The optics unit to eye distance ($D_{eo}$ in figure 3-1.) must be in the range of 18-40 inches. The recommended optics to eye distance is from the mid 20's to low 30's of inches.

2. There must be a clear optical path between the optics unit and the eye.

3. Wherever the optics unit is placed, the measurable field of view will be about 25 degrees visual angle to either side of the optics, about 25 degrees above the optics and about 10 degrees below the optics as shown in figures 3-1, and 3-2. The method for calculating visual angles is shown in figure 3-3.

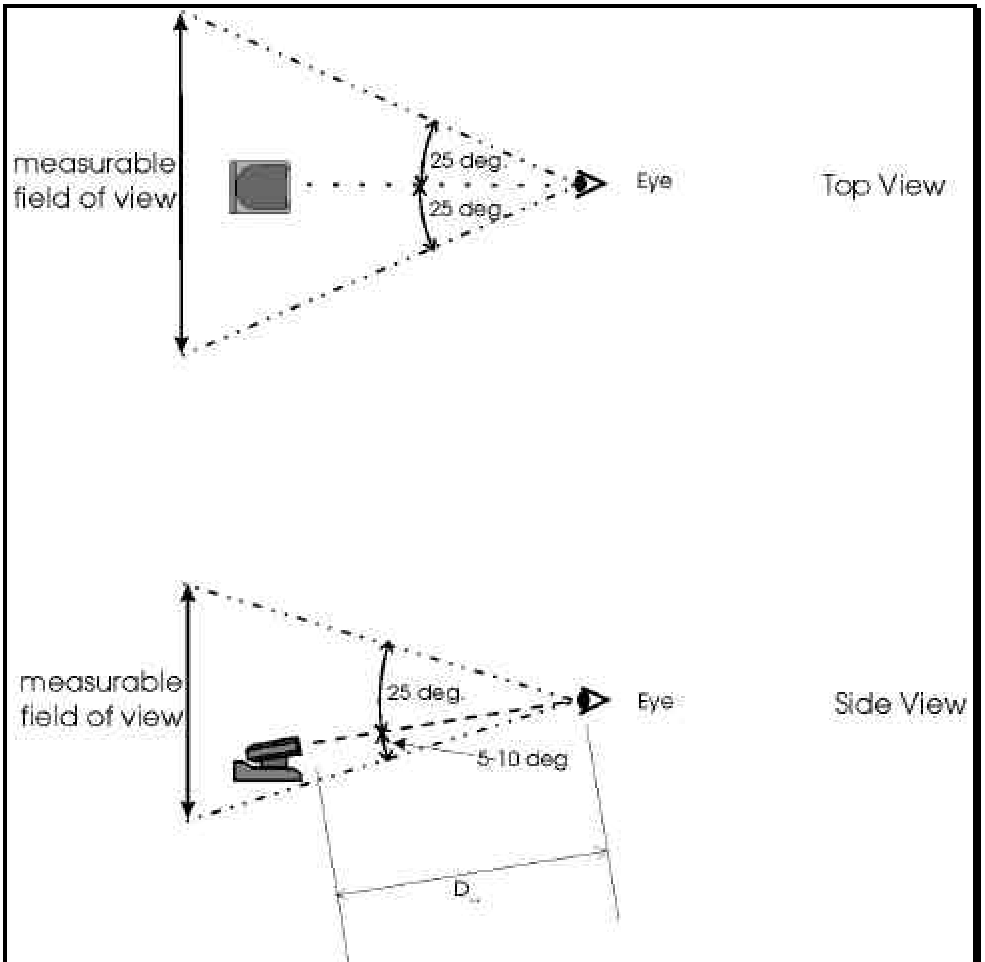



Figure 3-1. Measurable field of view as seen from the top and side

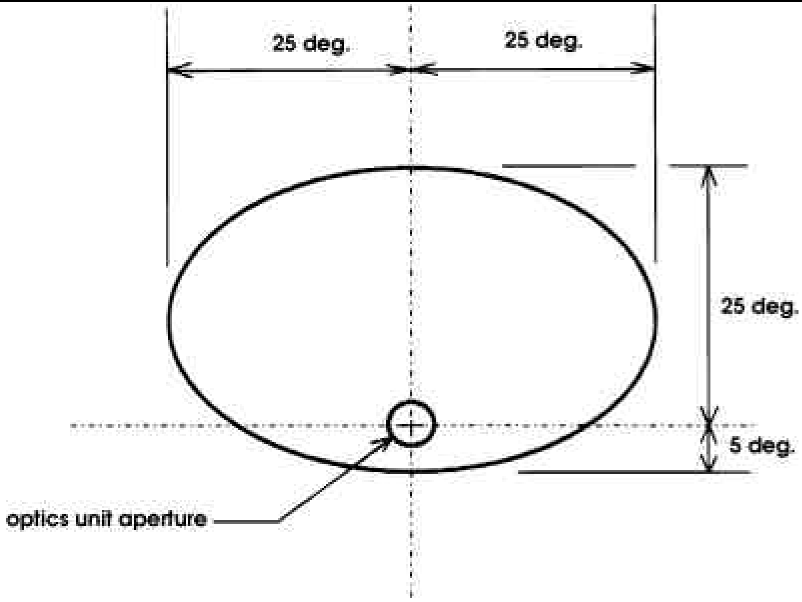



Figure 3-2. Measurable field of view shown from subject's view point The field is approximate since precise boundaries will vary from subject to subject.

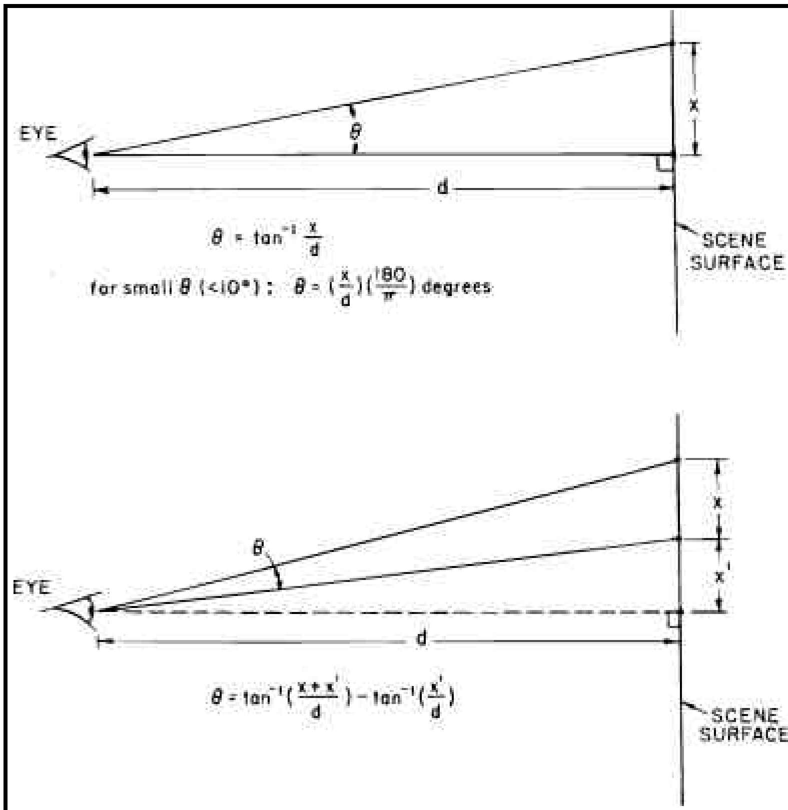



Figure 3-3 Computation of visual angle between points on a flat surface.

Although the optics-to-eye distance is restricted as previously described, there is no such restriction on eye-to-scene distance. The scene may be a video display, a slide projection, or any other display. It may be at any distance so long as it falls within the visual field defined by figures 3-1 and 3-2. Errors in point of gaze measurement due to head motion will be minimized when the scene being viewed by the subject is at the same distance from the subject as the front of the pan/tilt module. Such optimal placement may not always be practical, however, and other arrangements do not preclude successful gaze measurement.

Figures 3-4 through 3-7 show some typical scene and pan/tilt module arrangements. In figures 3-4 through 3-6 the scene being viewed by the subject is a monitor. Note that only figure 3-4 satisfies the optimal conditions by placing the optics module and scene surface the same distance from the subject, and placing the optics module just below the scene but centered horizontally. Figure 3-5 shows the optics placed to one side of the monitor. This will work well so long as the upper right corner of the monitor remains within about 25 degrees visual angle from the optics module. (Measurements could also be made when the subject looks to the left of the pan/tilt module, but in the case of figure 3-5 this is wasted capability since there is nothing there for the subject to look at.) If the surface to be viewed by the subject is especially large, like the very large monitor shown

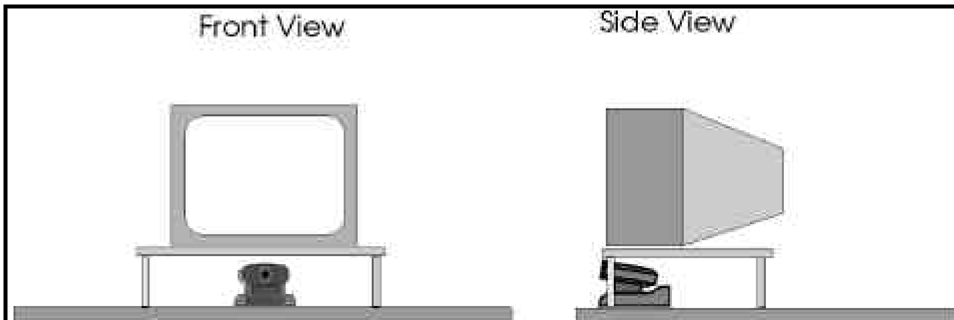



Figure 3-4. Optimal placement for .the pan/tilt optics module and a monitor to be viewed by eye tracking subjects. The pan/tilt unit should be as close as possible to the bottom of the monitor screen.

by figure 3-6, the optics module may have to be placed just in front of the surface as shown in figure 3-6. If the pan/tilt module were placed below this large monitor, points at the top of the monitor screen would probably be more than 25 degrees visual angle from the pan/tilt optics, and the top of the monitor screen would be beyond the measurable field. In other cases, such as a subject viewing a large projection screen, the pan/tilt optics module may have to be even further from the scene surface as shown in figure 3-7.

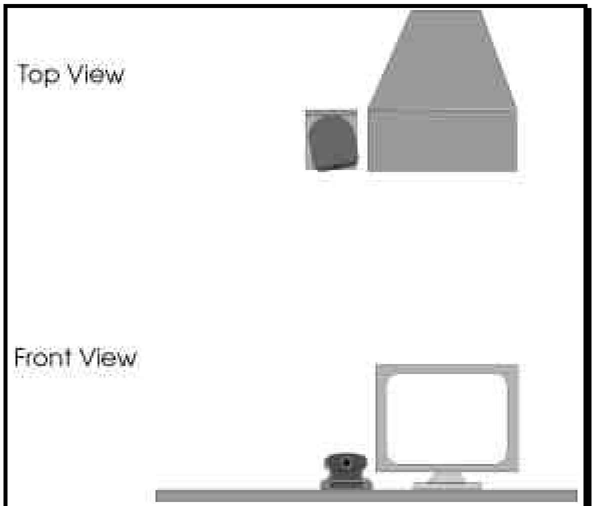



Figure 3-5. Pan / tilt optics module placed beside monitor to be viewed by eye tracking subjects.

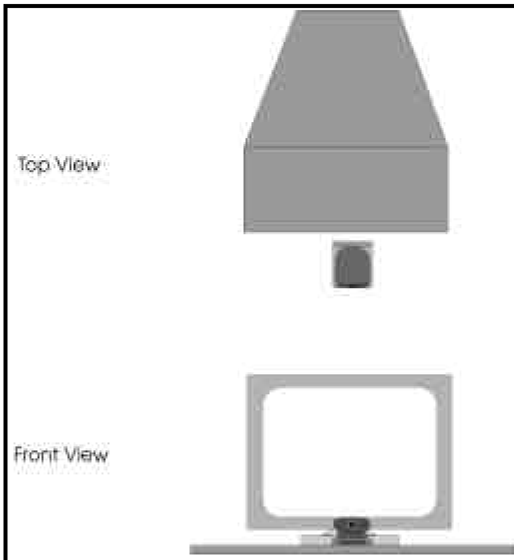



Figure 3-6. Pan / tilt optics placed in front of a very large monitor.

There must also be a method for displaying a nine point target pattern on the display scene surface. This calibration target display is explained in more detail in section 5.1.

The scene camera should be placed so that it captures the scene of interest, i.e., the scene that the

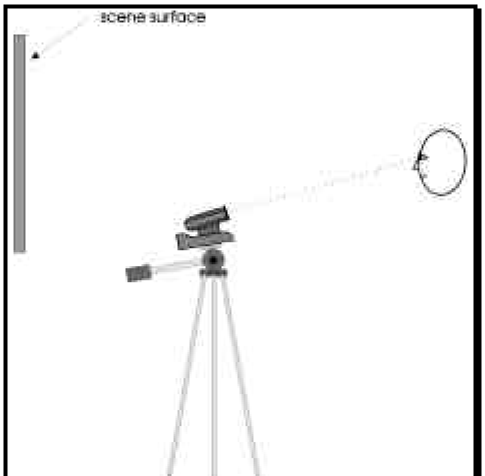



Figure 3-7. Pan / tilt module mounted on tripod in front of projection screen.

subject will be viewing. It should be placed as close to the subject's head as possible so that the scene camera image shows the same perspective as that seen by the subject. If scene video can be used directly or with the help of a scan converter, as described in section 2.1.2, a scene camera is not required at all.

Although a tripod is provided for the scene camera the camera may also be mounted in any other way that is convenient. It is recommended that the scene camera be mounted securely enough so that its position will not often be changed accidentally by someone bumping it or brushing against it. As will be seen in section 5, system calibration requires that the scene camera be stationary and certain procedures must be repeated if it moves.

### 3.2.2 Magnetic Head Tracker Placement

If the system is equipped with the magnetic head tracking option (MHT), the MHT transmitter (source) module must be mounted to a stable, nonmetallic surface using the nylon screws provided. It is suggested that the transmitter be mounted so that it will be just above and behind the subject's head as shown in figure 3-8; so that when the subject's head is in the nominal center (or average) position, the transmitter is about 6 inches behind the head. If possible the source should be oriented such that the x axis is directed toward the subject and so that the y axis points down. It is also very important that the transmitter be rigidly supported, since any motion of the transmitter will introduce an error in the data.

A common mounting arrangement for the transmitter is a wooden post (E.g. American 4" by 4" lumber) with a metal or wooden base as shown in figure 3-9.

## 3.3 Interconnections

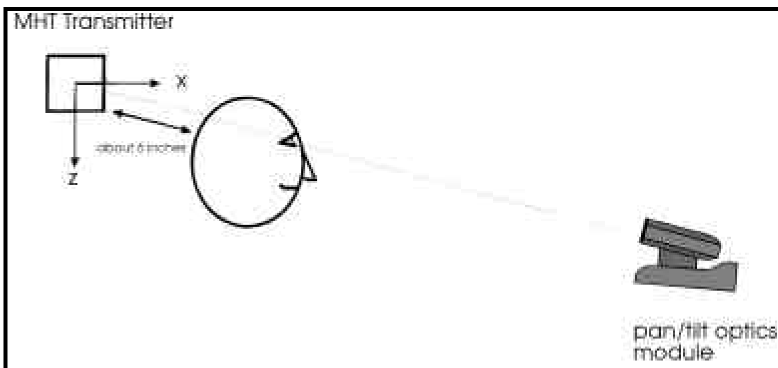



Figure 3-8. Suggested placement of optional magnetic transmitter

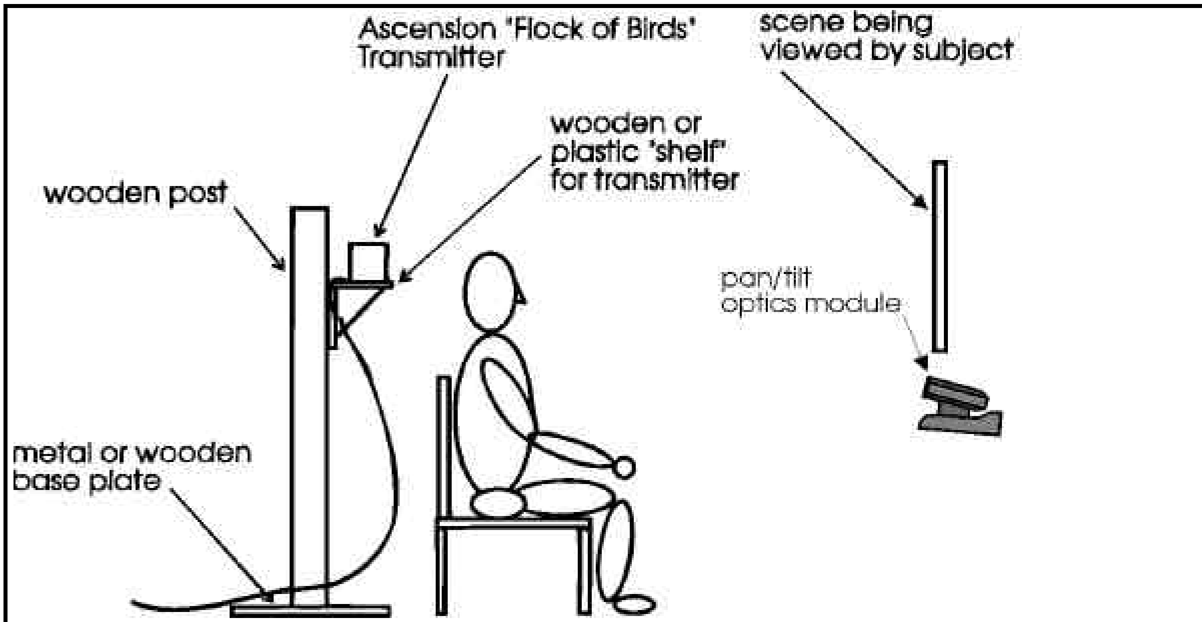



Figure 3-9. Suggested mounting arrangement for magnetic transmitter.

Figure 3-10 shows interconnections for a standard model 504 eye tracker and optional magnetic head tracker.

### 3.3.1 Pan/Tilt Optics module Connections

1. Be sure that system power and pan/tilt module power are OFF.
2. Connect the 13.5 VDC power supply to the pan/tilt module “DC IN” connector, and to an AC wall outlet.
3. Find the camera/control-unit cable. It has 25 pin D type connector at one end, and multiple connectors at the other. The standard length is 7.6 meters (25 ft.) although other lengths are available (consult ASL).
4. Plug the 25 pin D type connector into the connector labeled “Camera” on the model 5000 Eye Tracker Control Unit.

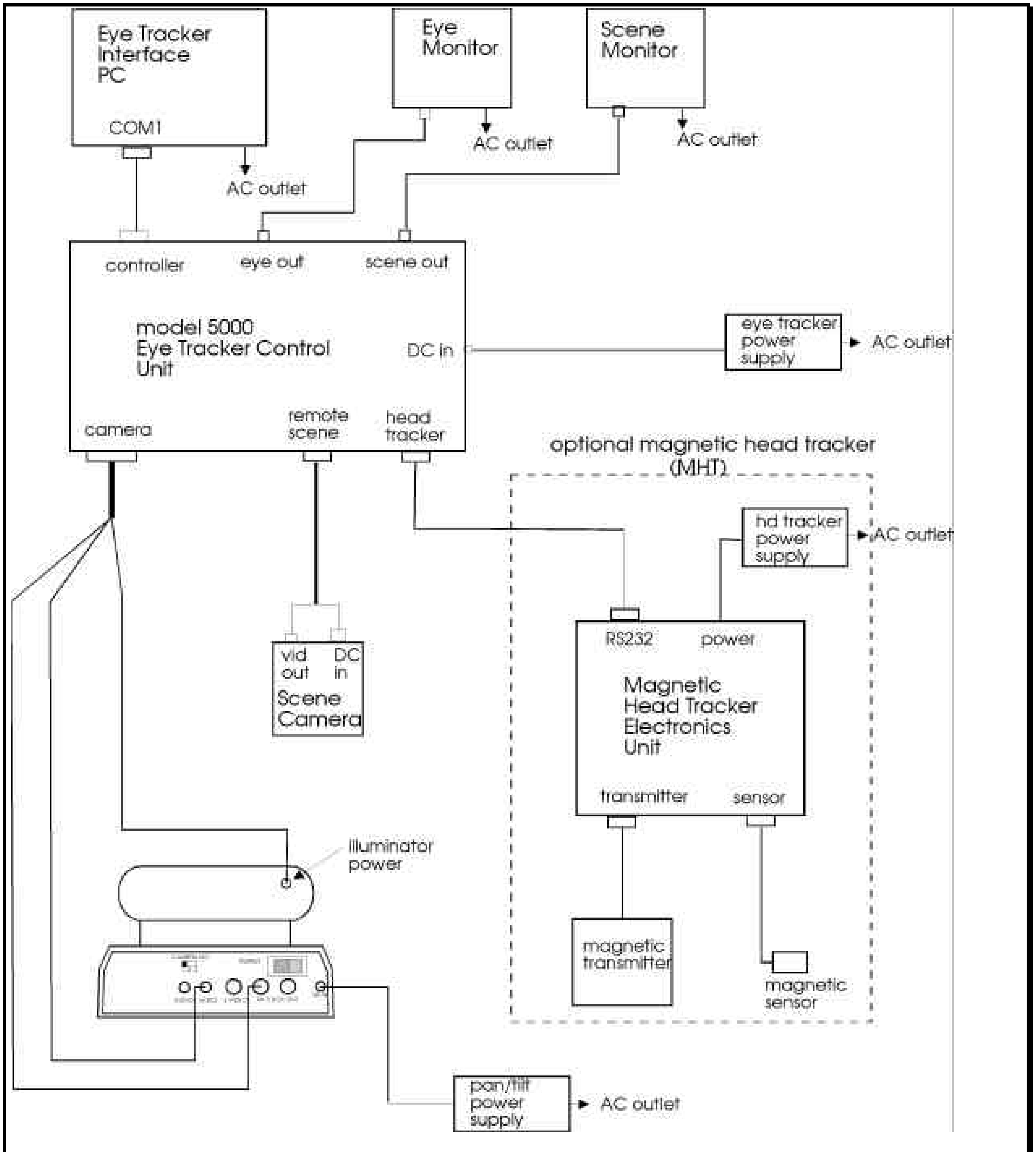



Figure 3-10. Interconnections for model 504 Eye Tracker with optional magnetic head tracker (MHT)

1. At the other end of the cable connect the plug with the yellow boot into the socket labeled “VIDEO OUT” and the multi-in plug to the socket labeled “VISCA IN” on the rear panel of the pan/tilt base. Plug the remaining socket into the connector on the rear of the moving pan/tilt assembly (see figure 2-3).

2. Strain relieve the cable at the pan tilt end by taping it to the table or tripod leg, etc. Cable ties or other strain relief techniques may also be used. Be sure that the illuminator cable (the lead that is connected to the moving part of the pan/tilt mechanism) has enough slack to accommodate full panning motion of the mechanism. If the point where the cable separates into multiple leads is fixed close to the pan/tilt rear panel, there will be sufficient slack.

### 3.3.2 Eye Tracker Interface PC Connections

Use the provided cable to connect the port labeled “Controller” on the model 5000 Eye Tracker Control Unit to the COM1 or COM2 port on the Interface PC.

### 3.3.3 Monitors

Connect a video cable from the eye monitor video input, to the control unit connector labeled "Eye Out”. Connect a video cable from the scene monitor video input, to the control unit connector labeled "Scene Out”.

### 3.3.4 Magnetic Head Tracker Connection (Optional)

The transmitter (source) and sensor modules attach to the clearly labeled connectors on the MHT electronics unit. See the manual packaged with the MHT system for details. Connect one end of the provided MHT interface cable to the RS232 port on the MHT control unit. Connect the other end of the MHT interface cable to the model 5000 Eye Tracker Control Unit connector labeled “Head Tracker”. Set the DIP switches on the MHT electronics unit for 19200 Baud RS232 communications (consult manufacturer’s manual packaged with the MHT system for proper DIP switch settings). The E5000 EYEPOS software must be the appropriate version for the type of MHT system being used (consult ASL).

### 3.3.5 Direct Use of Scene Video

If the subject will be viewing a video image (E.g., a video tape displayed on a monitor) the same video signal can be used directly as the scene video signal for the eye tracker, rather than using a separate scene camera. If the subject will be viewing a computer screen, a scan converter can be used to convert the computer image (E.g. VGA) into a composite video signal, which in turn can be used as the eye tracker scene video signal. Note that ASL can supply a scan converter instead of, or in addition to a scene camera. Recommended connection for these configurations are shown in figures 3-11 and 3-12 (also see figure 2-2).

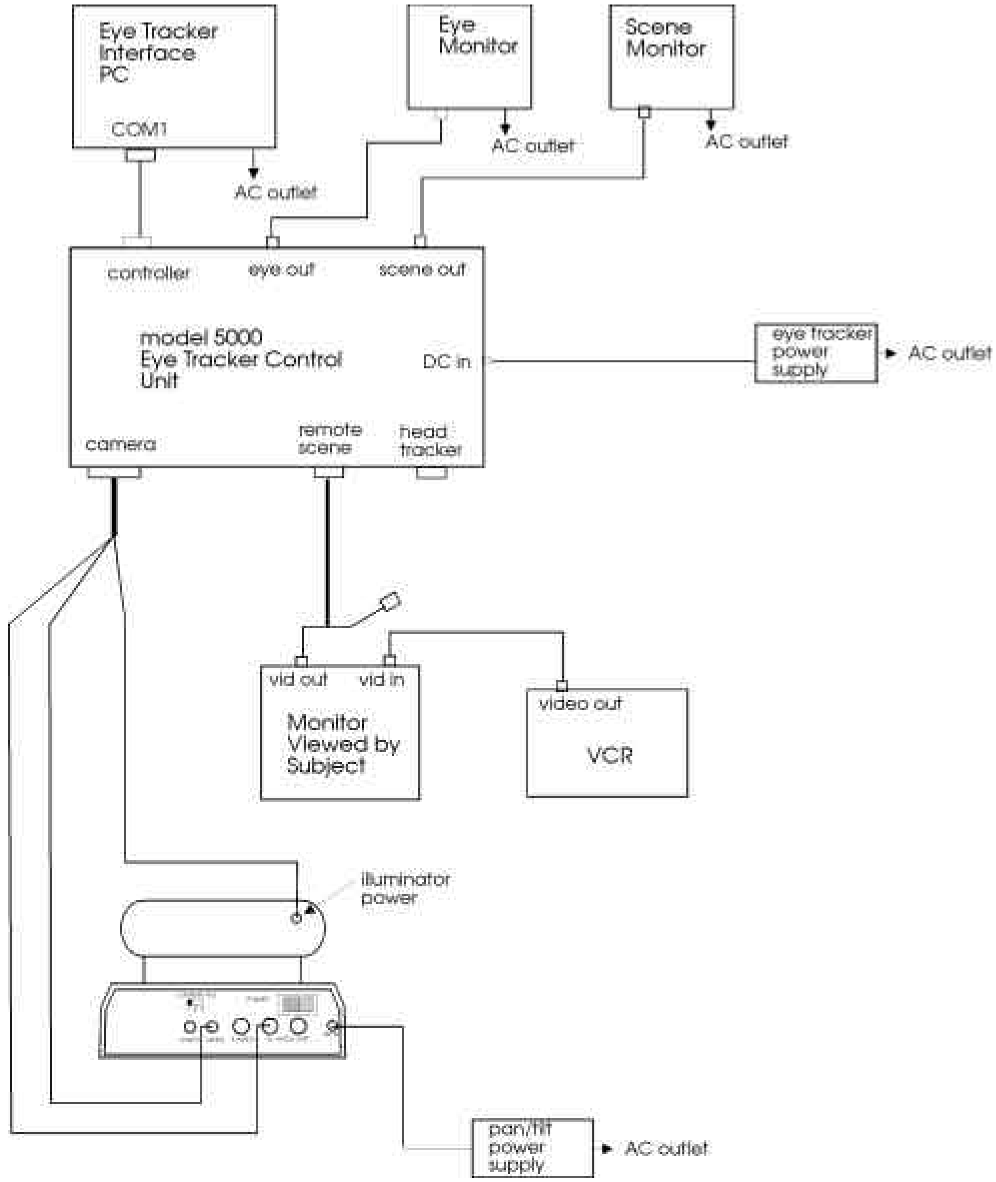



Figure 3-11. Connections for direct use of scene video signal (in place of scene camera). Optional MHT system is not shown.

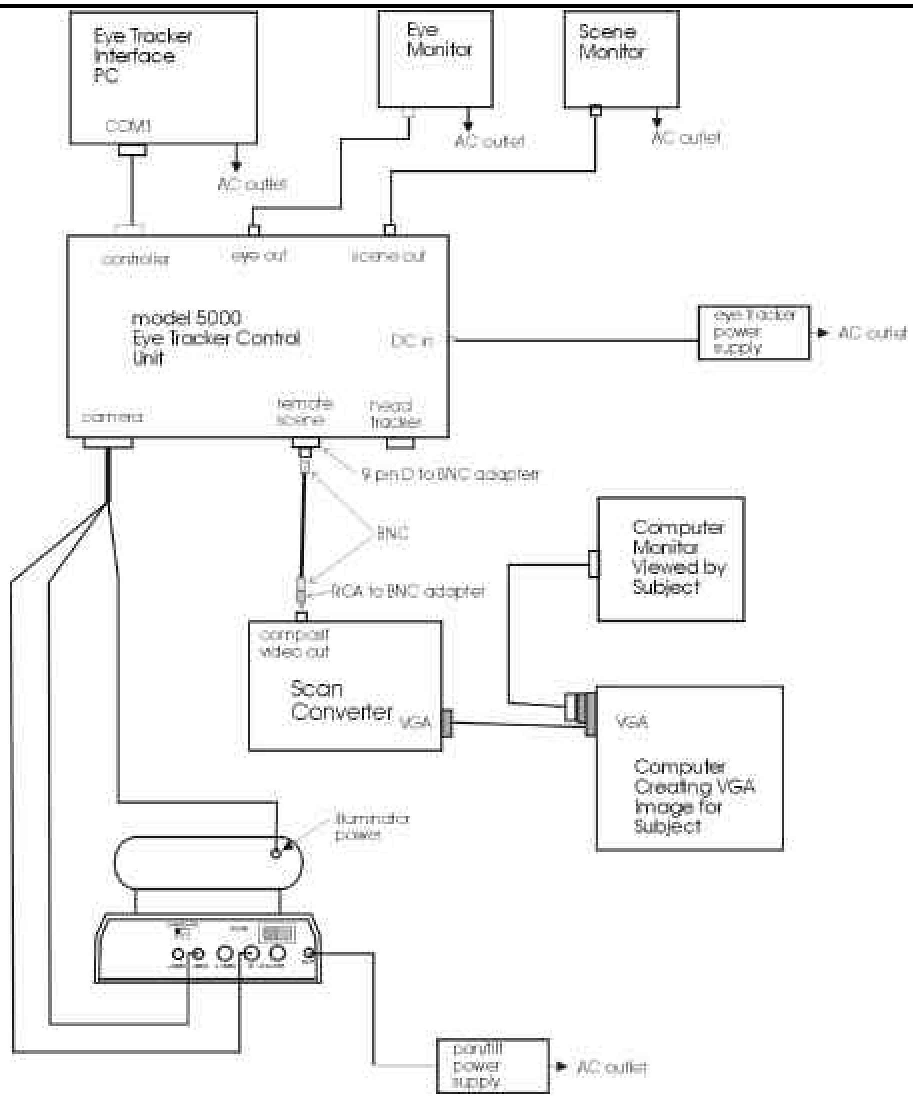


Figure 3-12. Connections when using scan converter to supply scene video signal

## 3.4 Software Installation

Eye Tracker software is shipped on a CD or on 3 inch floppy disks. If the Eye Tracker Interface PC has been supplied by ASL, the appropriate software will already be installed on the hard disk.

If installed by ASL, the eye tracker and PC interface software will be on a hard disk sub-directory named “EYEPOS”. If the computer was not supplied by ASL locate the CD labeled “Eye Tracker Software”. Follow the directions on the label to install the EYEPOS eye tracker operating software, EYENAL offline data analysis software, and ACCESS C language subroutines for reading binary data files recorded by the EYEPOS software. The CD will also copy to the hard disk the install files for FixPlot, the fixation scan path plotting program. As a default, the CD will create a directory names “ASL software” with subdirectories named “EYEPOS”, “EYENAL”, “ACCESS”, and “FIXPLOT”, containing the corresponding software files. To actually install FixPlot, run *setup.exe* in the FIXPLOT directory.

If a CD drive is not available, the software can be requested on 3 inch floppy disks. Locate the disk labeled “EYEPOS” and copy the entire contents onto a single hard disk sub-directory. By convention, the sub-directory is usually named “EYEPOS”, but this is not a requirement. The files copied should include files named *E5Win.exe*, *E5nnn.bxt*, *E5nnn.lxr*, *upload.exe*, *upld_nt.exe*, *load.bat*, and *load_nt.bat*. If it is anticipated that the DOS eye tracker interface program will sometimes be used (as opposed to the standard windows interface), locate the floopy disk labeled “E5000”, and copy the files named *e5000.exe*, and *E5000.str* onto the EYEPOS directory as well.

A separate floppy disk labeled “ACCESS” will contain C language subroutines, for accessing binary data files recorded by the EYEPOS software

The data analysis software (EYENAL) is supplied on a set of three 3 inch floppy disks labeled EYENAL. If the Eye Tracker Interface PC has been supplied by ASL the analysis software will be installed in a sub-directory "EYENAL". If not, simply copy the entire contents of EYENAL disks 1 and 2 onto a single hard disk sub-directory. Use of the data analysis software is explained in a separate “EYENAL” manual.

A utility for converting binary data files created by the PC interface program to ASCII format is included as part of the EYENAL data analysis software package. Separate operating instruction manuals are provided for EYENAL and FixPlot.

If desired, use Windows Explorer to make shortcuts for the files called “E5Win.exe” and “Load.bat”, in the EYEPOS directory, and “drag these shortcut icons onto the desktop for more convenient use. If running under Windows NT, use “Load_nt.bat” instead of “Load.bat”.

The Load.bat (or Load_nt.bat) function will run in a DOS window (or “command line window” if running under NT), and it will be most convenient if Load.bat is set so that it will automatically close the DOS window when it is finished. To check this, right click on the “Load.bat” in Window Explorer and select “Properties”. Select the “Program” tab and be sure that there is a check in the ”Close on exit” check box, then click “OK” to close the “Properties” window. If a shortcut Icon (shortcut to “Load.bat”) has been put on the desk top, repeat the procedure for the shortcut. Right click on the shortcut Icon, select “Properties” and check “Close on exit”.

If the “Controller” port on the model 5000 eye tracker control unit is connected to a PC COM port other than COM1, then Load.bat (or Load_nt.bat) must be modified as follows. Use a text editor (for example, Micorsoft Notepad) to view Load.bat, in the EYEPOS directory. The file contains one line as shown below.

```
@upload e5vvv.bxt e5vvv.lxr
```

The letters shown as “vvv” are file version numbers will differ depending on the software version in use. After “upload” insert a space followed by “/P:n” where n is the desired COM port number. For example, to use COM2 modify the file to read:

```
@upload /P:2 e5vvv.bxt e5vvv.lxr
```

As previously discussed in section 2.1.5, system requirements are an IBM compatible PC capable of operation with Windows 95, Windows 98, or Windows NT, if using the Windows eye tracker interface or DOS if using the DOS eye tracker interface. The computer must also have available COM1 or COM2 serial ports using standard interrupts and device addresses. The minimum recommended system is a 200 MHz Pentium, but slower systems will probably work adequately so long as they can effectively run Windows 95, 98, or NT. In any case, running other simultaneous applications that take up a significant portion of the PC processor time may cause eye data to be lost. When not recording data the only consequence of the PC not having enough time will be a sluggish interface program display.

# 4 EYE-TRACKER INTERFACE SOFTWARE

The EYEPOS (E5000) software package contains software that must be uploaded to the model 5000 eye tracker control unit as well as a user interface program that runs on the Eye Tracker Interface PC. The following sections assume that all appropriate interconnections have been made and software installed, as described in section 3. This manual also assumes that Windows interface program (e5Win) will be used. A manual can be provided by ASL, upon request, that describes system operation in terms of the DOS Interface program (e5000). .

## 4.1 Upload software to the model 5000 Eye Tracker Control Unit

Power up the model 5000 control unit. If it is already powered up, use the power switch to power cycle it off and back on again to be sure that it is “reset”. Switch on the power switch at the rear of the pan/tilt module. (When first powered on, the pan/tilt module will turn all the way in one direction and then return to a center position.)

Upload software to the model 5000 eye tracker control unit by running *Load.bat.* This can be done by any of the following methods:

- use Window Explorer to display the EYEPOS directory, and double click the file name *load.bat*,
- open a DOS window (select “MSDOS prompt” under Start, Programs), use the DOS change directory command to change to the EYEPOS subdirectory, and type **Load<Enter>**,
- or double click the desktop shortcut icon for *Load.bat* (assuming that a shortcut icon was created as suggested in the Installation section).

NOTE: If running under Windows NT, follow the same instructions, but use *Load_nt.bat* instead of *Load.bat.*

In all cases, the upload program will begin to execute in a DOS box (or in a “command line” box if running under NT).

The PC monitor will display

**UPLOAD Vn.n - Program/Pattern upload program for ASL ETE**

**Loading: *path*/E5nnn.BXT (*nnnnn* bytes)**
**bytes left: *nnnnn***

The “bytes left” number will count down to zero and then the PC monitor will display

**Done**

**Loading: *path*/E5nnn.LXR (*nnnnn* bytes)**
**bytes left: *nnnnn***

The "bytes left:" value will count down to zero and the monitor will display.

**Done**

If Load.bat (or Load_nt.bat) properties were set to "Close on Exit" as previously described, the DOS window will automatically close. If not, be sure to close the DOS window (by clicking the "X" in the upper right corner) before proceeding.

Once the control unit has been "loaded" the on board software will continue to run until power is turned off. If an attempt is made to reload the control unit without first resetting it (by cycling power), an error message will appear on the PC monitor and no upload will take place.

The user interface PC software, described in the following section, is needed to change settings such as pupil and corneal reflection discrimination thresholds, launch procedures such as calibration, and to record data on the interface PC. All eye tracking functions are performed by the model 5000 control unit. Once proper settings are established, and if data is not being recorded on the interface PC, the eye tracker will continue to function normally even if the cable to the interface PC is disconnected.

## 4.2 E5000 User Interface Program

Once software has been successfully uploaded to the model 5000 eye tracker control unit (as described in the previous section) run the interface program by double clicking the *e5win.exe* file in Windows Explorer (EYEPOS directory), or by double clicking the corresponding shortcut icon on the desktop (assuming a shortcut icon was created as suggested in the Installation section). If the PC is correctly connected to a model 5000 control unit and software has successfully been uploaded to the control unit (as described in the previous section) the "Online" light, near the top left of the interface program screen should be green.

*Note that a DOS interface program e5000.exe can be used instead of e5win. Simply double click e5000.exe, in the EYEPOS directory, instead of e5Win.exe. A separate manual is available from ASL which describes system operation in terms of DOS Interface. This manual assumes that e5Win is being used.*

To exit (close) the interface program, click the "**X**" at the upper right of the program window, select "close" from the pull down "File" menu, or type **<Alt>x**..

### 4.2.1 User Interface Screen

The main interface program window has a menu bar at the top, a shortcut bar directly underneath the menu bar, a column of controls extending down the left side of the screen, two graphics windows labeled "eye" and "scene POG" to the right of the control column, and some additional digital information displays below the graphics windows.

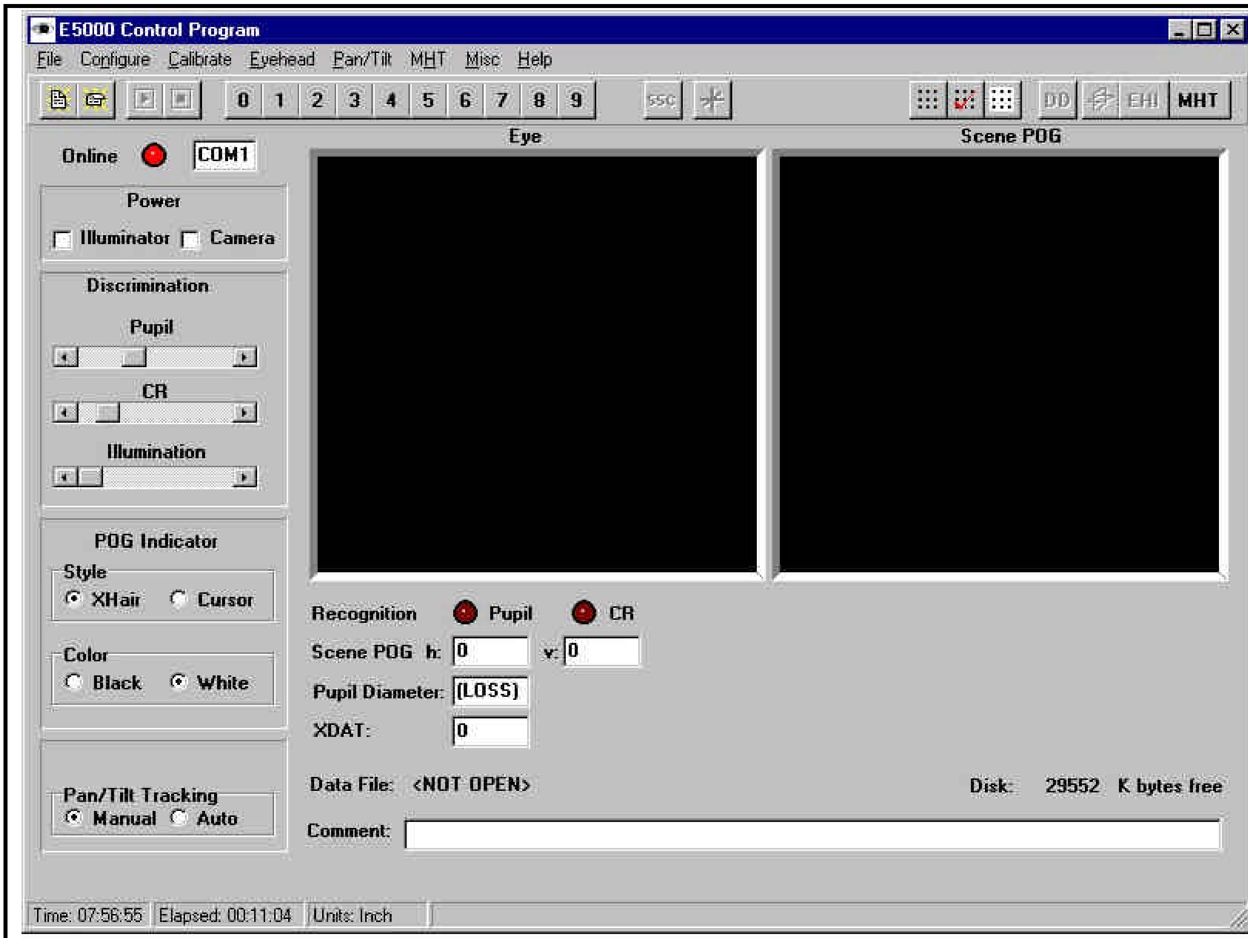



Figure 4-1. e5Win screen -- main window

The controls consist of standard windows slide switches, check boxes, and radio buttons. The data displays consist of indicator lights (to indicate "on-line" or "off-line", and pupil and CR recognition), and text windows displaying COM port assignment, PC time of day, elapsed time, free disk space, point of gaze coordinates, pupil diameter, external data values (XDAT), and data file information. The "on-line" indicator light and COM port assignment displays are at the top of the control column. The rest of the data displays are beneath the two graphics windows. If a magnetic head tracker is connected and enabled, an additional data display appears beneath the Scene POG window showing head tracker position and orientation coordinates. If the system is a head mounted eye tracker (Model 501) with a magnetic head tracker, and if Eyehead Integration is enabled, Eyehead scene plane number, point of gaze coordinates, and distance from the eye to the scene plane are also displayed under the Scene POG window.

The “eye” graphics display at the top, left side of the screen, shows pupil and corneal reflection (CR) center positions and diameters, as detected by the eye tracker. The pink pupil center cross hairs and blue CR center cross hairs are essentially the same as the white and black cross hairs that show pupil and CR centers on the eye video monitor. *The pupil and CR circles are not the same as the pupil and CR outlines displayed on the video monitor. The computer display simply draws circles about the cross hair positions with diameters proportional to detected pupil and CR diameters. These circles do not show the actual pupil and CR outlines detected by the eye tracker. True outlines are displayed on the video eye monitor.*

Another graphics window, labeled "Scene POG" and located near the top right of the screen, shows a point of gaze cursor. This is essentially the same as the cursor movement on the video scene monitor.

If the model 5000 control unit is not running (powered off or reset) or if the cable connecting the interface PC to the control unit is disconnected, the light labeled “On line”, at the top left of the screen will turn red. If the communication is reestablished, for example by reconnecting the cable, this light will change back to green.

### 4.2.2 System Settings

Pull down the Configure menu by clicking on “Configure” in the menu bar at the top left of the screen, and select “System Settings” to pop up the System Settings dialog window. Use the radio buttons in the box labeled “System Type” to select the system type that reflects the current hardware configuration. Set the eye camera speed to correspond to the update rate of the eye camera being used by clicking on the down arrow next to the corresponding camera speed box and selecting from the drop down list.. (If the optional high speed camera is being used, remember that the camera dip switches must also be properly set for the selected update rate). The “speed” setting in the interface program System Settings window does not actually control the camera update rate, rather it informs the program of the type of eye camera being used.

Use the drop down list, in the System Settings window, to assign a COM port (usually either COM1 or COM2) as the interface program port. Be sure that this assignment corresponds to the physical connection between the PC and the “Controller” port on the eye tracker control unit.

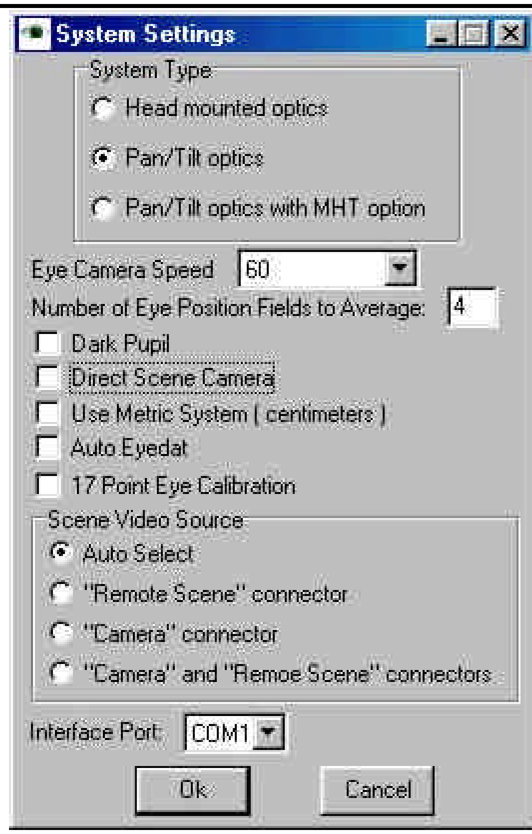



Figure 4-2. System Settings Dialog Window

The eye position data output will be averaged over the number of fields specified by the item, labeled "Number of eye position fields to average". Simply type in the desired number of fields. The recommended value for the pan/tilt optics system is 4. This means every eye position value computed will be averaged with the previous 3 values before being displayed or recorded. To eliminate any averaging, enter 1 or 0. It is important to note that after a period during which a pupil was not recognized (no valid gaze measurement could be made) the first valid measurement is not averaged. The next measurement is averaged with just the previous valid field, and the number of fields averaged increases in this way until the specified value is reached.

The check boxes on the System Settings window should usually be left unchecked. The 17 point calibration capability is explained in section 5.10 and the auto Eyedat function is explained in section 5.8. “Use Metric System” applies only to setup of a magnetic head tracker for use with pan/tilt optics, as discussed in section 5.1.3. The other two check boxes do not apply to pan/tilt optics and should be left unchecked.

The “Scene Video Source” radio button should normally be left on “Auto Select” when using pan/tilt optics. When “System Type” is set to “Pan/Tilt Optics” or “Pan/Tilt Optics with MHT option" the system will automatically select the "Remote Scene" connector, on the control unit rear panel, as the scene video source. (When using Head mounted optics with a head mounted scene camera, the scene video signal is usually part of the cable that connects to the "Camera" connector on the control unit).

Click "OK" to save system settings and close the System Settings dialog window.

If software has been properly uploaded to the eye tracker control units, and the COM ports have been properly assigned the "Online" light, near the top left of the screen should be green to indicate that the PC is communicating with the eye tracker control unit. If this light is red, indicating lack of communication between the PC and eye tracker control unit, check connections and try re-uploading software to the control unit. (To upload, exit the interface program and follow the directions in section 4.1).

### 4.2.3 Saving and Retrieving Default Data ("Save As" & "Read")

The current subject calibration data and configuration settings are stored on the same directory as the E5Win program, in files called *E5000.CAL* and *E5000.CFG* respectively. If the EYEHEAD Integration option is being used with a head mounted system (Model 501), environment data is stored on a file called *E5000.ENV*. If a pan/tilt optics module is being used (model 504), information about the pan/tilt module settings and its position with respect to the optional magnetic head tracking system (MHT) is stored in a file called *E5000.PTC*.

These files are all automatically updated whenever changes are made to the data they contain, and are loaded whenever the E5000 program is loaded. For example, *E5000.CAL* is automatically updated at the completion of every subject calibration. Thus, the last calibration performed is remembered and reloaded the next time the E5000 program is executed. Similarly, the *E5000.CFG* file is updated whenever <OK> is clicked to exit from the "System Settings" dialog window.

To save a one of these default files for future use, or to retrieve an old file previously saved, use the "Save As" or "Read" selections from the corresponding pull down menu. For E5000.CAL, use the "Calibrate" menu; for E5000.CFG, use the "Configuration" menu; for E5000.ENV, use the "Eye-Head" menu (eye-head integration option only), and for E5000.PTC, use the "Pan/Tilt" menu.

For example, to save a particular set of calibration data, use the "Save As" selection on the "Calibrate" menu. In response to the prompt, enter a file name other than *E5000.CAL*, such as *PETER.CAL*, and click <Save>.

To use calibration data previously saved in this way, select "Read" from the "Calibrate" menu, browse to the previously saved file, highlight it and click <Open>. It will be used as the current data until overwritten by a new calibration.

If preferred, the same file manipulations can be done with Windows Explorer. Simply copy the E5000.*xxx* file to a different name to save it, and copy it back to E5000.*xxx* (in the same directory as the E5Win program) to re-use it.

### 4.2.4 Enabling Magnetic Head Tracker (Optional)

The following section applies only if an optional magnetic head tracking (MHT) system has been connected as described in sections 2.3.2 and 3.3.4.

The pull down MHT menu has the following choices:


The “Set boresight” command will be grayed (inactive) until the MHT system is enabled.

Before attempting to enable the MHT system for the first time, choose “Select MHT system” and be sure the radio button on the resulting pop up window is set to the type of MHT hardware actually being used. If unsure of the proper type, consult ASL.

Use the "Enable " selection to start communication between the MHT system and the eye tracker computer. Alternately, click the MHT button at the far right side of the shortcut bar. If communication is successful the MHT data display, labeled “Raw MHT” should appear under the “Scene POG” display window. If an error message box appears; press <Enter> or click on “OK” to close the error box; then power off the MHT system, check all connections and the MHT baud rate setting (baud rate should be set to 19200 -- refer to manufacturer’s manual), restore power to the MHT system, and try to enable it again. If there is still a problem, consult ASL.

The “Enable” menu selection as well as the MHT short cut button are toggle switches, so once the MHT system is enabled, the top item on the MHT menu reads “Disable” and the MHT shortcut button appears activated (pressed down). The “Disable” selection or clicking the activated MHT button will disable MHT communication and the MHT data display will disappear.

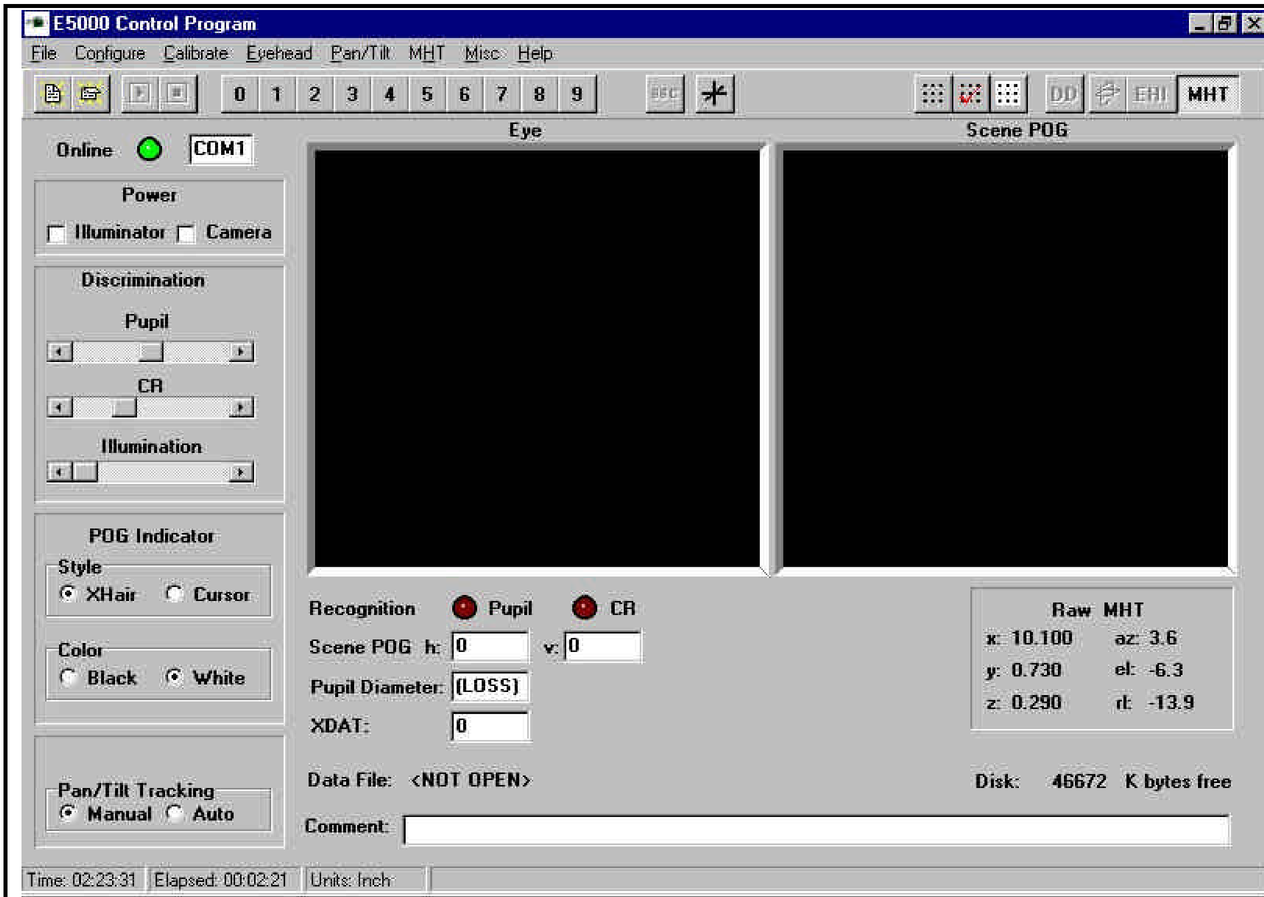



Figure 4-3. Main window with MHT enabled. Notice "Raw MHT" display near lower right.

The MHT data display consists of 3 position and 3 orientation values. The position values are the position of the magnetic sensor with respect to the transmitter x, y, and z axes. The orientation values are the azimuth ("az"), elevation ("el"), and roll ("rl") angles (often called Euler angles) that describe the orientation of the sensor axes with respect to the transmitter axes. Position values are expressed in inches, and orientation values are expressed in degrees.

If the MHT system is communicating properly with the eye tracker computer, the MHT display values should change when the sensor moves, and should match the actual position of the sensor with respect to the transmitter. Actually, the values will probably be constantly changing, even when the sensor is stationary, due to noise in the system.

The “Set Boresight” command (under the MHT menu) will cause the sensor coordinate frame to rotate, so that sensor orientation angles are zero for the current sensor orientation. When using the Eyehead Integration option or MHT mirror tracking, boresights are done automatically at appropriate times, so this command need never be used during normal system operation. It may sometimes be useful, however, for checking to see that the MHT system is functioning properly.

Some additional explanation of "boresight" may be helpful. The origin of the sensor coordinate frame is in the center of the sensor. Upon power up, or after a reset, the sensor coordinate frame x axis extends away from the sensor cable, and the z axis extends down from the sensor mounting surface. If looking in the positive x direction with the z axis pointing down, the sensor y axis extends to the right. The MHT system reports the orientation of the sensor coordinate frame with respect to the transmitter coordinate frame. In other words, if the sensor is held so that sensor axes are aligned with transmitter axes, the MHT system will report zero orientation angles.

If the sensor is held still in any orientation, and the boresight command is issued, the sensor axes will be rotated to align with transmitter axes. The sensor coordinate frame will maintain this new orientation, with respect to the physical sensor, until a reset is issued or until the unit is power cycled.

The third choice, "Reset MHT", sends the same MHT initialization command string that is automatically sent during the MHT enable operation. The affect of any previous boresight (discussed above) will be canceled.

# 5 EYE TRACKER OPERATION

In order to successfully operate the eye tracker in the standard fashion the following steps are necessary.

1. The model 5000 eye tracker control unit must be powered up and loaded with software from the Interface PC, and the E5Win user interface program must be started. If an optional magnetic head tracker is being used it must be activated.

2. A calibration target point pattern must be entered using the E5Win user interface program (if appropriate values are not already stored on the default calibration file).

3. The pan/tilt optics eye camera optics must be properly aimed at the subject and zoom must be adjusted to accommodate the proper focus range.

4. The illuminator intensity, and pupil and CR discriminators must be properly set using the E5Win user interface program.

5. A subject calibration procedure must be executed.

6. Eye movement monitoring: the test, experiment, or mission may be performed.

Step one was described in the previous chapter (section 4). The following sections provide a detailed description of the remaining steps as well as descriptions of some special features.

There are some additional procedures needed in order to use the optional magnetic head tracker to assist pan/tilt operation and these are described in sections 5.1.3 and 5.2.3.

## 5.1 Setting Up Calibration Target Points

During the calibration procedure it will be necessary for the subject to look at nine target points that are at known positions. If a scene camera (or other composite video source) is being used, the actual distribution of the nine points are usually taken from the scene monitor, and entered into memory with the eye tracker “set target points” function. If a scene camera is not being used, then the “set target points” routine must be used to enter a pattern of points that have the same relative positions as the points being viewed by the subject.

If the stimulus scene is a video monitor, the target pattern can also be a video display on the same monitor. If the display is a projected slide, the calibration target can also be on a slide. If the scene is an instrument panel, the calibration target pattern can be created by positioning small pieces of tape in appropriate places on the panel. Other methods are also possible.

If a scene camera is being used, be sure that the scene camera is properly positioned to view the scene by observing the nine calibration target points on the scene monitor. It is necessary that the positional relationship between the scene camera and the scene be maintained constant in order that the calibration remain valid. The scene camera should be, therefore, stable and fixed.

Generally, the points cover about 80 percent of the monitor screen area and are separated by 15-20 degrees visual angle horizontally, and 10-15 degrees vertically. Optimally, the middle vertical and horizontal points should be co-linear and perpendicular. These are ideal specifications. Compromises will often have to be made with no serious consequences. All points must be numbered from left to right; 1-3 for the top row, 4-6 for the middle row and 7-9 for the bottom row (see figure 3-2).

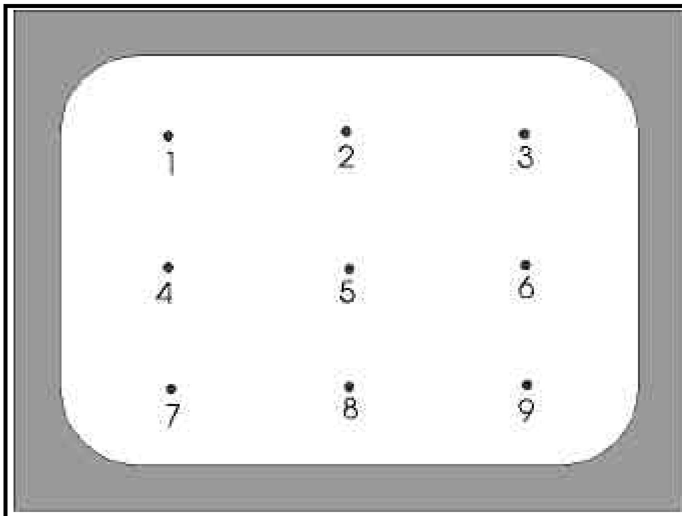
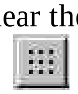
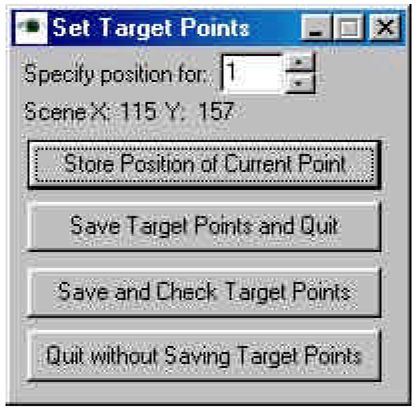



Figure 5-1. Calibration target point pattern on scene monitor.

*If the scene monitor was supplied by ASL it may be modified to have a reverse/normal switch on its rear panel (for potential use with head mounted optics).. If this is the case, confirm that the scene monitor is switched to the "normal" video mode. If the scene monitor is not set for "normal" video display, the calibration target point numbering described in this section will be incorrect.*

### 5.1.1 Set Calibration Target Points

The “Set target” pop up window is used to set or modify the calibration target point coordinates and can also be used to determine the eye tracker coordinates associated with any point on the scene monitor. Select “Set Target Points” from the Calibrate pull down menu, or click on the Set target point shortcut button near the right side of the shortcut bar. The Set Target Points icon is a 9 dot pattern on a gray field.  The Set Target Point window can be moved to a convenient position on the screen by using the mouse to drag the window title bar. Be sure to drag it to some position where it does not cover up any of the “Scene POG” graphics display on the main Window.



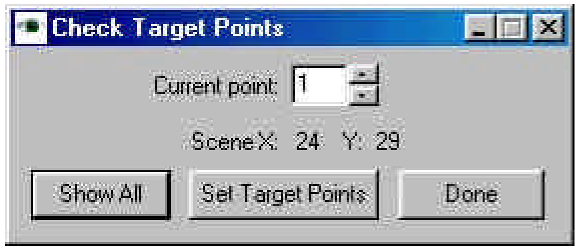

If the Set Target Point window is present, when ever the mouse cursor enters the "Scene POG" Display area, it changes to a cross and its position coordinates with respect to the Scene Display are shown as "**Scene X: *nnn* Y: *nnn*"** on the Set Target Points Window**.** When the mouse is moved within the Scene Display the cursor on the video scene monitor is also displayed in the corresponding position. The Set Target Point window indicates the target point number that will be specified the next time the mouse is left clicked ("specify position for:…"). When Set Target Point display is first selected the next point number is initially set to point 1.

Move the mouse (within the "Scene POG" area on the computer screen) to position the cursor on the video scene monitor over point 1, and left click to enter point 1. Similarly click on points 2-9, in sequence, to enter the other points. If preferred, use the up or down arrow keys to highlight the "Store Position of Current Point" button on the Set Target Point window, and use the <Enter> key instead of the left mouse button to set points. If a scene video image is not available, use the position of the Scene Display cursor on the interface program screen, or the coordinate values on the Set Target Point window to determine the target point positions. To enter target points out of order, click the small up or down arrow buttons, at the right of the "specify position for:" indicator, to set the desired point.

Once all target points have been entered click "Save target points and Check" to save the points and bring up the "Check Target Points" window (see next section), or the "Save target points and Quit" button to save the points and close the Set Target Points window. To close the Set Target Points window without saving the points just specified, click "Quit without saving Target Points".

### 5.1.2 Check Calibration Target Points

Pop up the "Check Target Point" dialog window by selecting "Check Target Points" from the Calibrate menu, by clicking the Check Target Points icon on the shortcut bar (9 point pattern with red check mark) , or by selecting "Save target points and Check" on the Set Target Point window. Use the up and down arrows next to the "Current Point:" indicator to select the desired point number. The indicated point will be displayed on both the interface program Scene Display window and the video scene monitor. The "Show all Points" button can be used to display all points at once on the interface program Display Window, but only the indicated “Current Point” will appear on the video scene monitor display.




Use the “Set Target Points” button to bring back the Set Target Point window, or the “Done” button to simply close the Check Target Points window.

### 5.1.3 MHT Pan/Tilt Tracking Calibration (MHT option only)

If a system is equipped with the magnetic head tracker (MHT) option, the magnetic head tracker can be used to assist pan/tilt tracking. Normally, the pan/tilt mechanism is driven in response to motion of the eye image on the eye monitor. When the image moves towards one side of the eye camera field of view, the system drives the mirror in an appropriate direction to re-center the image

Optical tracking will not work once the eye image is lost from the eye camera field of view (for example, due to a very fast head motion). A system equipped with the MHT option can use information about head position to find the eye even when "lost" by the eye camera.

In order for MHT assisted tracking to function properly, the computer must know where the pan/tilt optics are with respect to the magnetic transmitter (source). Furthermore, it must know the relationship between MHT coordinate space (defined by the orientation of the magnetic transmitter), and pan/tilt coordinate space (defined by the mechanism pan and tilt angles). A calibration procedure must be performed to provide the computer this information. The MHT calibration procedure need be performed only once for a given magnetic transmitter and pan/tilt module placement. If either component is moved, the calibration must be redone.

The following description assumes that the transmitter has been mounted and that the MHT electronics unit along with all other components have been connected as described in section 3 of the model 504 manual. Before proceeding, be sure that the MHT system is “Enabled” and is communicating properly with the Eye Tracker computer as described in section .3.3. If not already powered up, switch on the power switch at the rear of the pan/tilt module. When first powered up, the unit will turn all the way in one direction and will then return to a center position. The unit will power up in the auto focus mode, and should be left in that mode. Be sure "illuminator" check box is checked to turn the illuminator on, and move the “illumination” slide switch to at least midway. Move the Pupil and CR Discrimination slide switches all the way to the left. Be sure that Pan/tilt Tracking radio button (near bottom left of the screen) is set to manual.

The MHT calibration procedure will probably require two people, one person to work the keyboard, and another to hold the magnetic sensor in various positions. The first task is to aim the pan/tilt module so that the magnetic transmitter is visible on the eye monitor.

Pull down the “Pan/Tilt” menu and select “Setup”. To start out with, the “Zoom”, “Gain”, and “Iris” slide switches should be all the way to “Max”; and the “Shutter” slide switch should be at “Long”. The slide switches can be moved by dragging them with the mouse, by clicking the right or left arrows on either end of the slide, or by clicking in the slide channel on either side of the current slide switch position.

Hold a finger, pencil, or some other object in front of the camera about 18-20 inches from the camera lens. The system should be able to focus on the object at this distance. Slowly move the object back away from the camera towards the magnetic transmitter. Once it gets to more than about 22 inches from the camera, the camera will probably no longer be able to focus well. Move the “Zoom:” slide to the left until focus is restored. The zoom slide will not need to be moved far and it is probably best to move it by clicking the left arrow, at the left side of the slide, rather than by dragging the slider with the mouse. In this fashion try to achieve focus when the object is at about the same distance from the camera as the magnetic transmitter.

Use either the Pan/tilt “Set up” window on the program screen, or the remote control to aim the pan tilt at the magnetic transmitter. Imagine a line from the pan/tilt lens to the center of the very center of the transmitter block. Notice that this imaginary line would intersect the front face of the transmitter a bit below the center of that surface (see figure 3-8 of the model 5.4 manual). It is approximately this point that should be centered in the eye monitor.

Be sure that the “System type” radio button on the “System settings” dialog window (under the Configure menu) is set to “Pan/Tilt optics with MHT option”.

Pull down the Pan/Tilt menu and select “MHT Pan/Tilt calibration”. (Note that this selection will be grayed out if the MHT system is not enabled). A pop-up dialog box will appear asking "MHT Transmitter/Pan Tilt Calibration?". If the transmitter-to-optics calibration has not yet been done, click "Yes" and proceed to section 5.1.3.1. If "No" is selected, proceed to section 5.1.3.2.

### 5.1.3.1 Transmitter to Optics Calibration

This procedure specifies the position of the Pan/Tilt module with respect to the magnetic transmitter. The system must know both the distance between the two components and the diretion of the imaginary line that connects them.

A pop up box will prompt “Enter distance from pan tilt to mht transmitter”. The box will display whatever value is currently stored on the E5000.ptc file.


If the pan/tilt is not already aimed at the MHT transmitter, aim the pan/tilt as described in the previous section. Use a tape measure to measure the distance from the optics module center of rotation to the center of the magnetic transmitter. The center of rotation is about 2 inches (5.1 cm) behind the plate that holds the illuminator LEDs (see figure 5.2), so a measurement can be made from this front plate, next to the lens opening, and then 2.5 inches can be added.

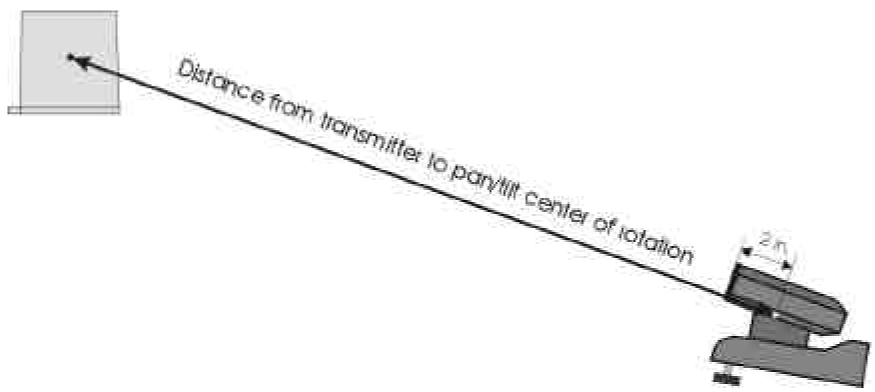



Figure 5-2. Distance from center of transmitter to pan/tilt center of rotation.

Note that the desired value is really the distance to the center of the transmitter, but of course the tape measure can only be held against an outer face of the transmitter. Estimate the distance to the center as closely as possible by holding the tape measure along side the transmitter, or by separately measuring to the front surface of the transmitter and then, along the side of the transmitter, from the front surface to the approximate center.

Enter the appropriate value in the dialog box. THE VALUE MUST BE ENTERED IN UNITS OF INCHES, unless the "Use metric system" check box has been selected in the "System settings" dialog window. If "Use metric system" has been checked, THE VALUE MUST BE

ENTERED IN UNITS OF CENTIMETERS. (See section 4.2.2 for instructions on using the System settings dialog window). If the value being displayed in the dialog box is correct, no change is necessary. Click “OK”. Note: selection of "Cancel” will simply not change the currently stored value (no matter what value is displayed in the dialog box).

A new dialog box will appear with the message "Place sensor between pan tilt and transmitter”. With the transmitter still centered in the eye monitor hold the small magnetic sensor so that it appears in the center of the eye monitor. Note that the orientation of the sensor does not matter, only its position in space matters. Hold the sensor so that one of its faces is directed toward the pan/tilt unit and appears centered in the eye monitor. Be sure the sensor is no more than about 18 inches from the transmitter.

Note that since the pan/tilt optics were first "aimed" at the transmitter, centering the sensor in the eye monitor places it along the line (vector) connecting the camera lens and transmitter. The MHT system measures the position of the sensor, and can, therefore, determine the direction of the vector connecting the transmitter and camera.

With the sensor centered in the eye monitor, click "OK". A pop up box will announce “MHT Transmitter -to-Pan-Tilt Cal complete”. Click “OK” and proceed to the next section.


### 5.1.3.2 Sensor to Pan-Tilt Calibration

This procedure allows the system to compute the relationship between the pan/tilt and head tracker coordinate frames. It involves aiming the pan/tilt camera at the sensor when the sensor is at several different positions.

A dialog box will appear asking "MHT Sensor/Pan Tilt Calibration?". To continue with the MHT calibration procedure click "Yes". To abort the procedure, select "No".


If “Yes” is selected, a new pup up window will prompt to “Place sensor. LEFT”.


1. Starting with the magnetic sensor approximately where a subjects eye will normally be, move the sensor about 6 inches to the left (left when facing the optics unit).

2. Use the remote control to move the pan/tilt until the sensor is centered in the eye monitor.

3. With the sensor centered in the eye monitor, click “OK”.

4. The command window will now prompt "Place sensor RIGHT". Move the sensor back towards its center position (about where a subject's eye will normally be) and continue until the sensor is about 6 inches to the right of the center position. As the sensor is moved to the right, track it with the pan/tilt, and attempt to move it along the pan/tilt horizontal (pan) axis; in other words, so that only the horizontal (<>) remote control buttons need be used.

5. Repeat steps 2 and 3 with the sensor in the "right" position. The command window will next prompt "Place sensor UP".

6. Move the sensor about 6 inches above the nominal center position and repeat steps 2 and 3. The command window will prompt "Place sensor DOWN".

7. Move the sensor about 6 inches below center. This time attempt to move the sensor so that the mirror can follow without changing its horizontal position. Repeat steps 2 and 3.

8. The command window will prompt for “Place sensor CLOSE”. Move the sensor to the center position and use the remote control to center it in the eye monitor. Move the sensor several inches closer to the pan/tilt optics module, but not so close that auto-focus no longer focuses on the sensor. Do not reposition the pan/tilt. Move the sensor so that it remains centered in the eye monitor. Click “OK”.

9. The command window will prompt for “Place sensor FAR”. With out moving the pan/tilt module, move the sensor back to center position, and then several inches further from the pan/tilt optics module, but not so far that auto focus no long focuses on the sensor. As in step 8 ,do not reposition the pan/tilt. Move the sensor so that it remains centered in the eye monitor. Click “OK”.

10. After the “FAR” point is entered, the system will automatically do the necessary computations. If the computations are successfully completed, a pop up box will display "MHT Sensor/Pan Tilt Calibration complete". Click “OK”.

The above procedure can be aborted at any point by clicking “Cancel”. Points can be entered out of order by clicking the small up down arrows next to the box that specifies where to “Place sensor”.

To quickly check the calibration proceed as follows.

1. Be sure that the “System type” radio button on the “System settings’ dialog window (under the Configure menu) is set to “Pan/Tilt optics with MHT option”.

2. Hold the sensor about where a subject's eye will normally be and be sure that pan/tilt tracking is switched to manual (Check box at lower left of screen).

3. Turn pupil and CR discriminators OFF (slide switches all the way to the left), and use the pan/tilt remote control to center the sensor in the eye monitor.

4. With the sensor centered in the eye monitor, pull down the Pan/Tilt menu and select "MHT Sensor Calibration" or click the short cut button (the icon is a drawing of 3 dimensional coordinate axes, next to button labeled SCC, near center of shortcut bar).
   
   A pop up box will display “MHT Sensor Calibration Complete”. Click “OK”. *Note that the sensor should be centered in the eye monitor when the shortcut button or the menu item is clicked (not when “OK” is clicked in response to the “….Complete” message).*

5. Set the pan/tilt tracking radio button to "Auto".

6. Move the sensor to different positions within the motion box used during the MHT calibration procedure. The pan tilt should automatically re-aim itself at the sensor each time the sensor is moved. Don't expect the system to exactly center the sensor image in the eye monitor when doing this test, if it brings the sensor image to anywhere in the eye camera field of view (even at the very edge of the monitor) the calibration can be considered successful.

7. If not successful, repeat the steps in this section. If still not successful, repeat the procedure in section 5.1.3.1 as well as the procedure in this section.

MHT calibration results are stored in the *E5000.ptc* file. If a very good calibration is achieved for a particular set up, it can be copied to a different file name for safe keeping. If the E5000.ptc file is then accidentally changed or destroyed, the archived copy can be copied back as E5000.ptc.

## 5.2 Subject Set-Up and Calibration

Subject set-up consists of seating the subject in an appropriate position, obtaining a suitable eye image on the eye monitor, and setting the pupil and CR discriminators properly.

### 5.2.1 Subject Seating

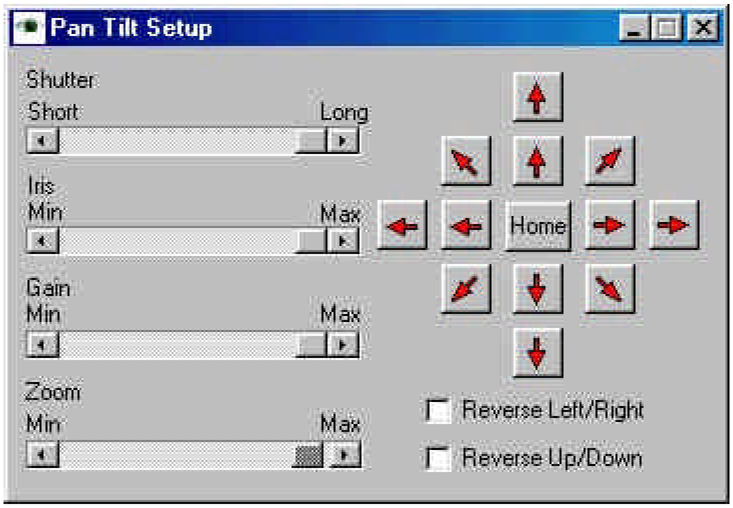
Any stationary chair can be used, but to the extent that the type of chair can minimize subject motion, eye tracking accuracy will be maximized.

### 5.2.2 Obtaining an Eye Image

Note: This section and the next section on pupil and CR discrimination require the operator to Check the "Illuminator" check box on the program screen to turn on the illuminators. Be sure the "Pan/Tilt Tracking" radio button, near the bottom left of the e5000 screen, is set to manual. Be sure that the slide switch on the control unit rear panel is in the "P/T" position.

Pull down the "Pan/Tilt" menu and select "Setup". To start out with, the "Zoom", "Gain", and "Iris" slide switches should be all the way to "Max"; and the "Shutter" slide switch should be at "Long". The slide switches can be moved by dragging them with the mouse, by clicking the right or left arrows on either end of the slide, or by clicking in the slide channel on either side of the current slide switch position.

Hold a finger, pencil, or some other object in front of the camera about 18-20 inches from the camera lens. The system should be able to focus on the object at this distance. If the subject's eye will at a greater distance, slowly move the object back away from the camera. Once it gets to more than about 22 inches from the camera, the camera will probably no longer be able to focus well. Move the "Zoom:" slide to the left until focus is restored. The zoom slide will not need to be moved far and it is probably best to move it by clicking the left arrow, at the left side of the slide, rather than by dragging the slider with the mouse. In this fashion try to achieve focus when the object is at about the same distance from the camera as the expected distance of the subject's eye.




Next, either have a subject sit down in front of the system, or position the model eye target bar (black plate with white 4mm spot and ball bearing) so that the white spot is about where a subject's eye will be. The model eye is useful for practicing set up and discrimination of the pupil and corneal reflection (CR) without requiring a cooperative subject.

If using a real subject, and if the system is equipped with the magnetic head tracking option, have the subject put on the provided headband and attach the magnetic sensor (the mounting surface of the sensor and the head band are equipped with mating Velcro) so that the sensor is located just above the eye being monitored. Be sure that the magnetic head tracker is enabled (as described in section 4.2.4), that the system type radio button (System settings dialog window, under the Configure menu) is set to "Pan/Tilt Optics with MHT option", and that the set up procedure described in section 5.1.3 has been performed.

Use either the infra red remote control or the arrows on the Pan/Tilt, Setup window to aim the pan/tilt camera at the eye (or model eye). If the "Reverse left/right" and "Reverse up/down" boxes near the bottom right of the Pan/Tilt Setup window are not checked, clicking an arrow moves the eye monitor image in the direction of the arrow. If the "Reverse" boxes are checked then the pan/tilt assembly will move in the direction of the arrow and the image will appear to move in the opposite direction (as thought the "window" through which the image is being viewed were moving in the direction of the arrow). The inner ring of arrows move the module a short distance for each click, while the outer arrows move the module a greater distance for each click.

Once the pan/tilt module is aimed at the eye or (or at the model eye) pull down the Pan/Tilt menu and select "Set Home". This will cause the program to memorize the current position of the pan/tilt module. Subsequently selecting "Home" from the Pan/Tilt menu will cause the module to return to this memorized position.

If not using a magnetic head tracker, leave Pan/tilt tracking set to manual until proper pupil discrimination is achieved as described in section 5.2.4.

### 5.2.3 MHT sensor to eye calibration (MHT option only)

If using a magnetic head tracking system and a real subject (as opposed to the model eye), be the subject is wearing the Velcro head band as described in the previous section and shown in figure 5-3. Be sure that the MHT system is enabled as described in section 4.2.4.

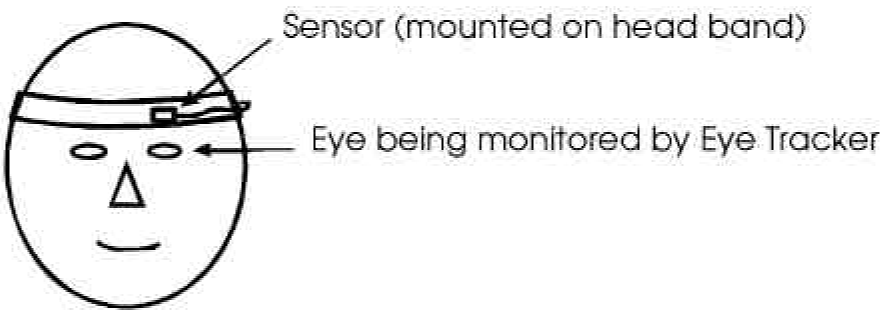



Figure 5-3. Proper position for MHT sensor.

Have the subject hold as still as possible, and with the subject's eye image centered in the eye monitor click "MHT Sensor Calibration" under the "Pan/Tilt" menu, or click the shortcut button (the icon is a drawing of 3 dimensional coordinate axes, next to button labeled SCC, near center of shortcut bar). A pop up box will display "MHT Sensor Calibration Complete". Click "OK". *Note that the eye image should be centered in the eye monitor when the shortcut button or the menu item is clicked (not when "OK" is clicked in response to the "..Complete" message).* Pan/tilt tracking can now be set to Auto by using the radio button at the bottom left of the Interface program screen.

This "Sensor to eye" calibration allows the system to compute the vector connecting the magnetic sensor and the eye. *(Remember that every time the head band and sensor are put on, the sensor will wind up in a slightly different position with respect to the eye.)* Pan/tilt tracking can now be set to Auto by using the radio button at the bottom left of the Interface program screen. If the MHT Cal has been done properly as described in section 5.1.3, and assuming the subject remains within about 6 inches of his initial head position, the mirror should now be able to find the eye even when lost from the eye monitor.

If not using a magnetic head tracker, leave Pan/tilt tracking set to manual until proper pupil discrimination is achieved as described in section 5.2.4.

### 5.2.4 Pupil and CR Discrimination

The first stage in recognition of the pupil and CR by the eye tracker is performed by edge detection logic. Threshold levels for pupil and CR edge detection are adjusted with the slide switches labeled "Pupil" and "CR", under the "Discrimination" label heading. The current discriminator levels are shown by the slide switch positions, with the far left slide switch positions indicating that no edges will be noticed, and positions at the right of the slides indicating even dim edges may be detected.

Proper pupil and CR discrimination, as seen on the video eye monitor (not the computer screen) is shown in Figure 3-1. Note that a white circle designating the pupil outline, and black circle designating the CR outline are displaced slightly to the right of the actual pupil and CR features. Furthermore, note that the white cross hairs which indicate the pupil center actually appear at the center of the white discrimination circle rather than at the center of the pupil image. Similarly the black cross hairs appear at the center of the black circle rather than the CR image. This offset is purely cosmetic and has no effect on point of gaze computation or display. It is caused by a slight time delay between detection of an edge point and display of the corresponding dot on the monitor, and makes the discrimination outlines easier to see. It is the true feature edge coordinates that are being detected.

To achieve proper pupil and CR discrimination, proceed as follows.

1. Start with pupil and CR discriminator slide switches all the way to the left

2. Begin to increase the pupil discriminator level by moving the slide switch to the right. White dots will begin to appear on the eye monitor. These are discrimination points indicating video levels which are high enough to trigger the pupil edge threshold. As the discriminator is turned up further, these white dots begin to form an outline within the pupil and when the discriminator is turned up far enough, the dots will form a line that circumscribes the pupil. At this point white recognition cross hairs should appear through the center of pupil. (The circle and cross hairs will actually be offset slightly to the right of the pupil as shown in figure 5-4).

3. Move the discriminator to the right just far enough so that a solid white circle forms about the pupil and white cross hairs designate the center of pupil. (Pupil diameter changes over time and as a function of where the subject looks.) Observe the eye monitor for several seconds as the subject looks around to be sure that recognition is maintained even when the pupil is at its smallest. There may be other areas in view which have white discriminator dots, but the pupil should be the only smoothly enclosed area and should have white recognition cross hairs designating its center. If the pupil is very dim and difficult to distinguish from surrounding features, Move the Illumination slide switch to the right to increase illumination intensity. This will probably not be necessary unless ambient illumination or the scene display is especially

bright. If illumination intensity is increased be sure not to make the pupil as bright as the corneal reflection (CR). It is important that the CR remain visible within the pupil image.

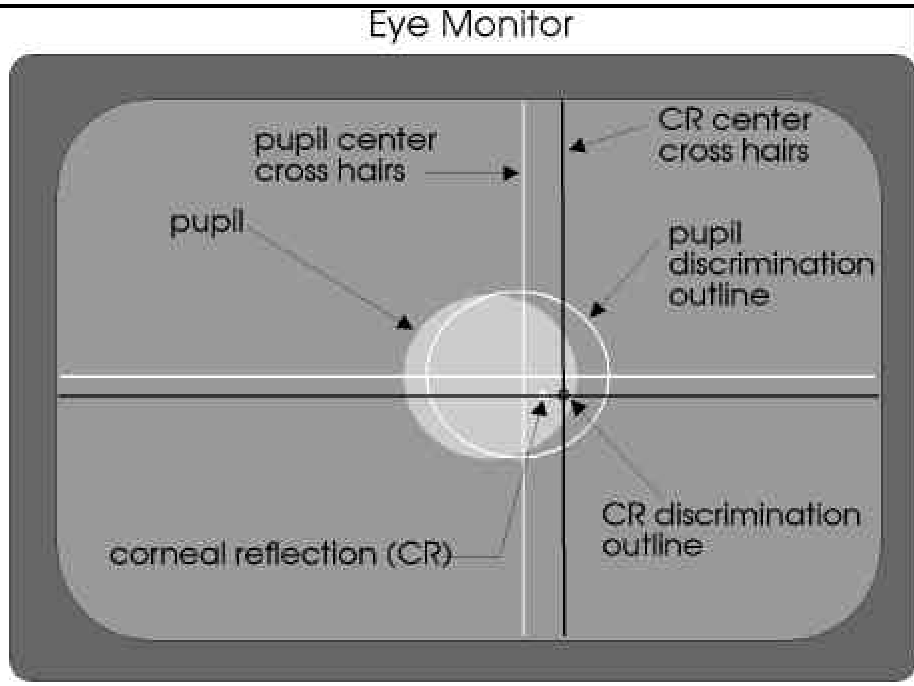



Figure 5-4. Proper pupil and CR discrimination.

4. If the pupil discriminator is too far to the right, other areas may be mistakenly recognized as the pupil and the recognition cross hairs may jump to these areas. Should this happen, lower the pupil discriminator setting by moving the slide switch left If the white circle does not remain solid, increase the discriminator level (move the slide right), even if this means a few white dots appear in other areas. CAUTION: if the pupil discriminator is much too far to the right, the cross hairs and all the white dots may disappear (an edge may be detected about the entire monitor screen, and all the white dots will be hidden behind the monitor bezel). Small adjustments of the discriminator are probably best made by clicking the right or left arrow buttons at either side of the slide. This allows finer control than dragging the slider.

5. With the subject looking straight ahead, move the CR slide switch right until a black outline forms about the CR and black recognition cross hairs designate the center of the CR (the circle and cross hairs will actually be offset slightly to the right as shown in figure 5-4). CAUTION: If the CR discriminator is too far to the right, the pupil recognition cross hairs as well as the CR recognition cross hairs may disappear.

6. Be sure that the CR is properly recognized as the subject looks about the field of view of interest. If the black dots form about more than one geometrically satisfactory "corneal reflection," the computer software will select the one closest to the pupil for recognition.

7. When the pupil and CR are properly recognized for a given eye image, as shown in figure 5-4, set the “Pan/Tilt Tracking” radio button to “Auto” to enable automatic pan/tilt tracking. With automatic tracking enabled and the pupil properly recognized as described above, the pan/tilt camera should be able to follow slow head motions. Auto-focus should keep the eye image in proper focus over a range of several inches (the range will vary from about 6 inches at high zoom and close distances to 10 inches at slightly lower zoom and longer distances). If the focus range seems asymmetrical (auto focus can follow further in one direction than the other) zoom in (Zoom switch on Pan/Tilt, Setup window to the right) very slightly to increase the close focus range or zoom out (Zoom switch on Pan/Tilt, Setup window to the left) very slightly to increase the far range. If using a magnetic head tracker, be sure to follow the instructions in section 5.2.3 before setting the Pan/tilt tracking mode to Auto.

The optics module shutter speed, video gain, and iris (lens aperture) opening can all be adjusted if necessary (select “Setup” from Pan/Tilt menu) to achieve the best eye image. The default values are no shutter (long open shutter duration), maximum video gain, and maximum iris opening. If satisfactory pupil and CR images are obtained with out using these adjustments, it is recommended that iris, gain and shutter be left in the default positions. If, for example, even at the lowest illuminator level setting the pupil is so bright that the CR cannot be distinguished when it is within the pupil, then any one of these parameters can be altered, from the Pan/Tilt Setup window slide switches, to dim the pupil thus allowing proper CR discrimination.

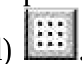
Lower iris values (move slide towards the left) will make the image appear dimmer but with sharper focus and depth of field, while higher iris values (slide towards the right) will make the image brighter.

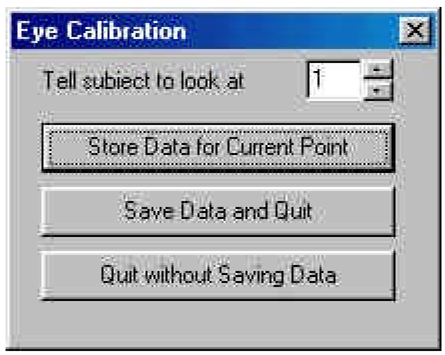
Lower gain values will make the image appear dimmer while higher gain values will make the image brighter.

Shorter open shutter duration will make the image appear dimmer (although moving images will be “crisper”), while longer open shutter duration will make the image appear brighter.

### 5.2.5 Subject Calibration

The raw data measured by the Eye Tracker is the separation between the pupil center and the corneal reflection (CR). The relation between these raw values and eye line of gaze differs for each subject and for different optical unit and scene camera positions. The purpose of the eye calibration is to provide data that will allow the Eye Tracker processor to account for individual subject differences. The objective is to have the subject look at (fixate) each of the nine calibration points. This procedure must be performed for every subject.

Pop up the eye calibration window by selecting “Eye Calibration” from the Calibrate pull down menu or by clicking on the eye calibration icon (9 point pattern on white background) . Tell the subject to look at the point number as prompted on the Eye Calibration window. Be sure that pupil and CR discrimination are correct, and click the “Store Data for Current Point” button. The “Tell subject to look at point number” value will automatically increment. If preferred, use the up or down arrow keys to highlight the “Store Data for Current Point” button and use the <Enter> key instead of clicking the button with the mouse. To enter points out of order or to repeat points already entered, simply use the associated up and down arrow buttons to set the “Tell subject to look at point number” value as desired.




Note that when the Eye Calibration window is active, the interface program Scene Display and the video scene monitor both show the location of the next target point to be entered.

**During the calibration procedure it is important to look at the eye monitor**. It is very important to be sure that stable recognition cross hairs continue to properly indicate the pupil center and the corneal reflection (CR). If not, make the appropriate correction to the discriminator settings. The discriminator settings can and should be adjusted during the calibration procedure if necessary.

When data for point 9 is entered, the Eye Calibration window will automatically close, and calibration computations will be made and stored. To close the window and do the computations before point 9 is entered, click “Save Data and Quit”. To close the window without computing new calibration coefficients or saving results, click “Quit without saving”.

Note that it usually does not make sense to “Save Data and Quit” before getting to point 9. Occasionally, however, it may be noticed that after completing the calibration procedure the result does not seem to be accurate for one of the points (when the subject looks at that point, the scene monitor cursor is significantly offset from the point). In this case it is possible to reopen the Eye

Calibration window as before, enter data only for the "bad" point, and then click "Save Data and Quit".

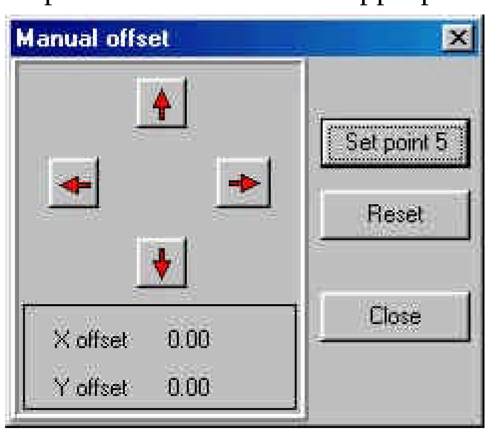
The calibration procedure tends to work best when performed rapidly. If the procedure takes too long, subjects become fatigued and have difficulty maintaining accurate fixations on the target points. With some experience on the part of the equipment operator, it should be possible to perform the calibration in less than thirty seconds

To confirm accuracy of calibration, ask the subject to look at each target point again. At each point note the position of the line of gaze cursor or cross hairs on the scene monitor. Each target point position should be correctly indicated on the scene monitor by the line of gaze cursor or cross hairs to within about 1 degree visual angle. If one or more target points are not correctly indicated on the scene monitor, either repeat the entire calibration procedure or just part of it as described above.

### 5.2.6 Manual Eye Position Offsets

E5Win allows the user to add offsets to the final calculated eye position value from the Interface PC terminal. If the optics module is bumped, or calibration shifts slightly for some other reason this feature can often be used to correct the point of gaze data without re-doing the eye calibration. Pull down the "Calibrate" menu and select "Eye Position Offset". Instruct the subject to gaze at one point and use the arrow buttons on the pop up window to position the cursor over that instructed point of gaze. Exit the offset mode by clicking **<Close>**.

Alternately, instruct the subject to fixate on point number 5 of the calibration target and select "Quick Offset" from the calibrate menu, or select the "Eye Position Offset" pop up window and click "Set point 5". The computer will calculate the appropriate offset value both vertically and




horizontally to move the current gaze point to the point 5 location.

To reset both the horizontal and vertical offsets to zero, select "Reset Offsets" directly from the "Calibrate menu, or from the "Eye Position Offset" pop up window. Offsets are automatically set to zero when the calibration sequence is entered.

### 5.2.7 Saving and Loading Calibration Files ("Save As" & "Read")

Calibration and target point values are automatically saved to the default calibration file (*E5000.CAL*) whenever calibration or set target procedures are performed. The current values can be saved to a file of the users choice at any time with the Save Calibration selection (under the "Calibrate" menu) as described in section 4.2.3. To load target point and calibration data from a previously saved file, use the Read Calibration selection from the "Calibrate" menu, also described in section 4.2.3. Note that the calibration files save only target point and calibration data. Offset values are not saved. Current offsets are automatically zeroed whenever a calibration file is loaded.

## 5.3 Eye Movement Monitoring

Throughout the eye monitoring session the operator should frequently look at the eye monitor to make sure the pupil and CR are being correctly recognized as described in section 5.2.4. The operator should also look frequently at the scene monitor point of gaze display to be sure that the data makes sense.

The operator can select a white or black cursor or set of cross hairs as the point of gaze indicator by using the check boxes under the "POG Indicator" heading on the main e5Win screen. Note that digital eye position values are continuously displayed on the Interface PC terminal screen ("Scene POG"). Data can be recorded as described in section 5.5.

When the session is complete, close any open data file (see section 5.5), and turn off the illuminator power ("Illuminator" check box on main Interface program window).

## 5.4 Blink Handling

A setting on the *e5000.cfg* file (in the same directory as e5Win) controls the behavior of the scene monitor cursor during blinks. The default condition causes the following behavior:

If the subject's eye closes, or if pupil recognition is lost for some other reason, the scene POG cross hairs (or cursor) will freeze at the current position for 12 video fields (200 msec at 60 Hz), and will then jump to a default position of (0,0). The cursor is not visible when in the default position and will appear to have disappeared. The affect of this logic is to prevent the cursor from disappearing during blinks (usually shorter than 200 msec), but to make the cursor disappear when the pupil is lost due to extended eye closure, poor system adjustment, etc. If digital data is being recorded, as described in the next section, the recorded gaze coordin ate values also behave as described above, but the pupil diameter value is always zero for any data field during which a pupil is not recognized.

This feature can be modified to change the number of fields during which gaze coordinates freeze, or can be disabled altogether so that the cursor will jump to the default position (seem to disappear) immediately upon loss of pupil recognition. To modify this feature, look at the *e5000.cfg* file with a text editor, and find the line that reads

**`eye_position_blink_filter_value=12`**

To change the number of fields during which gaze coordinates freeze, change the “12” to the desired number of fields. To disable the feature, replace the “12” with “0”. Be sure to re-save the modified file as *e5000.cfg*. The next time e5Win is run, or the next time “Calibrate, Read Calibration, e5000.cfg” is selected the new value will be used.

Note that if using a 50 Hz eye camera (PAL format), 12 fields correspond to more than 200 msec, and it may be desirable to change this value to 10 fields. If using an optional high speed camera, the value must be increased proportionately if it is to correspond to about 200 msec. At 120 Hz, the corresponding value would be 24 fields, and at 240 Hz the corresponding value would be 48 fields.

## 5.5 Data Recording

Eye position vertical and horizontal coordinates, pupil diameter, and 16 bits of external data, called XDAT (see section 5.7), can easily be recorded on the Interface PC hard disk. In addition, event marks can be entered from the keyboard. A field of data, consisting of the elements just listed, is recorded every 60th of a second (60 Hz update rate).

If averaging has been specified, on the “System Settings” window, it is the averaged gaze coordinate data that is recorded. Remember that after a period during which a pupil was not recognized (no valid gaze measurement could be made) the first valid measurement is not averaged. The next measurement is averaged with just the previous valid field, and the number of fields averaged increases in this way until the specified value is reached. Only gaze coordinates are averaged. Neither pupil diameter, nor any other recorded values are averaged.

Open a new data file by selecting “new”: from the pull down File menu or by clicking the new file icon on the shortcut bar. Use the standard Windows file browser and dialog pop up to specify a directory and file name. If “Save as Type” is left set to “Eyedat file” a “.eyd” extension will automatically be appended to the file name. This is the recommended procedure.

After opening a file, type any desired text in the “Comment” field on the interface program screen and the text will be saved on the file. Once a file is opened, the file name will be displayed on the interface program screen just above the comment field. Initially the file name will be displayed in black letters with the message “(paused)” after the file name. To start recording data on the file click the record icon (right arrow icon on the shortcut bar) or select “Start Recording” from the File menu. The file name will change to red letters and the message following the file name will change to “(recording)”. The disk “bytes free” indicator will also change as disk space is used up.

Add one of 10 manual mark flags to the data at any time by clicking one of the numbered mark buttons (icons labeled 0 through 9) on the shortcut bar.

Stop recording by clicking the "recorder stop" icon (black square) on the shortcut bar or by selecting "Stop Recording" from the File menu. The file name will change back to black letters and the "(paused)" message will reappear. Start and stop recording as many times as desired. Each interval of continuous data (between a start and stop recording) is referred to as a *data segment*.

Eye point of gaze coordinates, pupil diameter, and XDAT values for both eyes are simultaneously recorded on the data file with a common time line.

## 5.6 View Recorded Data

A file viewer is provided within the interface program as a means of quickly spot checking raw data files to be sure something has been recorded. To use the viewer pull down the "Misc" menu and select "View Data File". If a file is currently opened, it will automatically be loaded into the viewer. Otherwise, click the browser button (3 dots on a gray field) next to the "Data File:" box, select the desired file in the browser box, and click "Open". Depending on file length, the file may take several seconds to load. The load can be aborted by clicking the "Close" button at the bottom of the viewer. Once the file has loaded, file header information is displayed in the top section of the viewer window and data is displayed in labeled columns in the scrolling window on the bottom section of the viewer box. Use the standard scroll bar to scroll to move through the data.

## 5.7 XDAT (external data)

A female, 25 pin, D type connector labeled "XDAT" is provided on the back panel of the model 5000 control unit. The XDAT connector provides access to a parallel digital port that is used as a means of inputting external data (of the users choice) for recording on the Interface PC hard disk along with eye tracker data. Sixteen bits of parallel, TTL level, positive true data, from any source, can be recorded by the E5000 program, along with the other eye tracker data. The pin out specifications for the XDAT connector are listed below. Each bit is interpreted as 0 when the corresponding pin is low (ground), and as 1 when the corresponding pin is high (5 Volts). The XDAT port is sampled by the eye tracker once every eye camera video field, and is recorded along with the eye position data from corresponding eye camera video field. The current XDAT value is always displayed near the bottom center of the interface program screen.

Table 5-1. XDAT connector

| FUNCTION | PIN NUMBER (25 pin female D type ) |
|---|---|
| XDAT bit 0 (LSB) | 2 |
| XDAT bit 1 | 3 |
| XDAT bit 2 | 4 |
| XDAT bit 3 | 5 |
| XDAT bit 4 | 6 |
| XDAT bit 5 | 7 |
| XDAT bit 6 | 8 |
| XDAT bit 7 | 9 |
| XDAT bit 8 | 10 |
| XDAT bit 9 | 11 |
| XDAT bit 10 | 12 |
| XDAT bit 11 | 13 |
| XDAT bit 12 | 17 |
| XDAT bit 13 | 15 |
| XDAT bit 14 | 14 |
| XDAT bit 15 (MSB) | 1 |
| Ground | 18,19,20,21,22,23,24,25 |

## 5.8 Auto Eyedat

When “auto EYEDAT” is enabled, on the System Settings dialog window, EYEDAT recording is controlled by the most significant XDAT bit (XDAT bit 15, which is pin 1 on the XDAT connector). To enable auto EYEDAT, pull down the Config menu and select system settings. Check the box labeled “Auto Eyedat”.

To record data, first open an EYEDAT file in the usual fashion. The file type and name will be displayed on the monitor as usual. Note that the “Record” and “Stop” buttons on the short cut bar, as well as the “Record” and “Stop” selections on the “File” menu will be gray and inoperative.

If XDAT bit 15 is 0 (ground), the “paused” message will be displayed next to the file name to indicate that no data is currently being recorded. When the most significant XDAT bit is set to 1 (+5 V), a data segment will begin recording, and the message next to the file name will change to “recording”. When the most significant XDAT bit is returned to 0, recording will stop, and the “paused” message will reappear. Note that setting or resetting the most significant XDAT bit is equivalent to clicking the “Record” or “Stop” button in the normal operation mode.

When the auto EYEDAT check box, on the system settings dialog window, is not checked, record and stop commands operate normally on the Interface program. In this case the XDAT value has no affect data recording starts or stops.

XDAT values are recorded on data files, along with other data, whether or not the auto EYEDAT feature is being used.

## 5.9 Working with EYEDAT files

Recorded data can be accessed off line by including a provided set of C routines within user created software to read the binary data files, by using a provided binary file description to write access software from scratch, by using the ASL's EYENAL data analysis program, or by converting the files to a simple ASCII format with a provided CONVERT function (part of the EYENAL data analysis program). . EYENAL is described in a separate instruction manual.

Source code for the C access routines and the binary file description are provided on a disk labeled "ACCESS".

The eye position coordinates can be thought of as point of gaze coordinates on the scene monitor screen or on the Interface PC "Scene POG" display. The coordinate frame origin (0,0) is in the upper left corner of the monitor screen. Horizontal position values increase to about 261 at the right edge of the monitor, and vertical values increase to about 241 at the bottom of the monitor. It is possible to have negative data values, and values that exceed the maximums just cited, since the subject may be looking beyond the extent of the scene monitor field.

A Zero pupil diameter value indicates that no pupil was found for that field. This may be due to an eye blink, an incorrect discriminator setting, or some other occlusion of the pupil. Pupil diameter values are not scaled to metric units. The scale factor depends on the magnification of the eye camera lens, and the eye to camera distance. The scale factor is usually very close to 0.15 millimeters/eye-tracker-unit. To compute a precise scale factor, see section 8.5.

If an optional magnetic head tracker (MHT) system is connected and enabled, MHT data will be recorded along with Eye Tracker data. The MHT data consists of x, y, and z position values, and azimuth, elevation, and roll orientation values. MHT data recorded by the e5000 program is recorded with the same binary scaling used by the MHT device. After retrieving these values as integers, with the data access routines provided by ASL, they can be converted to meaningful units using the scale factors listed below.

| **MHT type** | **position scale factor (inches)** | **position scale factor (centimeters)** | **angle scale factor (degrees)** |
|---|---|---|---|
| Ascension Bird or Flock | 0.00109867 | 0.0027906 | 0.00549303 |
| Polhemus FASTRAK | 0.00360443 | 0.00915525 | 0.00549316 |
| Polhemus 3Space or ISOTRAK | 0.00199835 | 0.00507584 | 0.00699423 |

If averaging has been specified, on the “System Settings” window, it is the averaged gaze coordinate data that is recorded. Remember that after a period during which a pupil was not recognized (no valid gaze measurement could be made) the first valid measurement is not averaged. The next measurement is averaged with just the previous valid field, and the number of fields averaged increases in this way until the specified value is reached. Only gaze coordinates are averaged. Neither pupil diameter, nor are any other recorded values are averaged.

## 5.10 17 point calibration option

The 17 point calibration mode uses 17 calibration target points instead of the usual 9 to map a more distorted relationship between the pupil and corneal reflection features on the eye and point of gaze on the scene. In most cases the normal 9 points will be sufficient, but if scene image itself is significantly distorted (E.g., image from a scene camera with a wide angle lens that produces “fish eye” distortion) or the eye feature to point of gaze relation is especially complicated for some other reason, the 17 point mode may improve accuracy. If after doing a normal 9 point calibration it is found that data is accurate at the normal 9 calibration points, but inaccurate when the subject is looking between the locations of the normal 9 points, then the 17 point mode will probably improve results.

To enable the 17 point mode check the “17 point eye calibration” check box, on the System Settings dialog window, under the Configuration pull down menu. Target points 10-17 should be arranged about half way between outer points of the normal 9 point set and the center point, as shown in figure 3-3.

Procedures for setting target points and performing the eye calibration are unchanged except all 17 points must be designated by the Set Target Point procedure, and the subject must look at all 17 points during calibration. The Eye Calibration window is automatically closed, and computations performed, after the $17^{th}$ point is entered rather than after the $9^{th}$ point is entered.

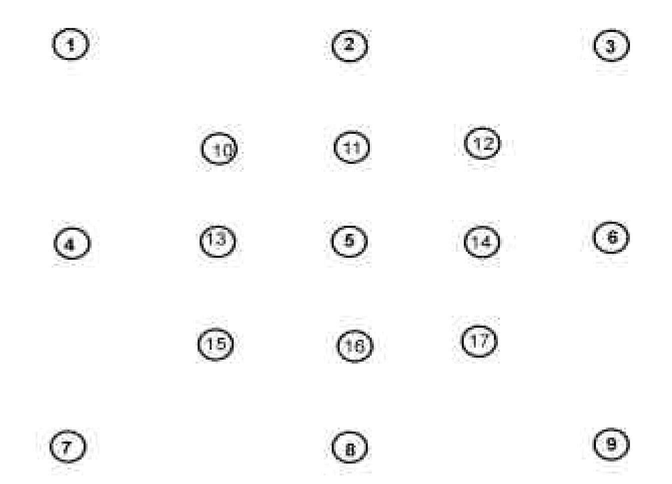



Figure 5-4. 17 point calibration target pattern

## 5.11 Operation Notes and Precautions

The eye tracker works best when used in environments with subdued and diffuse ambient lighting. Improper ambient lighting may cause difficulty with pupil signal quality due to extraneous reflections and an overly constricted pupil. Avoid sunlight illumination of the subject's face. If the subject must sit close to an outside window, it is best to shade the window. If possible, avoid bright light sources directly over the subject's head, or right next to the scene being viewed by the subject, since these may cause extraneous corneal reflections. The eye tracker will not work well outdoors in sunlight due to the very bright ambient environment and too much stray IR

It is often helpful to have low room lights while specifically illuminating the area of visual interest with auxiliary lights. "Dimmer switch" control of room lighting is often helpful.

If the scene image being viewed by the subject is a computer monitor or video monitor, it may help to use the brightness control to decrease the brightness slightly. An anti glare shield on the subject display monitor may be extremely helpful and may improve eye tracker performance significantly..

# 6 REAL TIME, SERIAL and ANALOG DATA OUTPUT

## 6.1 Serial data output

Eye tracker data can be output through an RS232 port, labeled "Serial Out" on the model 5000 Eye Tracker Control Unit. The port is set to 57600 baud, 8 data bits, 1 stop bit, no parity. Other baud rates are also possible (consult ASL for details).

### 6.1.1 Interface Cable

The model 5000 Eye Tracker Control Unit "Serial Out" connector is a 9 pin male D type. Only "Transmit", "Receive", and "Ground" lines are used.

```
SERIAL OUT      Signal

   3   ------ serial data from host to 5000CU
   2   ------ serial data from 5000CU to host
   5   ------   Ground
```

An example is shown below of wiring for a cable to connect the eye tracker "Serial Out" port to a standard 9 pin COM port on a PC.

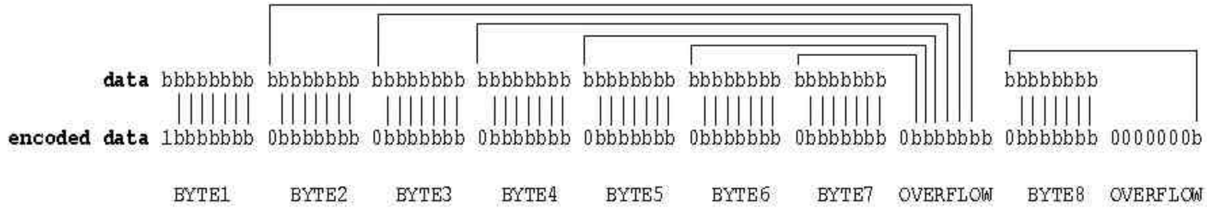
```
9 pin female          9 pin female

     2 -------------------- 2

     3 -------------------- 3

     5 -------------------- 5
```

### 6.1.2 Protocol and data format

The data output port can be set to use either a demand mode or a streaming mode. In the demand mode, the host computer requests a data field by transmitting a single byte of any value. In response, the eye tracker transmits a field of data. After a data request is received from the host, the eye tracker PC will begin to transmit the requested field within one update interval.

In the streaming mode, no data request is required. Data will continually stream from the "SERIAL OUT" port. The data is encoded, however, so that the first byte of a data field can be identified.

Encoding of the standard 8 byte data field is shown below




Note that most significant bit of the first data field byte is always set (1). The most significant bit of all other bytes in the data field are always reset (0). For the standard data set, the encoded data field is 10 bytes long rather than 8 bytes. The host computer must find 10 sequential bytes starting with a byte whose most significant bit is 1, then decode the data by reversing the encoding process shown above. Sample source code for decoding streaming data can be provided by ASL upon request.

The standard data buffer consists of the 8 bytes listed in Table 6-1.

Table 6-1. Standard Serial Out data feild

| byte | description |
|---|---|
| 1 | Status (0 = normal, >0 = error condition) |
| 2 | Pupil diameter, most significant byte (0=loss) |
| 3 | Pupil diameter, least significant byte |
| 4 | <Used only by model 501 system with EYEHEAD Integration> |
| 5 | Point of gaze horizontal coordinate most significant byte (scene monitor coordinates) |
| 6 | Point of gaze horizontal coordinate least significant byte |
| 7 | Point of gaze vertical coordinate most significant byte |
| 8 | Point of gaze vertical coordinate least significant byte |

Note that if using the streaming mode, the above list shows the data after decoding. Each coded data field read by the host will consist of 10 bytes.

The system can also be set to provide alternate data buffer contents. The buffer contents and the output mode (demand or streaming) are controlled by a value in the *e5000.cfg* file. View *e5000.cfg* (in the same directory as e5Win) with a text editor. Find the line that reads:

**`serial_data_output_format_type=`**

For the standard 8 byte output buffer, in demand mode, set the value after the equal sign to 1. For the same buffer contents, but in streaming mode, set the value to 129. For other alternatives, consult ASL. Resave the file as *e5000.cfg*.

## 6.2 Analog data output

Two channels of analog output are available on the eye tracker control unit port labeled "Analog I/O". One analog channel outputs a voltage corresponding to the horizontal eye position coordinate, and the other outputs a voltage corresponding to the vertical eye position coordinate. The voltages are proportional to the horizontal and vertical positions of the point of gaze cursor on the scene monitor and the digital gaze coordinates. Pupil diameter is not normally output, but when no pupil is recognized, the analog outputs are set to a specific default value.

Although the maximum voltage swing on each channel is from 0 to 12V, when the cursor is within the scene monitor display space the swing is actually from +3V to +9V. The voltage should exceed 9 V only if the subject looks beyond the part of the scene shown at the bottom or right edge of the scene camera image, or if the system mistakes some extraneous reflection for a pupil or CR and produces nonsense data. Normally, approximately 3V from both channels corresponds to the upper left corner of the scene monitor, and 9V from both channels corresponds to the lower right corner. The center of the scene monitor screen should correspond to about +6V.

The analog outputs do respond when in "Set target" or "Check target" point modes. For example the "Set target" function, which allows the point of gaze cursor to be controlled with the mouse, can be used to check the precise correspondence between any point in the scene image and the analog outputs.

Analog outputs are on pins 3 (vertical) and 4 (horizontal) of the nine pin connector, and signal ground is on pins 6-9. The entire pinout list for the nine pin "analog I/O" connector is shown in a table at the end of this section.

The analog output will reflect averaging (number of fields to be average is specified in "System settings" dialog window, under config menu) as does the digital data and the scene monitor cursor.

The scene monitor cursor position as well as the analog values will freeze at their last position during pupil or CR loss for a number of fields specified in the *e5000.cfg* file ("eye_position_blink_filter_value ="), and will then jump to a default value until the pupil is once again recognized. This is to prevent blinks from causing the values to "jump", as previously explained in section 5.4. The default analog values are approximately 3 Volts (corresponding to the point of gaze cursor at the upper left corner of the scene monitor). The default for the number of fields during which the value will freeze during losses is "eye_position_blink_filter_value=12". Simply edit the *e5000.cfg* file (with any text editor) to change this to any desired value. Setting it to zero will cause the values to immediately jump to the default value during any field in which the pupil is not recognized. In other words, neither the scene monitor cursor nor the analog values will freeze at their previous value for any period of time during pupil losses, but will go to the default position for the entire period during which the pupil is not recognized.

Note that the “blink_filter” value is a number of fields, not a time. When running at 60 Hz, 12 fields corresponds to about 200 msec, but at 240 Hz it only corresponds to about 50 msec. The value must be adjusted depending on the update rate being used. Setting the number of fields to be averaged to either 0 or 1 disables averaging.

The analog values remain “live”, rather than showing target positions, during calibration.

Table 6-2. Analog I/O connector

| Pin | Function |
|---|---|
| 1 | (not currently implemented) |
| 2 | (not currently implemented) |
| 3 | Vertical eye position |
| 4 | Horizontal eye position |
| 5 | +12V |
| 6,7,8,9 | ground |

# 7 THEORY OF OPERATION

## 7.1 Pupil and CR Recognition

The Eye Tracker optics module is designed so that the near infrared eye illumination beam is nearly coaxial with the optical axis of the pupil camera. Because it is coaxial with the light source, the camera lens captures the partially collimated beam that is reflected back from the retina, and the image reaching the camera sensor is that of a back lit bright, rather than dark, pupil. This bright pupil image can usually be much more easily discriminated from the iris and other background than could a black pupil image.

Note that the amount of reflected light that reaches the camera from the retina is approximately proportional to the fourth power of pupil diameter. Pupil brightness therefore varies significantly with pupil diameter. Even when a subject's pupil is at its largest and brightest, the reflection of the illuminator from the front surface of the cornea (corneal reflection or CR) is normally much brighter than the pupil. Thus the pupil can usually be distinguished from the background and the CR can be distinguished from the pupil on the basis of brightness.

When a subject's pupil becomes very small (3 to 4 mm diameter), sections of the eyelid, cheek, or sclera that are also on the camera field often appear as bright as the pupil. In these cases, size, shape, and smoothness criteria must be used to help identify the pupil.

In some cases more than one area will be as bright as the CR. If more than one bright spot will satisfy the proper size and shape criteria, the computer selects the spot closest to the pupil center as the CR. Once the pupil and CR are identified, the computer calculates their centers for use in determining eye line of gaze. Note that when the eye looks away from the illuminator more than about 25 degrees, the CR no longer appears on the cornea and cannot be detected.

## 7.2 Eye Line of Gaze Computation

The separation between the pupil and the corneal reflection (CR) varies with eye rotation (change in point of gaze) but does not vary significantly with eye translation (head movement with respect to the eye camera). A change in pupil-CR separation is approximately proportional to the change in point-of-gaze.

The precise relationship between eye line of gaze and the pupil-CR separation (*PCR*) as seen by the camera is diagrammed in Figure 7-1 for a single axis. Note that the relation reduces to

$$PCR = K \sin(q) \qquad (1)$$

where $q$ is eye line of gaze angle with respect to the light source and camera, and $K$ is the distance between the iris and corneal center of curvature. The corneal reflection (CR) is detectable over about a 30-40 degree diameter visual angle field.

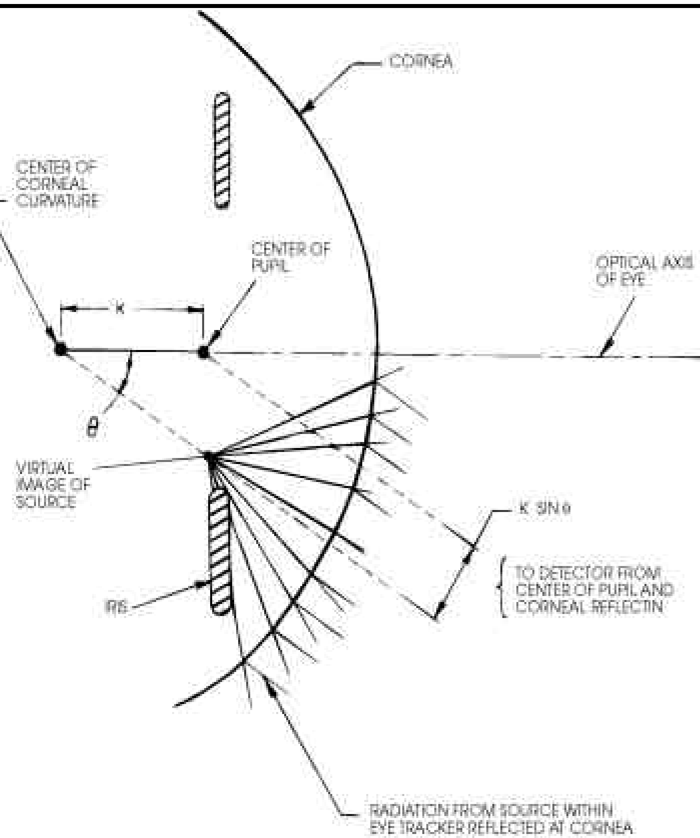



Figure 7-1. Relation between line of gaze and pupil/CR separation (after Merchant and Morisette, 1974)

In addition to the geometry described by the above equation, it is necessary to account for intra subject differences in corneal shape and other second order effects. The Eye Tracker therefore computes eye azimuth and elevation angles as polynomial functions of pupil CR separation along each axis including cross talk and corner terms. Data stored during the calibration procedure is used by the computer to calculate the polynomial coefficients for each subject.

## 7.3 Timing

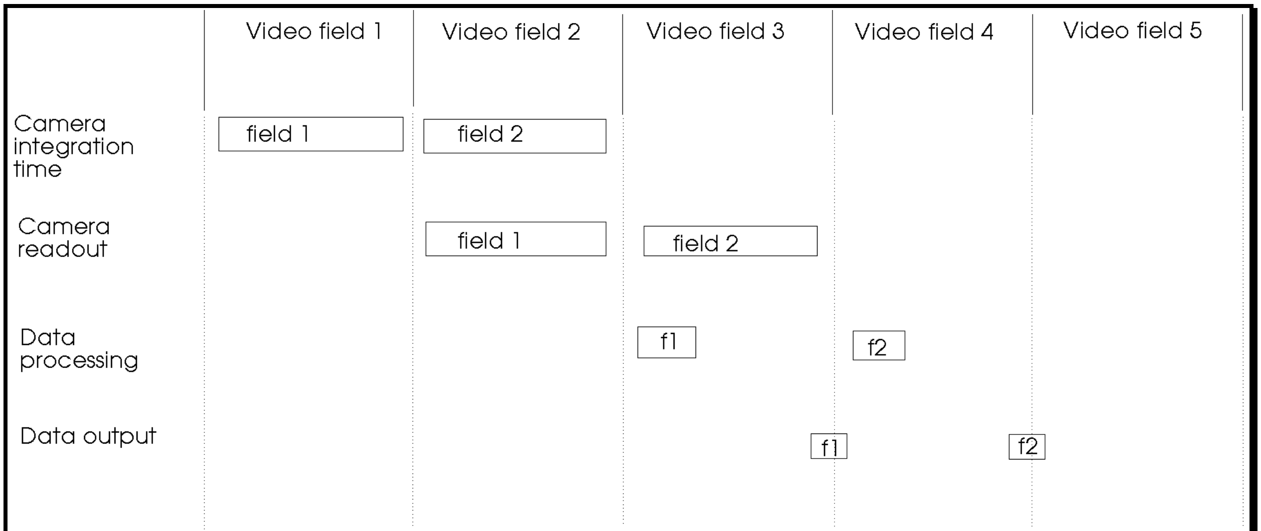



Figure 7-2. Eye tracker timing

A data sample is output by the eye tracker control unit for every eye camera video field. There is a transport delay of about 3 video fields, as shown in figure 7-2. The camera pixels charge up during 1 video field, the video data is transmitted to the system and digitized during the next field, and is processed by the system during part of the third field. The new data is available at the serial or analog output port near the end of the third field, so each data sample contains information that is about 3 fields old. With a 60 Hz (NTSC format) eye camera, this corresponds to a trasport delay of about 50 ms (3/60 of a second). With a 50 Hz (PAL format) eye camera the delay is 60 ms (3/50 of a second). With an optional high speed camera running at 240 Hz, the delay is 12.5 ms.

Note that averaging, as specified in the "System Settings" window (see section 4.2.2), will add lag to the gaze coordinate data, since each sample will be the average of the most recent computation and the specified number of previous computations.

# 8 FAULT DIAGNOSIS

## 8.1 General Approach

The following information is essential to determining the cause and solution to occasional system problems. In the event that help is sought from the factory, the basic concepts in this section will facilitate discussions.

The first step in troubleshooting a problem with the eye tracker is to determine which sub-system(s) is the cause of the problem. Clearly, the upstream, or most initial point of difficulty, will cause problems subsequent to it. In most cases, the symptom of the problem itself will lead to an immediate determination of the general location of the difficulty and a number of diagnostic tests can be undertaken to pinpoint the problem.

## 8.2 Functional System Description

The eye tracker consists of five sub-systems:

1. Optics. This consists of the eye camera and illuminator, the scene camera, associated lenses, etc., and is responsible for producing eye and scene video signals that are sent to the processor.

2. Processor. This consists of the model 5000 Eye Tracker Control Unit. The processor supplies power to the eye camera, scene camera, and illuminator; accepts video input from the eye and scene cameras; recognizes pupil and CR features, and determines their centers; computes point of gaze; superimposes edge discrimination dots and cross hairs or cursors on the eye and scene video images for display on eye and scene monitors; sends commands to the pan/tilt mechanism; receives command input from the Interface PC; and sends data to the Interface PC.

3. Interface PC. The User Interface PC uploads software to the processor (model 5000 Control Unit); sends commands to the processor to adjust discriminator values, illuminator values, launch the calibration process, etc.; receives data from the processor for display and digital recording.

4. Display This consists of the eye monitor and scene monitor.

5. Power The power supply module receives AC power from a standard outlet (100-240 VAC, 50-60Hz) and supplies 12 VCD to the control unit.

## 8.3 Functional Priorities

It is important to understand what functions are dependent on other functions in the operation of the eye tracker system. In this way, no time is wasted servicing or troubleshooting dependent or secondary operations. The following elements of the system must be present in the order shown. If there is a service problem, the top-most one should be approached first.

1. A successful software upload to the Eye Tracker Control Unit.
2. Successful communication between Control Unit and Interface PC (E5Win Interface program indicates "online:")
3. A good eye monitor picture
4. Pupil discrimination outline on the eye monitor
5. Corneal reflection discrimination outline on the eye monitor
6. Pupil and corneal reflection recognition cross hairs on the eye monitor
7. Pupil and corneal reflection cross hairs on the Interface PC display.
8. Automatic tracking by the pan/tilt mechanism of a properly recognized pupil
9. A good scene image (if a scene camera is being used)
10. Successful eye calibration
11. Fixation cross hairs or cursor on the scene monitor (if a scene camera is being used).
12. Reasonable point of gaze cursor on the Interface PC "Scene POG" display.
13. Serial Output to external device

## 8.4 Preliminary Trouble Shooting

If there is a problem with the eye tracker system, then the following steps should be undertaken first:

1. Check all power switches and AC connectors for all individual assemblies.
2. Check all the connections and connectors to ascertain that they are all going to the proper points.
3. Check eye tracker functions in the order listed in section 8.3.
4. Consult ASL.

## 8.5 Using the model eye

One of the accessories supplied by ASL is a model eye, or "target bar", that can be used to simulate the image received from a real eye. It consists of a thin, 2 inch by 6 inch piece of aluminum, painted black; and containing a white, approximately 4 mm diameter circle, and a small ball bearing. The exact diameter of the white circle is actually 3.96 mm. When viewed by the eye tracker optics, the white circle looks like a bright pupil image, and the reflection from the ball bearing looks like a corneal reflection. The model pupil and corneal reflection (CR) images will not mimic the relative motion of the pupil and CR when a real eye rotates. They do, however, provide stationary models that can be used to test eye tracker discrimination functions, to practice discrimination adjustments, and to calibrate pupil diameter.

To use the model eye, simply place it so that the white 4mm circle is at a normal eye distance from the optics, turn on the illuminator, aim the pan/tilt camera at the model eye, and adjust discriminator settings to obtain discrimination outlines and center cross hairs, just as for a real eye (see section 5.2.4).

To compute a scale factor for pupil diameter values displayed on the computer screen, or recorded by the Interface PC program, first obtain proper discrimination on the model pupil, then note the pupil diameter value on the computer screen digital display window ("PupDiam: *nnn*"). To compute a scale factor, divide 3.96 by this value. Convert displayed or recorded pupil diameter values to millimeters by applying this scale factor (value in millimeters = scale factor * recorded value).

# 9 SPECIFICATIONS

| | |
|---|---|
| **Measurement** | Eye line of gaze with respect to a stationary viewing surface. |
| **Allowable eye movement** | Along the horizontal axis, 50 degrees or more. Along the vertical axis, 35 degrees or more depending on optics placement and eyelids. (Field will generally be oval in shape.) |
| **Precision** | Better than 0.5 degree. |
| **Accuracy** | Spatial error between true eye position and computed measurement is less than 1 degree. Errors may increase as the head moves significantly from its initial position. Errors may also increase when gaze is beyond the outer boundary of the calibration pattern. |
| **Eyeglass and contact lens acceptance** | Most are accepted. Eyeglasses may need to be tilted with respect to the head if a specular refection from the glasses interferes with the pupil image. |
| **Ambient illumination** | Complete darkness to moderate illumination resulting in pupil diameters greater than 3mm. Brighter environments possible with special precautions. |
| **Sampling and output rate** | 60 Hz (or the country's television scan rate standard). 120 Hz and 240 Hz available as options |
| **Physical dimensions (approx.)** | • Control unit is 3.25"h X 10.0"w X 10.25"d and weighs 4.5 lb.<br>• Pan/Tilt module is 4"h X 5.5"w X 6"d and weighs 2.75 lb. (note: shape is irregular). |