ETVision

Instruction Manual

MANUAL VERSION   3.7

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ARGUS SCIENCE

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1 Introduction and General System Description

ETVision (ETV) is a lightweight wearable system for measuring binocular point of gaze 180 times per second.

The wearable unit resembles an eyeglasses frame that can be worn by itself or over the participant's prescription eyeglasses. It contains miniature "eye cameras" that view each eye and a "scene camera" that views the scene in front of the participant, and a microphone. An optional visor can be mounted to front of the headgear.

A cable extending from the earpiece connects to a small Controller (slightly larger than a smart phone) that easily fastens to an adjustable belt or can be held by the participant (or near the participant) in some other way. The Controller holds a mico SD card for video and audio data recording, and includes a rechargeable battery. It can also be powered directly from a DC power supply.

The *ETVision* system also includes a laptop PC that connects to the Controller in real-time via a LAN cable or via WiFi. Alternately, the PC can read video and audio data from a microSD card previously recorded by the wearable Controller. Note that by using the WiFi connection or recording to an SD card for later data processing, the subject can be completely un-tethered while data recording takes place.

An application running on the laptop PC uses the video images from the wearable cameras to compute point-of-gaze with respect to a scene camera coordinate frame. The laptop can record the digital gaze coordinates 180 times per second. This digital file also includes pupil diameter of each eye, and can optionally include upper and lower eyelid positions, blink information, and other feature detection measurements used as part of gaze computation.

In addition to recording a digital file, the PC application shows a real time display of the eye and scene camera images and records these as wmv type video files. The 1280x720p scene image updates 30 times per second and includes a superimposed cursor showing the participant's point of gaze in the scene image. The scene video also includes audio from the head gear mic or a local mic. The eye camera video displays include superimposed outlines and crosshairs to show proper recognition by the system of eye image features.

The laptop PC can stream the 180 Hz, real-time, digital data to external devices via LAN, or stream the real-time video scene image to external devices via LAN.

The Argus Science *ETAnalysis* application, usually included with the basic system, can be used to play back and analyze gaze data recorded with *ETVision*. Detailed instructions for use of the *ETAnalysis* application are provided in a separate manual.

An optional addition to the basic system, called *ET3Space*, uses head position and orientation data from one of several third party motion tracking devices to compute gaze with respect to a room fixed coordinate system and to determine point-of-gaze on multiple surfaces in the environment. This optional feature is described in a separate manual.

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, "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 that includes the Argus *ETVision* LEDs.

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 the *ETVision* illumination is at least an order of magnitude below this level. The largest irradiance value that will be produced with the Argus *ETVision* optics is 0.75 mW/cm² (@ 870nm wavelength), at the plane of the eye.

ETVison uses non-coherent illumination. There are no lasers in the headgear.

2.2 Compliance

This device complies with Part 15 of the FCC Rules and complies with Industry Canada license-exempt RSS standards. Operation is subject to the following two conditions:
1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

The Argus Science *ETVision* device is CE-marked, indicating compliance with requirements set out in applicable European Directives.

The Argus Science *ETVision* device complies with the relevant sections of the following standards:

ANSI C63.4:2014, 47 CFR FCC:2014, ICES-001:2014, Issue 4, AS/NZS 61000-3-1:2018, AS/NZS 610003-3: 2017, EN 55032:2015, CISPR 32:2019, CISPR 11:2015+A1-2016, EN 55011:2016+A1:2017, Class B requirements, IEC 61000-4-2:2008, IEC 61000-4-3:2010, IEC 61000-4-4:2010, IEC 61000-4-5:2013, IEC 61000-4-6:2008, IEC 61000-4-8:2009, IEC 61000-4-11:2004 as pertains to IEC 61326-1:2013.

2.3 Safety Disclaimer

Argus Science LLC has taken due care in preparing this manual and accompanying documentation including research, development and testing.

This manual reflects the state of Argus Science's knowledge respecting the subject matter herein at the time of its publication, and may not reflect the state of knowledge at all times in the future. Argus Science has carefully reviewed this manual for technical accuracy. If errors are suspected,

the user should consult with Argus prior to proceeding. Argus Science makes no expressed or implied warranty of any kind with regards to this manual or accompanying documentation.

Argus Science makes no representation, condition or warranty to the user or any other party with respect to the adequacy of this manual or accompanying documents for any particular purpose or with respect to its adequacy to produce a particular result. The *ETVision* system is intended for use in research conditions and Argus Science makes no declaration of suitability for safety critical uses, including, but not limited to, clinical diagnoses, heavy machine operation or other safety dependent activities.

3 System Components

ETVision **headgear--** including eye cameras, scene camera, optional visor, and " type-A-to-micro" HDMI cable.

ETVision **Controller**

ETVision **PC**

CAT 5 cable (for connecting ETV PC and Controller).

DC power supply for recharging (or directly powering) the Controller.

Micro SD card and adapter for use in Controller and *ETVision* PC**.**

3.1 *ETVision* Wearable Optics

The wearable optics unit resembles an eyeglasses frame that can be worn by itself or over the participant's prescription eyeglasses. It contains miniature "eye cameras" that view each eye and a "scene camera" that views the scene in front of the participant, and a microphone. An optional visor can be mounted to front of the headgear.

The left and right bottom sections of the frame each include a panel containing a camera and a pair of LEDs. The panels rotate within an outer enclosure so that it is possible to adjust the camera vertical aiming direction with respect to the optics frame. Although these panels are usually best left in their

standard position, it may be necessary to use this adjustment if facial structure makes the optics frames sit in an unusual position or angle on the face. See Appendix H (section 9.8) for details.

The frame comes with two nosepieces that can be interchanged to adjust the vertical position of the entire frame with respect to the face. The part of each nose piece that actually rests against the nose is flexible and minor adjustments can be made by squeezing the sides together to hold the optics higher on the face or separated more to lower the frames. To remove a nosepiece, simply pull the nosepiece horizontally away from frame. Attach a nosepiece by pressing the two pins on the nosepiece into the mating holes in the frame. The frame can also be worn with no nosepiece to position the frame at the lowest possible position on the face.

A microphone is located in the part of the frame that sits just above the participant's eyebrows.

An optional sunshield ("visor") attaches and detaches from the frame by mating small slots at the upper corners of the visor with small hooks on the frame. See Appendix J (section 9.10) for mounting instructions.
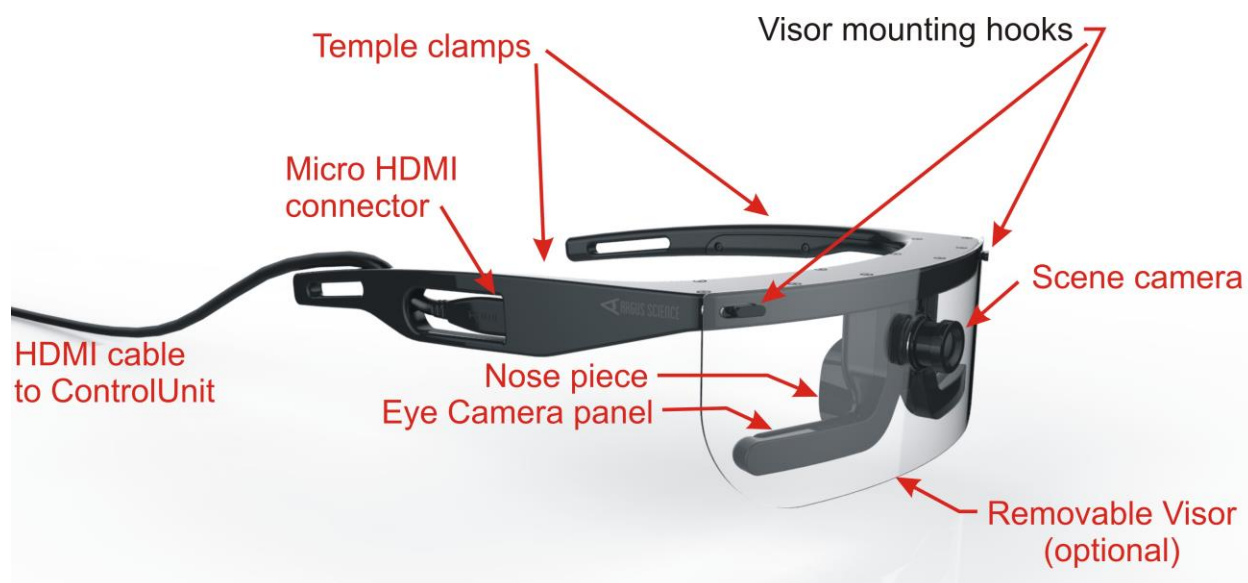
The scene camera lens protrudes from the frame just above the nosepiece. Scene camera focus is adjusted by rotating the lens. An M2, hex head, nylon tip setscrew, located at the bottom of the lens assembly, controls the "tightness" of the focus adjustment, and should be tight enough to prevent unintentional rotation of the lens.

An HDMI type cable extends from the right temple clamp (piece that extends from the temple to the top of the ear). It connects to the frame with a micro HDMI connector in the temple clamp, but

is intended to be disconnected only if it necessary to replace the cable. Normally the cable should remain connected to the frame. The other end of the cable has a standard type A HDMI connector and

connects to the *ETVision* Controller. The cable is a standard "type-A-to-micro" HDMI cable and instructions for removing and replacing the cable are in Appendix F (section9.6).

3.2 *ETVision* Controller

The *ETVision* Controller connects to the *ETVision* Wearable Optics with the HDMI cable extending from the wearable optics frame. Besides the type A HDMI port, the Controller has a micro SD card slot, a phono jack, a LAN port, a power supply connector, a power button and power LED, and a record button and record LED. Both LEDs have multiple colors to indicate various possible states as described in Appendix A (section9.1) of this manual.
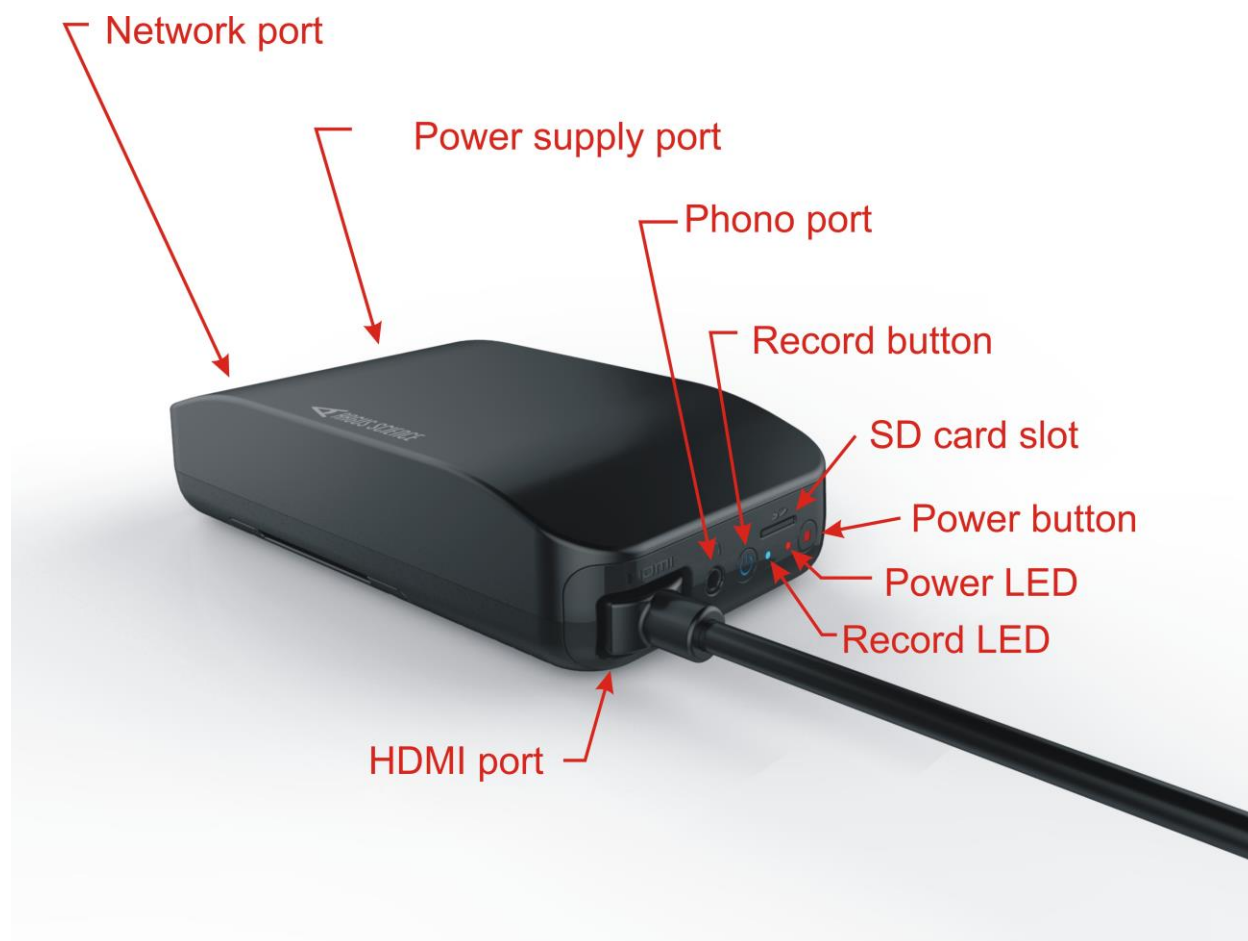
The HDMI port accepts the type A HDMI connector from the ETVision Optics cable. A set screw on the bottom of the Controller, directly under the HDMI port is used to secure the HDMI cable connector after insertion.

The Controller can be connected to the *ETVision* Laptop using the LAN port and standard LAN cable, or via Wifi. Alternately, the Controller can record video and audio data directly to a micro SD card.

If the Controller is connected to the *ETVison* Laptop, either with a LAN cable or Wifi, audio from the microphone on the optics frame is transmitted to the   application on the Laptop, and audio from the

Laptop microphone is transmitted to the phono jack on the Controller. If headphones or earbuds are connected to the Controller phono jack and worn by the participant, this enables two way communication with someone near the laptop.

An adjustable belt, supplied with system, threads through two removable "loops" on the Controller Case and can be used hold the Controller on the participant's waist. The Controller "loops" are each attached to the case with two screws. The screws can be loosened to remove or install the belt.

The Controller contains a Lithium Polymer battery. The battery charges whenever the provided DC power supply is connected to the Controller power connector and plugged into an AC socket. The power unit supplied with the system is equipped with the appropriate AC adapter for the AC power specifications of the intended destination country. The system can be run using the DC power supply even when the battery is fully discharged, however the battery will charge most rapidly when the system is idle. When fully charged the battery will power the system for about 5 hours when all system features are being used. The battery will recharge in about 4.5 hours when the system is idle.

3.3 *ETVision* PC

ETVision systems usually include a laptop PC running Windows 10 ("ETV PC"). When supplied by Argus Science, as part of the ETVision system, the *ETVison* software application is pre-installed by Argus Science. If the *ETVision* PC ("ETV PC") is not supplied by Argus Science see Appendix E (section 9.5) for required PC specifications and software installation instructions.

The ETV PC laptop includes WiFi capability, a LAN port, USB ports, and an SD card slot. The ETVision system uses micro SD cards. Micro SD cards must be placed in a micro-to-standard SD card adapter before inserting in the SD card slot on the ETV PC.

If the ETVision PC was supplied by Argus Science as part of the *ETVision* system, the PC should automatically connect to the controller via the LAN port if a cable is connected or via WiFi if a cable is not connected. If the ETVision PC was not supplied with the system, or if *ETVision* software is being updated from a version prior to v.1.0.3.4, see Appendix E for software installation instructions.

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4 Interconnections

ETVision LapTop PC

LAN port

WiFi   OR

CAT 5
Ethernet Cable

HDMI connector   Ethernet connector

phono connector

micro SD card

ETVision Controller

Power connector

AC
Power
Source

**Control Unit
Power Supply**

optional
headphones

ETVision Wearable Optics
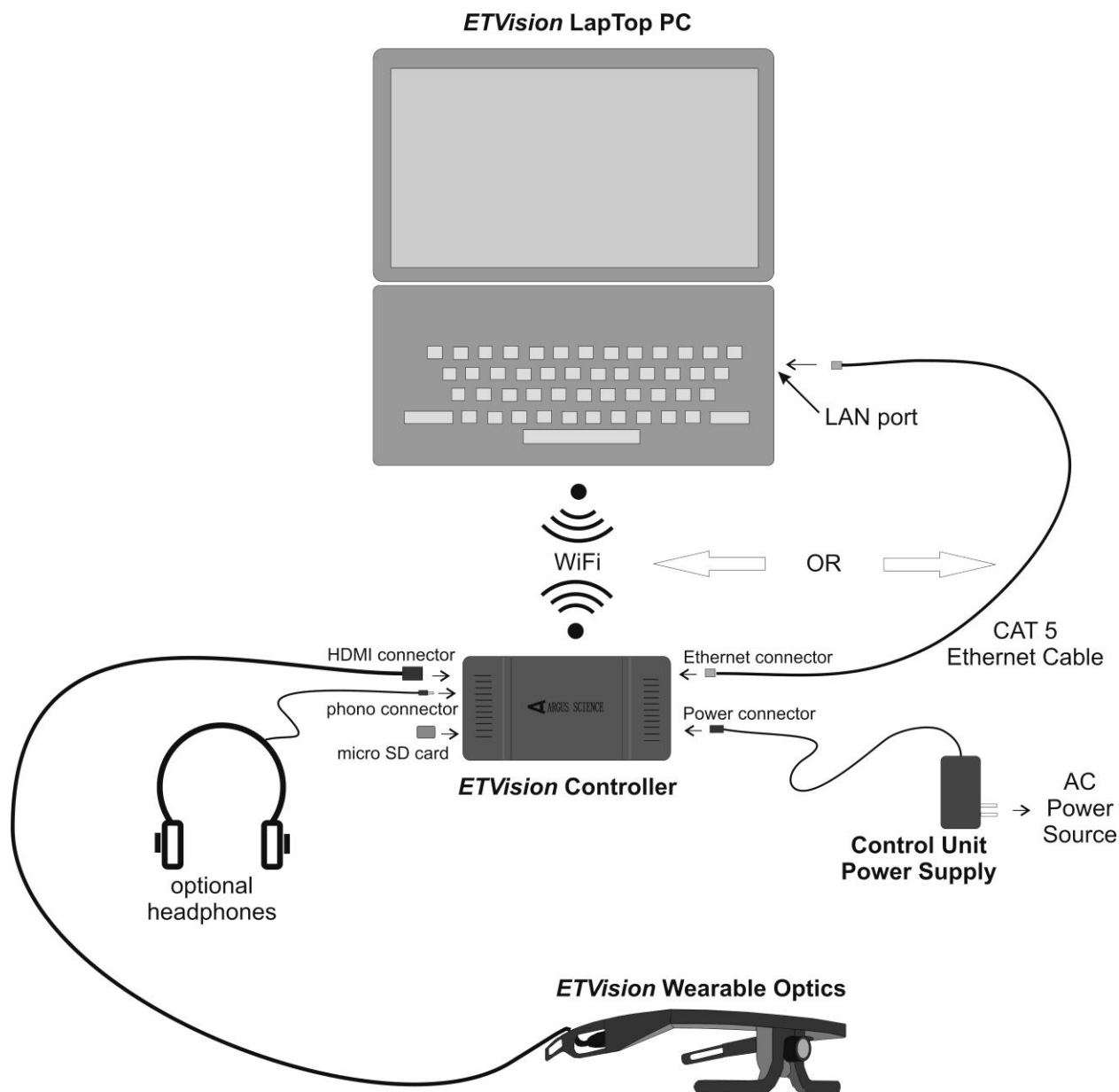
Basic ETVision System Interconnections
(headphones not normally supplied as part of ETV system)
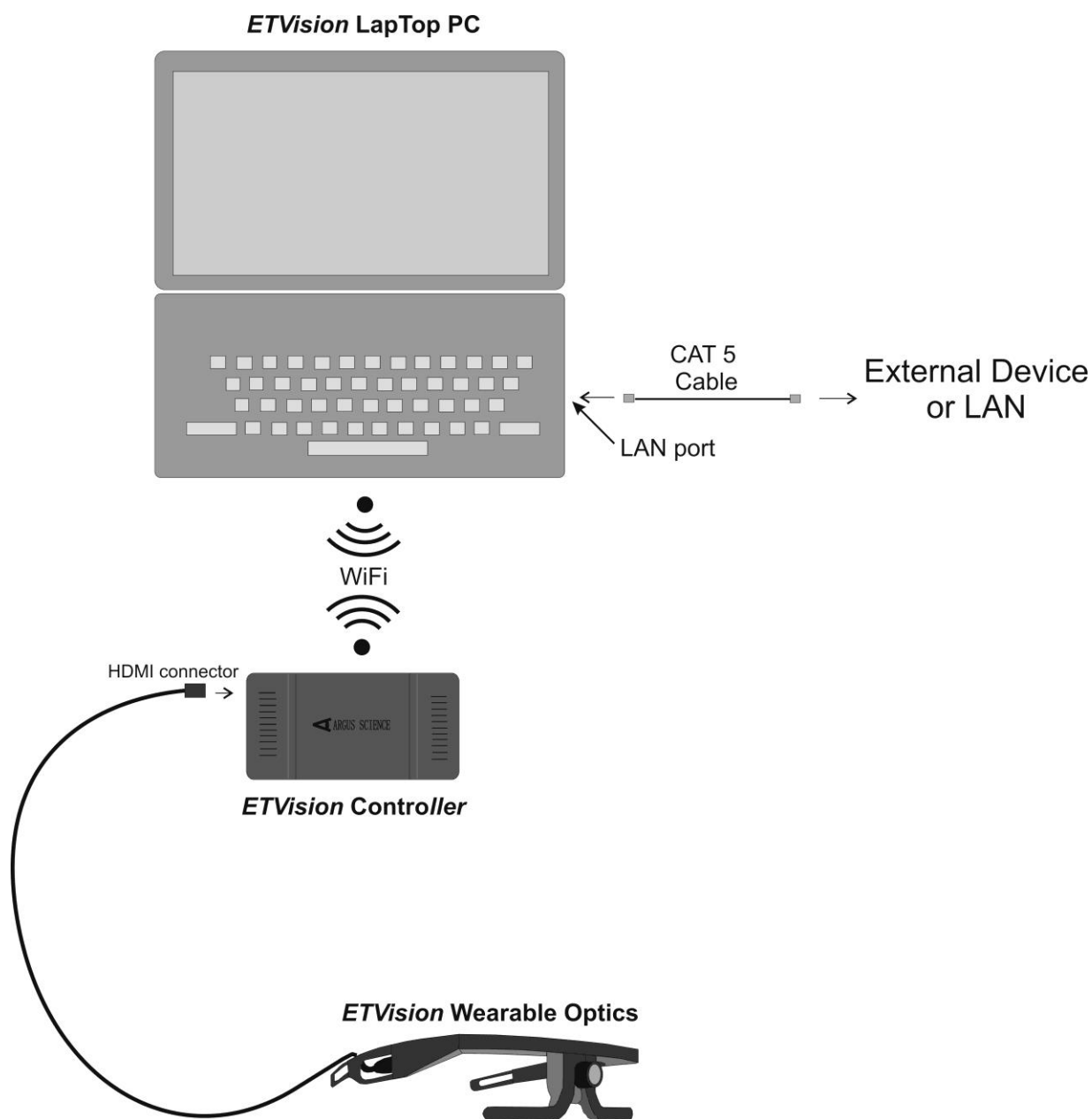
ETVision connection to External Device – Method 1
(All other connection are as shown in the "Basic System Interconnections" diagram)

ETVision LapTop PC

External Device or LAN

USB port

USB to Ethernet Adapter

LAN port

CAT 5 Ethernet Cable

HDMI connector

Ethernet connector

ETVision Controller

ETVision Wearable Optics
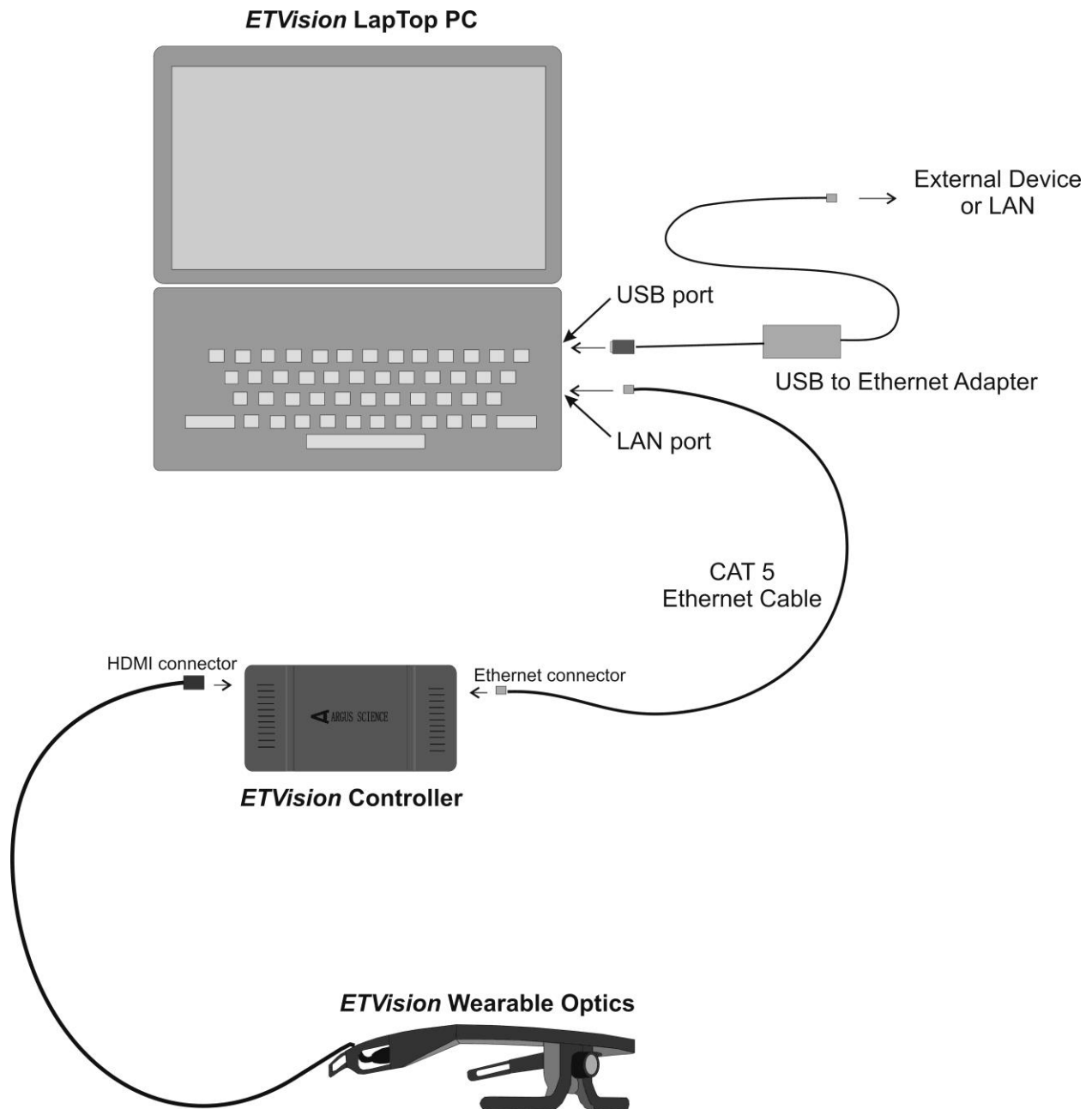
ETVision connection to External Device – Method 2
(All other connection are as shown in the "Basic System Interconnections" diagram)

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ETVision LapTop PC

WiFi

(((Local Area Network

LAN port

CAT 5
Ethernet Cable

HDMI connector

Ethernet connector

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ETVision Controller

ETVision Wearable Optics Unit
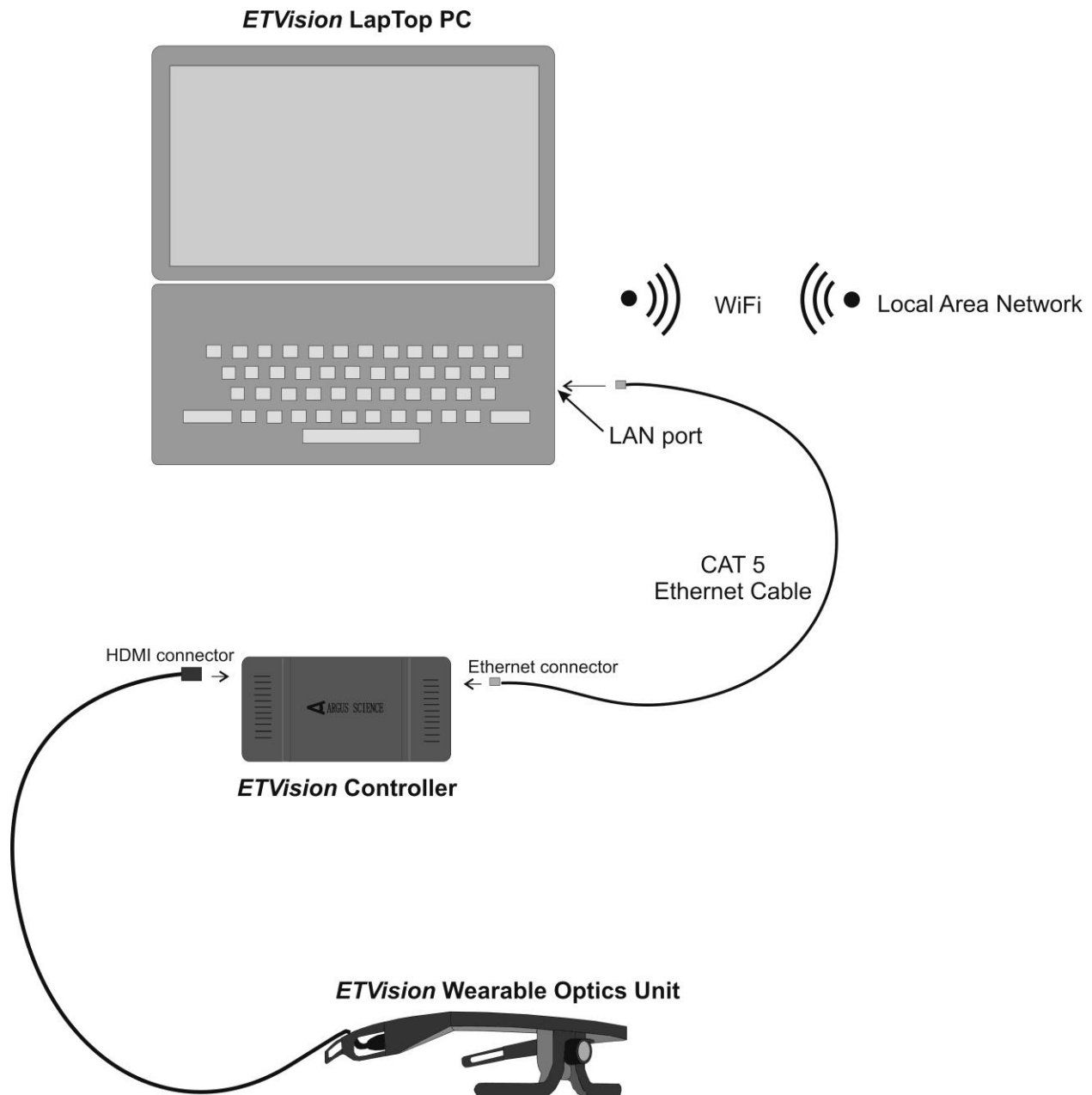
ETVision connection to External Device – Method 3
(All other connection are as shown in the "Basic System Interconnections" diagram)

If the ETVision PC was supplied by Argus Science as part of the system, *ETVision* will be set to always "load as administrator". If a cable connection between the Controller and the PC is detected, the system will automatically connect via the cable. If a cable connection is not detected, the system will automatically connect via WiFi. If the ETVision PC was not supplied with the system, or if the *ETVision* app is reset to not have administrator privileges, see Appendix E (section 9.5) for LAN setup instructions.

To connect ETVision to an external device using "Method 3" (last diagram, above), click the WiFi Network Icon in the Window 10 "system tray" (near bottom right of screen) to bring up a list of possible WiFi connections, and select an available WiFi access point. To once again use WiFi to connect the ETVision controller and PC, it will be necessary to close this connection. When connection to the access point is closed, the connection should automatically revert to "ETV*nnnn*" where *nnnn* is ETVision Controller serial number. If it does not, see section 9.5.2 for instructions to manually re-establish this connection.

5 Abbreviated Instructions

- **Be sure controller battery is charged, that controller is connected to optics unit, and that controller is communicating with *ETVision* PC** (see sections 7.1-7.3).

- **Position wearable optics unit on participant** (see section 7.5).
    - **Select proper nosepiece** (or no nosepiece) to insure that eye images are in correct position near vertical center of camera image
    - **If** nosepiece selection is **not sufficient** to position both eyes properly, **use the eye camera tilt adjustment** on one or both eyes to insure that both eye images are in acceptable positions (section 9.8).

- **Calibrate participant** (see section 7.6)
    - Do Auto Calibration (section 7.6.1).

        - Click Auto Calibration icon 	.
        - Have the subject fixate the black dot at the center of an Auto Cal target display.
        - When the auto cal target displayed on the ETV PC screen disappears, auto cal is complete. <u>If sufficient accuracy is observed, proceed to data collection</u>.
    - If auto cal target cannot be automatically recognized due to lighting conditions, or if more calibration points are needed for additional accuracy, do manual single or multiple point calibration .
        - Manual single point calibration (section 7.6.2)

            - Click manual calibration icon 	.
            - have participant fixate point near horizontal center and just below vertical center of scene camera image
            - Left click the point on the scene camera image.
        - <u>If needed</u>, add another 4 points
            - Have participant fixate points to upper left, upper right, lower left and lower right of center point, and click on each as it is fixated. (see section 7.6.3 for suggested position of 4 "corner" points).
        - Click active calibration icon 	 to close calibration mode.

- **Record gaze data directly on *ETVision* PC** (see section 7.8.1).

- **Or record eye and scene video to an SD card on the controller** (see section 7.8.2).

6 Eye Tracking Basics

To understand how eye tracking works, it is important to have a basic knowledge about the structure of the eye.

The *pupil* is an aperture, or opening, in the iris that allows light to enter into the eye. Unless viewed exactly on-axis with a light source, the pupil appears black.

The *iris*, which is the colored part of the eye, opens and closes to control the pupil size.

On its way to the pupil, light passes through the *cornea*, which is a thin, film-like tissue that covers the eye. The cornea is mostly transparent; however, some light is also reflected from the cornea.

The *sclera* is the white part of the eye.

ETVision uses a technique of eye tracking known as "Pupil to CR" Tracking. This method uses the relationship between two eye features, the black pupil and mirror reflections from the front surface of the cornea (Corneal Reflections, or CRs), to compute gaze within a scene.

Light from a pair of harmless near infra-red LEDs on the head gear illuminate the eye area. The near IR light is almost invisible to the user, so it does not cause a distraction, however it is visible to the eye camera. The mirror reflections of these light sources from the front surface of the cornea (CRs) appear in the camera image as a pair of bright dots.
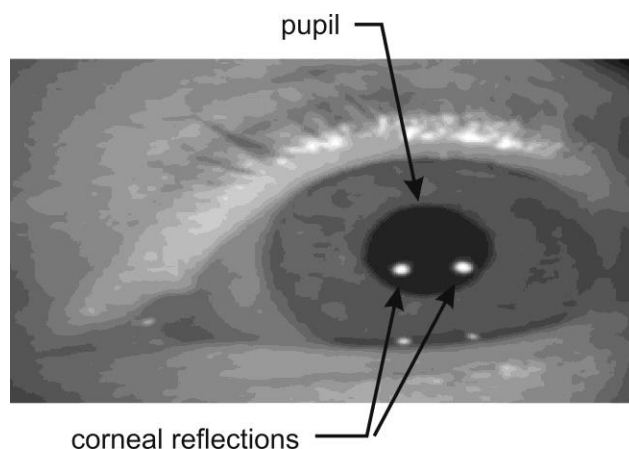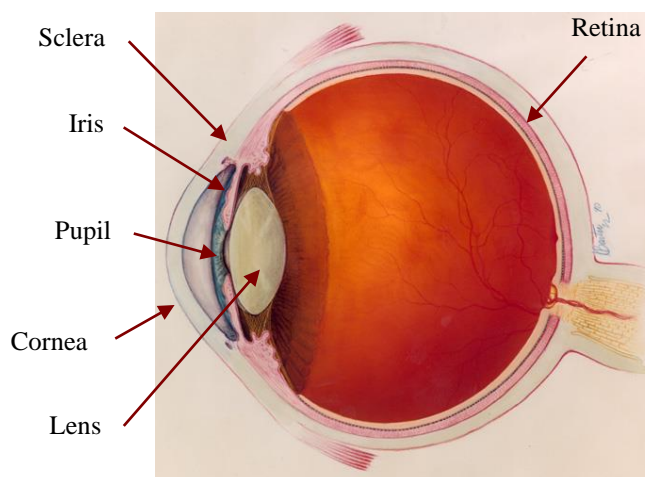
When the eye rotates in its socket, the center of the pupil moves relative to the spots. By comparing the relative position of the pupil and the CRs, the eye tracking system can compute the pointing direction of the eye visual axis relative to a coordinate frame centered at the scene camera. During periods when the headgear remains stationary on the head, eye gaze direction can also be computed from pupil or CR position alone, and this can allow the system to continue to compute gaze when only a subset of the eye image features can be successfully identified.

By computing the point at which the lines of gaze from the two eyes converge, the gaze point can represented as spot on the scene camera image.

Since the geometry of the eye structures and the position of the optics with respect to the face vary somewhat from person to person, gaze computation accuracy can be improved by incorporating data from calibration points (points at which the person wearing the optics is known to be fixating a particular point on the scene camera image). Excellent accuracy is often achieved with a single calibration point, but can sometimes be improved with additional points.

7 Basic System Operation

7.1 Charge Controller battery

To be sure that the Controller battery will have maximum use time fully charge the battery as follows.

- Connect the Controller power supply to the Controller and to the AC power source.

- If the power LED is off the battery is already charged. Disconnect the power supply, and proceed to the next section.

- If the power LED is white, the battery is charging. When fully charged the LED will turn off. (This may take up to 4.5 hours if the battery was fully discharged). Disconnect the power supply, and proceed to the next section.

- If the power LED is green or yellow when the power supply is connected this means that the system has been booted up (it is not in its idle state) and will not charge at the fastest rate. Press and hold the power button for 5 seconds and then release it to put the system in the "idle" state. The LED should turn off if the battery is already fully charged or white if the battery is charging. When fully charged the LED will turn off. (This may take up to 4.5 hours if the battery was fully discharged). Disconnect the power supply, and proceed to the next section.

When the Controller is communicating with the *ETVision* laptop application (see section 7.3) the battery charge percentage is displayed. Note that even if the battery is fully discharged, the system can be operated, and including all system functions, with the power supply connected to the Controller and plugged into AC power. The battery will charge in this case, but charging may take substantially longer than when the Controller is in the idle state.

7.2 Connect Controller to Wearable Optics Unit

Connect the cable extending from the optics unit temple clamp (ear piece) to the Controller HDMI port. After inserting the HDMI connector, use the setscrew on the Controller bottom panel, just below the HDMI connector, to secure the connector. Note that it is not necessary to "tighten" this set screw. Turn the setscrew just far enough for it to make contact with the connector and create enough friction to keep the connector in place. ***Remember to loosen the setscrew before trying to disconnect the HDMI cable from the Controller.***

7.3 Establish communication between Controller and *ETVision* application

If a LAN (CAT 5) cable is connected between the ETV PC and the ETV Controller, the system will communicate via the LAN cable. This is the most stable type of connection, but the participant is "tethered" to the laptop. If a LAN cable is not connected between these components, the ETV PC and Controller will communicate via WiFi. In this case the participant will be free to move about so long as the participant carries the Controller by wearing it on the provided belt or by some other means, and does not move beyond WiFi range from the PC.

7.3.1 Boot up Controller

Assuming the power supply is not connected to the Controller (battery only), the power LED will be off if the Controller is not yet booted up. Press the power button and release after 1 sec. The power LED should turn blue to indicate that the battery has at least a 15% charge and the system is booting. The boot process will take about 1 minute. The LED will remain blue after boot up is complete.

If the power LED turns red, this means that the battery has less than 15% charge. Either return the unit to idle and charge the battery as described in section 7.1, or plug in the power supply (LED will turn yellow) and proceed with the power supply connected.

7.3.2 Run the *ETVision* Application on the *ETVision* PC

Run the *ETVision* application either by clicking the *ETVision* application icon on the Win10 desktop or selecting "Argus Science->ETVision" from the Windows 10 Start menu. Note that it is also OK to launch the *ETVision* application before booting up the Controller (as described in the previous section). *Note: if ETV PC was not supplied by Argus Science as part of the system, see Appendix E for proper LAN and Wifi setup.*

The *ETVision* application will appear as shown below. A menu shortcut (tool) bar appears at the top, with two eye image windows just below it, and a scene image window below that.
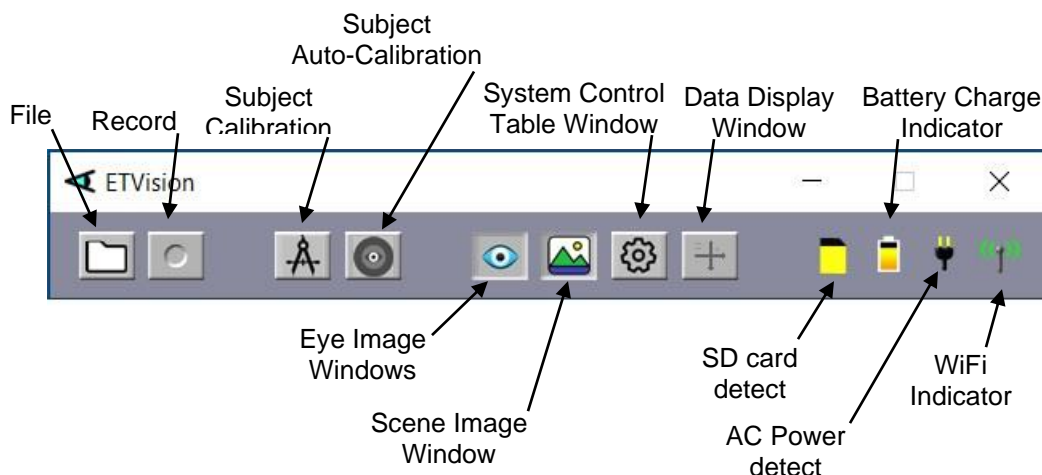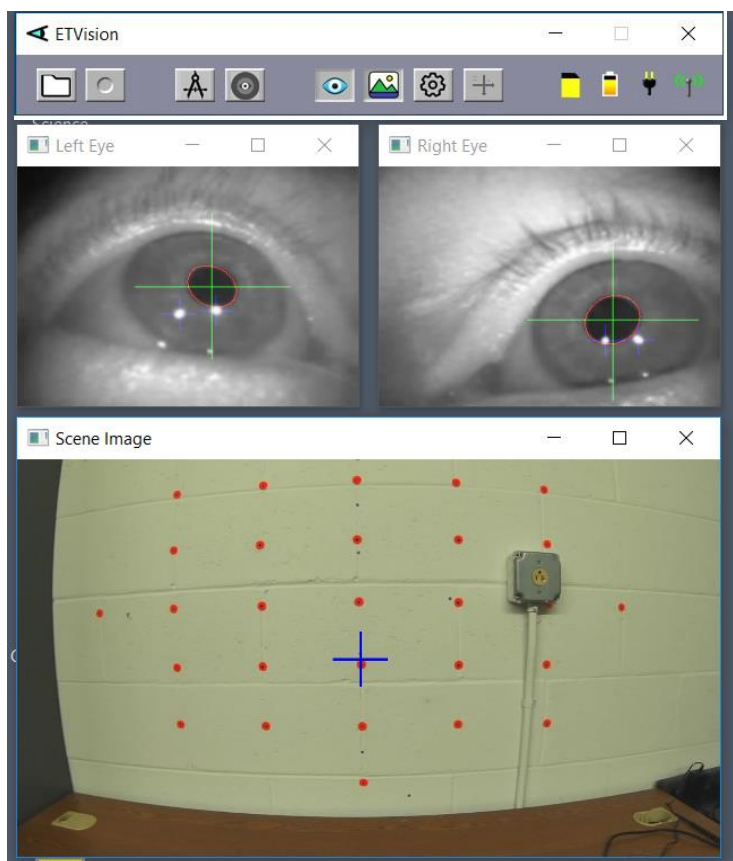
If the *ETVision* Controller has not finished booting, the three video windows (left eye, right eye, and scene) will be blank. Live video should appear in the video windows as soon as the Controller finishes its boot sequence.   The SD card indicator will appear only if an SD card is detected. The battery charge indicator will appear if there is either a LAN or WiFi connection to the Control Unit. The AC power detect indicator will appear only if the AC power supply is connected. The WiFi indicator will appear only if there is a WiFi connection to the Control Unit. If a LAN (as opposed to WiFi) connection is detected a LAN icon will appear in place of the WiFi icon.

Clicking the "Settings" icon on the *ETVision* tool bar will open a *System Control Table* window. If running *ETVision* for the first time after installation, the default settings should be in place and will be appropriate. These can be checked, if desired, as described in Appendix D (section 9.4).

7.4 Designate scene image objects to be tracked in real-time (Live Areas of Interest)

It is possible to designate objects in the scene camera image to be recognized and tracked in real-time. If "Gaze_LAOI" is checked on the *Data Selection* dialog (section 7.8.1.1), and real-time data is being streamed to an external device (section 7.9), the data will indicate to the external device when the participant's gaze is detected to be on one of the specified objects and which object it is on. A column on data files recorded by *ETVision* will also indicate when gaze falls within the boundaries of a recognized object.

Use of this feature is optional. It is not necessary to specify any image objects for real time tracking.

The "Live Areas of Interest" (LAOI) feature is usually used when some external device must react in real-time to gaze information received from the eye tracker. LAOI data on recorded files can also be used by the Argus Science *ETAnalysis* program to quickly display some basic statistics, and to create its own Moving Areas of Interest (MAOIs) for more detailed analysis. (See *ETAnalsis* manual for details).

The procedure for specifying scene image objects as "Live Areas of Interest" (LAOIs) in the scene image is described in detail in Appendix K (section 9.11). Note that LAOIs can be defined in advance, before a real test subject dons the optics frames. Once an image object is defined as an LAOI, an outline can be superimposed to indicate the area whenever it is recognized in the scene image, and the associate area name is displayed whenever gaze is within the LAOI. Check boxes on the Video Source dialog control whether this information is displayed on the real-time scene image and on recorded scene videos (see section 9.4.2).

Red outline showing that the clock is recognized as an LAOI

Indication that gaze is detected to be within the "clock" LAOI

POG cursor
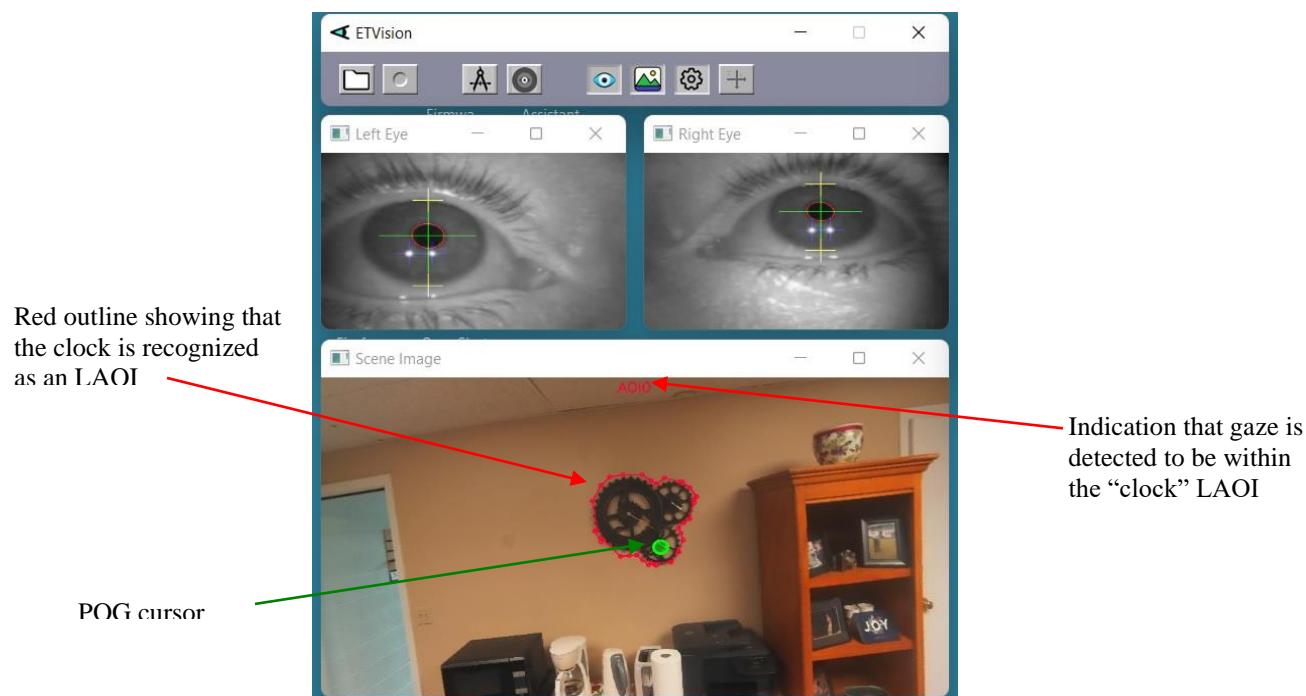
LAOIs <u>cannot</u> be defined once a data file is opened in ETVision. If a data file is opened, it must be closed before defining LAOIs.

The detection and tracking of image objects requires a variable amount of computer resources depending on the number of objects specified, the complexity of image content within the objects, and the amount of scene camera movement. Of course, performance also depends on the power of the PC being used as the *ETVision* PC. For best performance, it is suggested that the number of objects tracked be the minimum required.

7.5 Position wearable optics unit on participant

If desired, use the provided belt to fasten the *ETVision* Controller to the participant's waist. Alternately, have the participant hold the Controller in some other way, or support the Controller on a surface near the participant. Assuming indoor use, it is usually not necessary to use the optional filtered visor, but the visor may be used if desired. (See section 8 for outdoor use).

Have the participant put on the optics frame just as they would a pair of eyeglasses. If the participant is wearing prescription eyeglasses, the *ETVision* frame can simply be worn over the glasses as shown in one of the photos below.

When the subject is wearing the *ETVision* frame, the top of frame should be just above the eyebrows. If the person is wearing prescription eyeglasses, the bottom of the *ETVision* frame should be near the bottom of the eyeglasses frame. An image of the left and right eye should appear in the *Left Eye* and *Right Eye* windows, on the *ETVision* application. When the subject is looking more or less straight ahead, the iris and pupil of each eye should be more or less centered vertically in the window (although it need not be "precisely" centered). Correct positioning is shown in the photos and screen shots below. ***It is important that both eye images be vertically centered (at least approximately) when the subject is looking straight ahead.***
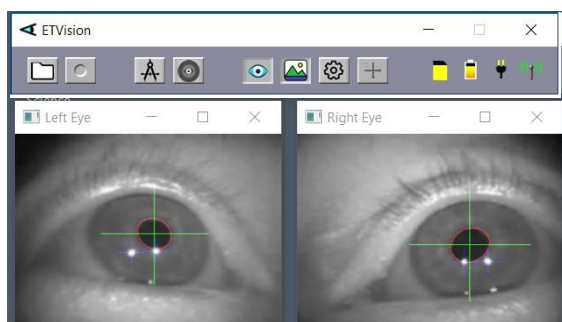
subject not wearing eye glasses
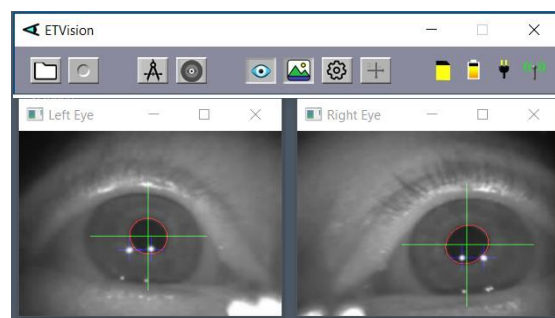
subject wearing eye glasses (note specular reflections near bottom inner corners)

If the *ETVision* frame is not positioned correctly on the face, as described above, bend the two sides of the nose piece for small vertical adjustments. For larger adjustments, select the alternate nosepiece or remove the nosepiece altogether to position the frame higher or lower on the face as necessary. It is suggested that the participant completely remove the frame before the nosepiece is swapped or removed. The photos, below, show examples of positioning that is correct as well as examples of positioning that is either too high or too low on the face.

Correct optics position

Correct optics position on subject with eye glasses

Optics too low (choose a taller nosepiece)

Optics too high (choose a shorter nosepiece)

In some cases, facial structure may be such that the optics frames are severely tilted on the face, and the two eye images appear in radically different vertical positions on the eye camera images. In this case, choose a nosepiece that properly positions one eye, and use the eye camera panel tilt adjustment to correct the position of the image on the other eye. Follow instructions in Appendix H (section 9.8) to adjust the camera panel tilt angle. In even more unusual cases, facial structure may be such that none of the nosepiece choices correctly position either eye. In this case both eye camera panels can be adjusted to properly position the eye images.

When the subject is looking more or less straight ahead both the eye pupils, and the corneal reflections (mirror images of the two LEDs that are directed towards each eye) should be visible as shown in the screenshot on the next page. System recognition of the pupil is shown by a red ellipse superimposed on the pupil boundary and a large green cross indicating the pupil center. Recognition of the corneal reflections (CRs) is shown by smaller blue crosses indicating their centers.

The yellow crosses show detection of the upper and lower eyelid boundaries just above and below the pupil center. Note that the upper and lower boundaries of the iris are often obscured by the eyelids. If the upper or lower boundary of the iris is visible, that boundary, rather than the eye lid boundary, might sometimes be indicated by the yellow bar. The vertical position of the upper and lower eyelid boundary markers (yellow crosses) are available as data items for recorded data files as well as streaming data, but are not default items and must be selected on the *Data Selection* dialog (see section 7.8.1.1).
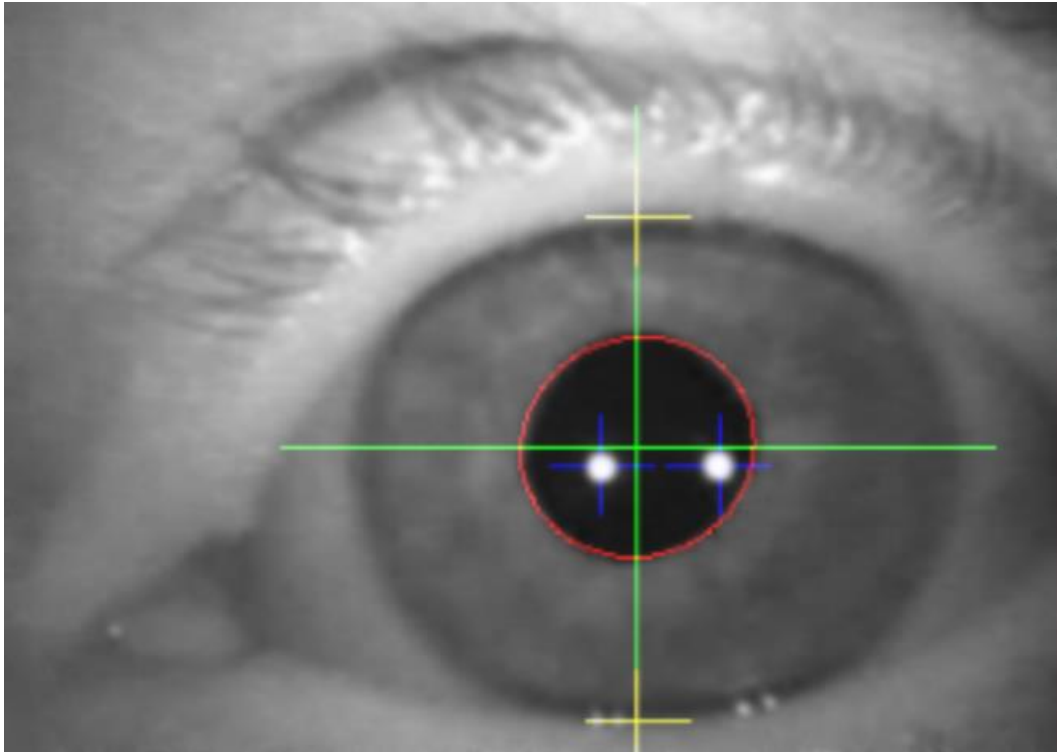
When the participant looks above the center of the scene camera field of view, or to extreme horizontal angles, one of both corneal reflections may reach the edge of the cornea or be obscured by an eyelid and become undetectable or unreliable. The pupil, however should usually remain visible and be stably detected by the system until eye angles become quite extreme. Of course, both the pupil and corneal reflections will be obscured during eye blinks.

The *Scene* window shows the image from the head mounted scene camera with a blue cross indicating the participant's point-of-gaze (POG). If both pupil images are being recognized, this cursor will probably be present, but may not be a very accurate representation of POG until subject calibration is performed, as described in the next section.

7.6 Calibrate participant

This section is a simple description of the recommended calibration procedure. A more complete description of the calibration function capabilities and options is presented in Appendix B (section 9.2).

The simplest and quickest procedure is the Auto Calibration described in section 7.6.1. It is suggested that this be used first and that manual procedures described in sections 7.6.2 and 7.6.3 be used only if Auto Cal results are not satisfactory.

7.6.1 Auto Calibration

Once Auto-Calibration is activated, the participant simply has to fixate the black dot at the center of a red and blue target pattern. The system will recognize both the target and steady gaze near the target and will automatically complete a single point calibration.

The target pattern is displayed on the ETV PC screen when Auto-Calibration is activated, and is also provided as a bit map image file that can be printed as well as one that can be displayed on a cell phone screen. (Consult Argus Science for link to download the Auto-Calibration Target image files).
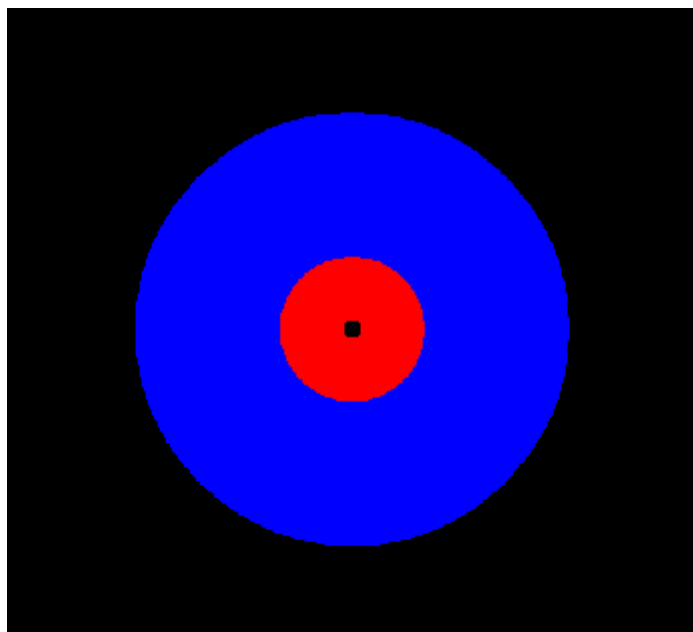
First, be sure the wearable optics are properly positioned as described in section 7.4.

To use the Auto-Calibration feature proceed as follows:

1. Click the "Subject Auto-Calibration" icon ⊙ on menu bar. The Icon will change from gray scale to a color image ⊙ to show that Auto Cal is active, and an Auto-Calibration target will appear in the data display window, to the right of the scene image window.
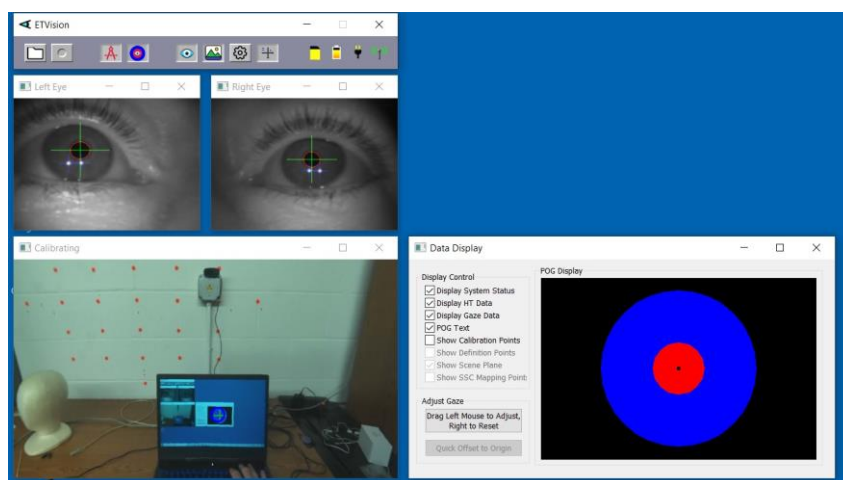
2. Have the subject hold their head so that a target display (either on the ETV PC screen, a paper printout, or a cell phone screen image) is about arms length from their face and near the center of the ETV scene image, and ask them to fixate the black dot at the center of the target image.

3. The ETV system will indicate recognition of the target by placing a small yellow cross over the target image on the scene image window. When the system detects that gaze is near the target and steady, calibration data will be automatically entered, the target displayed on the ETV PC screen will disappear, and the Auto-Calibration icon will return to a gray scale image.

4. Check calibration accuracy by asking the subject to look at some landmarks or targets visible in the scene image and observing the accuracy of the point-of-gaze cursor.

In most cases, a single point calibration using the Auto-Calibration Target as described above will provide sufficient accuracy over the visual field of interest. **If Auto-Calibration results are satisfactory, proceed to section 7.7.**

As described above, system recognition of the Auto-Calibration target is indicated by a yellow cross, superimposed on the center of the target image on the *Scene Image* window. If lighting conditions or other factors make it difficult for the ETV system to recognize the Auto-Calibration target (yellow cross does not appear on target center), a manual single point calibration can be done as described in section 7.6.2.   If accuracy over the required visual field is not satisfactory after Auto-Cal, or after a single point manual calibration, the manual calibration procedure described in section 7.6.3 allows additional calibration points to added.

7.6.2 Single Point Manual Calibration

If the Auto-Calibration described in the previous section produces satisfactory results, proceed to section 7.7. Otherwise proceed as described below.

Sections 7.6.2 and 7.6.3 describe the recommended procedure for manual single and multiple point calibrations. A more complete description of the calibration function capabilities and options is presented in Appendix B (section 9.2).

To be sure that *ETVision* is set for the default manual calibration procedure described in this section, click the "Settings" icon if necessary to bring up the *System Control Table* window and select the "Subject Calibration" tab. Be sure "Calibration Type" is set to "Click on Scene Image Points", and "Total Calibration Points" is set to 9. Note that this does not mean that nine calibration points must be used, but rather that the maximum number of points is 9.

Click the Calibrate icon ⬧ on the *ETVision* tool bar. The Calibrate icon will turn red to indicate calibration in progress. At this point the blue POG cursor on the *Scene* window will probably begin to move in the same pattern as the participant's gaze, but will often be significantly displaced from actual gaze points. A yellow cross will show the position of the first point used in the previous calibration, and gray crosses will show other points used in the last calibration. This is for information only. The same positions <u>do not</u> need to be used for the current calibration.

1. **Have the participant hold their head still and look at a point near horizontal center and at or just below the vertical center of the scene camera image (somewhere within the yellow circle on the scene camera image below).** This can be done by asking the person to fixate an existing visual target in the environment or by asking the person to fixate the tip of a pointer (or laser pointer spot) being positioned by the equipment operator or an assistant. Theoretically the target can be at any distance from the participant, but it is usually most convenient to use visual targets that are 2 or 3 feet (1/2 to 1 meter) away.
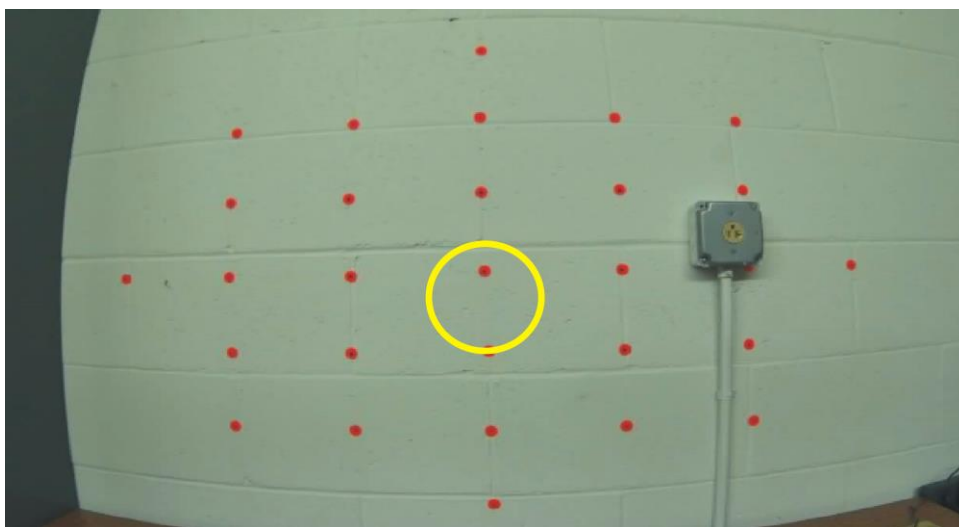
Yellow circle shows approximate area on the scene image within which a target point should usually be located for single point calibration.

If the person is asked to fixate an existing visual target in the environment it may be necessary to have them rotate their head a bit either up or down, or side to side, so that the target point appears near or slightly below the center of the scene camera image. If the participant is asked to look at the tip of a pointer, it is usually easiest if the person holding the pointer can also see the ETV PC screen so that they can hold the pointer tip at the right place.

When the subject looks at the requested central visual target the *Left Eye* and *Right* Eye windows should indicate that the system is recognizing the pupil and the corneal reflections for both eyes.

2. **In the *Scene* window, left click on the target that the participant is attempting to fixate.** A small green cross will appear at that point in the *Scene* window, and the blue POG cursor should jump right to that visual target and remain there until the subject looks away from the target. If the blue cursor jumps to some different position (for example, if the subject blinks or looks away from the point just as the mouse is clicked) right click on the same spot to "undo" the data entry, and repeat steps 1 and 2.

3. **Check for satisfactory performance over the desired visual field region**. Have the subject look at visual targets at several points within the scene image area that will important for the experiment or task and notice whether the blue point-of-gaze cursor correctly indicates the points being fixated.

4. **If performance is suitable for the task at hand click the "Calibrate" icon to close the calibration procedure** ("Calibrate" icon will revert to black), and proceed to section 7.7. **Otherwise, add calibration points** to improve accuracy as described in the next section.

7.6.3 Adding Calibration Points if Needed

A single point calibration as described in the preceding section will often result in better than 1 degree accuracy over the central 40 degree diameter field of view, and sometimes beyond that range. The yellow outline shows approximately the central 40 degree diameter field of view.
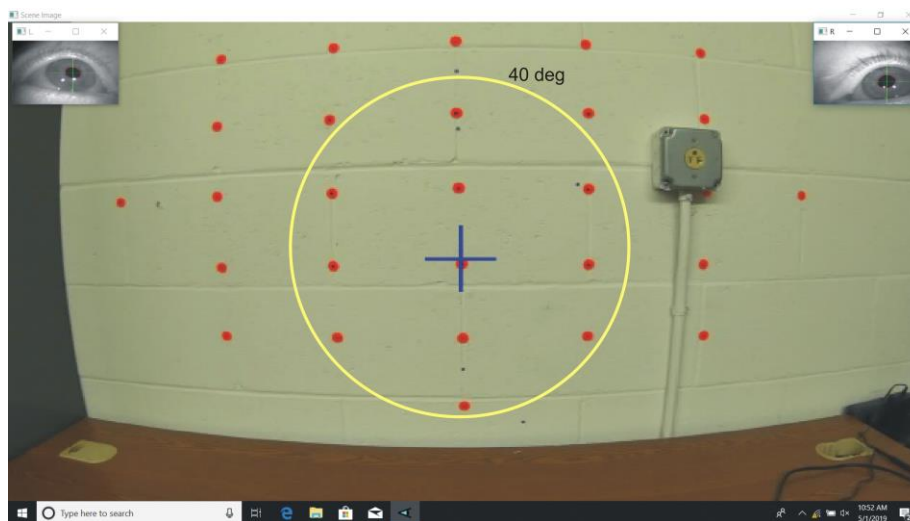
If the point-of-gaze measurement error tends to grow significantly as the subject looks away from the central point, accuracy can usually be improved by adding calibration points.

Not all tasks require that gaze point be known with maximum accuracy, and sometimes very rapid calibration may be more important than best possible accuracy. If measurement accuracy is judged to be suitable for the task at hand, the user may elect to close the calibration procedure (click the "Calibrate" icon so that it reverts to black) and proceed with data collection, etc.

If, after the single point calibration, accuracy needs to be improved, it is suggested that at least an additional 4 calibration points be added in approximately the positions indicated by the yellow circles superimposed on the *Scene* window screen shot below. Note that these points are 15 to 20 degrees visual angle from the center of the scene camera field of view.
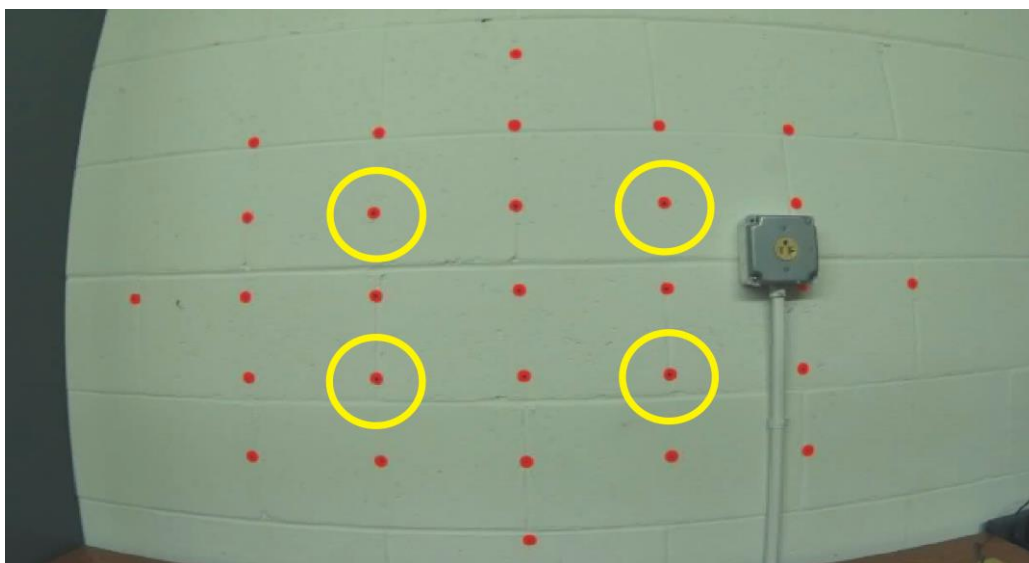
Yellow circles show approximate areas on the scene image within which additional 4 target points should usually be located.

1. <u>Do not</u> close the calibration procedure after the single point calibration described in the previous section (Calibrate icon should remain red).

2. Ask the participant to continue holding their head fairly still and look at a visual target at one of the 4 positions shown in the screen shot. As with the single point calibration, it can be an existing target in the visual environment or the tip of a pointer device, etc. Also as with the single point calibration, the subject can be asked to rotate their head slightly to ensure that visual targets appear at the appropriate positions in the scene camera image.

3. Left click on the point in the *Scene* window. A small green cross will appear at that point in the *Scene* window, and the blue POG cursor will usually move slightly closer to the true point of gaze. As with the single point calibration if the blue POG cursor jumps to a point

significantly farther away (probably because the subject blinked or looked away just as the data was entered) right click to "undo" the data entry and repeat steps 2 and 3.

4. Repeat steps 2 and 3 for the other three points. Note that the eye pupils must be recognized for all of the points. The corneal reflections should be recognized on the bottom 2 calibration target points, but often may not be recognized on the top two points, and this is OK.

5. Check for satisfactory performance over the desired visual field region as previously described. If satisfactory, click the "Calibrate" icon to close the calibration procedure ("Calibrate" icon turns black) and proceed to the next section.

The procedure described above should almost always result in good measurement accuracy with in the visual field enclosed by the boundary connecting the outer 4 calibration points. Accuracy will often be quite good significantly beyond this range, but error may sometimes increase significantly as the subject looks progressively farther away from this region. In this case, accuracy can usually be improved, before closing the calibration procedure, by adding an additional 4 points approximately in the areas shown by the red circles, below. Simply repeat the procedure described above for these points before clicking the Calibrate icon to close the calibration procedure.
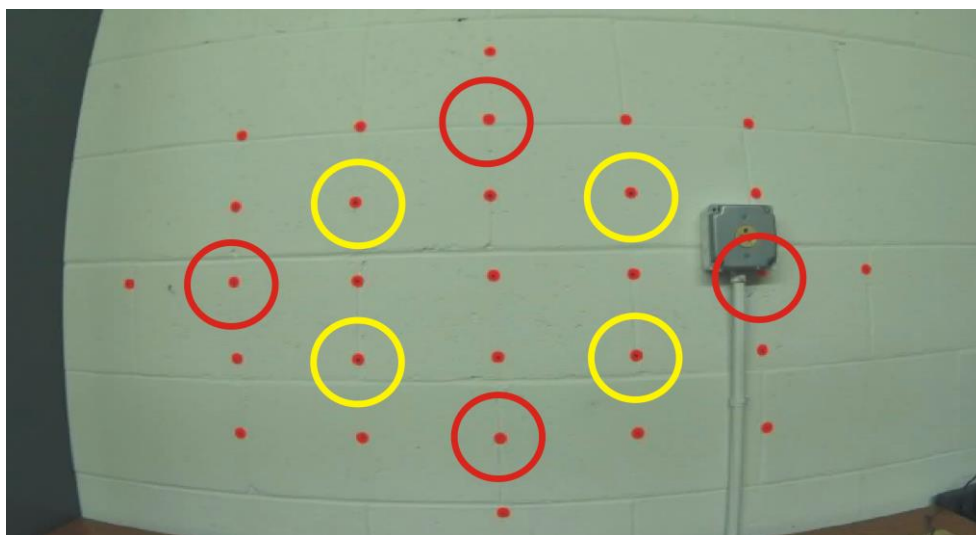
Red circles show suggested areas for calibration target points 6-9.

With default settings, the maximum number of calibration points is 9. (This maximum value can be changed as described in Appendix B). Additional left clicks on the Scene window, beyond 9 points, will result in the point closest to the click being replaced by the new click. Once the Calibrate procedure is closed (black "Calibrate" icon), the current calibration cannot be modified. If the calibration process is re-opened, by clicking the "Calibrate" icon, the current calibration result is deleted and the process begins again "from scratch".

After each calibration point is entered (left mouse click), a "confidence" value for that point appears in the scene window title bar. Proper interpretation of the "confidence" value is discussed in Appendix B.

The current and previous sections describe the most common (and recommended) use of the calibration procedure. The system actually allows far more flexible use of the calibration function and a more complete description is in Appendix B.

7.7 Monitor gaze data and system status

As long as the *ETVision* laptop is connected to the *ETVision* Controller with a LAN cable, or remains within WiFi range (approximately 150 ft in absence of interference), point of gaze and eye image feature recognition, as well as battery charge and data recording status can be monitored in real time on the *ETVision* application. Gaze data is monitored by observing indicators superimposed on the *Left Eye*, *Right Eye*, and *Scene Image* windows, and if desired by a plot shown on a *Data Display* window.

7.7.1 Status Indicators

Battery charge is indicated by a battery icon towards the right side of the *ETVision* tool bar. "Hover" the mouse over the battery icon to see a battery charge percentage value. The charge values are displayed to the nearest 5%. Similarly, an SD card icon indicates that an SD card is detected, and when the mouse hovers over this icon, the percentage used is displayed. A symbol at the far right of the tool bar indicates whether there is a WiFi ⏶ or LAN ⏶ connection to the Controller. Hovering the mouse over either of these symbols will show the Controller firmware version

7.7.2 *Left Eye* and *Right Eye* windows

The images from the left and right eye cameras are displayed in real time on the *Left Eye* and *Right Eye* windows. These windows are opened by default but can be closed, re-opened, or embedded in the scene image by clicking the "Eye" icon on the menu bar. The Eye icon has 3 different forms and is really a 3 way toggle switch. The standard view icon ⏶ indicates that the two eye widows are opened, as in the screen shot below.
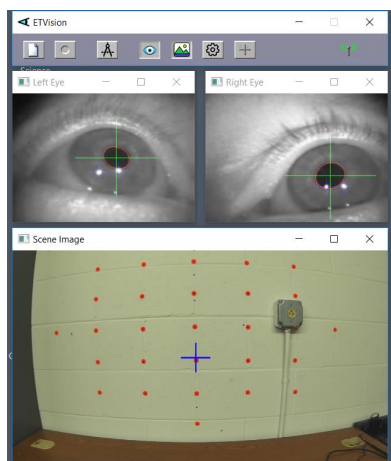
Clicking the standard view icon will change its form to the "embedded view" icon . In embedded view, the two eye images, rather than appearing in their own windows, are embedded at the corners of the scene image, as shown to the right. When in embedded view, the eye images are part of the scene video image and scene video recordings will contain the embedded eye images
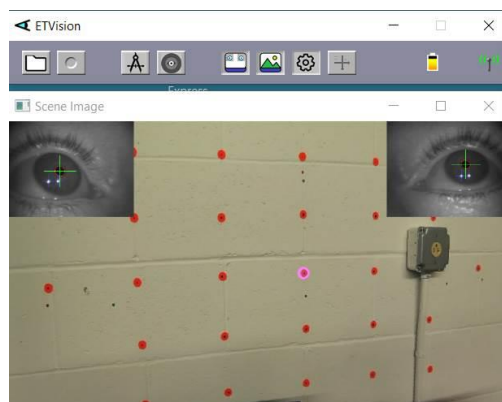
Clicking the embedded view eye icon will cause it to change to an "eye image closed" icon . In this case the eye images will not be shown at all. Clicking the eye image closed icon returns to the standard eye image windows view.

In embedded mode, the relative transparency of the scene and eye images can also be adjusted. Click the "System Control Table" icon to bring up the *System control Table* dialog, and select the "Video Source" tab. The slider labeled "Transparent" controls the transparency of the scene image. When the slider is all the way to the right (100%) the scene image will be completely transparent and will not cover the eye images at all. When the slider is all the way left (0%) the scene image will be completely opaque and the eye images will not be visible. At positions in between the scene image will be partially visible over the eye images.
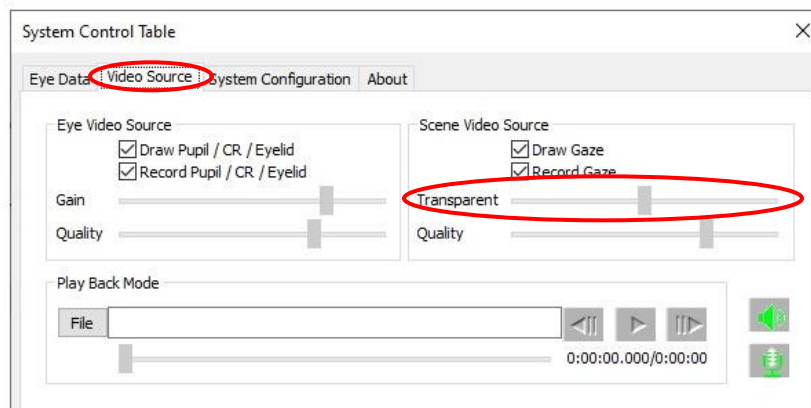
Whether eye images are shown in standard windows view or embedded view, pupil recognition is indicated by a red ellipse outline to show the detected pupil outline and a large green cross to indicate the center of the ellipse. Yellow crosses show detection of the upper and lower eyelid boundaries just above and below the pupil center. If pupil is not being properly recognized, the red ellipse outline will unstable or will form around the incorrect feature, and the green cross will not be in a stable position over the pupil center. The yellow eyelid boundary crosses may sometimes indicate the upper or lower iris boundary, if this is visible, rather than the eyelid. These feedback indicators can disabled for the real time eye window displays by unchecking the "Draw Pupil / CR/ Eyelid" check box, on the *System Control Table* "Video Source" tab; and can be disabled for recorded eye video files by unchecking the "Record Pupil / CR/ Eyelid" check box.

If in standard Windows view, either eye window can be moved by dragging the title bar, can be resized by dragging a corner of the window, or can be set to "full screen" by clicking the "maximize" symbol on the Eye window title bar. When "maximized" the selected Eye window will show as full screen, with the other eye window in one top corner and the Scene image window in the opposite bottom corner. Clicking anywhere within the full screen Eye window will cause it to cover the

alternate eye image and the scene image window displays. Click the "restore" icon to return the window to normal size.

Although the eye video data is actually updating 180 times per second (and point-of-gaze is computed and recorded 180 times per second), the *Left Eye* and *Right Eye* video displays on the laptop update at 30 Hz.

7.7.3 *Scene Image* window

The image from the head mounted scene camera is displayed in real time on the *Scene Image* window. Point-of-gaze, computed using binocular eye image data, is displayed as blue cross, superimposed on the image. This window is opened by default but can be closed and re-opened by clicking the "Scene" icon on the menu bar. After calibration the point-of-gaze (POG) cursor, superimposed on the scene video image, should accurately show the subjects instantaneous point-of-gaze so long as the eye pupils are correctly detected.   (For some subjects, the pupil may not be detectable or pupil detection may not be stable when they look at extreme positions near the edges or corners of the scene image field.)   The POG cursor can be either a cross or a circle with user adjustable size, line weight, color, and transparency. An adjustable smoothing filter is also applied to the POG cursor. Controls for POG cursor appearance and adjustable smoothing filter are accessed from the *System Control Table* window, "System Configuration" tab, "Advanced Configuration" dialog (see section 9.4.4.5 in Appendix D).
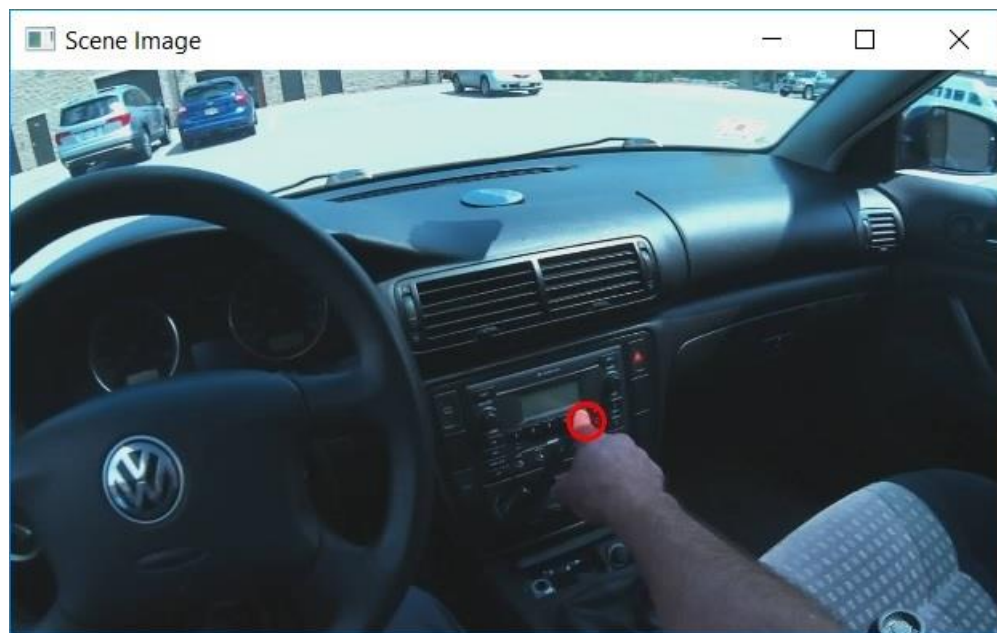
In the screen shot, above, the POG cursor is the red circle near screen center

The *Scene Image* window can be moved by dragging the title bar, can be resized by dragging a corner, or can be set to "full screen" by clicking the "maximize" symbol on the *Scene Image* window title bar. Click the "restore" icon to return the window to normal size.

If the *Scene Image* window is maximized when eye image windows are in standard mode, the left and right eye windows are displayed at the upper left and right corners. In this case the eye images are separate windows which can be independently manipulated, and left clicking anywhere on the maximized *Scene Image* window display will cause it to cover the eye window displays.   If the *Scene Image* window is maximized when eye images are in embedded mode, they are simply part of the maximized scene image and cannot be independently manipulated, although relative transparency can be adjusted as described in the previous section.

The *Scene Image* window display updates 30 times per sec. The underlying scene image is 1280x720 pixels (as is the resolution of the scene video file recordings). Resolution of the maximized real-time *Scene Image* display on the *ETVision* application may be slightly different depending on the laptop screen resolution.

7.7.4 *Data Display* window

Click the "Data Display" icon ⊞ to bring up the *Data Display* window. It will first appear to the right of the normal *Scene Image* window, but can be moved and resized in the usual way. It can also be "maximized" to full screen and "restored" using the icons on the title bar. Click the "Data Display" icon again to close the window.

The *Data Display* window shows point-of-gaze with respect to the scene camera graphically, as a real-time X-Y plot point, and also displays real-time digital values for data computed by the system.

The "POG Display" area plots point-of-gaze as a moving spot on a display area that represents either the two-dimensional head mounted camera scene space or, if in *ET3Space* mode, the current scene plane surface. The same adjustable smoothing filter applied to the *Scene Image* window POG cursor is applied to *Data Display* window POG display (see section 9.4.4.5 in Appendix D). 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. Note that the X-Y plot essentially duplicates the movement of the point-of-gaze cursor in the *Scene Image* window (described in the previous section), but without the background image.
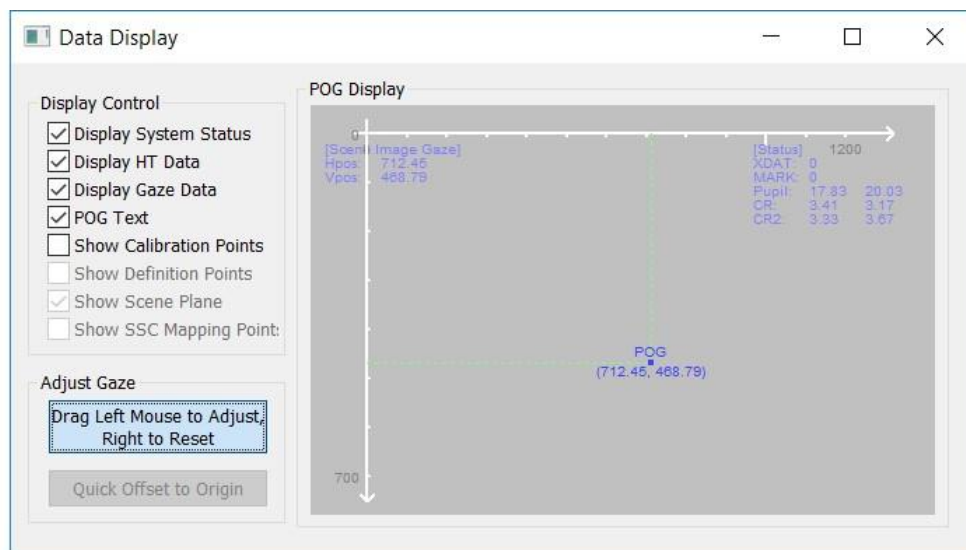
The real time digital values appear within the POG (point-of-gaze) plot display. If the "Display Gaze Data" check box is checked, the gaze position values are displayed at the upper left corner of the POG display. These values represent a position with respect to the 1280x720 scene camera image, reported to the nearest hundredth. The upper left corner of the scene camera field has coordinates (0.00,0.00), the lower right corner is (1280.00, 720.00), center is (640.00, 360.00), etc. If the "POG text" box is checked, the same information is displayed just below the point-of-gaze dot on the X-Y plot.

If the "Display System Values" check box is checked, a set of additional values is displayed at the top right corner of the POG display. These include external data values, manual event mark values, pupil diameter values for both eyes, and corneal reflection (CR) diameter values for both CRs on each eye.

XDAT values are external data values that can optionally be sent by an external device via LAN connection. Network communication protocol is described in a separate "Network Communication" manual. Manual data event marks can be set from the System Control Table window, "Eye Data" tab. Either click one of the "Quick Mark" buttons, use the up or down arrow to increment or decrement the current value, or type in a value and press the <Enter> key.

Pupil and CR diameter values are expressed in "eye camera units" based on an eye camera coordinate space of 320 horizontal by 240 vertical. Pupil diameter is the length of the major axis of the ellipse that is fit to the pupil outline. (Note that a circular disk appears elliptical when viewed at an angle; but the length of the major axis does not vary with the view angle). When the pupil or a CR is not recognized, the diameter value is replaced by "loss".

Check boxes at the top left of the window are used to select or de-select various display items, and most of these have already been mentioned above. If a separate head-tracking device is communicating with *ETVision* the head position and orientation data can be displayed at the bottom left of the POG display, and the "Display HT" box determines whether or not the head tracking data will be displayed. (Head tracking devices are usually used as part of the optional *ET3Space* function and are discussed in a separate *ET3Space* manual). If the "Show Calibration Points" box is checked, the position of manually entered calibration points (from the most recent manual calibration) are shown as "X" marks on the plot. Other check boxes apply only to the optional *ET3Space* function and are explained in the separate *ET3Space* manual.

The "Adjust Gaze" buttons at the lower left of the window are used for a manual gaze data offset feature that is explained in section 7.7.6.

If the manual offset function has not been enabled (see section 7.7.6), 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.

7.7.5 Window Control

All *ETVision* windows can be moved by dragging the title bar, can be resized by dragging a corner, or can be set to "full screen" by clicking the "maximize" symbol on the *Scene Image* window title bar. Click the "restore" icon to return the window to normal size.

When the *Scene Image* window is maximized, the left and right eye windows are displayed at the upper left and right corners. Left clicking anywhere on the maximized *Scene Image* window display will cause it to cover the eye displays. Similarly, when an Eye window is maximized the selected Eye window will show as full screen, with the other eye window in one top corner and the Scene image window in the opposite bottom corner. Clicking anywhere within the full screen Eye window will cause it to cover the alternate eye image and the scene image window displays.

Clicking the "X" at the upper right of any *ETVision* window title bar will individually close that window. It can be re-opened by clicking the associated icon on the *ETVision* menu bar. Clicking the "minimize" icon on one the windows will hide that window. In this case it can be restored by clicking the "ETVision" icon on the Windows 10 task bar twice. The first click will hide the entire *ETVision* app and the second will restore all currently opened windows in the app.

7.7.6 Manual offset correction

If, sometime after subject calibration, gaze data appear to be in error by a constant amount, for example always slightly to the right of the object being fixated, this can be corrected without repeating the calibration process. Such an offset error might be caused by a significant change in pupil diameter after calibration.

On the *Data Display* window, 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* window 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 whenever 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 accidentally creating offsets, click the button to un-depress it.

The Manual offset correction feature can be used even while recording data on *ETVision*, as described in section 7.8.1.

7.7.7 Monitor Battery Charge

When the battery charge level drops below 15%, the battery LED on the Controller will turn red. If this LED turns red, or if the battery indicator on the *ETVision* PC application shows less than 15% battery charge, it is recommended that either the power supply be connected to the Controller and plugged into AC power, or alternately that any opened data files be closed and the Controller be

recharged as described in a previous section. If the battery charge drops significantly below 15% the voltage may become too low for proper operation and the system will automatically shut down.

7.7.8 Audio

Audio picked up by the microphone in the optics frame can be heard, if desired, on the *ETVision* PC speakers. If headphones are connected to the *ETVision* Controller, audio picked up by the PC microphone can be sent to the headphones. These features can be individually enabled or disabled, and may be very useful in environments where the participant and the equipment operator cannot easily hear each other directly.

The *ETVision* PC microphone and speaker are enabled or disabled from the "Video Source" dialog on the *System Control Table* window. Click the "System Control Table" icon, on the *ETVision* menu bar to open the *System Control Table* window, then select the "Video Source" tab. The speaker symbol and microphone symbol at the lower right of the dialog are enabled when green and disabled when red. Click the each symbol to toggle between states.
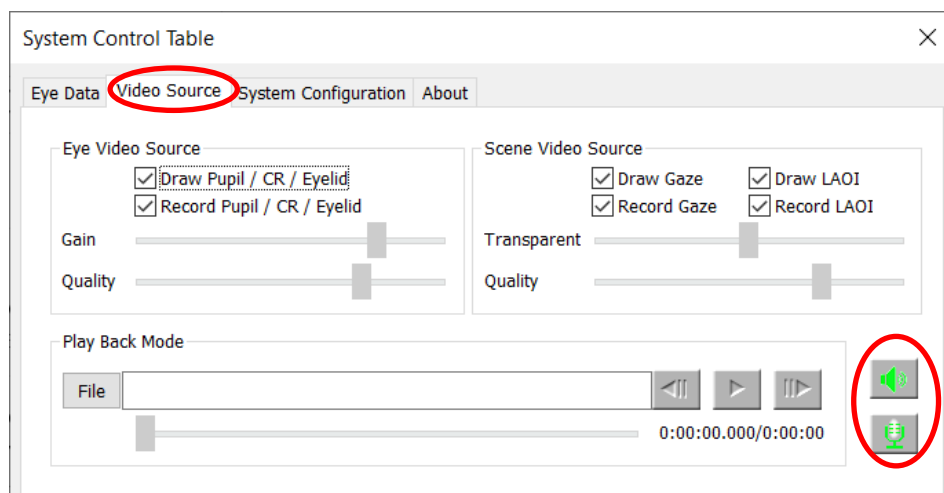
If the PC speaker is enabled, sounds detected by the wearable optics unit microphone will be heard on the PC speaker. The microphone gain can be adjusted with a slider control at the bottom left of the *Advanced Configuration* dialog (click the Advanced Configuration button on the *System Control Table* window "System Configuration" tab to open the *Advanced Configuration* dialog). Note that audio detected by the wearable optics microphone is always recorded on the scene video file whether or not the PC speaker is enabled.

If the PC microphone is enabled, audio detected by the microphone will be recorded on scene video files (data and video recording is described in the next section).

In order for audio from the PC microphone to be heard on headphones connected to the Controller, it is also necessary to enable audio "broadcasting". To enable audio broadcasting first select the "Eye Data" tab on the *System Control Table* window. In the "Real-Time Input/Output" box, at the top right of the dialog, click the "Configuration" button. This will bring up a *Network Configuration* dialog. Check the "Broadcast Audio" box, near the center of this dialog, to enable audio "broadcasting". Note that two conditions are required for audio to be heard on Controller headphones: PC microphone

enabled, and audio broad casting enabled. If the equipment operator wants to make comments that are recorded on the scene video file but are not heard by a participant wearing headphones, enable the PC microphone, but do not enable audio broadcasting.

7.8 Record data

Point of gaze with respect to the scene camera image, pupil diameter, and other computed values can be directly recorded, in real-time, by the *ETVision* application. Alternately, video data can be recorded by the Controller, on a micro SD card, for subsequent playback on the *ETVision* application.

7.8.1 Record gaze data directly on ETV PC

If the *ETVision* application is connected to the Controller via LAN cable, or is connected via WiFi and remains within WiFi range, both digital and video data can be recorded by *ETVision* in real-time.
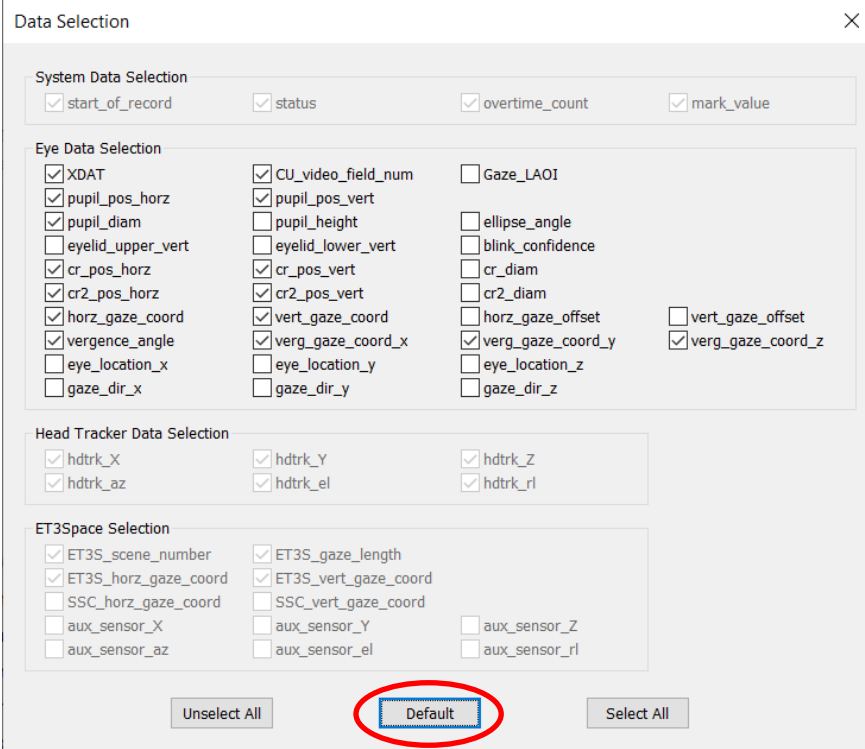
Open the *System Control* Table window (if not already opened) by clicking the *System Control* Table icon. Click the "Eye Data" tab. To record video data along with the digital data file, check the "Auto-Record" box or boxes, in the "Record Data File" group, corresponding to the desired video files. It is recommended that "Auto-Record Scene Video with Data File" always be checked. Note that if the eye image display is in embedded mode (see section 7.7.2), embedded eye images will be part of the scene image video file.
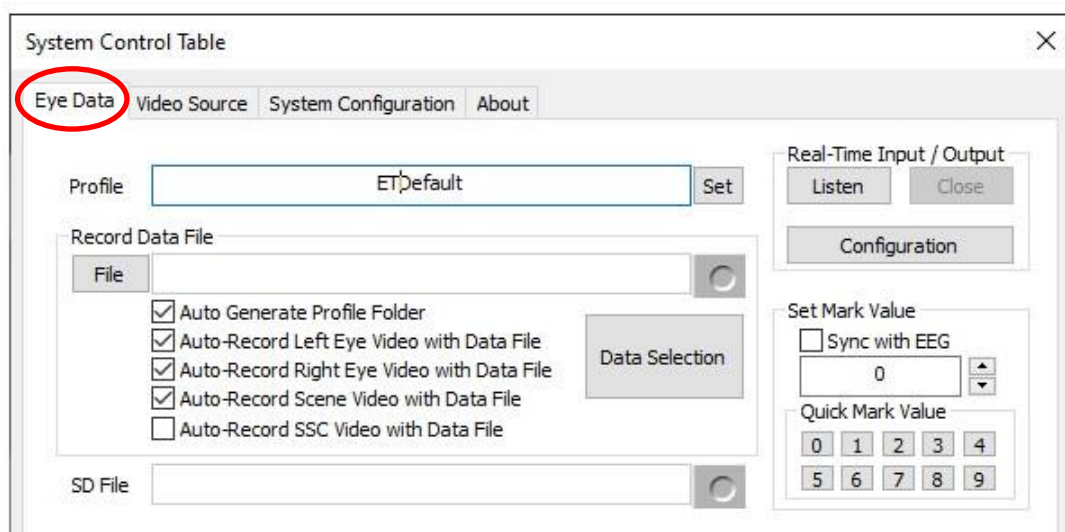
The user also has the option of including or not including the blue point-of-gaze cursor on the recorded scene image. If *ETAnalysis* or some other application will be used to superimpose gaze feed back on the recorded scene image video, it may be less confusing to <u>not</u> also have the real-time gaze cursor permanently superimposed. This is controlled by a "Record Gaze" check box on the "Video Source" tab. See section 9.4.2.2 for more details.

7.8.1.1 Select the data items to be recorded

On the *System Control Table*, "Eye Data" tab, click the "Data Selection" button, under the "Record Data File" group, to select the data items to be recorded on the digital file. A "Data Selection" window will appear. A "Default" button at the bottom of the window will select the recommended data item set. Individual data items are explained in Appendix C.

7.8.1.2 Record data and video

Click the File button, under "Record Data File (or click the file icon on the main menu bar) to bring up a standard browser window and navigate to the desired destination directory if different from the folder shown. If the "Auto Generate File Folder" check box is <u>not</u> checked, the data file and video files will be opened in the folder shown by the browser. If the "Auto Generate File Folder" check box <u>is</u> checked, a folder with the profile name will be created (or opened if it already exists) within the folder indicated by the browser, and the data and video files will be created in that subfolder.

For normal use, <u>be sure that "Save as Type" is set to "ETVision Files(*.eyd)"</u>. If it is not, use the pull down menu to select this setting. The "eyd" file is recorded in a binary format, which is described in Appendix C (section 9.3).

Although binary eyd format is recommended for most applications, it is also possible to record data in "csv" text format (rather than "eyd" binsary format) and this is described in Appendix I (section 9.9).

> *(It should be noted here that Argus Science offers an optional feature, called ET3Space, which combines gaze data with information from a separate head tracking system. ET3Space files binary files have an ".ehd" extension, and this becomes the default file type when ET3Space is enabled. This is discussed in a separate ET3space manual).*

Click "Save" to use the default file name shown, or type in a modified file name before clicking "Save".

A *File Description* window will pop up. Type in a description if desired, or just leave this blank, and click "OK" to close the window. Any description entered will be included in the digital file header. *Note that if the subject calibration mode is opened (calibrate symbol on subject calibration icon appears red) opening a data file will automatically close the calibration mode.*

To change the profile name, before clicking the File button type a new name in the box next to the "Profile" label, and click "Set". Then use the File button to select a path and file name as previously described.

Once the data file is opened, the "File" button will change to a "Close" button and a button with a red "Record" symbol will appear to the right of the file name. The menu bar file icon will also change to an "opened file" symbol and a red "Record" symbol will appear just to the right of the "opened file" symbol. To start recording data simply click the "Record" button on either the "Eye Data" dialog or the main menu bar. The button will change to show a "Pause" symbol. If any of the video Auto-Record boxes are checked, the corresponding video files will begin recording at the same time. Video files will have the same file name as the digital data file, but with "_Leye", "_Reye", or "_Scene" appended to the end of the name, and a ".wmv" file extension.

To pause recording, click the "Pause" button on either the "Eye Data" dialog or the main menu bar. Recording of the digital as well video files will stop and the button will once again show the "Record" symbol. To resume recording on the same files, click the "Record" button. To close the files, click the "Close" button on the "Eye Data" dialog or click the "opened file" symbol on the main menu bar.

When recording is paused and then resumed on a single file, multiple data "segments" are created on the digital (eyd) file, and this file keeps track of the start and end times of each segment.

Digital (eyd) files record 180 data samples per second and are recorded in a binary format. The files can be read and processed by the Argus Science *ETAnalysis* program which can also translate the binary data to a text file. Use of *ETAnalysis* is fully explained in a separate manual. The binary files can also be read by a user created application using the Microsoft "Com library" or the binary file description provided in a separate manual.

Video files are recorded by *ETVision* as wmv files. These can be read by most video player applications as well as by *ETAnalysis*. The eye video file resolutions are 320x240 pixels, and the scene image file resolution is 1280x720 pixels. The update rate for both eye and scene files is 30 Hz. Scene video files include audio tracks for the wearable optics microphone and for the ETV PC microphone audio. The wearable optics microphone audio is always recorded. PC microphone audio is also recorded only if the PC microphone is enabled as described in section 7.7.8.

7.8.1.3 Record 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. Ten different event marks (numbered 0-9) 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.
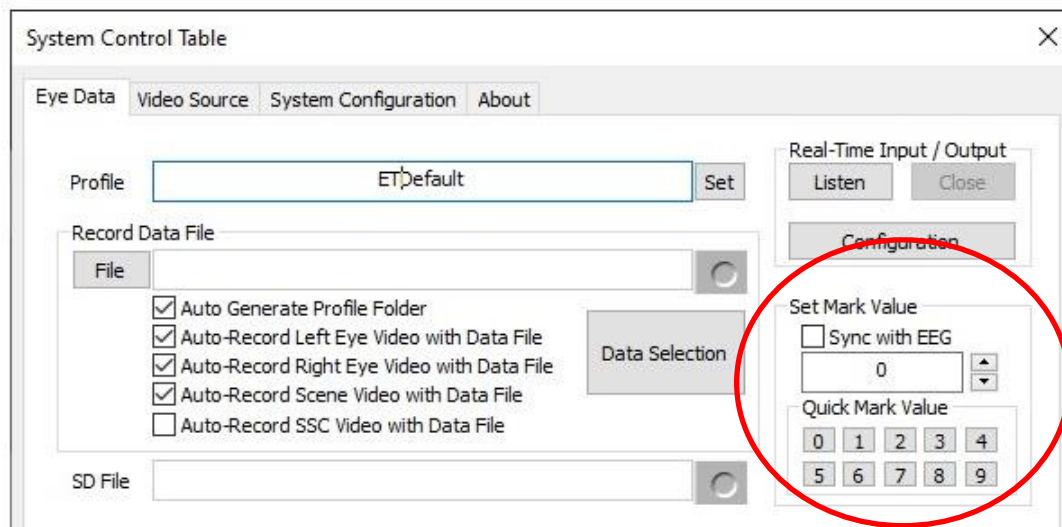
Alternately a value can be typed into the "Set Mark Value" box. In this case the value in the box will be set when the <Enter> key is pressed, or when focus is moved out of the box, and will remain the "Mark" value until changed. The Mark value can be quickly incremented or decremented by clicking the 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.

7.8.1.4 Record external data (XDAT) and control *ETVision* recording from external devices

ETVision keeps track of a 16 bit integer data value labeled "XDAT" (short for "external data") which is displayed on the *Data Display* window, 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. *ETVision* will also accept commands from the external device to open data files and to start and stop recording via the same LAN connection. Section 7.9 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 *ETVision Real-Time Communication with External Devices*.

7.8.2 Record video/audio data on micro SD card

Video data and audio data from the wearable optics cameras and microphone can also be recorded directly onto a micro SD card by the *ETVision* Controller for later playback to the *ETVision* PC application. This allows data recording to take place when the Controller is beyond WiFi range of the ETV PC. Data cannot, however, be simultaneously recorded by the *ETVision* PC application even if it is in WiFi range or connected via LAN cable.

While SD card recording is in progress, the *ETVision* application will display live data at the reduced rate of 10 frames/sec if it remains within WiFi range or remains connected with a LAN cable. If the optics move beyond WiFi range (or a LAN cable is disconnected), the reduced speed live display will freeze until once again within WiFi range (or LAN cable is reconnected). If SD card recording is

stopped, the *ETVision* application will resume full speed operation with recording capability (when in WiFi range or with LAN connection).

If an *ETVision* file is opened, it will be automatically closed if SD card recording begins.

Before recording to an SD card, first position the optics on the subject and determine that there is proper feature recognition as described in section 0.   This must be done while the Controller is in WiFi range or is connected to the ETV PC with a LAN cable.

Subject calibration can be done using the *ETVision* application before SD card recording begins, or later on, during playback of SD card data to the *ETVision* app. If calibration is done before SD card recording begins, be sure to save the configuration so that the calibration parameters are saved.   To save system configuration (including calibration parameters) open the *System Control Table* window (click *System Control Table* icon ⚙ on the menu bar), and select the *System Configuration* tab. At the lower left of the dialog, under "Configuration Settings", click "Save" to bring up a standard browser dialog. Navigate to the desired directory and type in a file name. The file will automatically be given a ".xml" extension. To re-load this configuration at a later time, click "Load" on the same *System Configuration* dialog, and select the previously saved file.
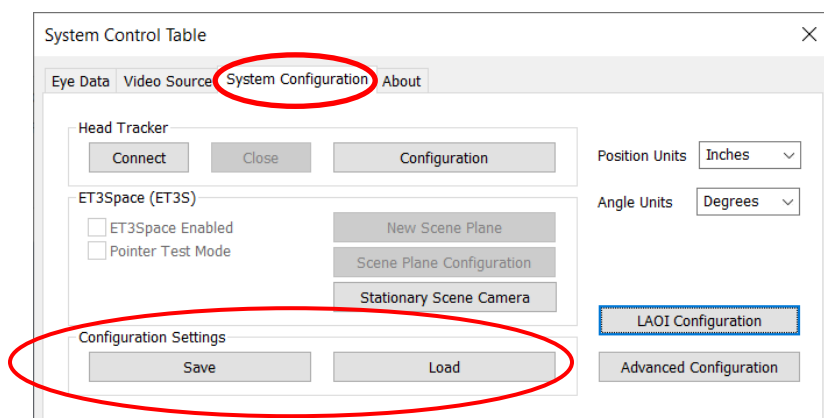
If calibration will be done during playback from the SD card recording, be sure that the subject is instructed to look at a set of calibration points sometime during the recording. It will also be important that either a pointer is used (which will be visible on the scene image playback), or verbal queues are used so that it will be possible to know, during playback, precisely when the subject was looking at each calibration target point.

7.8.2.1   SD card file names

The names of files recorded to the SD card will be determined by the "Profile name" currently stored in the Controller. To use the default name (or name most recently set in the Controller) simply proceed to the next section. To modify the profile name, the Controller must be connected to the *ETVision* PC application, and within WiFi range if a WiFi connection is being used. Open the *System Control Table*, on the *ETVision* application and select the "Eye Data" tab. Next to the "Profile" label, at the top left of the dialog, type in a new Profile name and click "set".

File names on the SD card will always be given the current Profile name, with a date and time stamp appended to the end. The extension will always be ".emv". The "emv" files are custom binary files that encode 180 Hz left and right eye camera video; 30 Hz, 1028x720, scene camera video; and audio detected by the microphone in the wearable optics frame.

7.8.2.2 Start and stop SD card recording

Insert a micro SD card in the SD card slot on the Controller. Be sure fully inserted. The record LED should blink green. When the SD card is fully detected and ready to record, the record LED will turn solid green if the SD card is less than 90% full, or will turn yellow if the SD card is already more than 90% full. In the later case, it is suggested that a different SD card be used or that files be deleted from the current card before use.

Wait for the record light to turn solid green before starting to record data. To start recording, press and hold the record button for 1 second and release. The record LED will blink red for a brief period as the system prepares to record, and should then turn solid red to indicate that recording has begun. If the *ETVision* PC application is connected, the eye and scene video windows will freeze and no longer show live data; however, the status indicators on the tool bar will continue to operate as long as the Controller is in range.

To stop recording, press the record button again and hold for 1 second. If the ETV PC is in range and *ETVision* is running, the video displays will once again be live within 1 to 5 seconds. The record light will change to green (or yellow if more than 90% of the SD card if full), however it may take several additional seconds for the LED color to change.

Alternately, if the ETV PC remains within WiFi range of the Controller, SD card recording may be stated and stopped from the *ETVision* application. Open the *System Control Table* (click the settings icon 🔧) on the *ETVision* application and select the "Eye Data" tab. If an SD card is detected by the Controller, the record symbol, next to the "SD File" label, will be red. Click the record symbol to start SD card recording. When recording starts the symbol will change to a pause symbol. Click the pause symbol to stop recording.
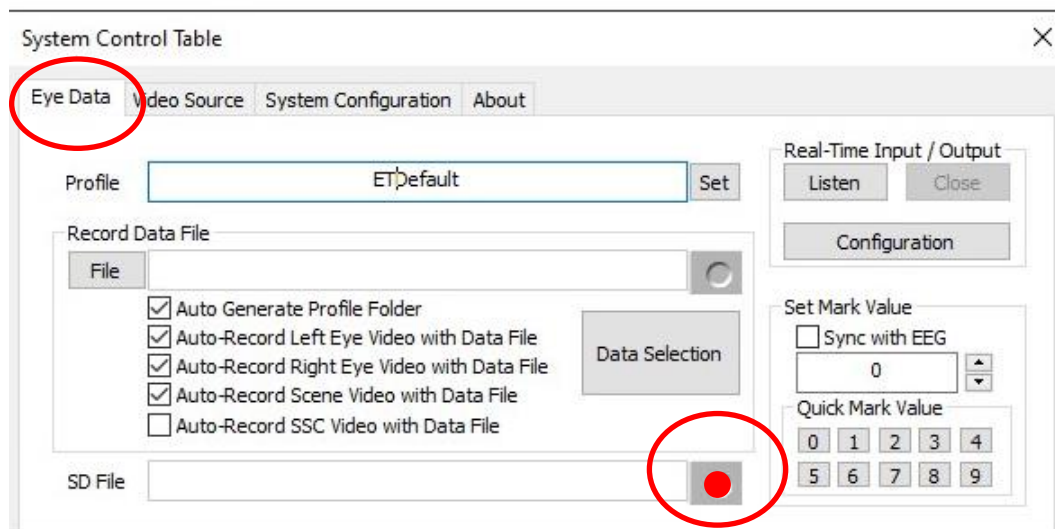
7.8.3 Compute gaze data from an SD card file

To compute gaze measurements, SD card "emv" files must be read and processed by the *ETVision* application on the *ETVision* PC.

Press and release the micro SD card to remove it from the Controller SD card slot. Insert the micro SD card in a micro-to-standard SD card adapter and insert the adapter in the PC standard SD card slot. The SD card should now appear as a device drive on Windows 10 File Explorer. Although the emv files can be read, by *ETVision*, directly from the SD card, it is suggested that files first be copied to PC hard drive. Be sure to copy emv files to a directory on the PC hard drive that has read/write permission (for example, some directory folder under C:\Users\Public). The files can then be renamed if desired as long as the ".emv" file extension is preserved. Once files are copied to the PC hard drive, Windows File Explorer can be used to delete them from the SD card if desired in order to make room for additional recording on the SD card.

Select the "Video Source" tab on the *ETVision*, *System Control Table*. In the "Play Back Mode" box, at the bottom of the dialog, click the "File" button, and use the resulting browser dialog to select an emv file. As previously mentioned, it is suggested that this be an emv file that has been copied to a location on the PC hard drive rather than a file on the SD card.
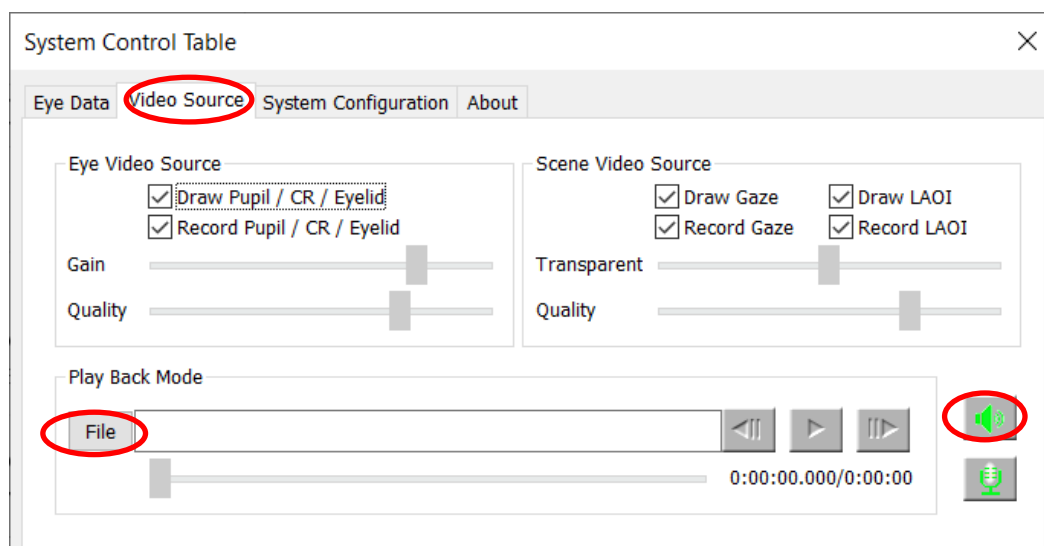
First be sure that the PC speaker is enabled, and then click the Play icon, to the right of the file name, to play the emv file. The eye and scene video should appear in the *Left Eye*, *Right Eye*, and *Scene Image* windows just as if the system were receiving live data from the optics unit. Use the File beginning and end symbols, on either side of the play symbol to jump to the beginning or end of the file. Use the scroll bar, just below the file name, to advance or return to any point within the file.

To use calibration parameters previously saved on a configuration file, open the Advanced Configuration dialog (click "Advanced Configuration" button on the *System Control Table*, *System*

Configuration tab). Click "Load" under "Configuration Settings" at the bottom right of the dialog and select the previously saved file.

To calibrate using the emv file data, advance to the place on the recording where the subject was instructed to look at known target points, and proceed just as though using live data (see section 7.8.1). The only difference is that the video file slider can be used to advance or back up to a previous point whenever necessary. If, for example, a visual target on the scene image is not successfully clicked in time (before the point on the data file where the subject's gaze moved away from the target), simply use the slider to back up to the appropriate spot. If necessary, it is OK to pause the playback on the appropriate video frame and click the target point while the playback is paused. The playback will automatically resume as soon as the target point is "clicked".

Digital (eyd) and video (wmv) data files can be recorded during emv file playback, just as though *ETVision* were receiving live data. The resulting eyd and wmv files can then be use in the *ETAnalysis* application. If the emv file playback is paused when the start recording button is clicked on *ETVision*, the emv file will automatically start to play. *ETVision* will automatically stop recording and close the *ETVision* file when playback reaches the end of an emv file.

As long as the "Speaker" symbol is enabled (green), as previously described, the play back will be at the normal speed. If the "Speaker" symbol is disabled (red), the play back will proceed as fast as the data can be processed. If the equipment operator wants to record audio comments (on the scene wmv file) during playback, it is suggested that normal speed be used ("Speaker" symbol enabled).

7.9 Communicate in real-time with an external device

The *ETVision* 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*.

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 *ETVision* PC and the external device must be connected to the same LAN. Connect a network cable from the Ethernet port on the *ETVision* PC 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. The ETVision PC LAN port being used must have IPv4 set to "find IP address automatically".

In all cases the *ETServer* acts as the "server" (or "host") while the external device acts as the "client". A *Network Configuration* dialog on *ETVision* is accessed from the "Eye Data" tab on the *System Control Table* window. In the "Real-Time Input/Output" box, at the top right of the dialog, click the "Configuration" button. This will bring up a *Network Configuration* dialog.
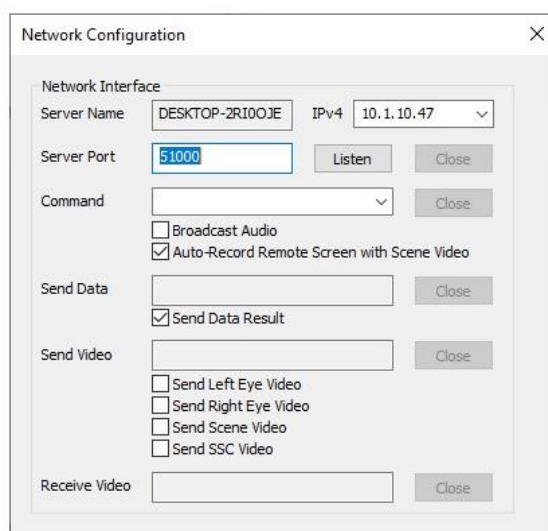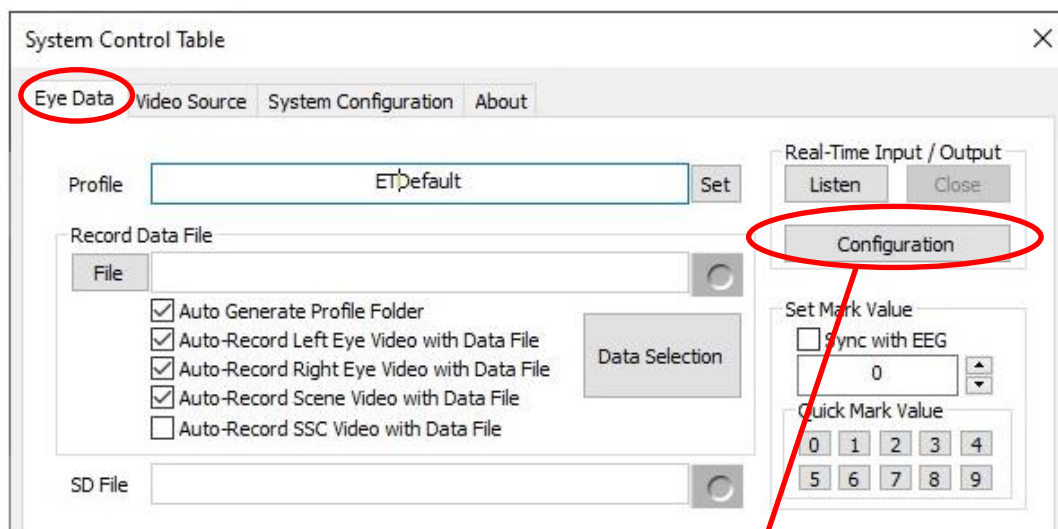
The *Network Configuration* dialog shows the "server" name, IP address and port number. The "IP Server Name" or "IPv4 address", and "Server Port" number will be needed by the client device to connect.

To stream real-time digital data to the external device, check the Network *Configuration* dialog box labeled "Send Data Result". To stream one of the video channels to the external device, check "Send Right Eye Video", "Send Left Eye Video", or "Send Scene Video". Note that only one channel of video data can be sent. Digital data may be sent in addition to a channel of video data so long as the receiving device opens a separate channel for each. The digital data items streamed will be the same set of items recorded by *ETVision* data files. These items are selected as described in section 7.8.1.1.

Click the "Listen" button near the top of the *Network Configuration* dialog. The "Listen" button will turn grey to indicate that *ETVision* is "listening" and the "Close" button will become active. Clicking this "Close" button will terminate all connections. If a client on the network opens a connection for any of the checked functions, the "Close" button for that function will become active. Clicking that "Close" button will terminate the connection for that function.

Note that multiple external devices can be connected to ETVision, but ETVision can stream data or video to only one device at a time. If multiple devices are connected, data or video will be streamed only to the last device that sends a stream command.

7.9.1 Connecting to *ETVision* with *ETRemote*

Argus Science provides an application called *ETRemote* which can run on an external Windows 7 or Windows 10 PC. *ETRemote*, running on the external device, can receive both digital and video data from the *ETVision*, can send data bytes to be recorded on gaze data files by *ETVision*, and can control data recording by *ETVision*.

Be sure both the *ETVision* 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, be sure "New Connection" is selected and type in the *ETVision* network name or IP address. These can be found on the *ETVision*, *Network Configuration* dialog as described in the previous section. In the case of a direct connection from *ETVision* 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 *ETRemote* should default to the correct port number (usually 5100), but check to be sure it is the same as that shown on the *ETVision*, *Network Configuration* dialog.

On the *ETVision, Network Configuration* dialog, click "Listen", as previously described.
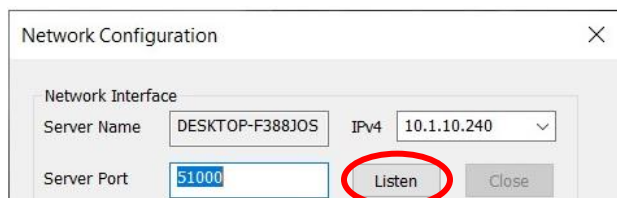
On the external PC *ETRemote* application, click "Connect".
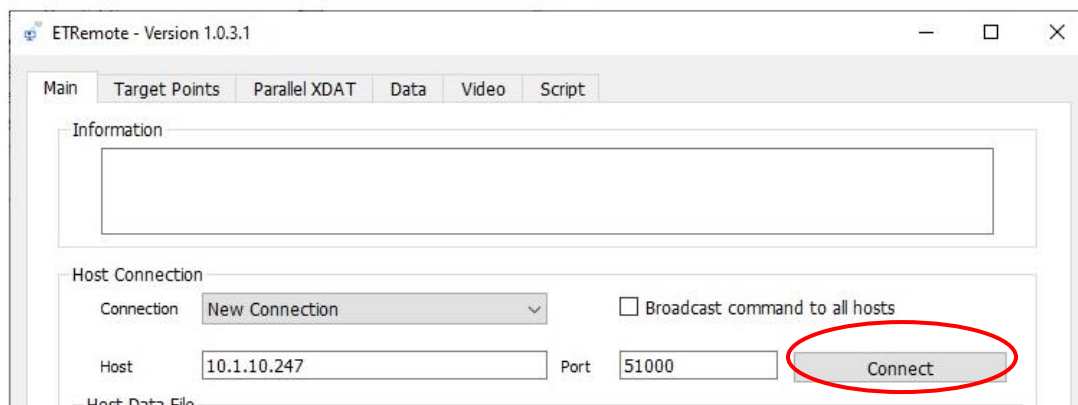
If the connection is successful *ETRemote* "Connect" button changes to "Disconnect", the *ETVision* "Listen" button turns gray, and the "Close" button becomes active.
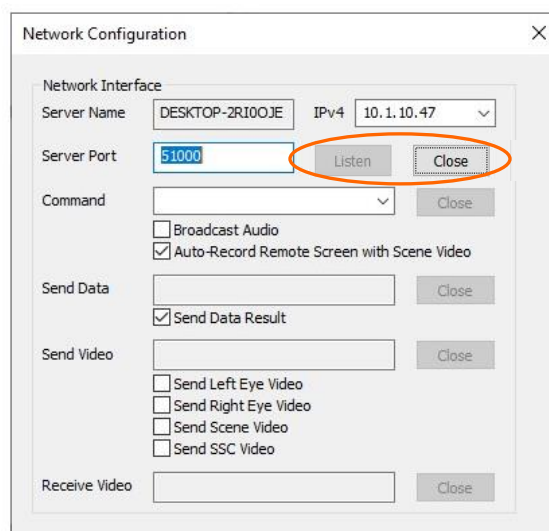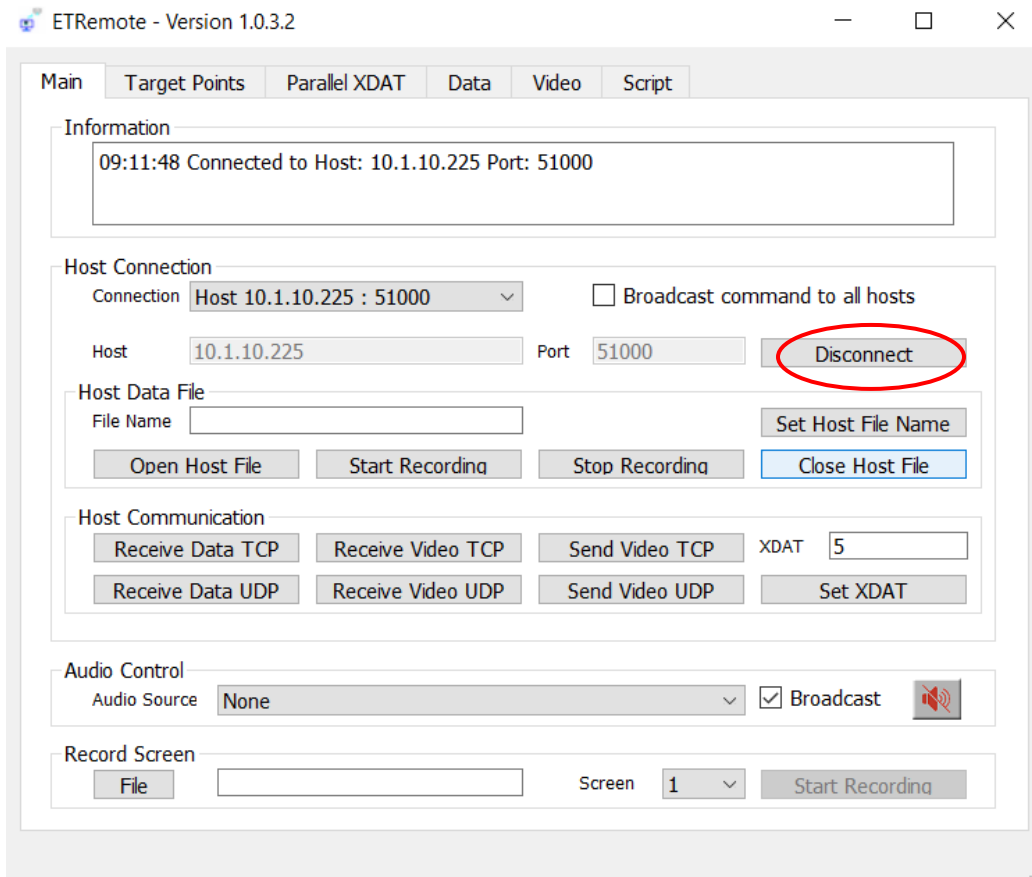
If "Send Data Result" was checked on the *ETVision, Network Configuration* dialog, click "Receive Data TCP" or "Receive Data UDP" on the *ETRemote* application to start data streaming in the "Eye Tracker Data Result" scrolling window. If one of the "Send" video boxes was checked on the *ETVision, Network Configuration* dialog, click "Receive Data TCP" or "Receive Data UDP" on the *ETRemote* application to begin receiving the video stream. Select the "Video" tab on *ETRemote* to view the video data.

To send an external data value, type in the desired value next to the "XDAT" label, under "Host Communication", and click the "Set XDAT" button to send it. The value should appear on the *ETVision*, *Data Display* window. Use the buttons in the "Host Data File" group box to set an *ETVision* file name, open the file, start and stop recording on *ETVision*, and close the file.

ETRemote is described in more detail in a separate manual.

7.9.2 Connecting to *ETVision* with a user created application

Any application on an external device can connect to the *ETVision* 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 *ETVision Real-Time Communication with External Devices*.

7.10 External ("Stationary") Scene Camera

It is possible to display and synchronously record video from an external camera. This may be useful for recording an external view of the subject that is synchronized with the gaze data and head mounted scene camera video. When the *ET3Space* feature is used, a point-of-gaze cursor can also be superimposed on the image from the external camera, and this is explained in the *ET3Space* manual.

The external video source can be any video source recognized by Win10, on the *ETVision* PC, but is most commonly a Web cam with a USB interface. The *ETVision* application allows selection of either the default resolution and update rate for the video source, the highest resolution offered by the video source, or the fastest update rate offered by the video source. Video sources with up to 1080p resolution at 30 Hz, and USB3 interface, usually work without affecting system performance on a minimum spec *ETVision* PC. Depending on the capabilities of the *ETVision* PC, use of higher resolution external video may cause some slow down in gaze computation performance including overtimes (missed data fields) on the gaze data. Use of a higher bandwidth video source may slow gaze computation performance resulting in overtimes (missed data fields), depending on the capabilities of the *ETVision* PC.

To connect an external video source to *ETVision*, first open the "System Configuration" tab on the *System Control Table* dialog. Under the "ET3Space" group box, left click the "Stationary Scene Camera" button to open the Stationary Scene Camera dialog.
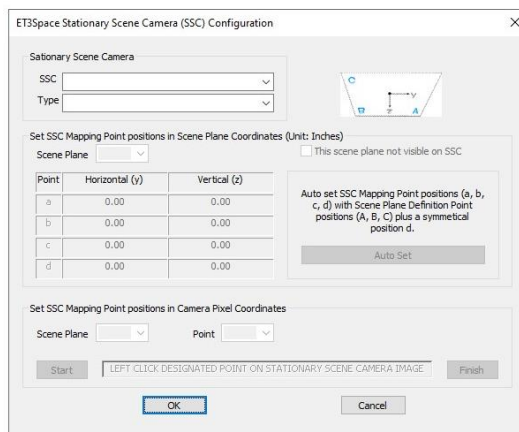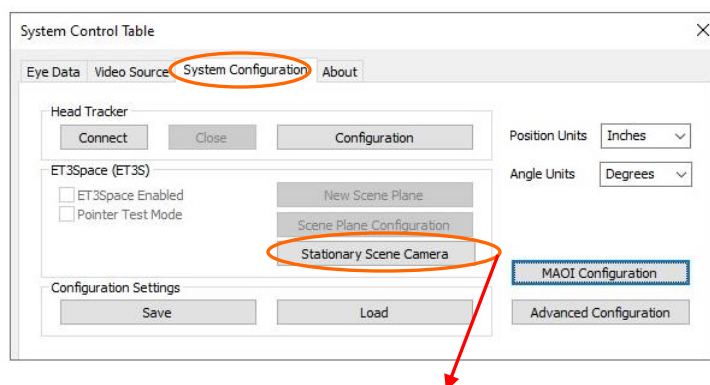
Be sure that the external video source is powered on and connected to the ETVision PC so that it can be detected by Windows 10. Usually this means that a USB cable connects the external camera to a USB3 port on the ETVision PC.

Use the "SSC" pull down menu to see the video sources recognized by Windows 10. One of the choices will usually be the camera built into the ETVision laptop ("Integrated Webcam"), and should also include any other external video sources recognized by the operating system. In the example below, "USB 2.0 Camera" is a USB web cam connected to the ETVision laptop, "Integrated Webcam" is the camera built into the laptop, and "Network" is a video source detected on the local area network. Left click to select the desired video source from the pull down menu. Note that the top choice is always blank, and selecting the blank indicates that no external video will be used.
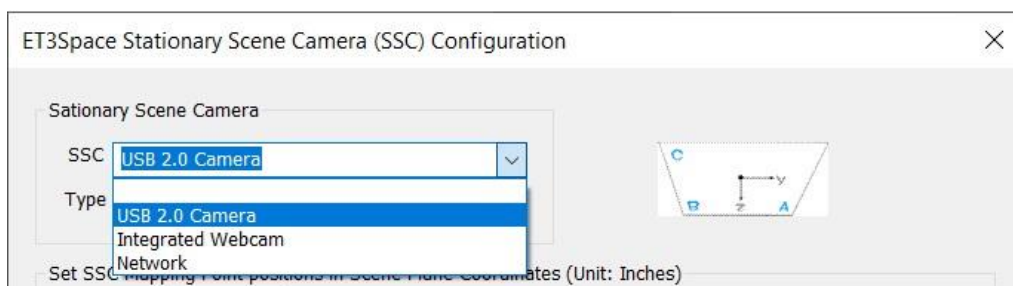
Use the "Type" pull down menu to select the camera update rate and resolution. The *ETVision* application will detect the choices available from the video source selected, and will present three options: the video source default; the choice with highest available resolution; and the choice offering the highest available update rate. Select one of the "Type" choices by left clicking the item.
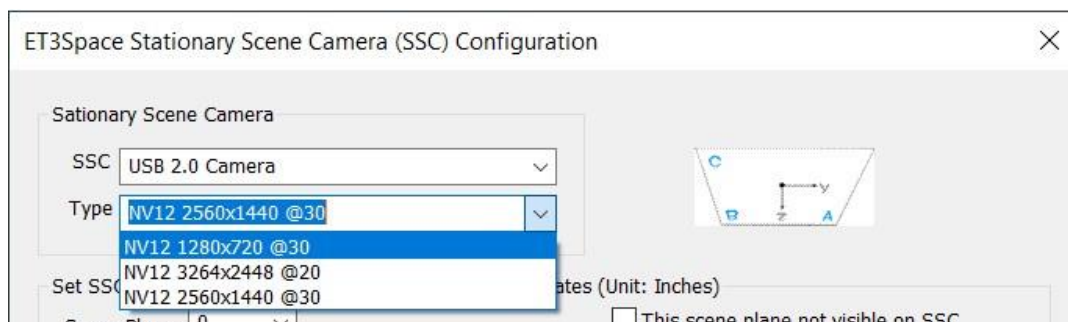
The video from the selected source will appear in a new window below the head mounted scene camera video window, as shown circled in the screenshot, below.
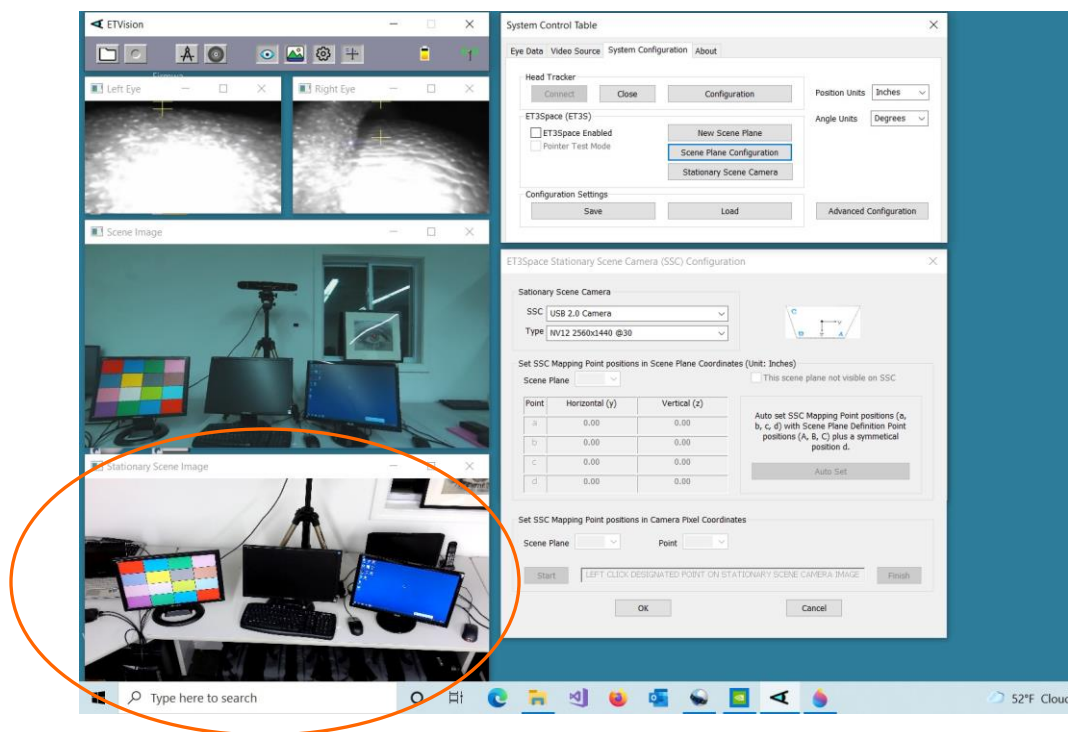
The other items on the dialog, below the Stationary Scene Camera group box, apply only to use with *ET3Space*, and will be grayed out when *ET3Space* is not in use. (See the ET3Space manual for an explanation of these items.)

Once the external video source and type have been selected, the "Stationary Scene Camera Configuration" dialog can be closed by clicking "OK".

To record the external video along with gaze data, open the "Eye Data" tab on the System Control Table dialog, and be sure that "Auto-record SSC Video with Data File" is checked. The external video file will start and end recording at the same time as the digital gaze data. Note that unless *ET3Space* is being used, a point-of-gaze indicator is <u>not</u> superimposed on the SSC video. As an example, the SSC video feature may be useful, without *ET3Space*, to record an external video of an athlete whose gaze is being tracked.

To disconnect the external video source from *ETVision*, open the "Stationary Scene Camera Configuration" dialog, pull down the SSC menu, and select the blank at the top of the list.

8 Using *ETVision* system outdoors

At night, outdoor use of *ETVision* should be no different from indoor use. In daylight conditions the following procedure modifications are suggested.

1. It is strongly suggested that the darkened visor (sunshield) be clipped to the wearable optics frames. This will minimize the tendency of the participant to squint and occlude eye camera view of the pupils. See Appendix J (section 9.10) for mounting instructions.

2. It is suggested that eye camera gain be set to a lower value than the normal indoor setting. If the *System Control Table* window is not already open, click the "Settings" icon ⚙ to open *System Control Table* and select the "Video Source" tab.   The "Gain" slider, under "Video Source" is usually set to "10" for indoor use. Drag the slider to the left, to approximately the 5-7 range for outdoor use. Note that the pupil and CRs should still be recognized by the system when indoors (red ellipse around pupil outline, green cross at pupil center, blue crosses on CRs), although the entire eye image will appear significantly darker and may be more difficult for the equipment operator to see when indoors.   Outdoors, in bright daylight, the eye images with lower camera gain will appear much as they did indoors with the normal gain setting
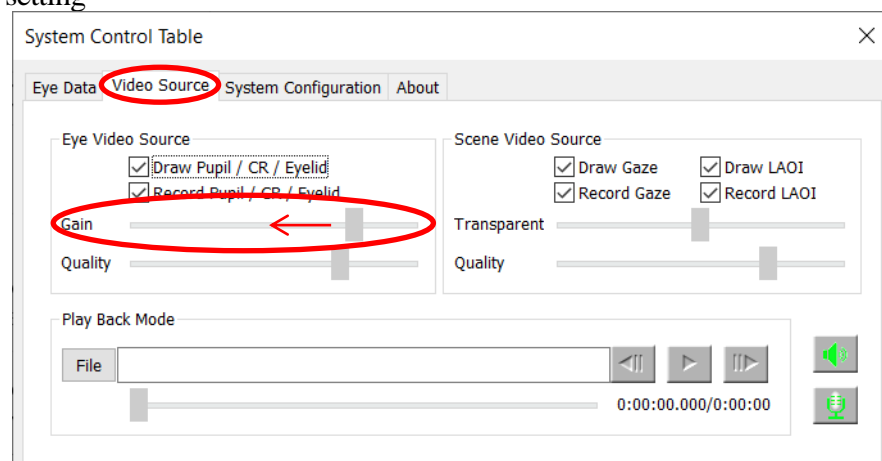
3. Be aware that in daylight, even with the darkened visor in place, the eye pupils will likely appear significantly smaller than when indoors. This is perfectly OK as long as the pupils are properly recognized by the *ETVision* system.

4. After lowering eye camera gain (as previously described) it should still be OK to calibrate indoors and then have the participant walk outside; but be aware that pupil diameter may change very significantly when the participant first walks outside, and this may cause a small offset in the point of gaze data. For example, the point of gaze cursor may suddenly appear to be always slightly above the point the participant is fixating (or slightly offset in some other direction).   In this case, ask the participant to fixate a visible target in the environment, and use the manual offset correction (see section 7.7.6) to adjust the POG cursor.

5. If the participant is wearing prescription eyeglasses, bright sunlight may create reflections on the eyeglass lenses that will interfere with the eye camera view. This is especially likely to be a problem when the subject is facing the sun.

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9 Appendicies

9.1 Appendix A – LED color codes

Power LED

Color	Power supply	Condition
OFF	Not connected	Controller off
Blue	Not connected	Controller booted or in boot process and battery has >15% charge
Red	Not connected	Controller booted or in boot process and battery has <15% charge
OFF	Connected	Controller in idle state (not booted) and Battery fully charged
White	Connected	Controller in idle state (not booted) and Battery charging
Yellow	Connected	System is booted and battery is charging
Green	Connected	System is booted and battery is fully charged

Record LED

Color	Condition
OFF	No SD card detected
Green	SD card detected and <90% full; not currently recording
Yellow	SD card detected and >90% full; not currently recording
Red	SD card is recording

9.2 Appendix B – Manual Calibration function details

Since the geometry of the eye structures and the position of the optics with respect to the face vary somewhat from person to person, gaze computation accuracy can be improved by incorporating data from calibration points (points at which the person wearing the optics is known to be fixating a particular point on the scene camera image).

Section 7.6 provides a simple description of a recommended procedure for subject calibration. It is suggested that Auto Calibration be done first, since this is the quickest procedure and is usually quite sufficient. Manual calibration procedures are available if needed, and section Section 7.6 also describes a recommended procedure for manual subject calibration. This appendix provides a more detailed description of the manual calibration function and its flexible features.

The *System Control Table*, *System Configuration* Tab, *Advanced Configuration* dialog can be used to set the maximum number of calibration points ("Total Calibration Points").

The subject calibration function allows any number of calibration points to be used in any order, up to a maximum ("Total Calibration Points") that is set on the *Advanced Configuration* dialog. The highest "Total Calibration Points" number that can be set is 20 and the lowest that can be set is 1. The suggested setting for "Total Calibration Points" is 9. <u>Note that this setting does not mean that all 9 different points must be used, but rather that any number between 1 and 9 can be used</u>. Once 9 points have been entered during a calibration procedure, the program will assume that any additional points entered are intended to replace one of the 9 points.

Clicking the subject calibration icon ![icon] on the *ETVision* menu bar, or clicking the "Start" button on the "Subject Calibration" dialog, opens Manual Subject Calibration mode. When Manual Calibration mode is open the calibration icon symbol will appear red ![icon] rather than black. Clicking the menu bar icon again will close calibration mode and change the icon symbol back to black.

A small yellow cross on the scene image will show the scene image position of point 1 on the previous calibration. Gray crosses will indicate position of other points from the previous calibration. The yellow and gray crosses are for information only. There is no requirement that points used during the current calibration be at or near the same positions.

Ask the subject to fixate a visible target point and left click the same visual target on the Scene Image window. If at least the pupil is being recognized by the system, a green cross will appear at that point on the scene image. The system will note the pupil and CR position data at the instant of the mouse click, and will associate that data with the indicated point on the scene image. Assuming "Total Calibration Points" is set to greater than 1, a yellow cross will now indicate the position of point 2 on the previous calibration. The scene image POG cursor will begin to show the best estimate of POG based on data from the single calibration point so far entered.

Right clicking near the same scene image point will "undo" entry of calibration point 1 and queue up the system for a new entry of point 1.

Each left click on the scene image screen will cause the pupil and CR data to be entered and associated with the next scene image point and calibration point number, until the "Total Calibration Points" value is reached. The scene image POG cursor will begin to show the best estimate of POG based on data from the points so far entered. Right clicking will undo the last point entered.

A "confidence" value, which appears in the Scene Image window title bar after each calibration point data entry, indicates whether the pupil and CR positions were near the value that the program would "expect" for the indicated position in the scene space.   A very low confidence value means that the detected feature positions were far from their expected position. In this case it is possible that either the subject was not looking where directed, or a feature position was incorrectly detected. If this value is less than 50% on the first point, the operator should check to be sure that the optics frames are properly positioned on the subject.   If less than 75% on a subsequent point, the operator may want to right click and then re-enter that point.

If the calibration mode is closed (by clicking "Subject Calibration" icon or clicking the "Finish" button on the "Subject Calibration" dialog), the calibration icon will turn black and the green calibration position crosses will disappear. The scene image POG cursor will continue to indicate the best estimate of POG based on data from the calibration points used (even if less than "Total Calibration Points" were entered) .

Assuming calibration mode remains open, once the number of points specified by "Total Calibration Points" have been entered, additional left clicks on the scene image will replace one of the calibration points previously entered. Specifically, the point whose position on the scene image was closest to the new point will be replaced by the new pupil data, CR data, and scene position data. POG computation will begin to reflect the modified set of data points.

Whenever calibration mode is closed the POG computation will continue to use the data from the last calibration until calibration mode is opened once again.   When calibration mode is re-opened, all data from the last calibration is cleared, and the process starts "from scratch" (as though no subject calibration has ever been done).

Although calibration points can be entered in any order, it is recommended that the first be near horizontal center of the scene camera image, and at or slightly below vertical center. This will usually ensure that the pupils and all CRs can be properly recognized at this point.   It is further recommended that additional points be added as described in section 7.6.3, since that sequence will most likely show progressive POG accuracy improvement as each additional point is added. Ultimately, a set of points in given locations will yield the same final result no matter the order in which they are entered.

A 9 point value for "Total Calibration Points" allows for the maximum number of points that are likely to make sense before "diminishing returns" set in.

9.3 Appendix C – *ETVision* recorded and transmitted Data items

The normal file types are "*.eyd" when *ET3Space* is not enabled, and "*.ehd" when *ET3Space* is enabled. Both of these file types are binary files that can be read by the Argus Science *ETAnalysis* application. *ETAnalysis* can be used to convert eyd and ehd files to text files, or to XML files that can be read by Microsoft Excel (see *ETAnalysis* manual). It is also possible to record data in "csv" text format (rather than "eyd" binary format) and this is described in Appendix I (section 9.9).

Real-time data is also transmitted in binary format. The same data item selection dialog in *ETVision* (see section 7.8.1.1) applies to both recorded and transmitted data. Scaling and data type are specified in the following section, and the meaning of each data item is explained in the subsequent section.

9.3.1 Data Item List

The first 5 bytes of a data record in a data file recorded by *ETVision*, or real time streaming data packet transmitted by *ETVision*, always contain the following items. ***The "Byte Position", "Type", and "Size" columns apply to streaming binary data and binary ("eyd" and "ehd") files. On "csv" (comma separated value) files all these values appear as text integers, except for the first data item listed, which is replaced by a text floating point time value.***

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 7.8.1.1). Whichever items have been selected will appear in the order listed below, both on data files recorded by *ETVision* and real time streaming data packets transmitted by *ETVision*. Note that some items that have "left" and "right" eye values have only one corresponding entry in the selection table that selects both "left" and "right" values. For example the "pupil_pos_horz" check box selects both "left_pupil_pos_horz" and "right_pupil_pos_horz". Some items are available only when using the optional *ET3Space* feature. ***The "Byte Position", "Type", "Size", and "Scale Factor" columns apply to streaming binary data and binary ("eyd" and "ehd") files. On "csv" (comma separated value) files "XDAT", "CU_video_field_num", and "ET3S scene_num" appear as text integers, and all other values appear as properly scaled, text floating point numbers.***

Data Item	Type	Size (bytes)	Scale Factor	Comment
XDAT	UInt16	2	1	Always available
CU_video_field_num	UInt16	2	1	Always available
left_pupil_pos_horz	UInt16	2	1	Always available
right_pupil_pos_horz	UInt16	2	1	Always available
left_pupil_pos_vert	UInt16	2	1	Always available
right_pupil_pos_vert	UInt16	2	1	Always available

left_pupil_diam	UInt16	2	0.01	Always available
right_pupil_diam	UInt16	2	0.01	Always available
left_pupil_height	UInt16	2	0.01	Always available
right_pupil_height	UInt16	2	0.01	Always available
left_cr_pos_horz	UInt16	2	1	Always available
right_cr_pos_horz	UInt16	2	1	Always available
left_cr_pos_vert	UInt16	2	1	Always available
right_cr_pos_vert	UInt16	2	1	Always available
left_cr_diam	UInt16	2	1	Always available
right_cr_diam	UInt16	2	1	Always available
left_cr2_pos_horz	UInt16	2	1	Always available
right_cr2_pos_horz	UInt16	2	1	Always available
left_cr2_pos_vert	UInt16	2	1	Always available
right_cr2_pos_vert	UInt16	2	1	Always available
left_cr2_diam	UInt16	2	1	Always available
right_cr2_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
vergence_angle	Single	4	1	Always available
verg_gaze_coord_x	Single	4	1	Definition depends on whether ET3S enabled
verg_gaze_coord_y	Single	4	1	Definition depends on whether ET3S enabled
verg_gaze_coord_z	Single	4	1	Definition depends on whether ET3S enabled
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
SSC_horz_gaze_coord	Single	4	1	Available only if ET3S enabled
SSC_vert_gaze_coord	Single	4	1	Available only if ET3S enabled
left_eyelocation_x	Int16	2	0.01	Coord frame depends on whether ET3S enabled
right_eyelocation_x	Int16	2	0.01	Coord frame depends on whether ET3S enabled
left_eyelocation_y	Int16	2	0.01	Coord frame depends on whether ET3S enabled
right_eyelocation_y	Int16	2	0.01	Coord frame depends on whether ET3S enabled
left_eyelocation_z	Int16	2	0.01	Coord frame depends on whether ET3S enabled
right_eyelocation_z	Int16	2	0.01	Coord frame depends on whether ET3S enabled
left_gaze_dir_x	Int16	2	0.001	Coord frame depends on whether ET3S enabled
right_gaze_dir_x	Int16	2	0.001	Coord frame depends on whether ET3S enabled
left_gaze_dir_y	Int16	2	0.001	Coord frame depends on whether ET3S enabled
right_gaze_dir_y	Int16	2	0.001	Coord frame depends on whether ET3S enabled
left_gaze_dir_z	Int16	2	0.001	Coord frame depends on whether ET3S enabled
right_gaze_dir_z	Int16	2	0.001	Coord frame depends on whether 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
left_eyelid_upper_vert	UInt16	2	1	Always available
right_eyelid_upper_vert	UInt16	2	1	Always available
left_eyelid_lower_vert	UInt16	2	1	Always available
right_eyelid_lower_vert	UInt16	2	1	Always available
left_blink_confidence	UInt16	2	1	Always available
right_blink_confidence	UInt16	2	1	Always available
left_ellipse_angle	single	4	1	Always available
right_ellipse_angle	single	4	1	Always available
Gaze_LAOI	UInt32	4	1	Always available

9.3.2 Data Item Explanation

Data values accessed directly from binary streaming data, or directly from binary (eyd or ehd) data files must be scaled by the factors listed in the previous section to represent the units described in the data item explanations. For example, to convert a gaze coordinate value to the scene camera pixel units described, first convert the integer value to a float and then multiply by 0.1.

Data items on csv (comma separated value) files are properly scaled as they appear on the file, and all data (from any file type) viewed using on Argus Science ETAnalysis application are properly scaled as shown.   See Appendix I (section 9.9) for csv file description.

Start of record byte (binary eyd and ehd files only) – fixed value 0xFA. On csv files, the first data item is a time value, in seconds, represented as a floating point number, and starting with 0.000 for the first data record.

Status byte – contains eye tracer status information.
Bit	Meaning (if 1)
0 (least significant)	Not used
1	Head tracker enabled
2	Right eye Corneal Reflection 1 found
3	Right eye Pupil Found
4	Left eye Corneal Reflection 1 found
5	Left eye Pupil Found
6	Right eye Corneal Reflection 2 found
7	Left eye Corneal Reflection 2 found

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 eye camera frames received from the eye cameras since the *ETVision* program was activated, and rolls over to 0 after every 180 frames. Useful mostly for debugging purposes.

pupil_pos – coordinates proportional to horizontal (0.00 to 320.00) and vertical (0.00 to 240.00) 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. This pixel value is the value displayed on the *ETVision* application (on the *Data Display* window), and the value shown by the Argus Science data analysis program, *ETAnalysis*.

Pupil_height – the minor axis of the ellipse shape identified as the pupil image. Note that unlike "pupil diam" (major ellipse axis) the minor axis of the ellipse image shape <u>will</u> change length as degree of ellipticity changes due to eye movement, even if true pupil diameter remains constant.

Ellipse_angle – the angle of the major axes of the pupil ellipse (ellipse shape identified as the pupil image) with respect to the eye camera horizontal axis. Reported values range from + 90 degrees to – 89.99 degrees. (Note that +90 and –90 degrees defines the same ellipse orientation).

cr_pos -- coordinates proportional to horizontal (0.00 to 320.00) and vertical (0.00 to 240.00) corneal reflection position 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 1280 x 720 pixel field-of-view (fov). 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 1280 horizontal or 720 vertical represent positions to the right of, or below the camera fov. The reported values have been processed by the adjustable smoothing filter described in Appendix D, section 9.4.4.5.

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

vergence angle – The angle, in degrees, between the left and right eye lines of gaze.

verg_gaze_coord – <u>When ET3Space is **not** enabled</u>, these are the X, Y, and Z coordinates for the computed point of gaze expressed in the scene camera coordinate frame. The scene camera coordinate frame has its origin at the scene camera lens aperture; with an x axis pointing along the camera optical axis; a y axis pointing to the subject's right, parallel to the horizontal camera pixel rows; and a z axis pointing down, parallel to the camera pixel columns. The coordinate values correspond to real distance values with units of either inches or centimeters depending on the "Position Units" selected on the *System Control Table*, "System Configuration" tab. For item definition when *ET3Space* **is** enabled, see *ET3Space* manual.

hdtrk – X, Y, Z position values and azimuth, elevation, and roll orientation values received by the *ETVision* system from a head tracker. Position values are in units of inches or centimeters (depending on which unit system was set in *ETVision,* "System Configuration" dialog). Angles are in degrees.

eye_location – When ET3Space is **not** enabled, these are X, Y, and Z coordinates specifying the location in space, of each eye with respect to the scene camera coordinate system. It does not depend on eye pointing direction. The units are inches or centimeters (depending on which unit system was set in *System Configuration* dialog). (If *ET3Space* **is** enabled, these locations are with respect to *ET3space* global coordinates – see *ET3Space* manual for explanation).

eye_dir – When ET3Space is **not** enabled, these are X, Y, and Z coordinates specifying a 3 dimensional unit vector (vector with a total length of 1) in the direction of line-of-gaze for each eye, represented with respect to the scene camera coordinate system   These are dimensionless quantities that specify a direction and have no units. (If ET3Space **is** enabled, this vector is with respect to *ET3space* global coordinates – see ET3Space manual for explanation).

eyelid_lower_vert – best estimate of the vertical position of the lower eyelid boundary, directly below the pupil center. The position is reported with respect to the eye camera field of view, in camera pixel units. The range is from 1 at the top of the camera field of view to 239 at the bottom. A value of 0 means that no position was detected. If the bottom boundary of the iris is exposed, the system may sometimes report the position of the bottom of the iris instead of the lower eyelid. In these cases the lower eye lid and iris bottom are usually very close to each other.

eyelid_upper vert – best estimate of the vertical position of the upper eyelid boundary, directly above the pupil center. The position is reported with respect to the eye camera field of view, in camera pixel units. The range is from 1 at the top of the camera field of view to 239 at the bottom. A value of 0 means that no position was detected. If the top boundary of the iris is exposed, the system may sometimes report the position of the top of the iris instead of the upper eyelid. In these cases the upper eye lid and iris top are usually very close to each other.

blink_confidence – Estimated probability that an eye blink is in process. The range is 0 – 100. 0 indicates that either the system is very sure that the eye lids are opened and the pupil is exposed, or the pupil is undetected for some reason other than a blink.   Higher values indicate increasing probability that a blink is in progress. Note that if the pupil remains undetected for a time that is much longer than a typical blink, the blink confidence will change to a low value, indicating that something other than a blink must be preventing pupil recognition.

Gaze_LAOI -- 32 bit integer specifying which currently defined Live Areas of Interest (LAOIs), if any, contain the current point of gaze. If no LAOIs are defined (see section 7.4), this value will always be zero. Currently defined LAOIs are always numbered in the order that they appear on the "List" drop down menu, on the *LAOI Configuration* dialog. The first LAOI at the top of the list is 0, and next is 1, the next is 2, and so on. Each data record includes an integer value with each bit corresponding to one of the currently defined LAOIs. Bit 0 (the least significant bit) corresponds to LAOI 0, bit 1 corresponds to LAOI 1, etc. If gaze is not detected to be within an LAOI, the corresponding bit will be 0 on that data record. If gaze is detected to be within an LAOI, the corresponding bit will be 1.

NOTE: other data items are available only when using the optional *ET3Space* feature and are described in a separate *ET3Space* manual.

9.4 Appendix D – *System Control Table* settings and Default values

The *System Control Table* window is opened and closed by clicking the "settings" icon [⚙] on the *ETVision* menu bar. The *System Control Table* has 5 different tabs labeled "Eye Data", "Video Source", "Subject Calibration", "System Configuration", and "About". Changes to settings on the *System Control Table* are remembered. Whenever *ETVision* is started, the settings will be those that were in place when it was last closed.

9.4.1 Eye Data tab
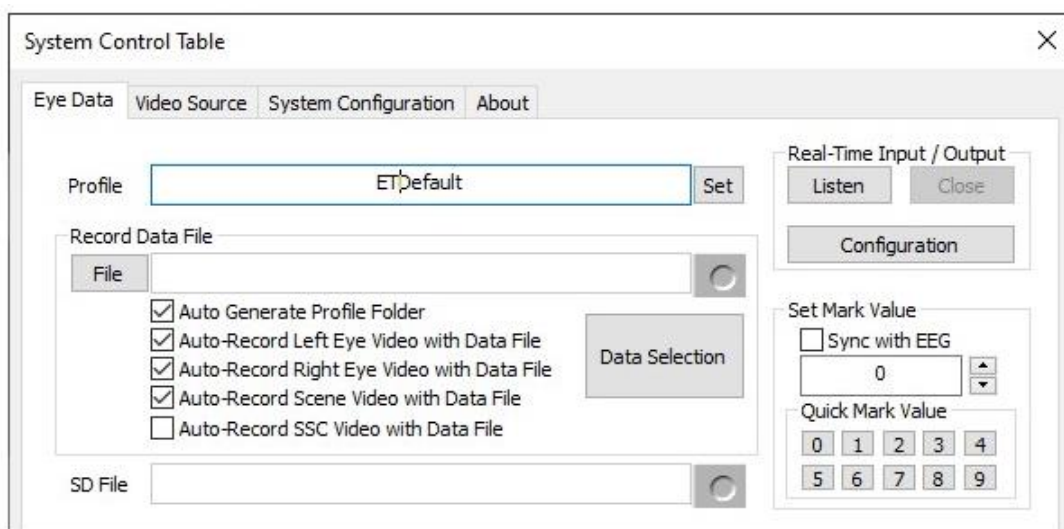
9.4.1.1 Profile
The Profile name is default prefix for data file names, and can be sent to the Controller for use as the file name prefix on SD card recordings (see section 7.8.2.1). The default profile name is "ETDefault". If "AutoGenerate Profile Folder" is checked (under "Record Data File") data files recorded on the ETVision PC will always be placed in a folder with the profile name (see section 7.8.1.2)

9.4.1.2 Record Data File
The controls in the "Record Data File" group box are used to determine which, if any, video files will be automatically recorded by the *ETVision* application along with digital data files; to open and close *ETVision* data files; to start and stop recording on those files; and to specify the data set to be recorded on *ETVision* data files. See section 7.8.1 for a description of these functions. The Data Selection dialog, displayed by clicking the "Data Selection" button, has buttons to select the default set, or to select all items or clear all selectable items.

9.4.1.3 SD File

If *ETVision* is connected to the Controller (either via cable, or via WiFi and within WiFi range) the field next to the "SD File" label will show the name of the last file recorded to an SD card. If the Controller has an SD card inserted, the record button, to the right of the file name, will be active and recording to the SD card can be started and stopped using this control (see section 7.8.2.2).

The "Set Mark Value" group box can be used to manually set event marks on digital data files being recorded by *ETVision* (see section 7.8.1.3).

The Real-Time Input/Output group box is used to set up communication with external devices. See section 7.9

9.4.1.4 Real Time Input/Output

If *ETVision* is properly configured for network communication with an external device, clicking the "Listen" button will enable the program to open a communication channel if requested by the external device ("Listen" will turn gray and "Close" will become active). The "Configure" button opens a dialog used to configure *ETVision* for network communication. The Network Configuration dialog is explained in section 7.9.

9.4.1.5 Set Mark Flag

While a file is recording, it is possible to manually enter a mark value of from 0 to 255 on the file. This feature is explained in section 7.8.1.3.

9.4.2 Video Source tab
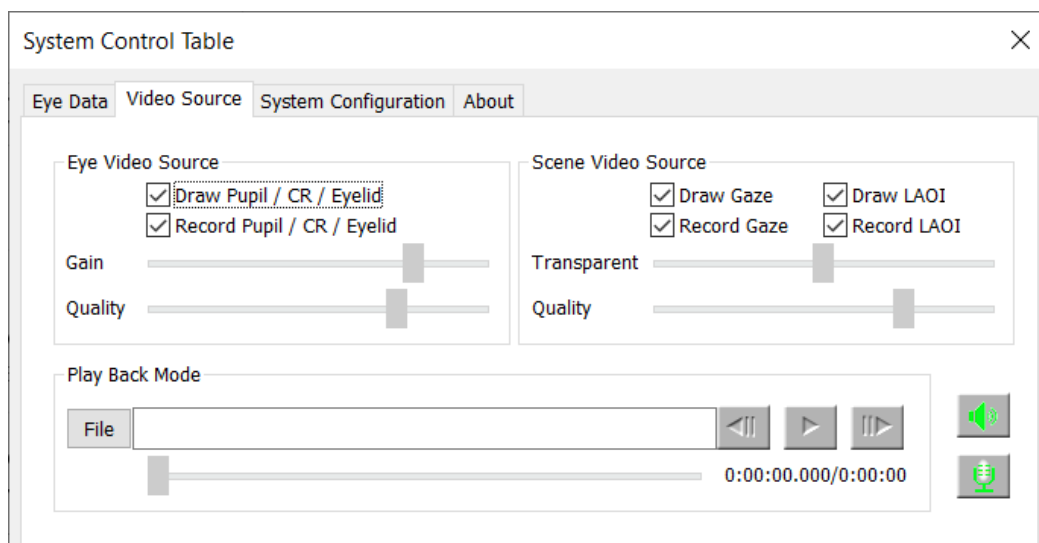
9.4.2.1 Eye Video Source

The two check boxes enable the feedback overlays on the eye images that show recognition of the pupil outline (red ellipse), pupil center (green cross hairs), Corneal Reflections (blue cross hairs), and upper and lower eyelid boundaries. The top check box ("Draw Pupil / CR / Eyelid") enables or

disables the feedback indicators on the real time display. The bottom check box ("Record Pupil / CR / Eyelid") enables or disables the feedback indicators on recorded eye image video files. If these boxes are not checked the feedback overlays will not appear. The default condition is feedback enabled for both real time display and recorded videos (boxes checked).

The sliders control eye camera "Gain" and image compression "Quality" of the eye images. The slider value shows when the mouse is over the slider control. The gain slider is scaled from 0 at the left to 15 at the right. The default for normal use is 10. For use outdoors in sunlight, a value of 5-7 is often preferable (see section 8). The quality slider is scaled from 0% at the left to 100% at the right (higher values correspond to better quality and less compression). The default and suggested value is 70%. This usually produces very good image quality without using excessive computer resources.

The "Transparent" slider, under Scene Video Source, controls the relative transparency of the scene and embedded eye images when the eye images are in "embedded mode" (see section 7.7.2). When the slider is all the way to the right (100%) the scene image will be completely transparent and will not cover the eye images at all. When the slider is all the way left (0%) the scene image will be completely opaque and the eye images will not be visible. At positions in between the scene image will be partially visible over the eye images.

9.4.2.2 Scene Video Source

The "Draw Gaze" check box enables the point-of-gaze crosshair superimposed on the real-time scene image. If this box is unchecked the point-of-gaze crosshair will not appear. The default is "Draw Gaze" enabled.

The "Record Gaze" check box includes the superimposed point-of-gaze crosshair on wmv file recordings of the scene image. The default is "Record Gaze" enabled. If this box is <u>not</u> checked, recorded scene video files will <u>not</u> include the point-of-gaze cursor. If *ETAnalysis* or some other application will be used to superimpose gaze feed back on the scene image video, it may be less confusing to <u>not</u> also have the real-time gaze cursor permanently superimposed.

If Live Areas of Interest (LAOIs) have been defined, the "Draw LAOI" check box enables display of LAOI outlines on the real-time scene image. The "Record LAOI" check box determines whether these outlines will be displayed on recorded scene video files.

If eye images are embedded in the scene image (see section 7.7.2), the "Transparent" slider controls the transparency of the embedded eye images.

The "Quality" slider controls scene image compression quality. The quality slider is scaled from 0% at the left to 100% at the right (higher values correspond to better quality and less compression). The default and suggested value is 70%. This usually produces very good image quality without using excessive computer resources.

9.4.2.3 Play Back Mode

 The "Play Back Mode" controls are used to play and process video from "emv" type files, recorded, on SD card, by the *ETVision* Controller. See section 7.8.3 for instructions.

9.4.3 Subject Calibration tab
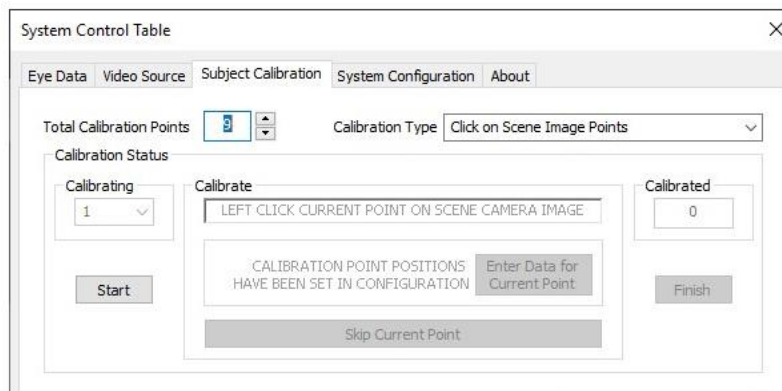
The Subject Calibration dialog is used to set optional parameters for the calibration function, can be used to enter and exit the system calibration mode, and displays calibration status information.

The default value for "Total Calibration Points" is 9. The default "Calibration Type" is "Click on Scene Image Points". A detailed explanation of the parameter settings, status information, and Subject Calibration functionality is in Appendix B (section 9.2). A shorter description of the recommended calibration procedure is in section 7.6.

9.4.4 System Configuration tab
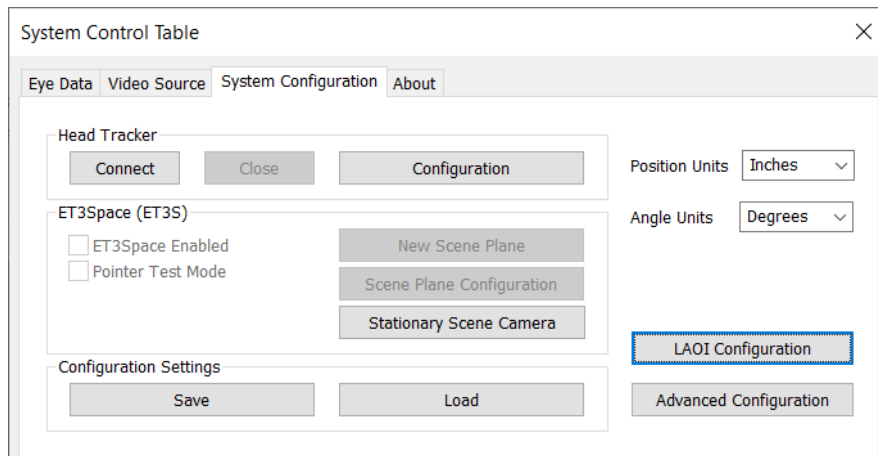
9.4.4.1 Position and angle Units

"Position Units" can be selected, from the pull down menu, as either "inches" or "centimeters". Angle Units are always "degrees". The data items available for recording and streaming by *ETVision* include a Vergence Angle and point of gaze expressed in a 3 dimensional coordinate system with an origin at the scene camera. See Appendix C (section 9.3). The "vergence angle" value is reported in degrees. The point-of-gaze X, Y, and Z coordinates are reported in the "Position Units" selected. Use of the optional *ET3Space* feature requires entry of some information about the environment using the selected "Postion Units", and reports data as position coordinates also using the selected "Position Units". (Instructions for *ET3Space* feature are in a separate manual).

9.4.4.2 Head Tracker

Separate motion tracking systems are usually used to track head motion as part of the optional *ET3Space* feature, but *ETVision* can connect to compatible motion tracking systems whether or not *ET3Space* is in use. Consult Argus Science for a list of compatible motion tracking systems.

The Configuration button, in the "Head Tracker" group box, brings up a dialog to configure *ETVision* for communication with a specific motion capture system. Instructions are in the *ET3Space* manual and a separate manual or Tech Note associated with the particular motion capture system to be used. Once properly connected and configured, the "Connect" button establishes communication with the motion-tracking device. For details, see *ET3Space* manual and separate manual or Tech Note associated with the particular motion capture system.

9.4.4.3 ET3Space

Controls and dialogs accessed from the "ET3Space" group box are used to set up and implement the optional *ET3Space* feature. Instructions are in a separate *ET3Space* manual. The "Stationary Scene Camera" function may sometimes be useful for recording external video data even when not using *ET3Space*, and this usage is described in section 7.10.

9.4.4.4 Configuration Settings

The "Save" button, under "Configuration Settings", is used to save a file with all current *ETVision* configuration settings, including the most recent subject calibration and any currently defined MAOIs. Click the "Save" button and use the resulting browser dialog to select a file name and directory. The "Save as Type" specification should usually be left as "XML files". In this case, an ".xml" extension will automatically be added to the file name.   The default file name will be the current "profile" name specified on the Eye Data Tab, with an appended date and time value.   The user can modify this file name as desired.

To re-load this configuration at a later time, click "Load" on the same dialog, and select the previously saved file.

9.4.4.5 LAOI Configuration

Click the "LAOI Configuration" button to specify objects in the scene camera image to be recognized and tracked in real-time.   The procedure for specifying scene image objects as "Live Areas of Interest" (LAOIs) in the scene image is described in detail in Appendix K (section 9.11).

9.4.4.6 Advanced Configuration

Click the "Advanced Configuration" button at the lower right of the "System Configuration" tab to bring up the Advanced Configuration dialog.
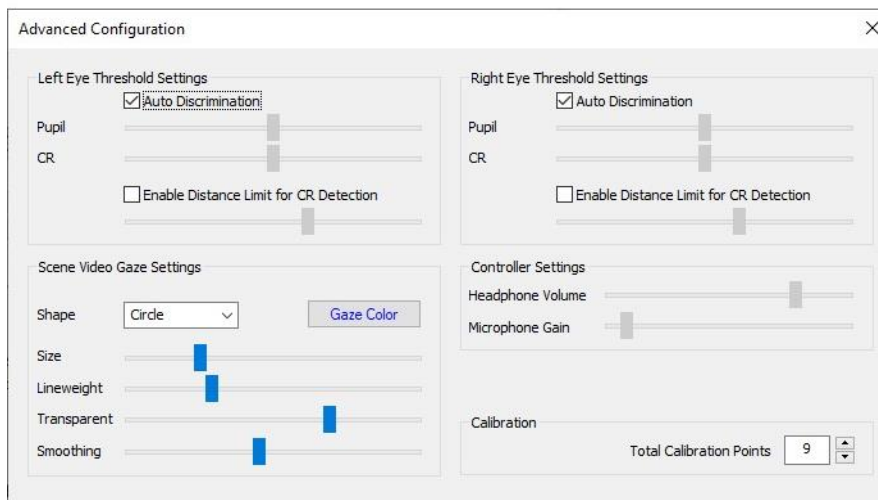
Eye Video Threshold settings

With "Auto Discrimination" enabled (box "checked"), *ETVision* finds the pupil and CR edges automatically, without any input from the equipment operator. In most cases "Auto Discrimination" is the best and most dependable way for the system to properly recognize these features, and is the default condition; however manual threshold settings are also provided. If "Auto Discrimination" is unchecked, the manual threshold sliders become active and the operator can try to find the best position for stable recognition of the pupil and CR.

Checking "Enable Distance Limit for CR Detection" creates a radius from the center of the detected pupil. Only image features within this circle will be recognized as possible corneal reflections from the *ETVision* illumination sources. When the feature is enabled, a yellow circle is superimposed on the eye image to show the CR exclusion circle. The radius is controlled by the slide bar under the check box. The *ETVision* system is usually able to reliably distinguish the desired CRs from other image artifacts without use of the this feature; but occasionally a small reflection from the bottom of a participants eye glasses or some other unusual artifact may fool the system. If the Distance Limit feature is enabled and the yellow circle size is set so that it encompass the correct CRs, but not the artifact, the system will recognize the proper corneal reflections.

The manual threshold settings and CR Distance Limit features can be separately enabled or disabled for the left and right eye by using the controls in either the "Left Eye Video" or "Right Eye Video" group box.

Scene Video Gaze Settings and Smoothing filter

The Scene Video Gaze Settings control the shape, size, line weight, color and transparency of the point-of-gaze (POG) cursor on the scene video image. The cursor shape is either a cross or a circle, selectable from the "Shape" pull down menu. Size, line weight, and transparency controls are sliders with minimum values towards the left and maximum values towards the right. The "Gaze Color" button brings up a standard color selection dialog for specification of the cursor color.

The "Smoothing" filter implements a running average of from 1 to 12 gaze data fields. The default value is 6 (slider center position), meaning that each reported gaze data value is the average of the latest computed gaze value and the previous 5. A "Smoothing" value of 1 (slider all the way left)

means there is no smoothing, while a value of 12 (slider all the way right) means that that reported gaze data values are the average of the latest computed gaze value and the previous 11. Only values from valid data fields (pupils properly recognized) are included in the average. Smoothing is applied only to the gaze cursor displayed on the *Scene Image* and *Data Display* windows and the corresponding transmitted, and recorded "gaze_coord" data values. Smoothing is not applied to pupil diameter data, vergence data, or any other reported data variables.

Controller Settings
If headphones are connected to the *ETVision* Controller, and the *ETVision* PC microphone is enabled (see section 7.7.8) the "Headphone Volume" slider controls headphone volume. The "Microphone Gain" slider is used to adjust gain on the microphone that is in the wearable optics frame.

Calibration
The "Total Calibration Points" setting can be used to specify the maximum number of calibration points used during manual calibration. The default value is 9. For a more detailed explanation, see Appendix B (section 9.2).

9.4.5 About Tab
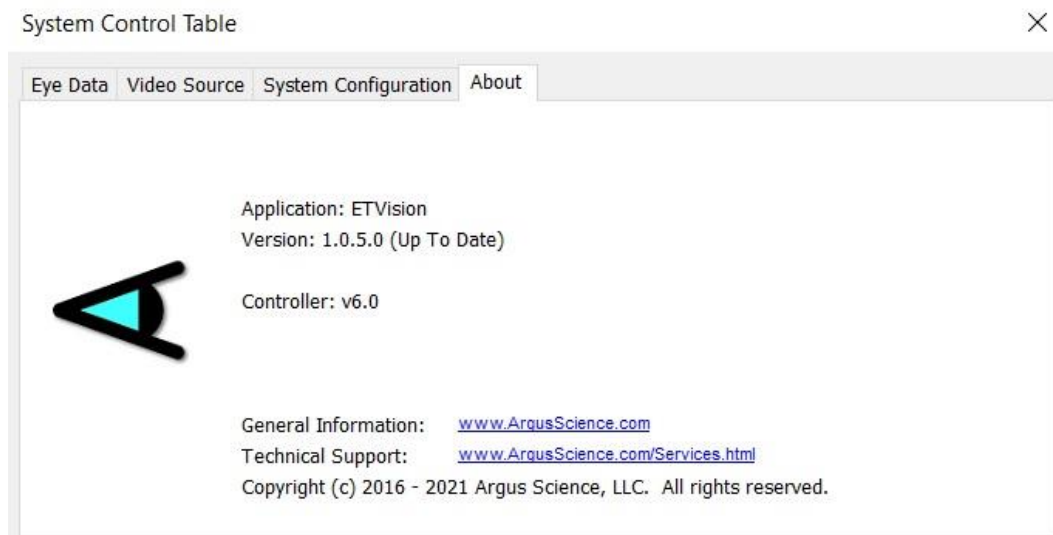
The "About" tab shows the current program and controller firmware version numbers. If the PC is connected to the Internet, it also indicates whether the version is "up to date" or whether there is a newer version. If the version is not "up to date" a link will lead to an update installer.

9.5 Appendix E – Minimum specifications for *ETVision* PC and software installation instructions

9.5.1 PC specifications

To achieve the expected performance, ETVision must run on a PC (usually a laptop) with the following minimum specifications.

- CPU: Intel i7-8750H

- OS: Win10 Pro 64-bit

- Memory: 8 GB DDR4 RAM

- Wireless: 802.11ac

- Graphics: Nvidea GeForce GTX1060 – 6GB GDDR5 Memory

- Features: 10/100/1000 LAN, 2X USB3, SD Card Reader, Audio (Mic & Speaker)

9.5.2 *ETVision* software installation

9.5.2.1 Run Install program

If the ETVision PC has been supplied by Argus Science (as part of the *ETVision* system), the software will already be installed. If Argus Science has not supplied the PC, or if a software update is needed, a software installation program will be provided by Argus Science. The *ETVision* install program has the file name "iETVision_*n_n_n_n*.exe" where "*n.n.n.n*" is the program version number. It may be supplied on an SD card, a USB "thumb drive", or downloaded from an Internet link supplied by Argus Science. This manual assumes that v.1.0.3.4 or higher is being installed.

Run the install program, respond to the usual prompts, and allow the install program to run in the normal fashion. An *ETVision* application icon will be placed on the PC desk top, and an "ETVision" item will also appear in the Start menu, under Argus Science. "ETVision Uninstall", "ETVision Manual", and "ETVision Revision History" will also appear in the Start menu under Argus Science.

> *After license activation (section 9.5.2.2) a Windows security alert will prompt the user to "allow ETVision to communicate on these networks:". Be sure to "Allow access" as described in section 9.5.2.2.*

9.5.2.2 Activate license

When the program is run for the first time, the user will be prompted to activate the license. If the PC is connected to the Internet and if online activation codes have been supplied, click the "Activate on-line" button and enter the codes when prompted.

If the PC is not connected to the Internet or if activation codes have not been provided, click "Activate using by license key". A dialog will appear with 2 system generated codes and a place to enter a response code. Contact Argus Science by phone or email with the two system generated codes, and

Argus Science will provide the response code. Type in the response code and click OK. Note that the response code must be entered on the same day that the system codes were generated.

When first running the program after license activation, a Windows security alert will usually prompt the user to "Allow ETVision Application to communicate on these networks:" Be sure to check both boxes and click "Allow access" as shown below.
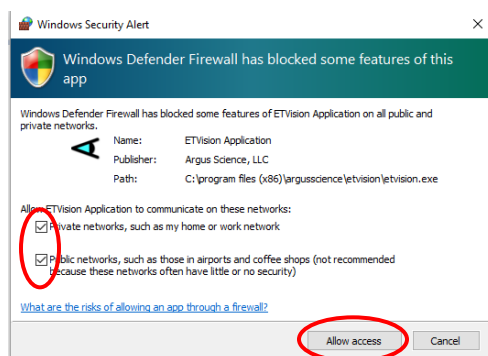
If the security alert does not appear, or is accidentally cancelled when it appears, Windows 10 firewall access can be granted as follows. Under "Control panel > System & security > Windows defender firewall > allow an app or feature thru windows defender firewall", select "Change settings". Scroll down to "ETVision Application". Note that it may appear twice; once with a check box labeled "private " and once with a check box labeled "public". Make sure both are checked.

9.5.2.3 Updating older _ETVision_ systems

If the _ETVision_ system was shipped after June, 2020, the procedure described in the previous sections for PC software installation or upgrade should be all that is required.

Systems shipped before this date may have a control unit with an older firmware version (version 2.0 as opposed to the newer version 3.0). These systems either need to run the PC software "as administrator", or need to use a static IP address for network communication between the PC and controller.   Since the PC running the system will have been set up properly to run the previous software version, everything should simply work properly once the new software is installed as described in previous sections.

Once the new software version is installed and communication with the controller is established, the controller firmware version can be checked by hovering the mouse over the WiFi or LAN connection symbol on the _ETVision_ shortcut bar. If the controller is firmware is v2.0, it can be updated to v3.0, if desired, by sending the controller to Argus Science for upgrade. Consult Argus Science for details.

If either the WiFi or LAN connection does not work properly after PC software upgrade as described in the previous sections, consult Argus Science for instructions to setup the PC properly for communication with a version 2.0 controller, or to upgrade the controller to version 3.0.

9.6 Appendix F – Removing HDMI cable from wearable optics

The HDMI cable should be removed from the optics frame only for repair or replacement.

The HDMI cable snaps into a strain relief channel towards the rear of the right temple clamp (ear piece) on the optics frame.   To remove the cable, first pull the cable out of the channel by pulling away from the temple clap starting at the rear end of the channel.   Once the cable is out of the snap channel, simply pull the micro HDMI connector towards the rear of the temple clamp to remove.   To replace the cable, first connect the micro HDMI connector and then press the cable into the snap channel for strain relief.
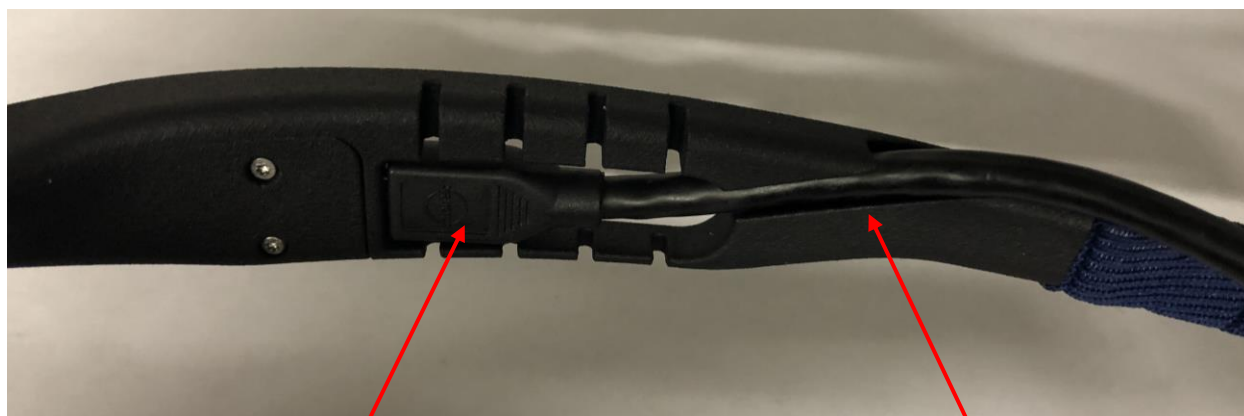
Micro HDMI connector

Snap channel

9.7 Appendix G – SD Card Selection & Preparation

Argus Science provides a Pre-Formatted 128GB microSDXC card (SanDisk SDSQUAR-128G-GN6MA) with adapter with each ETVision system delivered.

If additional microSDXC cards are purchased, the following is a list of Specifications and Preparation instructions that will ensure maximum performance with the *ETVision*.

Specification:

1. Form Factor: microSDXC

2. Read Speed: Up to 100MB/s

3. Video Speed: C10, U1, A1

4. Available from 16GB up to 400GB

Recommended:

SanDisk "Ultra" family of microSDXC Cards, SanDisk Part numbers:

1. Americas: SDSQUAR-<u>XXX</u>G-AN6MA

2. Global: SDSQUAR-<u>XXX</u>G-GN6MA

3. China: SDSQUAR-<u>XXX</u>G-ZN6MA

4. Note: <u>XXX</u> field indicates Capacity (i.e.: 016, 128 etc.)

Card Preparation:

1. Insert the microSDXC card into the SD card adapter

2. Insert SD card adapter with microSDXC card into SD slot of Win10 laptop

3. Open SD as folder options

4. Right Click on Drive> Select "Properties">Select "Hardware" tab>Select "Properties">Select "Policies" tab>Select "Optimize for Performance". Close.

5. Right Click on Drive>Select "Format" (make sure to select the CD card!)>Select "NTFS" and as an option, you may add a name to the "Volume Label" such as ETV.

9.8 Appendix H – Eye camera rotation adjustment

The left and right bottom sections of the frame each include a panel containing a camera and a pair of LEDs. The panels rotate within an outer enclosure so that it is possible to adjust the camera vertical aiming direction with respect to the optics frame. A "Phillips head" tension screw at the outer end of each panel enclosure controls the amount of torque required to rotate the panel, and should be just tight enough to hold the panel in position unless intentionally adjusted.

The standard position of the eye camera panel is such that the bottom edge of the eye camera panel is aligned with a seam in the outer enclosure, as shown in photo, below. It is not usually necessary to adjust this position, and it is intended that be left in its standard position under most circumstances.

Eye Camera adjustment tension screw

Enclosure seam

Eye Camera panel bottom edge
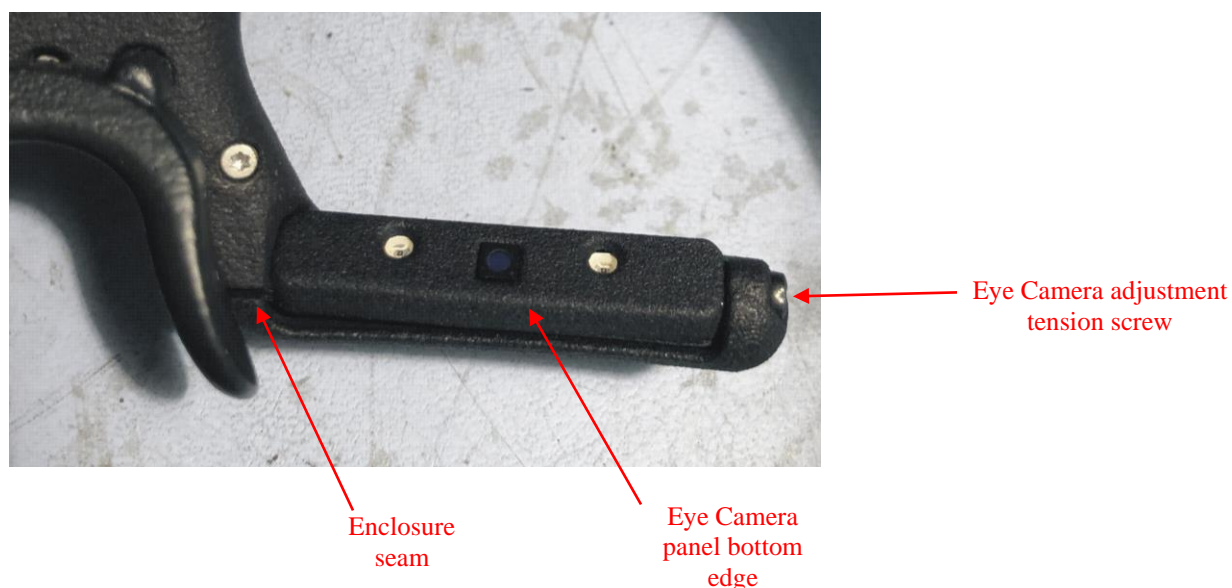
With the camera in its "standard" position, it is usually possible to center the eye images in the camera fields of view by selecting the appropriate nosepiece to control the vertical position of the entire *ETVision* frame assembly on the face (see section 0).   It may occasionally be necessary to adjust one or both eye camera rotation angles to accommodate unusual facial structures, especially if the frames are tilted on the face such that the two eyes are at significantly different vertical positions.

Be sure to remove the camera from the subject's face before attempting to rotate the eye camera panels. The eye camera panel can be rotated within its enclosure, if necessary, by pushing on either the top or bottom edge of the panel. If necessary, loosen the Eye camera adjustment tension screw slightly before adjusting the camera panel rotation, and then tighten just enough to prevent unintentional rotation of the panel.

9.9 Appendix I – Recording *ETVision* data in text (csv) format

With ETVision version 1.0.1.2 or higher it is possible to create csv type text files (rather than binary "eyd" files) when recording gaze data.

The "Save As" browser for creating a data file is opened by clicking the "File" button on the *System Control Table*, *Eye Data* tab, or by clicking the "File" shortcut button on the menu bar. The "Save as Type" field on the browser dialog offers pull down menu selections for "ETVision Binary Files (*.eyd)", or "ETVision Text Files (*.csv)". If *ET3Space* is enabled, the binary file choice will be for "*.ehd" rather than "*.eyd" files.

To record text files, use the pull down menu to select "ETVision Text Files (*.csv)".

Just as described in section 7.8.1.2 for eyd files, if the "Auto Generate File Folder" check box is <u>not</u> checked, the csv data file and video files will be opened in the folder shown by the browser. If the "Auto Generate File Folder" check box <u>is</u> checked, a folder with the profile name will be created (or opened if it already exists) within the folder indicated by the browser, and the data and video files will be created in that subfolder.

Note that the file type selection will be remembered even after the program is closed and re-opened. <u>To return to binary file recording it will be necessary to use the pull down menu again to select binary file recording.</u>

When "Save as Type" is set to "ETVision Text Files (*.csv)" data will be recorded in a csv type text format as described below. The set of data items to be recorded will still be the set selected on the data selection dialog as described in section 7.8.1.1. Recording is started and stopped in the usual fashion; however when a text file is stopped, it will also be automatically closed. When recording binary files it is possible to record multiple "segments" on the same file by starting and stopping multiple times without closing the file; but, it is <u>not</u> possible to record multiple data "segments" on a single text file.

If real time data is streamed, the same data set will be streamed with the format described in Appendix C (section 9.3).

Text files begin with a line of comma-separated text listing the *ETVision* version number, the selected measurement units (inches or centimeters), whether *ET3Space* is enabled (Yes or No), and the date and time that recording started. The second line of text is comma-separated list of data column labels. These labels are explained in Appendix C.

The following lines of text each contain a data record with comma-separated fields in the order indicated by the line of data column labels.

The first field is always a time value indicating seconds from the beginning of the data file. The time value is presented as a floating point number to the nearest 0.001 second.

The next field is always a status value displayed as a binary number to show the state of each status bit. The meanings of the status bits are explained in the *ETVision* manual.

Overtime_count, mark_value, XDAT, and CU_video_field_number are all displayed as integer values. All other values are displayed as floating point numbers with 2 places beyond the decimal point (hundreths), except that components of the "gaze_dir" unit vectors are reported with 3 places beyond the decimal point (thousandths). The scale factor is unity for all values.

A section of a typical text file is shown below.

```
ETVision: 1.0.2.2,Units: inches,3Space: No,Start_Recording: 2019-11-27 15:20:32:514
start_of_record,status,overtime_count,mark_value,XDAT,CU_video_field_num,left_pupil_pos_horz,right_pupil_pos
0.000,11111100,0,0,0,15,153.93,203.91,78.64,99.33,61.50,58.97,111.07,192.59,121.35,132.85,159.26,231.24,120.(
0.006,11111100,0,0,0,16,154.11,203.96,78.32,99.48,61.62,58.99,111.05,192.56,121.32,132.92,159.41,231.24,120.(
0.011,11111100,0,0,0,17,154.11,203.96,78.54,99.50,61.38,58.88,111.13,192.53,121.34,132.85,159.43,231.27,119.9
0.017,11111100,0,0,0,18,154.09,203.98,78.34,99.33,61.34,58.68,111.12,192.56,121.23,132.92,159.38,231.25,119.9
0.022,11111100,0,0,0,19,154.02,203.91,78.51,99.42,61.04,58.78,111.10,192.42,121.31,132.83,159.36,231.26,119.9
0.028,11111100,0,0,0,20,153.92,204.03,78.27,99.45,61.35,58.52,111.14,192.56,121.30,132.78,159.43,231.19,120.(
0.033,11111100,0,0,0,21,153.74,203.95,78.85,99.48,61.40,58.75,111.14,192.53,121.30,132.85,159.32,231.34,119.9
0.039,11111100,0,0,0,22,154.00,203.85,78.40,99.35,61.38,58.73,111.15,192.60,121.22,132.80,159.32,231.19,119.9
0.044,11111100,0,0,0,23,154.14,203.75,78.23,99.48,61.03,58.66,111.15,192.56,121.27,132.78,159.39,231.41,120.(
0.050,11111100,0,0,0,24,153.98,203.98,78.60,99.48,61.35,58.51,111.20,192.56,121.21,132.92,159.32,231.41,119.9
0.056,11111100,0,0,0,25,154.03,203.97,78.61,99.27,61.36,58.94,111.25,192.50,121.18,132.86,159.28,231.43,120.1
0.061,11111100,0,0,0,26,153.97,204.11,78.33,99.16,61.34,58.60,111.14,192.63,121.30,132.73,159.36,231.19,119.9
0.067,11111100,0,0,0,27,154.14,204.11,78.42,99.46,61.20,58.82,111.21,192.59,121.30,132.85,159.40,231.34,119.9
0.072,11111100,0,0,0,28,154.01,203.96,78.29,99.12,61.12,58.55,111.20,192.60,121.19,132.80,159.37,231.34,119.9
0.078,11111100,0,0,0,29,153.95,203.82,78.35,99.26,60.90,58.71,111.19,192.63,121.26,132.73,159.31,231.34,119.9
0.083,11111100,0,0,0,30,154.02,204.07,78.31,99.26,61.04,58.47,111.23,192.40,121.18,132.90,159.32,231.32,119.9
0.089,11111100,0,0,0,31,153.97,203.95,77.99,99.26,60.82,58.28,111.20,192.56,121.23,132.78,159.31,231.32,119.9
0.094,11111100,0,0,0,32,154.01,203.84,78.36,99.22,61.03,58.38,111.20,192.56,121.23,132.78,159.35,231.25,120.(
0.100,11111100,0,0,0,33,153.92,203.87,79.28,99.37,61.15,58.58,111.15,192.56,121.22,132.78,159.32,231.34,119.9
0.106,11111100,0,0,0,34,154.00,204.04,78.18,99.28,61.13,58.36,111.20,192.56,121.23,132.78,159.32,231.41,119.9
0.111,11111100,0,0,0,35,153.92,203.96,78.24,99.13,61.08,58.77,111.18,192.56,121.22,132.78,159.36,231.41,119.9
0.117,11111100,0,0,0,36,154.02,204.06,78.40,99.23,60.79,57.96,111.20,192.63,121.23,132.73,159.36,231.34,119.9
0.122,11111100,0,0,0,37,154.05,203.94,78.56,99.29,60.95,58.28,111.20,192.56,121.23,132.78,159.31,231.32,119.9
0.128,11111100,0,0,0,38,153.99,203.93,78.39,99.39,61.00,58.32,111.12,192.56,121.23,132.78,159.28,231.25,119.9
0.133,11111100,0,0,0,39,153.96,204.00,78.36,99.05,61.05,58.07,111.15,192.63,121.27,132.73,159.34,231.41,119.9
0.139,11111100,0,0,0,40,154.00,204.03,78.42,99.46,60.90,58.42,111.15,192.48,121.22,132.74,159.35,231.27,120.(
0.144,11111100,0,0,0,41,153.99,204.07,79.15,99.35,61.21,58.12,111.10,192.56,121.31,132.78,159.23,231.34,120.(
0.150,11111100,0,0,0,42,153.99,204.04,78.21,99.13,60.83,58.28,111.12,192.50,121.27,132.86,159.26,231.27,119.8
0.156,11111100,0,0,0,43,153.93,203.88,78.54,99.15,60.86,58.42,111.14,192.59,121.30,132.85,159.36,231.28,119.9
0.161,11111100,0,0,0,44,154.00,203.97,78.21,99.37,60.65,58.45,111.05,192.56,121.28,132.78,159.33,231.20,119.9
0.167,11111100,0,0,0,45,153.96,203.92,78.26,99.45,60.76,58.20,111.07,192.56,121.36,132.78,159.30,231.18,120.(
0.172,11111100,0,0,0,46,153.93,203.94,78.20,99.39,61.21,58.37,111.12,192.56,121.23,132.78,159.39,231.18,120.(
0.178,11111100,0,0,0,47,153.92,203.97,78.50,99.04,60.29,58.49,111.05,192.50,121.32,132.86,159.32,231.34,119.9
0.183,11111100,0,0,0,48,153.96,204.15,78.26,99.49,60.82,58.14,111.05,192.56,121.32,132.78,159.29,231.27,119.9
0.189,11111100,0,0,0,49,153.90,203.98,78.22,99.28,61.00,58.55,111.08,192.56,121.31,132.78,159.40,231.28,120.(
```

9.10 Appendix J – *ETVision* Sunshield Attachment

ETVision comes supplied with a sun shield that may be attached for use in outdoor environments.

The coating on one side is a metallic reflective surface, and on the other side is a blue colored coating. Both coatings contribute to outdoor use, and it is recommended that the metallic reflective coating be facing away from face. The substrate of the shield is a flexible plastic.

There are two slots on the shield, one in each corner, and a large hole in the center (Fig 1)

The large hole is just large enough to fit over the forward facing scene lens.

The two slots are to mate with the tabs on the front surface of the ETVision Frames.

Note: Please handle shield with care : Although both surfaces are treated with an anti-scratch hard coating, it may still be possible to scratch either surface. Only use a soft cloth with lens cleaning fluid to clean the lens: never paper towels or other rough material.

Fig 1

With the shield positioned to clear the scene lens, gently bend the shield and clear the glasses tab with the shield slot on one side, then slide shield to lock in place (Fig 2-4)

Fig 2   *Fig 3*   *Fig 4*

Repeat on other side as shown in Fig 5 for final attachment of shield :

Fig 5

## 9.11 Appendix K – Live (Real-Time) Moving Areas of Interest

It is possible to designate objects, or image features, in the scene camera image to be recognized and tracked, in real-time as "Live Areas of Interest" (LAOI). If "Gaze_LAOI" is checked on the *Data Selection* dialog (section 7.8.1.1), and real-time data is being streamed to an external device (section 7.9), the data will indicate to the external device when the participant's gaze is detected to be within one of the specified LAOIs. A record of when gaze was detected to be within each defined L AOI will also be preserved on data files recorded by *ETVision*.

This feature is usually used when some external device must react in real-time whenever gaze falls on some object in the environment. LAOI data on recorded files can also be used by the Argus Science *ETAnalysis* program to quickly display some basic statistics, and to create its own Moving Areas of Interest (MAOIs) for more detailed analysis. If there is no need for either real time detection or for very quick display of basic AOI statistics after data recording, it will usually be most effective to wait to define MAOIs in *ETAnalysis* rather than using the *ETVision* LAOI feature.

9.11.1   Create Live Areas of Interest (LAOIs)

Image objects or features in the environment can be designated as LAOIs in advance (before the participant wears the optics frames). With the *ETVision* application receiving live data from *ETVision* optics and controller, open the *System Configuration* tab on the *System Control Table* window. Hold the optics so that the scene camera is receiving a clear image of one of the objects of interest in the environment. The optics frames can be worn by the experimenter or an assistant, or simply held by someone. Eye recognition is not required. (Note that LAOIs cannot be created if a data file is opened. Close any opened data file before attempting to create LAOs.)

Click the "MAOI Configuration" button near the lower right of the *System Configuration* dialog. The current scene camera image will freeze, and an *LAOI Configuration* dialog will appear.
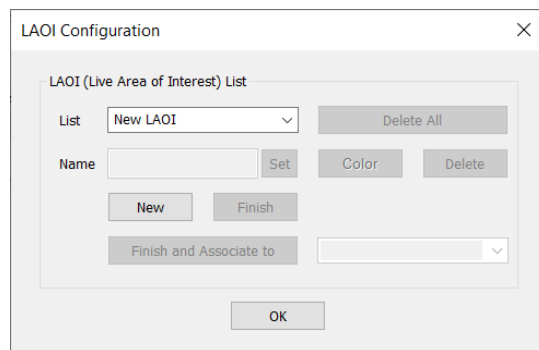
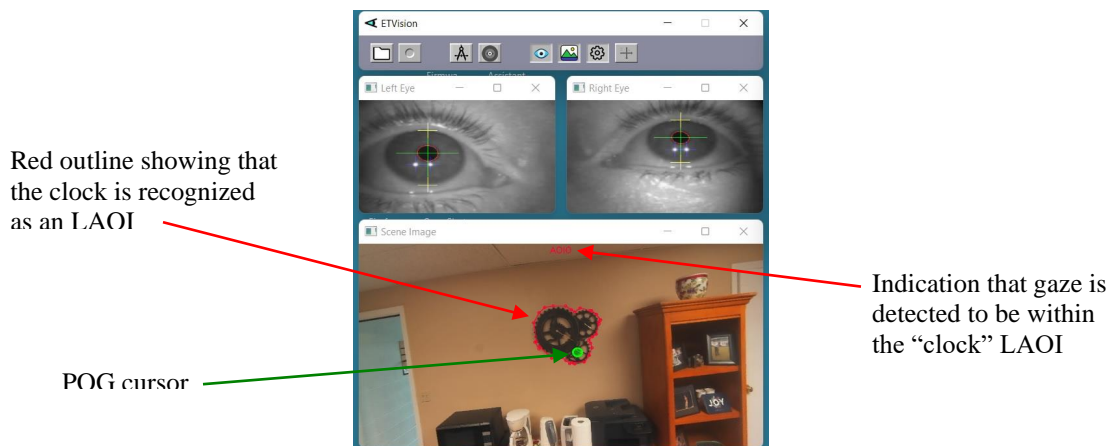Click "New". The dialog will change as shown below.
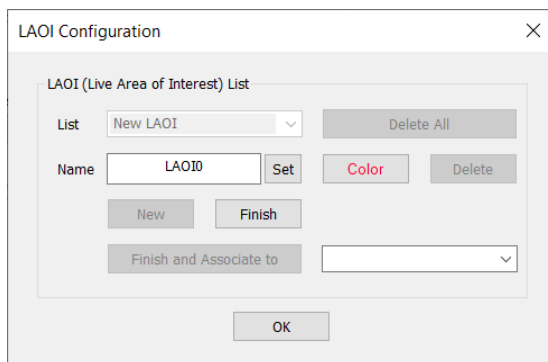
The default name for the first LAOI will be "LAOI0". If desired, type a different name in the "Name" field and click "Set".

Now left click points around the perimeter of the image object to create an outline. Each click becomes a vertex point. To delete a vertex point right click on the point. Note that if the object is rectangular, only 4 points will be required. More complex shapes will require more vertex points. To change the default color of the outline, click the "Color" button and select the desired color.

Click "Finish" to finalize the AOI specification. The LAOI Configuration dialog will return to its original form, except that the "List" pull-down menu will include the LAOI just defined.

To define another image object that is clearly visible on the same image freeze frame, simply click "New", and repeat the procedure from the previous 2 paragraphs. To define another LAOI from a different scene camera image, click "OK" to close the *LAOI Configuration* dialog, position the scene camera as desired, click "LAOI Configuration" on the *System Configuration* dialog to freeze the image and bring back the *LAOI Configuration* dialog, then click "New" and repeat the LAOI creation steps. Click OK when to close the *LAOI Configuration* dialog.

Once an image object is defined as a Live Area of Interest (LAOI), an outline can be superimposed to indicate the area whenever it is recognized in the scene image, and the associate area name is displayed whenever gaze is within the LAOI. Check boxes on the Video Source dialog control whether this information is displayed on the real-time scene image and on recorded scene video files (see section 9.4.2).

Red outline showing that the clock is recognized as an LAOI

Indication that gaze is detected to be within the "clock" LAOI

POG cursor

The automatic detection and tracking of the image feature designated as an LAOI will be most successful if the image object or feature is well defined (good contrast between image features within the defined area) and has an appearance that changes only in position and perspective, and remains in full view. Image features that appear two-dimensional will usually work best. For example, a picture hanging on a wall or a computer monitor that is showing a static image will usually work well. A computer monitor showing changing content, or a window with a changing outside view may not be tracked as reliably. A 3 dimensional object that is always viewed from a similar angle in the video will often work well, but if the viewing angle changes such that a different face of the object is shown, that may not be detected as reliably.

Note that the detection and tracking of image objects requires a variable amount of computer resources depending on the number of objects specified, the complexity of image content within the objects, and the amount of scene camera movement. Of course, performance also depends on the power of the PC being used as the *ETVision* PC. For best performance, it is suggested that the number of objects tracked be the minimum required.

9.11.2   Auto-Associate LAOIs

An LAOI can be "Associated" with (or "slaved to") the motion of another "parent" LAOI. The LAOI will change perspective and move in tandem with the associated LAOI. This is most often done with an image feature that is coplanar and adjacent to or within an LAOI that is being "Auto Detected", as described in the previous section. For example, a feature that is easily recognized may be adjacent to (or contain) an image feature that is too small or has too little contrast for reliable detection. If the easily detected feature is defined as an auto-detected LAOI, an outline designating the less easily detected feature can be "associated" with it. The "associated" LAOI will move and change perspective along with the auto-detected "parent" feature with out needing to be auto-detected itself.

To auto-associate an LAOI, first define the parent LAOI as described in the previous section. Next define the LAOI to be auto-associated just as though it were an other feature to be auto-detected; but instead of clicking "Finish" to complete the procedure, select the parent LAOI from the pull down menu next to the "Finish and Associate to" button; then click the "Finish and Associate to" button.

9.11.3   Save and delete AOIs

The *ETVision* application will continue to search for and attempt to detect all currently defined LAOIs. To delete an LAOI, open the *LAOI Configuration* dialog as previously described, select the LAOI to be deleted from the "List" drop down menu, and click the "Delete" button. The parameters defining that LAOI will be deleted and *ETVision* will no longer attempt to detect it. Other defined LAOIs will be unaffected. To delete all currently defined LAOIs click the "Delete All" button.

When the *ETVision* application is closed, recognition parameters for currently defined LAOIs are saved in the default configuration file, and will be automatically re-loaded when the application launched. If *ETVision* configuration is manually saved as described in section 9.4.4.4, all currently defined LAOI parameters are saved along with other configuration information.

It is strongly recommended that if LAOIs are not required for a data session, all currently defined LAIOs should be deleted so that the processor will not continue to search for them. If the same LAOI set (in the same environment) will be needed again in the future, <u>save a configuration file, as described in section 9.4.4.4, before deleting the LAOIs</u>. When the LAOI set is required again, load the saved configuration file as described in section 9.4.4.4.

9.11.4   Streaming and recorded LAOI data

To stream or record LAOI data, <u>be sure to check the "Gaze_LAOI" check box on the *Data Selection* dialog</u> (see section 7.8.1.1).

Internally, currently defined LAOIs are always numbered in the order that they appear on the "List" drop down menu, on the LAOI Configuration dialog. The first LAOI at the top of the list is 0, and next is 1, the next is 2, and so on.

On both streaming and recorded data, each data record includes an integer value with each bit corresponding to one of the currently defined LAOIs. Bit 0 (the least significant bit) corresponds to LAOI 0, bit 1 corresponds to LAOI 1, etc. If gaze is not detected to be within an LAOI, the corresponding bit will be 0 on that data record. If gaze is detected to be within an LAOI, the corresponding bit will be 1.

If only 1 LAOI has been defined, then the LAOI data value will always be either 0 if gaze is not within its boundaries or 1 if gaze is within the boundaries. As a different example, if there are 4 defined LAOIs (numbered 0 - 3), and if gaze is in LAOI 2 and none of the others, then only bit 2 will set, and the least significant 4 bits of the LAOI data value will be binary 0100 (corresponding to decimal 4). If gaze is within both LAOI 2 and LAOI 3, then bits 2 and 3 of the LAOI data value will be set, and the least significant 4 bits of the value will be binary 1100 (corresponding to decimal 12).

In addition to the LAOI data item described above, binary data files (eyd or ehd files) contain all of the LAOI definition information in the file header. When csv data files are created, if there are defined LAOIs, a separate xml configuration file is automatically created containing the LAOI definition information. This file will have the same name as the csv file, but will have an "xml" extension.

The Argus Science *ETAnalysis* application can use LAOI data column to quickly display some basic statistics, and can use the recorded LAOI definition information (from binary data file headers, or xml configuration files) to create its own set of Moving Areas of Interest (MAOIs). See the *ETAnalysis* manual for details.