ET Server Manual

ETSERVER **WITH STANDARD HEAD MOUNTED OPTICS (ETS HMO)**

MANUAL VERSION 1.1
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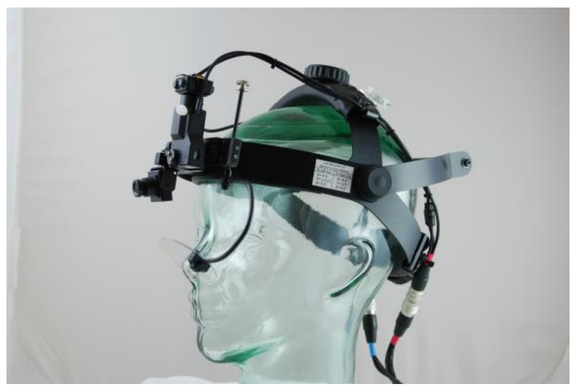
1 Introduction and General System Description

The *ETServer* (ETS) eye tracker, with head mounted optics (HMO), is designed to accurately measure a person's pupil diameter and point of gaze. When not using a head tracking option, the measurement is displayed as a cursor or set of crosshairs superimposed on the image from a second head-gear mounted camera acquiring video of the environment from the subject's perspective. Digital data specifies pupil diameter and point of gaze with respect to the scene camera field of view

When using a head tracker, a function called *ET3Space* can accurately map line-of-line of gaze onto multiple surfaces in the environment. In this case digital data specifies the surface on which gaze falls, and the exact point-of-gaze position on that surface. A point-of-gaze cursor can also be superimposed on the image from a stationary (non head mounted) camera, such as a web-cam, or on a real time image taken directly from a computer monitor that the subject is viewing.

In either case the scene image, with a superimposed cursor showing point-of-gaze, can be recorded as a wmv file, and can also be sent, in real time, to other computers over a LAN. Real time digital data as described above, can be sent via LAN to other devices and can be recorded by the *ETServer*.

The ETS can use either a bright or dark pupil type optics module to illuminate and image the eye. The bright pupil module is optimized for normal indoor lighting, and the dark pupil module is best for extremely bright environments.



The eye camera and eye illuminator are contained in the housing attached to the headband. The eye camera produces a close image of the eye by reflecting the image off of a hot-mirror attached to an adjustable boom arm.

The Illuminator is a near infra-red LED. In the case of the "bright pupil module", it is directed to be coaxial with the camera's direction of view, creating the "bright pupil" affect. In the case of the "dark pupil module" the near infra red LED is aimed at the eye from a position that is offset from the eye camera so that the camera "sees" the pupil as the familiar black disk.

An optional scene camera is also mounted on the headband to observe the environment from the subject's head perspective.

The Head Mounted Eye Tracker is designed to track gaze direction over approximately a 30-40 degree vertical visual angle and a 50-60 degree horizontal visual angle with respect to the head.

The *ETServer* computer (ETS PC) and all custom electronics are housed in a single unit.

The Head Mounted Optics Eye Tracker is part of a modular research tool that comes with many standard features. A variety of options are available which enhance its performance. The most common optional component is a head tracking system to track head motion and to compute intersection of gaze on surfaces in the environment.

2 Environmental and Safety Considerations

2.1 Statement on Safety Levels of Infrared Illumination

One of the most comprehensive and authoritative sources on the subject of light source safety is a handbook entitled ***Safety with Lasers and Other Optical Sources***, by David Sliney and Myron Wolbarsht, first published in 1980 by Plenum Press. Quoting from page 147 of this book, "However, safe chronic ocular exposure values, particularly to IR-A, probably are of the order of 10 mW/cm² or below". "IR-A" refers to the spectral band between 760 and 1400 nanometers, the range in which the Argus optics module operates.

We are aware of no data, made available since the book was published, that would challenge this conclusion. Most people might wish to be more conservative than the figure cited above, and Argus Science eye tracker optics modules operate at least an order of magnitude below this level. The power of the illuminator beam varies somewhat from sample to sample. The largest irradiance value that we have measured with an Argus Science head mounted optics module is 0.8 mW/cm², at the plane of the eye. Under normal use, eye irradiance will be less than 0.3 mW/cm².

The *ETServer* optics use non-coherent illumination. There are no lasers in the system.

3 System Components

Please refer to this table to aid in identifying the various parts of your eye tracker. Depending on the individual configuration, you may not have all parts pictured here and you may have additional parts not listed. Some items may not look exactly as pictured.

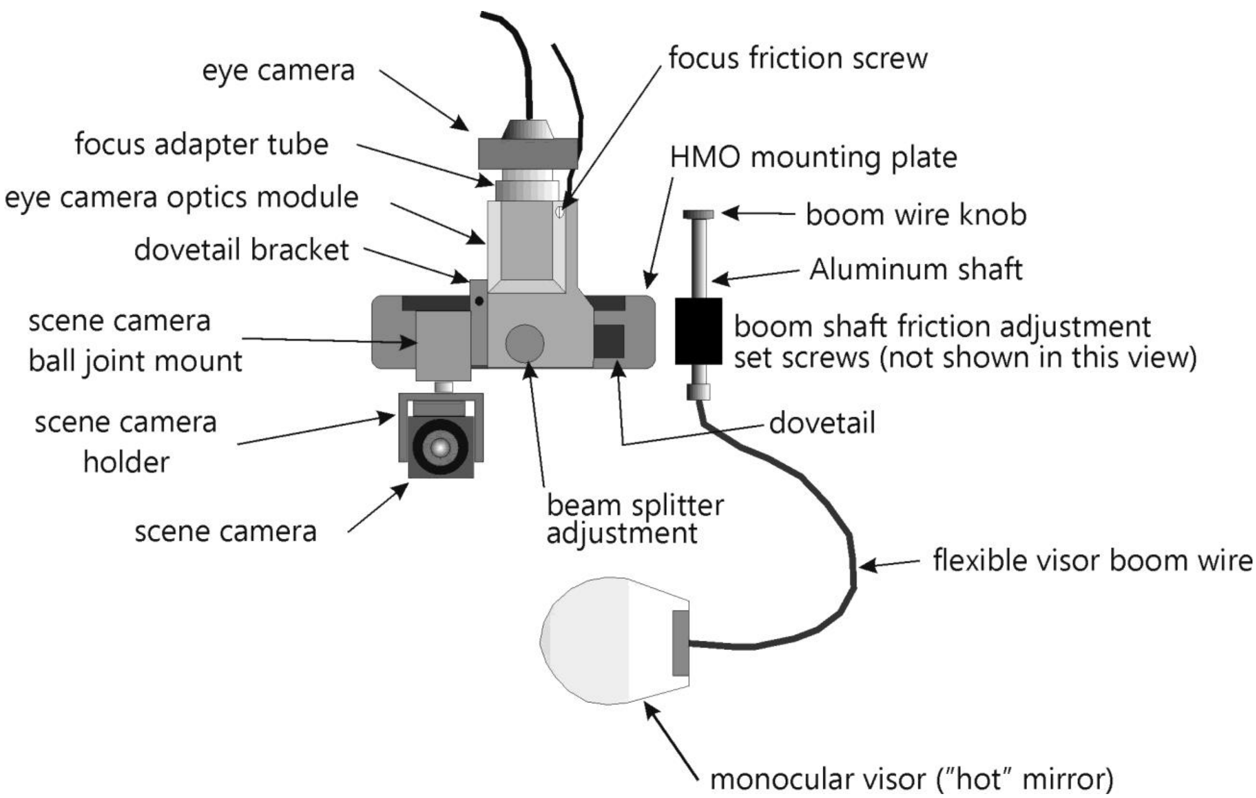
What it looks like	*What it is*	*What it does*	*comments…*
	**Argus *ETServer* Processing unit (includes keyboard, mouse and monitor)**	Desk top (tower style) PC containing eye tracker electronics. Performs all system processing, and gaze calculation. Records data and runs User Interface application	All Systems
	**Head Mounted bright pupil Optics**	Headband with Camera, Illuminator, & head mounted Scene Camera.	All Systems
	**Camera Cable**	Connects head mounted optics module to *ETServer* PC	All Systems
Depends on Head Tracker Type (consult Argus Science)	**Head Tracker**	Measures head position and orientation	Optional component required for *ET3Space*
Depends on Head Tracker Type (consult Argus Science)	**Mounting Bracket for Head Tracker Sensor**	Provides mount for attaching head tracker sensor to head gear	Required only if using head tracker
Depends on Head Tracker Type (consult Argus Science)	**ET3Space Tools**	Used when specifying *ET3Space* environment	Required only if using *ET3Space*
	**USB Web Cam**	"Stationary Scene Camera" for use with *ET3Space*	For use only with *ET3Space*

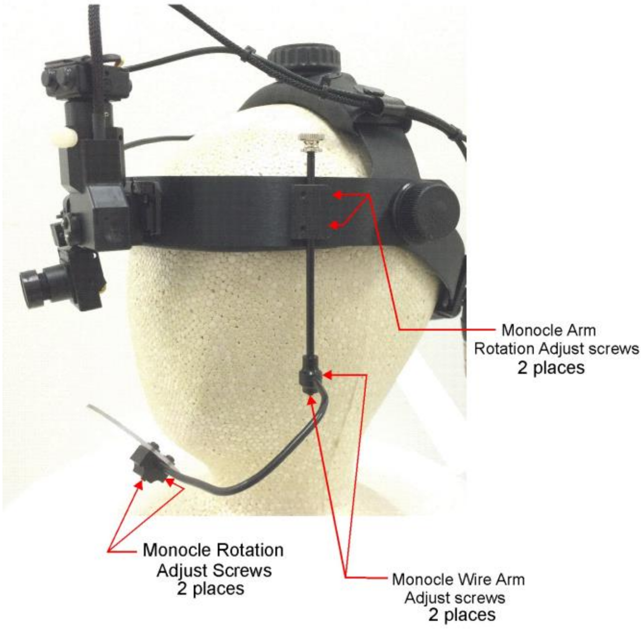
3.1 Head Mounted Bright Pupil Optics

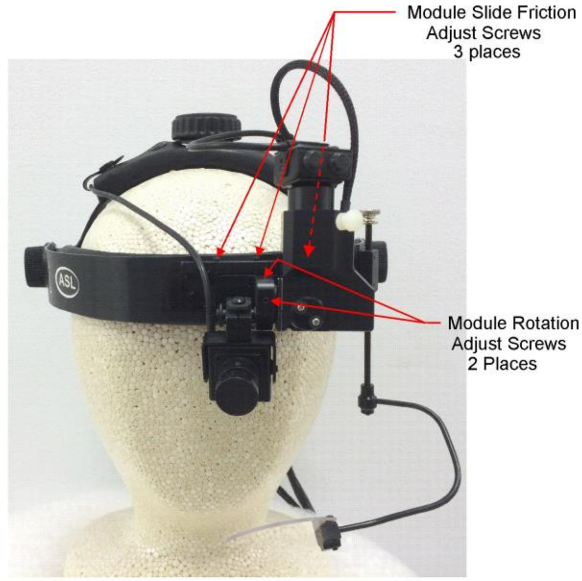
The head mounted optics are usually supported by an adjustable head band, although other custom mounting arrangements are possible. The standard headband has a rear knob to adjust the "hat band" size, and a top knob to adjust the height of the top strap. It can include mounting brackets for various types of head trackers.

The eye tracker optics include the eye camera module, containing the illumination LED, a scene camera, and a small visor. The visor is a beam splitter that is very reflective in the near IR and transparent in the visible spectrum. The eye camera views the reflected image of the eye from the visor so that the subject's visually field is does not need to be obstructed. All of these components can be moved in multiple degrees of freedom so that the optical path can be adjusted to accommodate a wide range of situations and applications.

The diagram below shows the 60 Hz, bright pupil optics module. A similar diagram showing the high speed optics module can be found in section 14.1.3.







Note: There are eleven nylon tipped friction adjust screws that may need periodic adjustment to maintain proper friction. Adjust as necessary, using the .050 hex key provided with these instructions

3.2 ETServer Processing Unit

The *ETServer* (ETS) Processing Unit is a desktop PC with a tower style case that contains all of the eye tracker processing electronics. It includes a monitor and keyboard, and is the station from which a user controls the eye tracker. The *ETServer* Processing Unit runs the User Interface Application, receives video from eye and scene cameras, and performs all of the gaze computations, records data, sends real time data via LAN to external devices, and accepts mark flags or other data from external devices. When the *ET3Space* feature is used, it also accepts input from a head tracking device. The associated monitor displays annotated eye, and scene images to provide feedback to the user.

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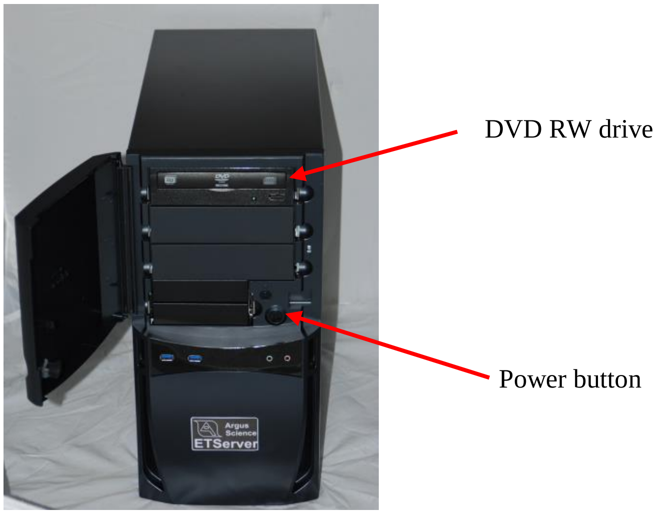


If the system is equipped with optional High Speed Eye Camera, switches for setting the camera update rate (not shown in photo) are located just to left of the power button.

4 Installation

4.1 Software Installation

The ETServer PC (ETS PC) comes with eyetracker operating software and manuals already installed. The an *ETServer* CD is provided with the system. It contains system manuals, and install programs including *ETServer_Install* and *ETRemote_Install*. The *ETServer* software is preinstalled on the ETS PC and the installer is provided only as a backup. **Do not reinstall *ETServer_Install* on the ETS PC, unless directed by Argus tech support.** *ETRemote* is intended for installation on other Windows 7 computers (for example, a subject display PC) that may be communicating with ETS.

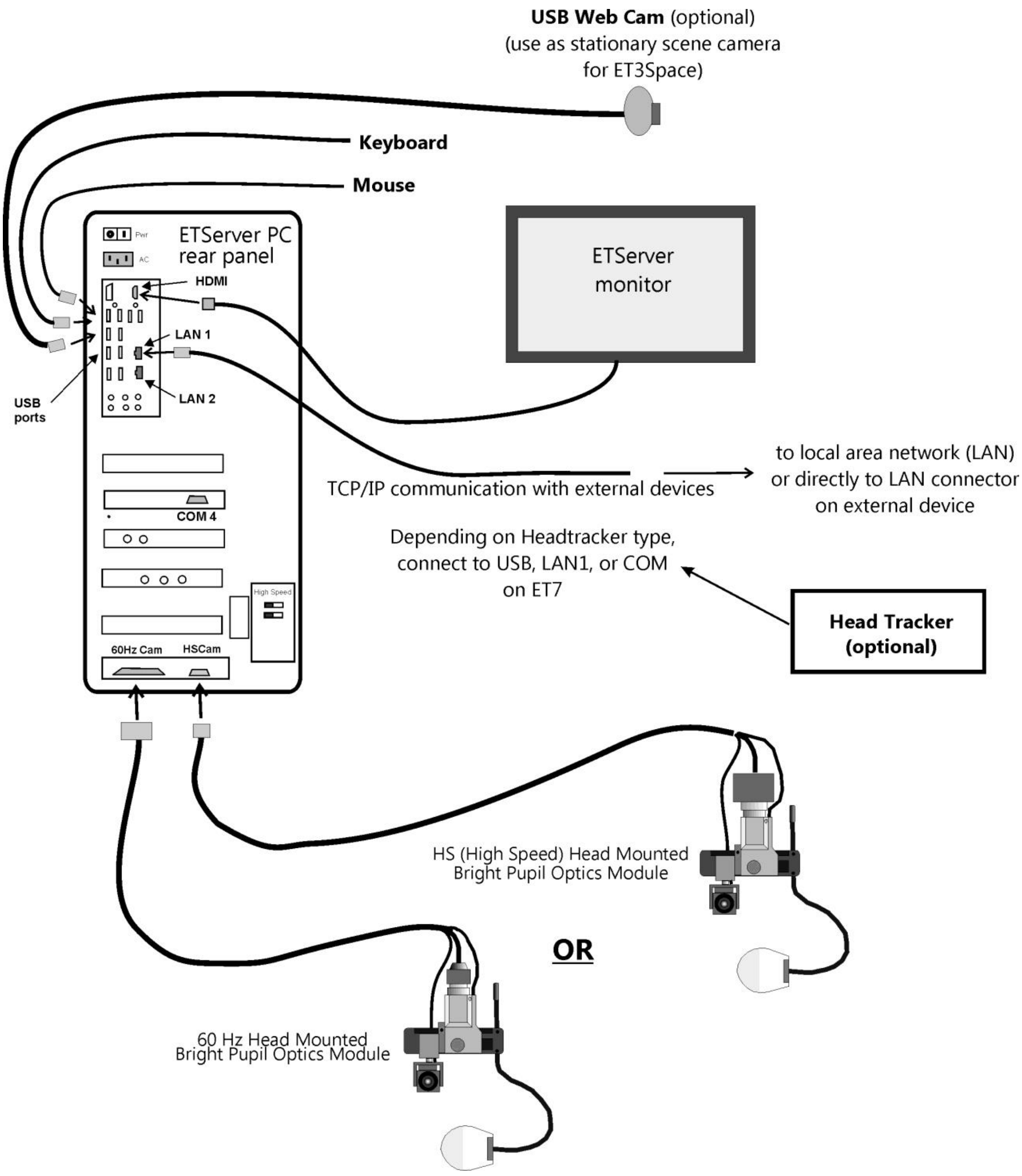
The latest software can also be downloaded from the Argus Science website (www.argusscience.com/download.htm).

4.2 Interconnections of Components

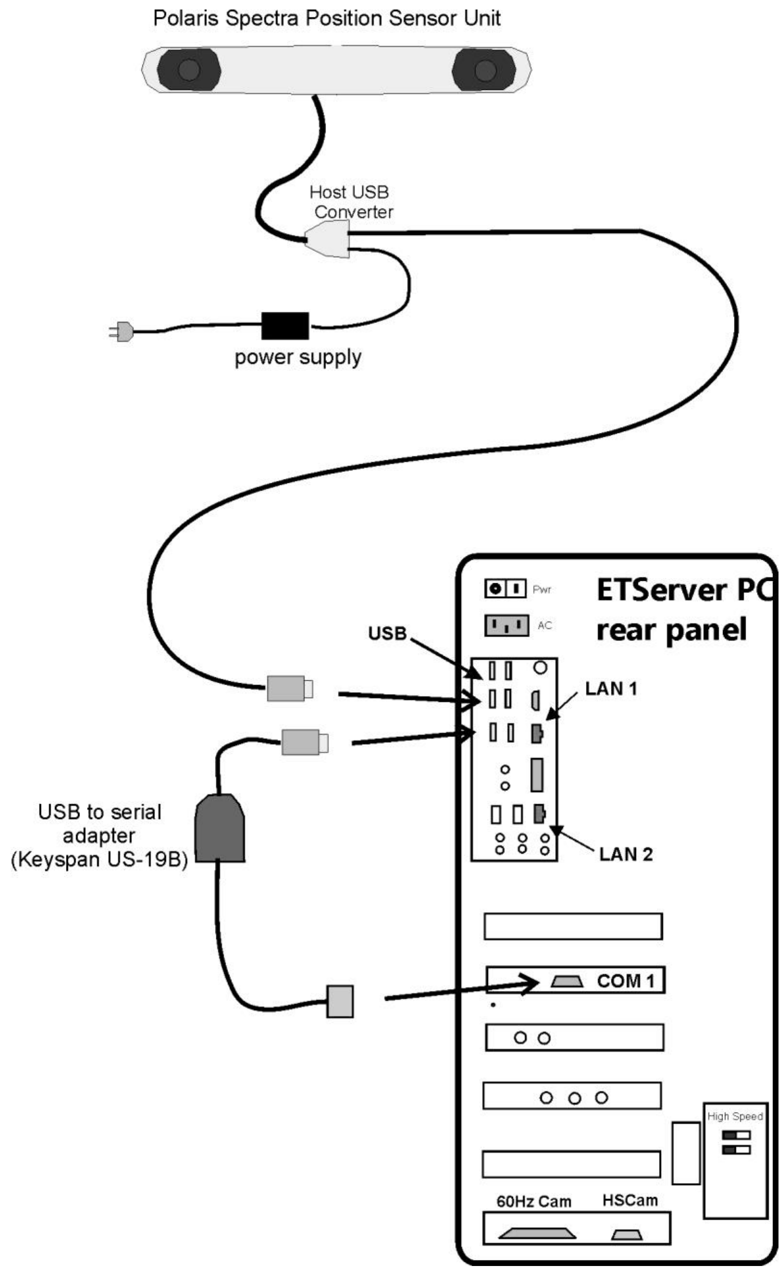
Since the ETServer Eye Tracker is inherently a modular system, there are many potential configurations possible. The head mounted eye tracker can be used in combination with several different types of 3d party head tracking devices, can accept scene image input from different external devices and can send and receive communication from various external devices. This section will diagram connections for the most common components and configurations.

4.2.1 General connections for head mounted optics

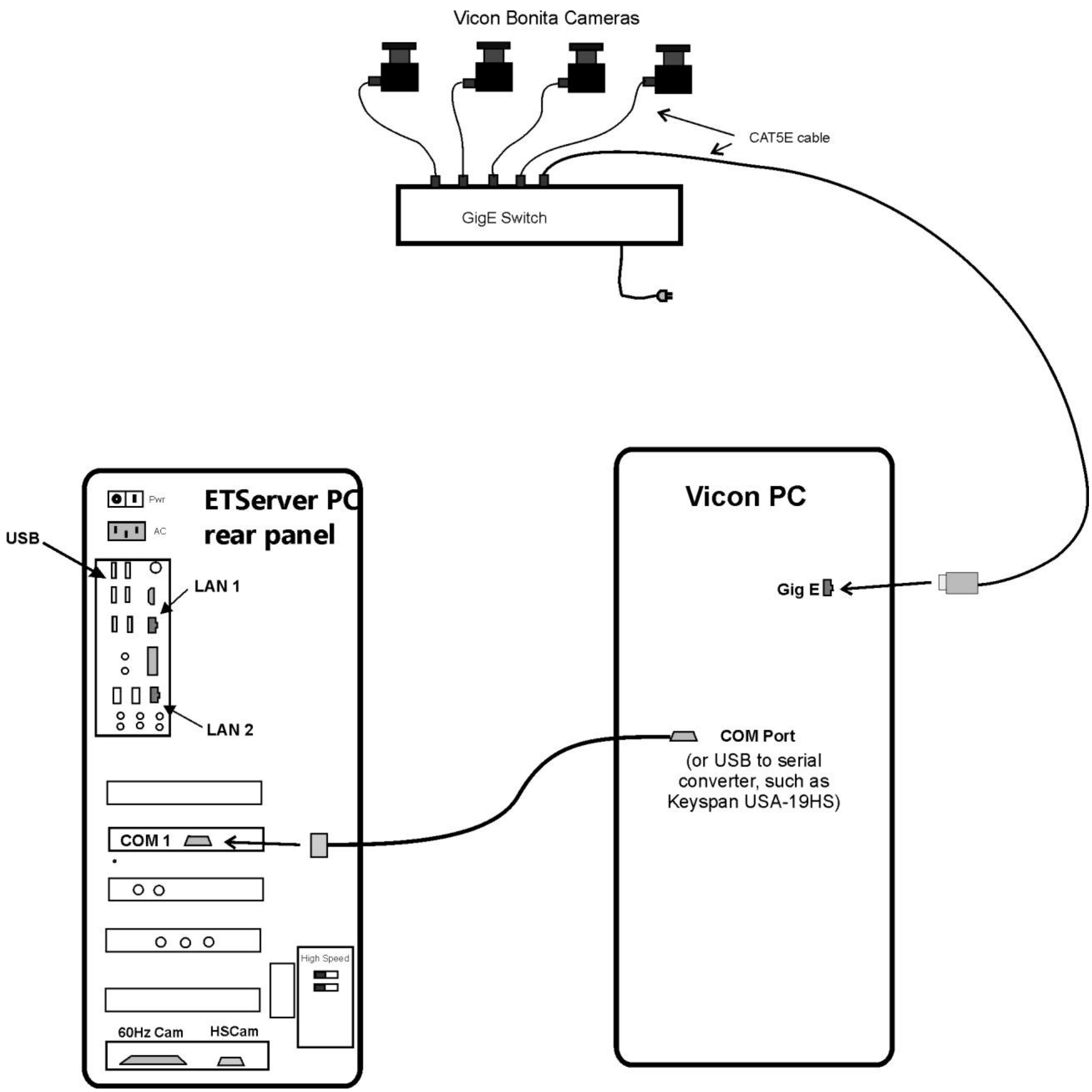
The "High Speed Camera" connector may not be present if the *ETServer* system has not been equipped with the high speed (HS) option. If not an HS system, the "60 Hz Camera" connector may just be labeled "Camera". Note: placement of connectors may vary somewhat from system to system. Please follow labels and color codes.



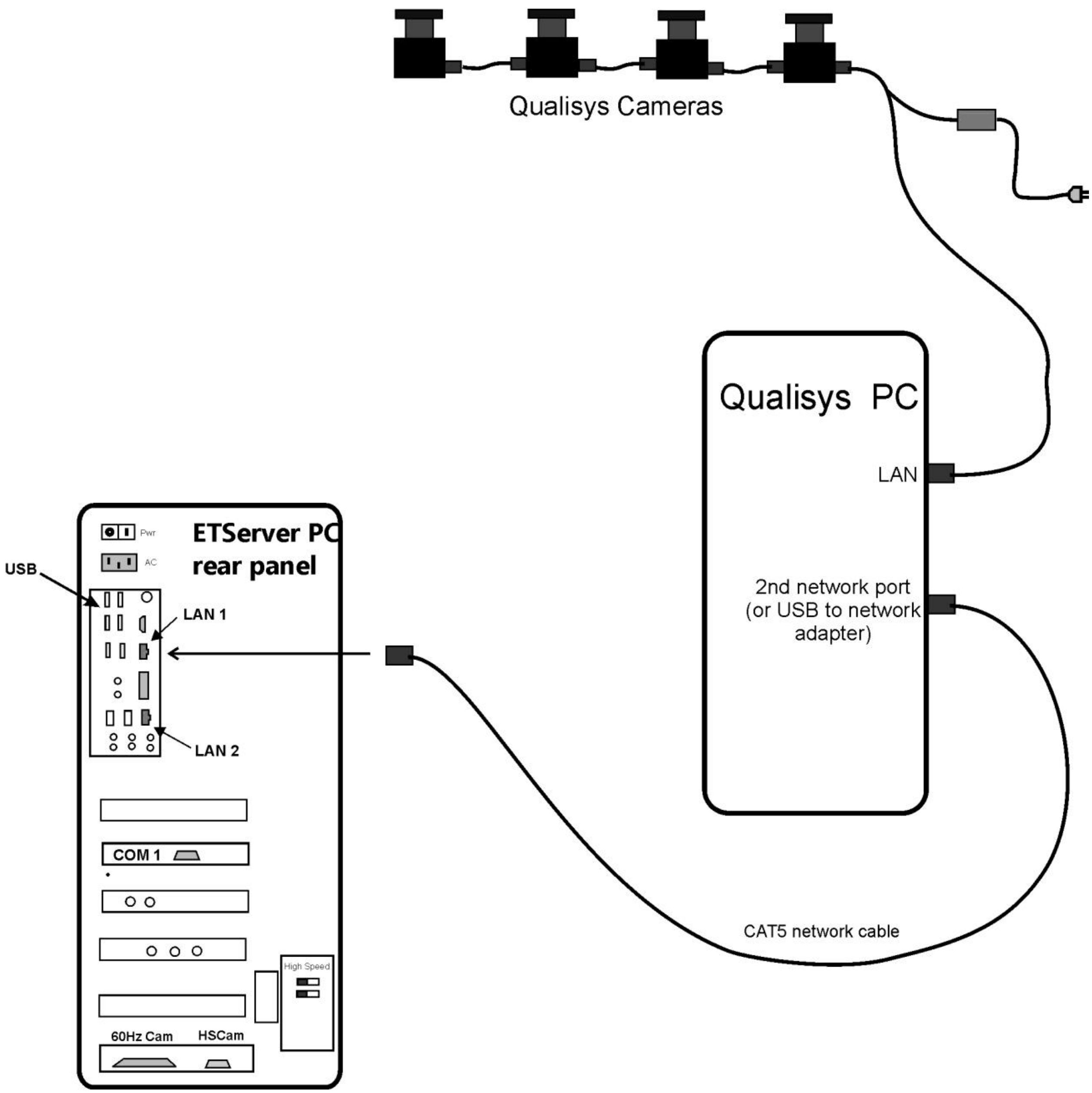
4.2.2 ETServer connection to *NDI Polaris Spectra* Head Tracker



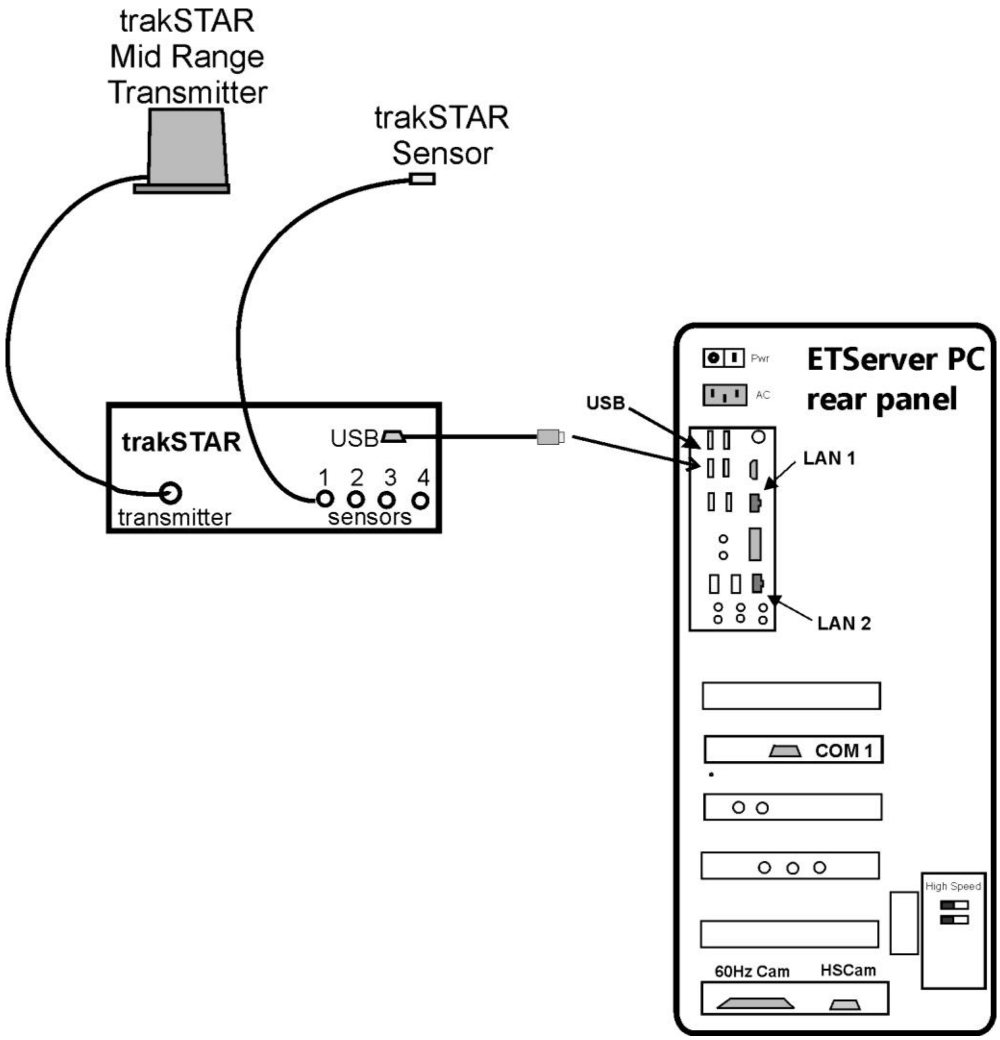
4.2.3 ETServer connection to *Vicon* Head Tracker



4.2.4 ETServer connection to *Qualisys* Head Tracker

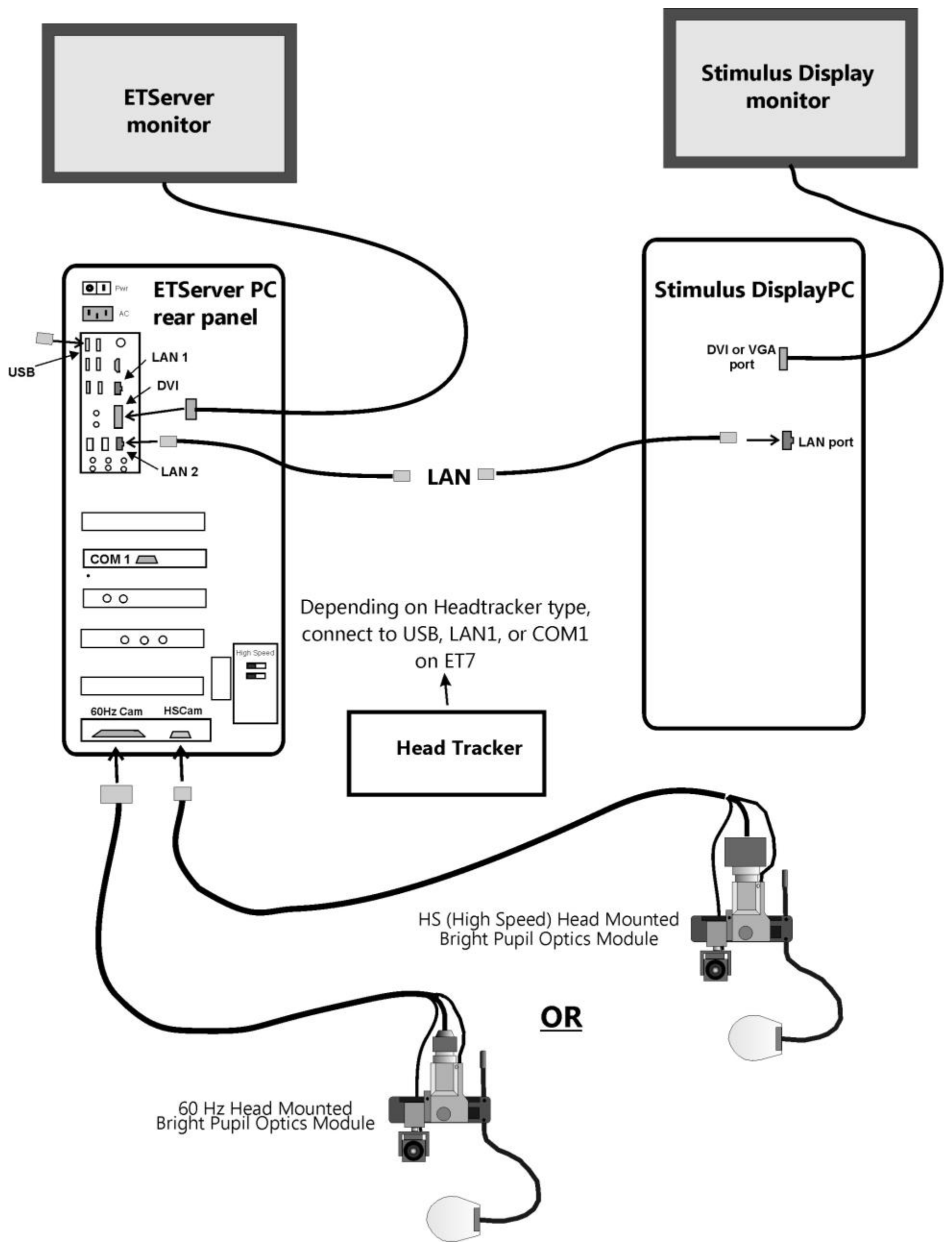


4.2.5 ETServer connection to Ascension TrakStar



4.2.6 Windows Computer Monitor as scene video source

When used with a head tracking device and the Argus *ET3Space* function, the *ETServer* can show gaze superimposed on the image from an external video source. If the primary scene plane is a Win 7 or Win 10 computer monitor being viewed by the subject, the *ETRemote* program, provided by Argus, can be used to send the screen image to the eye tracker via local area network (LAN). This image will be displayed as the "Stationary Scene Camera" image by *ETServer*. See previous sections for head tracker connections.

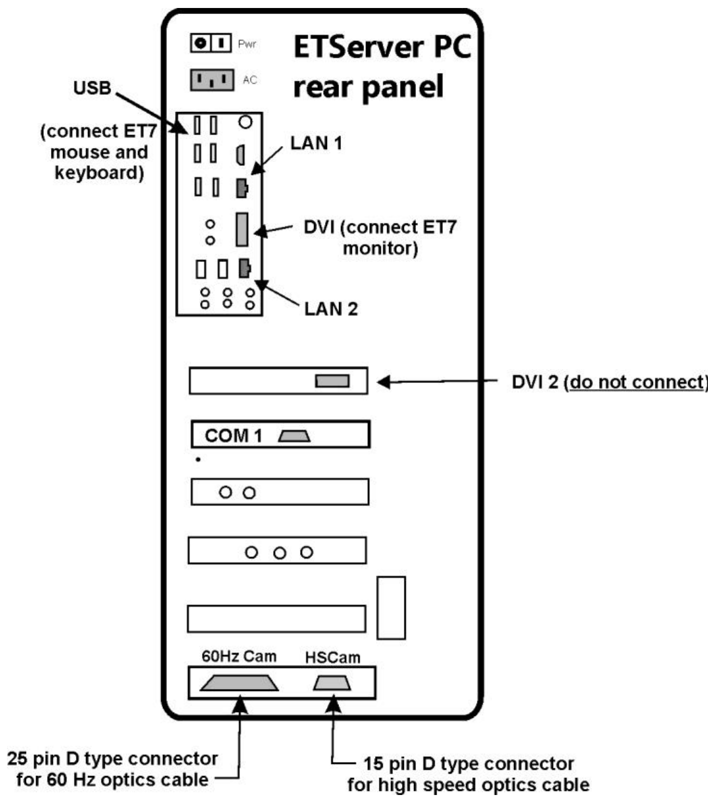


4.2.7 Web cam video scene source

When used with a head tracking device and the Argus *ET3Space* function, the ETS PC can show gaze superimposed on the image from an external video source. If the scene area is captured by a room mounted USB Web camera, this can be input to a USB connector, on the ETServer, and will be displayed as the “Stationary Scene Camera” image. This is shown in the section 4.2.1 diagram.

4.2.8 EYE-TRAC PC rear panel

The "High Speed Camera" connector may not be present if the *ETServer* system has not been equipped with the high speed (HS) option. If not a HS system, the "60 Hz Camera" connector may just be labeled "Camera". Note: placement of connectors may vary somewhat from system to system. Please follow labels and color codes.



4.3 Connection to External Devices

The primary means for communication between the *ETServer* and external devices is Ethernet Local Area Network (LAN). If both the *ETServer* and external device are connected to a LAN, the external device can receive real-time data and imagery from the eye tracker, and can send event mark data as well as display imagery to the eye tracker.

4.4 ET3Space

Please see the *ETServer – ET3Space Manual* for details on setting up an ET3Space environment. *ET3Space* is necessary for obtaining meaningful digital data (x/y coordinates) from head mounted optics when the subject's head is not fixed in place.

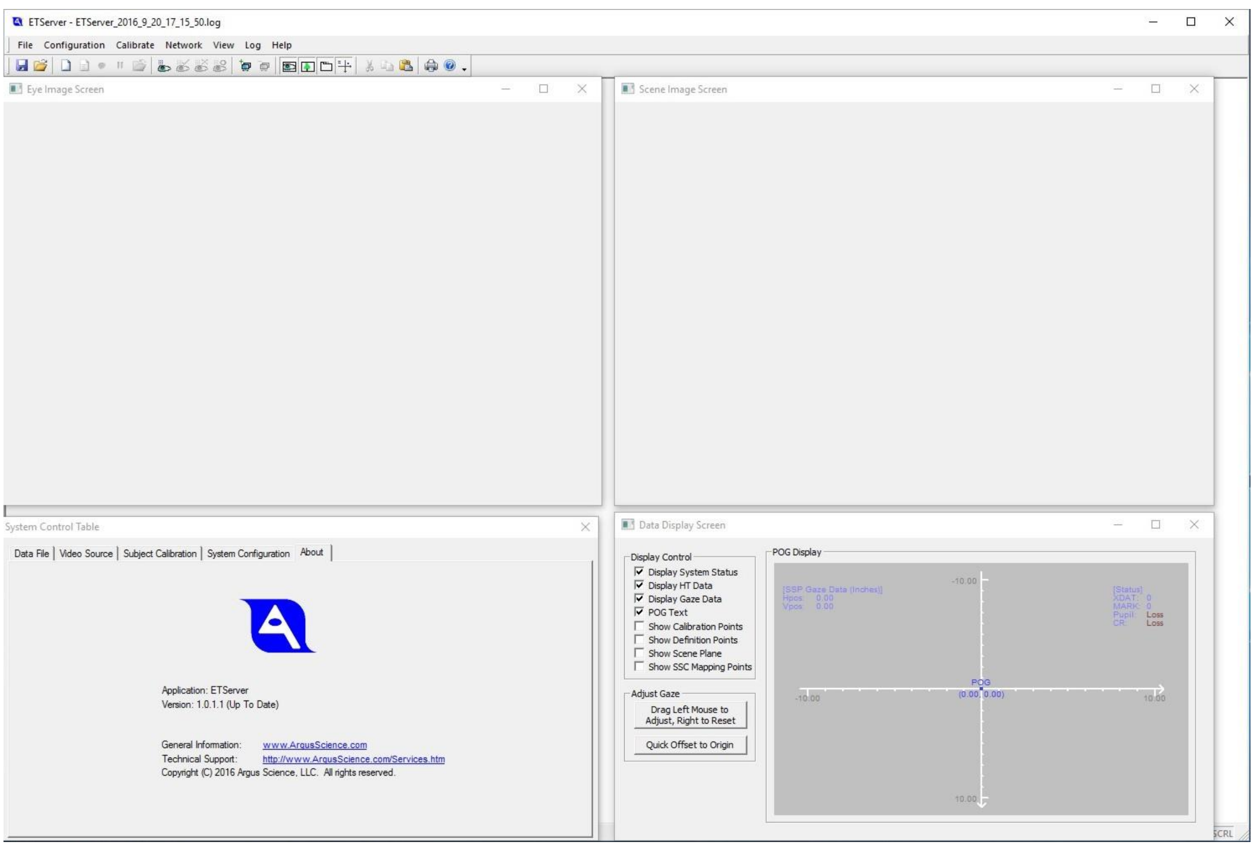
5 System Start up and Configuration

5.1 Power up System

Be sure connections between components are made properly, as discussed in section 4.2. Turn on the computer power switch on the ETS PC. The PC will boot Windows 7 or Windows 10 in the usual way.

Use the *ETServer* Icon on the desktop or use the Start menu to launch the *ETServer* application.

The main screen has a menu and shortcut bar at the top of a blank window. On top of the blank window, an *Eye Image Screen* window and *Scene Image Screen* window will appear by default at the left and right, respectively, just below the short cut bar. (The image windows are blank because the video sources have not yet been specified.). Below these, a *System Control Table* will appear at the lower left and a Data Display window at the lower right. The "About" tab on the *System Control Table* will indicate the current version number, and if the PC is on-line, will also indicate if there is update available.



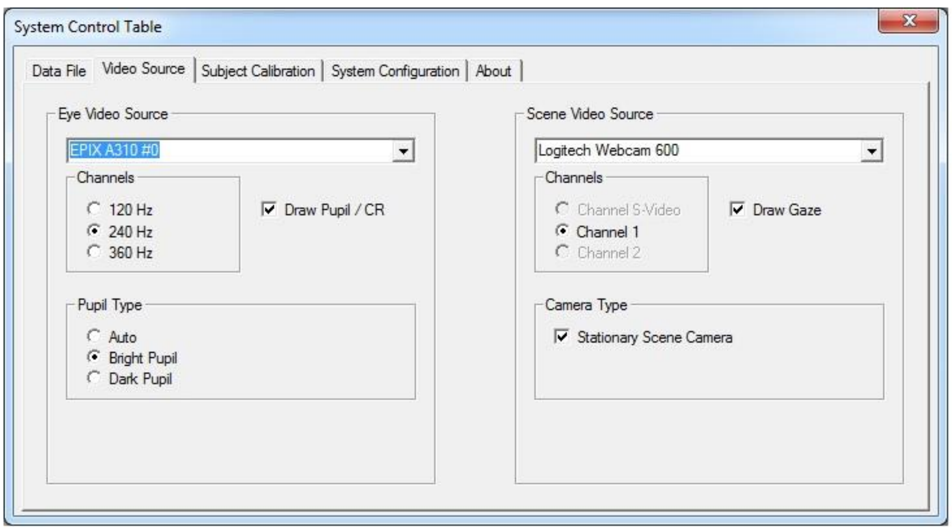
5.2 Configure System

The *ETServer* PC can be used in various configurations and with various types of optics. The software will generally be set at the factory to the configuration consistent with the optics provided along with the system. However, there will still be some configuration choices, and some systems may be equipped with more than one type of optics. This manual will describe the configuration settings applicable to head mounted, bright pupil type, optics.

System configuration can be checked or customized using the Video Source and System Configuration tabs on the "System Control" window.

5.2.1 Video source tab

The ETS system can accept video input from multiple sources. The "Video Source" tab, on the "System Control" Window is used to specify the source and function of the video that will be used for the eye and scene video image.



For systems with head mounted optics, the eye video source will be either a 60 Hz or high speed camera. If *ET3Space* will not be used, the scene image source will be from a head mounted camera. If *ET3Space* will be used, the scene video may still come from the head mounted scene camera, but alternately may come from a stationary room-mounted camera (usually a USB "Web Cam"), or may come directly from a PC that is creating a display image for the subject to view.

1. Select the "Video Source" tab on the "System Control" Window. Under pupil type, set the radio button to "Bright Pupil".

2. If the eye tracker is a standard 60 Hz system (is not equipped with the high speed option) set the Eye Video pull-down menu to EPIX SV7 #2, and set "Channels" is to 1. The Eye image window (upper left window) should now show the image from the optics module eye camera. Wave a hand or some other object under the eye camera to be sure.

3. If the system has the High Speed Option, set the Eye Video pull-down menu to "EPIX A310 #0". In this case set "Channels" to the desired update rate (120Hz, 240Hz, or 360Hz). There are a pair of small slide switches, on the ETServer PC front panel, next to the power button, labeled HS settings. This set of switches must be set to the same speed as software radio button. *If using the system for the first time, it is suggested that 120Hz be selected first, and higher update rates be used after gaining some initial familiarity with the system.* The *Eye Image Screen* (upper left window) should now show the image from the optics module eye camera. Wave a hand or some other object under the eye camera to be sure.

4. If the head mounted scene camera will be used, set the Scene Video pull-down menu to "EPIX SV7#1" and set Channels set to 1. The Scene Image Window (upper right window) should now show the image from the head mounted scene camera.

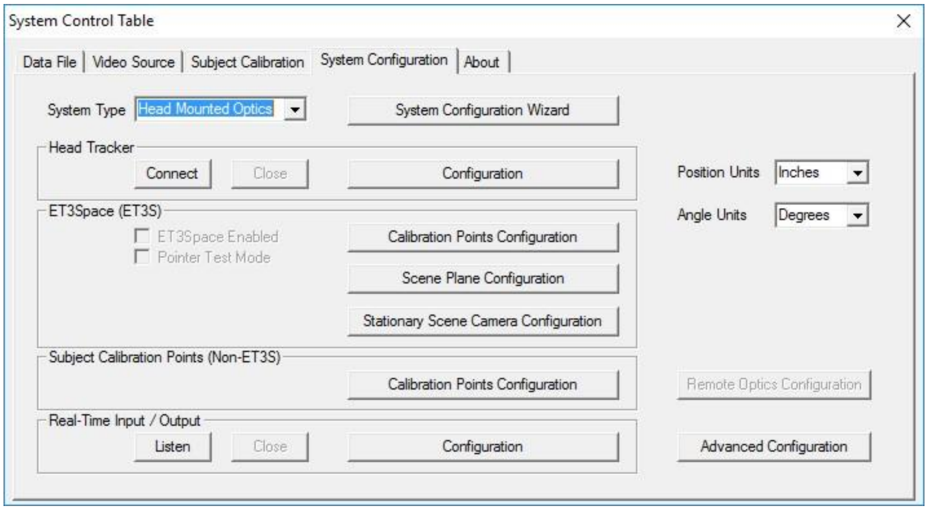
5. If the system will be using *ET3Space* and a web cam is connected for use as a stationary (non head-mounted) scene camera, set the "Scene Video Source" pull-down menu to the Web Cam model being used (for example, "Logitech Webcam 600"). The *Scene Image Screen* (upper right window) should now show the image from the Web Cam.

6. The scene image may also come from an external PC via a LAN connection. This is applicable only if using *ET3Space* and if the primary scene plane will be a PC monitor viewed by the subject. Section 11 has detailed instructions for setting up a network connection.

5.2.2 System Configuration tab

The "System Configuration" tab, on the "System Control" Window, specifies the type of optics the system will use (for example, head mounted or table mounted optics). If *ET3Space* will be used, this tab also opens a dialog to specify the head tracker that will be used, and launches the procedures for setting up the *ET3Space* environment. The eye tracker can communicate, in real-time, with other devices via LAN connection, and the dialog to set up these connections is also launched from the "System Configuration" tab.

With head mounted optics subject calibration points will usually either be specified as part of the *ET3Space* environment set up, or will be indicated on the head mounted camera scene image during calibration. Occasionally, it may be convenient to preset the location of target points on the head mounted scene camera image, and the dialog to preset these points is another thing that can be launched from the "System Configuration" tab.



5.2.2.1 Set System Type

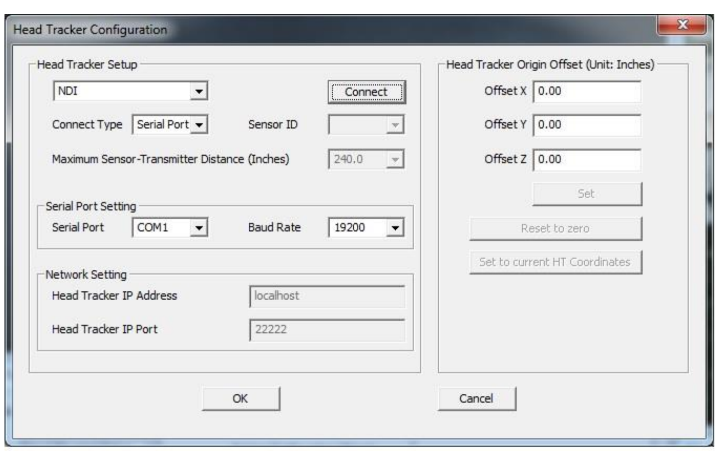
Select "Head Mounted Optics" from the "System Type" drop-down menu. Other selections are associated with other types of optics, such as table mounted optics, and are described in separate manuals.

5.2.2.2 Set Head Tracker Type & Enable Head Tracker (if using *ET3Space*)

If not using a head tracking device (a head tracking device is required if using *ET3Space*), skip to section 5.2.5.

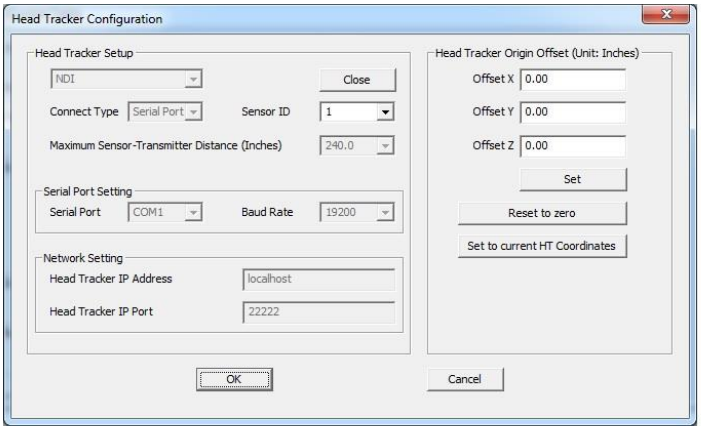
If a head tracker is connected and has previously been configured, simply click the "Connect" button to establish communication between the head tracker and the ETS. If successful, the "Connect" button will turn gray, and head tracker data will appear on the Data Display window. The position units will be those indicated on the "System Configuration" tab window. Position values can be chosen to be either inches or centimeters. Orientation angles are always shown in degrees.

If using a head tracker for the first time, click the "Configuration" button, in the "Head Tracker" box. The Head Tracker configuration dialog will appear as shown below.



Choose the head tracker type and connection type from the drop-down menus. If a connection type is not supported for the chosen head tracker type, that selection will not be allowed. If the connection type is serial or network, associated RS232 or network parameters can be set. There is a separate manual or tech note devoted to each type of currently supported head tracker, and more detailed information about settings for that particular head tracker type is provided there. The "Head Tracker Origin Offset" values should normally be left at zero. (There may be unusual instances for which it will be convenient to have the head tracker report position from an origin other than the natural origin associated with the head tracker device.)

Assuming that the head tracker is properly connected, click the Connect button on the *Head Tracker Configuration* dialog, or click OK to close the dialog and click "Connect" on the *System Configuration* tab window. If communication with the head tracker is successfully established the "Connect" button will change to a "Close" button, and live head tracker data will appear on the Data Display window (circled in red, below).



5.2.2.3 *ET3Space* Environment & Activation

If an environment has already been configured for *ET3Space*, and the associated Head Tracker is already "Connected" and running (see previous section), check the "ET3Space Enabled" box to activate the *ET3Space* computation mode. "Pointer Test" mode is designed to check the *ET3Space* environment configuration, and is explained the *ET3Space for ETServer* manual.

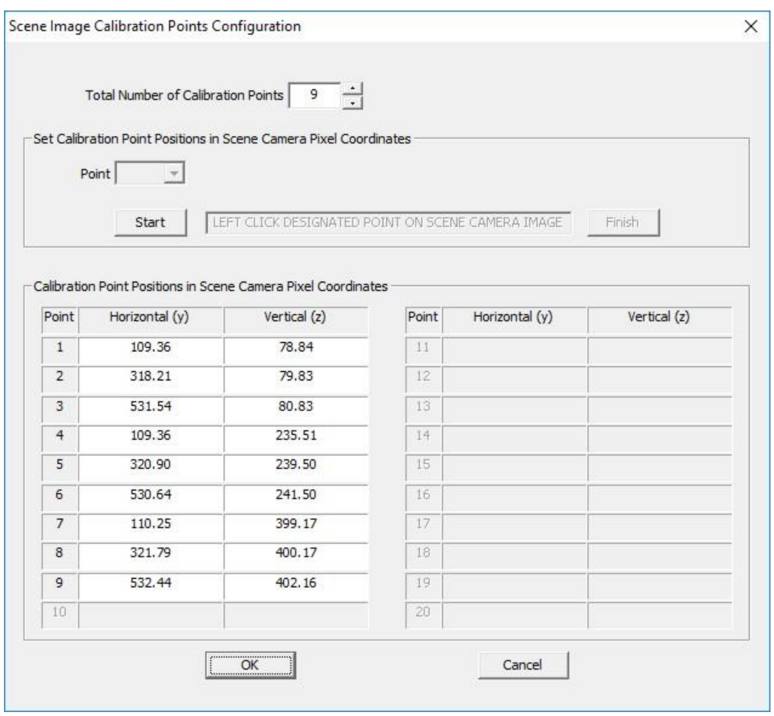
If *ET3Space* will be used, and the environment has not yet been configured, the three buttons in the "ET3Space" box bring up the dialogs required to "tell" the system about the surfaces in the environment and coordinates that will specify gaze positions on each of them. These procedure are explained in detail in the separate *ET3Space* manual.

5.2.2.4 Subject Calibration Point Configuration

The *System Configuration* tab dialog includes a box labeled "Subject Calibration Points". This is primarily for use with system types other than head mounted systems, and can usually be ignored if using a head mounted system.

If using *ET3Space* with stationary scene camera image, calibration target points are set as part of the *ET3Space* environment configuration (see previous section). If using the head mounted scene camera, the location of calibration targets on the scene camera image are usually specified by pointing and clicking with the mouse during the subject calibration procedure.

There may be unusual occasions when it is convenient to pre-set the location of target points on the head mounted scene camera image. In this case, click the "Calibration Points Configuration" button in the "Subject Calibration Points" box to bring up the dialog shown below.



Either type the scene camera pixel coordinates for the target points into the provided table, or click "Start", and click on the position for each target point in the *Scene Video Screen* image. In this case remember to click on a position for the number of target points specified (box labeled "number of points"), and then click the "Finish" button. Click OK to exit the dialog. See section 8.1.2 for more information about when this feature may be appropriate and how to use it.

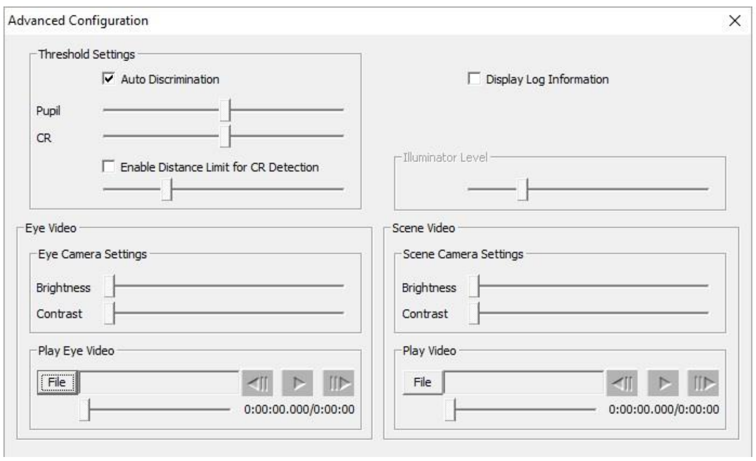
The *Calibration Points Configuration* dialog can also be used to find the scene camera pixel coordinates associated with any point in the scene image. Hover the mouse over any spot in the scene image display, which this dialog is open. The horizontal and vertical pixel coordinates will be displayed next to the mouse arrow.

5.2.2.5 Advanced Configuration dialog

A button is provided on the, on the *System Configuration* tab dialog, which brings up an *Advanced Configuration* dialog. Initially the settings on this dialog should be left at the factory default positions. Slider numerical setting values are displayed by left clicking on the slider control.

Recommended position of the eye image controls are as follows (left click slider control to see numeric values):

- Descrimination: Auto
- Brightness: 50
- Contrast: 26



The best illuminator setting may vary for different subjects and different update rates. For 60 Hz systems the recommended range is 25-35. For systems with high speed option, recommended values are about 30, 35, and 40, for 120Hz, 240Hz, and 360 Hz operation, respectively. These should be considered guidelines.

It may sometimes be convenient to turn the illuminator up for easiest viewing while positioning and focusing the optics, and then down to a lower value for best performance. If the illuminator is too bright, the CR recognition cross may sometimes jump to a spot in the pupil. If it is too dim, the pupil boundary outline may begin to appear unstable. Of course, if the illuminator is turned down far enough, the image will disappear entirely. **Note:** For convenience, the illuminator control is duplicated on the *Subject Calibration* tab of the *System Control Table*.

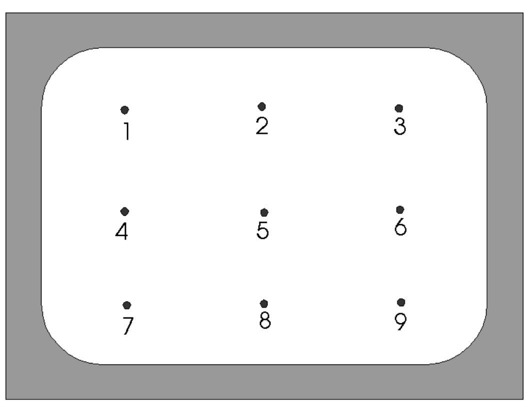
Except for the illuminator, once the “advanced” controls are positioned properly it should rarely, if ever, be necessary to adjust them. The scene brightness and contrast controls may be sometimes be used to optimize the appearance of the scene image if using the head mounted scene camera. The “discrimination” controls should normally be set to “Auto”, but if unusual circumstances require manual adjustment, the “Auto” box can be unchecked, activating the manual sliders. This is discussed in more detail in section 7.

The ETServer program will automatically create a log file of every program session. These files are normally stored under C:\Program Files (86)\Argus Science \ETServer\Log, and may prove useful if it is ever necessary to consult Argus Techsupport about a question or problem. There is a “Log” check box on the *Advanced Configuration* dialog. If this box is checked, log information will be displayed on the main program window as it is generated. If the “Log” box is not checked, log information will not be displayed, but the log file will still be created and can be examined off-line.

5.3 Setting Up Calibration Target Points

During the subject calibration procedures described later in section 8, it will be necessary for the subject to look at several target points, and arrangements must be made to display these. If the primary subject display is computer monitor, the points may be displayed on this monitor (Argus provides an application called *ETRemote* that can be used if the display PC is running Win 7 or Win 10) . If the primary surface being viewed is a instrument panel (for example, in a simulator cockpit) the points can be small stickers or existing visible landmarks on the surface.

Although any number of points between 2 and 20 may be used, the recommended number is nine, arranged in a pattern of 3 rows and 3 columns, as shown below. If possible, the calibration target points should cover an area that corresponds to 40-50 degrees of visual angle horizontally, and 30-40 degrees vertically. When using the standard head mounted scene camera lens this will correspond to about two thirds of camera field of view. Optimally, the middle vertical and horizontal points should be collinear and perpendicular, but this is not a requirement.



If using *ET3Space*, the calibration points must be displayed on the surface designated as “Scene Plane 0”. This is discussed further in the *ETServer 3Space* manual.

If not using *ET3Space* it is possible to calibrate the subject without having the target points physically displayed on a surface. This is explained in the section on subject calibration.

5.4 Saving and Reading Configuration Data

When the *ETServer* program is closed, all configuration information is automatically saved, and restored next time the program is opened. Configuration data can also be explicitly saved, at any time, by the user, in a user named file. Configuration files saved in this way can be re-loaded by the user at any time.

To save configuration data click "Save Configuration" under the File menu on the main *ETServer* screen. The system will default to a file name consisting of "cfg_" followed by the current date and time, and in the current directory. Use the normal browser function to change the file name and path if desired. The "xml" extension should be maintained. To re-load that configuration information at a later time, click "Load Configuration" under the File menu, and browse to the saved file.

After setting up an ET3Space environment, for example, it is probably prudent to explicitly save the configuration before starting to take important subject data. If someone accidently changes something, it will always be possible to return to the saved state.

6 Adjusting the Headgear

If using the system for the first time, be sure the system is properly configured as described in the previous section. On the “Video Source” tab, uncheck the box labeled “draw pupil/CR” so that the system will not superimpose feedback indicators on the eye image. (On subsequent sessions, this box can be left checked). The goal of headgear adjustment will be to aim and focus the eye camera to obtain and eye image like that shown below.

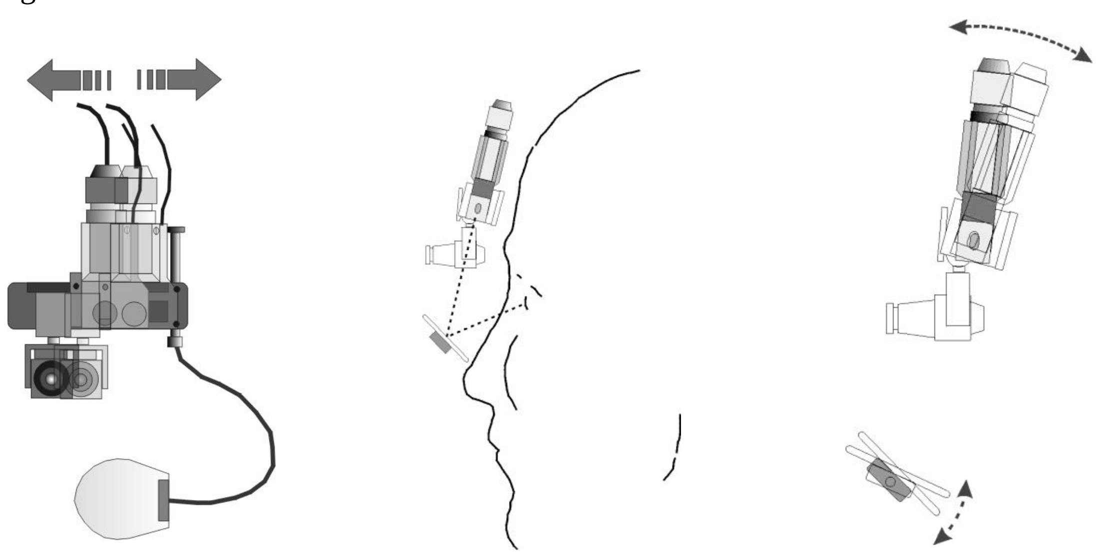
The large bright disk is the pupil and the small bright spot within the pupil is the corneal reflection. The pupil looks bright because the camera is seeing the light reflected back from the retina. The corneal reflection (CR) is a mirror image of the optics module LED reflected from the cornea (clear covering over the pupil). The CR may sometimes appear within the pupil boundary, as shown below, but may sometimes be outside of the pupil area.

6.1 Placing Gear on Participant’s Head

With the visor and scene camera safely out of the way, and with the hat band strap all the way opened, hold the head band by the top strap and gently lower it onto the subjects head. If possible, adjust the top strap (knob on top) so that when the top strap rests on the subject’s head, the hat band strap rests about a half inch above the subject’s eye brows. If well balanced the hatband strap (adjusted with knob at back) can remain quite loose allowing maximum comfort over time.

6.2 Positioning the eye camera optics module

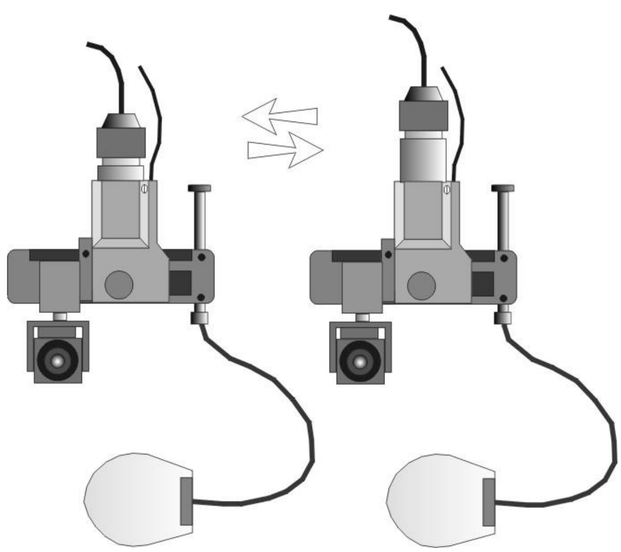
Ask the subject to look straight ahead, and move the optics module laterally (see figure 2-9), along the dove tail track, to position the optics module aperture (small hole on the bottom surface of the module, directly below the beam splitter adjustment plate) directly over the subject’s pupil. Tilt the optics module and position the visor approximately as shown below. Be sure the eye camera module is pointing at the visor.



Looking at the *Eye Video Screen* image, try to adjust the optics to find, focus, and to center the pupil image. The pupil image should appear as a bright disk on the display. If there is no pupil image visible, some other facial feature or skin will probably be visible. Move the image up or down by rotating the visor about the horizontal axis that is parallel to the plane of the subject's face, as shown above right, or by rotating the eye camera module about a horizontal axis as shown in the same figure.

Move the image from side to side by rotating the knob at the top of the visor mounting shaft (this will change the visor angle about a vertical axis) or, or by moving the module small amounts along the dove tail track. If necessary, the image can also be moved from side by side by bending the flexible boom.

Focus by moving the camera further in or out of the focus tube as shown below. Hold the body of the optics module with one hand, and twist the camera slightly while gently pushing or pulling to move the camera up or down. Rotate the camera within the focus tube to make the eye image appear right side up and straight.

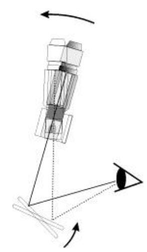


As the eye image comes into good focus, the corneal reflection (CR) should become visible as a small spot that is even brighter than the pupil. The CR is the reflection of the illuminator light source on the front surface of the cornea. If the subject is looking straight ahead, the CR should appear slightly below the center of the bright pupil, but within the pupil circle. To achieve best focus, attempt to make the CR image on the pupil monitor as small and as round or crisp as possible.

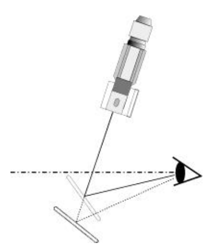
6.2.1 Eye camera module Fine Adjustment

Vertical eye tracking range will be maximized when the camera optical path is below the subject's central line of gaze. When the subject is looking straight ahead (at the center of the field of view of interest), notice the position of the CR relative to the pupil. If the camera is viewing the eye from below the line of gaze, the CR will be below the center of the pupil. (Note that the CR need not be entirely below the pupil, just below the center of the pupil). If the camera is viewing the CR from above the line of gaze, the CR will appear to be above the center of the pupil. It is best for the camera to look at the eye from below the central line of gaze because this makes it less likely that the upper eye lid will obscure the eye image when the subject looks down.

One method for making the camera look at the eye from a "lower" position is to first rotate the optics module so that the aperture points more towards the subject's face. Note that this will cause the pupil image to move towards the top of the *Eye Video Screen* display. Next, rotate the visor to re-center the pupil image.

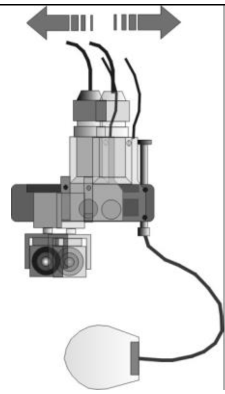
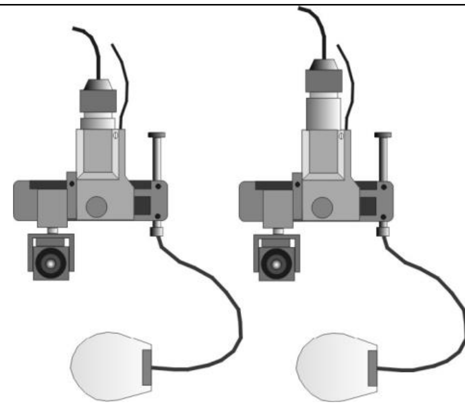
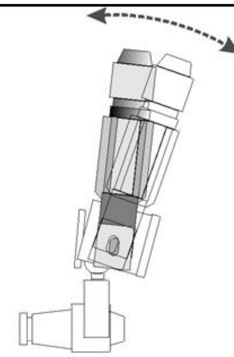
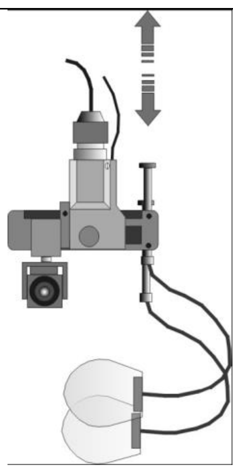
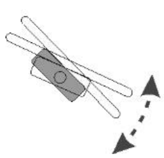


If the camera optical path needs to be lowered still further, move the visor farther away from the optics module. This can be done by by sliding the monocular visor boom in its mounting bracket and, if necessary, bending the boom wire. This will again cause the pupil image to move up and it will be necessary rotate the visor to recenter the image.



If the CR is too far below the pupil disappears under the lower eyelid when the subject looks up, then raise the eye camera angle by following the above procedures in

6.2.2 Summary of Eye Camera Optics Movement Capabilities

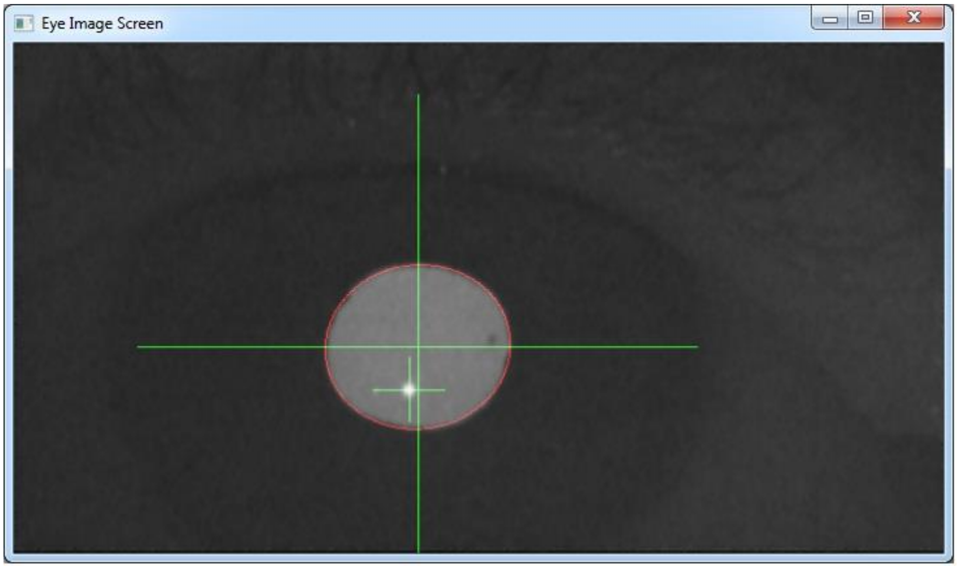
 Lateral movement to adjust for differences in eye laterality.	 Camera in and out of housing to adjust **focus**.	 Camera pitch angle to adjust vertical image position and optical path angle (for CR placement).
 The boom arm's gross height can be adjusted.	 The boom arm can be rotated coronally to move eye image side to side.	 The boom arm can be rotated sagitally.
 The monocle pitch angle can be changed.		

6.3 Head Mounted Scene Camera Adjustment

If using the head mounted scene camera, rotate the camera to aim at the desired field of view. Ask the subject to look towards a target that is at the center of the field of view of interest, or ask the subject to stretch out one arm and hold a finger at what feels like the center of their field of view. Rotate the scene camera so that this target (or the subject's finger) appears at the center of the *Scene Video* display window, and so that the scene image appears upright (not tilted). Scene camera focus can be adjusted by turning the scene camera lens barrel. Note: if using *ET3Space* it is often unnecessary to use the head mounted scene camera.

7 Pupil and CR recognition

When the pupil and CR images are in focus and the pupil is centered on the pupil monitor, check the box on the *System Control Table*, *Video Source* tab, labeled "draw pupil/CR". The system should draw a red circle around the boundaries of the pupil image with a large green cross indicating pupil center. A smaller green cross should appear over the CR image as shown below.



It is essential that the pupil and CR centers be correctly detected as shown above, and that the pupil and CR center indicators are stable. The relative position of the pupil and CR is the information used by the eye tracker to compute line-of-gaze. If one or both of these indicators are jittery, then the gaze measurement will be noisy; and if either indicator has grabbed the wrong object (I.E. reflection from eye glasses or some other bright light source) gaze computation will be incorrect. If either indicator is missing gaze direction cannot be measured. Of course it is normal for these indicators to disappear during eye blinks.

The illuminator intensity has different optimal settings for different eye camera update rates (the optimal intensity increases with update rate). If the system has the high speed (HS) option and the update rate is changed, the Advanced Configuration dialog can be used to modify the illuminator intensity as described in section 5.2.2.5.

If the eye image is in good focus (smallest, sharpest corneal reflection spot) and recognition of the pupil or the CR is not stable, open the *Advanced Configuration* dialog (*System Control Table*, *System Configuration* tab, "Advanced Configuration" button). Note where the adjustment sliders are so that they can be returned to those positions.

Try making the eye image slightly brighter or darker first with the illuminator intensity control. If the problem is that the CR recognition cross sometimes jumps off the of the CR to a spot in pupil, try lowering the illumination level. (Note that the pupil will usually continue to be recognized even if the pupil image appears very dim to the observer). If the pupil boundary appears unstable, try increasing the illuminator level slightly. Of course, if the illuminator is turned down far enough, the image will disappear entirely.

If there is still an issue with stable recognition of the pupil or CR, uncheck “Auto” in the “Discrimination box” and try small adjustments to the pupil or CR sliders. Try only one control at a time, and consult Argus Science.

Except for the illuminator level, the Advanced Configuration adjustments should be required very infrequently, if at all. Any changes that are made to the control positions will be remembered next time the *ETServer* program is launched.

8 Subject Calibration Procedures

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 angles differs for each subject and for different visor and scene camera positions. The calibration procedure provides data to enable the processor to determine this relation and must be performed for each subject.

The calibration procedure consists of directing the subject's fixation to a set of target points (usually 9 target points) and entering the corresponding raw eye position data into memory.

Subject Calibration procedures differ slightly depending on whether or not *ET3Space* is being used. The following sections discuss Subject calibration first assuming ET3S is not being used, and then assuming that ET3S is enabled.

In both cases subject calibration is initiated from the *Subject Calibration* tab on the *System Control Table* window.

8.1 Subject Calibration when NOT using ET3Space

When not using *ET3Space*, the "Calibration Type" pull-down menu will offer two choices: "Click on Scene Camera Image Points", and "Use Preset Points on Scene Image". The first of these is usually more convenient and is the default. The second may sometimes be useful when it is inconvenient to place physical markers on a surface in front of the subject.

8.1.1 Calibrate by clicking points on head mounted scene camera image

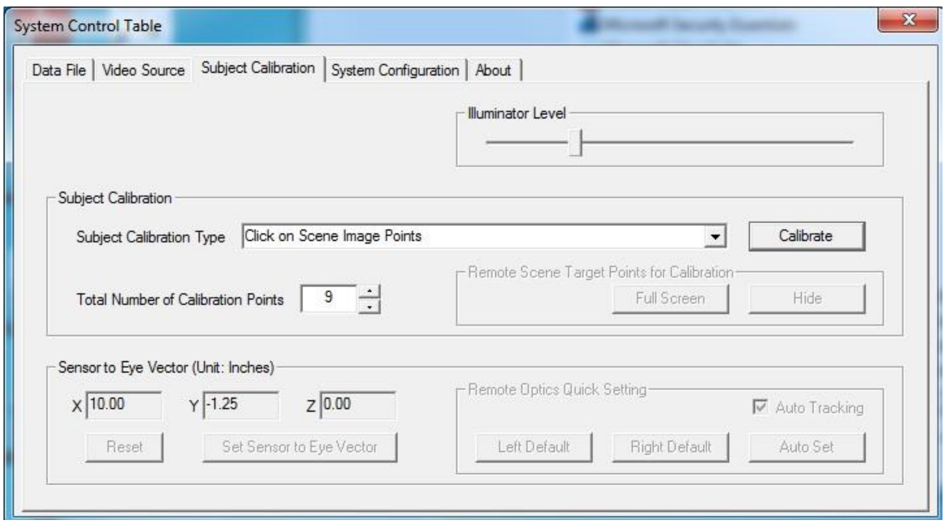
This method essentially consists of clicking on target points in the head mounted scene camera image as the subject looks at them. It requires that there be visible target points on a surface. A neutral gray, non-glare surface is best since it minimizes pupil constriction. A computer monitor may be used as the calibration surface, but any surface can be used so long as it contains visible target points as described below.

For the calibration procedure, the surface should be located in a position covering the subject's primary field of view, and should be marked with points that will be visible on the scene camera image. As discussed in section 5.3, the recommended target set consists of 9 points arranged in a pattern of 3 rows and 3 columns. When the subject is seated comfortably in front of the calibration surface, the points should cover an area in the scene camera view corresponding to about 40-50 degrees visual angle horizontally, and a bit less vertically. It is also recommended that the calibration surface be roughly the same distance away from the subject as the scene that the subject will be viewing after calibration.

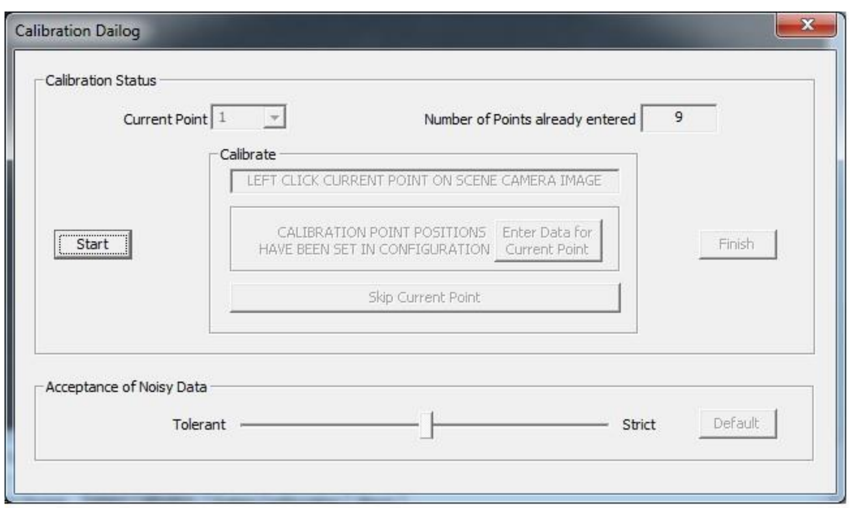
Although target points must be visible on some surface in front of the subject, the target point positions need not be specified to the system in advance.

The subject should assume a comfortable body and head posture in front of the calibration surface. It is often helpful to ask a subject to hold his head so that the center of the calibration pattern appears at what he perceives to be the center of his field of view. This will confirm that the subject's view axis is perpendicular to the surface and that the scene camera center of view has been adjusted to be similar to the subject's. Adjust the scene camera position if necessary.

On the *System Control Table* window, *Subject Calibration* tab, **be sure "Calibration Type" is set to "Click on Scene Image Points"**, and that the "Number of calibration points" is set to the number of target points being displayed (usually 9).

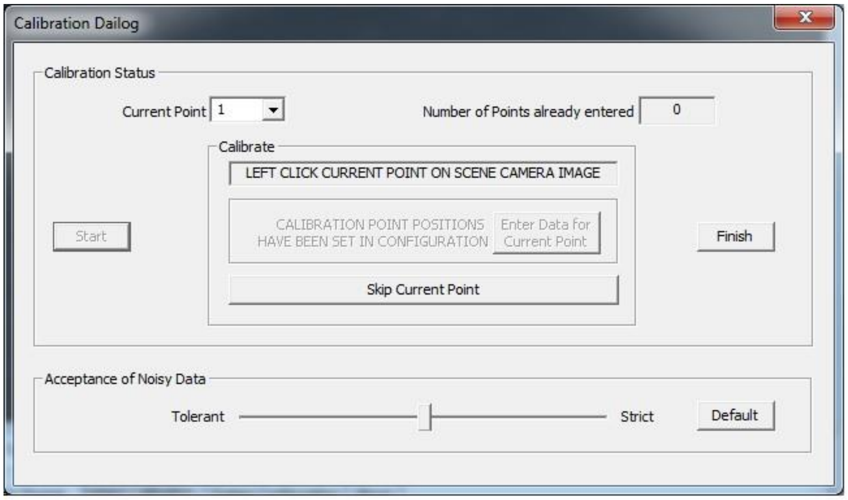


Click Calibrate. A Calibration Dialog window will appear.



If necessary, ask the subject to make slight adjustments in head position or adjust the scene camera, so that the target points on the scene surface appears centered on the scene monitor, and then ask the subject to hold his head still. It is actually OK if there is some head motion, but it is best if this is minimized by having the subject attempt to stay fairly still.

1. In the "Calibration Status" box **click "Start"**. The "Current Point" should be 1. The default position for the "Acceptance" slider is center.



2. **Have the subject fixate the current target point**, and be sure that the pupil and CR are being correctly recognized on the eye image window.

3. **Left click on the image of the target point in the scene image window**. Data for the point is entered at the mouse click. It is important that the mouse arrow is accurately pointing at the target point image and that pupil and CR recognition is good when the left mouse button is clicked. The system assumes that the subject is fixating the spot that is clicked.

4. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image, and the "Current Point" will advance.

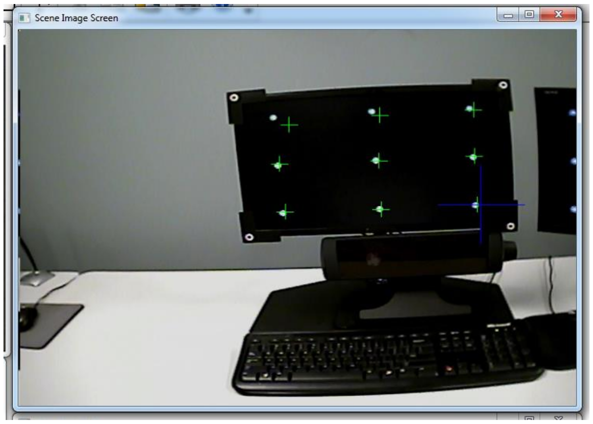
5. **If data is not accepted** (no green cross), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the "Data Acceptance" slider towards "More Tolerant" and repeat the mouse click, or click "Skip" to calibrate without using that point.

6. **Repeat the above steps 2 through 6 for all target points.**

7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, should accurately indicate the subject's point-of-gaze.

8. If desired, **re-enter data for any calibration point** by setting the "Current Point" value to the desired point and repeating steps 3-5.

9. When satisfied with the result, **click "Finish".** Once "Finish" is clicked, points cannot be re-entered without repeating the entire process from step 1.



The screen shot shows the Scene Image window after all 9 points have been entered (green crosses) , before "Finish" was clicked. (Note that some of the green crosses appear slightly offset from the target points. This is because the subject's head has moved since those points were entered, and is perfectly OK as long as they were accurately on the fixation point when entered.)

10. **Click OK to close the Subject Calibration dialog.**

8.1.2 Calibrate using pre-determined positions on the head mounted scene camera image

This calibration method requires that target point positions be specified in advance as positions relative to the head mounted scene camera field of view. For this method, the points do not have to correspond to physical targets in the scene. In fact it probably makes sense to use this method only when it is not convenient to place physical markers on a surface in front of the subject.

To use this method, it is necessary that the equipment operator, or a helper be able to see the *ETServer* monitor screen from a position where her or she can also manipulate a pointer (finger tip, pen tip, etc.) that will be in the subject's field of view.

On the *System Control Table* window, *Subject Calibration* tab, use the pull down menu to **set "Subject Calibration Type" to "Use pre-determined points on scene image"**. Be sure that the "Number of Calibration Points" is set to the desired value (usually 9). If the predetermined target point positions have been entered, they should be visible as gray crosses superimposed on the scene image, except for the first point with will be a yellow cross. In this case, skip to, ***Calibrate Subject,*** further below. If not yet set, or to change the target point positions, pre-set the points as described directly below.

Preset Calibration Points

Open the "System Configuration" tab on the *System Control Table*, and Click the "Calibration Points Configuration" button. This will bring up the Calibration Points Configuration dialog.

Previously entered points (or default values) will appear as gray crosses on the Scene Image diaplay. Recently entered points will appear as green crosses. Typing pixel values into the table will cause the corresponding cross to move to the new position.

To enter points graphically, click “Start”, and click on the position for each target point in the scene video image window. In this case remember to click on a position for the number of target points specified (box labeled “number of points”). Each time a point is entered, by clicking a position on the scene image display, a green cross (instead of gray) should appear at the indicated position on the scene image. Note that if “Start” has been clicked, the system assumes points will be entered by clicking on the image, and points cannot be typed into the table until “Finish” is clicked.

It is suggested that 9 points be entered in a rectangular pattern of 3 rows by 3 columns, such that the pattern extends over about two thirds of the camera field of view. When all points are specified, click the “Finish” button, and Click “OK” to exit the “Calibration Point Configuration” dialog. Return to the Subject Calibration tab of the *System Control Table*.

Calibrate Subject

The calibration target point positions should be visible, on the scene image as gray crosses, except for the cross representing the first target point position, which will be yellow. The subject should be relaxed but should try to remain reasonably still. The operator or a helper may then move a pointer in front of the subject in such a manner that it can be seen on the *ETServer* screen scene video image (image from the head mounted scene camera). The pointer may be the tip of a pen or finger, or may be a the spot from a laser pointer on a surface in front of the subject.

1. In the “Calibration Status” box **click “Start”**. The “Current Point” should be 1, and its position should display as a yellow cross on the scene image display.

2. **Instruct the subject to hold his head still and use just his eyes to fixate the pointer tip. The operator, or helper must move the pointer so that its tip appears, on the *ETServer* scene video window, under the yellow cross showing the current calibration point position.**

3. **Left click “Enter data for current point” button**. Data for the point is entered at the mouse click. It is important that the pointer tip appears at the same position as the cross that shows the target point position. accurately pointing at the target point image and that pupil and CR recognition is good when the left mouse button is clicked. The system assumes that the subject is fixating the spot that is clicked.

4. **If the data is accepted by the system a green cross will appear** at the target spot on the scene image, the “Current Point” will advance, and the next target point will appear as a yellow cross.

5. **If data is not accepted** (cross did not turn green), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the “Data Acceptance” slider towards “More Tolerant” and repeat the mouse click, or click “Skip” to calibrate without using that point.

6. **Repeat the above steps 2 through 6 for all target points.**

7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, should accurately indicate the subject's point-of-gaze.

8. If desired, **re-enter data for any calibration point** by setting the "Current Point" value to the desired point and repeating steps 3-5.

9. When satisfied with the result, **click "Finish".** Once "Finish" is clicked, points cannot be re-entered without repeating the entire process from step 1.

10. **Click OK to close the Subject Calibration dialog.**

8.2 Subject Calibration when using ET3Space

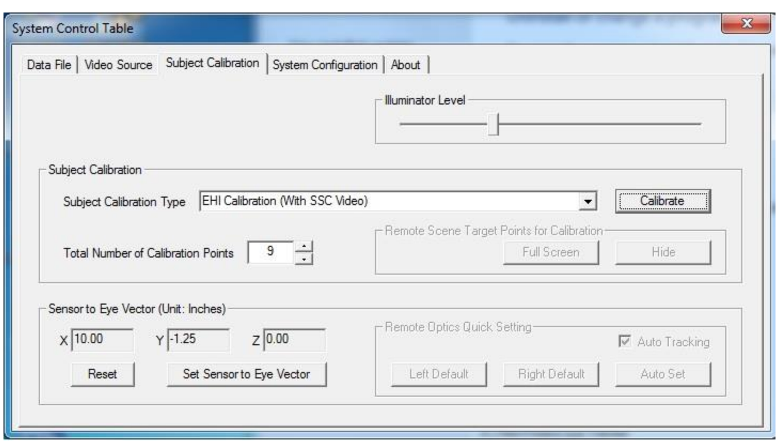
When ET3Space is enabled, and if also using a "Stationary Scene Camera", the "Calibration Type" pull-down menu will offer only one choice: "ET3S with SSC video". If a Stationary Scene Camera (SSC) is not enabled, there will be two choices: "ET3S with no scene video", and "ET3S with head mounted scene camera".

In all cases, the calibration target points must be visible to the subject on the surface designated as "Scene Plane 0". The location of these points is specified as part of the *ET3Space* environment configuration procedure, which must be completed before calibrating a subject. See section 5.2.2.3 and the separate *ETServer 3Space* manual for details.

8.2.1 ET3Space with SSC video

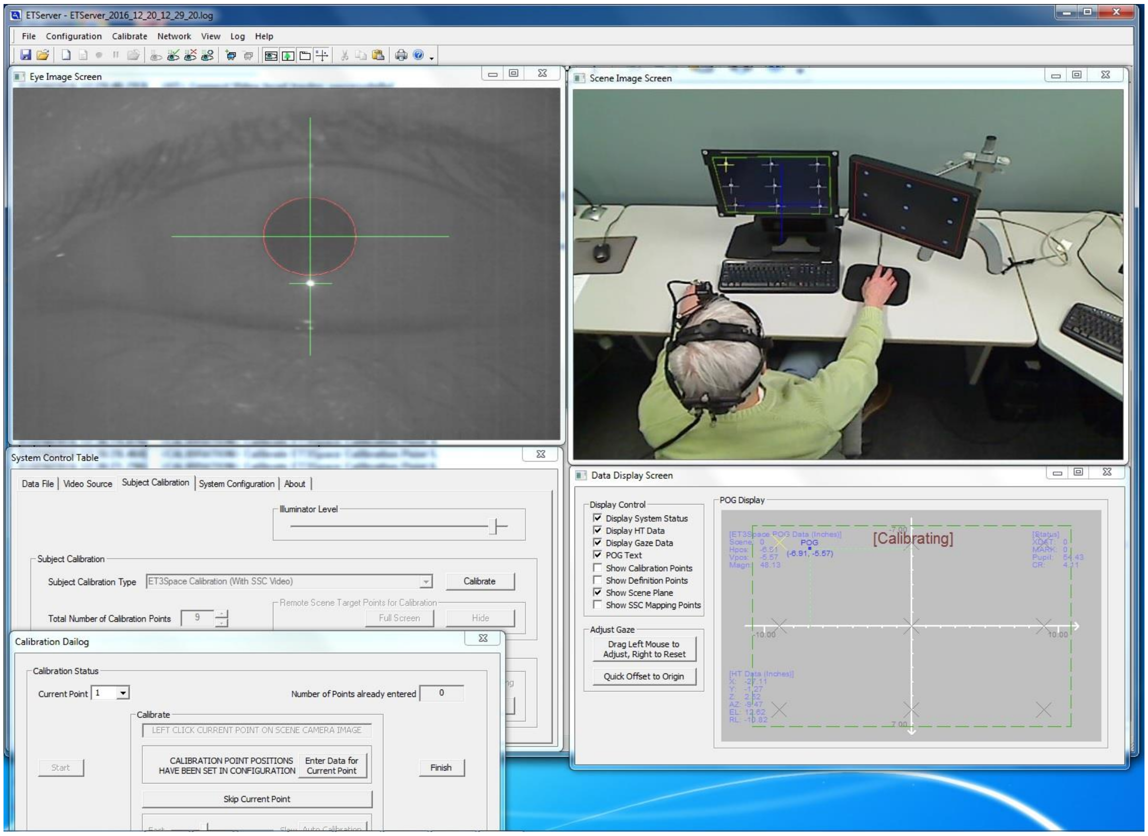
ET3Space must be enabled ("ET3Space Enabled" check box on the *System Configuration* tab of the *System Control Table*). On the *Video Source* tab of the *System Control Table*, under "Scene Video", "Camera Type", the "Stationary Scene Camera" check box must be checked.

On the *System Control Table* window. *Subject Calibration* tab, "Calibration Type" should be "ET3Space Calibration with SSC video".



The subject should be relaxed but should try to remain reasonably still. A small amount of head motion will be OK, but it is best for the subject to try to remain still.

1. In the "Calibration Status" box **click "Start"**. The "current point" that the system expects the subject will be fixating will display as a yellow X or cross on the *Data display* and *Scene Image Screen* display. Other points will display as gray X's or crosses.



2. **Instruct the subject to hold his head still and use just his eyes to fixate current calibration target point.**

3. When satisfied that the subject is looking at requested point, and the eye features (pupil and CR) are being stably recognized by the system, **Left click "Enter data for current point" button**. Data for the point is entered at the mouse click. It is important that the subject be fixating that point and that pupil and CR recognition is good when the left mouse button is clicked.

4. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image.

5. **If data is not accepted** (cross did not turn green), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the "Data Acceptance" slider towards "More Tolerant" and repeat the mouse click, or click "Skip" to calibrate without using that point.

6. **Repeat the above steps 2 through 6 for all target points.**

7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, as well as the cursor and digital data on the Data Display window, should accurately indicate the subject's point-of-gaze.

8. If desired, **re-enter data for any calibration point** by setting the "Current Point" value to the desired point and repeating steps 3-5.

9. When satisfied with the result, **click "Finish".** Once "Finish" is clicked, points cannot be re-entered without repeating the entire process from step 1.

10. **Click OK to close the Subject Calibration dialog.**

8.2.2 ET3Space with head mounted scene camera

ET3Space must be enabled ("ET3Space Enabled" check box on the System configuration tab of the *System Control Table*). On the Video Source tab of the *System Control Table*, under Scene Video, Camera Type, the Stationary Scene Camera Check box must be unchecked.

On the "System Control" window "Subject Calibration" tab, set "Calibration Type" to "ET3Space with head mounted scene camera".

The calibration target points must be visible to the subject on the surface designated as "Scene Plane 0", and the location of these points must have been specified as part of the *ET3Space* environment configuration procedure.

The subject should assume a comfortable body and head posture in front of the calibration surface. It is often helpful to ask a subject to hold his head so that the center of the calibration pattern appears at what he perceives to be the center of his field of view. This will confirm that the subject's view axis is perpendicular to the surface and that the scene camera center of view has been adjusted to be similar to the subject's. Adjust the scene camera position if necessary.

If necessary, ask the subject to make slight adjustments in head position or adjust the scene camera, so that the target points on the scene surface appears centered on the scene monitor, and then ask the subject to hold his head still. It is actually OK if there is some head motion, but it is best if this is minimized by having the subject attempt to stay fairly still.

1. In the "Calibration Status" box **click "Start"**. The scene video display will not yet show any calibration points, but the Data display should show all the *ET3Space* subject calibration points as gray crosses, except for the first, which will be yellow. The "Current Point" should be 1.

2. **Have the subject fixate the current target point**, and verify that the pupil and CR are being correctly recognized on the eye image window.

3. **Left click on the image of the target point in the scene image window**. Data for the point is entered at the mouse click. It is important that the mouse arrow is accurately pointing at the target point image and that pupil and CR recognition is good when the left mouse button is clicked. The system assumes that the subject is fixating the spot that is clicked.

4. **If the data is accepted by the system a green cross will appear** at the indicated spot on the scene image, as well as on the Data display. The current point will advance, and the new point will appear as a yellow cross on the data display.

5. **If data is not accepted** (no green cross), it means that either the pupil or the CR was not recognized or recognition was too noisy. Either repeat the mouse click, move the "Data Acceptance" slider towards "More Tolerant" and repeat the mouse click, or click "Skip" to calibrate without using that point.

6. **Repeat the above steps 2 through 6 for all target points.**

7. After all points have been entered, ask the subject to look at all the points again to be verify accuracy. The point of gaze cursor, on the scene video image, <u>and</u> the cursor on the Data display window should accurately indicate the subject's point-of-gaze.

8. If desired, **re-enter data for any calibration point** by setting the "Current Point" value to the desired point and repeating steps 3-5.

9. When satisfied with the result, **click "Finish".** Once "Finish" is clicked, points cannot be re-entered without repeating the entire process from step 1.

10. **Click OK to close the Subject Calibration dialog.**

It is very important to note that the point of gaze displayed on the head mounted scene camera image computed without regard to the head tracker *data or ET3Space computations*. This is the same data that can be obtained without using *ET3Space*. The *ET3Space* data is shown on the *Data Display Screen*. Be aware that it is possible for one of these displays to be more or less accurate than the other. For example, if the head tracker device is making an error for some reason, this error will show up as error in the *ET3Soace* data on the *Data Display Screen*, while the cursor on the head mounted scene camera image is unaffected.

8.3 Checking the Calibration

To confirm accuracy of calibration, ask the subject to look at each target point again. At each point note the position of the point-of-gaze cursor or cross hairs on the scene monitor, and, in the case of *ET3Space*, on the *Data Display Screen*. Each target point position should be correctly indicated to within about 1-degree visual angle.

If one or more target points are not correctly indicated repeat the calibration procedure.

If using *ET3Space*, be sure to note performance on the *Data Display Screen* as well as the stationary or head mounted scene camera displays. Discrepancies between these results can provide a clue to the source of the error. For example, if the cursor on the Stationary Scene camera image shows a large error while the cursor on the *Data Display Screen* does not, then there is likely to be a problem with the stationary scene camera configuration (see *ET3Space* manual) since that computation is downstream of the *ET3Space* computation. Error on the *Data Display Screen* window might mean that calibration needs to be repeated. If there seems to be the same systematic error over repeated calibrations, or across several subjects, there may be an error in *ET3Space* environment set-up (see *ET3Space* manual).

Any error caused by poor subject calibration will show up when the subject looks at the plane 0 calibration points. If the gaze measurement is accurate on plane 0 but has more error on other scene planes, this is will not be improved by repeating the subject calibration. Large errors only on scene planes other than plane 0 may indicate some error or inaccuracy in *ET3Space* environment set-up. Some variation in offset error between scene planes is expected and can be quickly corrected as described in section 8.4.2.

8.4 Manual data offset correction

There is a means to quickly correct offset errors (errors of approximately the same direction and size over the entire field) without needing to repeat the subject calibration procedure.

8.4.1 Gaze with respect to Head Mounted Scene Camera

If, after subject calibration, the point-of-gaze (POG) cursor on the head mounted scene camera image appears to be offset (in error) in a similar direction and by a similar amount over the entire field, this can be corrected quickly, without repeating the calibration.

Be sure *ET3Space* is <u>not</u> enabled, and the *Data Display Screen*, as well as the *Scene Image Screen* is showing point of gaze with respect to the head mounted scene camera field of view.

On the *Data Display Screen*, click the button labeled "Drag Left Mouse Button to Adjust". The button will remain depressed (feature is "on") until clicked again. Ask the subject to look at some landmark on the scene image, and use the left mouse button to drag the mouse arrow in the "POG Display" area of the *Data Display Screen*. The POG cursor on the *Data Display Screen*, as well as the *Scene Image Screen* will be offset in the direction and by the amount that the mouse is dragged. Drag the POG cursor to the point in the scene image being fixated by the subject. The offset correction can be reset to zero, while the "Drag Left Mouse Button to Adjust" feature is on, by dragging the mouse in the "POG Display" area with the <u>right</u> mouse button depressed. Offsets are automatically re-set to zero when ever a subject calibration is performed.

Note that when the "Drag Left Mouse Button to Adjust" feature is on, the mouse cannot be used to adjust the scale and origin of the "POG Display" area graphics. These capabilities are restored when the "Drag Left Mouse Button to Adjust" feature turned off.

To disable the "Drag Left Mouse Button to Adjust" function (turn the feature "off"), and protect against accidently creating offsets, click the button to un-depress it.

8.4.2 Gaze with respect to ET3Space scene planes

ET3Space has a separate manual offset correction capability for each scene plane. In addition to dragging the POG cursor as described in the previous section, there is a quick offset capability that requires the subject to look at the origin of a scene plane, and also a place to type in a manual offset correction value on the set-up dialog for each scene plane.

If *ET3Space* is enabled, the *Data Display Screen* will show the number of the scene plane on which gaze is currently detected, and the point-of-gaze with respect to that scene plane. Point of gaze may also be displayed on the *Scene Image Screen* if a “Stationary Scene Camera” is enabled. If point of gaze on any particular scene plane appears to have an offset error (error of about the same amount and direction over whole surface), it can be corrected by the following methods.

To correct an offset with a single mouse click, have the subject look at the origin point on the scene plane in question; verify, on the Data Display window, that the system is detecting gaze on that scene plane; and click the *Data Display Screen* button labeled “Quick Offset to Origin”. The appropriate data offset will automatically be entered to place gaze at the scene plane origin.

Note that this feature can be used routinely to maximize *ET3Space* data accuracy on all scene planes. Right after subject calibration, ask the subject to look at the origin of each scene plane and click the “Quick Offset to Origin” button each time, as described above.

To correct an offset by dragging the POG, click the button labeled “Drag Left Mouse Button to Adjust” and left drag in the “POG Display” area of the *Data Display Screen*. Observe either the *Data Display Screen* POG cursor or the Stationary Scene Image cursor (on the *Scene Image Screen*), and drag it to the correct position. Note that this affects only the scene plane on which the system currently detects point of gaze, and affects only *ET3Space* data. If the *Scene Image Screen* is showing the image from a head mounted scene camera, the POG cursor on this image will not be affected.

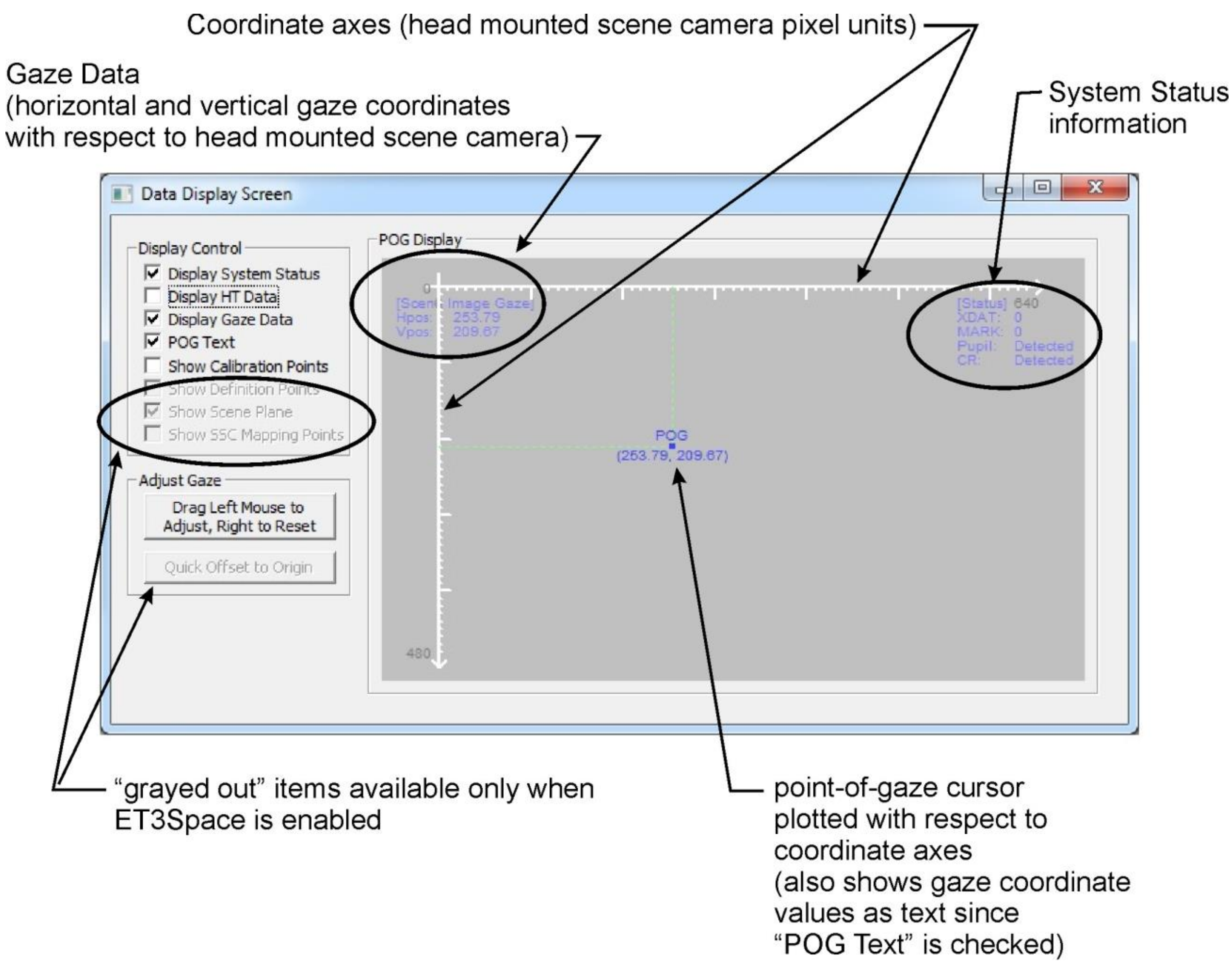
ET3Space offsets for each scene plane can also be typed into the *Scene Plane Configuration* dialog. If digital values displayed on the *Data Display Screen* are offset from the known point of gaze coordinate by a given amount, type in the negative of that amount. For example, if the subject has been asked to look at a scene plane origin point (0,0) and the horizontal point of gaze coordinate is showing **5.0** on that scene plane, rather than **0**, type in **–5.0** as the horizontal offset correction for the scene plane in question.

Offsets for all scene planes are automatically re-set to zero whenever the subject calibration procedure is performed.

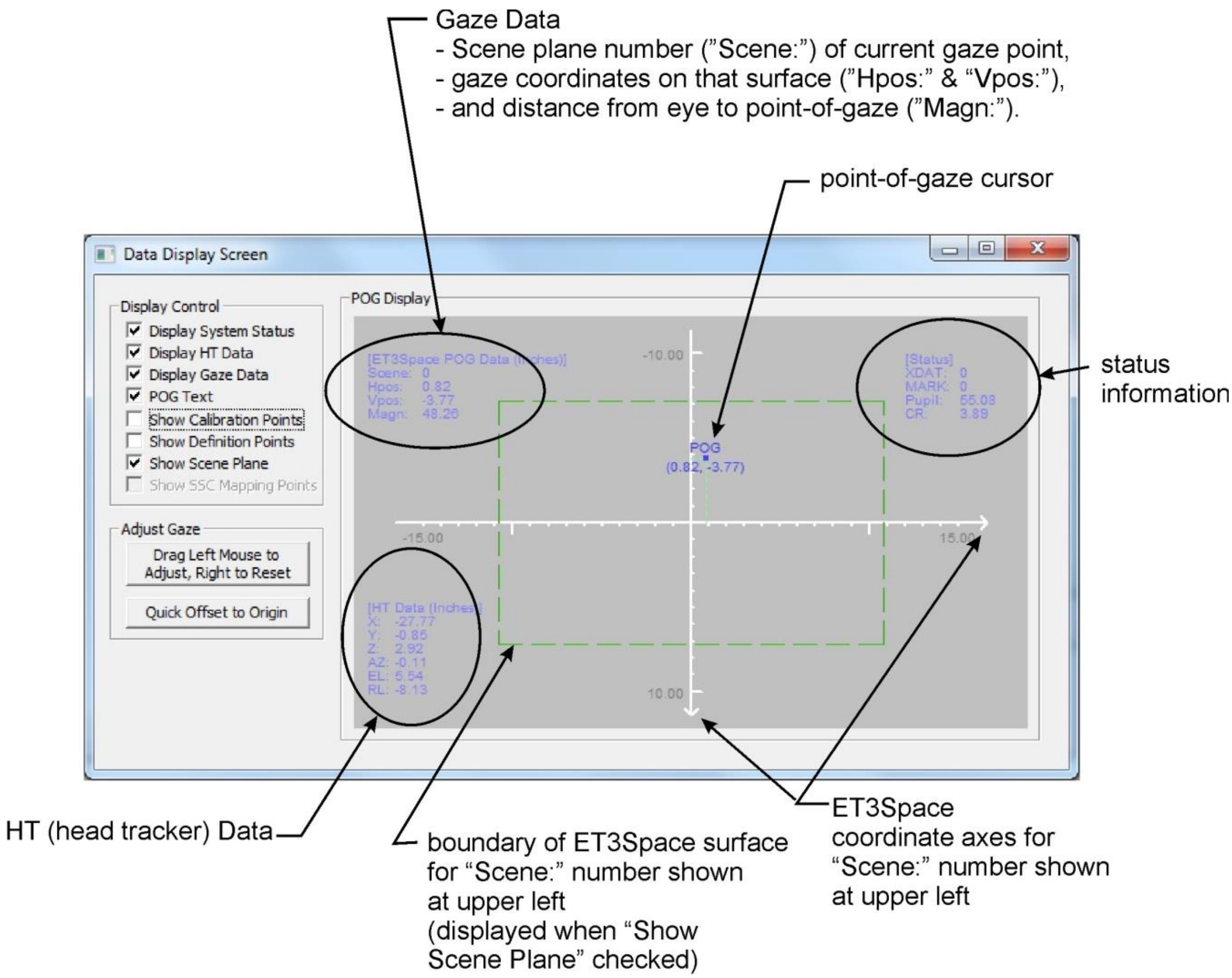
If *ET3Space* is enabled and a head mounted scene camera is also being used (rather than a stationary scene camera), *ET3Space* must be temporarily disabled to make offset adjustments to the head mounted scene camera cursor. Uncheck the “ET3Space Enabled” box on the *System Control Table, System Configuration* tab, and make the offset correction as described in the previous section. Check the “ET3Space Enabled” box to resume *ET3Space* computations.

9 Data Display Screen

The *Data Display Screen* displays the digital data available from the ETServer as well as a graphical point-of-gaze (POG) display. A set of check boxes on the *Data Display Screen* determine display content. In addition, the Data Display Screen contains controls for entering manual offset corrections to the point-of-gaze data. Note that pupil and CR status will list pupil and CR diameter if these features are detected.



Screen shot showing Data Display Screen when ET3Space is <u>not</u> enabled



Screen shot showing Data Display Screen when ET3Space is enabled

9.1 Display Control Box

The Display Control Box is in upper left corner of the *Data Display Screen*. Items listed are displayed when checked, and are omitted when not checked.

The first 4 items are digital text displays which are superimposed on POG Display area. “System Status” values appear at the upper right corner of the POG Display area. “HT Data” is available only if a head tracker (HT) is communicating with the *ETServer*, and appears in the lower left corner of the POG Display area. “Gaze Data” is displayed in the upper left corner of the POG Display area. If *ET3Space* is available, gaze data includes the number of the scene plane on which gaze is currently detected, and the distance of the eye from the point-of-gaze (“Magn”). “POG text” are point of gaze coordinate values displayed in text form under the graphical POG cursor display.

The remaining check boxes control graphic display elements.

If "Show Calibration Points" is checked the subject calibration points will be plotted as crosses on the POG Display. (If in *ET3Space* mode, calibration points are shown only if the current plane is the calibration surface). The calibration target points will also be shown on the *Scene Image Screen* when this box is checked.

The final 3 check boxes apply only when *ET3Space* is enabled. "Definition Points" are the 3 points used to define each scene plane. If this box is checked the definition point locations on the current scene plane are plotted as black crosses on the POG Display area plot. If a "Stationary Scene Camera" (SSC) is enabled, scene plane definition points are also displayed as black crosses on any scene planes visible to the SSC. "Show Scene Plane" draws a box on the POG Display plot to indicate the boundaries of the current scene plane, and draws boxes on any scene planes visible to a Stationary Scene camera to show the plane boundaries. The boxes are different colors for each scene plane.

The "Stationary Scene Camera Mapping Points" are the 4 points on each scene plane used, as part of the *ET3Space* setup procedure, to relate the Scene Plane coordinates to the corresponding scene camera pixel coordinates. These are plotted as green crosses on the Stationary Scene Camera Image and are shown as green X's for the current scene plane on the POG Display plot.

9.2 POG Display area

The "POG Display" area plots point-of-gaze as a moving spot on a display area that represents the two dimensional either the head mounted camera scene space or, if in *ET3Space* mode, the current scene plane surface. If "POG text" is checked, digital horizontal and vertical coordinate values will appear just below the POG dot and travel with it. These values are in the form "*(h, v)",* where *h* is the horizontal coordinate and *v* is the vertical.

If not using *ET3Space*, the POG positions represent head mounted scene camera pixel coordinates, with (0,0) in the upper left corner of the scene camera field of view, and 640 horizontal by 480 vertical in the lower right. The coordinates are shown along horizontal and vertical coordinate axis lines. The default position for the axes origin point is the upper left corner, since this (0,0) point usually represents the upper left corner of the scene camera field of view. Note that it is sometimes possible for the system to have a valid measure for a gaze point beyond the scene camera field of view, and such points may have negative coordinate values (above or to the left of the camera field of view), or values greater than the maximum camera pixel value (below or to the right of the camera field of view).

If *ET3Space* is enabled, the POG positions represent the gaze position on the scene plane surface specified by the current scene plane number. The units are inches or centimeters from the scene plane origin, along the scene plane y ("horizontal") and z ("vertical") axes. These axis lines are shown on the plot and labeled with distance values (inches or cm). In this case the default position for the axes origin point is the center of the POG Display area, since the (0,0) point is usually at the center of an *ET3Space* scene plane. If the appropriate boxes are checked, scene plane boundaries, scene plane definition points, stationary scene camera mapping points, and, if the calibration surface, calibration point positions are also shown for the current scene plane.

If the manual offset function has not been enabled (see section 8.4), the mouse can be used to left drag the axes display origin to different positions on the display area. The mouse wheel can be used to zoom in or out. Right dragging the mouse in the area restores default origin position and zoom.

10 Recording Data On ETServer

Digital point of gaze and pupil diameter data can recorded to a data file by the *ETServer* PC. In addition, the eye and scene images with feedback indicators, as displayed on the *ETServer* screen, can be recorded as video "wmv" files that begin and end at the same time as the digital data.

If not using *ET3Space*, digital data (*.eyd files) will specify the location of gaze with respect to the head mounted scene camera field of view. *ET3Space* data (*.ehd files) specify gaze with respect to stationary surfaces in the environment.

10.1 Configure Data file

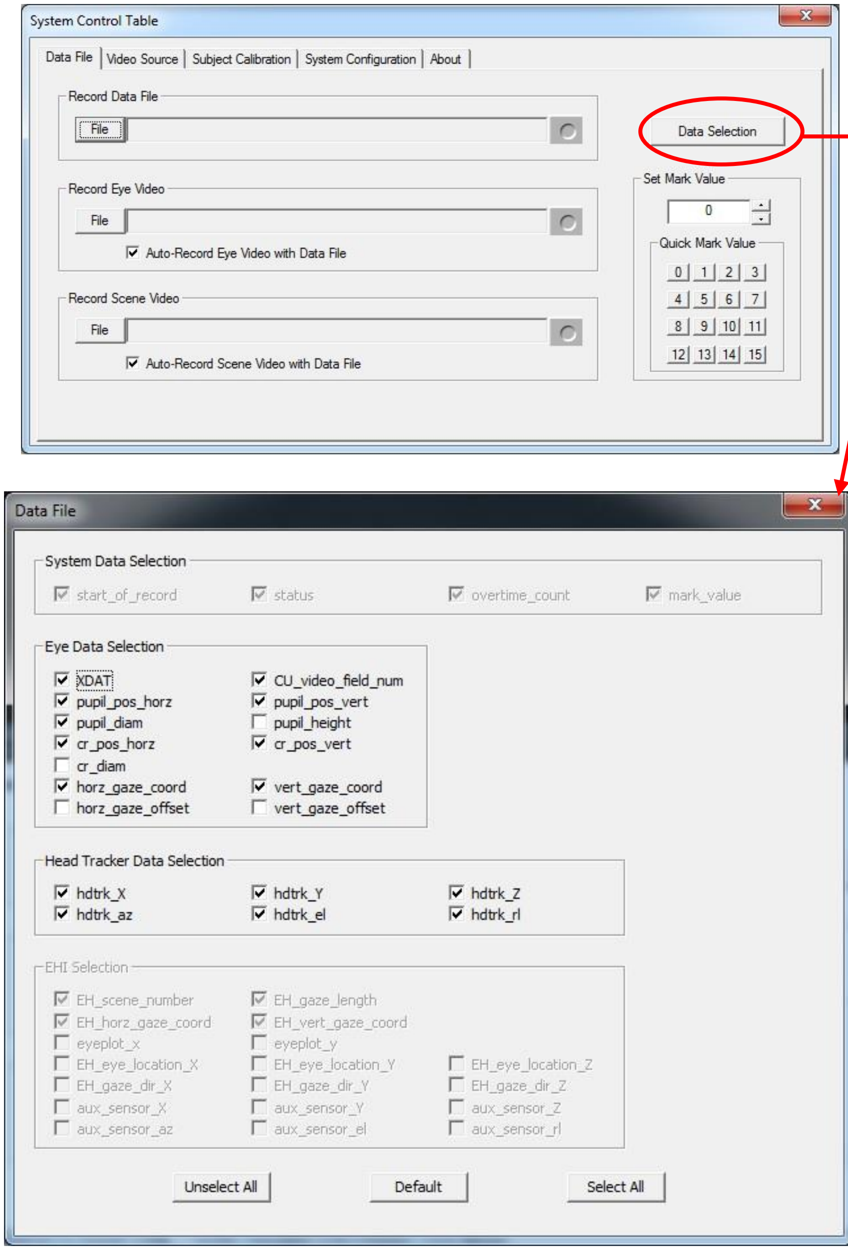
Information about the system configuration and the most recent subject calibration are always stored in the file header. The information recorded on every data record (every eye tracker update interval) can be configured by the user, but the following are the default items.

- Status value
- Manual Event Marks
- XDAT (external data values)
- Pupil position coordinates (eye camera pixel coordinates)
- Pupil diameter (see section 12 for scaling information)
- CR (corneal reflection) position coordinates (eye camera pixel coordinates)
- Horizontal Gaze Coordinate (scene camera pixel coordinate)
- Vertical Gaze Coordinate (scene camera pixel coordinate)

If a head tracker is installed and enabled
- Head Tracker position and orientation values (only available if a head tracker is installed and enabled

If *ET3Space* is enabled
- *ET3Space* Scene Plane number (integer from 0 to 20 indicating which *ET3Space* surface gaze point is on)
- *ET3Space* Horizontal Gaze Coordinate (horizontal or "y" coordinate of gaze, in inches or centimeters, on the surface specified by scene plane number)
- *ET3Space* Vertical Gaze Coordinate (vertical or "z" coordinate of gaze, in inches or centimeters, on the surface specified by scene plane number)

This set of data items can be modified by the user, and additional items, not part of the default set, can be included. Click "Data Selection" on the *System Control Table, Data File* tab to open the *Data File* dialog. Check "Default" to select the default configuration, or use the check boxes to select the desired data set. The data items are listed and explained in more detail in Section 16. The selections on this dialog apply not only to data recorded by *ETServer*, but also serve to specify the set of data items output in real-time, via local area network connection, by ETServer (see section 11.5). Click OK to close the *Data File* dialog.



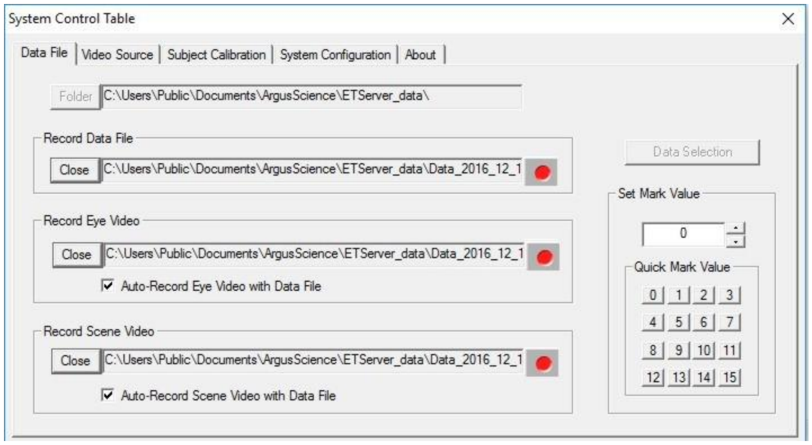
10.2 Open a digital data file and begin recording

It is strongly advised that the subject calibration be done before opening a data file. This will ensure that information about the calibration is included on the file header.

Either click the “File” button on the “Data File” tab, or select “New Data File” from the File menu on the main *ETServer* screen. Browse to the desired path, and type in a file name. It is not necessary to type the extension. If *ET3Space* is not enabled, the file will be given an “eyd” extension and the “Eye Data” data set will be recorded. If *ET3Space* is enabled, the file will be given an “ehd” extension and the *ET3Space* data set will be recorded.

A dialog titled *Enter File Description* will pop up. Enter up to 200 characters (to be included in the file header), if desired, and click OK.

Once the file is opened, the file name will appear in the "Record Data File" box on the *Data File* tab, the "File" button will change to "Close", and a record symbol (red disk) will appear to its right. Start recording by clicking the record symbol or selecting "Record" from the File menu.



When recording begins, the record symbol changes to the Pause symbol (two vertical bars). Pause recording by clicking the pause symbol or selecting "Stop" from the *File* menu. The record button will reappear in place of the pause button. Resume recording to the same file by clicking the record button. Each successive *Record* command will create a new "Segment" in the data file.

When finished recording, click the "Close" button, or select "Close" from the File menu.

10.3 Recording Manual Event Marks

While a file is recording, it is possible to manually enter a mark value of from 0 to 255 on the file. 16 different event marks (numbered 0-15) can be manually entered by clicking one of the "Quick Mark Value" buttons. The "Mark" value will be attached to the latest (most recent) data record at the time the button is clicked, and all subsequent records until the Mark value is changed .

Alternately a value can be typed into the "Set Mark Value" box. In this case the value in the box will be set when the <Enter> key is pressed, or when focus is moved out of the box, and will remain the "Mark" value until changed. The Mark value can be quickly incremented or decremented by clicking the up or down arrow next to the Mark Value box. In this case the new mark value is set when the arrow key is clicked.

10.4 Recording Eye and Scene Video

To record Eye and/or Scene video with start and stop times that are synchronized with digital data, check the "Auto-record with data file" box in the "Record EyeVideo" and/or "Record Scene Video" box. It is OK to check both of these or only one. If "Auto-record" is checked, there is no need to type anything into the video file name field. The video file will be given the same name as the data file, but with "_eye" or "_scene" appended to the file name. Simply record a data file as described in the previous section and the eye and/or scene video will be recorded along with the data file.

To record eye or scene video separately from digital data, simply click the File button in the Eye or Scene Video box, enter a file name, and click the record button to start. Click the pause symbol to pause, and the "Close" button to close the file. While the video file is still open, it is possible to record and pause multiple times.

10.5 Record external data (XDAT) and control ETServer recording from external device

The eye tracker keeps track of a 16 bit integer data value labeled "XDAT" (short for "external data") which is displayed on the *Data Display Screen*, recorded along with gaze data, and which can be controlled by an external device via a LAN connection. It is most often used for marking events. For example the XDAT channel might be used by an external device to mark the onset of a particular stimulus, etc. ETServer will also accept commands from the external device to open data files and to start and stop recording via the same LAN connection. The next section has instructions for setting up a LAN connection and communicating with an Argus Science application called *ETRemote*. The protocols for sending and receiving data with a user application are specified in a separate manual, titled *ETServer Real-Time Communication with External Devices*.

11 Communication with External Devices

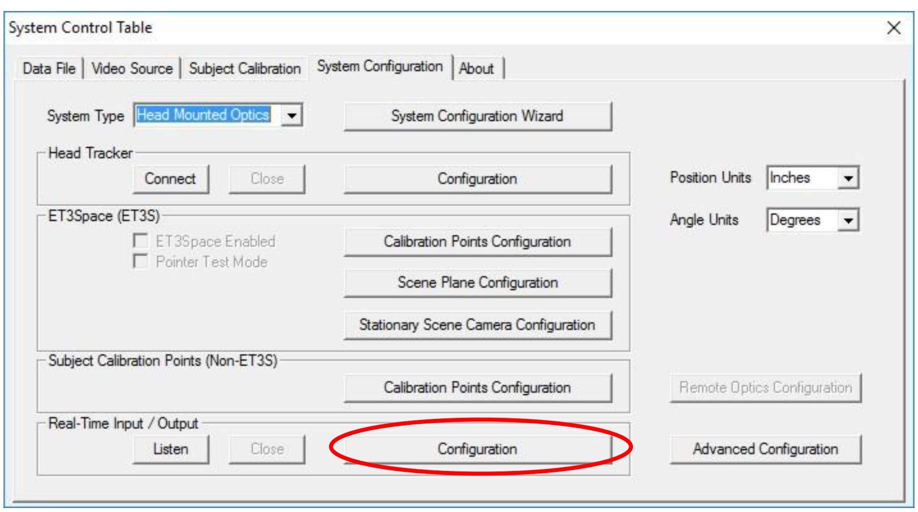
The *ETServer* can communicate with external devices via a Local Area Network (LAN) Ethernet port.

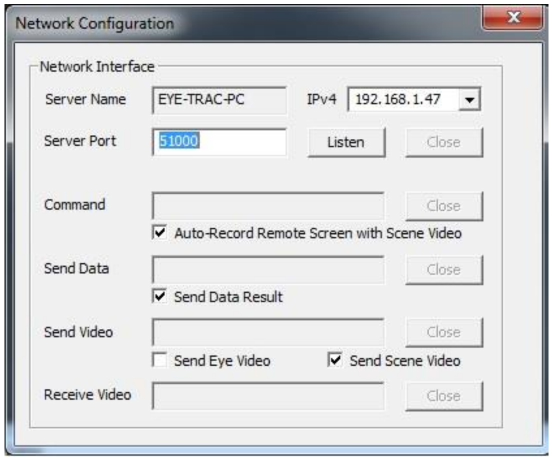
- Devices connected to the LAN can receive real time digital gaze and pupil diameter data, as well as the scene or eye video images.
- A device connected to the LAN can send a channel of data to be recorded by *ETServer* along with gaze data, and can remotely open and close data files, and start and pause data recording on the *ETServer*.
- If the primary scene image being viewed by the subject is a computer display screen, and the computer is running Microsoft Widows 7, the display screen image can be sent to the *ETServer* via LAN connection for use as the "Stationary Scene Camera" image.

Argus Science provides a sample application called *ETRemote* which can be installed on external devices running Win 7 or Win 10, and can used for all of these functions.

Both the *ETServer* PC and the external device must be connected to the same LAN. Connect a network cable from the Ethernet port on the *ETServer* PC rear panel either directly to an Ethernet port on the external device or to a LAN. In the latter case, the external device must be connected to the same LAN.

In all cases the *ETServer* acts as the "server" (or "host") while the external device acts as the "client". A *Network Configuration* dialog on *ETSever* is accessed from *System Configuration* tab, on the *System Control Table*, by clicking the "Configuration" button .





The *Network Configuration* dialog shows the "server" name, IP address and port number. The "IP Server Name" or "IPv4 address", and "Server Port" number will be needed by the client device to connect. Use the appropriate check boxes to have *ETServer* send digital data or video, or to receive video, and click listen. If a client on the network opens a connection for any of these functions, the "Listen" button will turn gray and the "Close" button (or buttons) will become active.

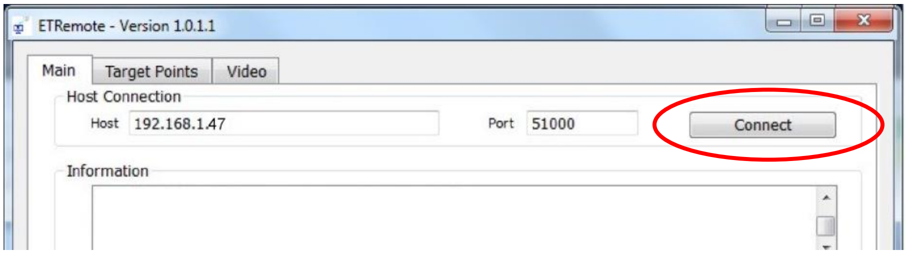
11.1 Connecting to *ETServer* with *ETRemote*

Argus Science provides an application called *ETRemote* which can be installed on external devices running Win 7 or Win 10. *ETRemote* can receive real time data and video from ETServer, and can send a real-time image of the display PC screen to *ETServer*.

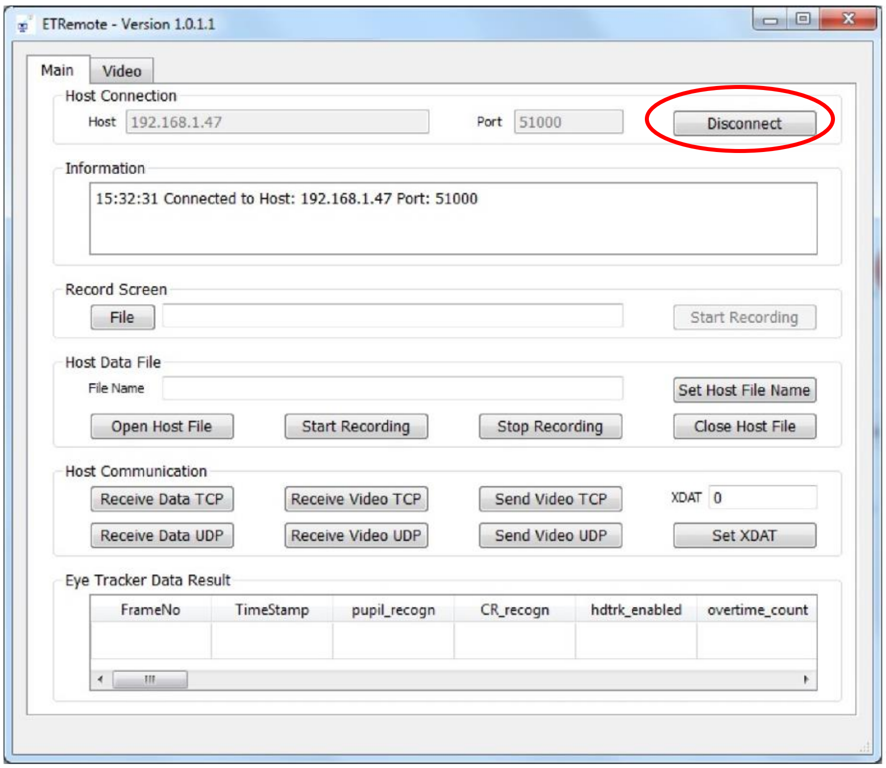
Be sure both the ETServer and the external PC are connected to the same local area network (LAN) as previously described. Install *ETRemote* on the external PC. Run *ETRemote* and, on the *Main* tab of the *ETRemote* application window, type in the *ETServer* network name or IP address. These can be found on the ETServer *Network Configuration* dialog (See previous section). In the case of a direct connection from ETServer to the external device (rather than connection of both devices to a LAN), use the IPv4 address rather than the device name. The port number on *EyeTrac Remote* should default to the correct port number (usually 5100), but check to be sure it is the same as that shown on the *ETServer*, *Network Configuration* dialog.

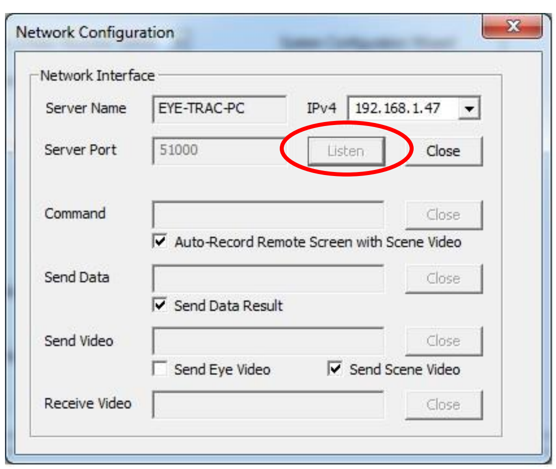
On the *Network Configuration* dialog, click "Listen".

On the external PC *EyeTracRemote* application, click "Connect".



If the connection is successful (*EyeTracRemote* “Connect” button changes to “Disconnect”, and the ETServer “Listen” button turns gray).





11.2 Connecting to ETServer with a user created application

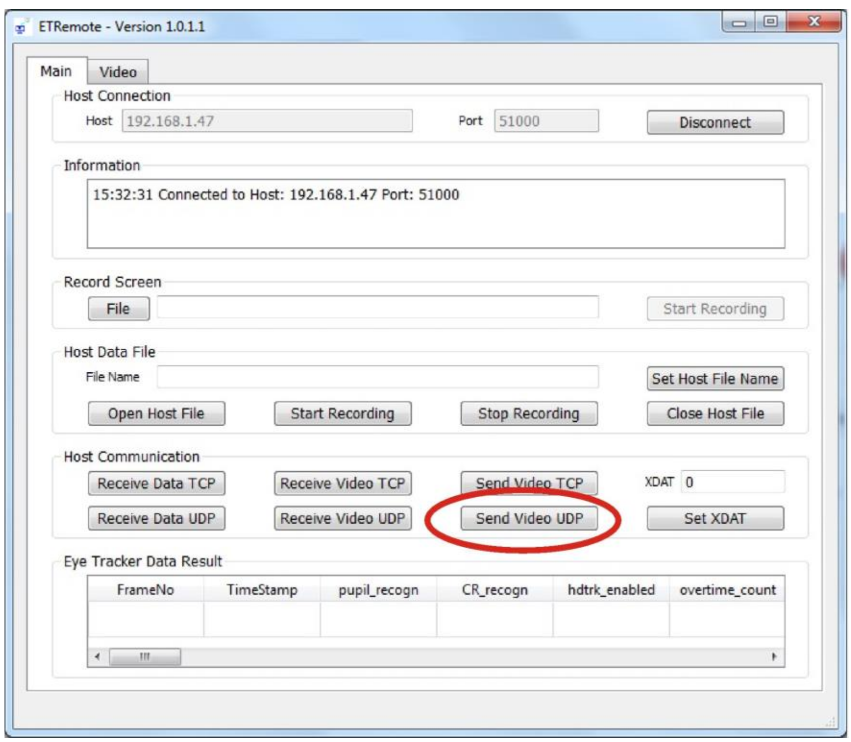
Any application on an external device can connect to the ETServer if the device is connected to the same LAN. The application must be able to open a socket, connect to the Host IP address and port number and send/receive data over this connection via TCP/IP . The detailed protocol for sending commands and receiving data are specified in a separate manual, titled *ETServer Real-Time Communication with External Devices*.

11.3 Use external PC display as remote scene image

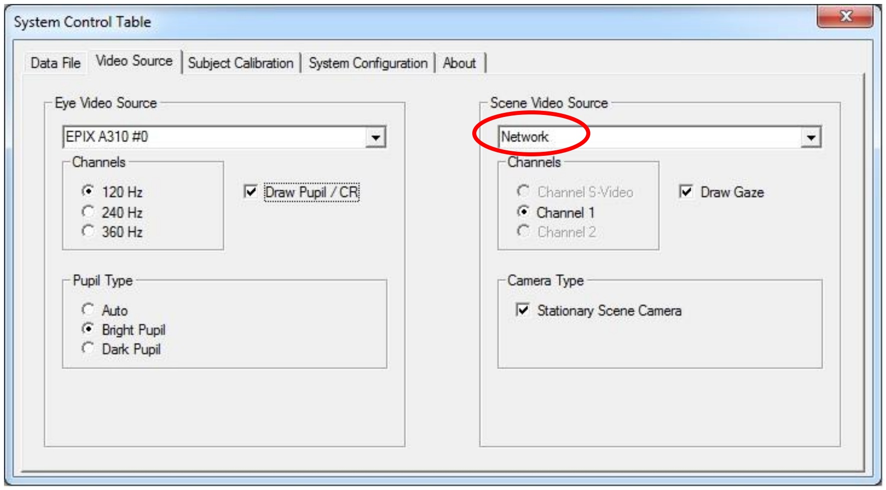
The scene image source may come from an external PC via a LAN connection. It usually makes sense to do this only if using *ET3Space* and if the primary scene plane will be a PC monitor viewed by the subject. The PC driving the monitor must be using the Win7 or Win 10 OS.

Establish a connection between ETServer *and ETRemote* as described in section 11.1.

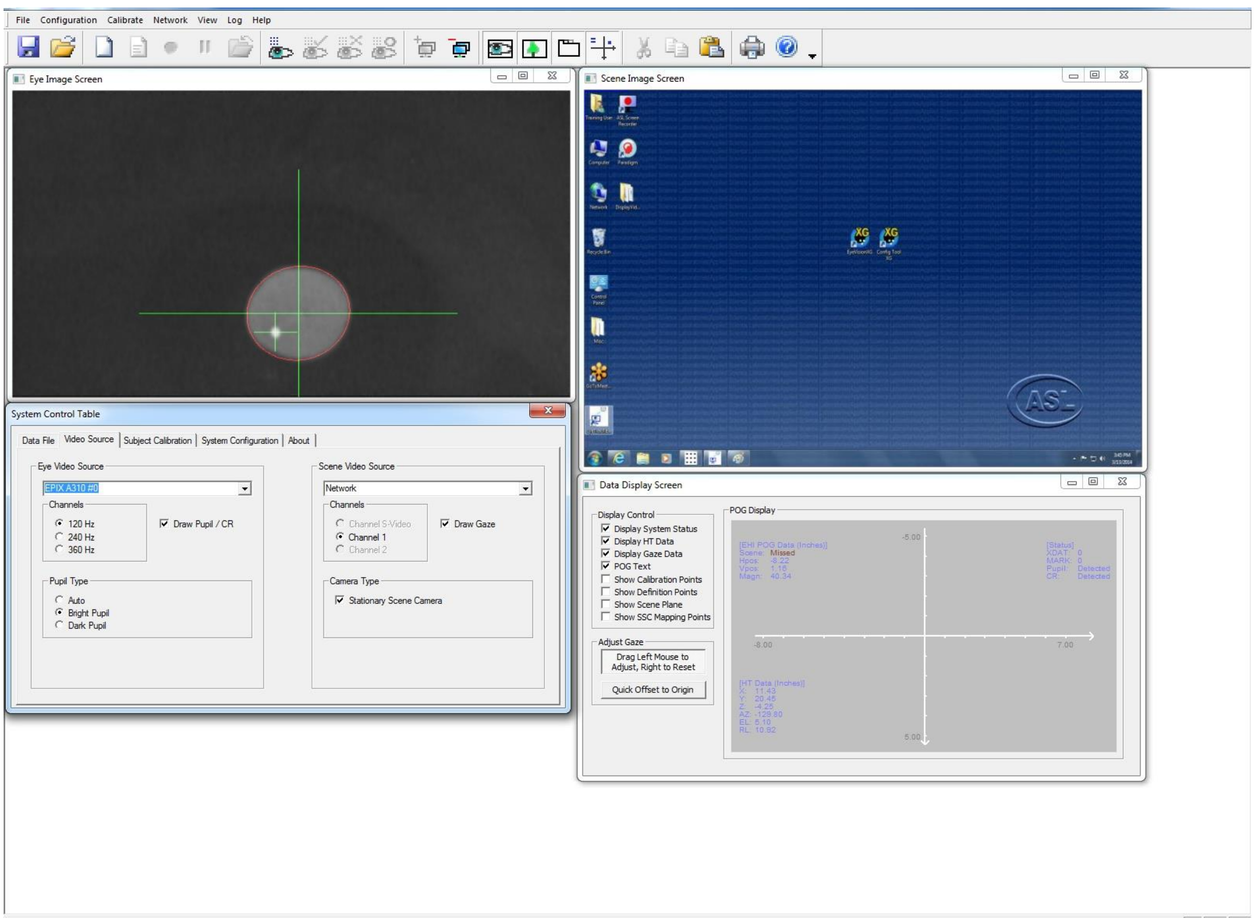
On *ETRemote*, in the “Host Communication” group box, click “Send Video UDP”.



On the ETServer *Video Source* tab set the Scene Video Source to “Network”.



The *Scene Image Screen* window on *ETServer* should now show the display from the external PC. No matter what the display resolution on the external PC, it will display as 640 x 480 on the *Scene Image Screen*, with a 10 Hz update rate.



11.4 Send external data to ETServer and control ETServer data recording

To use *ETRemote* to control data recording and to send data to the *ETServer* from an external PC, first establish a connection between *ETServer* and *ETRemote* as described in section 11.1. To open a file on *ETServer* using the current date and time as the file name, simply Click "Open Host File" on the *ETRemote* dialog window. On *ETServer*, the *Data File* tab should show an open file with an active record button just as described in section 10.2. To choose a file name, type the file name in the "Host Data File" box, on *ETRemote*, and click "Set Host File Name" before clicking "Open Host File". The Start and Stop recording buttons on *ETRemote* will command *ETServer* to start and stop recording on the open file.

To change the *ETServer* XDAT (external data) value from *ETRemote*, type a value between 0 and 255 next to the "XDAT" label, in the "Host Communication" box, on *ETRemote*, and click "Set XDAT". The XDAT value shown on the *ETServer Data Display* window should reflect the change.

The same functions can implemented by a custom user application running on an external device if the device is connected to the same LAN as the *ETServer*. The application must connect to the *ETServer* as described in section 11.2. The command protocol for opening and closing files, starting and pausing data recording and changing the XDAT value is detailed in a manual titled *ETServer Real-Time Communication with External Devices*.

11.5 Send real-time digital gaze data to external device

An external device can receive real time digital data and video data from *ETServer* via LAN connection. To demonstrate this with *ETRemote*, first establish a connection between *ETServer* and *ETRemote* as described in section 11.1. On the *ETServer, Network Configuration* dialog, check the box labeled "Send Data Result". Live gaze and pupil diameter data should begin to appear in the *Eye Tracker Data Result* window on the "Main" tab of the *ETRemote* application.

The set of data items output via the network connection is the same set specified for local recording by *ETServer*. The list of data items is specified on a "Data Selection" dialog. The dialog is opened by clicking the "Data Selection" button on the *System Control* Table, *Data File* tab, and was discussed in section 10.1. Although the same list controls the content of the data set for local recording and for transmission over the network, data can be transmitted even if not recording locally and visa versa.

If either the "Send Eye Video" or "Send Scene Video" box on the *ETServer, Network Configuration* dialog, is checked, the corresponding video should appear on the *ETRemote* "Video" tab.

To receive data on a custom user application the application must connect to the *ETServer* as described in section 11.2. If "Send Data Result" is checked on the *ETServer*, *Network Configuration* dialog, the specified set of data items will be streamed over the connection. The order and size of data items is described in section 16, and the command protocol is described in the *ETServer Real-Time Communication with External Devices* manual.

12 Using the model eye

One of the accessories supplied by Argus Science 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 4 mm circle is at a normal eye distance from the optics. If optics focus is left unchanged after running a real subject, this will be the distance at which the model pupil is in sharp focus on the eye monitor. This can most easily be accomplished by swinging the visor out of the way, and placing the model eye directly below the optics module. It is suggested that the model be oriented so that the corneal reflection (ball bearing) appears below the pupil (white circle).

The system should recognize the pupil and CR just as it would a real eye (see section 7).

To compute a scale factor for pupil diameter values displayed on the computer screen, or recorded by the *ETServer*, first be sure the system is properly recognizing the model pupil, then note the pupil diameter value on the *ETServer, Data Display Screen* ("PupDiam: *nnn*"). To compute a scale factor, divide this value by 3.96. Convert displayed or recorded pupil diameter values to millimeters by applying this scale factor (value in millimeters = scale factor * recorded value).

13 Generalized Operating Procedures

The following describes a routine for setting up a subject for an eye tracking session. Individual procedures may differ depending on your setup, equipment, and conditions.

13.1 Systems with ET3Space

13.1.1 For each new environment (physical arrangement of scene plane surfaces, etc.)

- **Power up** all components.
- **Lauch *ETServer* application.**.
- Make sure that all configuration settings are correct on *System Control Table, Video Source* tab and *System Configuration* tab .
- **Enable Head Tracker,** if not already enabled, by clicking "Connect" on the *System Control Table System, System Configuration* tab. *Data Display Screen* should show live head tracker values.
- **Configure the *ET3Space* environment.** Use the procedure buttons in the "ET3Space" group box, on the *System Control Table, System Configuration* tab as described in the *ET3Space* manual .

13.1.2 For each session of equipment use

- **Power up** all components.
- **Lauch *ETServer* application.**.
- Make sure that all configuration settings are correct on *System Control Table, Video Source* tab and *System Configuration* tab .
- **Enable Head Tracker,** if not already enabled, by clicking "Connect" on the *System Control Table, System Configuration* tab. *Data Display* window should show live head tracker values.
- **Enable *ET3Space*,** if not already enabled, by checking "ET3Space Enabled" on the *System Control Table, System Configuration* tab. .
- If there is any suspicion that the *head tracker or scene plane surfaces may have moved, it may be prudent to* ***test the*** **ET3Space Environment** by performing a pointer test (See the *ET3Space Manual*). If something critical has moved, it may be necessary to re-setup some of the surfaces.
- Make sure the **Head Tracker Sensor is attached to the headgear**.

13.1.3 For each subject

- **Place the Headgear on the subject. Be sure that the head tracker sensor is properly fastened to the head gear**
- **Adjust the camera and monocle** so that the eye image is properly displayed on the Eye Video Display. When the subject is looking straight ahead, the pupil should be centered on the screen and the CR should be relatively near the center of the pupil. There may be some variation in placement for different types of tasks.
- If necessary, adjust the **eye image focus** to achieve sharp focus by sliding the eye camera slightly in its housing. Make sure that the image of the eye is horizontal.
- **Verify proper feature recognition.** Observe the feedback indicators on the Eye Image Display to verify that the system is properly recognizing the pupil and CR.
- **If using the head mounted scene camera, be sure it is properly aimed.**
- **Subject Calibration.** Using the *System Control Table, Subject Calibration* tab, select the calibration type (with or without head mounted scene camera). If using the head mounted scene camera, click “Start” and then click the image of each calibration target point, on the *Scene Image Screen*, as the subject looks at that point. If not using the head mounted scene camera, click the “Enter Data for current point” button as the subject looks at each calibration point. Be sure pupil and CR recognition is correct, as shown on the *Eye Image Screen*, before data is entered for any point.
- **Check Calibration**. Before clicking Finish, have the subject look at all the points to be sure the *Scene Video Screen* and *Data Display Screen* point-of-gaze cursors correctly indicate the points.
- Repeat the calibration or portions of the calibration if necessary and click “Finish” when satisfied.
- **Open Data File:** If desired, open data file by selecting *NewData File* from the *File* menu or by using the “File” button on the *System Control Table, Data File* tab .
- **Start Recording:** Begin experiment task, and if desired begin collecting data by clicking the Record button on the *System Control Table, Data File* tab, or selecting *Start Recording* under the *File* menu.
- **Stop & Close Data File** When finished, stop recording by clicking the Pause button on the *System Control Table, Data File* tab, or by selecting *Stop Recording* under the *File* menu. Close data file by clicking the *Close* button *System Control Table, Data File* tab or by selecting *Close* under the *File* menu.

13.2 Systems Without ET3Space

13.2.1 For each session of equipment use

- **Power up** all components.
- **Lauch *ETServer* application.**.
- Make sure that all configuration settings are correct on *System Control Table, Video Source* tab and *System Configuration* tab .

13.2.2 For each subject

- **Place the Headgear on the subject.**
- **Adjust the camera and monocle** so that the eye image is properly displayed on the *Eye Image Screen*. When the subject is looking straight ahead, the pupil should be centered on the screen and the CR should be relatively near the center of the pupil. There may be some variation in placement for different types of tasks.
- If necessary, adjust the **eye image focus** to achieve sharp focus by sliding the eye camera slightly in its housing. Make sure that the image of the eye is horizontal.
- **Verify proper feature recognition.** Observe the feedback indicators on the *Eye Image Screen* to verify that the system is properly recognizing the pupil and CR.
- **If using the head mounted scene camera, be sure it is properly aimed.**
- **Subject Calibration.** Using the *System Control Table, Subject Calibration* tab, select calibration type (normally “Click on Scene Image Points”). Click “Start” and then click the image of each calibration target point, on the *Scene Image Screen*, as the subject looks at that point. Be sure pupil and CR recognition is correct, as shown on the Eye Video Display, before data is entered for any point.
- **Check Calibration**. Before clicking Finish, have the subject look at all the points to be sure the *Scene Image Screen* and *Data Display Screen* point-of-gaze cursors correctly indicate the points.
- Repeat the calibration or portions of the calibration if necessary and click “Finish” when satisfied.
- **Open Data File:** If desired, open data file by selecting *NewData File* from the *File* menu or by using the “File” button on the *System Control Table, Data File* tab .
- **Start Recording:** Begin experiment task, and if desired begin collecting data by clicking the Record button on the *System Control Table, Data File* tab, or selecting *Start Recording* under the *File* menu.
- **Stop & Close Data File** When finished, stop recording by clicking the Pause button on the *System Control Table, Data File* tab, or by selecting *Stop Recording* under the *File* menu. Close data file by clicking the *Close* button *System Control Table, Data File* tab or by selecting *Close* under the *File* menu.

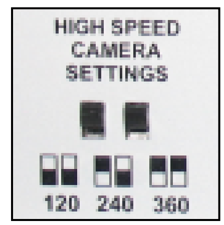
14 High Speed Operation

If the *ETServer* is equipped with the high speed (HS) option, the system is capable of functioning at 120, 240, or 360Hz. Procedures when using a high-speed system are performed in the same manner as with a standard (60 Hz) system. However, there are a number of configuration and minor functional differences.

14.1.1 High Speed Configuration

If the system has the High Speed Option, be sure the cable from the head mounted optics are plugged in to the connector labeled High Speed Optics on the ETServer PC rear panel.

Set the Eye Video pull-down menu, on the *System Control Table* Video Source tab, to "EPIX A310 #0". The "Channels" box will show a set of radio buttons with a choice of update rates (120Hz, 240Hz, or 360Hz). There are a pair of small slide switches, usually on the ETServer PC front panel, to the left of the power button, labeled High Speed Camera settings. (On some units these switches might be located on the PC rear panel.) This set of switches must be set to the same speed as software radio button. *If using the system for the first time, it is suggested that 120Hz be selected first, and higher update rates be used after gaining some initial familiarity with the system.* The Eye Image window (upper left window) should now show the image from the optics module eye camera. Wave a hand or some other object under the eye camera to be sure.



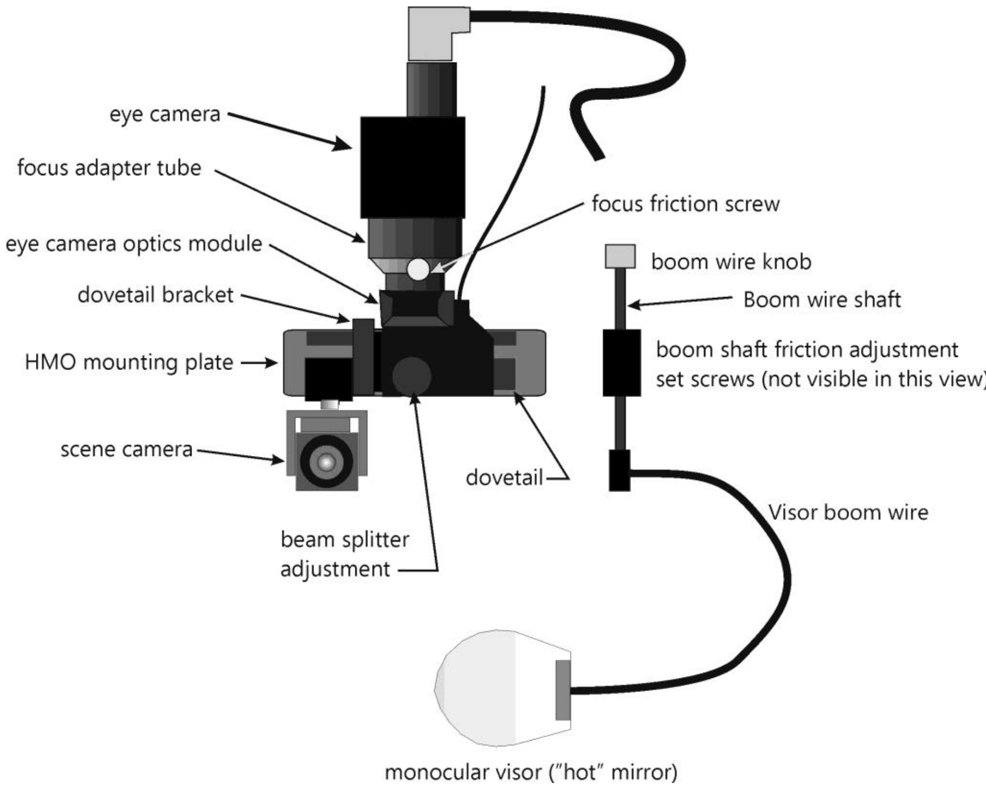
14.1.2 Eye Image

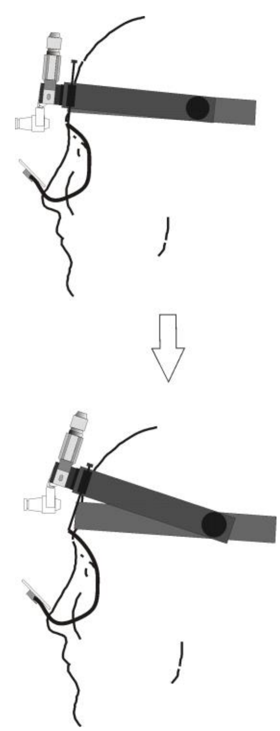
As the speed is increased from 120 Hz, the horizontal camera field of view will remain the same, but the vertical field of view of the eye camera becomes smaller. This means the optics will need to be aimed more carefully to keep the eye in the camera field of view over the desired range of vertical eye rotation. At higher speeds it may be desirable to tilt the head band front mounting plate up to a higher position on the forehead to increase camera to eye distance and cover a slightly larger field of view. The two large black nuts, located approximately over each ear, can be loosened slightly and re tightened to allow the mounting plate position to be changed.

When update rate is increased, the eye camera sensitivity will appear to decrease (the image will appear to dim), since the camera pixels have less time to charge for each imaging field. It may be necessary to increase the illumination intensity on the *Advanced Configuration* dialog (*System Control Table*, *System Configuration* tab, "Advanced Configuration" button). The standard settings for each update rate are listed in section 5.2.2.5.

14.1.3 HeadGear Adjustments with high speed optics

The eye camera field of view can be adjusted by changing the path length from the camera to the eye. The distance from the monocular visor can be adjusted by moving the boom wire shaft up and down in its mount to lengthen or shorten the path.





The entire eye camera assembly can also be raised or lowered by tilting the aluminum mounting band about the its joint at each side of the head band.

Performance is usually best when the eye camera field of view is the minimum size that will still allow the pupil and CR images to remain within the camera field of view during normal eye motions. Since the vertical field of view becomes smaller at higher update rates, it may be necessary to increase the eye to camera path length in order to keep the pupil and CR in the camera field of view.

If the camera to eye distance becomes too great, the CR may become too small for the system to easily recognize; so at the highest speed, good feature recognition may require a camera field of view that does not allow quite as much vertical gaze range.

It is strongly recommended that users become proficient operating the system at 120 Hz before using higher update rate.

15Advanced Theory of Operation

15.1 Pupil and CR Recognition

The Eye Tracker bright pupil optics module is designed so that the near infrared eye illumination beam is 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. In most indoor light conditions this bright pupil image can 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 addition to brightness, the eye tracker uses edge detection algorithms as well as size, shape, and smoothness criteria 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 or 30 degrees, the CR no longer appears on the cornea and cannot be detected.

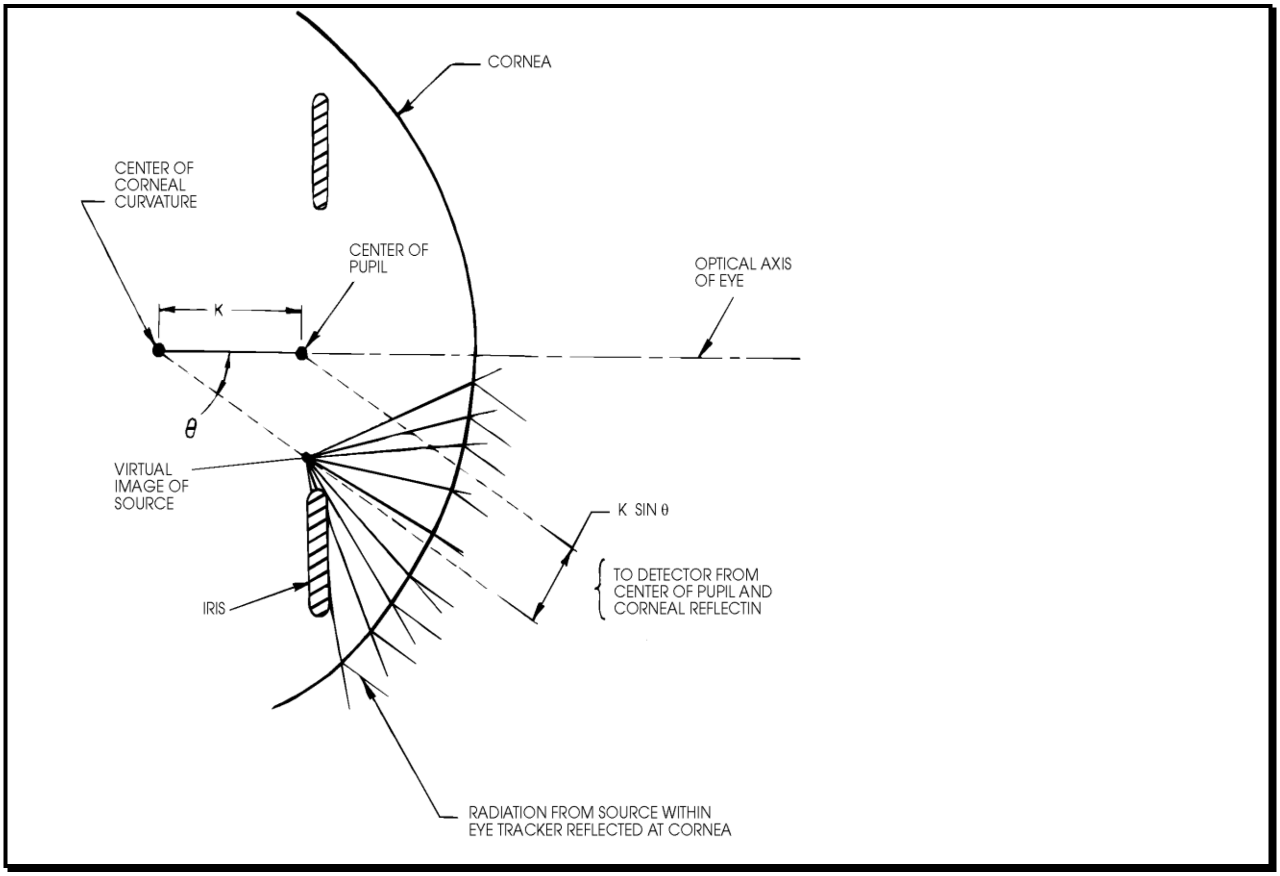
15.2 Eye Line of Gaze Computation

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 the accompanying sketch for a single axis. Note that the relation reduces to

$$PCR = K \sin(\theta)$$

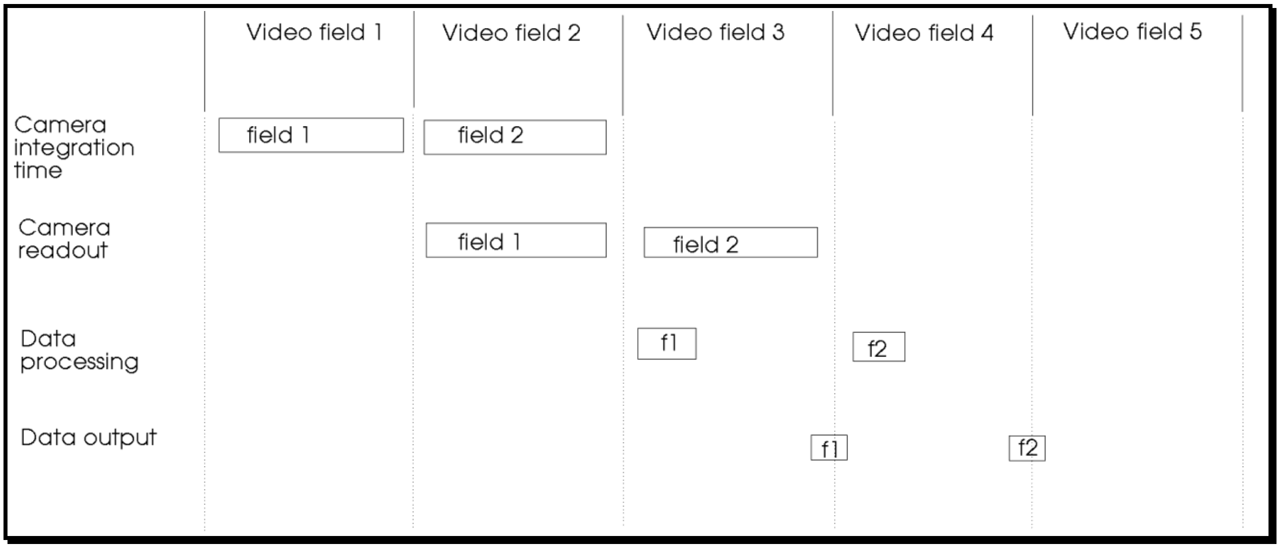
where θ is eye line of gaze angle with respect to the light source and camera, and K is the distance between the iris and corneal center of curvature.



Relation between line of gaze and pupil/CR separation

In addition to the idealized geometry described by the above equation, it is necessary to account for intra subject differences in corneal shape and other second order effects. Therefore, rather than use this simple equation, the Eye Tracker uses an empirical technique to compute a set of polynomial functions, including cross talk and corner terms, that will map pupil CR separation to point of gaze on the scene space. Data stored during the calibration procedure is used by the computer to calculate the polynomial coefficients for each subject.

15.3 Timing



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 above. 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 transport delay of about 50 ms (3/60 of a second).

16Recorded and Transmitted Data Items

16.1 Data Item List

The first 5 bytes of a data record in a data file recorded by *ETServer*, or real time data packet transmitted by *ETServer*, always contain the following items:

Data Item	**Byte position**	**Type**	**Size (bytes)**
start_of_record	1	Byte	1
status	2	Byte	1
overtime_count	3	Uint16	2
mark_value	5	Byte	1

The items in the table below are selectable (see Section 10.1). Which ever items have been selected will appear in the order listed on both data files recorded by *ETServer* and real time data packets transmitted by *ETServer*. Some items are available only when using *ET3Space*.

Data Item	Type	**Size (bytes)**	**Scale Factor**	Comment
XDAT	UInt16	2	1	Always available
CU_video_field_num	UInt16	2	1	Always available
pupil_pos_horz	UInt16	2	1	Always available
pupil_pos_vert	UInt16	2	1	Always available
pupil_diam	UInt16	2	0.01	Always available
pupil_height	UInt16	2	0.01	Always available
cr_pos_horz	UInt16	2	1	Always available
cr_pos_vert	UInt16	2	1	Always available
cr_diam	UInt16	2	1	Always available
horz_gaze_coord	Int16	2	0.1	Always available
vert_gaze_coord	Int16	2	0.1	Always available
horz_gaze_offset	Int16	2	1	Always available
vert_gaze_offset	Int16	2	1	Always available
hdtrk_X	Int16	2	0.01	Available only if head tracker installed
hdtrk_Y	Int16	2	0.01	Available only if head tracker installed
hdtrk_Z	Int16	2	0.01	Available only if head tracker installed
hdtrk_az	Int16	2	0.01	Available only if head tracker installed
hdrtk_el	Int16	2	0.01	Available only if head tracker installed
hdtrk_rl	Int16	2	0.01	Available only if head tracker installed
ET3S_scene_number	Byte	1	1	Available only if ET3S enabled
ET3S _gaze_length	Single	4	1	Available only if ET3S enabled
ET3S _horz_gaze_coord	Single	4	1	Available only if ET3S enabled
ET3S _vert_gaze_coord	Single	4	1	Available only if ET3S enabled
eyeplot_x	Single	4	1	Available only if ET3S enabled
eyeplot_y	Single	4	1	Available only if ET3S enabled
ET3S _eyelocation_X	Int16	2	0.01	Available only if ET3S enabled
ET3S _eyelocation_Y	Int16	2	0.01	Available only if ET3S I enabled
ET3S _eyelocation_Z	Int16	2	0.01	Available only if ET3S enabled
ET3S _gaze_dir_X	Int16	2	0.001	Available only if ET3S enabled

ET3S _gaze_dir_Y	Int16	2	0.001	Available only if ET3S enabled
ET3S _gaze_dir_Z	Int16	2	0.001	Available only if ET3S enabled
aux_sensor_X	Int16	2	0.01	Available only for certain head trackers
aux_sensor_Y	Int16	2	0.01	Available only for certain head trackers
aux_sensor_Z	Int16	2	0.01	Available only for certain head trackers
aux_sensor_az	Int16	2	0.01	Available only for certain head trackers
aux_sensor_el	Int16	2	0.01	Available only for certain head trackers
aux_sensor_rl	Int16	2	0.01	Available only for certain head trackers

16.2 Data Item Explanation

Start of record byte – fixed value 0xFA

Status byte – contains eye tracer status information.

Bit	Meaning (if 1)
0 (least significant)	Head tracker enabled, monocular system or left eye binocular
1	Head tracker enabled, right eye (binocular system only)
2	Cornea Reflection found, right eye (binocular system only)
3	Pupil Found, right eye (binocular system only)
4	Cornea Reflection found, monocular system or left eye binocular
5	Pupil Found, monocular system or left eye binocular
6	Right eye data was simulated for left/right eye data synchronization (binocular only)
7	Left eye data was simulated for left/right eye data synchronization (binocular only)

overtime count, 2 bytes, unsigned integer. Shows how many records were lost prior to this one. Typically contains the value zero.

Mark value byte – will be last integer “Mark” value entered by user.

XDAT – 16 bit integer set by external device.

CU video field number – Internal field (or record) number kept by system. It is the number of vertical sync pulses received from the eye camera since the *ETServer* program was activated, and rolls over to 0 after every 65535 fields. Useful mostly for debugging purposes.

pupil_pos – coordinates proportional to horizontal (0 to 640) and vertical ()0 to 480) pupil position with respect to the eye camera field of view.

Pupil_diam – value proportional to diameter of the pupil image on the eye camera. More specifically, the value is major axis of the ellipse shape identified as the pupil image. Note that this value is computed to a fraction of a pixel. Note also that this value will not be affected by degree of image ellipticity, and will not change (except for measurement noise) if the diameter of the actual pupil does not change and camera to eye distance does not change. The units are eye camera pixels multiplied by 100. To find the value in pixel units, the value recorded on the file or transmitted in real-time must be converted to a float and multiplied by 0.01 (the scale factor shown on the chart, above). This pixel value is the value displayed on the *ETServer* Interface (on the Data Display Screen), and the value shown by the Argus Science data analysis program, *ETAnalysis*. To convert the pixel value to real distance units (I.e., millimeters) use the model eye target bar as described in the *ETServer* manual section titled "Using the Model Eye" (section 12).

Pupil_height – the minor axis of the ellipse shape identified as the pupil image. Scaling is the same as that described above for pupil_diam. Note that unlike pupil diam (major ellipse axis) the minor axis of the ellipse image shape will change length as degree of ellipticity changes due to eye movement, even if true pupil diameter remains constant.

cr_pos -- coordinates proportional to horizontal (0 to 640) and vertical ()0 to 480) corneal reflection with respect to the eye camera field of view.

cr_diam – Diameter of the corneal reflection image in eye camera pixels.

gaze_coord – horizontal and vertical coordinates of computed point of gaze with respect to the head mounted scene camera 640 x 480 pixel field of view (fov), multiplied by 10. Convert to float and multiply by the scale factor 0.1 to get the pixel coordinate value. Note that fractional pixel positions are represented. Also note that the values are signed. Negative values represent positions to the left, or above the scene camera fov, while values greater than 640 or 480 represent positions to the right of , or below the camera fov.

gaze_offset – Manual offset added to horizontal or vertical gaze coordinate in scene camera pixel units.

hdtrk – X, Y, Z position values and azimuth, elevation, and roll orientation values received by the *ETServer* system from a head tracker. Values are multiplied by 100, and stored or transmitted as signed integers. Convert to float and multiply by the scale factor 0.1 to get original values. Position values are in units of inches or centimeters (depending on which unit system was set in *ETServer, System Configuration* dialog). Angles are in degrees.

ET3S_scene_number – number of scene plane first intersected by line of gaze, as computed by the *ET3Space* feature.

ET3S _gaze_length – Distance from the eye to the point of gaze on the scene plane designated by EH_scene_number, as computed by the *ETServer, ET3Space* feature. The value is recorded or transmitted as a single precision floating point value with units of either inches or centimeters (depending on which unit system was set in ET7 configuration dialog).

ET3S _gaze_coord – The point of gaze in scene plane coordinates, on the scene plane designated by EH_scene_number, as computed by the *ETServer, ET3Space* feature. Coordinates are with respect to the coordinate frame defined on the scene plane by the *ET3Space* environment specifications. The "horizontal" value is the Y scene plane coordinate, and the "vertical" value is the Z coordinate. The value is recorded or transmitted as a single precision floating point value with units of either inches or centimeters (depending on which unit system was set in *ETServer* configuration dialog).

eyeplot – The point of gaze values that would have been computed on the calibration surface (scene plane 0) if the subject's head had not moved since subject calibration. (Only available when using

ET3Space). Another way to think of these values is to image that during calibration a duplicate of the calibration surface is magically connected to the subject's head so that moves with the head. "eyeplot" values are the *ET3Space* gaze coordinates on this imaginary surface. When using *ET3Space*, they are a convenient measure of gaze-with-respect-to-the-head. The units are inches or centimeters. "eyeplot_x" is really the Y or "horizontal" coordinate and "eyeplot_y" the Z or "vertical" coordinate of gaze on this imaginary scene plane.

ET3S _eye_location – The location in space, with respect to the *ET3Space* "global coordinate system, of the subject's eye. This location is computed, by the *ET3Space* feature, based on data received from the head tracker, and knowledge of the location of the eye with respect to the head tracker sensor. It does not depend on eye pointing direction. The units are inches or centimeters multiplied by 100, and are stored or transmitted as signed integers. Convert to float and multiply by the scale factor 0.01 to get the values in inches or cm.

ET3S _eye_dir – A 3 dimensional unit vector (vector with a total length of 1) in the direction of gaze, represented with respect to the *ET3Space* "global coordinate system". The unit vector is multiplied by 1000 and stored or transmitted as a signed integer. Convert to floats and multiply each by the scale factor 0.001 to get a vector with unit length. These are dimensionless quantities that specify a direction and have no units.

aux_sensor – Not available with most head trackers. Consult Argus Science.

17Specifications

Measurement	Eye line of gaze with respect to the head mounted optics. Optional: *ET3Space* can provide line of gaze with respect to a motion tracker source reference frame and surfaces that are stationary in that frame.
Allowable measurement field	Essentially unlimited due to free head motion.
Allowable eye movement	Nominal: Along the horizontal axis, 45 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	0.5 degrees visual angle for the eye tracker component. ET3Space results include some additional head tracker error. Errors may increase to less than 2 degrees in the periphery of the visual field.
Eyeglass and contact lens acceptance	Most are accepted. Eyeglasses may need to be tilted with respect to the head if a specular reflection from the glasses interferes with the pupil image. Soft contacts are usually viable. Hard contacts may be problematic.
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. 120, 240, 360 Hz available as options